Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

OCTOBER 1959

PRINTED IN U. S. A.

SAVING CONTAMINATED OSCILLOSCOPES

Tektronix Field Engineer Fred Lenczynski on a call to a Nuclear Research operation discovered they were destroying Tektronix scopes that had become contaminated. They were very happy to learn that Tektronix scopes could be washed with the Kelite solution and retrieved from the atomic junk man. Ask your Tektronix Field Engineer for details on this money saving operation.

HIGH Gm TUBES OSCILLATING IN TYPE 570

There is a tendency for some high Gm tubes being tested with the Type 570 Characteristic-Curve Tracer to oscillate despite the use of resistor patch cords and shielding with Belden braid.

Tektronix Field Engineer Earl Williams reports considerable success in suppressing these oscillations through the use of Ferramic cores installed on each bare-wire lead connecting pin jack to tube socket lug. Ferramic cores are the ferrite material beads that can be strung on wire to act as suppressors to high-frequency currents flowing in wire. Earl says that brief test did not show that use of beads could eliminate possible need for resistor patch cords, but he was able to display curves he had not seen to date.

REACTIVATING THE CATHODES OF STORED CATHODE-RAY TUBES

A cathode-ray tube that has been in storage for some time should be "reactivated" before being placed in service. To reactivate the cathode, operate the CRT with 8 volts on the heater (other operating conditions normal) for about one hour, and follow with 24 hours of operation at normal heater voltage. During the reactivation period the beam should be positioned off the face of the CRT.

SERVICING YOUR AIR FILTERS

Reliability of Tektronix Oscilloscopes is improved if the washable Lumaloy air filter is clean. The filters should be inspected every three or four months, for dirt content, by holding the filter up to the light. The following filter cleaning instructions are given by the filter manufacturer:

"To Clean:

(1) If grease or dirt load is light, remove filter from installation and flush dirt or grease out of filter with a stream of hot water or steam.

(2) If load is too heavy for treatment in (1) above, prepare mild soap or detergent solution in pan or sink deep enough to cover filter when laid flat. Agitate filter up and down in this solution until grease or dirt is loosened and carried off filter.

(3) Rinse filter and let dry.

(4) Dip or spray filter with fresh Filter Coat, or other approved adhesive."

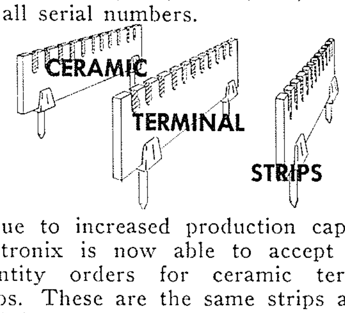
Filter Coat should be easy to get locally; look in the Classified Section of your phone book for RP Air Filters, or EZ Kleen Air Filters. If you have any trouble, we can supply you from Portland at $1.00 per pint.

CHANGING TO SILICON RECTIFIERS

Field-Modification Kits for several Tektronix Oscilloscopes facilitate changing from selenium to silicon rectifiers for increased reliability. Kits contain all necessary parts and instructions.

Field-Modification Kit 040-201 ...... $60
for Type 531 serial numbers 101 through 7600
for Type 535 serial numbers 101 through 8627

Field-Modification Kit 040-202 .... $60
for Type 531 serial number 7601 and up
for Type 535 serial number 8628 and up
for Types RM31, 533, RM33, RM35, 541, RM41, 543, RM43, 545, RM45—all serial numbers.



Due to increased production capacity, Tektronix is now able to accept large quantity orders for ceramic terminal strips. These are the same strips as are used in current production instruments: one, two, and three notch strips with one-yoke mounting, and four, seven, nine, and eleven notch strips with two-yoke mounting. Yokes are made of nylon, and are press-fit mounted to the chassis with spacers. Please consult your Tektronix Field Engineer for complete particulars and prices.

AVOID BURNING CRT SCREENS

Turning down the intensity before changing plug-in units in Tektronix Oscilloscopes eliminates any danger of burning the CRT screen during this operation.

USED INSTRUMENTS WANTED

1	524 or 514	Frank Valencic 718 E. 200 St. Cleveland 19, Ohio
1	315 or 511	Robert Anderson University of Illinois Chicago Control Systems Lab. Urbana, Illinois Phone: EMpire 7-6611
1	511, 514 or 515	Dr. R.B. Marion, Physicist University of Maryland U. S. Rt. #1 College Park, Maryland
1	511	A.C. Nielsen Company 807 Howard Street Evanston, Illinois Phone HO 5-4400
1	512	Willis Smith 5449 La Jolla Hermosa Ave. La Jolla, California
1	310 (or 315 512 514 515	H.J. Wood, Jr. Garwood Development Lab. P. O. Box 412 Las Cruces, New Mexico Phone JA 4-4044

QUESTIONS FROM THE FIELD

Q. Is the HV power supply in the 530-540 Series scopes capable of operating a slave CRT?

A. Yes, but if there is a regulation problem, it may be necessary to change the 6AU5 screen resistor (56 K 2 W) to a 47 K or 39 K 2 W resistor.

Q. What is the frequency response of P170CF and P500CF probes when used with 545/G?

A. We made some measurements and found the P170CF to be 3 db down at 22 mc and the P500CF 3 db down at 11.7 mc.

Q. Is it possible to use a 5BG or 5BH with the 530A and 540A?

A. Yes, it is possible if other minor changes are made. The 5BG crt is directly interchangeable with the T533 crt when it is used in the 531A, 533 or 535A Oscilloscopes except for the different vertical sensitivities of the

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two crt's. The vertical sensitivities are:

5BG	11.2 - 13.7 v/cm
T533	8.6 - 10.5 v/cm

The Vertical Gain Adj. in the scope should have enough range to overcome this difference. (Although changing the gain means you will have to retune the delay line and possibly the other coils in the amplifier.)

The 5BH crt is directly interchangeable with the T543 crt if pins 11 and 12 on the 5BH crt are jumpered together with a strap. The deflection sensitivities are the same in both of these crt's.

The T533 and T543 crt's have photo-etched horizontal deflection plates to minimize flare when the sweep in the 533 and 543 Oscilloscopes are used in the 50 and 100 times magnifier position.

VERTICAL INTERFIELD TEST MODIFICATION KIT FOR TYPE 525 TV WAVEFORM MONITOR

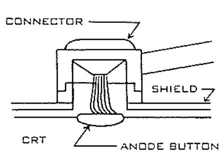
A modification kit with step-by-step instructions is now available. To permit observation of the VERTICAL INTERFIELD TEST SIGNAL which is inserted between horizontal sync pulses on the porch of the vertical blanking pulse of the composite video signal.

The kit includes all parts, wired VIT chassis, photos and instructions for modifying the Type 525 Oscilloscope. Also included are operating instructions and internal adjustment procedure with theory of operation.

When ordering, please specify Type 525 Vertical Interfield Test Modification Kit, Tek Number 040-171. Price $35.00.

CRT REPLACEMENT TECHNIQUE

We have an occasional note from the field, indicating trouble with the new brush-type CRT anode connectors.



The new anode connectors were designed so that they would not have to be removed when replacing the CRT. The connector mounts on the shield and when the CRT is installed the brush makes contact with the CRT anode button.

If the connector is installed after the CRT is in place, the brush is apt to become frayed and bent resulting in a poor connection. It is recommended that you do not remove the connector from the shield when installing or replacing the CRT.

USE of TYPES 535, 535A, 545 and 545A for DOUBLE SWEEPS

Two single sweeps may be obtained utilizing the principle that when the Horizontal Display switch is placed in the Main Sweep Delayed ('A Delayed by B')* position, the trigger gate circuit can be armed either by depressing the Reset button or by a pulse from the delay pickoff circuit. Thus a sequence can be set up with a short main sweep and a longer delayed sweep, such that when both sweeps are triggered at the same time the main sweep will complete its cycle and lock out until the delayed sweep (through the delay pickoff) resets the trigger gate circuit; then the main sweep will accept one more trigger pulse and lock out until the Reset button is pressed. The details of this are as follows:

1. Set the Horizontal Display switch to Main Sweep Normal (A)*.
2. Adjust Main Sweep (Time Base A)* for sweep time desired and adjust triggering controls to trigger internally on the signal to be displayed.
3. Reset the Horizontal Display switch to Main Sweep Delayed ('A Delayed by B')*.
4. Set the Delaying Sweep Time/cm (Time Base B, Time/cm or Delay Time)* to a setting greater than the total time needed for displaying both main sweeps. (See note 1)
5. Set the Delaying Sweep Delay-Time Multiplier (Delay-Time Multiplier)* to the desired delay time needed to arm the Main Sweep (Time Base A)* for its second sweep.
6. Connect the +Gate Main Sweep (+Gate A)* to the Delaying Sweep Trigger or External Sweep In (Time Base B Trigger Input)* and set the Slope (Time Base B Trigger Slope)* switch to the + (+Int.)* position.
7. Adjust the Delaying Sweep (Time Base B)* Stability and Triggering Level controls to trigger on the leading edge of the main sweep +gate. When this is properly adjusted it should be possible to get lock out after main sweeps.

*(Captions in parenthesis apply to Types 535A and 545A instruments.)

Note 1: The total delaying sweep time must be greater than the total time needed for displaying both main sweeps, otherwise the delaying sweep could be retriggered during the second main sweep which would allow continuous sweep operation. In the Type 535 and 545 the total delaying sweep time is limited to 10 msec/cm. If a total delaying sweep time in excess of 10 msec/cm is required we suggest a K535-S1 modification kit (Tek #040-063) which gives a maximum delay sweep range of 1 sec/cm. This kit is available for $40.00 including a new front panel. When ordering please specify the instrument type and serial number.

Note 2: This double sweep type of operation is applicable to all A to Z plug-in units, however the Type C-A unit can be used in the alternate position to observe a separate single sweep each of two signals which are displaced in time. The Type C-A unit is switched at the end of each main sweep when used in the alternate position.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix In-

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JANUARY 1960

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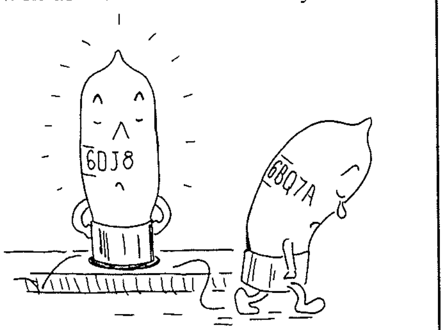
FIELD CONVERSION OF SOME TEKTRONIX OSCILLOSCOPES to Use Type 6DJ8 Tubes

All type 6BQ7A electron tubes in Tektronix Type 531, 535, 541, 545, RM31, RM35, RM41, and RM45 may be replaced with their more reliable counterpart, the type 6DJ8, provided certain precautions are observed. These tubes have been substituted without making any circuit changes. Minor recalibration checks are required in some instances. In most cases better performance may be obtained, as well as much better reliability.



"Raw-stock" tubes are used as replacements. The type 6DJ8 tube appears to have inherently good short-and-long-term stability. Also, the operating characteristics are very consistent between both sections and from tube to tube. It is anticipated that the need of aged and checked tubes in the several positions that now use aged and checked 6BQ7A's will be eliminated with the change to 6DJ8's.

An instruction sheet with a tube replacement table covering this field conversion is available. Address your request for these sheets to Field Communications Department, Tektronix, Inc., P. O. Box 831, Portland 7, Oregon. Ask for FMR-115.

EXCUSE US PLEASE

The article appearing in the October issue of "Service Scope" under the title "Use of Types 535, 535A, 545, and 545A for Double Sweeps" contained a typographical error. The last part of step 6 should read: ".... and set the Slope (Time Base B Trigger Slope)* switch to the + (+Ext.)* position." With this correction the procedure should work. It did for us.

* (Captions in parenthesis apply to Types 535A and 545A instruments)

THIS'N THAT

Type 310 has a typical problem:

When the high voltage power supply goes out of regulation, the vertical and horizontal gain or sensitivity is decreased. This has usually been caused by an open connection on the printed circuit board and almost always seems to be in the heater connection to V701A, a 12AT7 tube. Usually it turns out to be a separation of the solder from the copper strip on the printed circuit board at the tube socket. Visual inspection, of course, shows that V701A does not light up.

Reports from Tektronix Field Engineers Geoff Gass and Marvin Crouch, indicate fast oscillograms are being taken with Agfa Isopan Record Film developed for 25 minutes in D76 at 68° F. Ken Davis in Portland informs us that developing 26 minutes in D19 at 68° F., also gives excellent results. Measurements made by Ken indicate that at these developments, Agfa Isopan Record has a writing rate about equal to that of Tri-X.

Compensated Probes are no longer being adjusted to the particular instrument with which they are shipped. Experience indicates that past practice of matching probes and instruments at time of shipment is not necessary or desirable. The probe compensation should always be adjusted by the operator at the time he uses a probe with an instrument. A properly compensated probe is a necessity when accurate readings or measurements are desired.

Quite a few 531 manuals were shipped into the field showing pin 6 of V20 tied to 225 volts through R32. This was a typographical error in the 531 Manuals. R32 should go to 350 volts. This error was reported in the serial number range about 9000.

When adjusting C706 and C735 Trimmer capacitors in the 575's collector sweep circuit, be sure that the transistor adapter is in place. Tektronix Field Engineer Lee Cooper reports that the small amount of capacity introduced by the adapter results in a different setting of the trimmers.

In early "R" units, some of the power transistors had what appeared to be unworkmanlike solder connections. The first power transistors used in the "R" unit did not have tinned leads so were very difficult to solder. Later transistors have tinned leads, and a good solder job is being done.

QUESTIONS FROM THE FIELD

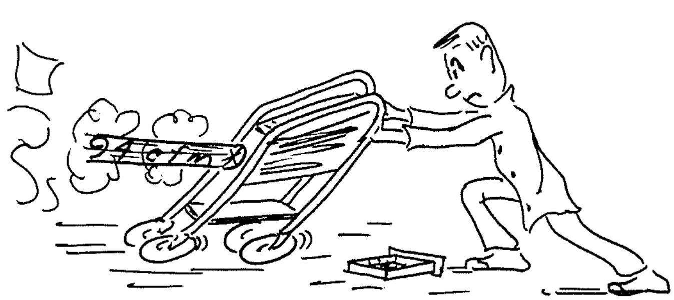
1. Q. When using the very fast Polaroid† Land film, why do some exposures give a bright haze on the picture?

   A. When the CRT phosphors are exposed to ambient room light, the absorbed energy in the phosphor must be given sufficient time to decay. The new Polaroid † Land No. 47 film, faster than Tri-X, can give a bright haze on the picture from the energy retained in the phosphor.

2. Q. Can the Type 110 produce both positive and negative pulses?

   A. Yes. The operator can choose plus pulses or minus pulses from a plus or minus internal charging supply. (See tentative spec. sheet, "Pulse Polarity" knob selects plus or minus pulses.) Pulse widths may be identical or alternately dif-

AIRFLOW WITH SCOPEMOBILE FAN KIT



Several customers have requested information on the volume of air provided by the Scopemobile Fan Kit modification when it is installed in the Type 500A Scopemobile.

With the Scopemobile drawer in place the airflow is 84 c.f.m. With the drawer removed and a panel covering the drawer opening the airflow is increased to 94 c.f.m. These figures are with line voltage at normal.

† Polaroid is a registered trademark of the Polaroid Corporation.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

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ferent. On "external", the pulses may not only have alternately different widths, but also different polarities if desired.

3. Q. What is the vertical response of the 581 at the 3, 6, 9 and 12 db points with a sinusoidal input?

A. Approximately: 3db down at 100 mc
6 db down at 140 mc
9 db down at 180 mc
12 db down at 200-250 mc

These values are approximate. The roll-off is not very smooth below the 9-12 db points, and any small termination bump in the vertical will give peaks and dips in responses above 200 mc. and in some cases down as low as 100 mc.

4. Q. What tubes manufactured outside the U.S. do we use in our instruments?

A. 12AT7, 12AX7—Telefunken.
GZ34/5AR4, ECC88/6DJ8, 6360, 6939, E180F/6688—Amperex
12AU7—Telefunken and Amperex

5. Q. What shift in trace is permissible when changing the CA from a condition of having two traces, both centered, to the Added Algebraically position?

A. Not more than 3-cm shift is allowable. This can be adjusted by changing the vertical position and range (R4376).

6. Q. Can the attenuators for the P80 probe be stacked to provide less sensitivity than 5 volts/cm? Are there any larger attenuators in sight?

A. At present, the attenuators for the P80 probe cannot be stacked. We are working on a 10 x attenuator which has resistive and capacitive characteristics similar to the P80 probe. With this attenuator, it will be possible to use any of the present attenuators, increasing their attenuation ratios by a factor of 10. It will be another month or two coming, however.

7. Q. What are the limiting factors in the vertical amplifier of a 545 with a C unit when you overdrive the amplifier with a pulse, and try to look at the top one-volt portion of the pulse which is in the order of 260 volts in amplitude? I realize a differential method of making this measurement can probably be accomplished, but I am looking for limitations in the vertical amplifier.
One of the reasons this question arises is the fact that you can position the top part of this pulse to the center of the CRT.

A. One of the Staff Engineers ran a test on this, and found a signal that filled the graticule twice, 8 cm in amplitude, caused some distortion. He used a square wave from a Type 105.

CATHODE-FOLLOWER PROTECTION FOR TYPE 524AD OSCILLOSCOPE S/N 5001-5899

When the instrument is first turned on an excessive voltage exists between the grid and cathode of the cathode-follower sections of V23 and 24. A modification is recommended for all Type 524-AD instruments, S/N 5001-5899.

Two NE2 neon bulbs are installed which will ignite for several seconds when the instrument is first turned on. This will hold the grid-to-cathode voltage to a reasonably safe value until the instrument is warmed up and in operation. These neon bulbs are available from your local electronic supply sources.

Procedure:

( ) 1. Remove the right and left side panels.

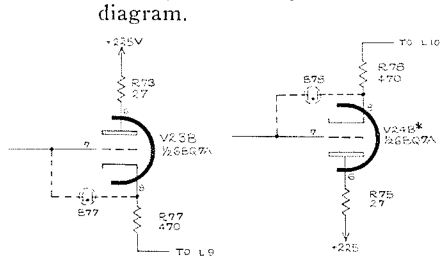
( ) 2. Locate V23 (6BQ7) near the center of the VA chassis.

( ) 3. Locate ceramic turret near V23 on which is mounted C31. This capacitor is a variable compression type which has large eyelets on both terminals.

( ) 4. Place the glass tip of one of the new neon bulbs in the lower hole of C31 so that the leads may be soldered to pins 7 and 8 of V23. Designate this neon bulb B77.

( ) 5. Locate V24 and repeat the procedure with the second neon bulb, placing the neon bulb tip in the corresponding eyelet of C28 and soldering the leads to pin 7 and 8 of V24. Designate this neon bulb B78.

( ) 6. Add the parts list to your instruction manual and add the neon bulb symbols to your schematics diagram.



* THE LEGEND IN THE INSTRUCTION MANUAL DIAGRAM FOR THE 524AD VERTICAL AMPLIFIER IS INCORRECT. IT SHOWS THIS TUBE AS V24A INSTEAD OF V24B.

USED INSTRUMENTS WANTED

1 Type 532/B	George Peterson The Aircraft Instrument Co. King of Prussia Rd. Radnor, Pa.
1 Type 512 or 514	Allen W. Kurtz International Electronics Mfg. Co. 515 East Grand Ave. Springfield, Ohio
1 Type 514 or 515	Patrick Close Westgate Laboratories Box 63 Yellow Springs, Ohio
1 Type 531 or 535 with B or C Plug-In Unit	Rex V. Johnson 39 Newell Avenue. Haddonfield, New Jersey
1 Type 531 or 535 or 541 or 545	O. Kienow 5813 E. 19th Street Tucson, Arizona

One of the engineers of Maico Co. would like a 3" scope for his basement lab. Tek, Minneapolis will act as go-between.

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AUGUST 1960

DOES THE SQUARE WAVE RESPONSE OF YOUR SCOPE LOOK LIKE THIS?

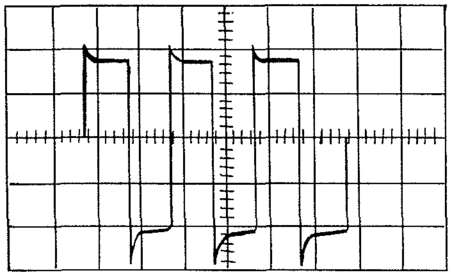


Fig. 1

OR LIKE THIS?

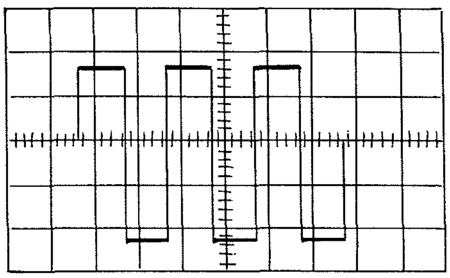


Fig. 2

Unless the squarewave response of your scope resembles the waveform shown in Fig. 2....better keep reading!

A condition known as cathode interface can gradually develop in the vertical amplifier tubes of any oscilloscope, causing degeneration of medium and low frequencies....leaving an overshoot on the leading edge of fast-rise (2 μsec or less) squarewaves (see Fig. 1).

Low frequency degeneration is caused by the series resistance (50 ohms or more) of an interface layer of chemical impurities that forms between cathode sleeve and the barium oxide cathode coating.

Leading edge overshoot is caused from the by-passing effect of the capacitance (.005μf or greater) between oxide coating and cathode sleeve.

NOTE: In a true sense, this is not a pure capacitance, as the electronic action within the interface layer (serving as the dielectric) is highly complex.

The rate at which an interface layer forms within a tube is a function of cathode temperature, number of hours the tube is used, average cathode current, and the amount of impurities originally present in the cathode sleeve material. For example, high cathode temperature, long hours of operation, a high percentage of impurities in the nickel used to make the cathode sleeve, and a low cathode current flow will hasten the formation of the impurities layer....in many tubes the time required is less than 500 hours.

However, a sizable current flow through the tube tends to minimize the effective formation of an interface layer by penetrating the accumulated impurities with random low resistance current paths (holes) between nickel sleeve and barium oxide coating.

Evidently, interface will manifest itself in any instrument employing vacuum tubes to either display or generate fast-rise square waves. We can assume that since a tube in operation can form an interface layer in less than 500 hours, instruments in operation 8 hours a day should be checked for evidence of this defect every 30 to 60 days, or at least every 500 hours of operation.

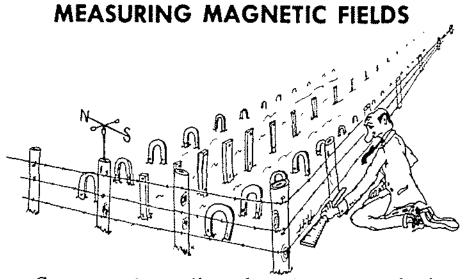
To check the vertical amplifier of an oscilloscope for indications of cathode interface, feed in a fast-rising square wave of about 500 kc. Set the sweep rate to display several cycles. If an overshoot of about ½ microsecond time constant is apparent, some of the vertical amplifier tubes have probably developed cathode interface. For absolute proof, plug the oscilloscope into an ac power source with a variable control. An increase in the output voltage of the power source will increase heater voltage and **reduce** overshoot caused by cathode interface. A decrease in the output voltage of the power source will decrease heater voltage and **increase** overshoot due to cathode interface.

The only cure for the problem caused by cathode interface is replacement of the offending tubes.

The entire instrument should be checked and recalibrated at least every six months. Only through periodic maintenance, can the full usefulness, accuracy, and dependability built into Tektronix oscilloscopes be realized.

Earl Anderson
Customer Service Staff
Tektronix, Inc.

MEASURING MAGNETIC FIELDS



Suggested reading for those people interested in the measuring of magnetic fields, is the article "Wavemeter, Oscilloscope Measure Magnetic Field By Paramagnetic Resonance". This informative article, which appeared in the December 1959 issue of ELECTRICAL DESIGN NEWS, claims an accuracy of ±0.06 percent in measuring the gap flux density of a magnet by the method described in the article. A further advantage claimed for this new technique over conventional methods is the speed with which these measurements can be made.

TYPE 502 TRIGGER AMPLIFIER TUBE PROTECTION

Here is a simple modification to protect the Type 502 trigger amplifier tube (V24) from high amplitude signals when used with external trigger input.

Locate R10, a 1-meg, ½-watt, 10% resistor. This resistor runs from ground to a point on the TRIGGER SELECTOR switch. From this point a wire strap connects to the PLUS-MINUS switch. Replace this strap with a 470-k, ½-w, 10% resistor shunted by a .001-μf, 500-v discap.

Type 502's with serial numbers above 623 do not require this change.

SUGGESTED READING

For an excellent discussion on the connection between bandwidth and frequency response, composition of rise-time and other details associated with square wave testing, see Vol. 18, Radiation Laboratory Series, "Vacuum Tube Amplifiers" (McGraw-Hill)

HOT SCOPE!

Tektronix Field Engineer Hal Dosch reports he has received word from Naval Intelligence that a Tektronix Type 515A Oscilloscope, S/N 3645 is missing from the U.S. Navy Electronics Laboratory at San Diego and has apparently been stolen.

If you should see this instrument, know of its whereabouts, or have any information regarding it, contact the nearest office of the Naval Intelligence Department immediately.

TYPE 536 AMPLIFIER MODIFICATION

A modification kit, to convert the type 5894 tubes in the Type 536 vertical and horizontal circuits to type 6340's is available. This conversion, which provides improved reliability and simplifies tube

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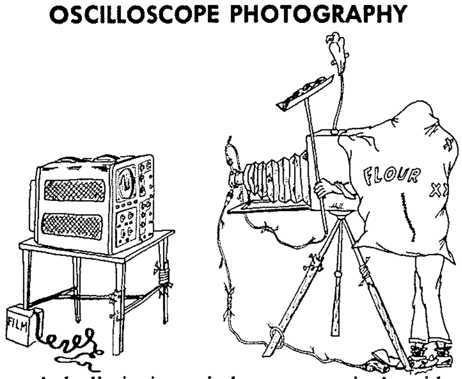
replacement, is applicable to instruments with serial numbers below 615. Instruments with serial numbers above 614 have been factory converted to use the type 6340 tubes. The kit contains: two wired tube socket mounting-plate assemblies, one step-by-step check-off instruction booklet with photos, schematic and parts list, all other components and hardware required in the conversion.

Ask your Tektronix Field Engineer for Type 536 VA-HA Tube Conversion Modification Kit No. 040-192.

OSCILLOSCOPE PHOTOGRAPHY



A bulletin intended as a practical guide to the photography of traces on the cathode-ray tube of Tektronix 5-inch oscilloscopes is available. This is a revised and up-dated edition of a former bulletin many oscilloscope users found helpful. Suggestions are offered and some of the topics discussed are: Polaroid-Land* films, exposure guides and how to photograph different types of traces.

Ask your Tektronix Field Engineer for FIP-3, "Notes on The Practical Photography of Oscilloscope Displays."

*Polaroid is a registered trademark of the Polaroid Corporation.

THIS 'N THAT

Occasionally the graticule studs on a Tektronix 5" oscilloscope work loose. You can replace these with a tapped stud

Ask your Tektronix Field Engineer for:

Tek No.	Description	Price
355-043	Replacement graticule stud	N/C
212-507	Screw, 10-32x3/8"BHS	N/C
210-010	Lockwasher	N/C

We do not recommend the operation of a Tektronix Plug-In Oscilloscope with the side panels removed. The fan will not distribute air properly to the plug-in preamplifier area when the side panels are not in place. Continued operation of the instrument under these conditions will decrease tube reliability.

Sometimes on the older Type 524 instruments it is difficult to time the .1 μsec/cm sweep range. Tektronix Field Engineer Hal Dosch offers this suggestion to correct the difficulty: Be sure the horizontal sweep amplifier is properly compensated. Then, if adjusting the variable capacitor C231A will not bring the .1 μsec/cm sweep into range, try reducing or shorting out R274. This 1.5-k, ½-w, 10% resistor is in series with C231A.

USED INSTRUMENTS WANTED

1 Type 524	Larry Hine 120 Elmwood Place Shearill, N. Y.
1 Type 310 or 310A	J. M. Gottschalk 108 Charles Drive B-2 Bryn Mawr, Penn.
1 Type 541 or 541A and CA Plug-in Unit	D. A. Nina Elion Instruments 701 Canal Street Bristol, Pa.
1 Type 515A or 503	Jack Holcomb MacLeod Instrument Corp. Micro-Dyne Division 4250 N.W. 10th Avenue Ft. Lauderdale, Fla. Phone: LO. 4-8518
1 Type 515 or 535/CA	Norm Haugen Communitronics 2012 Longwood Road West Palm Beach, Fla. Phone: TE. 3-8320
1 Type 530 Series or preferably 540 Series	John Sutherland 2706 21st Avenue S. Seattle, Wash.
1 Type 524	James Scharman Alvarado TV Co., Inc. Albuquerque, New Mexico
1 Type 514	H. L. Ziegler 275 Middle Street East Weymouth, Mass.
1 Type 511 or 514	Jim Williams 4424 Juniper Avenue Wichita 16, Kansas
1 Type 514	E. J. Crossen 81 Cherry Lane Levittown, Penn.
1 Type 514 or 531	Herbert L. Rosenblatt Dept. 694, Burroughs Corp. Great Valley Labs. Paoli Penn.
1 Type 514 or 531	H. Stuart Dodge Reliability Dept. Burroughs Corp. Great Valley Labs. Paoli, Penn.

USED INSTRUMENTS FOR SALE

2 Type 511AD S/N 3690 and 3692	C. W. Penque Sperry Products Co. Danbury, Conn.
1 Type 511A S/N 4544	Larry Garcey Electronic Transiston North Bergen, New Jersey
1 Type 515A S/N 2298	Gilbert Levy Semi-Con Electronics River Road Edgewater, New Jersey

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

TEKTRONIX

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

OCTOBER 1960

VERTICAL AMPLIFIER TUBE PROBLEM

The Type 541A, 543, 545A, 551, and 555 instruments use 6DK6 vacuum tubes in the distributed-amplifier section of their vertical-deflection circuits. Most 6DK6 tubes develop cathode interface after a few hundred hours of operation in these circuits. Tests made at our factory (and in the field) have shown that certain commercially-available 6DK6's, when used in these circuits, develop somewhat less cathode-interface resistance. If you are having trouble with one of the above instruments, we suggest a call to your local Tektronix Field Engineer. He will be glad to help you pin-point the trouble and suggest recommended corrective measures.

TYPE 535/545 DELAYING SWEEP-RANGE MODIFICATION KIT

The sweep delay available in a Type 535 or 545 oscilloscope can be increased one hundred fold. A modification that extends the upper limits of the sweep delay to 10 seconds (upper limit of original equipment is 0.1 second) is available in kit form. The desirable feature of continuous calibrated adjustment has been retained and any period of delay from 1.5 microsecond to 10 seconds can be accurately selected.

The modification is accomplished by replacing the standard 2 microsecond/cm to 10 millisecond/cm delaying-sweep range with a 3 microsecond/cm to 1 second/cm range.

This modification applies only to the Type 535 and Type 545 instruments—all serial numbers. The Types 535A and 545A instruments come equipped with a 2 microsecond/cm to 1 second/cm delaying-sweep range.

The modification kit contains a wired-switch assembly, step-by-step instructions, photos, schematic and parts list. Order through your Tektronix Field Office. Ask for Type 535/545 1 second/cm Delaying Sweep-Range Modification Kit, Tek number 040-179. Price is $30.00.

THIS'N THAT

In Tektronix instruments, a special silver-bearing solder establishes the bond to the ceramic terminal strips. Repeated use of ordinary solder or the application of too much heat will break this bond.

We recommend the use of a solder containing about 3% silver when soldering on Tektronix instruments. This type of solder is often used in printed circuitry and should be readily available from your local supply source. If you experience difficulty in obtaining this solder, it may be ordered through your Tektronix Field Office. Ask for Tektronix number 251-514 Solder, Silver Bearing 1# spool (3% silver). Price $4.50.

The fan motors of most Tektronix instruments should be oiled periodically (see the maintenance section of your instruction manual). A couple of drops on the end of a toothpick is sufficient. A good suggestion would be to oil the motor every time the air filter is cleaned. If the air cleaner is never cleaned, you can oil the new motor you install!

AN INEXPENSIVE COATING FOR WORK BENCH SURFACES

Jack Bannister, a Tektronix Field Maintenance Engineer, has sent in a suggestion for improving the surface of a work bench. He coated his bench top with an epoxy resin. In addition to being easy to keep clean, the resin wears away at a much slower rate than masonite and keeps one from gouging a hole in the work bench when turning instruments—especially the older square-cornered ones—over.

Jack first faced the front of his bench with wood to eliminate a metal rim and then put the resin over this wood also. The resin sticks well to masonite, wood, painted metal and plastic wood. Be sure the plastic wood is completely dry before the resin is applied, otherwise the resin tends to stay soft over it. The material to be covered should be clean and free of wax. All cigarette or soldering-iron burns should be sanded down to clean material—the resin doesn't want to stick to charred surfaces—and any holes, gouges, or indentations filled with plastic wood. Care should be used in this phase as the resin is clear, slightly amber in color and tends to accentuate any messy work. Work the resin in well. It has a tendency to not stick to the surface while it is liquid and working it into the surface helps to overcome this fault. Once dry it adheres very well. A quart provides a two coat finish for a 6' x 3' bench top and the completed surface will be smoother if you sand a bit between coats.

Surface coat, the desirable type of resin for this work, is made by several companies. Your supplier can provide you with measured amounts of resin and catalyst as well as a 2" inch brush to apply the coating. The brush should have a special resin-resistant glue to hold the bristles.

Cost of the resin, catalyst and brush to do Jack's job was $5.50.

SILICON RECTIFIER MOD KITS

Below is a partial list of the currently available silicon rectifier field modification kits. These kits replace the selenium rectifiers in the low-voltage power supply of some Tektronix instruments with the silicon type rectifiers. These more reliable rectifiers give longer service and the kits are designed to be installed with a minimum of effort.

Each kit contains a prewired chassis with silicon rectifiers mounted, step-by-step instructions, photos, schematic and parts list.

We strongly recommend that you place your order for these kits through your Tektronix Field Engineer. He can apply the special considerations necessary when ordering some of the kits and thus assure you speedy delivery of the correct kit for your instrument.

Type 310 Oscilloscope, all serial numbers below 7141. Order Tektronix Type 310 Silicon Rectifier Modification Kit, Tek number 040-195. Price: $40.00.

Type 513 Oscilloscope, all serial numbers. Order Tektronix Type 513 Silicon Rectifier Mod Kit, Tek number 040-211. Price: $30.00

Type 515 or 515A Oscilloscopes, serial numbers below 4030. Order Tektronix Type 515/515A Silicon Rectifier Mod Kit, Tek number 040-205. Price: $24.00.

Type RM15 Oscilloscope, serial numbers below 756. Order Tektronix Type RM15 Silicon Rectifier Mod Kit, Tek number 040-208. Price: $35.00.

Type 524 Oscilloscope. There are special considerations to be made when ordering a silicon rectifier for this instrument. Consult your Tektronix Field Engineer before placing your order.

Type 525 Television Waveform Monitor, serial numbers below 526. Order Tektronix Type 525 Silicon Rectifier Mod Kit, Tek number 040-207. Price: $28.00.

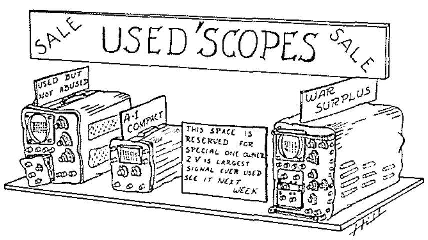
As previously stated, this is but a partial list of the available silicon rectifier modification kits. Contact your Tektronix Field Engineer for information on instruments not included in this list.

IMPROVED TRIGGERING LEVEL CONTROL WHEN TRIGGERING FROM EXTERNAL WAVEFORMS

The TRIGGERING LEVEL control of a Type 530 Series, a Type 540 Series, or a Type 551 Oscilloscope becomes extremely sensitive when the instrument is triggered externally from very low amplitude signals. To some, the ability to trigger reliably from these signals is important. More so than the ability to range through the positive or negative slope of relatively large signals. For these people, Tektronix Field Engineer, John Mulvey, suggests the following modification: Locate, on the TRIGGERING MODE-TRIGGER SLOPE switch a 56 k, ½ w, 10% resistor and a 0.001 μf, 500 v capacitor. These are designated on the Type 531, 535, 541, and 545 schematics as R19 and C17; on the Type 533, 543, and 551 schematics as R21 and C20; and on the Type 532 schematic as R319 and C317. Jumper the top of the resistor to the top of the capacitor. This reduces, by almost 10 to 1, the sensitivity of the TRIGGER LEVEL control to low-amplitude external signals. A switch can be wired in the jumper to allow the operator to select the correct triggering-level range for the external triggers being used.

This modification applies only to the instruments in the Type 530 and 540 Series and to the Type 551. The Type 531A, 535A, 541A, 545A, and 555 trigger reliably on external signals of from 0.2 v to 10 v.

USED INSTRUMENTS FOR SALE



1 Type 511AD Ser. #5160	Pennon Electronics, Inc. 7500 South Garfield Ave. Bell Gardens, California.
1 Type 513D Ser. #691	Bill Johnson Station W P C A-TV, Ch. 17 Mermaid Lane Philadelphia 18, Penn.
1 Type 531 Ser. #114 with 1 Type C Plug-In Unit Ser. #116 1 Type 53D Ser. #118	Dr. Harry Williams Pharmacology Department Emory University Atlanta, Georgia
1 Type 53/-54C Ser. #7414	Argonaut Attn: Ken Mollenauer 250 Middlefield Road Menlo Park, California.

INSTRUMENTS TO TRADE

1 Type 532 wants a Type 575	John Kimber Transitron Electronics Denver, Colorado

He is willing to pay some additional for the Type 575.

USED INSTRUMENTS WANTED

6 Type 514's or 524's	DeVry Technical Institute Brendan Hawkins 4141 W. Belmont Ave. Chicago, Ill.
1 Type 524 or any Tektronix Wide-Band (10 MC) scope	Robert Breed P. O. Box 372 Camden 1, New Jersey
1 Type 530 or 540 Series Price $300 to $400 (condition no object)	L.F. Gilbert Bailey Meter Company 1040 Ivanhoe Road Cleveland 10, Ohio
1 Type 517	Warren F. Stubbins University of Cincinnati Eden and Bethesda Ave. Cincinnati 21, Ohio

TROUBLE-SHOOTING HINT

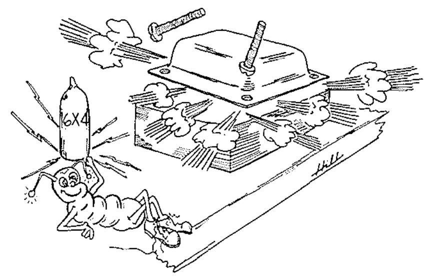
If you are troubled by an erratic triggering problem in your Type 316 Oscilloscope that has defied your efforts to correct it, you might consider the following information.

Tektronix Maintenance Engineer Joe Vistica, when confronted with this problem, determined that the trouble was caused by about 5 to 10 mv of 60 cycle ripple between the sub-panel and the sweep chassis. He eliminated the problem by removing the front panel and sub-panel and sanding the sub-panel, sweep chassis and vertical chassis at their points of contact with each other. Disassembly, sanding and reassembly required about 2½ hours. Joe says, "I am happy to report that after all this the instrument worked perfectly."

CORRECTION

A typographical error slipped past the "not so" eagle eye of your editor in the August issue of SERVICE SCOPE. In the article "Type 536 Amplifier Modification", the tube type number 6340 should read 6360.

TYPE 524D OR 524AD TRANSFORMER MODIFICATION KIT



Early models of the Type 524D and 524AD (instruments with serial numbers below 5729) used 6X4 rectifier tubes in their low-voltage power supply. An internal short developing in this tube could cause a current surge through the transformer that would damage the transformer and require its replacement. A fuse resistor can be installed in the plate leads of the 6X4 tubes to prevent this damage. A modification kit containing schematics, instructions and necessary components to make this installation is available. Ask your Tektronix Field Engineer for Type 524D or 524AD Transformer Protective Modification Kit, Tek number 040-196. There is no charge for this kit.

FLASH! HOT SCOPES!

We have just received word from the Bendix Computer Division of Bendix Aviation Corporation that Tektronix Type 310 Oscilloscopes have apparently been stolen from three of their field engineers. Instruments with serial numbers 10415 and 10867 disappeared from the Chicago area and one with serial number 11735 from the Kansas City, Missouri area. If you have any information on these instruments contact Harvey W. Renfeldt, Customer Engineering Computer Division, The Bendix Corporation, 5630 Arbor Vitae Street, Los Angeles 45, Calif.

Any Tektronix instrument offered for sale without a serial number or one that shows signs of attempts to alter or remove the serial number should be viewed with suspicion. If you have an instrument with these indications, contact your local Tektronix Field Office. In most instances there are ways to trace the instrument and determine if it has been stolen or not.

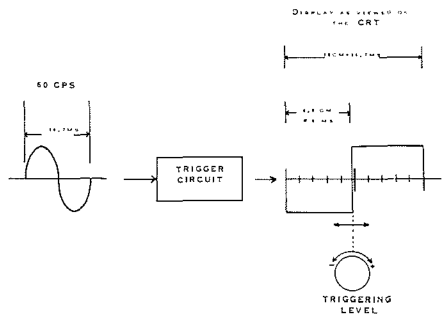
TEKTRONIX OPENS TWO NEW FIELD OFFICES

With the opening of two new field offices, the services offered by a Tektronix Field Office have been made more conveniently available to people in the Indianapolis, Indiana area and in the section of California composed of Santa Maria, Vandenberg Air Force Base and the San Fernando Valley areas. The office serving this California area is located in Encino.

The Indianapolis Office is located at 3937 North Keystone Avenue, Indianapolis 5, Indiana. The phone number is Liberty 6-2408 or 6-2409. At this location you can call on Tektronix Field Engineer Ted Anderson or Field Secretary Ann Dollars to avail yourself of the field services.

The Encino Office is located at 17418 Ventura Boulevard, Encino, California. A phone call to State 8-5170 will put you in touch with Tektronix Field Engineers Duncan Doane, Jim Cook, or Field Secretary Phyllis Worth. This staff will gladly assist you in matters pertaining to Tektronix instruments or services.

TIMING IN A "PINCH"



The following method may be used to adjust the sweep timing in any Tektronix oscilloscope which has a variable sweep-time control and triggering-level control. The oscilloscope itself is the only instrument used in making this adjustment.

The 60-cycle line frequency and the trigger circuit are used to establish a time reference. Set the TRIGGER SLOPE control to + or — LINE and the TRIGGERING MODE control to AC or DC. Using a probe, connect the output of the trigger circuit to the vertical input and set the TIME/CM and VARIABLE TIME/CM to display one cycle in 10 cm of graticule length (see Fig. 1). With the TRIGGERING LEVEL control, adjust the display until the first portion (negative half cycle) occupies 4.8 cm of graticule length (see Fig. 2). This establishes a time reference of 8 milliseconds.

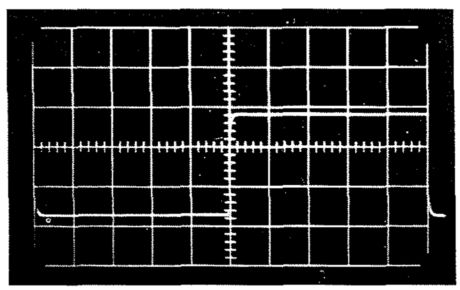


Figure 1

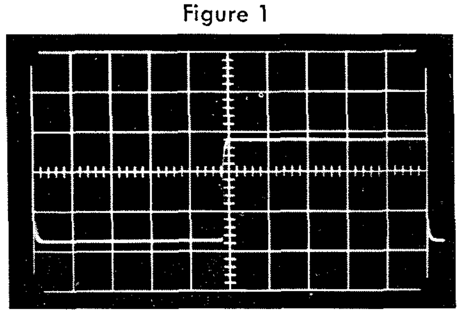


Figure 2

Now that the time reference has been set up, turn the VARIABLE TIME/CM to the CALIBRATED position, set the TIME/CM control to the 1 millisecond position and adjust SWP CAL control so that the first half cycle of the display covers 8 centimeters—between the 2nd and 9th vertical graticule lines (see Fig. 3).

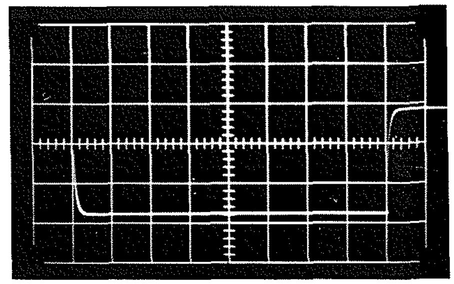


Figure 3

NOTE: This method is not recommended except in instances where an accurate time mark generator such as the Tektronix Type 180 is not available. See your Tektronix Field Engineer for a copy of the factory recommended calibration procedure.

Mike Nash
Customer Service Staff
Tektronix, Inc.

A HELPING HAND

Tektronix Field Engineers are in daily contact with users of cathode-ray oscilloscopes in almost all branches of industry and research. These contacts afford a continually varying experience in oscilloscope uses and applications. For help with an oscilloscope problem that has defied your efforts at solution or one that you feel may have a better solution, consult the Tektronix Field Engineer in your area. He is no farther away than your telephone and he may have the answer to your problem. In any event he will be happy to consult with you and show how to use Tektronix instruments to their fullest capabilities.

CHANGE IN STANDARD P2 PHOSPHOR

A new improved-type phosphor is now used in all Tektronix cathode-ray tubes calling for a P2 phosphor. This new Type P2 phosphor can be distinguished by its blue fluorescence. The older P2 phosphor, as you will recall, fluoresced green.

The primary reason for the phosphor change was to improve the writing rate of the tubes. The new P2 phosphor has a writing rate approximately 75% that of the P11.

Even though the new Type P2 phosphor decays to 10% of full brightness in only 2 milliseconds (compared to about 100 milliseconds for the old type), the long-term persistence components of the two types have nearly the same energy. Futhermore, the brightness of the new phosphor is much better than the old.

There are two peaks in spectral response of the new phosphor. A major peak occurs at 5300 Angstrom units (0.5300 micron) and a minor peak occurs at 4500 Angstrom units (0.4500 microns).

One other desirable characteristic of the new phosphor: it has distinct advantages for oscilloscope photography.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

USERS OF TEKTRONIX INSTRUMENTS

USEFUL INFORMATION FOR

Service Scope

Tektronix, Inc., P.O. Box 500 Beaverton, Oregon

Telephone: MItchell 4-0161 TWX—BEAV 311 Cable: TEKTRONIX

AN OREGON CORPORATION

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***ALSO REPAIR CENTERS**

A-2045

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

DECEMBER 1960

PRINTED IN U. S. A.

TIMING THE TYPE 530A/540A SERIES OSCILLOSCOPES

Here is a procedure that will save the technician, generally familiar with the Type 530A/540A Series Oscilloscopes, considerable time when calibrating the sweep circuits of these instruments. This procedure is not recommended for the technician attempting such calibration for the first time. Technicians in this category will do well to adhere to the instructions as outlined in the factory recommended calibration procedure, copies of which can be obtained through your Tektronix Field Engineer.

This procedure requires the use of a Tektronix Type 180A Time-Mark Generator or any other frequency generator accurate to within 1%. Remember, while timing, position top of marks near the graticule horizontal center line and focus carefully.

Mechanically presetting of the controls as shown in the sketch is the key to saving time in this shortcut procedure. Positions of the controls after final adjustment will not vary appreciably from those shown in the diagram unless tubes or other components are not up to standard. Substandard tubes or components should be located and replaced.

The sketch as shown looks into the instrument with the side panel removed and from a position to the right and slightly above the instrument.

After setting the SWP. CAL. and MAG. GAIN in the normal manner, mechanically preset the identified controls as shown in the sketch. See Fig. 1.

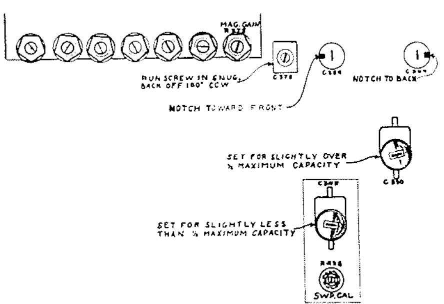


Fig. 1.

Step 1 Set the TIME/CM switch to .1 millisec/cm, 5X MAGNIFIER to ON. Apply 10 μsec markers to the VERTICAL INPUT. Place first mark near the center vertical graticule line. Rotate the TIME/CM switch between the .1 millisec and the 50 μsec positions and adjust C330 for no shift of the start of sweep.

Step 2 Set 5X MAGNIFIER to OFF, TIME/CM switch to 10 μsec/cm. Apply 10 μsec markers to VERTICAL INPUT. Position start of sweep on first vertical graticule line and adjust C160E for one mark per centimeter between the second and tenth vertical graticule lines, (disregard the first and tenth centimeter divisions). See Fig. 2.

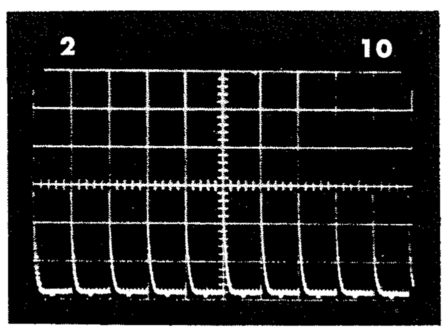


Fig 2.

Step 3 Set TIME/CM switch to 1 μsec/cm. Apply 1 μsec markers to the VERTICAL INPUT and adjust C160C for one mark per cm between the second and tenth vertical graticule lines.

Step 4 Set TIME/CM switch to .5 μsec/cm. Apply 1 μsec markers to VERTICAL INPUT. Adjust C160A for 1 mark per 2 cm using the third and ninth vertical graticule lines. See Fig. 3.

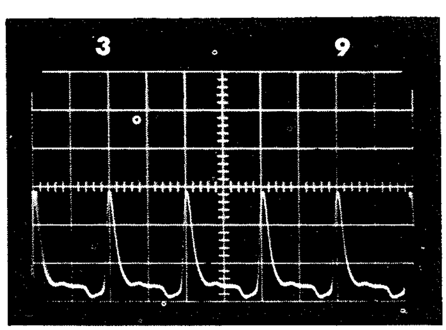


Fig. 3.

Step 5 Set TIME/CM switch to .1 μsec/cm. Apply a 10 mc sine wave to VERTICAL INPUT. Apply 10 μsec markers to the TRIGGER INPUT. Set TRIGGER SLOPE switch to + or — EXT. Adjust C348 for one cycle per cm between the second and tenth vertical graticule lines (C375 should not be adjusted at this time).

Step 6 Set TIME/CM switch to .5 μsec/cm. Apply a 50 mc sine wave to VERTICAL INPUT. Apply 10 μsec markers to the TRIGGER INPUT. Set TRIGGER SLOPE to + or — EXT. Place start of trace on first vertical graticule line. Turn 5X MAGNIFIER to ON. Adjust C384 for maximum space between cycles of the display. Now adjust C364 precisely for one cycle per cm between the second and tenth vertical graticule lines. If timing will not adjust precisely, reverse the order of adjustment of C384 and C364 above. If this does not allow accurate timing, interchange the two horizontal-output 6DJ8 tubes. As a last resort try replacing **one at a time** the 6DJ8 output tubes. If the instrument still will not come into adjustment, refer to the trouble shooting section of the particular instrument's instruction manual.

Step 7 Using the HORIZONTAL POSITION control, place the "fifth cycle in" from the left hand side of the trace on the second vertical graticule line and observe the timing between the second and tenth vertical graticule lines. Tolerance is 3%. Check the right hand side of the sweep in the same manner using the "fifth from last cycle" and placing it on the tenth vertical graticule line.

This procedure is used to good advantage by the Field Training and Customer Training Department here at the factory in their training course. We are indebted to Tom Smith of this department for the procedure and for his assistance in bringing it to you.

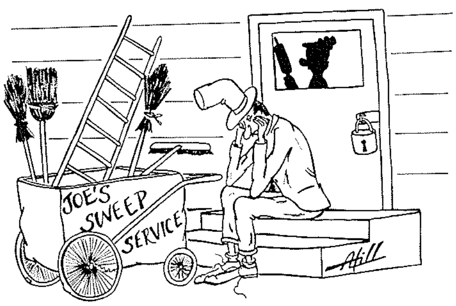
TYPE 517 SWEEP LOCKOUT MODIFICATION KIT

The Sweep Lockout feature, standard on all Type 517A Oscilloscopes, can be added to your older model Type 517 instruments. Installation of the Type 517 Sweep Lockout Modification Kit will accomplish this. This feature makes possible the study of one-shot phenomena with the Type 517 Oscilloscopes. All Type 517 instruments with serial numbers above 926 will accept this modification. Type 517 instruments below serial number 926 require the installation of another modification (Duty Cycle Limiter Mod*) before the Type 517 Sweep Lockout Modification can be installed.

The Type 517 Sweep Lockout Mod Kit contains the necessary components, wired chassis, step-by-step instructions, schematic, photos and parts list.

Order from your Tektronix Field Office or Engineer. Specify Type 517 Sweep Lockout Mod Kit, Tek number 040-203. Price is $45.00.

* To obtain this kit, order Type 517 Duty Cycle Limiter Field Mod Kit, Tek number 040-107. Price is $10.00.



TYPE 502 SWEEP LOCKOUT MODIFICATION KIT

Your Type 502 (all serial numbers) can be modified for the study of one-shot phenomena by installation of a Type 502 Sweep Lockout Mod Kit.

The Sweep Lockout feature permits you to arm the sweep to fire on the next trigger to arrive. After firing once, the sweep is locked out and cannot fire again until rearmed by pressing a RESET button.

The modification kit converts your Type 502 Oscilloscope for this type of operation and retains the original features of the instrument. The kit includes a wired chassis assembly, new panel, necessary components, photo, schematic, step-by-step instructions and parts list.

Order from your Tektronix Field Office or Engineer. Specify Type 502 Sweep Lockout Mod Kit, Tek number 040-209. Price is $45.00.

IMPORTANT: Give serial number of your instrument so new panel can be numbered at factory.

TYPE 575 COLLECTOR CURRENT MULTIPLIER MODIFICATION KIT

This modification increases the current range of the vertical axis of the early models (serial numbers below 862) Type 575 Transistor Curve Tracer. The addition of a X-2 and a X-0.1 push button Collector Current Multiplier controls provides a means of multiplying by 2 or dividing by 10 the 24 calibrated steps of the Vertical Current or Voltage/Division switch. This increases the current range of the switch from 1000 — 0.01 ma per division to 2000 — 0.001 ma per division.

Included in the modification kit is a .8 amp circuit breaker to replace the 1 amp fuse in the collector sweep, a wired Collector Current per Division switch, step-by-step instructions for drilling the front panel and for installation of the switch and other parts, and a parts list.

Order from your Tektronix Field Office or Engineer. Specify Type 575 Collector Current Multiplier Mod Kit, Tek number 040-197. Price is $35.00.

AN ENVIABLE PERFORMANCE RECORD

Recently, we received a report from Tektronix Field Engineer Howard King attesting to a remarkable reliability performance by eight Type 502 Oscilloscopes. These instruments are a permanent part of the Bevatron control system at the University of California Radiation Laboratory. Here they are subjected to a periodic maintenance inspection and a thorough recalibration every six months. Except for the time required to make these inspections and recalibrations, these instruments have been in continuous operation since their installation in March of 1959. The group in charge of this installation has kept very complete maintenance and failure charts. A check of these charts reveals a truly phenomenal record—only 14 failures in a total of almost 100,000 hours of operation. All except two failures were from tubes. Of these exceptions, one was from a defective high voltage transformer, the other from a shorted lead to a tube socket.

QUESTIONS FROM THE FIELD

1. Q. How much can be cut from the cable of the standard P410 probe before running into trouble?

A. A couple of inches can be cut from the standard P410 cable before overshoot is seen with critical eyes. About four inches can be cut from the eight-foot cable.

2. Q. What is the purpose of the small plastic board, containing four adjustable coils, located in the Type 551 upper beam-vertical amplifier? Why is it sometimes left unconnected?

A. Normal manufacturing tolerances will sometimes result in a slight delay between vertical amplifiers. These additional coils compensate for this delay and thus offer superior beam registration. Often it is not necessary to use the additional delay.

3. Q. On a Type 517 where is a likely place to look for stray pickup?

A. A likely place for this is a poor ground connection. This can occur between the grounded portion of the coax input connector and the pre-amplifier sub-chassis. When checking for pickup, the preamp grids should be shorted as close to the tube as possible. This will eliminate pickup between the input connectors and the grids.

4. Q. Can the Collector Sweep of a Type 575 be modified to provide a plus and minus voltage, automatically switched, for viewing symmetrical zenner diodes?

A. Yes; this can be accomplished by shorting out one of the power diodes in the collector sweep and disconnecting the opposite diodes. This will give a sine wave at the C terminal.

5. Q. On the RM16, what causes the .02-v/div. position to sometimes seem under compensated while the 0.2-v/div. is OK?

A. C545, a 500-mfd cathode by-pass capacitor, has a mechanical ground through its case. A poor ground connection here can cause apparent under compensation of the .02-v/div. setting.

6. Q. Can the Type 310 Oscilloscope (60 to 800 cycle power supply) be operated on 50 cycle for short periods? If so, how long would external fan cooling help?

A. We strongly recommend against using the 60 to 800 cycle Type 310 on 50 cycles. Gordon Sloat, of our Transformer Department, says this is equivalent to operating the primary at 145 volts, 60 cycles. External-fan cooling wouldn't help much as heat builds up fast inside the transformer.

7. Q. We have a Type 545A which keeps blowing fuses as soon as the instrument is turned on. Investigation has not revealed a short. Have you any solution to this problem?

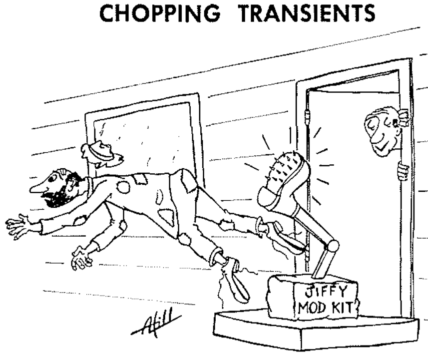
A. Check the silicon rectifiers. Perhaps you have one that has shorted. Because the opposite diode is good, a four-ohm short circuit appears across the winding on one half of the cycle only. The defective diode fuses open completely or becomes intermittently shorted and open. The opposite diode should also be changed since it would be damaged by the high short-circuit current. Either diode could become intermittent if one shorts out.

8. Q. We have run into some oscillation problems in checking 500-megacycle-type transistors on the Type 575. Are there any other tricks besides the use of ferrite beads to eliminate or minimize these oscillations?

A. Here are two other possible solutions to the problem:

   1. Place a small series RC between collector and emitter at the panel socket. Approximate values of 47 pf and 82 ohms seem to do the job with very little effect on the desired curve. The same RC connected from emitter to ground also does the trick for some transistors.
   2. The simplest method is to plug another transistor into the unused socket. However, this solution doesn't work every time. The dummy transistor need not be a mate to the one being checked.

MODIFICATION KIT FOR BLANKING CHOPPING TRANSIENTS



This modification applies to the Type 531, 535, 541, 545, RM31, RM35, RM41 and RM45 Oscilloscopes. When a Type 53C, Type 53/54C or Type CA Dual Trace Plug-In Unit is operated in its chopped mode with these instruments, transients appear with the trace. If you find these transients objectionable, you can eliminate them by the installation of a modification kit.

This modification supplies a blanking voltage that can be applied to the crt cathode (by means of a switch) when a dual-trace plug-in unit is operated in its chopped mode.

The mod kit includes a complete set of components, parts list, schematic, photos and step-by-step instructions. Please order through your Tektronix Field Office or Engineer by the following description:

For Type 531, 535, 541 and 545 Oscilloscopes, serial numbers 101 through 4999, specify Type 530/540 Series Chopping-Transient-Blanking Mod Kit, Tek number 040-200. Price is $5.25.

For Type 531, 535, 541 and 545 Oscilloscopes, serial numbers 5000 and up, and Type RM31, RM35, RM41 and RM45 Oscilloscopes, all serial numbers, specify Tek number 040-198. Price is $5.25.

TYPE 162 WAVEFORM GENERATOR SOLVES SINGLE SHOT UNBLANKING PROBLEM

A customer, using a Type 536 Oscilloscope to plot plate current against plate voltage in a diode, was having difficulty. He was using a hand-operated mercury switch to pulse the diode. Because of the single shot type of operation plus the fact that the Type 536 has no unblanking for this type of operation, the crt beam was standing in one spot most of the time. A photograph taken under these conditions was worthless. The brightness of the spot completely wiped out the desired information in the trace.

This customer had recently received a Type 162 Waveform Generator. A feature of this instrument is that one of the output waveforms is a 50-volt pulse gate. Tektronix Field Engineer Bill Carter suggested to the customer that he trigger the Type 162 with either the current or voltage waveform of the diode and then use the 50-volt pulse gate of the Type 162 to unblank the Type 536 during the trace period. The duration of the gate pulse could be adjusted for the proper amount of unblanking time by varying the sweep rate of the Type 162.

The customer called Bill the next day and expressed his gratitude saying that this was the only method that had worked on his problem.

TRANSISTORIZED CIRCUITRY

If you are interested in transistorized circuitry, you will probably enjoy the article "Battery-Operated Transistor Oscilloscope". This article appeared in the March 18, 1960 issue of ELECTRONICS, a trade magazine devoted to the electronic industry and published by the McGraw-Hill Publishing Company.

Oz Svehaug, Project Design Engineer for the Tektronix Type 321 Transitorized Oscilloscope, and John R. Kobbe, Chief Circuit Design Engineer for Tektronix, co-authored the article. Several circuits of the Type 321 are briefly discussed and schematics of some are included in the article.

If you do not have a copy of the March 18, 1960 issue of Electronics, suggested sources are your firm's technical library or the local community library. Reprints of articles are generally available from the magazine publisher, in this case the McGraw-Hill Publishing Company, Inc., 330 W. 42nd Street, New York 36, New York.

DOES CONTINUOUS OPERATION OF ELECTRONIC-TUBE EQUIPMENT REDUCE THE INCIDENCE OF TUBE FAILURE?

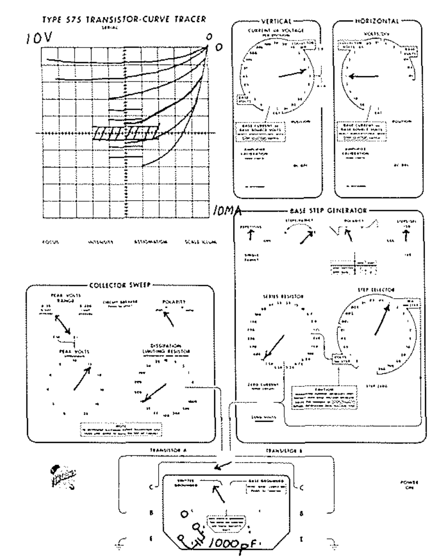
Andy Jackson, Chief Engineer for Station WAVY, Tidewater Teleradio Inc., Portsmouth, Virginia, evidently believes that it does. He told Tektronix Field Engineer Eb Von Clemm that the control equipment at station WAVY is never turned off except for major repairs. Since this equipment has been on this continuous-operation basis, monthly tube expenditures have shown a marked decrease. Mr. Jackson has collected some rather convincing cost data. Before WAVY instituted their 24-hour operation policy, their equipment contained a total of 3200 tube sockets. Tube-replacement costs for this equipment fell between $1500 and $1800 per month. Since these figures were gathered, WAVY has added additional equipment that has increased the tube socket total to 5500. In spite of this increase in tube sockets, tube-replacement costs under the continuous-operation plan have been reduced to an average of around $900 per month. Although the tube replacement potential was increased by 75%, actual tube-replacement costs were reduced up to 50%. Mr. Jackson says he feels that their policy of 24-hour operation was a big factor in this tube-replacement cost reduction.

It would be interesting to know our readers' opinions on this question. Why not drop us a line giving your answer to this question and the reasons for your stand? We will try to evaluate the answers, determine the consensus and publish the results in a future issue of SERVICE SCOPE.

Addess your answers to Walt Dederick, Editor, SERVICE SCOPE, Tektronix Inc., P. O. Box 500, Beaverton, Oregon.

TEST-SETUP CHARTS AVAILABLE FOR FOUR INSTRUMENTS

TYPE 575 TEST SET-UP CHART



COMPONENT: 2N700 151-027

TESTING: BETA SEGREGATION

PROCEDURE: USE SPECIAL SOCKET WITH BY-PASSED BASE LEAD

Test-Setup charts are now available for the Type 502, 503, and 545A Oscilloscopes and the Type 575 Transistor Curve Tracer. The charts provide a ready means of recording instrument control settings for any given test or production setup. A facsimile of the trace resulting from the setup can be drawn on the chart graticule or a photograph of the waveform attached to the chart.

For production testing, an engineer devises the test procedure required to attain the desired result. He then designates the control settings on the chart and draws a picture of the display on the chart graticule, outlining the limits for acceptance or rejection. (If desired, separate instrument graticules for each test can be marked with colored lines or tapes). The production-test facility takes over at this point and performs the test operation with speed and accuracy. Often a non-technical employee can handle this phase and release a highly trained person for more important work.

Your Tektronix Field Engineer will be glad to give you more detailed information on the Test-Setup charts and their uses.

TYPE 575 TEST-SETUP CHART PROVES ITS WORTH

During a recent demonstration on the Type 575 Transistor Curve Tracer, one of the engineers in attendance remarked that engineers could operate the unit without any trouble, but what about the

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Beaverton, Oregon

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

girls on the line who would be making incoming inspection of transistors? They are all non-technical people. Will they be able to set up and use the Type 575 in their inspection routine?

Tektronix Field Engineer Harvey Worth, who was presenting the demonstration, suggested that one of the girls on the line be brought in. He explained that he felt sure that within five minutes she could set up the instrument from a Test-Setup chart.

Accordingly, one of the girls was brought in and given a previously prepared Test-Setup chart. With very little instruction, she set up the Type 575 and, to the complete satisfaction of the observing engineers, made the incoming inspection check.

USED INSTRUMENTS WANTED

1 Type 531 or preferably Type 533	Russel Jensen 223 E. Dean Ave. Madison 4, Wis.
1 Any Tektronix Scope	Christy Laboratories Mr. Kazarlan 118 St. Clair Cleveland 14, Ohio
1 Type 511, 514 or 524	Carl Smith 5449 Culver Indianapolis, Ind.
1 Type 315D or Type 514	Palo Alto Engineering Co. C. J. Biggerstaff 620 Page Mill Road Palo Alto, Calif.
1 Type 535 or 545	John T. Campbell, III 7906 Pickering St. Philadelphia 50, Pa.
1 Type 535 with Type 53/54C Plug-In Unit (Approx. $800)	John West Tektronix, Inc. 1122 Main Street Stamford, Conn.

USED INSTRUMENTS FOR SALE

1 Type 545A with Type CA Plug-In Unit 1 Type 130 L-C Meter	P. J. Gentile Vamco Machine & Tool, Inc. 2 Sedgwich Street Pittsburgh 9, Pa. Phone TAylor 1-6000
1 Type 524AD	Allan T. Powley Chief Engineer WMAL, WMAL-TV The Evening Star Bcstg. Co. 4461 Connecticut Ave., N.W. Washington 8, D.C.
1 Type 570 s/n 336	Corbett Electronics Henry Corbett 2014 S.W. Jefferson Street Portland, Oregon
2 Type 514D s/n's 2143 and 2144 1 Type 511AD s/n 1375 2 Type 514AD s/n's 4874 and 4895	Cornell University Joe Sanford Lab of Nuclear Studies Ithaca, N. Y.
1 Type 310A s/n 10089	Digitronics, Inc. Mr. Targia Albertson Ave. Albertson, L.I., N.Y.
1 Type 511 s/n 1751	Fred Pack Technical Materiel Corp. 700 Fenimore Road Mamaroneck, N.Y.
1 Type 53/54E (will trade)	Eldema Corporation Dwayne MacDonald 1805 Belcroft Elmonte, California

ANOTHER "HOT" SCOPE

Our Chicago office reports the loss of a Type 321, s/n 200, Transistorized Oscilloscope. This instrument disappeared from a group of instruments waiting to be returned to the Chicago office after the recent N.E.C. show in Chicago.

If you see this instrument or have any information regarding its whereabouts, please contact your Tektronix Field Office or Engineer, or call the factory collect at Beaverton, Oregon. The phone number is MItchell 4-0161. Ask for Walt Dederick.

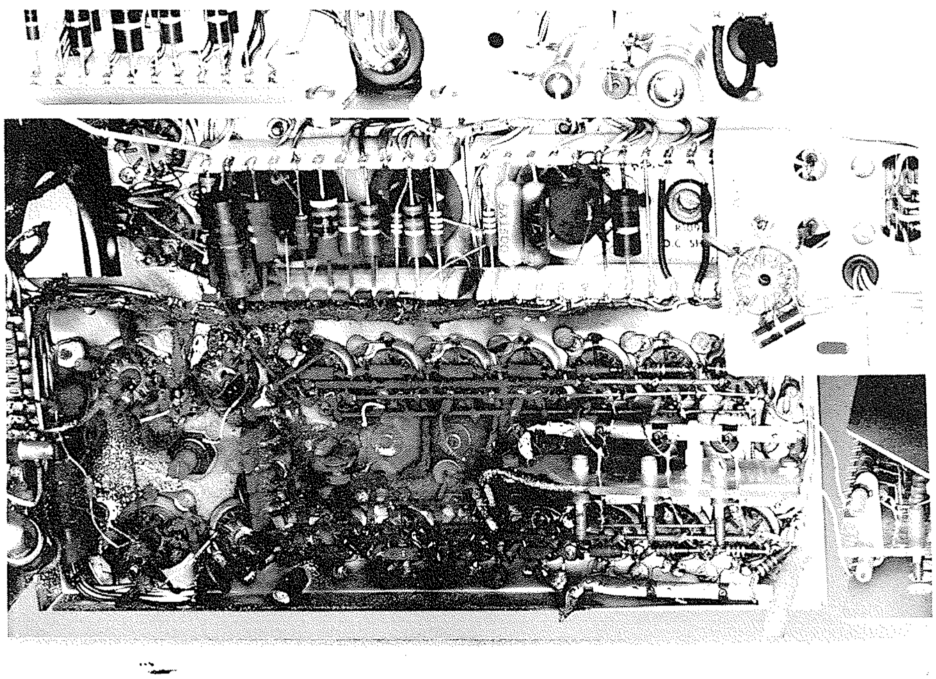
Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

TEKTRONIX

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 6 PRINTED IN U.S.A FEBRUARY 1961



Damage caused in the distribution amplifier of a Type 545A Oscilloscope as a result of a shorted crt lead.

NOTICE! IMPORTANT INFORMATION

A seriously damaged distributed amplifier CAN occur in any of the following oscilloscopes:

Type 541, all serial numbers above 6565
Type RM41, all serial numbers above 111
Type 545, all serial numbers above 9720
Type RM45, all serial numbers above 132
Type 541A, all serial numbers
Type RM41A, all serial numbers
Type 543, all serial numbers
Type RM43 all serial numbers
Type 545A, all serial numbers
Type RM45A, all serial numbers
Type 551, all serial numbers
Type 555 all serial numbers

In these instruments, certain types of short circuits (such as a crt lead becoming disconnected and shorting to ground) will cause the terminating resistor to burn. Secondary effects caused by the burning of these resistors can result in extensive damage as shown in the picture above. Repairs in such an event are costly, both in money and down-time for the instrument. This is indeed a regretable situation, but one that only time and experience in the field with the instrument could have brought to light. Since becoming aware of the difficulty, we have developed a field modification kit that protects the distributed amplifier from damage due the these short circuits. We offer this modification kit free of charge.

We earnestly recommend that owners of these instruments consider the installation of this modification a must.

Order the modification kit through your Tektronix Field Engineer. For Type 551 and Type 555 Oscilloscopes, order: Field Modification Kit—"Fuse for Protection of the Distributed Amplifier", Tek number 040-226.

For all other instruments listed above, order: Field Modification Kit—"Fuse for Protection of the Distributed Amplifier", Tek number 040-227.

Immediate steps are being taken at Tektronix plants to incorporate this modification in all affected production instruments. The Type of oscilloscope and the serial number at which the modification become effective will be announced in a future issue of SERVICE SCOPE. For the present, please consult your Tektronix Field Engineer to determine if instruments you have on order or have recently received are affected by this notice.

TYPE 530/540 OR TYPE 530A/540A SERIES OSCILLOSCOPES AND COMPOSITE VIDEO SIGNALS

Part I

Several TV Broadcast Studios have been using Type 530/540 or Type 530A/540A Oscilloscopes and trying to trigger on a nonintegrated composite video signal. There are three different pulse trains, all very close in amplitude, at the start of a composite video signal. Most oscilloscopes, when presented with this signal, will try to trigger on each pulse of the three trains. The result is an unstable display.

Television engineers generally will prefer the Type 524AD over other oscilloscopes for viewing the composite video signal. This instrument, specifically designed for television broadcast studio requirements, contains carefully planned trigger separator and sync separator circuits that enable the instrument to trigger reliably on composite video signals. It also provides other characteristics desirable for the maintenance and adjustment of television transmitter and studio equipment. The Type 524AD enables the engineer to observe any portion of the television picture—from complete frames to small portions of individual lines.

However, the Type 530/540 or 530A/540A Series Oscilloscopes give usable results if an integrator circuit is employed. A suitable integrator circuit consists of a 10 k resistor and a 0.01 μfd capacitor.

To use this circuit with these instruments, patch the VERT SIG OUT of the oscilloscope to the TRIGGER INPUT via the integrator circuit.

For the Type 531, 532, 533, 541, and 543 or Type 531A, and 541A proceed as follows:

Step 1. Use a wide band Plug-In Preamplifier in the oscilloscope and apply the composite video signal to the INPUT. Adjust the VOLTS/CM to give 3 or 4 centimeters of vertical deflection.

Step 2. Patch the VERT SIG OUT to the TRIGGER INPUT via the integrator circuit. See fig. 1.

Step 3. Set the TIME/CM switch to 5 MILLISEC.

Step 4. Set the TRIGGER SLOPE switch to −EXT for negative-going signals or +EXT for positive-going signals and the TRIGGER MODE switch to AC or AC SLOW.

Step 5. Turn the STABILITY and

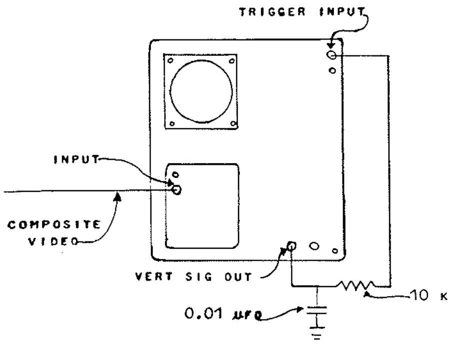


FIG. 1

TRIGGERING LEVEL controls full right.

Step 6. Turn the STABILITY control to the left until the sweep ceases to operate. Continue to turn the control to the left for several more degrees.

Step 7. Turn the TRIGGERING LEVEL control to the left until a stable display is obtained.

On instruments for which this procedure is intended, the operator can view either a field or line presentation. Limitations of these instruments, however, will not permit the operator to select the line to be presented.

Editors note: Part II of this article will appear in the next (April) issue of SERVICE SCOPE. The procedure for viewing composite video signals on the Type 535, 545, 535A, and 545A will be given at that time.

HELP IN USING AND UNDERSTANDING YOUR TYPE 535A OR TYPE 545A OSCILLOSCOPE

The Type 535A and Type 545A Oscilloscopes are extremely versatile instruments. To fully utilize their capabilities, an operator must be completely familiar with each control and its function. The new operator, the partially informed operator, or even the experienced operator will find the booklet "Using Your Oscilloscope Type 535A or Type 545A" a great aid in acquiring this desired degree of familiarity with these instruments.

This booklet is a revised and up-dated version of one originally written for operators of the old Type 535 and Type 545 instruments*. It is written in two parts. Part 1, "Getting Acquainted", describes the effect of each front-panel control, explains in detail the unique Tektronix features: Delayed Trigger, Delayed Sweep and Single Sweep modes of operation (that give to these instruments their high degree of flexible versatility), and outlines some of the more frequently encountered oscilloscope operations.

Part 2 of the booklet includes the information in the "Getting Acquainted" section, in condensed form for easy reference, plus simple, easily-understood instructions on other applications of the oscilloscopes.

To obtain a copy of this booklet, ask your Tektronix Field Engineer for FIP-8 "Using Your Oscilloscope Type 535A or Type 545A".

*A limited number of the booklets for the Type 535 and Type 545 are still available. Ask your Tektronix Field Engineer for FIP-1, "Using Your Type 535 or Type 545 Oscilloscope.

TEKTRONIX FIELD MAINTENANCE FACILITIES AND SERVICES

The Field Maintenance Facilities and Services available through your Tektronix Field Engineer are described in a recently published booklet. Also in the booklet are some pictures of a typical maintenance facility and a map of the United States showing the location of Tektronix Field Offices. Those Field Offices having a Repair Center are identified and they, their addresses and telephone numbers are listed for ready reference.

For your copy just call your Tektronix Field Engineer and ask him for the Field Maintenance Facilities and Services booklet.

QUESTIONS FROM THE FIELD

1. Q. What is the risetime of the P500CF Probe?

   A. We used the following equipment: a Type 545A Oscilloscope with Type K Plug-In (Passband of this combination was 30.5 mc), a Type 108 Fast-Rise Mercury Pulser, and a P500CF Probe. Risetime figures obtained under these conditions were as follows:

   P500CF (with no attenuation) 13.0 nsec.
   P500CF (with 10X attenuator) 17.5 nsec.

2. Q. Do you have any drift figures on the Type 503 Oscilloscope?

   A. We have never quoted any drift specifications for the Type 503. However, we ran some checks on ten production Type 503's. After an initial warm-up period to allow the instruments to stabilize, the following drift figures were recorded at a sensitivity of 1 mv/cm. Remember, these are only typical figures and are not to be considered drift specifications for the Type 503.

   Average drift 1.5 cm/hr.
   Minimum drift 0.5 cm/hr.
   Maximum drift 3.0 cm/hr.

   The input 6DJ8's have the greatest effect on drift. Also, the two 2N544 transistors designated Q454 and Q464 in the vertical amplifier affect the drift.

3. Q. In the Type 580 Series Oscilloscopes can a signal be connected directly to the vertical deflection plates of the CRT?

   A. According to Vaughn Weidel (Engineering), we have not developed an acceptable method for inserting signals directly into the vertical deflection plates of the crts in these instruments. The problem is to match the signal source to the approximate 900-ohm impedance of the distributed plates. If any matching device such as a transformer is used, much ringing and distortion occurs.

4. Q. Can you suggest a device for coupling the output of a sine-wave or square-wave generator to the P6016 Current Probe when testing the passband or square wave response of the probe?

   A. A 1½" piece of No. 18 solid wire, formed into a question mark, in series with a small 50 Ω—1% resistor and soldered to a female uhf connector will do the trick. (See fig. 2). This test jig has a VSWR

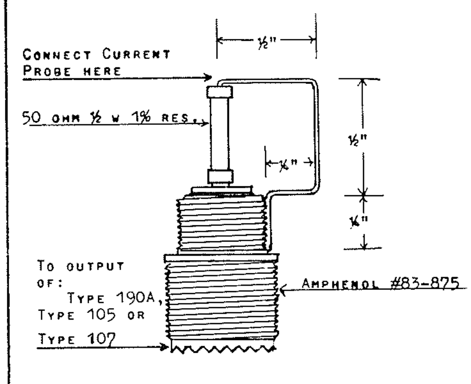


Fig. 2

   of 1.05 at 20 mc and can be used with a Tektronix Type 190A Constant Amplitude Signal Generator for passband response, and a Type 105 or Type 107 Square Wave Generator for square wave response.

5. Q. We have noticed a spurious pulse on a Type 575 Transistor-Curve Tracer. This is a positive pulse which occurs between each normal cycle for P-N-P transistors). The pulse length is about 5 milliseconds and about 4 volts in amplitude when the base current is set for 1 milliampere per step. Could this pulse damage transistors having a low reverse rating between base and emitter? If so, how can it be eliminated?

   A. The transistor is driven from a constant-current source. If the Step Zero is set so that the first base step occurs when the transistor is cut off, the maximum voltage capabilities of the Base Step Generator will be present at the base terminal of the transistor under test. Since the first step current is limited to the scale setting, there is small chance of damage to the transistor under test. The Step Zero control can be set to eliminate this pulse if desired.

6. Q. Can a Type 502 Dual-Beam Oscilloscope be modified to provide variable controls on the vertical amplifiers?

   A. Yes, a field modification kit is available to accomplish this. The kit adds a VARIABLE VOLTS/CM control to the front panel for both the UPPER and LOWER beam vertical amplifiers. It includes a complete set of components, parts list, schematic, photos, and step-by-step installation instructions. Order the kit from your Tektronix Field Office. Specifiy; Type 502 Variable Volts/cm Mod. Kit, Tek part number 040-222. The price is $10.50.

USED INSTRUMENTS FOR SALE

1 Type 315 s/n 198 2 Type 512 s/n's 1817 & 2717	Eric Vaughan Superior Electric Co. 83 Laurel Street Bristol, Connecticut
1 Type 524	Boco Wu Livingstone, New Jersey Tel. Wy 2-4790
1 Type 514D s/n 2615	Walt Jannsons Isomet Corporation Palisades Park, New Jersey Tel. Windsor 4-3070
1 Type 512 s/n 1111	Gus Winston 227 Marina Way Pacifica, California

USED INSTRUMENTS WANTED

1 Type 310A	Milton D. Post 460 N.W. 30th Terrace Ft. Lauderdale, Florida
1 Type 517	G. Connell 212 Wensley Lane East Islip, Long Island, New York
1 Type 535 or Type 545	Purcell Robinson 1442 North 62nd Street Philadelphia 31, Penna.
1 Type 511 or Type 524	Weaver County School District L. O. Keys Salt Lake City, Utah Elgin 9-7691
1 Type 535 or 535A 1 Type CA 1 Type C	Robert Sinn Ultronics 118 North 3rd St. Camden, New Jersey Woodlawn 4-4664
1 Type 530 or 540 Series with a Type 53/54C or CA Plug-In	Professor George C. Newton, Jr. Electronic Systems Laboratory Massachusetts Institute of Technology Cambridge 39, Mass.
1 Type 112 Preamplifier	Westinghouse Electric Corp. Cletus Hostetler P. O. Box 284 Elmira, New York
1 Type 531 or Type 535	Richard Van Lunen 9203 Alcona Street Lanham, Maryland
1 Type 530 Series or Type 540 Series or Type 550 Series 1 Type CA, or K, or L Plug-In	Leonard M. DeBall 5247 S. Avers Avenue Chicago, Illinois

MORE LOST OR STOLEN SCOPES

Tektronix Field Engineer Ron Bell reports that a Type 316S1, serial number 902, is missing from the Goodyear Aircraft Corporation in Akron, Ohio. If you have any information on this instrument notify the Goodyear Aircraft Corporation.

Tektronix Field Engineer Duncan Doane reports the disappearance of a Type 310A, serial number 011213, from the Electronic Specialty Company, 5121 San Fernando Road, Los Angeles 39, California. If you run across this scope in your area, notify the Electronic Specialty Company by collect wire, or phone, Chapman 5-3771.

The following instruments have disappeared from the custody of the Philco Corporation, Government and Industrial Group, 4700 Wissahickon Avenue, Philadelphia, Penna.

1 Type 541A Oscilloscope s/n 20379
1 Type CA Plug-In Preamplifier s/n 10031
1 Type L Plug-In Preamplifier s/n 5235
1 Type 107 Square-Wave Generator s/n 625

If you know the whereabouts or have any information on these instruments, please contact the Philco Corporation, Computer Division, Test Equipment Control Section, Willow Grove, Pennsylvania, Oldfield 9-7700, Extension 537.

The Florida Power Corporation at Winter Park, Florida, reports that their Type 310S2 Oscilloscope s/n 6674 is missing and may have been stolen. Please contact them if you have any information on this instrument.

DO YOU UNDERSTAND THE SWEEP DELAY FEATURE OF YOUR TEKTRONIX OSCILLOSCOPE?

The Sweep Delay* is an important feature of the Type 535A, 545A, 555 and 585 Oscilloscopes. However, some users of these instruments are completely unaware of the flexibility this feature provides or the many applications made possible by it.

It is not within the scope of this publication to explain the Sweep Delay feature—space will not permit it—but we can tell you how you can have it explained and demonstrated to you. Call your Tektronix Field Engineer!

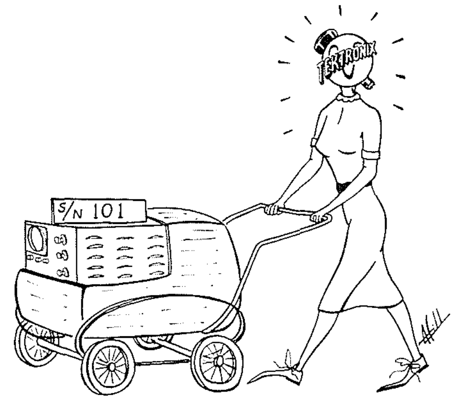
The explanation and demonstration, if you desire, can be given before a group of your technicians and engineers at a convenient time and place.

You will find your Tektronix Field Engineer to be a competent instructor with a minimum of six months factory training in the use and service of Tektronix instruments. Furthermore, he is keenly and genuinely interested in your scope related problems and anxious to help in their solution.

This is an economical program offered on a no charge basis. The only thing we ask you to spend is your time!

*In the Type 535 and 545 this feature is known as the Delaying Sweep.

ORIGINAL PRODUCTION OSCILLOSCOPE RETURNS TO TEKTRONIX



In July of 1947 Tektronix shipped its first production oscilloscope—a Type 511, serial number 101. Dr. A. R. Tunturi; Director of Navy Acoustic Research at the University of Oregon Medical School in Portland, Oregon, took delivery on this instrument for the purchaser, the U. S. Navy.

For 13½ years this Type 511 aided in providing Dr. Tunturi with reliable information in his research work—electronic mapping of the brain. Knowledge gained in this research is valuable in the diagnosis and treatment of neurological diseases and for the possible importance of applying how the brain works to the development of a mechanical brain for guided missiles. During this time installation of several factory-developed improvement modifications aided this Type 511 to keep abreast of Dr. Tunturi's oscilloscope requirements. The instrument remained, however, essentially a Type 511 while Dr. Tunturi's work continued to advance. Eventually the need for a more sophisticated oscilloscope became undeniable.

Rudy Vuksich of the Tektronix Advertising Department could see reciprocal benefits in Dr. Tunturi's need for a more advanced oscilloscope and the Tektronix desire to return their original production instrument to its place of origin.

Accordingly, he assisted in working out a mutually beneficial agreement between the interested parties. In exchange for the Type 511, serial number 101, Dr. Tunturi accepted for the U. S. Navy a Tektronix Type 515 Oscilloscope, an instrument admirably suited to his present oscilloscope requirements.

Type 511, serial number 101 now stands proudly on display in the reception area of the Tektronix factory in Beaverton, Oregon. Every Tektronix employee expresses his thanks to the U. S. Navy and Dr. Tunturi for their co-operation in returning this instrument to us. We are proud of our "first born"!

Service Scope
USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

COMPUTER ENGINEERS SAY P6016 CURRENT PROBE A NECESSITY

Tektronix Field Engineer Owen Harrison reports many of the computer engineers he calls on consider the Tektronix P6016 Current Probe a necessity in computer service work. They claim that considerable savings in computer service time can be realized by the use of this probe. Compared to the method where a one ohm resistor must be inserted into the circuitry to obtain readings, the use of a P6016 Current Probe can cut computer service time by as much as 50%.

If you are not acquainted with the Tektronix P6016 Current Probe, call your Tektronix Field Office. A Field Secretary or a Field Engineer will be happy to arrange a demonstration at your convenience. In addition to being informative, the demonstration may aid in solving (or making it easier to solve) some of your engineering or servicing problems.

TEKTRONIX TOUCH-UP PAINT

Touch-up paint to match the colors and finishes of Tektronix instruments is now available. The paints for touch-up jobs on gray-wrinkle, blue-wrinkle, or blue-vinyl finished cabinets come in 2 ounce jars. Also, the blue-wrinkle and blue-vinyl paints thinned for spraying, are available in 1 quart cans.

Order through your Tektronix Field Engineer or Field Office from the following chart.

TEK NO.		DESCRIPTION	QTY.	PRICE
252-083	Gray	Wrinkle Touch-up	2-oz	$1.10
252-084	Blue	Wrinkle Touch-up	2-oz	1.10
252-085	Blue	Wrinkle Thinned*	1-qt	3.00
252-086	Blue	Vinyl Touch-up	2-oz	1.10
252-087	Blue	Vinyl Thinned*	1-qt	2.80

*These thinned paints are intended for spray-gun application

FINDING BURIED CABLES

You may easily determine the position of a single conductor, buried eight to 10 feet below the ground surface, by magnetic detection.

A 10 to 15-ampere 60-cycle current passed through a buried conductor will create a strong magnetic field that a simple pickup loop and detector can locate easily.

If two wires of 117 v ac circuit must be located, one of them must be disconnected and an alternate external lead substituted. (A good ground will do.) If both wires are used, the magnetic flux from one will cancel the magnetic flux of the other.

An effective pickup loop consists of four to 10 turns of wire formed into an oval about five feet long and a foot wide. Bypass the two leads from the loop with a .01 μf capacitor to reduce any radio frequency energy from broadcast stations.

(If cable near a broadcast antenna is to be located, you may need an additional low-pass filter to keep r-f from reaching the detector.)

The detector needs enough sensitivity to indicate signals at a maximum of about .05 volts rms. A simple battery-powered transistor amplifier with frequency multiplication will raise both the signal level and the frequency for headphones.

A Tektronix Type 321 battery-powered portable oscilloscope may be used to make a visual measurement. It will do this job without an external preamplifier. Using the 321 with the pickup loop and a .01 μf capacitor, you may locate each ground radial of a broadcast antenna while the station is on the air. In this case the signal will be the station's carrier.

You search with the pickup loop flat on the ground. When the loop is on both sides of the buried conductor, it will pick up energy from the conductor.

As the loop passes directly over the conductor, the signal disappears. When it moves past the conductor, the signal reappears.

For cables deeper than 10 feet, increase all dimensions of the coil to maintain the same accuracy.

CORRECTION

We must call your attention to three errors, one typographical and two of omission, in the article "Timing the Type 530A/540A Series Oscilloscopes". This article appeared in the December 1960 Service Scope.

In Step 6 of this article the .5 μsec/cm setting of the TIME/CM switch should read .1 μsec/cm.

Instructions for adjustment of C375 should have followed the instructions for adjusting C364. Here they are: Adjust C375 for best linearity between the 2nd and the 6th vertical graticule lines.

Finally, if it is necessary to replace the two 6DJ8 output tubes, the whole timing procedure should be run through again.

Now, if you don't mind, we will go apply a soothing lotion to a very red face.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

Service Scope

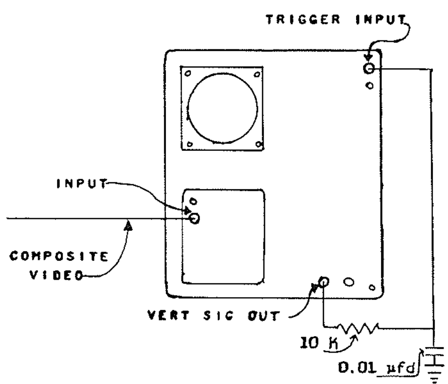
USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 7 PRINTED IN U.S.A. APRIL 1961

TYPE 530/540 OR TYPE 530A/540A SERIES OSCILLOSCOPES AND COMPOSITE VIDEO SIGNALS

Part 2

Fig. 1, which appeared with Part 1 of this article in the February issue of SERVICE SCOPE, was incorrectly drawn. The circuit as shown was not an integrator circuit. Notice that in the corrected drawing (fig. 1 below) the 10 k resistor precedes the 0.01 μfd capacitor in the circuit from the VERT. SIG. OUT to the TRIGGER INPUT.



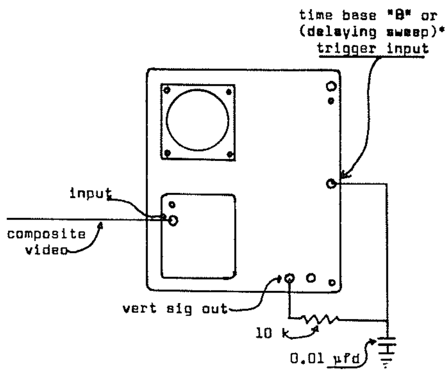
Instructions in Part 1 of this article dealt with the Type 531, 532, 533, 541, 543, 531A and 541A instruments. Part 2 will deal with the Type 535, 535A, 545 and 545A oscilloscopes.

These more sophisticated oscilloscopes provide the Tektronix unique Delaying Sweep feature and can also display either field or line presentations. In addition, the Delaying Sweep feature permits the operator to select the line presented. Also, once the instrument is set up, the operator can switch from line to field presentation by simply turning the HORIZONTAL DISPLAY switch.

Here's how you set it up:

Step 1. Use a wide-band Plug-In Preamplifier in the oscilloscope and apply the composite video signal to the INPUT. Adjust the VOLTS/CM to give 3 or 4 centimeters of deflection.

Step 2. Couple the VERT SIG OUT to the TIME BASE B (DELAYING SWEEP) TRIGGER-IN with an integrator circuit consisting of a 10 k resistor and a 0.01 μfd capacitor. See fig. 2



(Note: If available, Field sync pulses are preferable for triggering the Delaying Sweep.)

Step 3. Set the HORIZONTAL DISPLAY switch to the 'B' INTENSIFIED BY 'A' (DELAYING SWEEP)* position. Turn the TIME BASE B (DELAYING SWEEP)* STABILITY and TRIGGERING LEVEL controls full right. Set the TIME BASE B (DELAYING SWEEP)* TIME/CM switch to 5 MILLISEC and the LENGTH control for 9 to 10 centimeters of sweep. For displaying positive-going video signals, turn the TIME BASE B (DELAYING SWEEP)* TRIGGER SLOPE switch to +EXT (+)* and the TIME BASE B TRIGGERING MODE switch to AC (Type 535 and Type 545 instruments do not have a triggering mode switch on the DELAYING SWEEP section of their front panel), for negative-going signals, switch the TRIGGER SLOPE to —EXT (—)*. Turn the TIME BASE B (DELAYING SWEEP)* STABILITY control to the left until the sweep ceases to operate. Continue turning the control several more degrees to the left. Now turn the TIME BASE B (DELAYING SWEEP)* TRIGGERING LEVEL control to the left until a stable display is obtained. This should occur when the index mark is at or near the straight up position.

Step 4. Set the HORIZONTAL DISPLAY switch to the 'A' DEL'D BY 'B' (MAIN SWEEP DELAYED)* position. Set the TIME BASE A (MAIN SWEEP)* TIME/CM switch to display any desired number of lines. Trigger the 'A' DEL'D BY 'B' (MAIN SWEEP DELAYED)* from the first line sync pulse after the delayed trigger by turning the TIME BASE A (MAIN SWEEP)* STABILITY and TRIGGERING LEVEL controls full right and then turning the STABILITY control to the left until the sweep ceases to operate. Continue turning the STABILITY control to the left for several more degrees.

If you are displaying video signals of positive-going polarity, switch the TIME BASE A (MAIN SWEEP)* TRIGGER SLOPE control to +INT: if you have negative-going signals, switch TIME BASE A (MAIN SWEEP)* TRIGGER SLOPE control to —INT. Turn the TIME BASE A (MAIN SWEEP)* TRIGGERING LEVEL control to the left until a stable display is obtained.

The display will now be similar to the display obtained when using the Type 524 Oscilloscope; the line presentation will jump from one line to the next as the DELAY TIME MULTIPLIER is turned through its range.

Step 5. By switching the HORIZONTAL DISPLAY control from 'A' DEL'D BY 'B' (MAIN SWEEP DELAYED)* position to the 'B' INTENSIFIED BY 'A' (DELAYING SWEEP)* position, you can have either line or field presentation. The TIME BASE A (MAIN SWEEP)* brightening on the TIME BASE B (DELAYING SWEEP)* will indicate the horizontal lines being observed with reference to the entire frame. +GATE A (+GATE MAIN SWEEP)* could be used to modulate the 'Z' axis of a monitor kinescope.

Step 6. If dual trace operation with a Type 53/54C, 53C, or CA Plug-IN is desired, the trigger must be derived from an external source rather then the VERT

SIG OUT, due to the switching signals present. TIME BASE A (DELAYING SWEEP)* sweep rates and length should be adjusted to give proper presentation of interlaced pairs of lines.

The above method will give usable results, but for specific applications most engineers will prefer a Type 524AD Oscilloscope with its carefully designed sync-separator circuits.

* (Captions in parenthesis apply to the Type 535 and Type 545 instruments.)

SERVICE HINTS

Tektronix Field Maintenance Engineer Jack Banister finds a pressure can of contact cleaner a handy service tool. The use of this cleaner has usually been with tube sockets in jittery vertical amplifiers. He squirts the cleaner into the vertical-amplifier tube sockets. Several times this operation has cleared up the trouble just fine. Indications of faulty pin contacts can generally be made apparent by wiggling a tube in its socket.

The brand name of the contact cleaner Jack uses is "Injectoral". There are probably other good contact cleaners in pressure cans on the market, but this is the only one Jack has had experience with.

Occasionally, when a Type 530/540 Series Chopping-Transient-Blanking Mod Kit (Tek. No. 040-200) is installed in an instrument, the unblanking-spike phasing occurs too early and does not cover the switching transient.

Increasing the blanking period should correct this condition. To do this, change the resistor on the grid (pin 5) of V78 from 270 k to 390 k.

The 390 k resistor will generally increase the blanking period enough to cover the switching transient and enable the modification to work correctly. However, isolated cases may require a resistor of an even higher value. Tektronix Maintenance Engineer Udo Lindenmeyer found one instrument that required a 560 k resistor to give correct results.

SOLVING POWER LINE PROBLEMS FOR BETTER SCOPE PERFORMANCE

Problems arising from excessively high or low line voltage continue to plague users of Tektronix oscilloscopes in some areas. Tektronix oscilloscopes are designed to accommodate line-voltage variations up to roughly ±10% from design center without loss of stability or accuracy; however, variation beyond these limits (105-125 volts for most instruments wired for domestic use) causes loss of accuracy and often, severe instability.

The problems reported seem to fall into three main categories: (1) continuously high or low line voltage; (2) fluctuation between high and low line voltage; and (3) serious waveform distortion, giving the effect of low line voltage. Some suggested solutions to these problems are:

(1) The first problem is easily solved for the owner of a Type 310(A), 316, 317, 502 or 516 Oscilloscope. These instruments are equipped with multi-tap power transformers, for use at various "high" or "low" line-voltage ranges. For other instruments, it is necessary to provide some external step-up or step-down transformer to provide the necessary operating voltage to the scope. A variable autotransformer of the "Variac" or "Powerstat" type is particularly useful in accomodating a wide range of input voltages. An inexpensive filament transformer may also be used as an autotransformer in cases where the line voltage is consistently high or low. Reconnected as shown in Figure a, the transformer's

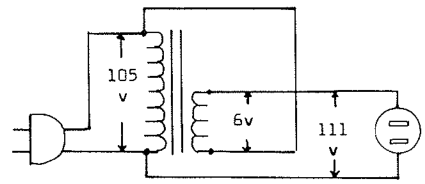


Figure A. Low-cost line-voltage boost or drop circuit, using a filament transformer. Connect as shown for 6 v boost; reverse secondary connections for 6 v drop. Filament winding must have minimum rating indicated in Figure B.

secondary voltage is added to or subtracted from the incoming line voltage to bring it within range. Be sure the filament-winding current rating is adequate to carry the oscilloscope load (Fig. B).

Scope Type	Max. Power Consumption	Recommended Transformer Rating (Min)
310(A)	175 W	2 Amp
315	375 W	4 Amp
316	260 W	3 Amp
317	260 W	3 Amp
321	20 W	¼ Amp*
502	280 W	3 Amp
503	107 W	1 Amp
504	93 W	1 Amp
507	600 W	8 Amp
511(A)	240 W	3 Amp
512	280 W	3 Amp
513	475 W	6 Amp
514(A)	375 W	4 Amp
515(A)	300 W	3 Amp
516	300 W	3 Amp
517(A)	1250 W	15 Amp
519	660 W	7 Amp
524(A)	500 W	5 Amp
525	380 W	4 Amp
526	340 W	4 Amp
527	240 W	3 Amp
531(A)	455 W	5 Amp
532	475 W	5 Amp
533	500 W	6 Amp
535(A)	550 W	6 Amp
536	650 W	7 Amp
541(A)	520 W	6 Amp
543	530 W	6 Amp
545(A)	600 W	6 Amp
551	900 W	10 Amp
555	1050 W	12 Amp
561	175 W	2 Amp
570	400 W	5 Amp
575	410 W	5 Amp
581	640 W	7 Amp
585	725 W	8 Amp

*Power-line regulation not required if batteries are in place and line voltage does not exceed 125 v.

Figure B. Chart of Tektronix oscilloscope power requirements.

(2) The second problem is a little more difficult. Although slow periodic fluctuations in power-line voltage can be conveniently handled with a variable autotransformer, as above, there are many areas where wide line-voltage variations are so frequent that a constant-voltage-transformer type of regulator appears to be the only solution. However, for proper operation of the oscilloscope power supplies, it is extremely important that the regulator does not cause waveform distortion. The electronically-regulated power supplies in Tektronix oscilloscopes require not so much a certain rms voltage on which to operate, as a certain minimum peak-to-peak voltage. Many regulating transformers of the saturable-reactance type regulate primarily by limiting the peaks of the incoming sine waves. Either an rms or average-reading AC voltmeter (most voltmeters are of the latter type) may indicate the proper rms voltage for scope operation. However, the actual peak-to-peak voltage supplied by most of the common "constant-voltage" transformers is insufficient for proper operation of the scope's power supplies. Under these circumstances excessive ripple, jitter, and instability will result. Therefore, it is important to use only a low-distortion type of regulator — one having less than, say 5% distortion at the highest expected incoming line voltage under full oscilloscope load conditions. Regulators of this type are available through commercial channels, though at some increase in cost over the models without waveform correction.

The third problem — serious waveform distortion, giving the effect of low line voltage — will be discussed in Part 2 of this article which will appear in the June issue of SERVICE SCOPE. The discussion will include methods of determining whether waveform distortion will seriously affect the performance of your instrument and suggested solutions for the problem.

USED INSTRUMENTS WANTED

1 Type 515	Gene Pulaski 200 Maple Ave. Graterford, Penn.
1 Type 514 or Type 515 for cash or will trade Waterman USM-24C Pulse-scope	J. L. Hartke Elec. Eng. Res. Lab. University of Illinois Urbana, Illinois
1 Type 310	Carl C. Rosen Ray Jefferson, Inc. 4000 N. W. 28th Street Miami 42, Florida

1 Type RM16	Herb Evans, Chief Eng. WTHS-TV 1410 N. E. 2nd Avenue Miami 32, Florida
1 General Purpose DC to 1 or 5 mc scope 5″ crt	Robert W. Blair, M.D. 3761 Stocker Street Los Angeles 8, Calif. Phone: AX 5-4347
1 Type 575	Roger Hill Electronic Systems of America, Inc. 624 High Street Racine, Wisconsin Phone: ME 4-7747
1 DC-to-10 mc or better scope. 5″ crt	Phil Adelman 6332 W. 85th Place Los Angeles 45, Calif. Phone: OR 4-3504
1 Type 121 Amplifier	Stevens P. Tucker Physics Department Oregon State College Corvallis, Oregon
1 Type 512 or Type 513 or Type 514	Art Humphery Digitrols, Inc. 8 Industry Lane Cockeysville, Maryland
1 Type 531A or Type 533 1 Type 53/54C or CA Plug-In Unit	William Bowin 54-D Oak Grove Drive Baltimore 20, Md.

USED INSTRUMENTS FOR SALE

1 Type 53/54C Plug-In s/n 7414 — $125 or best offer	Ken Mollenauer Argonaut Underwriters 250 Middlefield Road Menlo Park, Calif.
1 Type 514D	Gene Phelps KPTV P. O. Box 3401 Portland, Oregon
1 Type 524AD s/n 2710	Seymor Schatz Rainbow TV Sales & Ser. 6302 Fifth Avenue Brooklyn 20, N. Y. Phone: HY 2-6662
1 Type G Plug-In Unit	R. L. Arntz The Hartman Electrical Mfg., Co. 175 N. Diamond Street Mansfield, Ohio
1 Type 543 with Type CA Plug-In	Mr. MacDonald Sports Network 36 West 44th Street New York 36, N. Y. Phone: MU 2-0117
1 Type 513D s/n 1887 Asking $495	Ronald Knight Pulse Engineering, Inc. 560 Robert Avenue Santa Clara, Calif. Phone: CH 8-6040

BEWARE OF MISLEADING INSTRUCTIONS

The instructions for installing the Type 502 Horizontal Beam Registration Field Modification Kit (Tek #040-234) contain an error. On page 4, step 13 should read as follows:

( ) 13. Solder the white-blue wire to the #1 wafer, #4 position.

The possibility exists that there are Type 502 instruments in use with this mod installed with the white-blue wire going to the wrong (#3 position) contact. Under these conditions, one of the horizontal deflection plates will be left "hanging" or unconnected. The noticeable effect of this error is that with the HORIZ. DEF. PLATE SELECTOR switch in the UPPER BEAM AMP. position, the POSITION control on the UPPER BEAM section of the front panel will have only 5 cm of horizontal range (using normal intensity).

To correct the error, place the Type 502 on the bench with the left side facing you and remove the side panel. On the #1 wafer of the HORIZ. DEF. PLATE SELECTOR switch, locate the contact with two white-blue wires (Note: the #1 wafer is the one nearest the mounting bracket). Unsolder, from this switch contact, the white-blue wire that is dressed through one of the grommets on the bottom of the switch bracket (Caution: do not unsolder the white-blue wire running to the neck of the crt). Move the unsoldered wire one contact to the right and resolder (this contact will have a bare wire going to the #2 wafer of the switch). With this correction the instrument should operate properly.

TYPE 580 SERIES OSCILLOSCOPE TRIGGER CIRCUIT MODIFICATION

Installation of a Type 581/585 Tunnel-Diode Trigger Circuit Modification Kit will extend the reliable triggering capabilities of these instruments out to a full 100 mc. The modification will not impair the instrument's ability to trigger reliably on signals of low amplitude or pulses of very short duration.

Time required by a trained technician to install this modification is about six hours. Tentative triggering specifications of the instrument will then be as follows:

	Frequency	Amplitude
Internal Triggering	DC to 10 mc	2 mm
	10 mc to 30 mc	1 cm
	30 mc to 50 mc	2 cm
	50 mc to 100 mc	3 cm
	DC to 10 mc	0.2 v
External Triggering	10 mc to 50 mc	0.5 v
	50 mc to 100 mc	1.0 v

This modification applies to all Type 581 instruments below serial number 511 and all Type 585 instruments below serial number 1071. Please consult your Tektronix Field Engineer to order this modification.

TYPE 570 CHARACTERISTIC CURVE TRACER WILL SAVE THIS CUSTOMER MONEY

Tektronix Field Engineer Francis Frost reports that one of his customers had need of 19 matched tubes. This customer ordered the tubes from a supplier and the charges amounted to $800.00. The raw stock price of these tubes was $1.95 each. Based on this experience, the customer felt he could more than justify the purchase of a Type 570 Characteristic-Curve Tracer. By matching his own tubes, it would take only a couple of situations like the one described above to realize savings that would more than cover the purchase price of a Type 570 instrument. An extra bonus would be that the Type 570 would be readily available to the design engineers in tailoring circuits to fit the operating characteristics of available tubes. Also, tubes could be selected faster and more accurately for circuits requiring other than average electron-tube characteristics.

PREFIXES AND SYMBOLS

Reproduced in the chart below are the prefixes and symbols of electrical units as adopted by The National Bureau of Standards.

Your Tektronix Field Engineer has a supply of these charts in two sizes; a 4¾″ x 7″ card suitable for posting near your desk or in your work area, and a handy wallet-sized card convenient to carry with you as a quick and ready reference.

He offers these charts to you with his compliments and suggests you contact him if you have not received yours or if you require additional charts.

Tektronix, Inc.

P. O. Box 500 • Beaverton, Oregon
Phone Mitchell 4-0161 • TWX—BEAV 311 • Cable: TEKTRONIX

PREFIXES and SYMBOLS

of Electrical Units as Adopted by
The National Bureau of Standards

UNIT	PREFIX	SYMBOL
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	dk
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Compliments of your Tektronix Field Engineer

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

Service Scope

USEFUL INFORMATION FOR
USERS OF TEKTRONIX INSTRUMENTS

MISSING INSTRUMENTS

Our Chicago Field Office sends word that a Type 310A oscilloscope, s/n 13069 is missing and may have been stolen from the Toledo Scale Company, 2033 South Michigan, Chicago, Illinois.

If you have any information regarding this instrument, please wire or call the Toledo Scale Company collect. The telephone number is CA 5-7143.

TYPE 81 PLUG-IN ADAPTER PARASITIC OSCILLATIONS

Parasitic oscillations can occur on the trace of Type 581 and Type 585 Oscilloscopes when using the Type 81 Plug-In Adapter. These oscillations appear at a frequency of approximately 200 mc and have an amplitude of from two to four mm.

A simple modification of the Type 81 will eliminate these oscillations. This modification consists of 0.01 μf, 150 volt discap added in parallel to R549, a 3k, 5w, wire wound resistor.

To install this modification, remove the Type 81 from the oscilloscope and place it on the bench bottom side up. Locate contacts 14 and 16 on the male amphenol connector. Trace back from these connectors to where R 547 and R 548; two 93 Ω, ½ w, precision resistors, join R 549, a 3 k, 5 w, wire wound resistor. Solder one end of an 0.01 μf, 150 volt discap to this connection and solder the other end to the ground lug located on the female amphenol connector.

This modification applies to all Type 81 Plug-In Adapters except the following:

105	232	279	646
107	236	502	649
136	237	590	652
140	250	600	653
143	264	641	654
152	266	642	655
154	268	644	656
188	272	645	664

These instruments were modified out of sequence at the factory.

REACTIVATING THE CATHODES OF STORED CATHODE-RAY TUBES

A cathode-ray tube that has been in storage for some time should be "reactivated" before being placed in service. To reactivate the cathode, operate the CRT with 8 volts on the heater (other operating conditions normal) for about one hour, and follow with 24 hours of operation at normal heater voltage. During the reactivation period the beam should be positioned off the face of the CRT.

TEKTRONIX OPENS IN MONTREAL, MARCH 15

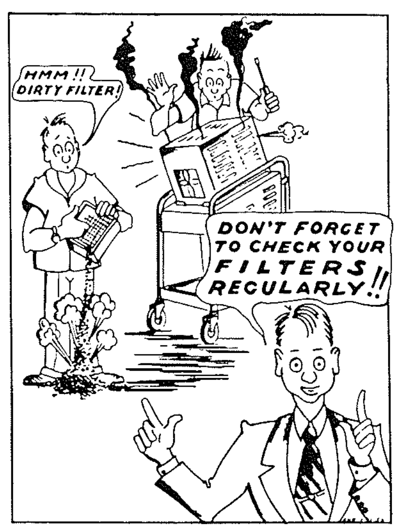
Opening the 36th Field Office provides more immediate attention to the needs of Tektronix customers in Quebec, Nova Scotia, Prince Edward Island, New Brunswick, and Newfoundland. These areas were formerly served from our Toronto Field Office.

CHECK YOUR SERVICE SCOPE ADDRESS!

Please, if you wish uninterrupted delivery of your copy of Service Scope, advise us of **any** change in your address immediately.

After every mailing of this publication, our returned mail contains a large number of copies marked "undeliverable". Investigation discloses that an addressee may have moved only from one room to another within the same building, however, Service Scope delivered to his old address may not reach him. The reason for their non-delivery seems to stem from the rapid expansion, both in size and activity, that many companies and military installations are experiencing. Apparently, the people responsible for internal distribution of mail at these organizations find it difficult to keep abreast of the many moves and changes of personnel resulting from this expansion.

As an aid in insuring the delivery of mail under these conditions, we would like to offer the following suggestions: Determine through the people responsible for distribution of mail within your organization, the address information required to assure delivery of mail intended for you. Advise your correspondents of this information. Notify them as quickly as possible when changes occur in this information.



Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 8 PRINTED IN U.S.A JUNE 1961

SOLVING POWER LINE PROBLEMS FOR BETTER SCOPE PERFORMANCE

Editor's note: Part 1 of this article appeared in the April 1961 issue of SERVICE SCOPE. As explained there, the problems that affect Tektronix instruments and arise from the condition of excessively high or low line voltage, seem to fall into three main categories: (1) continuous high or low line voltage; (2) fluctuations between high or low line voltage; and (3) serious waveform distortion, giving the effect of low line voltage. The first two of these categories were discussed in Part 1 and some suggested solutions outlined. Part 2, below, takes up the third category and concludes the article.

Part 2

The third major problem — serious waveform distortion — is the most difficult to overcome, since general-purpose correction systems are not always immediately available. To determine whether waveform distortion will seriously affect the performance of your instrument, use an oscilloscope to measure carefully the peak-to-peak voltage on the instrument's filament line, and compare this reading with the rms reading, as taken with a calibrated voltmeter. For 6.3 volts rms (indicating 117 volts rms power-line voltage) the peak-to-peak reading on the oscilloscope should be 17.8 volts. If this reading is less than 17.0 volts peak-to-peak, it indicates that the power supplied to the instrument is not adequate for proper power-supply regulation throughout the instrument's nominal 105-125 volts rms rating. The instrument will probably be in difficulty somewhere above 105 volts rms. A peak-to-peak reading of 15.5 volts or less for a 6.3 volts rms voltmeter reading indicates that the instrument's power supply will regulate only marginally even at 117 volts rms, on the power-line waveform supplied.

We have had reports of a few cases where local waveform distortion, combined with slight deterioration of tubes, rectifiers or capacitors in the oscilloscope, has caused a customer to go to considerable expense in component replacement because the instrument "dropped out" of regulation above what appeared to be 105 line volts. We suggest in these cases that an accurate measurement of the actual peak-to-peak line voltage be made before replacing other than obviously-failed components. An adapter such as that illustrated below (Figure C)

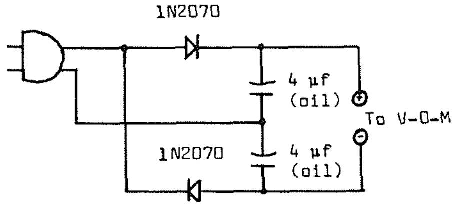


Figure C. Peak-to-peak reading adapter for 20,000 Ω/volt V-O-M.
Use of silicon diodes and oil-filled (or Mylar or paper) capacitors assures accurate voltage output.

RMS	Peak-to-Peak
105 v	297 v
117 v	331 v
125 v	354 v

can be used with a voltmeter to obtain peak-to-peak measurement of the line waveform at moderate construction cost. Alternatively an oscilloscope equipped for accurate differential voltage measurements in the 300-350 volt range can be used to make the peak-to-peak voltage measurement directly from the power line. It is **not** recommended that a scope be used "single ended" to measure its own power line voltage because of possible measurement errors and serious shock and damage hazards. The oscilloscope power supplies should continue to regulate properly down to 295 volts peak-to-peak. If the peak-to-peak line voltage is less than 295 volts for an rms reading of 105 volts, but the scope power supplies do regulate correctly at 295 peak-to-peak volts, then the trouble is mostly in the power-line waveform, and power-supply components are probably in good condition.

If power-line waveform distortion exists on the power lines into your building, the easiest solution may be to have the local power company correct the waveform for you. However, if it's caused by in-plant equipment (any high-current, nonlinear load will cause some distortion), it may be necessary to apply your own waveform-correction, using a filter of appropriate design and a transformer (to compensate for filter losses) between the power line and the oscilloscope. In extreme cases where severe fluctuations and transients are also involved, it may be necessary to employ a motor-generator set to obtain a steady, sinusoidal waveform. As before, be sure that the current rating of the filter or motor-generator set is adequate for oscilloscope operation (See Figure B).

Scope Type	Max. Power Consumption	Recommended Transformer Rating (Min)
310(A)	175 W	2 Amp
315	375 W	4 Amp
316	260 W	3 Amp
317	260 W	3 Amp
321	20 W	¼ Amp*
502	280 W	3 Amp
503	107 W	1 Amp
504	93 W	1 Amp
507	600 W	8 Amp
511(A)	240 W	3 Amp
512	280 W	3 Amp
513	475 W	6 Amp
514(A)	375 W	4 Amp
515(A)	300 W	3 Amp
516	300 W	3 Amp
517(A)	1250 W	15 Amp
519	660 W	7 Amp
524(A)	500 W	5 Amp
525	380 W	4 Amp
526	340 W	4 Amp
527	240 W	3 Amp
531(A)	455 W	5 Amp
532	475 W	5 Amp
533	500 W	6 Amp
535(A)	550 W	6 Amp
536	650 W	7 Amp
541(A)	520 W	6 Amp
543	530 W	6 Amp
545(A)	600 W	6 Amp
551	900 W	10 Amp
555	1050 W	12 Amp
561	175 W	2 Amp
570	400 W	5 Amp
575	410 W	5 Amp
581	640 W	7 Amp
585	725 W	8 Amp

*Power-line regulation not required if batteries are in place and line voltage does not exceed 125 v.

Figure B. Chart of Tektronix oscilloscope power requirements.

Incidentally, it should be mentioned that a step-up transformer alone should not be used where waveform distortion is the primary cause of power-supply regulation problems. If the peak-to-peak voltage of a seriously flattened power-line waveform is increased sufficiently to obtain good power-supply regulation, the unregulated filament lines in the scope will rise to excessive levels, causing premature tube failures from increased dissipation, gas, leakage, and filament burn-outs.

As with other problems in using or maintaining your Tektronix oscilloscope, you'll find your local Tektronix Field Engineer is anxious to help in identifying and solving any power-line problems that interfere with your instrument's best performance. A list of Tektronix Field Offices can be found in our current catalog, and is reprinted from time to time in Service Scope.

TESTING UNIJUNCTION TRANSISTORS WITH TRANSISTOR CURVE TRACER

By Walter Keller, Project Engineer, Cordis Corporation, Miami, Florida, with Jerry Kraxberger, Tektronix Field Engineer, St. Petersburg, Florida, assisting with write-up.

Editors note: If you are (as your editor was) *in a bit of a quandary as to* what is a unijunction transistor, a little research may be indicated.

The General Electric Transistor Manual, Fourth Edition, contains a description of unijunction transistors with an explanation of their theory of operation. I believe the short time required to read this material will be time well spent. It will aid in the more thorough understanding of Mr. Keller's and Mr. Kraxberger's article and perhaps give a greater appreciation of the versatility of unijunction transistors in many circuit applications.

The utility of a curve tracer for circuit design has proved itself to many. For those who have let it become a second "right arm", it is a major handicap when the curve tracer can not be employed to study one of the less conventional semiconductor groups.

In studying the uniformity of a few commercially acquired 2N492 transistors —particularly the intrinsic stand-off ratio[1] or the breakdown point of the emittor voltage as a function of the voltage between the bases—the following technique was used:

Employing any conventional transistor-curve tracer, connect B_1 of a unijunction transistor to ground and B_2 to the sweep voltage as the collector would be connected. Then connect the emitter to the stepping constant current source and shunt a 0.1 μf capacitor from B_1 to E. Sweep the bases with a positive half-sine-wave voltage and the emitter with a positive constant current just as one would do in the common emitter NPN connection. (See Figure 1.)

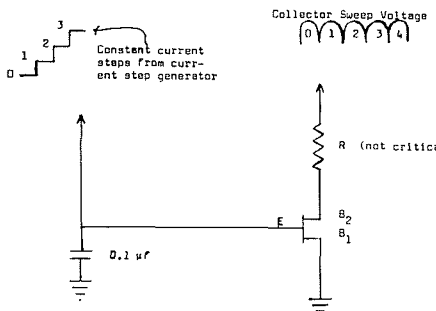


Figure 1

On a Tektronix Type 575 Transistor-Curve Tracer, connect B_2 to the terminal marked base, and B_1 to the terminal marked emitter (ground). Connect an 0.1 μf capacitor from emitter to ground. Apply voltages for the common emitter NPN transistor connection.

Consider a single emitter current step and the accompanying half-sine-wave voltage applied to B_2 (illustrated in Figure 2). Initially the current is stepped

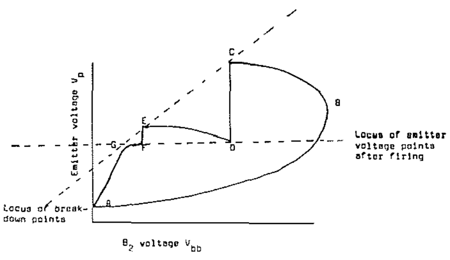


Figure 2

from zero to a positive value of constant current (say to step #1) as in Figure 1. This constant current step causes the capacitor C to charge at a linear rate and the instantaneous voltage is plotted as emitter voltage on the vertical axis in Figure 2. While the emitter voltage is increasing, the B_2 voltage (half-sine-wave which coincides with current in step #1) is increasing (moving to the right from A to B in Figure 2). Even though the voltage of B_2 reaches the peak value of B, the transistor is inactive because the capacitor charges rather slowly. As the B_2 instantaneous voltage decreases from point B to C, the capacitor voltage has increased sufficiently for the emitter to trigger the transistor into conduction causing the emitter voltage to discharge the capacitor voltage from C to D. Note that a second (E to F), and even a third, firing point can sometimes be observed. In Figure 2 we have shown only one complete emitter current step with its accompanying B_2 half-sine wave sweep. Figure 3 is an actual photograph of a General Electric Type 2N492 unijunction transistor (formerly called double-based diode) displayed on a Tektronix Type 575 Transistor-Curve Tracer. Front panel controls of the instrument were set as follows:

- Vertical—0.5 Base Volts/Div.
- Horizontal—1 Collector Volt/Div.
- Base Step Generator—Polarity to + and Step Selector to 0.01 ma/step.
- Collector Sweep—Polarity to + and Peak Volts to 10 volts on 20 volt range.
- Dissipating Limiting Resistor—to approx. 2 Ω.

Transistor Mounting Board—to grounded emitter position.

If one considers the locus of breakdown points (point C for each curve), a complete relation of emitter breakdown voltage as a function of B_2 voltage is obtained. All points below and to the right are nonconducting points; above and to the left are emitter and base voltages where conduction would occur with the conventional unijunction characteristics.

$$V_P = N\,V_{bb} + \frac{200}{T_J}$$

V_P=peak emitter voltage
N=intrinsic stand-off ratio (1) (2) (3)
V_{bb}=interbase voltage
T_J=junction temp. (Deg. Kelvin)

In Figure 2 V_P is the emitter voltage on the vertical axis and V_{bb} is the B_2 voltage on the horizontal axis for point C.

References:

1. "Silicon Unijunction Transistor Types", General Electric Company Brochure #Ecg357 Rep 1/60
2. General Electric Company Transistor Manual, 2nd. Edition, pp 40-44.
3. "A Handbook of Selected Semiconductor Circuits", NavShips 93483, NObsr 73231, BuShips, Navy Dept., pp 6-57, circuit #6-15.
4. T.P. Sylvan, "Bistable Circuits Using Unijunction Transistors", Electronics, December, 1958.

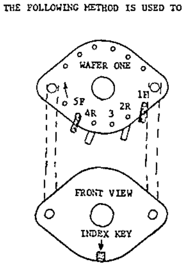
TYPE Z UNIT DAMAGE HAZARD

We have found a problem in the Type Z Differential-Comparator Units (with serial numbers below 749). Under a particular set of conditions this problem can cause trouble. The contacting sectors of the MODE switch are a few thousandths too wide. Consequently, if you turn the MODE switch too slowly when changing from one mode to another you may ground the input signal through the 10-Turn Precision Potentiometer...we traced several potentiometer failures to this problem. Also, you may short INPUT A directly to INPUT B as you turn the MODE switch.

You can minimize the chances of this trouble occurring by turning the MODE switch quickly when changing from one position to another—the trouble is more apt to occur if you hesitate between switch positions. However, a more practical way to protect the instrument is to install a Z-Unit Field Modification Kit, Tek number 040-262. The Kit contains four each 0.02μf, 150 v capacitors and 33 k, ¼ w, 10% composition resistors, a schematic diagram and installation instructions. There is no charge for this kit. Place your order through your Tektronix Field Engineer and be sure to include the serial number of the Z Unit for which the modification is intended.

If you prefer, you may obtain the capacitors and resistors locally and make the modification using the instructions that follow as your guide. First, however, consult the switch identification aid shown in figure 1 below.

THE FOLLOWING METHOD IS USED TO IDENTIFY SWITCH WAFERS AND CONTACT POSITIONS.



1. Wafers are numbered from front to rear; wafer one being "W1", etc.
2. All contact positions are numbered relative to the switch index key as shown.
3. Contacts on front or rear of wafer have an "F" or "R" suffix, respectively.
4. Positions without contacts are also counted to determine the location of a certain contact number.

   Example: Wafer one, contact one, is "W1-1F", etc.
5. This method applies to all types of wafers.

Figure 1

Here are the instructions for the modification:

INSTRUCTION:

( ) 1. Remove the strap connecting W2-12F to W1-12R of the mode switch (see figure 2, step 1).

( ) 2. Remove the white-violet wire from W1-12R (see figure 2, step 2).

( ) 3. Replace the .01 μf capacitor (located between W2-12F and the metal shield plate of the mode switch) with a .02 μf 150 v capacitor (see figure 2, step 3).

( ) 4. Solder one end of a .02 μf 150 v capacitor to W1-12R and solder the other end to the metal shield separating W1 and W2 (see figure 2, step 4).

( ) 5. Solder one end of a 33 k, ¼ w, 10% resistor to W2-12F (see figure 2, step 5).

( ) 6. Solder one end of another 33 k, ¼ w, 10% resistor to W1-12R (see figure 2, step 6).

( ) 7. Solder the remaining ends of the 33 k, ¼ w, 10% resistors (just installed) and the white-violet wire (removed in step 2) together (see figure 2, step 7).

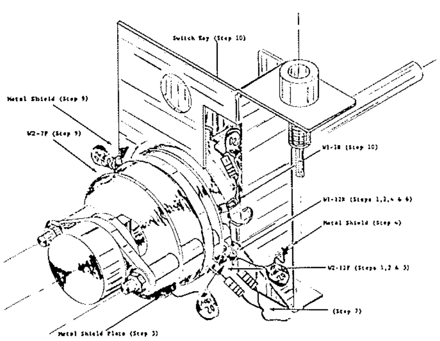
( ) 8. Parallel each of the remaining 33 k, ¼ w, 10% resistors with the remaining .02 μf 150 v capacitors. Clip both combinations to leads of approximately ¼ inch.

( ) 9. Replace the ground strap connecting W2-7R to the shield (separating W1 and W2) with one of the 33 k—.02 μf combinations described in step 8 (see figure 2, step 9).

( ) 10. Using a scribe or a sharp soldering aid, unsolder W1-1R from the shield. Solder the remaining combination of the 33 k—.02 μf from this contact to the key of the switch (see figure 2, step 10).

( ) 11. THIS COMPLETES THE INSTALLATION. Recheck your work.

Figure 2—Drawing showing installation steps for the above Z-Unit field modification.



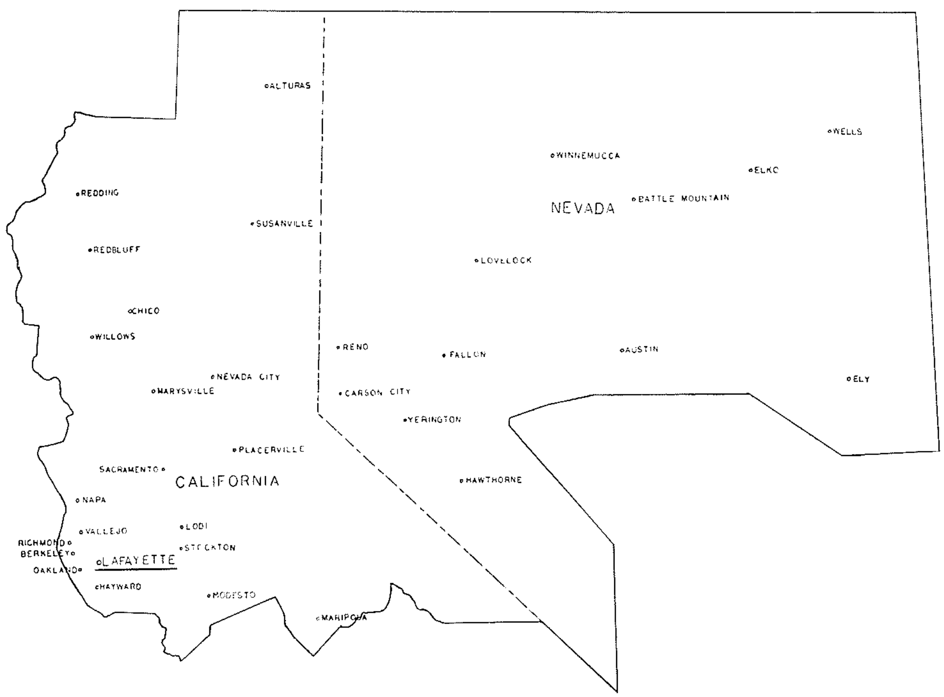
USED INSTRUMENTS FOR SALE

1 Type 524D	Jim Robertson Chief Engineer WLEX TV Lexington, Kentucky Phone LE 4-8747
1 Type 511AD s/n 1730	Harry Nickerson Chief Engineer Chalco Engineering Corporation 15126 Broadway Street Gardena, California
1 Type 511AD s/n 1223	Erich Frank University of Chicago Enrico Fermi Institute 5630 S. Ellis Street Chicago 37, Illinois Phone MI 3-0800, Ext. 3757
1 Type 535 s/n 7189	Chas. Hagen, Test Eng. Microsonics, Inc. 349 Lincoln Street Hingham, Mass.

USED INSTRUMENTS WANTED

1 Type 531 or Type 532	Donald Lusk 2521 South Pearl St. Denver 10, Colorado
1 Type 512 or Type 514	Douglas Waltz 410 West Park Avenue Kokomo, Indiana
1 530 Series (or equivalent) scope	George Jacobson 2931 Anzac Avenue Roslyn, Pennsylvania Phone TU 4-1345
1 Type 317 or other DC to 10 MC scope	Charles Woll 361 Holmes Road Holmes, Pennsylvania
1 Type 514D or Type 515	John Creedon Applied Radiation 2404 N. Main Street Walnut Creek, Calif.
2 Type 310 (instruments in need of repair preferred)	Howard E. Winch, CWO, W3 Det. 2, 714th AC& WRON Driftwood Bay, Alaska
1 Type 121 Amplifier (condition of instrument not important)	John West Tektronix, Inc. 442 Marrett Road Lexington 73, Mass.
1 Type 545	Chas. Hagen, Test Eng. Microsonics, Inc. 349 Lincoln Street Hingham Mass. Phone RI 9-3100
1 Type 524 and 1 Type 511	Test Equipment Co. 9012 Diana El Paso, Texas

ANOTHER NEW FIELD OFFICE



To better serve the area outlined by the map above, we have opened a new Tektronix Field Office at 3530 Golden Gate Way in the community of Lafayette, California. Strategically located in the fast-growing East Bay region, this office makes the many services offered by a Tektronix Field Office more conveniently available to people in this area.

Tektronix Field Engineer Howard King will be in charge of the new office. Howard joined Tektronix as a Field Engineer in 1956 serving in this capacity in our Long Island Field Office until June 1959 and more recently in our Palo Alto Field Office.

Tektronix Field Engineer Tony Bryan, presently with our Field Office in Endicott, New York, will join Howard in the new location on about July 1st.

Field Secretary Virginia Brown will assist Howard and Tony with details in the new office.

Telephone numbers of the new office are: For the Oakland, Berkeley, Richmond, Albany, San Leandro communities CLifford 4-5353; for all others YEllowstone 5-6101. TWX Number: LAF CAL 1639.

Form 3547 requested

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

Service Scope

USEFUL INFORMATION FOR
USERS OF TEKTRONIX INSTRUMENTS

BULK RATE
U. S. POSTAGE
PAID
Beaverton, Oregon
Permit No. 1

MISSING OSCILLOSCOPES

Our Union, New Jersey Field Office sends word that a Type 310A Oscilloscope, serial number 29959, is missing and may have been stolen from the National Cash Register Co. of Newark, New Jersey. If you have any information on the whereabouts of this instrument, please contact the National Cash Register Co. in Newark, New Jersey.

A WORD OF THANKS AND A SUGGESTION

The February issue of SERVICE SCOPE carried an article warning against damage that can occur to the distributed amplifier of some Type 540/550 Series Oscilloscopes.

We wish to thank the many, many people who wrote us expressing appreciation for our candor in bringing the situation to your attention. Requests for the modification kits have been so numerous we have not been able to procure enough components to fill your orders promptly. We are asking for your patience until we are able to do so.

In the meantime we would like to emphasize the fact that chances are **extremely** small that you will have any trouble. If you wish to reduce these chances still further, we suggest that you check to see that the base of the CRT is clamped securely. Most cases of trouble have been caused by the vertical deflection-plate leads shorting to the edge of the CRT shield opening after the CRT has moved in its clamp; rough handling may cause slippage if the clamp is not secure. Some plastic electricians' tape placed around the shield opening will also help.

We do not wish to retract the recommendation that the modification be made—it can prevent a costly repair. However, some have felt a degree of panic which we did not intend and which cannot be justified.

Field Engineering Offices

ALBUQUERQUE* ..... Tektronix, Inc., 509 San Mateo Blvd. N. E., Albuquerque, New Mexico....TWX—AQ 96 .... AMherst 8-3373
Southern New Mexico Area: Enterprise 678
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Huntsville, Alabama Area: WX 2000
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St. Louis Area: ENterprise 6510

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TWX: W L A 6698 From Los Angeles telephones call .... BRadshaw 2-1563
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MONTREAL ....Tektronix, Inc., 3285 Cavendish Blvd., Suite 160 Montreal 28, Quebec, Canada .... HUnter 9-9707

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*ALSO REPAIR CENTERS

Norfolk, Portsmouth and Hampton Virginia Area: Enterprise 741

17-19

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

TEKTRONIX

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 9 | PRINTED IN U.S.A | AUGUST 1961

ADVANTAGES OF INSTRUMENT CYCLING AND A DESIGN FOR A CYCLING UNIT

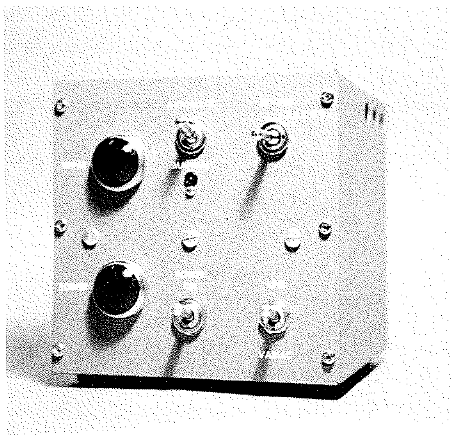


Figure 1—Instrument Cycling Unit.

The cycling of an instrument after repair invites incipient failure from any cause before placing the instrument in service. Periodic switching of the instrument on and off over a span of from 16 to 24 hours can precipitate tube failure (opens or shorts), electrolytic breakdown, transformer breakdown or failure of components in marginal condition. Cycling will also accomplish the gradual aging of any new tubes installed in the repair process.

Changes in original characteristics of tubes and other newly installed components will most likely occur during the cycling period. For this reason, cycled instruments require a recheck of calibration before returning to service.

Typical check points are:

Vertical balance and gain

Plug-in gain and D.C. balance

Sweep timing (sweep cal. at 1 msec/cm)

Complete check and final adjustment of trigger operation.

Les Hurlock of the Tektronix Field Training staff has designed a unit to control the cycling of repaired instruments. It provides simplicity of operation with reliability and at the same time incorporates sufficient versatility to cover most anticipated cycling conditions.

The unit cycles a maximum of four instruments at a time—two on at a time and two off at a time. This arrangement limits the current drawn through the wall outlet and associated breakers.

The unit offers a normal duty cycle of 15 minutes on and 15 minutes off. However, by turning the REVERSE-RACKS switch, you can leave a particular instrument on or off for a longer period of time. Under these conditions, a MANUAL-WARNING neon indicates that the instrument will not cycle unless done so manually. Apart from providing manual operation, the REVERSE-RACKS switch facilitates initial setting up when adding an instrument to or removing an instrument from the racks.

By applying the output of a variable autotransformer to the AUTOTRANSFORMER-IN connector and switching the LINE-AUTOTRANSFORMER control to AUTOTRANSFORMER you can cycle an instrument at a voltage other than that supplied by the line.

Note: Some means of monitoring the auto-transformer voltage should be employed.

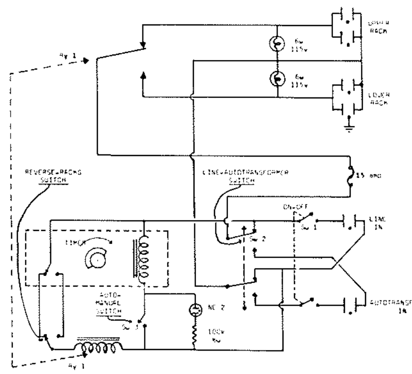


Figure 2 shows the circuit design used in this cycling unit. Notice the 15 amp fuse in the common supply to the upper and lower racks. This fuse prevents excessive current drain in the event of short circuits in the unit or the instruments under-going cycling.

CYCLE UNIT PARTS LIST

QTY.	PART
	SWITCHES
1	DPST 25 amp (Sw. 1)
1	DPDT 25 amp (Sw. 2)
1	SPST (Sw. 3)
1	DPDT (Sw. 4)
	RELAY
1	Ryl-Power* DPDT 25 amp
	TIMER
1	Harco HR026* 2R.P.H.-standard 15 min. on 15 min. off
	or
	Harco HR027* 1R.P.H.-optional 30 min. on 30 min. off
	INDICATOR LIGHTS
1	Socket for candelabra bulb-red jewel (Upper)
1	Socket for candelabra bulb-green jewel (Lower)
2	S6 115V-6W bulbs
1	Neon bulb socket
1	NE15 neon bulb
	CONNECTORS
2	3 pin recessed, male (Line-In and Autotransformer-In)
4	3 pin, female (2 for Upper Rack and 2 for Lower Rack)
	MISCELLANEOUS
1	Fuse holder
1	15 amp fuse
1	100 K ½W comp. resistor
1	Metal Cabinet Budd AU1039-HG*

* or equivalent

Figure 3 shows a chart of the parts required to build the cycling unit.

SERIAL NUMBERS OF INSTRUMENTS MODIFIED TO PROTECT THE DISTRIBUTED AMPLIFIER

The February 1961 issue of SERVICE SCOPE carried an article warning of possible damage to the distributed amplifiers of Type 540A and 550 Series Oscilloscopes. At that time we promised to announce the serial numbers at which a corrective modification became effective.

Here is that information. For the:

Type 541A s/n 21701 RM41A s/n 1271
Type 543A s/n 3151 RM43A s/n 101
Type 545A s/n 29162 RM45A s/n 2191
Type 551 s/n 3180
Type 555 s/n 1683

ALL respective instruments above these serial numbers have the modification. Also; many, many instruments with serial numbers below those listed were modified out of sequence. Visually check the distributed amplifier of your instrument to determine its status. If, after this examination, you are still confused as to your instruments status, contact your Tektronix Field Engineer. He has a complete list of modified instrument serial numbers.

MISSING OSCILLOSCOPES

Through our Chicago Field Office we have learned of the loss of a Type 310 Oscilloscope, serial number 2241 by the G. E. X-Ray, 1061 Jackson Boulevard, Chicago, Illinois. This instrument disappeared from a car parked in front of the G. E. X-Ray office on June 19th, 1961. Please contact these people at the above address if you have any information on this oscilloscope.

From our Long Island Field Office comes word of the disappearance of three Type 310 Oscilloscopes from the Royal-McBee Corporation at 2 Park Avenue, New York City, New York. Serial numbers of these missing instruments are 11496, 4510 and 4511. If you see any of these instruments or have any information regarding them, please contact the Royal-McBee Corporation or your nearest Tektronix Field Office.

Seems that the Type 310's handy size and convenient portability make it a highly desirable item for those who purchase on a "midnight requisition".

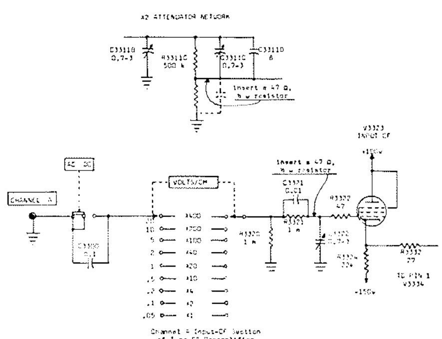
A Type 545A Oscilloscope, serial number 22088, and a Type L Plug-In Preamplifier Unit, serial number 6696, are missing from the Osborne Electronic Corporation, 712 S.E. Hawthorne Boulevard in Portland, Oregon. These instruments were apparently taken from the premises of the Osborne Electronic Corporation by unauthorized persons on the night of March 31, 1961. Please call the Osborne people if you have any information on these instruments. Their telephone number is BE 2-0161.

TYPE 53/54C AND TYPE C-A PARASITIC OSCILLATIONS

On some Type 53/54C and Type C-A Plug-In Units a parasitic oscillation occurs when the attenuator switch is in the .1 VOLTS/CM position and the input is grounded or connected to a low impedance source through a patch cord.

Where these oscillations are only an occasional problem the solution may be to use short ground straps or alligator clips to ground the input instead of patch cords, and use coaxial cables or shielded leads to couple the input to a low impedance source. If this is an impractical solution or the oscillations are a continuing problem, modification of the plug-in unit is recommended.

Type C-A units with serial numbers above 25730 will have this modification incorporated at the factory. For all other Type C-A or Type 53/54C units here's how you install the modification:



Shown in Figure 1 are the two portions of the channel A schematic affected by this modification. The two corresponding portions of the Channel B schematic are identical except for identifying component numbers. Whereas; identifying numbers for components in Channel A are in the 3300 range those of Channel B are in the 4300 range. Bear this in mind as you follow the ensuing instructions.

Channel A—

( ) 1. Locate C3322 (C3023*), a variable tubular-capacitor mounted on the chassis under the Channel A VOLTS/CM switch. From this capacitor, unsolder the 1 meg, ½ w, 10%, composition resistor paralleled by a 0.01 discap.

( ) 2. Solder one lead of a 47 Ω, ¼ w, 10%, composition resistor to the lead of the resistor-capacitor combination unsoldered in step 1. Solder the other lead to the variable tubular-capacitor C3322 (C3023*).

( ) 3. On the dielectric mounting board situated beside the Channel A VOLTS/CM switch locate the variable tubular-capacitor C3311C (C4823*). From this capacitor a bare wire runs to a contact on the second-from-the-front ceramic wafer of the Channel A VOLTS/CM switch. Replace this bare wire with a 47 Ω, ½ w, 10%, composition resistor.

Channel B—

( ) 4. Locate C4322 (C4823C*). a variable tubular-capacitor mounted on the chassis under the Channel B VOLTS/CM switch. Unsolder from this capacitor the 1 meg, ½ w, 10%, composition resistor paralleled by a 0.01 discap.

( ) 5. Solder one lead of a 47 Ω, ¼ w, 10%, composition resistor to the lead of the resistor-capacitor combination unsoldered in step 4. Solder the other lead to the variable tubular-capacitor C4322 (C4023*).

( ) 6. On the dielectric mounting board situated beside the Channel B VOLTS/CM switch, locate the variable tubular-capacitor C4311C (C4923C*). From this capacitor, a bare wire runs to a contact on the second-from-the-front ceramic wafer of the Channel B VOLTS/CM switch. Replace this bare wire with a 47 Ω, ½ w, 10%, composition resistor. This step completes the modification.

*53/54C Unit symbol numbers

TWO NEW SILICON- RECTIFIER MODIFICATION KITS AVAILABLE

Because they offer better reliability and longer life, the relatively new silicon rectifiers are generally preferred over selenium rectifiers.

You can enjoy the advantages of these new rectifiers in your Type 517 or Type 517A Oscilloscopes by installing a Type 517 Silicon Rectifier Mod Kit, Tek number 040-210. Each kit contains a prewired chassis with silicons mounted, schematic, parts list and step-by-step instructions. Type 517 or Type 517A instruments with serial numbers 101 through 1900 will accept this modification—instruments with serial numbers above 1900 come equipped with silicon rectifiers. Price of the Mod Kit is $50.00.

Users of Type 524D or Type 524AD Oscilloscopes can also enjoy the benefits of silicon rectifiers by the installation of a Type 524 Silicon Rectifier Mod Kit, Tek number 040-236. Price $32.00. All but the following Type 524D and Type 524AD instruments will accept this modification:

1. Those with serial numbers 941, 989, 991, 994, 996-998, 1000, 1002, 1006-1008, 1039-1044, 1046-1049, 1051-1053, 1055, 1057, 1058.
2. Those instruments that have had Mod Kit 040-055 or 040-056 installed (selenium stack relocated in line with the fan).

For instruments in the above categories, or for instruments with serial numbers above 1069 which do not have silicon rectifiers, we suggest Type 524 Silicon Rectifier Mod Kit, Tek number 040-177. Price $22.00.

Both the 040-177 and the 040-236 mod kits contain a completely wired chassis with silicons mounted, schematic, parts list and step-by-step installation instructions.

Order these kits from your Tektronix Field Engineer or Field Office. Be sure to include the serial number of the instrument you intend to modify.

CRYSTAL-OVEN MOD KIT FOR TYPE 180 TIME MARK GENERATOR

The installation of a Type 180 Crystal-Oven Mod Kit in a Type 180 Time Mark Generator will improve the frequency stability of this instrument. The modification replaces the original one megacycle crystal-controlled oscillator with a one megacycle crystal-controlled oscillator mounted in a temperature-stabilized oven. A trimmer capacitor provides a means of adjusting the crystal frequency to zero beat with W.W.V. The modification gives to the Type 180 a stability comparable to that of its successor instrument, the Type 180A.

In addition to the crystal oven with crystal, the kit contains: other necessary components, schematics, parts list, and step-by-step installation instructions that include photographs.

Order from your Tektronix Field Engineer or Field Office. Ask for Type 180 Crystal Oven Mod Kit, Tek number 040-252. Price is $35.00.

SERVICING HINT

Should you find it necessary to replace a precision resistor in the sweep timing circuits of Tektronix oscilloscopes, from stock you have on hand or purchased locally, we suggest you contact your local Field Engineer. One brand we have supplied in the past year has not proved to be as stable as most.

USED INSTRUMENTS WANTED

1 Type 502	Ralph Wiese 674 Sweetbriar Milford, Michigan
1 Type 515	Larry Rhoades Systems Research Labs. 500 Woods Drive Dayton 32, Ohio

1 each Type A, B, C, G, H, K, & L Plug-In Units	Jim Wright 2319 E. Indianola Phoenix 16, Arizona
1 Type 511, Type 513 or Type 514	John Padalino 35 Gail Road Morris Plains, N. J. Phone: JE 9-3918

USED INSTRUMENTS FOR SALE

1 Type R Plug-In Unit, s/n 342. Price $225.00	Bill Crouch Plug-In Instruments, Inc. 1416 Lebanon Road Nashville, Tenn.
1 Type 524, s/n 1161	Jack Bennet, Engineer C.B.S. Electronics 100 Endicott Street Danvers, Mass.
1 Type 127	William H. Read Continental Leasing Co. 5215 Hollywood Blvd. Los Angeles 27, Calif. Phone: HO 9-5371
1 Type 524AD, s/n 1813 1 Scopemobile Price for both $850.00	Monty Studio City Television 12504 Moorpark Street Studio City, California Phone: PO 6-4555 TR 7-1441

QUESTIONS FROM THE FIELD

1. Q: We are having difficulty with noise coming through our 115-v ac line; this noise is being generated by rf oscillations in a nearby department. Do you have any information regarding toroid filters that may help correct the situation?

   A: Toroid cores with an OD of 1", ID of ½" and a thickness of ¼" placed on the instruments power cord should help in filtering out the unwanted signal. It will probably be best to make up a special power cord. Remove the plug or "cap" from the power cord and thread the cord through the core repeatedly until the core center is tightly loaded. Use two or more cores if necessary. If you are unable to obtain the cores locally, you can order them through your Tektronix Field Engineer. Ask him for Tek part number 276-519. Price is 60 cents each.

2. Q: It looks as if the Type 81 Plug-In Adapter's plate dropping resistor R532 (4.7 k, ½ w, 10%, composition) for the output cathode follower might be a bit low on the wattage rating. A check of several adapters reveals this resistor to be blackened around its center. Could we replace this resistor with a 2 watt resistor of otherwise equal value and rating?

   A: Your tip is correct. Our check reveals that R532 is dissipating approximately 1.3 watts of power; that's a little too much. A modification has been submitted to clear up this problem on production instruments. On instruments in the field, this resistor should be replaced with a 2 watt resistor if it shows indication of overheating or burning.

3. Q: What is an easy way to check 6DK6's for cathode interface.

   A: Feed a signal from a Tektronix Type 105 or Type 107 Square Wave Generator into the oscilloscope. Contrive to shift (via a Variac, Powerstat or some similar instrument) the line voltage supplying power to the oscilloscope. If the overshoot in the response changes with line voltage you have it! (cathode interface). Interface will increase as you decrease line voltage.
   Editor's note: We refer you to the August 1960 issue of SERVICE SCOPE. An article in that issue dealt at some length on the problem of cathode interface. The title of the article—"Does the Square Wave Response of Your Scope Look Like This".

4. Q: Let us assume that by miscalculation a very high potential is applied to the signal input of the Type 507 Oscilloscope. Does the Type 507 have any protection for the operating personnel under these circumstances?

   A: We trust a good deal to the operator's judgment in using any oscilscope. However, included as an accessory with every Type 507 is a heavy copper buss. Mounted in this buss are three coaxial connectors and a ground post. In operation of the instrument, the connectors on the buss are attached to the connectors on the rear of the Type 507. The grounded side of the coaxial fittings provide connection between the oscilloscope, ground, and the ground post at the test setup. It is essential, and should be mandatory, that the observation-shack ground be tied to the oscilloscope also. This should be done by means of the ground post on the buss mentioned above.

5. Q: Is there a way of synchronizing the oscillators of a number of Q Units?

   A: Yes. Connect pin 5 of T5779 in the first Q Unit to pin 1 of V5770 in the second Q Unit through a 50 pf capacitor. Connect the second Q Unit to the third Q Unit in this same manner, etc. This injects enough signal from the first unit into the second, from the second into the third, etc., to bring the oscillators of the several units into synchronization. However, for this method to work the oscillators of the several Q Units must all be adjusted to operate at or very near the same frequency. Adjustment of oscillator frequency is explained on page 6-2 of the Q Unit Instruction Manual.

   The need for oscillator synchronism arises when long input leads to the Q Units are laid closely together or when the leads are not adequately shielded. Under these conditions, capacitive coupling of signals will occur and cause erroneous readings at the output of the Q Units.

DOUBLE PULSER OUTPUT FEATURE

The Tektronix Type 535, 545, 535A, 545A, 555 and 585 Oscilloscopes contain a double pulse generator. When these instruments are set up to provide the "superposition of waveform" feature, the +GATE A (+GATE MAIN SWEEP)* provides a double pulse output with the following variables:

a) The width of the pulse is variable via the Time Base A TIME/CM (Main Sweep TIME/CM)* switch and is variable with the concentric variable control.

b) The time of occurrence relative to the pulse is variable by way of the DELAY-TIME MULTIPLIER control.

c) The point of the double pulsing action can be varied by way of the Time Base B TIME/CM or DELAY TIME (Delaying Sweep TIME/CM or DELAY TIME)* switch and the concentric LENGTH control.

Here's how you set up the oscilloscope to provide the "superposition of waveform" feature:

1. Connect the VERT. SIG. OUT connector to the Time Base B TRIGGER INPUT (Delaying Sweep TRIGGER OR EXT. SWEEP IN)* connector. Connect a capacitor of about 100 $\mu\mu$f capacitance between the +GATE B (+GATE DEL'G SWEEP) * connector and the DEL'D TRIG. (DEL'D TRIG. FROM MAIN OR DEL'G SWEEP)* connector.

2. Set the HORIZONTAL DISPLAY switch to 'B' INTENSIFIED BY 'A' (DELAYING SWEEP)*. Connect the source of the wave train to the INPUT or CHANNEL connector of the plug-in preamplifier. Adjust the controls to obtain a delayed sweep. Turn the DELAY-TIME MULTIPLIER control to a setting in the upper part of its range. Adjust the Time Base B TIME/CM OR DELAY TIME (Delaying Sweep TIME/CM OR DELAY TIME)* control so that the desired number of waveforms is displayed.

3. You should now observe two brightened portions of the display—one at the start of the display at the left-hand end of the graticule, and the other at a later point along the graticule. Set the Time Base A TIME/CM (Main Sweep TIME/CM and MULTIPLIER)* control so

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

that the left-hand brightened portion includes the first waveform in the train. With the DELAY-TIME MULTIPLIER, move the second brightened area so that it includes the waveform you want to compare with the first waveform in the train.

4. Set the HORIZONTAL DISPLAY switch to 'A' DEL'D BY 'B' (MAIN SWEEP DELAYED)*. The display should now present both the first waveform in the train and the other waveform that was brightened in the preceding step. You can now use the DELAY-TIME MULTIPLIER to superimpose these two waveforms for precise comparison. The resulting reading of the DELAY-TIME MULTIPLIER, multiplied by the TIME/CM OR DELAY TIME setting indicates the delay time between the waveforms being compared. You can also now observe any jitter in the second waveform with respect to the first.

* Captions in parenthesis refer to the Type 535 and Type 545 instruments.

FUNDAMENTALS OF SELECTING AND USING OSCILLOSCOPES

Two authoritative articles covering the fundamentals of selecting and using oscilloscopes are now available in a single booklet. These articles originally appeared in ELECTRICAL DESIGN NEWS; the first one, "Factors Affecting the Validity of Oscilloscope Measurements", in the November 1960 issue and the second, "Appraising Oscilloscope Specifications and Performance", in the February 1961 issue.

Author of the articles is John Mulvey. John has been with Tektronix since 1952. He has worked in Test and Calibration, in Engineering and in Marketing. In addition, he has had nearly six years experience in the Philadelphia and Los Angeles areas as a Field Engineer. At present he is manager of the Field Information Group supporting Field Office activities. His wide experience enables John to write clearly and interestingly about his subjects. We believe you will find the booklet informative and helpful.

A copy of this booklet may be obtained through your Tektronix Field Engineer or the nearest Tektronix Field Office. A current list of Tektronix Field Offices appeared on page four of the JUNE 1961 issue of SERVICE SCOPE.

DC RELAY FIELD MODIFICATION KIT FOR "A" SERIES 530/540 OSCILLOSCOPES

Magnetic flux leaking from the ac relays will cause ripple on the crt trace of some 530/540 "A" Series instruments. Rack mounted instruments seem to be most susceptible to this difficulty because the crt shield is oriented differently with respect to relay location.

A way to tell how much, if any, ripple is caused by the relay is:

1. Short the vertical-deflection plates together and rapidly rotate the horizontal position control back and forth while looking for vertical ripple.
2. Short the horizontal-deflection plates together and rapidly rotate the vertical-position control back and forth while looking for horizontal ripple.

A Field Modification Kit that replaces the ac relay with a dc relay in the 530/540 "A" Series Oscilloscopes is now available. This modification will eliminate the ripple stemming from the ac relay in these instruments. It will also improve the relay and power supply reliability by eliminating the relay chatter.

The kit contains a complete set of components including; a new time-delay relay and power-supply relay, parts list, schematic and step-by-step instructions. Ask for DC Relay Field Modification Kit, Tek. No. 040-258. Price is $8.00.

We earnestly recommend you consult your Tektronix Field Engineer before ordering this modification kit. It is always to your advantage to avail yourself of his help when ordering Tektronix instruments, replacement parts or modification kits. It may be particularly so in this instance.

THE CORRECT TOOL

The correct tool makes a difficult job easier. It may also point to a successful solution for a seemingly impossible task. Conversely, the selection of an incorrect tool will result in costly delays and bitter disappointment.

The purchase of an accurate, reliable, high-quality oscilloscope involves a substantial sum of money. In these days of tight schedules and even tighter budgets, it is of prime importance that the instrument selected do the job as efficiently, as easily and as quickly as possible. It is to this end that a great measure of the Tektronix Field Engineer's training is directed.

There are many types of oscilloscopes, each designed for a specific application area...from the broad general-purpose oscilloscope to the highly specialized instrument. Your Tektronix Field Engineer can help you make the best possible investment by recommending the oscilloscope best suited to your present and future needs. He will be happy to back up his recommendation with an actual demonstration of the instrument in your application. But he will not hesitate to recommend some other method of attacking the problem if it appears to meet your requirements more efficiently. Try him. A no-pressure consultation with him can help you select the correct tool for your work.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

Tektronix Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 10 PRINTED IN U.S.A OCTOBER 1961

PROTECTION OF TYPE 321 VERTICAL AMPLIFIER AGAINST TRANSIENTS

Under certain conditions, the transistor Q443* in the vertical amplifier of the Type 321 Oscilloscope will fail. With the VOLT/DIV switch in the most sensitive (0.01 v/div) position, an inadvertent connecting of the signal input to a high-voltage overload will cause damage to this transistor. Or, with the INPUT switch in the AC position, C401—the AC-input coupling capacitor—can charge to a high negative voltage (150-500 v). If, immediately after reaching this charge, the capacitor should suddenly be discharged by the grounding of the scope input, the transistor will suffer damage. In either instance, the resulting positive surge will cause an excessive B-to-C voltage that will exceed the collector breakdown voltage of Q443.

A germanium diode connected between the cathode of V423 (5718 input CF) and the 6.3-v dc filament supply will protect Q443 against the positive-going surges generated under these conditions. The modification will in no way impair the instrument's performance. We recommend the use of the low-capacitance Type T12G (or equivalent) diode.

To add this protective circuit to the Type 321, connect the recommended diode from the cathode, pin 5, V423, to the +6.3 v (decoupled) source, which supplies filament power to pin 6, V423. The cathode (color-coded) end of the diode should be connected to the filament line so that in normal operation the diode is back-biased by about 5 volts. See figure 1 below.

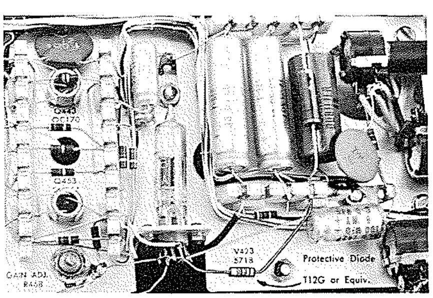


Figure 1

The schematic diagram for the instrument should be modified as shown in figure 2 and the new diode assigned the

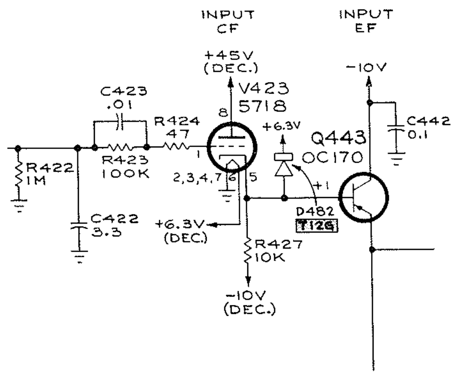


Figure 2

symbol D482 and added to the instrument-manual's parts list.

This modification applies to all Type 321 Oscilloscopes with serial numbers below 479. A factory installed modification protects Type 321's with higher serial numbers.

* This transistor is identified as Q433 on some early schematic diagrams.

FLORIDA OFFICE CONSOLIDATION BENEFITS CUSTOMERS

On September 1, 1961, our St. Petersburg, Florida Field Office consolidated with our Orlando, Florida Field Office. This consolidation will provide larger, more complete facilities and improved service benefits to Tektronix customers in the affected areas.

Among the factors recommending this action several are of particular importance to customers in these areas:

(1) Recent expansion of facilities at the Orlando Field Office provide an enlarged and more complete emergency repair-parts stock.

(2) Direct access to an enlarged repair-parts stock by your Tektronix Field Engineer. Also, more readily at his disposal are the field maintenance skills of the enlarged and well-equipped Field Repair Center.

(3) Installation of special equipment to wash instruments when the need for this treatment is indicated. This equipment includes an oven to dry or bake out residual moisture in washed instruments.

(4) Improvements in the Florida highway system now permit effective service of the eastern and southern parts of the state from this combined Field Engineering Office and Repair Center.

(5) Greater utilization of Field Office personnel and facilities are made possible under this consolidation. Customers in the affected areas—and this includes the St. Petersburg-Tampa area—will receive improved Field Engineering coverage and service benefits.

Customers in the St. Petersburg-Tampa area may call the Orlando Office toll free by using the telephone number WX2199.

For all others, the telephone number for the Orlando Office is GArden 5-3483.

Regular visits by our Field Engineers will continue to provide our Puerto Rico customers with the same service enjoyed by our customers in Florida.

From Puerto Rico call—Orlando, Florida, GArden 5-3483 or write to:

Tektronix, Inc.
205 East Colonial Drive
Orlando, Florida.

TEKTRONIX POLARIZED VIEWER FOR TEKTRONIX 5" OSCILLOSCOPES

To people who must view oscilloscope traces under high ambient light conditions, the problem of light reflections is an irritating one.

Interpreting an oscilloscope display under these conditions is always difficult and sometimes well nigh impossible. Even with the intensity turned up to maximum brightness this is true. And here one encounters another hazard. There is always the possibility of permanent damage to the crt phosphor when the INTENSITY control is set to give maximum trace brightness. This is particularly true when the instrument is operated at the slower sweep speeds.

The new Tektronix Polarized Viewer was designed to overcome these problems stemming from high ambient light conditions. Installed on your oscilloscope, it will reduce light reflection problems to a negligible factor and eliminate the need for dangerous intensity settings at slow sweep speeds.

The pictures shown below were taken in a well lighted office with large windows and a southern exposure. The day was very bright and sunny. These factors combined to give an extremely high ambient light condition.

Both pictures were taken without altering the position of the oscilloscope or camera. This fact is attested to by comparing the pattern of front panel light reflections. Close scrutiny will also disclose that the position of the front panel controls are the same in both pictures.

Figure 1 shows the oscilloscope without the Polarized Viewer. The Amplitude Calibrator waveform being displayed on the crt was barely discernable to the naked eye and does not show in the photograph at all. Figure 2 with the Polarized Viewer in place eliminates reflection from the crt and the Amplitude Calibrator waveform is readily visible.

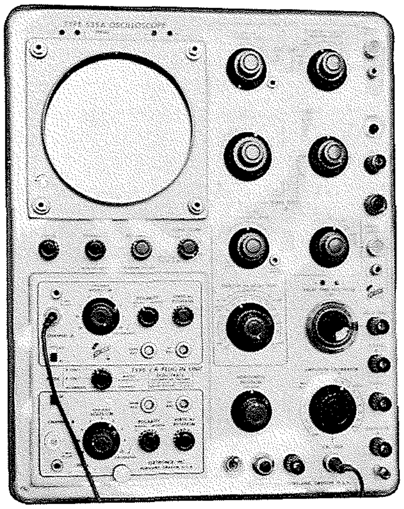


Figure 1

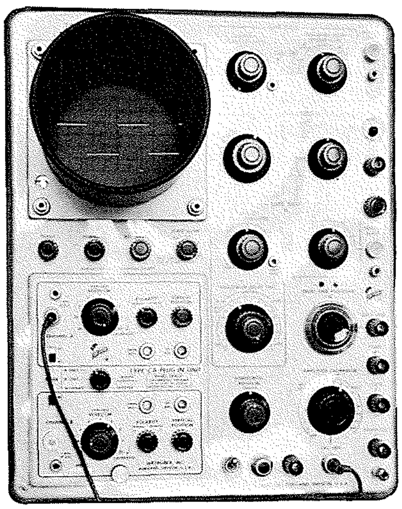


Figure 2

The Viewer slips on or off the oscilloscope in a matter of seconds. There are no nuts or bolts to loosen or tighten.

Ask your Tektronix Field Engineer for a demonstration of the Polarized Viewer. Tek part number is 016-035. Price is $10.00.

NEW FIELD MODIFICATION KITS

SILICON-RECTIFIER MODIFICATION KIT

For Type 532, s/n 101 to 6921, and Type RM32 Oscilloscopes, s/n 101 to 449.

This modification replaces the selenium rectifiers with silicon rectifiers which offer more reliability and longer life.

The kit includes a prewired chassis with silicon diodes mounted, step-by-step installation instructions, photo, parts list and schematic.

Approximate installation time by a trained technician is 30 minutes.

Order through your Tektronix Field Engineer. Specify Type 532 Silicon Rectifier Mod Kit, Tek. No. 040-218. The price is $12.00.

PRESET-STABILITY MODIFICATION KIT

For Type 532 Oscilloscopes, s/n 5420 to 5665.

This modification installs a new potentiometer and preset switch to enable the operator to quickly switch to a preset-stability setting.

The kit includes a Stability-Potentiometer-and-Preset-Switch assembly, step-by-step installation instructions, parts list and schematic.

Approximate installation time by a trained technician is one honr.

Order through your Tektronix Field Engineer. Specify Type 532 Preset-Stability Mod Kit, Tek. No. 040-244. Price is $6.50.

TYPE "N" PROBE-POWER FIELD MODIFICATION KIT

For Type N Plug-In Units, s/n 101 to 220.

This modification kit installs a probe-power socket on the front panel of the Type N Plug-In unit. It permits the use of the P6025 Cathode-Follower Probe* -a high impedance probe designed for use with the Tektronix Type N Plug-In Unit.

The kit includes a probe-power socket, necessary hardware, tags, photos and step-by-step installation instructions.

Approximate installation time by a trained technician is one hour.

Order through your Tektronix Field Engineer. Specify Type "N" Probe-Power Field Mod Kit. Price is $8.65.

* The P6025 Cathode-Follower Probe will be in full production by December 1961.

EXTERNAL-TIME-SWEEP MODIFICATION KIT

For Type N Plug-In Units, s/n 101 to 220.

This modification installs an External-Time-Sweep socket on the front panel of the Type N Plug-In Unit to permit the use of two N Units in the Type 551 or Type 555 Oscilloscopes.

The kit includes all the necessary hardware, tag, photo and step-by-step installation instructions.

Approximate installation time by a trained technician is 30 minutes.

Order through your Tektronix Field Engineer. Specify Type "N" External-Time-Sweep Mod Kit, Tek. No. 040-246. Price is $3.10.

SERVICING HINTS

TYPE 107 WAVEFORM DISTORTION

Some Type 107 Square-Wave generators prior to s/n 1450 may produce distorted waveforms. We find that hi-gain 12BY7's in V45 and V55 positions of the affected instruments produce oscillations which result in poor risetime and cause a step in the negative portion of the square wave (see Figure 1; a, b. c.).

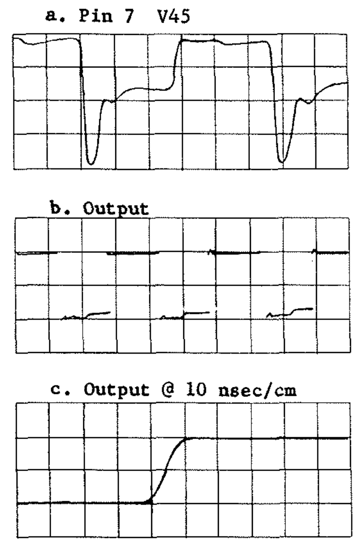


Figure 1

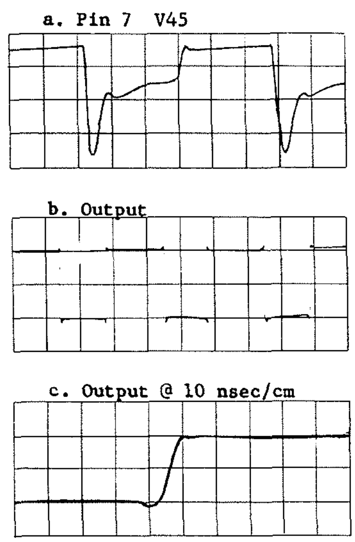


Figure 2

When viewed on a Type 585 scope, the risetime of the affected Type 107's ranged from 4.0 to 8.0 nanoseconds, depending upon the particular tubes used. In less extreme cases of oscillation, the risetime varied with frequency.

To correct this condition in your instrument, dress coupling capacitors C57 and C67 down close to the filament buss line. Relocate C49 and C59 directly over the tube sockets, and with leads as short as possible. Connect these capacitors between pins 1 and 8 of their respective sockets. C49 and C59 should be dressed

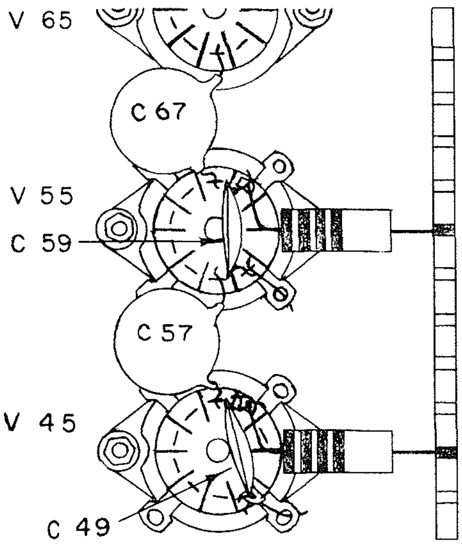


Figure 3

in an upright position (see Figure 3 for proper parts layout).

Type 107's from s/n 1450 on are modified at the factory and should not have this problem. (Figure 2; a, b, c, shows waveforms of a properly working Type 107).

TEKTRONIX TYPE 545 CALIBRATION AND MAINTENANCE PROCEDURE ERROR.

The figures given in the "Tektronix Type 545 Oscilloscope Calibration and Maintenance Procedure" (Tek. No. 070-282) contain an error. The figures given for the vertical amplifier stage gains (Step 7.7.3.1, page 3-30) are not correct. Corrected pages 3-30 will be distributed to Tektronix Field Offices as soon as possible.

Meanwhile, existing copies should be corrected as follows:

7.7.3.1 Insufficient Gain. Use a regular voltage measurement plug-in in the instrument under test. Check stage gains to assure even phase-splitting ahead of the main vertical-amplifier input. Measure amplitude at each grid comparing gain against the tables below:

	Gain Min.	Normal
12BY7A or 6AW8 (GAIN ADJ. clockwise)	4-4.5	5.5-6
6BQ7/6DJ8 Cathode-Follower Stage*	0.7	0.7
Distributed Amplifier (6CB6's or 6DK6's)	20-22	22-24

*Above serial numbers 9292, 0.7 gain is total for **both** cathode-follower stages. If input and output stages are at or near minimum gain, tubes in one or both stages may require replacement.

If overall amplifier gain is 70 or more, the trouble is probably not in the amplifier, and may be in crt sensitivity. Recheck high voltage supplies (4.1) and Deflection factor (6.4).

If vertical amplifier tubes are changed, be sure to repeat all parts of Step 7. If tube change does not provide correct gain, check plate-load resistors, screen potentials, decoupling networks, filament lines, etc. Also check calibrator accuracy (Step 8.)

USED INSTRUMENTS WANTED

1 Type 515 or Type 515A or Type 516	R.H. Dempey Electronic Services 3648 Harkness Street Napa, California Phone: BAldwin 6-7773
1 Type 531 1 Type 53/54C	Customer prefers his name be kept confidential. Please direct inquiries to the Tektronix Endicott Field Office, 3214 Watson Blvd., Endwell, New York
1 Type 513D, Type 514 or Type 310	R.H. Cook 1213 Webster Royal Oak, Michigan
1 Type 541AD or Type 511AD	Johny Russell 2870 Ronald Street Riverside, California Phone: OVerland 6-6119

USED INSTRUMENTS FOR SALE

1 Type 511AD s/n 1821	Dick Stivers Valor Electronics 13214 Crenshaw Gardena, California Phone: FAculty 1-2280
1 Type 531 s/n 2456 1 Type 53C s/n 3580	Dr. K.L. Cook University of Utah Geophysics Department Salt Lake City, Utah
1 Type 127 s/n 155	Dr. Geoorge Czerlincki Johnson Foundation University of Pennsylvania Philadelphia 4, Penn. Phone: Evergreen 6-0100, Ext. 8796
1 Type 555 s/n 282 2 Type CA Plug-Ins, s/n's 15262 & 18353	S. Olive, Vice-President R. D. Brew & Co. 90 Airport Road Concord, New Hampshire
1 Type 512 s/n 2567	Macan Engineering & Mfg. Co. 1564 N. Damen Avenue Chicago 22, Illinois Phone: BE 5-3386
1 Type 511AD s/n 5210	Wilbur McBride Standard Oil Research Laboratory 4440 Warrensville Center Road Cleveland 28, Ohio
1 Type 511AD s/n 4461 Price $200.00	Steve Evans Advanced Instrument Corp. 1475 Powell Emeryville, California

MISSING OSCILLOSCOPES

Bramco, Inc. of 4501 Belevidere, Detroit 14, Michigan, reports that the following instruments are missing from their plant and are presumably stolen:

1 Type 543 Oscilloscope, s/n 158
1 Type 535A Oscilloscope, s/n 20235
1 Type 53/54C Plug-In Unit, s/n 16971
1 Tye 53/54L Plug-In Unit, s/n 2745
1 Type 53/54L Plug-In Unit, s/n 2745

If you have any knowledge of the whereabouts of these instruments, Bramco, Inc. would appreciate it very much if you would contact them.

CORRECTION

"SOLVING POWER LINE PROBLEMS" (JUNE 1961 SERVICE SCOPE)

The method outlined in the June issue of Service Scope for determining power-line distortion by comparison of filament-line rms and peak-to-peak voltages is not valid for Type 517(A) and Type 555 Oscilloscopes, and—even with other model instruments—should only be taken as a rough indication of the line voltage distortion actually present. Gordon Sloat, Manager of the Tektronix Transformer and Coil Department, points out that the implication in the June article that this method provided more than an approximation of line-voltage distortion is incorrect.

The Types 517(A) and 555 Oscilloscopes employ a peak-limiting saturable reactor to provide regulation of the indicator unit filament lines, and the distortion on the filament lines in these instruments will not be representative of the line-voltage waveform. A typical VOM may show only 5.8 volts for a true rms of 6.3 volts on one of these regulated filament lines.

In other instruments, a certain amount of filament-line distortion may be introduced in the transformer because of the filament-winding positions and other transformer design parameters. Since these winding locations and parameters may vary considerably between serial ranges of instruments and between instrument types, Gordon has suggested that the technique of using filament-line distortion as an indicator of power-line

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distortion should **not** be relied on heavily.

Comparison of the actual peak-to-peak versus true rms-power-line voltages is preferred as a much more accurate method of determining the suitability of the power-line waveform for proper B+ regulation.

For the peak-to-peak measurement, the V-O-M adapter suggested in the June 1961 issue of Service Scope, or an accurate peak-to-peak reading voltmeter are recommended; for rms readings, an iron-vane or thermocouple meter will give the most accurate results.

A TIP FOR CLEANING TIPS

Figure 1

Figure 1 above shows a handy-dandy unit for keeping soldering-iron tips clean. We find this cleaner, much more efficient, and quicker than the old wipe-on-a-cloth method.

Easy to construct and simple to use, it does an excellent job. To use it, just draw the soldering-iron tip down through the brush bristles as shown in figure 2.

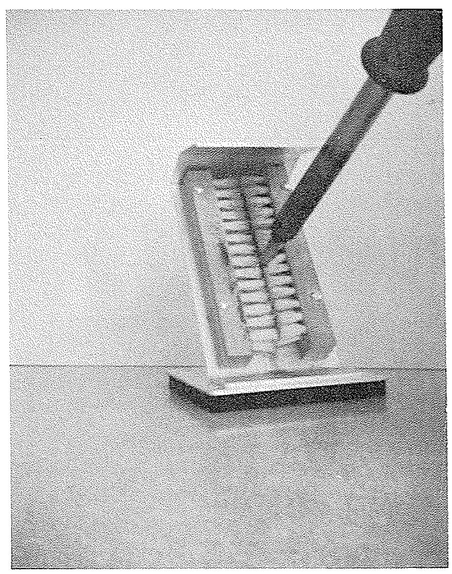


Figure 2

We used 0.064" aluminum in constructing the unit shown here. Base dimensions are 4" x 4". The bracket on which the brushes are mounted is, in this instance, spot welded to the base. You could just as easily mount the bracket to the base with two flat-head bolts counter sunk flush with the bottom side of the base. Locate the bracket 3/8" from the front edge of the base.

Form the bracket for the brushes from a piece of aluminum 3" x 8". One inch from the end of this material make a 60° bend. Five inches from this bend make a 45° bend. One and one quarter inches from the 45° bend make a 30° bend. Be sure you make each bend in the direction as shown in the picture.

On the five inch section of this bracket, 7/16" in from each side and 1¼" up from the 60° bend, drill four holes (two holes to a side) on three inch centers. Use a #27 drill. If you wish to be real fancy you can make slots about ½" long and as wide as the holes. Then as the brush bristles wear you can readjust the brushes close to each other.

The brush portion of the cleaner can be purchased at almost any hardware store. Ask for a white tampico hand brush. Dimensions of the brush should be 4¾" long by 1½" wide. One brush will be all you require per unit.

One and one eighth inches from one end of the wood handle and ¼" down from the top, drill two holes on three inch centers. Use a #14 drill. Now saw the handle through the center lengthwise. This will give you two brushes 4¾" long by 7/16" wide. Mount the brushes as shown in the pictures and you have a quick, convenient and efficient soldering-iron-tip cleaner.

You may mount the cleaner permanently in a convenient location by drilling holes in the base plate and securing the unit with screws or bolts. The one shown has sponge rubber strips ½"wide by ¼" thick cemented to the base. They hold the cleaner in place when it is used and have the added advantage of making the unit portable.

The metal extending out on the top of the cleaner (formed by making the 30° bend) is important. It deflects downward and away from the operator any hot solder or tip flakes dislodged by the cleaning brushes.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

TEKTRONIX

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 11 PRINTED IN U.S.A DECEMBER 1961

ACCURATE FREQUENCY MEASUREMENTS

By Jerry Kraxberger, Tektronix Field Engineer

The sweep-time accuracy of most Tektronix Oscilloscopes is specified to be ±3% on any range. Some oscilloscope operators find it necessary, at times, to make time or frequency measurements to much closer tolerances. Faced with these requirements, the oscilloscope operator will most likely rely on the highly accurate and well-known method of using Lissajous patterns to compare an unknown frequency with a standard frequency. This method has two drawbacks; one, it may not be suitable for the oscilloscope at hand; two, it requires considerable set-up time.

You may use a much simpler, yet equally accurate, method provided your oscilloscope possesses—as all Tektronix Oscilloscopes do—a triggered sweep. The accuracy of the instrument does not enter into the measurement and the wave shape of either signal, i.e. sine wave, sawtooth, pulse, etc., is not important.

To use this method, connect one signal to the external-trigger input and the other to the vertical-amplifier input of the oscilloscope. You may use either signal as the standard but you must connect the lower-frequency signal to the external-trigger input. Trigger the sweep in the normal manner. On Tektronix Oscilloscopes, set the TRIGGERING MODE switch to AC or DC. Do not use the AUTOMATIC or HF SYNC modes for this application. Make certain the sweep is not free running by temporarily removing the external-trigger signal. If the sweep is free running, a trace will remain on the crt.

Let's look at a specific application. Suppose you want to adjust a 400-cps signal to an accuracy better than ±0.01%. We suggest the use of a triggered-type oscilloscope and a Tektronix Type 180A Time-Mark Generator* since 400 cps is an integer of the time-mark generator's 1-mc (±0.001%) crystal-controlled oscillator frequency.

Here is a suggested procedure: (see block diagram, Fig. 1)

1. Adjust the oscilloscope sweep time to 1 msec/cm.
2. Trigger the oscilloscope externally from the 10-msec marker (100 cps) of the time-mark generator (external-trigger-input of oscilloscope).
3. Connect the 400-cps signal to the vertical-amplifier input of the oscilloscope.
4. Adjust the 400-cps frequency precisely until it does not move horizontally on the screen.

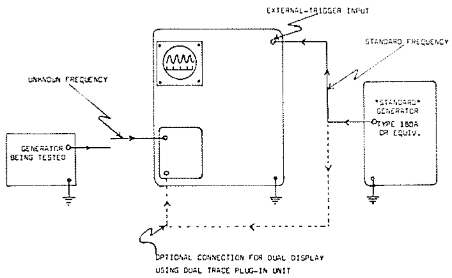


Fig. 1

Since the period of a 400-cps signal is 1/400 sec or 2.5 msec, you should now have 4 complete cycles of the 400-cps signal displayed in 10 cm horizontally (10 msec of time) on the screen.

If the 400-cps signal does not move horizontally, and if the Time-Mark Generator has zero tolerance, the signal under test will be 400 cps ±0.0.

With the Tektronix Time-Mark Generators specified in this article as the standard source, the signal under test can be adjusted to 400 cps ±0.001% or 400 cps ±0.004 cps.

Note that if the signal were off by ± 0.01 cps, one complete cycle would move past a given point on the crt screen in 10 seconds. When you consider the accuracy of the specified time-mark generators, this would be 400 cps ±0.104 cps.

You can use the above method of frequency comparison because the 400-cps signal under test and the 1-msec (1 kc) time-mark signals are exact integers of the 1-mc/sec frequency of the time-mark generators crystal-controlled oscillator. Note that the oscilloscope sweep time does not enter into the measurement. It is, however, an aid when making preliminary adjustments of the signal under test.

If you use a dual-trace preamplifier (Type C-A for example)** in the oscilloscope vertical channel, you can observe both signals on the crt screen simultaneously. To do this, run another jumper from the time-mark generator's 1-msec output to the dual-trace preamplifier's B channel. Set the preamplifier MODE switch to the ALTERNATE, CHOPPED, or ADDED ALGEBRAICALLY position. The 1-msec markers will remain stationary on the crt screen but the 400-cps signal will travel to the right or to the left if it is not exact.

To insure the accuracy of the Type 180A Time-Mark Generator, you can compare or calibrate its frequency with the Bureau of Standards' WWV station as follows: Tune a short-wave receiver to station WWV. Add a short length of wire to the 1-μsec output of the Type 180A Time-Marker Generator. The generator's 1-mc signal will beat with the incoming WWV signal in the short-wave receiver's A.M. detector. The difference frequency in cycles will be a measure of the time-mark generator's accuracy in parts per million. You can minimize this difference by adjusting the variable-trimmer capacitor across the oscillator crystal in the time-mark generator. Monitor this difference signal right off the detector of the short-wave receiver. Use an oscilloscope to do this. One cannot hear the low-frequency zero beat. Besides, the low-frequency response of the receiver's audio system may not be good.

* The following Tektronix Time-Mark Generators may also be used for this application; Type 180 with a Type 180 Crystal Oven Mod Kit (Tek No. 040-252) installed. Type 181 and Type RM 181 with Crystal-Oven Combination accessory (Tek No. 158-007) installed.

** Tektronix instruments on which you may observe these signals simultaneously are; Type 502 Dual-Beam Oscilloscope and Type 516 Dual-Trace Oscilloscope. Any Type 530, Type 540, Type 550-Series Oscilloscope with a multiple-trace, letter-type, Plug-In Preamplifier in the plug-in compartment (this would also include the Type 580 Series Oscilloscopes with a Type 81 Plug-In Adapter). Type 560 or Type 561 Oscilloscopes with a Type 72 Dual-Trace Plug-In Unit.

SHIPPING BLOCKS AND INSTRUMENT PACKAGING

A continuing problem for both Tektronix and our customers is the damage suffered by instruments in transit.

The most foolproof container a customer can use when shipping a Tektronix instrument is the original carton in which it was received. These cartons and their attendant packing materials are the result of much research and some sad experiences. An instrument, properly housed in one of these containers, will come through a normal shipment ordeal in excellent condition.

We earnestly recommend that, whenever possible, the original Tektronix shipping carton along with the dunnage and any shipping blocks be retained and stored for future use.

We would also like to make the following suggestions for packaging Tektronix instruments for shipment:

If you do not have the original shipping carton, contact your Tektronix Field Engineer. He very probably will be able to supply you with a factory-approved carton.

If the instrument has a shock-mounted

chassis, be sure the original shipping blocks are put in place. When these blocks are not available, make substitutes of corrugated paper, sponge rubber, styrofoam or similar material. Customers quite often send a shock-mounted-chassis instrument to us without the shipping blocks or a suitable substitute in place. Almost invariably the instrument will suffer some shipping damage because of the omission.

All instruments should be completely wrapped in kraft paper or other pliable dust-resistant material. Set the wrapped instrument in the original carton and place the dunnage around it. Close carton and seal with gummed tape.

If the original carton is not available, use a container of corrugated paper, wood, or metal construction. The container should be large enough to allow a minimum of one and one-half inches clearance around the instrument—top, sides, bottom and ends. Fill this clearance area with some type of compressible material, *and do not use wooden blocks to support the instrument rigidly in the carton*. Rubberized hair, wood excelsior or paper excelsior are preferred materials. Float the instrument so as to completely surround it with an even thickness of this protective material. In the absence of these materials, sheets of corrugated paper cut from other cartons will make an acceptable substitute filler. Most instruments so packed will survive ordinary shipping conditions in good shape. It takes a very resolute and satanically-minded shipping-agent employee to sucessfully damage an instrument packed in this manner.

If your copy of SERVICE SCOPE did not carry your correct address, we would like to know so that we can remedy the error. Also, if your friends or associates would like to receive their own copies, please tell them to write us—or you can send us their names, titles, and addresses.

NEW FIELD MODIFICATION KITS

TYPE 524 FOUR-POSITION VERTICAL SELECTOR SWITCH MODIFICATION KIT (with Revised IRE Response Network.)*

For Type 524D Television Oscilloscopes, s/n's 101 to 1399 inclusive except those instruments that have had the older Mod Kit, Tek No. 040-057, installed.

This modification kit installs a four-position vertical switch and an access panel to provide the following improvements:

a. A FLAT vertical response to 5 megacycles within 1%. This passband is necessary for measuring the radio-frequency "burst" used in color TV.

b. A new IRE Response Network which changes the roll off characteristics to conform with the Standard '58 IRE 23.S1, as amended July 1, 1961.

Order through your local Tektronix Field Engineer or Field Office. Specify Type 524D Four-Position Vertical Selector Switch Mod Kit, Tek. No. 040-271. Price is $17.25.

*This new modification kit replaces the old Type 524 Mod Kit Tek No. 040-057 which installed a four-position vertical selector switch and access panel but did not include the Revised-IRE-Response Network.

To install the IRE-Response Network in instruments that have been modified with Mod Kit No. 040-057, see Type 524AD Modification Kit described elsewhere in this column.

TYPE 524AD IRE NETWORK MODIFICATION KIT

For Type 524AD Television Oscilloscopes s/n's 1400 to 6584 inclusive and for Type 524D Television Oscilloscopes below s/n 1400 that have been modified (Field Mod Kit, Tek No. 040-057) to include a four-position Vertical Response switch and access panel.

This modification installs a new IRE Response Network in the Type 524AD Oscilloscope. This network changes the roll-off characteristics to conform with the Revised Standard '58 IRE 23.S1 as amended July 1, 1961.

The kit includes a Vertical-Amplifier-Response Selector switch, drawings, schematic and step-by-step installation instructions.

Order through your local Tektronix Field Engineer or Field Office. Specify Type 524AD IRE Response Network Mod Kit, Tek. No. 040-263. Price is $12.20.

TYPE 525 IRE RESPONSE NETWORK MODIFICATION KIT

For Type 525 Waveform Monitor s/n's 101 to 1299 inclusive.

This modification changes the IRE Response characteristics in the Type 525 to conform with the Revised Standard '58 IRE 23.S1, as amended July 1, 1961.

The kit contains all the necessary components, drawings, schematic and step-by-step installation instructions.

Order through your local Tektronix Field Engineer or Field Office. Specify Type 525 IRE Response Network Mod Kit, Tek No. 040-265. Price is $4.50.

TYPE 527 IRE RESPONSE NETWORK MODIFICATION KIT

For Type 527 Waveform Monitors s/n's 101 to 269 inclusive and Type RM527 Waveform Monitors, s/n's 101 to 331 inclusive.

This modification changes the IRE Response characteristics to conform with the revised Standard '58 IRE, as amended July 1, 1961. It also improves the transient response of the instrument when the Vertical-Selector switch is in the IRE position.

The kit contains all necessary components, drawings, schematic and step-by-step installation instructions.

Order through your local Tektronix Field Engineer or Field Office. Specify Type 527 IRE Response Network Mod Kit, Tek No. 040-266. Price is $3.00.

TYPE 531A/TYPE 541A SWEEP LOCKOUT MODIFICAION KIT

For Type 531A, Type RM31A, Type 541A and Type RM41A Oscilloscopes, all serial numbers.

This modification converts the above oscilloscopes for study of one-shot phenomena.

The mod kit includes a wired-chassis assembly, tags, schematic, parts list and step-by-step installation instructions.

Order through your local Tektronix Field Engineer or Field Office, Specify Type 531A/541A Sweep Lockout Mod Kit, Tek No. 040-235. Price is $47.00.

Note: Predecessor models of the above instuments were the Type. 531, Type RM31, Type 541 and Type RM41. These instruments may also be converted for the study of one-shot phenomena. To convert these instruments, order Type 531/Type 541 Sweep Lockout Mod Kit, Tek No. 040-118. Price is $47.00.

TYPE 555 OSCILLOSCOPE CRADLE-MOUNT MODIFICATION KIT

For Type 555 Oscilloscopes Indicator and Power Supply. All serial numbers.

This modification allows the rack mounting of the Type 555 Oscilloscope Indicator and Power Supply. The installation will require approximately 34" of vertical height in a standard rack mount.

The kit includes all the necessary parts, hardware and step-by-step installation instructions, including photographs.

Order through your local Tektronix Field Engineer or Field Office. Specify Type 555 Cradle Mount Mod Kit, Tek No. 040-251. Price is $85.00.

MISSING INSTRUMENTS

Shell Development Company of Emeryville, California, advises us that a shipment of Tektronix instruments consigned to them disappeared. These instruments were *not* taken from their premises, but from a truck during transit. The truck was parked in San Francisco, California overnight and the entire load disappeared.

Following is a list of the Tektronix instruments that were lost:

2—Type 163 Pulse Generators, s/n's 3300 & 3301

1—Type 162 Waveform Generator, s/n 6323

1—Type 160A Power Supply, s/n 5567

If you have any information on the whereabouts of these instruments, please contact the nearest office of the Federal Bureau of Investigation. Since this loss involves an interstate shipment, the F.B.I. is concerned in the case.

City College of San Francisco reports; that between September 15 and 18, of this year, a Type 515A Oscilloscope, s/n 6135 disappeared and is presumed to be stolen. Anyone with information on the whereabouts of this instrument should contact Roy Edmison, City College of San Francisco, California.

A Type 512 Oscilloscope, s/n 288, disappeared from the Benson Polytechnic High School in Portland, Oregon, during the summer vacation. A survey of authorized personnel failed to turn up the instrument, so it is presumed to have been stolen. Anyone with information on this instrument should contact Mr. Arnold Grant, Benson

Polytechnic High School, 546 N.E. 12th Avenue, Portland, Oregon.

The Bear Creek Mining Company of Denver, Colorado has asked us to keep an eye open for their Type 531, s/n 1960 and Type 53/54D, s/n 1351. These instruments disappeared and are thought to be stolen. If you see these instruments or have any knowledge of their present location, please contact your local Tektronix Field Office or the Bear Creek Mining Company, 1498 South Lipon Street, Denver 23, Colorado.

The University of Washington notifies us that a Type 504 Oscilloscope, s/n 214, appears to be stolen from one of their laboratories. If you have any information on this instrument, please contact Mr. R.W. Moulton, Executive Officer, University of Washington, Department of Chemical Engineering, Seattle 5, Washington.

USED INSTRUMENTS FOR SALE

1 Type 127	William H. Read Continental Leasing Co. 5215 Hollywood Blvd. Los Angeles 27, California Phone: HO 9-5371
1 Type 570, s/n 381	Brooks Research Corp. Attn.: Mr. Dallas Schutts Rochester, New York or contact Ray Lisiecki Tektronix, Inc. 961 Maryvale Drive Buffalo 25, New York
1 Type 517	Seller wishes to remain anonymous. Tektronix Field Engineer Dick Paterson, 2605 Westgrove Lane, Houston 27, Texas will serve as a contact.
1 Type 512, s/n 118	Marty Arnold Leesona Moos 90—28 Van Wyck Blvd. Jamaica 18, New York
3 Type 511AD, s/n's 1666, 2723, and 3637 2 Type 514AD, s/n's 1332 and 3080	James H. Kennedy Technitrol, Inc, 1952 East Allegheny Ave. Philadelphia 34, Penn. Phone: GArfield 6-9105
1 Type 517, s/n 625. Has duty Cycle Mod Kit installed and extra crt's. Price: $995.	Ian Isdale 825 Tall Timber Road Orange, Connecticut

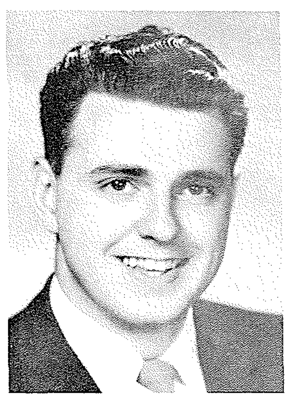
USED INSTRUMENTS WANTED

1 Type 514D or Type 514AD	R.B. Haigh Bendix Corporation Bendix Mishawaka Div. 400 S. Beiger Street Mishawaka, Indiana Phone: BL 5-2111, ext. 329
1 Type 315D or Type 310	Scott M. Overstreet 515 "Q" Central Avenue Mountain View, California
1 Type 535 or Type 535A	Dr. John F. McNall Phoenix Engineering and Computing Service 2462 Hubbard Avenue Middleton, Wisconsin

GREENSBORO FIELD OFFICE NOW SERVING SOUTHWEST VIRGINIA

As of September 15, 1961, the Tektronix Field Office in Greensboro, North Carolina increased its field office coverage. This move brings Tektronix Field Engineering services closer to the Southwest Virginia region.

That portion of Virginia lying within the area outlined by the following counties now comes under the jurisdiction of our Greensboro Office: Lee, Wise, Dickinson, Buchanan, Tazwell, Bland, Giles, Monroe, Greenbrier, Alleghany, Rockbridge, Nelson, Buckingham, Cumberland, Prince Edward, Lunenburg, and Mecklenburg. Customers in this area who formerly were served through our Washington, D.C. Field Office, should direct future inquiries to: Tektronix, Inc., 1838 Banking Street, Greensboro, North Carolina. The telephone number is 274-4647, TWX—GN 540.



Tektronix Field Engineer Rick Ennis of our Greensboro Office will provide field engineering services for customers in this area.

GRATICULE MOUNTING PROBLEMS

Tom Smith, Field Engineer with our Philadelphia Field Office, informs us that some of his customers have a problem. They are confused about the proper sequence for the installation of components over the face of crt's in Tektronix oscilloscopes.

We offer the following information in an effort to clear up some of this confusion.

Except for some instruments (which we will designate later), the light filter is shipped unmounted and as an accessory to the oscilloscope.

We ship all oscilloscopes employing a 5" -crt with a black plastic (Royal-lite) light shield installed. This shield has a 5" opening with a ½" flange at right angle to the opening. The face of the shield is slightly smaller than the graticule cover and contains seven holes. The edge with the four holes is the top. This shield is installed by inserting the flanged portion between the crt and the surrounding mu-metal shield. Properly installed, the light shield fits flush against the instrument panel. The four holes in each corner allow the graticule studs to protrude.

The two inner holes at the top permit the graticule lights to show through the light shield. The seventh hole, located in the lower left-hand corner and just above the graticule stud, permits access to the cam-adjust fitting on instruments containing the cam-adjust feature.

Over this light shield, we install the graticule making sure the etched-line side faces to the crt. The red-rimmed holes in the graticule are positioned at the top and surround the graticule lights.

On each graticule stud, we install a rubber washer. The graticule cover then goes over the whole assembly and the graticule-stud nuts hold all firmly in place. When installing the graticule cover, make sure the small hole in the circular flange of the cover is at the top. Placement in this position permits correct attachment of the Tektronix Viewing Hood with molded-rubber eyepiece (Tek No. 016-001) or the Tektronix Polarized Viewer (Tek No. 016-035).

Instruments shipped with the green light filter installed are; Type 524 AD Television Oscilloscope, Type 525 Television Waveform Monitor, Type 526 Color-Television Vectorscope, Type 527 Waveform Monitor, Type 575 Transistor-Curve Tracer, and all instruments ordered with a P-1 phosphor crt.

Installation of components around and over the face of the crt in these instruments differs from the foregoing instructions in only two respects: (1) We install the green light filter between the black light shield and the graticule. (2) We do not use the four rubber washers between the graticule and the graticule cover.

On oscilloscopes employing 3" crt's we do not install a light shield. The light filter is shipped unmounted as an accessory (unless the oscilloscope is ordered with a P-1 phosphor). Three-inch oscilloscopes do not have the cam-adjust feature. In all other ways, installation of components over the crt follow the foregoing instructions for 5" oscilloscopes.

We place the etched side of the graticules whenever possible next to the face of the crt. This avoids parallax and thus errors in reading oscilloscope measurements.

There is little to be gained by placing the light filter over the graticule. The graticule lines will not show through the filter sufficiently enough to be useable.

Should you prefer white graticule lines (such as when taking pictures of oscilloscope traces) you may, on the 5" oscilloscopes only, rotate the graticule 180°. Remember keep the etched side next to the face of the crt. On 3" oscilloscopes the

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graticule cannot be rotated in this manner. Only by removing the red plastic from around the graticule-light holes in the graticule can you obtain white lines on these instruments. Some solve this problem by keeping two graticules on hand. One for red lines, the other for white lines.

If you use the Tektronix Bezel*, Tek number 014-001, (for mounting cameras, other than Tektronix types, on Tektronix 5" oscilloscopes), it takes the place of the graticule cover in the above instructions.

We recommend the removal of the light filter and the use of white graticule lines when taking pictures of oscilloscope traces.

*Note: The Tektronix Type C-12, Type C-13 and Type C-19 Cameras have a hinged adapter and four coin-slotted graticule nuts. The adapter and its four nuts replace the standard graticule cover and graticule nuts. The cameras fit snugly into the hinged fittings, yet lift in and out with ease. Supported in this manner, the cameras have a swing-away action. This feature allows an unobstructed view of the crt without complete removal of the camera.

Tektronix, Inc., P.O. Box 500, Beaverton, Oregon
Telephone: MItchell 4-0161 TWX—BEAV 311 Cable: TEKTRONIX
AN OREGON CORPORATION

Field Engineering Offices

ALBUQUERQUE* ..... Tektronix, Inc., 509 San Mateo Blvd. N. E., Albuquerque, New Mexico....TWX—AQ 96 .... AMherst 8-3373
Southern New Mexico Area: Enterprise 678
ATLANTA* .... Tektronix, Inc., 467 Armour Circle, N.E., Atlanta 9, Georgia....TWX—AT 358..................... 873-5708
Huntsville, Alabama Area: WX 2000
BALTIMORE* .... Tektronix, Inc., 724 York Road, Towson 4, Maryland....TWX—TOWS 535 .... VAlley 5-9000
BOSTON* .... Tektronix, Inc., 442 Marrett Road, Lexington 73, Massachusetts TWX—LEX MASS 940 .... VOlunteer 2-7570
BUFFALO .... Tektronix, Inc., 961 Maryvale Drive, Buffalo 25, New York....TWX—WMSV 2.................... NF 3-7861
CHICAGO* .... Tektronix, Inc., 400 Higgins Road, Park Ridge, Illinois .... PK RG 1395 .... TAlcott 5-6666
CLEVELAND .... Tektronix, Inc., 1503 Brookpark Road, Cleveland 9, Ohio TWX—CV 352 .... FLorida 1-8414
Pittsburgh Area: ZEnith 0212
DALLAS* .... Tektronix, Inc., 6211 Denton Drive, P. O. Box 35726, Dallas 35, Texas....TWX—DL 264....... FLeetwood 7-9128
DAYTON ....Tektronix, Inc., 3601 South Dixie Drive, Dayton 39, Ohio....TWX—DY 363................ AXminster 3-4175
DENVER .... Tektronix, Inc., 2120 South Ash Street, Denver 22, Colorado......TWX—DN 879................ SKyline 7-1249
Salt Lake Area: Zenith 381
DETROIT* .... Tektronix, Inc., 27310 Southfield Road, Lathrup Village, Michigan...TWX—SFLD 938.............. ELgin 7-0040
ENDICOTT* .... Tektronix, Inc., 3214 Watson Blvd., Endwell, New York....TWX—ENDCT 290...................PIoneer 8-8291
GREENSBORO ....Tektronix, Inc., 1838 Banking Street, Greensboro, North Carolina....TWX—GN 540 274-4647
HONOLULU ....Kentron Hawaii, Ltd., 1140 Waimanu Street, Honolulu 14, Hawaii....Telex: MHU 0093......... Phone: 53975
HOUSTON .... Tektronix, Inc., 2605 Westgrove Lane, Houston 27, Texas....TWX—HO 743........... MOhawk 7-8301, 7-8302
INDIANAPOLIS ......Tektronix, Inc., 3937 North Keystone Ave., Indianapolis 5, Indiana....TWX—IP 361X .... LIberty 6-2408, 6-2409
KANSAS CITY .... Tektronix, Inc., 5920 Nall, Mission, Kansas....TWX—KC KAN 1112 .... HEdrick 2-1003
St. Louis Area: ENterprise 6510

LOS ANGELES AREA
East L. A. ....Tektronix, Inc., 5441 East Beverly Blvd., East Los Angeles 22, California....TWX—MTB 3855 ...RAymond 3-9408
Encino ....Tektronix, Inc., 17418 Ventura Blvd., Encino California....TWX—VNYS 5441 .... STate 8-5170
*West L. A. ....Tektronix, Inc., 11681 San Vicente Blvd., West Los Angeles 49, California..................... GRanite 3-1105
TWX: W L A 6698 From Los Angeles telephones call .... BRadshaw 2-1563
MINNEAPOLIS ...... Tektronix, Inc., 3307 Vera Cruz Ave. North, Suite 102, Minneapolis 22, Minnesota ..... TWX—MP 983 533-2727
MONTREAL ....Tektronix, Inc., 3285 Cavendish Blvd., Suite 160, Montreal 28, Quebec, Canada .... HUnter 9-9707

NEW YORK CITY AREA
*New York City and Long Island served by:
Tektronix, Inc., 840 Willis Avenue, Albertson, L. I., New York....TWX—G CY NY 1416............. PIoneer 7-4830
Westchester County, Western Connecticut, Hudson River Valley served by:
Tektronix, Inc., 1122 Main Street, Stamford, Connecticut....TWX—STAM 350 .... DAvis 5-3817
*Northern New Jersey served by:
Tektronix, Inc., 400 Chestnut Street, Union, New Jersey....TWX—UNVL 82 .... MUrdock 8-2222
ORLANDO* ....Tektronix, Inc., 205 East Colonial Drive, Orlando, Florida ..TWX—OR 7008.................... GArden 5-3483
(also serves Puerto Rico)
PHILADELPHIA* ..... Tektronix, Inc., 7709 Ogontz Ave., Philadelphia 50, Pennsylvania....TWX—PH 930............ WAverly 4-5678
PHOENIX * ....Tektronix, Inc., 7000 E. Camelback Road, Scottsdale, Arizona......TWX—SCSDL 52............ WHitney 6-4273
PORTLAND .... Tektronix, Inc., P. O. Box 500, Beaverton, Oregon .... MItchell 6-1926
POUGHKEEPSIE * ....Tektronix, Inc., 8 Raymond Avenue, Poughkeepsie, New York .. TWX—POUGH 5063 .... GRover 1-3620
SAN DIEGO .... Tektronix, Inc., 3045 Rosecrans Street, San Diego 10, California..............TWX—SD 6341 ACademy 2-0384

SAN FRANCISCO BAY AREA
Lafayette ....Tektronix, Inc., 3530 Golden Gate Way, Lafayette, California....TWX: LAF CAL 1639 .... YEllowstone 5-6101
From Oakland, Berkeley, Richmond, Albany and San Leandro .... CLifford 4-5353
*Palo Alto ....Tektronix, Inc., 3944 Fabian Way, Palo Alto, California........TWX—PAL AL 112 .... DAvenport 6-8500
SEATTLE .... Tektronix, Inc., 236 S.W. 153rd St., Seattle 66, Washington....TWX—SE 47.................. CHerry 3-2494
SYRACUSE* .... Tektronix, Inc., East Molloy Road and Pickard Drive, P. O. Box 155, Syracuse 11, New York
TWX—SS 423 .... GLenview 4-2426
TORONTO* .... Tektronix, Inc., 4A Finch Ave., West, Willowdale, Ontario, Canada .... Toronto, 225-1138
WASHINGTON D. C.*..Tektronix, Inc., 9619 Columbia Pike, Annandale, Virginia ...... TWX—F CH VA 760 ...... CLearbrook 6-7411
*ALSO REPAIR CENTERS — Norfolk, Portsmouth and Hampton, Virginia Area: Enterprise 741

17-19

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 12 PRINTED IN U.S.A FEBRUARY 1962

MEASURING A SMALL AC COMPONENT RIDING ON A DC VOLTAGE

If you wish to measure a small ac component riding on a dc voltage, a number of ways to do so present themselves. The following describes several of the more simple methods employing Tektronix oscilloscopes.

Perhaps the most simple method is to switch the input selector or AC-DC switch of the scope's vertical input to the AC position. Doing this switches a dc blocking capacitor into the circuit between the input terminal and the vertical amplifier. See Figure 1. The capacitor blocks the dc voltage but allows the ac component to pass through to the amplifier. This blocking or ac-coupling capacitor is usually a 0.1 μfd capacitor rated at 600 volts and the input-grid resistor a 1 megohm precision resistor. The rc time constant of this combination is 0.1 second which contributes 3-db attenuation for 2 cps (approximately) sine wave signals. Combined ac and dc voltage of the input signal should not exceed 600 volts.

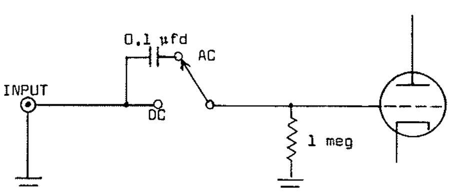


Figure 1

This method works well provided the above conditions are met and the frequency of the ac component is above 10 cps. The vertical-sensitivity control can be set to maximum if needed.

Now let's make the conditions a little tougher. We have a few millivolts of low frequency component riding on a dc voltage of about +2 volts. The frequency of the ac component is down below several cycles per second. Here a differential input (such as that available on the Tektronix Type 502 or Type 503 Oscilloscope, or the Type 63 or Type D or Type G Plug-In Preamplifier in a Tektronix Oscilloscope for which the preamplifier is designed) will help to solve the problem. Set the input-selector switch to A-B, and the AC-DC switch to DC. Apply the signal to INPUT A and feed an equal dc voltage to INPUT B. An inexpensive multi-turn potentiometer (such as made by the Chicago Telephone Supply Company), a battery and a bypass capacitor provide a convenient way to control the dc voltage to INPUT B. See Figure 2. The capacitor, potentiometer and the leads to the oscilloscope of this circuit, as well as the lead from the voltage under investigation to the oscilloscope, must be adequately shielded against stray hum pickup. A battery offers certain advantages over an ac power supply, i.e. low noise and no ripple. For signals having a negative dc component reverse the battery connections.

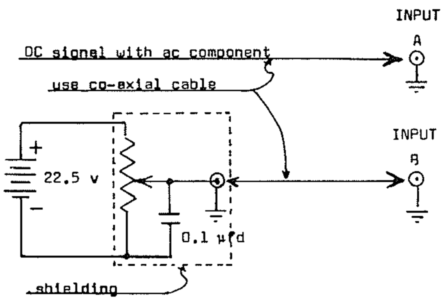


Figure 2

This method will work satisfactorily for dc components up to 2-5 volts depending on the instrument used; beyond that you may saturate the input stage of the differential amplifier unless the input is attenuated.

For dc components up to 20-50 volts, a pair of 10X probes (one for each input) plus 45 volts from batteries will work satisfactorily. This will, however, reduce the sensitivity of the oscilloscope by a factor of ten.

In the case of the Type G Plug-In Preamplifier which has separate input-attenuator controls for each input, you do not need 10X probes. Using these attenuators, a 1.5-volt battery is sufficient for balancing out a dc component up to 600 volts, though the display sensitivity under these extreme conditions is only 20 v/cm.

The Tektronix Type Z Differential Comparator Unit in a Tektronix Type 530, Type 540, Type 550, or Type 580* Series Oscilloscope, will eliminate the need for the extraneous circuitry shown in Figure 2. This versatile unit contains a built-in regulated dc comparison voltage. When the MODE switch is in the A-Vc or Vc-B position, the calibrated dc voltage is internally applied to cancel out any unwanted dc component in the applied signal. This allows accurate measurements of relatively small ac signals riding on relatively large dc signals. Precisely accurate selection of plus or minus dc comparison voltages over a range of from 1 to 100 volts is possible by means of a COMPARISON-VOLTAGE RANGE selector and a Heilidial control.

In using the Type Z Unit to measure signals discussed in this article, set the AC-DC switch to DC. Set the MODE switch to A-Vc if the signal is applied to INPUT A or to Vc-B if the signal is applied to INPUT B. Set the COMPARISON-VOLTAGE POLARITY selector to match the polarity of the dc component of the input signal and set the COMPARISON-VOLTAGE RANGE selector to a voltage value that exceeds the voltage of the dc component of the input signal. By means of the Heilidial, adjust the comparison voltage to cancel out the unwanted dc component of the applied signal. With the A-INPUT VOLTS/CM (ATTENUATOR) control in the .05 position, a 5 millivolt ac component will give 1 mm of deflection on the crt screen. Maximum voltage swing at this sensitivity is ± 100 volts combined ac-dc signal.

By using the VOLTS/CM (ATTENUATOR) control, mixed ac-dc signals up to a maximum of 500 volts peak-to-peak can be investigated in this manner. Bear in mind, however, that the sensitivity of the oscilloscope will be reduced by the factor to which the VOLTS/CM control is set.

* A Type 81 Adapter is required for use with Types 581 and 585.

CONSTRUCTIVELY CRITICAL COMMENTS ON "GRATICULE MOUNTING PROBLEMS"

Tektronix Field Engineer Bob Le Brun (Baltimore) writes us regarding the article "Graticule Mounting Problems," which appeared in the December '61 issue of SERVICE SCOPE, as follows:

"There are a couple of statements in this article that I'd like to comment about.

Statement: 'There is little to be gained by placing the light filter over the graticule. The graticule lines will not show through the filter sufficiently enough to be useable.'

Comment: Placing the light filter over the graticule reduces parallax by moving the graticule and trace one filter thickness closer together. The graticule lines can be made to show through enough to be useable under most ambient light conditions by using the white graticule lines. The red lines, of course, won't show through a colored filter unless it too is red.

Statement: 'If you use the Tektronix Bezel, Tek number 014-001, (for mounting cameras, other than Tektronix types, on Tektronix 5" oscilloscopes), it takes the place of the graticule cover in the above instructions.'

Comment: The Tek Bezel (for non-Tek cameras) can be used with the graticule cover and I believe should be because without it light leakage ruins pictures."

Bob's comments are good and we appreciate them. The idea of using the white graticule lines never occurred to this editor — just too simple a solution, I guess.

Bob is also correct in his belief that the graticule cover should be used with the Tek Bezel (for non-Tek cameras). With the graticule nuts removed, the bezel will mount on the graticule studs and right over the graticule cover. Reinstalling the graticule nuts will then hold all firmly in place.

A CLARIFICATION

In the December issue of SERVICE SCOPE, the article "Accurate Frequency Measurements" suggested a method for checking the accuracy of a Tektronix Type 180A Time-Mark Generator by beating the 1 μsec markers against the WWV carrier. The statement that the "difference frequency in cycles will be a measure of the time-mark generator's accuracy in parts per million" may be misunderstood.

The actual beat (difference) frequency will be between a *harmonic* of the 1 μsec (1 mc) 180A output and the particular WWV carrier used. If WWV's 5 mc carrier is used, a beat frequency of 5 cps will indicate a 180A error of 1 ppm. If the 10 mc WWV carrier is used, a beat frequency of 10 cps will indicate 1 ppm error in the 180A, and so forth.

The nominal accuracy of the 180A when shipped from the factory is ±.001%, or 10 ppm. After being zero-beat with WWV, it will remain accurate within ±3 parts per million over a 24 hour period.

FIELD MODIFICATION KITS

TYPE 551 CHOPPING-TRANSIENT BLANKING FIELD MOD KIT

For Type 551 Oscilloscopes, all serial numbers. The Type 53C, Type 53/54C and Type C-A Plug-In Preamplifiers will produce troublesome transients in a Type 551 Dual-Beam Oscilloscope when operated with the preamplifier MODE switch in the CHOPPED position.*

We have available a field modification kit that provides a circuit to blank the transients generated under these conditions. This kit provides individual CRT cathode-selector switches that allow blanking on either or both the LOWER and UPPER beams.

The modification kit includes a complete set of components, prewired amplifier assembly, parts list, schematic, photos and step-by-step instructions. A skilled technician can install the modification in approximately four hours.

Order through your local Tektronix Field Engineer. Specify Type 551 Chopping-Transient Blanking Field Mod Kit, Tek No. 040-224. Price is $17.50.

* Other Tektronix Oscilloscopes in which these Plug-In Preamplifiers will produce transients are:

(1). Type 531, Type 535, Type 541, Type 545, serial numbers 101 to 4999. For these instruments ask your Tektronix Field Engineer for Chopping-Transient Blanking Field Mod Kit, Tek No. 040-200. Price is $5.25.

(2). Type 531A, Type 535A, Type 541A, Type 545A, serial numbers 5,000 to 20,000. For these instruments ask your Tektronix Field Engineer for Chopping-Transients Blanking Field Mod Kit, Tek No. 040-198. Price is $5.25.

TYPE 502 SWEEP LOCKOUT MOD KIT

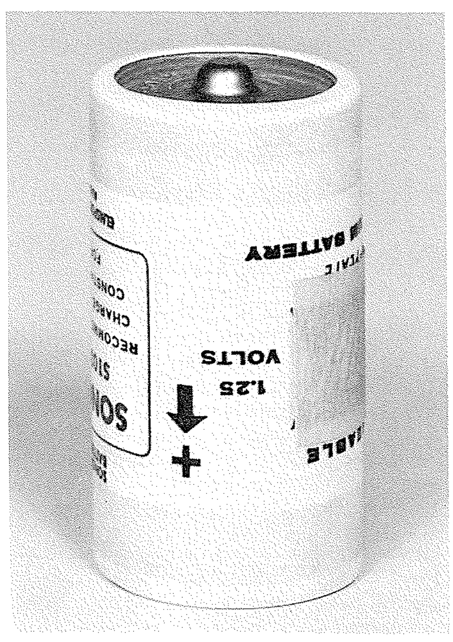
For Type 502 Oscilloscopes, all serial numbers.

This field modification kit converts your Type 502 Oscilloscope for the study of one-shot phenomena.

The mod kit contains a wired chassis assembly, new front panel, and necessary components to incorporate the sweep-lockout feature in your instrument. It also includes a photo, schematic, parts list and step-by-step instructions.

Order through your Tektronix Field Engineer. Specify Type 502 Sweep Lockout Mod Kit, Tek. No. 040-209. Price is $45.00.

A WORD OF CAUTION



Recently we came across a 1.25-v nickel-cadium battery with an improperly applied label—see picture above. Apparently the label has been applied upside down. The arrow supposedly pointing to the positive end of the battery actually points to the negative end.

Batteries of this configuration and voltage are used in the Tektronix Type 321 Transistorized Oscilloscope. An experienced and careful operator would probably notice this error in labeling and install the battery properly polarized.

It is not inconceivable, however, that the battery might be installed incorrectly (polarity reversed) by an inexperienced operator or one in a hurry. In an instrument operated under these conditions the incorrectly installed battery would eventually explode. The explosion could have sufficient force to seriously damage the oscilloscope.

For the benefit of those who may not know, in this type of nickel-cadium battery the protruding or nipple-like end is *always* the positive end. If there is any question about the polarity of a battery, check it out with a voltmeter.

Every nickel-cadium battery received at Tektronix from our suppliers is placed on a charging line. It would be virtually impossible for an incorrectly marked battery to get into a production instrument or to be shipped on a customers parts order.

However, this brand of battery is nationally marketed and may be purchased locally. We do, therefore, urgently recommend a careful inspection of locally purchased batteries of this type before installation in an instrument.

MISSING INSTRUMENTS

The National Broadcasting Company in Burbank, California, reports that a Tektronix Type 310 Oscilloscope, s/n 1864 disappeared from their premises on August 8th, 1961. They presume the instrument to be stolen since a check of authorized personnel failed to reveal the instrument. If you have any knowledge of the whereabouts of this oscilloscope, please contact Mr. Frank Sommers, Engineering Department, National Broadcasting Company, 3000 Alameda, Burbank, California.

A Tektronix Type 317 Oscilloscope, s/n 001771 is missing from the U.S. Air Force at Selfridge AFB, Michigan. The Air Force nomenclature of the missing property is as follows: Portable oscilloscope, Model #317, Serial #001771, Stock #676-1302, Class Symbol 6625, Listed value: $800.00

If you have any knowledge of this instrument contact Gene P. Moritz, Colonel, USAF District Commander, 507th OSI Detachment, Selfridge AFB, Michigan.

The Picatinny Arsenal at Dover, New Jersey, reports that a Tekronix Type 517 Oscilloscope is missing from their premises and is thought to be stolen.

If you have any information on the whereabouts of this instrument, please contact the Picatinny Arsenal or the Tektronix Field Office, 400 Chestnut Street, Union, New Jersey.

The Howe Precision Products Company reports that a Tektronix Type 317 Oscilloscope, serial number 879, was lost in transit to one of their Rail Flaw Detection Cars.

Information on the whereabouts of this instrument should be sent to: Mr. E. I. Cook, Maintenance Manager, Howe Precision Products Company, Shelter Rock Road, Danbury, Connecticut, Telephone: PIoneer 8-9243.

USED INSTRUMENTS FOR SALE

1 Type 561, s/n 889. Price $382.50 1 Type 72 Plug-In, s/n 565. Price $225.00 1 Type 67 Plug-In, s/n 1031. Price $135.00	Transitel International Corporation 615 Winters Avenue Paramus, New Jersey
1 Type 541, s/n 378	Bernie Stapler Columbia Technical Corporation 24-30 Queens Brooklyn Express, West Woodside 77, New York. Phone: YEllowstone 2-0800
1 Type 316, late model	August Schonefeld Precision Instrument Co. 1011 Commercial St. San Carlos, Calif.
1 Type N Plug-In, s/n 683 1 Type 110 Pulse Generator and Trigger Take-off, s/n 294 1 Type 113 Delay Cable, s/n 294	Morris-Cooper Corp. 3832 Terrace Street Philadelphia 28, Pa. Phone: IV 6-6533
1 Type 514AD	Engineering Associates 434 Patterson Road Dayton 19, Ohio
2 Type 551 scopes 2 Type CA Plug-In Preamplifiers	L. Nucci General Applied Science Laboratories Merrick & Stewart Avenues Westbury, Long Island, New York
1 Type 535, s/n 10751 3 Type 545, s/n 14669, 14670, 14671	R. N. Kampf, P. A. Computer Division Philco Corporation 13900 Welsh Road
8 Type 541, s/n 7471, 7472, 7474, 7490, 7491, 7492, 7493, 7494.	Willow Grove, Pa. Phone: Oldfield 9-7700

USED INSTRUMENTS WANTED

1 Type 502	Luis A. Rocha, Z. Kepco, Inc. 131-38 Sanford Ave. Flushing, New York
1 Type 545 or Type 545A	Chas. Wilson 501 Keebler Road King of Prussia, Pa.
1 3" Tektronix Oscilloscope	D. Cleveland 10 Museum Road, Beverly, Mass.

INSTRUMENTS TO TRADE

1 Type 515A scope for Type RM15 scope	Bart Healy Technical Instruments, Inc. 90 Main Street Reading, Mass.

KING SIZE HELMHOLTZ COILS USED FOR TEST AND RESEARCH

Tektronix IMSE (Instrument Manufacturing Staff Engineers) recently completed construction of a king size Helmholtz coil. (A Helmholtz coil consists of two equal-diameter coils spaced a distance equal to their diameter apart.) They will use the coil to measure the effects of magnetic fields on Tektronix oscilloscopes.

This Helmholtz coil contains two coils, each two meters in diameter and holding 90 turns of heavy copper wire per coil. A total of just under 4,000 feet of wire — 40 pounds of copper. Spacing the coils one meter apart and applying an electric current sets up a highly uniform magnetic field of about a cubic meter in size between them. That leaves plenty of room to insert an oscilloscope in the field and observe the effect it produces on the electron beam of the scope's crt.

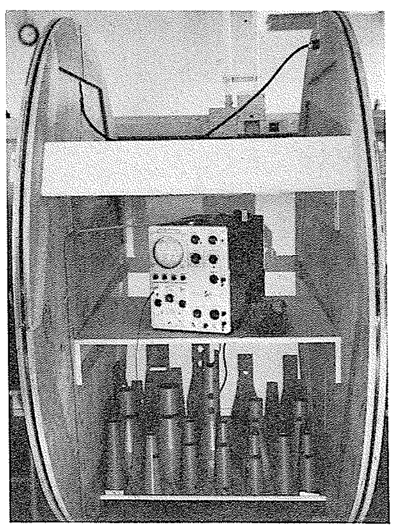


Figure 1

Figure 1 shows a Tektronix Type 531A Oscilloscope sitting in the magnetic field with a search coil (the wand-like device laying on top of the scope) connected to the scope input. The trace on the crt face indicates a pickup by the search coil of an ac magnetic field that measures 25 Oersteds peak-to-peak.

Figure 2 shows the same oscilloscope in

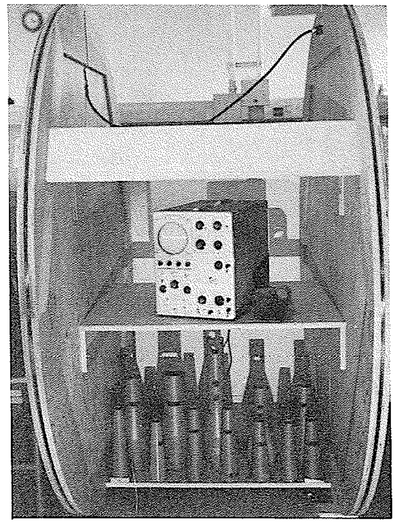


Figure 2

the same magnetic field with the sweep synchronized to 60 cycle ac and no signal applied to the scope input. Notice that in this 25 Oersted magnetic field the trace on the face of the crt shows only about 2 mm of ripple. This indicates that the crt shielding prevents all but a negligible amount of the magnetic field from reaching and influencing the electron beam of the crt.

Although built primarily to answer the question, "Can we put our oscilloscopes in a magnetic field 5 units (Oersteds) strong and not displace the crt spot more than 1/16th of an inch?", the Helmholtz coil will lend itself to many other uses as a test and research tool.

What's the answer to the question? Well, IMSE's best guess from previous work was that we could — but no one was positive. Now we *know* we can.

TRUANT SCOPES RETURN TO SCHOOL

Two oscilloscopes absent without leave from their respective schools returned to the halls of learning recently. Mr. R.W. Moulton, Executive Officer of the University of Washington Chemical Engineering Department, writes us that the Tektronix Type 504 Oscilloscope, serial number 214, reported missing in the December '61 issue of this paper, mysteriously reappeared in one of their laboratories.

Through our Palo Alto Field Office, we hear that the Tektronix Type 515A Oscilloscope, serial number 6135, (also reported missing in the December '61 issue of SERVICE SCOPE) has been returned to the San Francisco City College after a four months absence.

We have no way of knowing if the notices in the "Missing Instruments" column of SERVICE SCOPE played any part in the return of these instruments to the schools. We'd like to speculate, however, that maybe —just maybe—the borrowers or "kidnappers" of these instruments read the notices in SERVICE SCOPE and that either prudence or an uneasy conscience moved them to return the oscilloscopes.

Whatever the cause, the scopes were returned and that's the important thing.

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

A LIMITED OFFER

We have remaining a small quantity of the booklet entitled "Impulse Tests and Measuring Errors". We can best describe the material in this booklet by quoting the introductory paragraph:

"It has been shown . . . . in international comparisons of the work of various laboratories, that the accuracy of measurement in tests with impulse voltage does not fulfill the demands it has been thought appropriate to make. This article analyses a part of the question — the problem of measuring the amplitude and shape of impulse voltages and currents with sufficient accuracy for practical purposes. The methods of checking impulse circuits which have been used at the High-Voltage Laboratory at Ludvika for some years are described and the minimum demands which should be made on measuring circuits intended for various impulse tests are set out. Descriptions are given of a number of measuring circuits".

We offer these booklets to those readers of SERVICE SCOPE whose interests lie in this area. Place your requests for a copy with your local Tektronix Field Engineer. We must of necessity refer all requests sent direct to us to our Field Engineer serving the area in which the request originated. So, since this offer is on a first-come-first-served basis, you will expedite your request if you place it with your local Tektronix Field Engineer.

A CONVENIENT PROBE-TIP HOLDER

Tektronix Field Engineer Jerry Kraxberger sent in this idea for a convenient probe-tip holder.

If you, as this writer often does, spend frustrating minutes looking for mislaid probe tips, the do-it-yourself probe-tip holder pictured in Figure 1 will undoubtedly appeal to you.

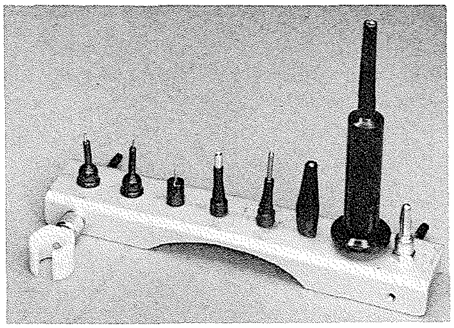


Figure 1

The design of the pictured holder permits attachment of it to any Tektronix 5″ oscilloscope (see Figure 2) except when an oscilloscope camera is in use.

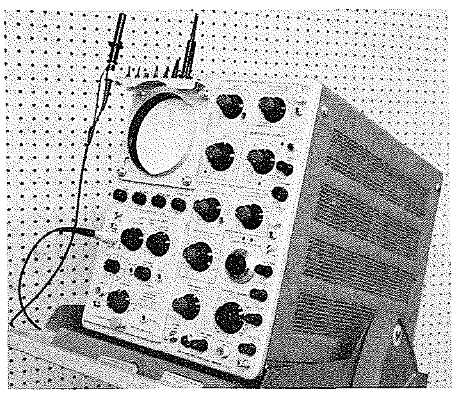


Figure 2

The circular cut out in the base of the holder allows it to fit over the new Polarized Viewer (see October '61 issue of SERVICE SCOPE) or a tubular light shield.

For the base of this holder, we used a piece of sheet aluminum 2″ wide by 6″ long. We formed the ½″ flanges by making two 90° bends using a sheet metal break. On one flange, equidistant from each end and on 5″ centers, we drilled and tapped two holes. We used a number 36 drill and a 6-32 tap. Into these holes we screwed the two banana plugs that attach the holder to an oscilloscope by fitting into the two top graticule studs. On the top surface of the holder, we laid out and drilled and tapped eight equi-distant holes again using a number 36 drill and a 6-32 tap. Into each hole, we screwed a 6-32 x ⅜″ binder head screw. Taking a 1⅝″ length or aluminum rod, we drilled and tapped it at each end for a 6-32 screw. We then mounted the rod on one of the installed 6-32 x ⅜″ screws. In the exposed end of the rod, we installed a 6-32 stud. We made the stud by running a 6-32 nut onto a 6-32 x ⅝″ screw, threading the screw into the rod until it bottomed and then turning the nut down snug against the rod. We then cut the screw off with a hack saw so that about ¼″ extended beyond the nut. After rounding off the edges of the stud, we ran the nut off the stud. This reforms and deburs any damaged threads on the stud.

Use the rod and stud to hold the pincher tip of the probe and the other seven screws to hold the other probe tips.

We used a rat-tail file to remove the metal from the circular cut out of our holder.

For attaching the probe holder (that white plastic object with a slot) to the probe-tip holder, we used an ordinary ground post mounted in a hole drilled in the front flange of the probe-tip holder.

Perhaps you do not care to mount your probe-tip holder on the graticule studs of an oscilloscope or to construct as functional a holder as the one described here. By applying the idea of the seven screws and the rod with stud, you can make a probe-tip holder to suit your individual ambition and needs. Install it any place that's handy—bench, wall, oscilloscope cart.

Installed and used, this probe-tip holder should save you time and put an end to your probe-tip hunting.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

TEKTRONIX

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 13 PRINTED IN U.S.A APRIL 1962

FAN-VIBRATION PROBLEMS: SOME CAUSES AND CURES

In Tektronix instruments employing forced-air ventilation, fan vibration is not normally a problem. Fan-vibration problems, when they do occur, generally stem from one of two sources—the fan motor or the fan-blade assembly (fins, spider and hub).

In most of our forced-air-ventilation instruments, the fan motors operate at relatively slow speeds. The fan motors used in these instruments are typically in proper balance as we receive them from the suppliers. In instruments where the rotation speed of the fan motor might conceivably cause a problem we shock mount the fan motor as a precautionary measure.

The fan-blade assemblies are fabricated by techniques designed to produce assemblies in balance both statically and dynamically. The fins in a properly balanced assembly are all aligned to operate in the same plane and all have the same pitch or angle relative to the axis of the fan-motor shaft. Troublesome fan vibration is most often caused by an unbalanced fan-blade assembly. Instruments undergo a check, before they leave our factory, to assure that they have a minimum of fan vibration.

However, any rough handling of the instrument can upset the balance of the fan-blade assembly by altering either the pitch or rotation plane (or both) of one or more of the fins.

Often you can restore the fins to their proper plane and degree of angle by the following procedure:

1. Check all fins to make sure they turn in the same plane by referencing a gauge bar (screw driver tip, pencil or etc.) within ⅛" of one of the side edges of the fins. While maintaining a slight axial pressure toward the fan motor, slowly rotate the fan-blade assembly and note the clearance between the gauge bar and the fin edges. If the fins are all turning in the same plane, the clearance will be the same for each fin. Correct any difference by grasping the tip of the offending fin between a thumb and forefinger and bending in the required direction.
2. Compare the pitch of all fins by checking both sides of the fin edges as in step 1. Twist and bend the fins with thumb and forefinger as necessary to make each side of each fin run in its proper plane. Correctly done, this should establish the same degree of pitch for each fin.

If vibration still persists, remove the fan-blade assembly from the motor shaft and run the motor. If the fan motor is the culprit, vibration will still be present but, most likely, considerably reduced. This will indicate that the fan motor, through wear, has developed excessive bearing play. More rarely, it may indicate a defective motor. In either case, the motor should be replaced.

Absence of vibration will indicate that the fan-blade assembly is too badly out of alignment to be corrected by the means described here. Under these circumstances you will no doubt find it most expedient to replace the old fan-blade assembly with a new one.

SERVICE HINTS

TYPE 551 DUAL-BEAM OSCILLOSCOPES

Filament wiring change to increase power supply reliability—s/n's 101 to 2357.

You can considerably reduce the possibility of heater-cathode breakdown in V734 (6AU6 error-amplifier tube in ±500 v power supply regulator) by changing the heater of this tube from a grounded supply to an elevated supply. Type 551 'scopes, serial numbers 2358 and up incorporate this modification.

To modify instruments in the field, remove the bare wires connecting the filaments of V734 (pins 3 and 4) to pin 7 (grounded) of V657 and the 6.3 v filament buss at pin 8 of V687.

Also, unsolder from pin 4 of V734, the bare wire coming from pin 9 of V616 and resolder it to pin 1 (grounded) of V619.

Wire the filaments of V734, in parallel with those of V747. For proper access, you will probably find it necessary to unsolder one or two of the components mounted above the V747 socket. Unsolder these components at one end only and bend them up out of the way. If you find it necessary to remove the PTM capacitor C744 (0.01 μf), unsolder it at both ends and temporarily remove it.

Use insulated or sleeved wire to connect pin 4 of V734 to pin 4 of V747. If you pay careful attention to lead dress, you may use bare wire when connecting pin 3 of V734 to pin 3 of V747.

After carefully checking the wiring and lead dress, replace and resolder any components unsoldered for access.

A resistance check should now show: Pin 3 or 4, V734 to ±350 v supply buss, approximately 100 k. Pin 3 or 4, V734 to ground, 110 k or more.

Correct the instruction manual (power supply diagram) for the modified instrument to show the filament V734 connected to the elevated (±350 v) filament supply.

TYPE 535A, TYPE 545A, TYPE RM35A, AND TYPE RM54A OSCILLOSCOPES

When operating the above instruments and using Time Base B triggered in the DC mode, tube V94 may go into oscillation. The problem can be overcome by tube selection. However, a very simple modification will give a more satisfactory solution and eliminate the necessity to select tubes.

To make the modification, locate R90, a 1.2 meg, 1 w, 10% resistor. You will find this resistor connected between the 4th and 8th notches (counting from the front of the oscilloscope) of the ceramic strip located almost directly over tubes V74 and V95. These tubes are in turn located on the swing-out chassis containing the Time-Base B Trigger and Generator, Delay Pickoff, and External Horizontal Amplifier circuitry. Replace this resistor with a 2.2 meg, ½ w, 10% resistor. Correct the instruction manual (Time-Base B diagram) to show the new value for R90.

This modification applies to instruments with serial numbers below the following:

Instrument	Serial Number
Type 535A	27860
Type RM35A	2550
Type 545A	33015
Type RM45A	2760

Respective instruments bearing serial numbers above those listed here have this modification incorporated at the factory.

TYPES (53/54) A, B, C-A, G, AND H PLUG-IN PREAMPLIFIERS—TRANSCONDUCTANCE AND GAIN CHECK.

It is sometimes difficult to determine in a low-level, low-gain, video amplifier stage, whether transconductance and gain are adequate or whether the tubes should be replaced.

Here's a trick that works well in Tektronix Plug-In Preamplifiers Types (53/54) A, B, and C-A for checking the in-circuit transconductance of the input-amplifier stages, and in Types G and H for checking the output-amplifier stage, using a display of the calibrator waveform or other convenient signal.

The trick is simply to rotate the VARIABLE VOLTS/CM control over its full range with the GAIN ADJ control fully clockwise. If the range of the variable volts/cm changes display amplitude by 2½-to-1 or more, the transconductance of the tubes in the affected stage is adequate. If the control range is less than 2½-to-1, the tubes are probably weak and should be changed.

This method will also work with the Type K and L Plug-Ins(input amplifier check). In these instruments, however, the range of the variable volts/cm change in the display amplitude will be 2-to-1 (2½-to-1 with new 360°, continuous rotation, potentiometer).

To determine the actual value of transconductance, set the VARIABLE VOLTS/CM control for exactly ½ maximum deflection. Turn off the scope, remove the plug-in and (after allowing several seconds for the tubes to cool), measure the resistance across the VARIABLE VOLTS/CM potentiometer terminals. Dividing this value of ohms into 2 will give you the average in-circuit transconductance (in mhos) of the two tubes whose cathodes are connected to the pot. To convert to micro-mhos, move the decimal point 6 places to the right.

This transconductance is set by the GAIN ADJUST control, which varies the tubes' cathode current. In instruments where the main amplifier gain has been set too high (and the preamp GAIN ADJUST set too low to obtain calibrated deflection), a full 2½-to-1 (2-to-1, or 2½-to-1, in the case of the Type K and L Plug-Ins) var-volts/cm range may not be obtainable at the normal GAIN ADJUST setting. The solution, of course, is to reset the oscilloscope main-amplifier gain to the standard 100 mv/cm, using the Type TU-1 or TU-2 Test Plug-In, or a Type EP-53A Gain Adjust Adapter and then increase the preamp GAIN ADJ setting to obtain a calibrated deflection.

REMINDING YOU —

. . . that blue vinyl touch-up paint for Tektronix instruments (with the smooth textured—not crackled finish) is available in 12 ounce pressurized spray cans (Tek no. 252-092). Price is $2.00.

. . . that in high-speed pulse measurement and observation techniques, impedance mismatching in coupling the oscilloscope to the signal source through coaxial systems must be avoided. Such a mismatch can have an extremely important effect on the accuracy of the information obtained.

6DJ8 CONVERSION

Type 6DJ8 tubes are improved versions of Type 6BQ7A tubes. They offer better performance, more reliability and characteristics more consistent from tube to tube and between sections of one tube. You can use 6DJ8's as direct replacements for 6BQ7A's in most Tektronix instruments including those using aged and checked 6BQ7A's.

In most cases you won't have to change any circuits. Minor adjustments are, however, often necessary. They usually amount to no more than routine calibration for the circuits in which you replaced the tubes. Your instruction manual describes how to make these adjustments.

A premium version of the 6DJ8 tube is available as the Type 6922 tube. We recommend its use where optimum reliability is imperative. Tektronix part numbers for these tubes:

(154-187) tube, electron Type 6DJ8 $2.75
(154-195) tube, electron Type 6922 $7.35

Circuit changes necessary:

Type 53C Plug-In Preamplifier, all serial numbers:

Reduce the gain of the first amplifier stage by changing R3553, R3573, R4553 and R4573 from 680 or 820 Ω resistors to 470 Ω ½ w, 10% composition resistors (Tek no. 302-471).

Type 315D Oscilloscope, all serial numbers:

Install a NE-2 neon bulb (Tek no. 150-002) between pins 7 and 8 of tube V2. This reduces the possibility of a grid-to-cathode short in V2 when the instrument is first turned on.

The MAG CENTERING control (R306) in the time-base amplifier may not have enough range when using 6DJ8's. If it doesn't, change R300 from 200 or 220 k to 250 k, ½ w, 1% precision resistor (Tek no. 309-109). Also, you may run into trouble using 6DJ8's in the time-base generator. If you can't calibrate this circuit with 6DJ8's installed, change back to 6BQ7A's.

Type 524D and Type 524AD Oscilloscopes:

These instruments, depending on the serial number, will require several of the following changes:

All serial numbers:

1. Decouple the plate of V15B by adding a 47 Ω, ½ w, 10% composition resistor (Tek no. 302-470) and a 0.005 μf, 500 v discap (Tek no. 283-001) as shown in Figure 1. This prevents the line-indicating video-output circuit from oscillating when V15 is a 6DJ8 and a 52 Ω load is used.

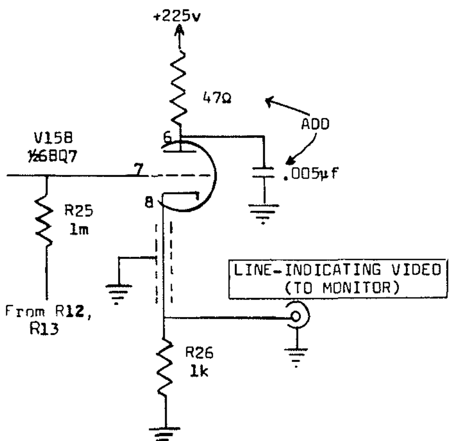


Figure 1. Type 524D/524AD Vertical Amplifier and Delay Line (partial schematic).

2. Shunt C28 and C31, 9-180 or 7-45 pf, variable capacitors in the vertical amplifier, with 82 pf, 500 v, 10% ceramic capacitors (Tek no. 281-528).

Serial numbers 1842 and below:

1. Refer to Figure 2. Decouple the 120 v plate supply of V601B by adding a 1.5 k, 1 w, 10% composition resistor (Tek no. 304-152) and a 0.02 μf, 600 v discap (Tek no. 283-006) as shown in Figure 2.

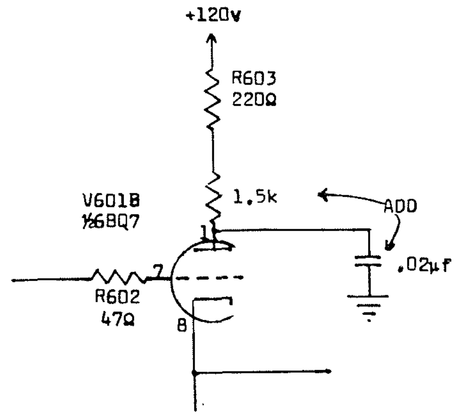


Figure 2. Type 524D/524AD Time-Mark Generator for serial numbers 1842 and below (partial schematic).

2. Refer to Figure 3. Decouple the 120 v plate supply of V601A by adding a 1.8 k, 1 w, 10% composition resistor (Tek no. 304-182) and a 0.1 μf, 500 v discap (Tek no. 283-008) as shown in Figure 3.

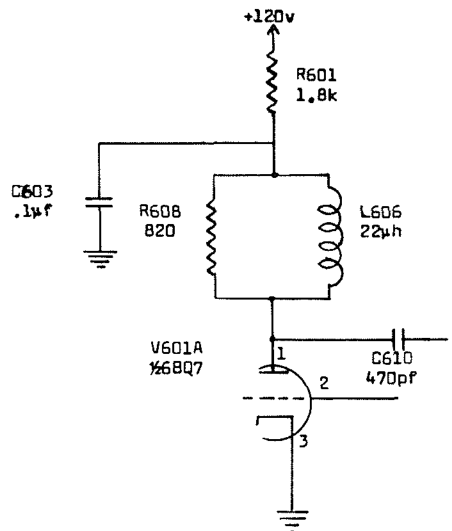


Figure 3. Type 524D/524AD Time-Mark Generator for serial numbers 1842 and below (partial schematic).

Serial numbers 1843 and up:

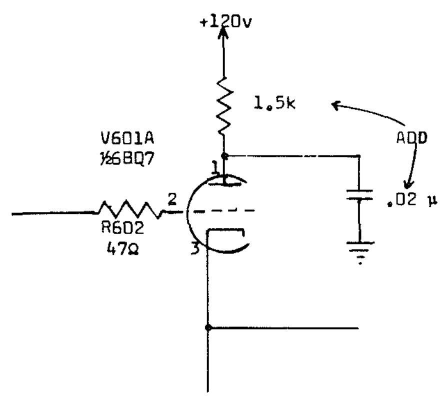


Figure 4. Type 524D/524AD Time-Mark Generator for serial numbers 1843 and up (partial schematic).

1. Refer to Figure 4. Decouple the 120 v plate supply of V601A by adding a 1.5 k, 1 w, 10% composition resistor (Tek no. 304-152) and a 0.02 μf, 600 v discap (Tek no. 283-006) as shown in Figure 4.
2. Refer to Figure 5. Decouple the 120 v plate supply of V601B by adding a 1.8 k, 1 w, 10% composition resistor (Tek no. 304-182) and a 0.1 μf, 500 v discap (Tek no. 283-008) as shown in Figure 5.

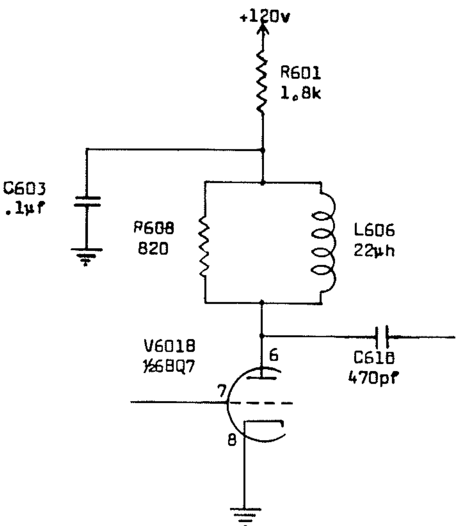


Figure 5. Type 524D/524AD Time-Mark Generator for serial numbers 1843 and up (partial schematic).

Serial numbers 101 through 2154:
Change C28 and C31 in the vertical amplifier from 7-45 pf to 9-180 pf variable capacitors (Tek no. 281-023.) Shunt each with an 82 pf, 500 v, 10% ceramic capacitor (Tek no. 281-574).

Serial numbers 101 through 5341:
Install two neon bulbs, NE-2 (Tek no. 150-002); one between pins 2 and 3 and one between pins 7 and 8 of V222. This helps to prevent grid-to-cathode shorts in this tube when the 524 is first turned on.

Serial numbers 101 through 5899:
Install two neon bulbs, NE-2 (Tek no. 150-002); one between pins 7 and 8 of V23 and one between pins 7 and 8 of V24. This helps to prevent grid-to-cathode shorts in these tubes when the 524 is first turned on.

Serial numbers 6650 and up:
Change R601 from a 1.2 k to 1.8 k, 1 w, 10% composition resistor (Tek no. 302-182).

Serial numbers 101 through 6649:
Refer to Figure 6. Shunt V412 by adding a 3 k, 10 w, 5% wire-wound resistor (Tek no. 308-020) as shown in Figure 6. This limits the power dissipation of V412 and V601.

Type 525, serial numbers 590 and below:
1. Change R19 in the calibrator circuit from a 2.7 meg, to a 2.2 meg, ½ w, 10% composition resistor (Tek no. 302-225). Readjust the CAL ADJ by referring to your instruction manual.
2. Change all 6BQ7A's in the sweep circuit to 6DJ8's at the same time.

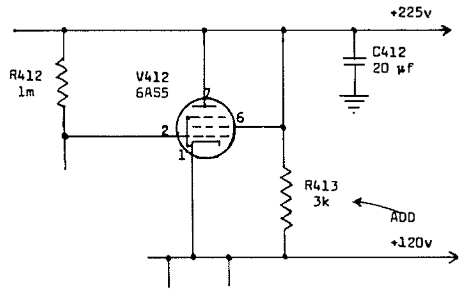


Figure 6. Type 524D/524AD Low-Voltage Power Supply all serial numbers (partial schematic).

3. Change R353 from 10 k to 12 k, ½ w, 10% composition resistor (Tek no. 302-123).
4. Change R354 from 15 k to 18 k, ½ w, 10% composition resistor (Tek no. 301-183).
5. Change R365 from 150 k to 120 k, ½ w, 10% composition resistor (Tek no. 301-124).
6. Change R366 from 150 k to 120 k, ½ w, 10% composition resistor (Tek no. 301-124).
7. Change wiring in the sweep as shown in Figure 7.

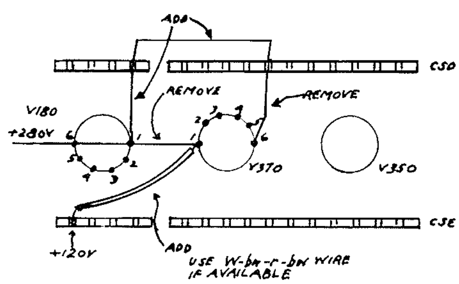


Figure 7.

Readjustments are necessary if you install 6DJ8's in the horizontal or vertical circuits. Refer to your instruction manual. No re-adjustments are necessary if you install 6DJ8's in the sync separator and trigger amplifier circuit.

Type 531, serial numbers 593 and below:
Type 535, serial numbers 1056 and below:
Reduce the gain of the vertical amplifier by changing the cathode circuits of the delay-line driver stage:
1. Check R503, located between pin 8 of V508 and pin 8 of V509. If it is 3.9 Ω or 5.6 Ω, remove it and the 0.047 μf capacitor, C503, connected in parallel with it. In place of this parallel combination put a series combination consisting of a 1.2 k, ½ w, 10% composition resistor (Tek no. 302-122) and a 100 pf, 500 v capacitor (Tek no. 281-530). Shunt this series combination with another 100 pf, 500 v capacitor (Tek no. 281-530).
2. Change the 10 Ω resistors connected between pin 3 of V508 and V509 and the ceramic strip with 39 Ω, ½ w, 10% composition resistors (Tek no. 302-390).

Type 531A, serial numbers 5969 and below:
Type 535A, serial numbers 6321 and below:
There is a possibility of vertical amplifier parasitic oscillations. This appears as a step on the leading edge on an input squarewave (calibrator waveform for instance). Prevent this by adding C560, a 0.01 μf, 500 v, discap (Tek no. 283-002), between pin 1 and V558 and ground. This is a desirable change even if 6DJ8's are not used in the vertical amplifier.

Type 541A, serial numbers 6475 to 7078:
Type RM41, serial numbers 149 and below:
Type 543, serial numbers 318 and below:
Type 545A, serial numbers 9292 to 11904:
Type RM45, serial numbers 208 and below:
Type 551, serial numbers 596 and below:
In the vertical amplifier (upper-beam vertical amplifier of Type 551) change R1033 from 1.5 k to 2.5 k, 5 w, wire wound resistor (Tek no. 308-127) and R1223 from 2.7 k to 4.7 k, 2 w, 10% composition resistor (Tek no. 306-472).
In the Type 551 lower-beam vertical amplifier, also change R2033 and R2223 to the new values.
Readjust the vertical amplifier and delay line according to your instruction manual. (This SERVICE SCOPE article supersedes FMR 157 - 3/24/61).

MISSING INSTRUMENTS

Tektronix Field Engineer John Griffin of our Stamford Field Office experienced a bit of bad luck recently. A Type 502 Oscilloscope, s/n 5070, and a Type C-12 Camera, s/n 348, with a Shutter Actuator, Model 1 disappeared from his car. John did not authorize anyone to remove these instruments from his car so we presume they have been stolen.

If you have any information regarding these instruments, please get in touch with the Stamford Field Office. Their address is 1122 Main Street, Stamford, Connecticut. Phone number—DAvis 5-3817. Or, if you prefer, contact your local Tektronix Field Engineer.

The Oklahoma State University reports that a Type 561 Oscilloscope, s/n 409, along with a Type 72 Dual-Trace Plug-In Unit, s/n 397, and a Type 67 Time-Base Plug-In Unit, s/n 433, is missing from the Electrical Engineering Department and is thought to be stolen.

Persons with information regarding the whereabouts of these instruments should contact: Gerald Stotts, Head Lab Technician, School of Electrical Engineering, Oklahoma State University, Stillwater, Oklahoma. The telephone number is FRontier 2-6211, Ext. 322.

Our Cleveland Field Office notifies us of a missing Type 321, s/n 883. This instrument disappeared from the Worden Road Plant of the Bailey Meter Company in Wickliffe, Ohio.

Mr. V. S. Rutherford of the Bailey Meter Company would like to hear from anyone who has information on the whereabouts of this instrument. Address information to: V. S. Rutherford, Bailey Meter Company, Worden Road Plant, Wickliffe, Ohio.

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

Service Scope

USEFUL INFORMATION FOR
USERS OF TEKTRONIX INSTRUMENTS

USED INSTRUMENTS WANTED

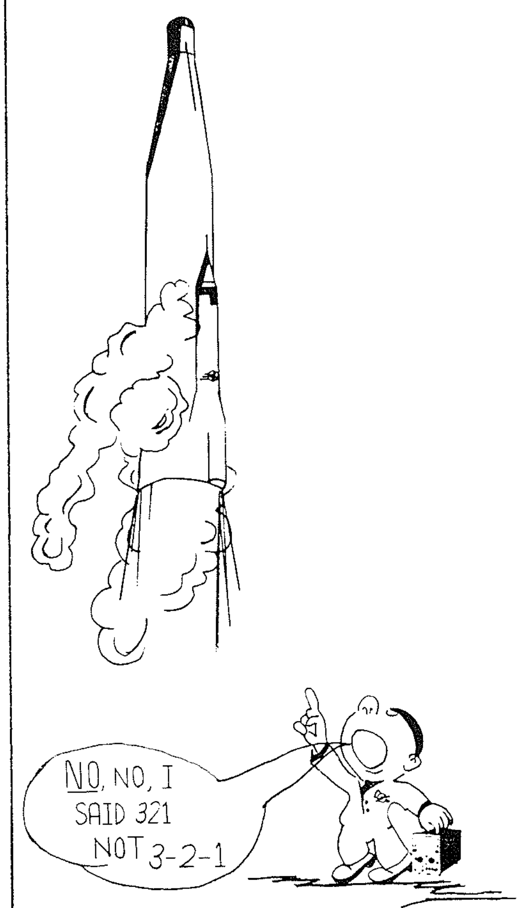
1 3″ or 5″ Tektronix scope.	John J. Arragnost DeVry Technical Inst. 4141 West Belmont St. Chicago, Illinois
Several Type 511, Type 512 and Type 513 Oscilloscopes.	James Palmer Engineering Department Gannon College Perry Square Erie, Pennsylvania
Several general purpose 10 to 15 MC Oscilloscopes, 3″ or 5″.	Bob Jones 2406 Eastern Avenue Wesleyville, Pa.
1 Type 524	Ed Shinholt Radio Corporation of America 3301 South Adams St. Marion, Indiana
1 Type 310 or Type 310A	Thomas A. Barr WAFG TV 1000 S. E. Monte Sano Blvd. Huntsville, Alabama
1 Type 502 or Type 503	Joe Posten 309 Benton Drive Indianapolis, Indiana Phone: TU 1-9771
1 Type 514D or Type 310	M. Perez & Sons Television Service Labs. 6475 Main Street Long Hill, Connecticut Phone: AM 8-3766
1 Type 310 or Type 315	Al Willis 70 Pilgrim Lane Westbury, Long Island Phone: ED 4-5604

USED INSTRUMENTS FOR SALE

1 Type 524AD, s/n 6347	Jerry A. Richards Chief Engineer WGTE-TV Toledo, Ohio Phone: 531-1451, Ext. 348
1 Type 502, s/n 1477	Col. Hoxie Lind Industries 2294 Mora Drive Mountain View, Calif. Phone: YOrkshire 8-0083
1 Type 514D, s/n 2812. Price $675.00 1 Type 524D, s/n 1665. Price $775.00	Pete Pappas Electronic Development Laboratories 4307 23rd Avenue Long Island, New York Phone: RA 8-7116

Seller says both scopes in better than average condition.

1 Type 575, s/n 2103. Has had very little use.	Travis Howell RAWCO Instruments 1400 Riverside Drive Fort Worth, Texas
1 Type 551, s/n 2011 2 Type CA Plug-Ins, s/n's 13443 and 13444	Dr. Verner J. Wulff Masonic Medical Research Laboratory Utica 2, New York Phone: RE 5-2217
1 Type R Plug-In Unit	Bob Billings Eldorado Electronics 2821 Tenth Street Berkeley, California
1 Type 533A, s/n 3039	Mr. Blair Eastern Specialty 3617 North Eighth St. Philadelphia 40, Penn. Phone: BA 8-0500



Tektronix Field Engineer Bob Browning with a Type 321 Oscilloscope calls at Cape Canaveral.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

Tektronix
Service Scope
USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 14 PRINTED IN U.S.A JUNE 1962

HORIZONTAL SAMPLING THEORY

By Hal Hardenbergh; until recently, assigned to our West Los Angeles Field Office.

To recreate a waveform using sampling techniques, samples must be taken over the entire waveform. Taking a sample of the leading edge of the waveform is easy; a trigger circuit is used to trip a strobe pulse generator directly. A block diagram of this system would take this form:

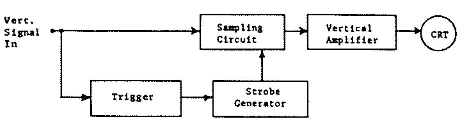


Figure 1

In practice, the system represented by the block diagram above wouldn't be able to sample on the very front of the waveform, because of the finite time delay in the trigger and strobe generator circuits. Therefore, a time delay must be introduced between the trigger input and the sampling circuit. If the vertical signal input is 50 Ω, a 50-Ω coax cable may be used to obtain the necessary delay. A delay of approximately 50 nanosec, representing about 33 feet of 50-Ω coax, is generally used.

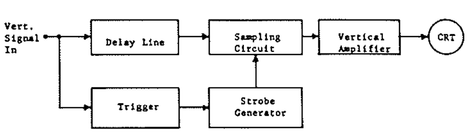


Figure 2

Although the system represented by Fig. 2 would be able to sample an incoming waveform on its leading edge, it probably wouldn't be able to sample in the middle of the waveform, or at the trailing edge. Practical trigger circuits can generally "recognize" only the leading edge (or transition) of a waveform. In order to sample in the middle of the waveform, a time delay must be inserted between the trigger circuit and the strobe generator.

Since long time delays may be necessary (up to a millisecond) and since the delay should be continuously variable, an electronic delay is used. The strobe generator is now tripped by the delayed trigger output of the variable delay circuit. If a sufficient range of delay is available, samples may now be taken over the entire waveform. Our block diagram now takes this form:

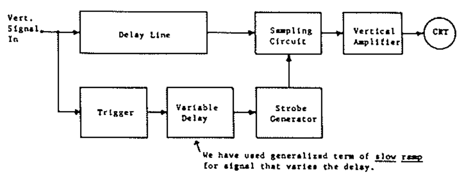


Figure 3

Functionally, this variable delay circuit is identical to the delayed trigger pick-off in the Tektronix Type 535/535A Oscilloscopes. The trigger circuit recognizes the incoming waveform and initiates a voltage ramp or sweep. The voltage ramp is fed into a comparison circuit, or comparator, along with a DC voltage. When the ramp reaches the level of the DC voltage, the comparator puts out a trigger pulse called the delayed trigger. The time delay between the trigger input and the delayed trigger output may be changed by varying either the DC voltage or the slope of the ramp. Usually the DC voltage is changed (by the DELAY TIME helipot on the Type 535 or Type 535A) to obtain a vernier delay, and the slope of the ramp is changed to change the range of the vernier. A block diagram of the delayed trigger circuits in the Type 535 or Type 535A would take this form:

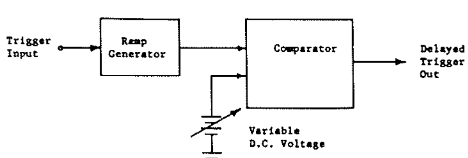


Figure 4

The delays needed in sampling systems are generally much shorter than those available from the delayed trigger of a Type 535 or Type 535A; therefore, the circuitry is different. However, a voltage ramp, now called the "fast ramp," is still compared to a variable DC voltage to obtain the variable time delay needed to sample along the full length of our waveform. Our sampling system block diagram now takes the following form:

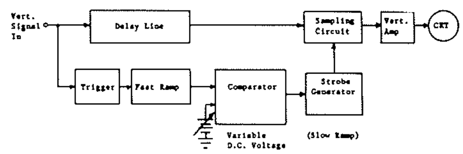


Figure 5

If the DC voltage in the above block diagram is increased each time a sample is taken, comparison will take place progressively further along the fast ramp. Thus, there is a progressive increase in the time delay between recognition and sampling. This causes each sample to be taken on a different part of the incoming signal.

A complete sampling system, therefore, includes an incremental voltage-advancing circuit or "staircase generator." The staircase generator is made to advance one increment immediately after each sample is taken, by feeding the delayed trigger output of the comparator into the staircase generator. By advancing the staircase immediately after a sample is taken, the staircase generator is given the maximum time to reach its new DC level before the next ramp arrives. We now substitute a staircase generator for the variable DC voltage in our block diagram:

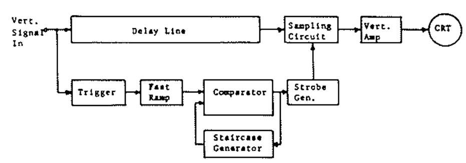


Figure 6

The *real time* spacing is determined only by the repetition rate of the waveform (up to the maximum sampling rate of the oscilloscope). The *equivalent time* spacing is determined only by the fast ramp slope and the amplitude of each stairstep. Therefore, the *equivalent time* of a sampling display is independent of the *real time* of the display and vice-versa.

When we reconstruct the shape of a waveform on the CRT of a sampling oscilloscope, we in effect pretend that all of the samples contained in one sweep were taken on one waveform. Therefore, the time/div calibration of a sampling scope is in *equivalent time*.

If the fast ramp is a linear voltage/time ramp and if the stairstep is advanced in uniform increments, the spacing of the samples along the incoming waveform will be uniform in *equivalent time.*

To understand the meaning of "equivalent time," consider the following case: If we reconstruct a repetitive pulse 12 nanoseconds wide by taking 12 samples, one *real time* between successive samples depends on the repetition rate of the waveform. However, by using our 12 samples to reconstruct a picture of the waveform, we are in effect pretending that all of the samples were taken on one pulse. If this were true, the time between samples would be only one nanosecond (12 samples along our 12 nsec pulse). This is the *equivalent time* between samples.

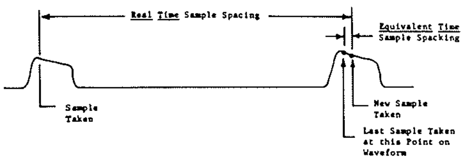


Figure 7

To reconstruct a waveform, the samples must be spaced horizontally in the proper time sequence. This is done by feeding the stairstep into the horizontal amplifier so that the trace moves one increment horizontally as each sample is taken. The relationship between the increment of horizontal distance per sample and the equivalent time per sample will determine the (equivalent) sweep time/div. Adding this function to our block diagram, we now have:

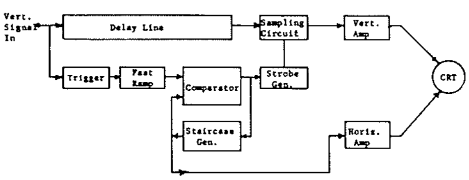


Figure 8

To take a specific example, suppose that the amplitude of staircase going into the comparator is 50 mv/step, where one step equals one sample. If the fast ramp rises 50 mv/nsec, the equivalent time per sample will be one nsec.

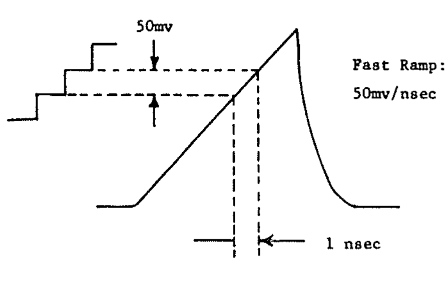


Figure 9

If we adjust the gain of the horizontal amplifier so that each step advances the trace horizontally 1 millimeter, 10 samples (at an equivalent time per sample of 1 nsec) will be required per cm; the sweep time/cm, therefore, will be 10 nsec.

In other words, the (equivalent) time per sample, times the number of samples per division, equals the (equivalent) time per division:

(Time/sample) (samples/div) = Time/div

Returning to our specific example, let's see what happens if we leave the fast ramp and the horizontal gain unchanged, but change the amplitude of each stairstep from 50 mv to 100 mv. This will result in a horizontal step of *two* mm/sample or 5 samples/cm. The equivalent time/sample will increase from 1 nsec to 2 nsec. The resulting time/cm may now be calculated:

(2 nsec/sample) (5 samples/cm) = 10 nsec/cm

Changing only the amplitude of each step within the staircase generator does not affect the time/cm calibration of the crt display—only the equivalent time between samples. However, attenuating the overall amplitude of a given staircase to the comparator will decrease the time/cm by an amount equal to the attenuation.

We've been using a staircase to sample at various points along a waveform (common practice is to say that the strobe pulse "slews" along the waveform). Under certain conditions the stairstep waveform won't resemble its namesake very closely. Actually, the staircase advances one step per sample, so that if we plot the voltage versus the number of samples taken, the graph looks like this:

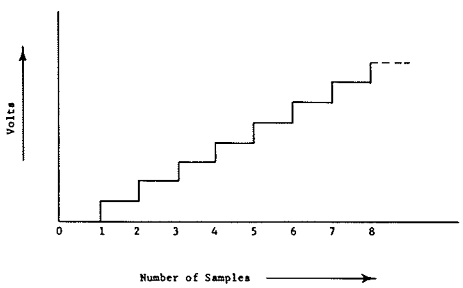


Figure 10

If the incoming waveform repeats at regular intervals, the spacing of the steps on the staircase will be uniform in real time; the waveform observed on a conventional scope will look like this:

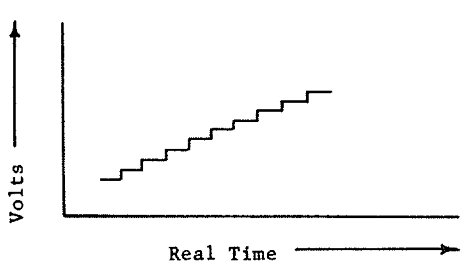


Figure 11

However, if the incoming waveform recurs at an irregular rate, the spacing of the samples (and steps) will be non-uniform in real time:

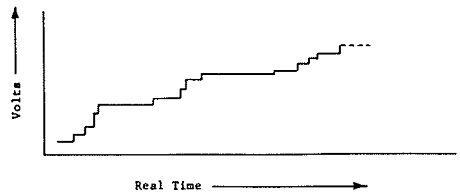


Figure 12

Therefore, do not expect the stairstep *always* to look like a uniform stairstep when observed in *real time.* Note that irregular spacing of samples in *real time* will not cause irregular spacing in *equivalent time,* since the equivalent time calibration is independent of the repetition rate of the incoming waveform. Problems will arise, however, when equivalent time phenomena are viewed on a real time (conventional) oscilloscope.

MEASURING N-PORT PARAMETERS OF NETWORKS

Research engineers at Page Communications Engineers, Inc., Washington, D. C., a subsidiary of Northrup Corporation, have developed techniques for measuring n-port parameters of networks with the aid of the Tektronix P6016 Current Probe and Type 131 Amplifier. Used together with a conventional voltage probe and either a dual-beam or electronically switched dual-channel oscilloscope, with the time base synchronized to the voltage-input channel, the current-probe channel provides both magnitude and phase measurements. With known terminations, such as open circuit and short circuit, a complete set of complex n-port parameters for the component z, y, and h matrixes can easily be determined.

Since the Tektronix Current Probe inserts very little reactance in the lead under test, short-circuit current measurements are feasible. Similarly, driving current and load current can usually be determined directly with little extraneous effort. In general, since the current probe disturbs the measurement less than the shunt capacitance of the voltage probe, the current probe should usually be clipped to a lead directly into the network, while the voltage probe should be on the generator side, not the network side of the current probe.

For passive systems, a check on the measured values is the fact that $z_{ij} = z_{ji}$ and $y_{ij} = y_{ji}$. Nonlinearities are made evident by distortion of the sine-wave signal. In the past, distorted current waveforms were difficult to detect, but this technique clearly displays any such effects.

SLAVING TYPE 560-SERIES SCOPES

In response to customer interest, Russ Fillinger, Project Engineer with the Medical-Instrument Development Group has come up with a method of slaving one Type 560-Series scope to another. Cost is low and minor modifications are required on the instruments.

The Master scope must furnish four signals to the Slave scope:

1. Vertical signal (single, dual, or four trace)
2. Sweep sawtooth
3. Deflection blanking (for sweep retrace)
4. Transient-spike blanking to CRT cathode (for dual-and four-trace applications)

Modifications required on the Master scope—refer to accompanying diagram:

1. *Vertical System*
   - A. Plug-in
     - (a) Improve transient response of internal trigger C.F.) For Type 72 remove C487 and replace with 1.5 to 7 pf variable.)
   - B. Indicator
     - (a) Bring out vertical signal from pin 11 of the indicator left-side Amphenol connector (or pin 12 of the right-side Amphenol connector) to the vertical input connector of the Slave.
     - (b) Bring out chopped transient blanking signal from pin 24 of the indicator left-side Amphenol connector to pin 24 of the left-side Amphenol connector of the Slave indicator. (For convenience, the first notch on the ceramic strip under the HV supply may be used instead.)
2. *Horizontal System*
   - A. Plug-In
     - (a) Patch sweep signal to pin 24 of right-side Amphenol connector (in Type 67 install a lead from the cathode of V333A to pin 24 of the Amphenol plug).
     - (b) For fast sweeps in Type 67, it may be necessary to decrease R138 to compensate for additional capacitive loading.
   - B. Indicator
     - (a) Bring out sweep signal from pin 24 of the right-side Amphenol connector in the indicator to the horizontal input connector of the Slave.
     - (b) Bring out sweep blanking signal from pin 13 of the right-side Amphenol connector of the indicator to pin 13 on the left-side Amphenol connector of the Slave indicator.

Modifications required on the Slave plug-ins are:

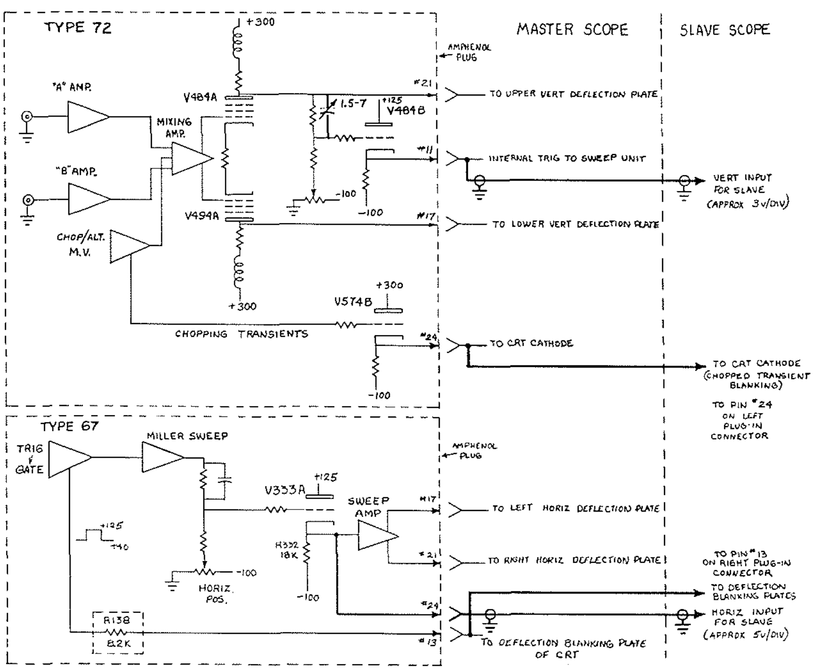
1. Cut tie strap between pins 13 and 14.
2. Remove ground strap from pin 24 (may not be present in early units)

By doing Steps 1 and 2 on both Slave plug-ins, you make them interchangeable from side to side in the Slave indicator.

Russ used a 561/72/67 for the Master and a 561/60/60 for a Slave. The Master had a frequency response of approximately 650 kc; the Slave 390 kc. You may wish to use a 561/59/59 combination for economy.

Linearity of signal will be approximately ±6% in 8 cm because we are using a single-ended sample of the vertical signal from the Master. Linearity is dependent on the output stage of the Master plug-in.

You may wish to install connectors on the back panel of the indicators. If so, you're cautioned that in this case we limited our coax length to four feet.



USED INSTRUMENTS WANTED

1 Type 121 Preamplifier	Harry W. Hammond 1095 Arlington Ave. Teaneck, New Jersey
1 Type 310, 316, 317 or 321 Oscilloscope	Phil Boehme U.S. Navy Electronics Laboratory Code 2623 San Diego 52, California
1 Type 531 or Type 535 with a Plug-In Preamplifier	Alex Levin Bureau of Ships Code 679C3F Washington 25, D. C.
1 Tektronix 5" crt oscilloscope. DC to 10 MC.	G. Servos 686 Fairview Avenue Elmhurst, Illinois
1 Type 502	S. Winston 104 MS U.C. Medical Center San Francisco, California
1 Type 310 or Type 321	James F. Bockelman Aircraft Space Electronics Apalachicola, Florida
1 Tektronix General Purpose Oscilloscope (10-15 mc.	Robert E. Jones 2406 Eastern Avenue Wesleyville, Pa. Phone: TW 9-3456

USED INSTRUMENTS FOR SALE

1 Type 575 Transistor Characteristic Curve Tracer, s/n 3565	Ortho Industries, Inc. 7-11 Paterson Street Paterson, New Jersey

Owner says this instrument was used only briefly to evaluate 24 transistors. Price $800.00

1 Type 127 Power Supply 1 Type E Plug-In Unit	Frank G. Carpenter Assoc. Professor of Physiology Dartmouth Medical School Hanover, New Hampshire
1 Type 541A, s/n 21509, with a Type L Plug-In Unit, s/n 11618	Sprague Engineering Co. 18435 Susana Road Compton, California
1 Type 517, s/n 625. Will sell or trade for either a Type 545A or Type 585 and cash	Ian Isdale 825 Tall Timber Road Orange, Connecticut

Service Scope
USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS
Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

1 Type 316, s/n 187 1 Type 181, s/n 259	Dale Brocker 3008 Lakeshore Avenue Apartment 6 Oakland, California
1 Type 517, s/n 1680	John Ivimey Room 2001 1428 South Penn Square Philadelphia 2, Penn. Phone: LO 3-6531
1 Type 512 with flat faced crt. Price $275. F.O.B San Francisco	S. Winston 104 MS U.C. Medical Center San Francisco, California

MISSING INSTRUMENTS

The University of Alabama reports a Tektronix Type 503 Oscilloscope, serial number 759, as missing from their Electrical Engineering Department. They presume it to be stolen. Information concerning this instrument should be sent to: Willard F. Gray, Department of Electrical Engineering, University of Alabama, University, Alabama.

A Tektronix C12 Camera, serial number 008-980, belonging to the Columbia University in New York City disappeared from the University and is presumed to be stolen. Information concerning the whereabouts of this camera should be sent to: Tektronix, Inc., 840 Willis Avenue, Albertson, Long Island, New York.

Our Chicago Office notifies us that a Tektronix Type 310A Oscilloscope is missing from the General Electric X-Ray Division in Chicago. This instrument is also believed to be stolen. If you have any information pertinent to this instrument, please notify: Tektronix, Inc., 400 Higgins Road, Park Ridge, Illinois.

QUESTIONS FROM THE FIELD

Q. When using my Type 543 at the fastest sweep speeds, the trace intensity is not uniform because of a 5-volt dip in the unblanking waveform. This intensity nonlinearity sometimes makes it difficult to take satisfactory photographs of the crt display. What will cure this?

A. Types 533 and 543 after serial numbers 3000 were modified to overcome this problem. You can make the modification to the sweep-gating multivibrator in the time-base-generator circuit of your instrument. Simply replace L 133 with a strap. Connect an 8 pf, 500 v, ceramic (Tektronix No. 281-503) between pin 8 of V135 and the junction of R133 and R134.

Q. The multivibrator in my 53/54C and CA Plug-In Units will not self-start when the units are warming up in the CHOPPED mode. How can I correct this problem?

A. This problem was solved by a modification installed in CA units with serial numbers above 34790. You can correct the condition in CA units below this number and in 53/54C units, all serial numbers, by adding R3383, a 330 k, ¼ w, 10%, comp. resistor (Tektronix No. 316-334) between the cathode of V3382* (6AL5, pin 5) and +225 v.

The 6AL5 caused the problem. Its cathodes were returned to —150 v through a 1.8 megohm resistor located in the oscilloscope (via pin 16 of the interconnecting plug). This resistor provided a current source for the 6AL5 that tended to balance the multi (V3375, 12AT7) plates; both halves saturated and prevented multi action. The 330 k resistor forms a divider that biases off the diodes.

*V3803 in Type 53/54C Units.

Q. What can I do to correct intensity modulation (noticeable at some sweep speeds when using low intensity) on my Type 321 Oscilloscope?

A. Change C852, an 0.01 µf, 1000 v, Hicap capacitor to an 0.02 µf, 1400 v, DC, Type U capacitor (Tektronix No. 283-022). Type 321's after s/n 1389 have this modification.

PINPOINTING INFORMATION ON POLAROID PRINTS

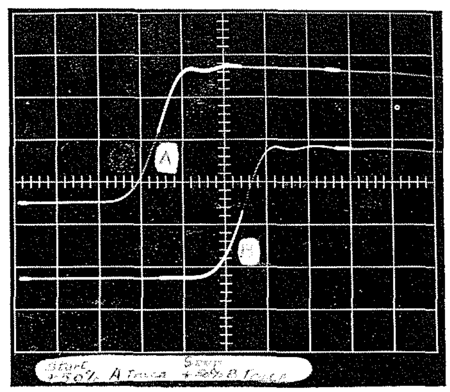


Figure 1

Use a draftsman's thin metal erasing shield and an eraser (an electric eraser is ideal if you're lucky enough to have one handy) to label or pinpoint information on Polaroid* Land prints. The shield and eraser will enable you to erase through the print to the underlying white paper. You can erase away a portion of the print to form an arrow or a space to write in a number or a brief description. See Figure 1.

* Polaroid is a registered trademark of the Polaroid Corporation.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 15 PRINTED IN U.S.A AUGUST 1962

SAMPLING OSCILLOSCOPES AND THE SLIDE-BACK BALANCED-BRIDGE TECHNIQUE

For those unacquainted with the term "sampling oscilloscope", a brief explanation may be in order.

A sampling oscilloscope measures recurrent waveforms point-by-point in progressive steps much as you would plot a graph of amplitude vs. time with a series of points on graph paper. Unlike a conventional scope display where one signal completes one picture, sampling uses up to 1000 individual amplitude-vs.-time points taken electronically. Each point on the plot is called a sample. After each repetition of the signal the circuit, which samples and measures the input waveform, is told to measure the next recurrence a small increment of time later on the waveform than the preceding sample. The process of advancing sampling time in regular fixed increments is sometimes referred to as "strobing". For each increment of strobing, the voltage present on the input at that particular instant is measured—or as we say "sampled"—and simultaneously plotted as vertical deflection on the crt. At this same instant the horizontal motion of the display moves an increment of time in synchronization with the strobing signal. In this manner, a reconstructed signal is reproduced on the crt.

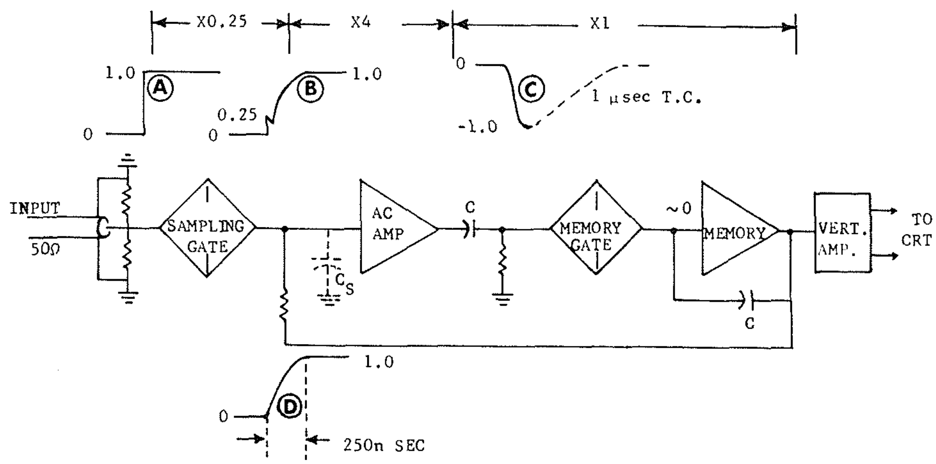


Figure 1

Basic block diagram of circuitry used in the Slide-Back Balanced-Bridge technique.

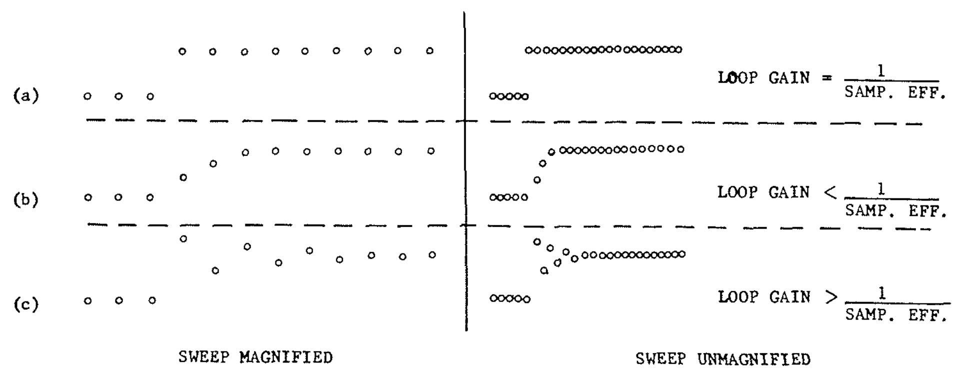


Figure 2

Dot transient response of input circuitry with different loop gains.

What we see is actually an amplitude-vs.-time, point-by-point graph. The reconstructed signal is much slower than the original signal. Thus, it can be handled by conventional, low-speed, high-gain amplifier circuits.

Several techniques are available for obtaining the point-to-point measurements of the applied recurrent waveform. Of these, the Slide-Back Balanced-Bridge technique offers certain distinct advantages. These are: better accuracy, improved linearity and dynamic range, and more effective suppression of noise—the balanced diode gate allows first order cancellation for noise on the interrogate spike.

Three Tektronix Oscilloscopes employ this technique in their vertical circuits. They are, the Type 661 Pulse Sampling Oscilloscope and (when combined with a Type 3S76 Dual-Trace Sampling Plug-In and a Type 3T77 Sampling Sweep Plug-In) the Type 561A and Type 567 Oscilloscopes.

Look at Figure 1. It s a basic block diagram of the circuitry used in the Slide-Back Balanced-Bridge technique. It works like this: The input signal is applied through the 50-ohm delay line to the Sampling Gate. (The Sampling Gate is a balanced diode bridge which acts as a gate for the signal, so you'll hear it referred to variously as the Sampling Gate and as the Sampling Bridge. In this article we'll refer to it, and other circuits like it, as gates. When a gate is "open", the signal can pass through; when a gate is "closed", the signal cannot pass through.)

The waveforms shown in Figure 1 illustrate the operation of the circuit for one sample. As you can see, the entire difference signal applied to the input does not pass through the Sampling Gate during the time it is open. This is due to diode resistance, circuit capacitances, gate-opening duration, etc. The ratio of the signal out of the gate to the signal into the gate is called the "sampling efficiency." The waveforms shown are based on a sampling efficiency of 25%, which is typical.

Waveform A indicates that the input signal has jumped from ground to +1 volt since the last sample was taken. Therefore, when the Sampling Gate opens, the AC Amplifier sees a difference signal of 1 volt. However, the AC Amplifier input is able to move only 0.25 volt before the gate closes again (waveform B). After the gate closes, the AC Amplifier input immediately begins to return toward zero. The AC Amplifier has a gain of minus four, so because its input was moved positively 0.25 volt, its output swung negatively one volt (waveform C). The Memory Gate is also open at this time so this —1 volt swing is applied to the Memory. The Memory is an inverting Integrator with a gain of one. Its output (waveform D) is applied through the feedback circuit to the input of the AC Amplifier. So this brings the AC Amplifier input up to +1 volt and it is now ready for the next sample to be taken.

Note that there is some time lag between the closing of the Sampling Gate and the arrival of the feedback voltage from the Memory output, as shown by the slight decay in waveform B before Memory output takes over. This is normal.

After the AC Amplifier has amplified the 0.25-volt step of Waveform B, its output decays back toward zero. The low-frequency gain of the AC Amplifier is low enough that it ignores the relatively slow change applied by the Memory at its input.

It can be seen that the gain of the AC Amplifier, Memory Gate, Memory Loop must be equal to the reciprocal of the sampling efficiency for the AC Amplifier input to be brought exactly to the level of the last input sample. Figure 2—waveform A shows the "dot transient response" of the circuit to a step input signal when the loop gain is properly set. If the loop gain is less than the reciprocal of the Sampling Efficiency, the response of the circuit to a step input will look like Figure 2 — waveform B. At each sample, the AC Amplifier input will be brought up only part way to the input signal amplitude, and it will take several samples before the output attains the same level as the input signal. Figure 3—waveform C shows what the output will look like if the loop gain is too high (by a factor of less than two). In this case, the output will overshoot the input signal on the first sample, undershoot the input signal on the second sample, overshoot on the third, etc., until the amount of overshoot and undershoot becomes negligible and the output settles down to the same level as the input. If the loop gain is too high by a factor of more than two, the output will overshoot and undershoot the input by increasing rather than decreasing amounts on each sample. In this case, the loop will be driven into saturation first in one direction and then the other, and there will be no useful output.

To increase the sensitivity of the unit (VOLTS/DIV), we need to increase the output of the Memory relative to the input signal. This is relatively simple; we can just increase the gain of the AC Amplifier. But as mentioned above, this gets us into trouble back at the input. So we must attenuate the feedback signal by exactly the same amount as we increase the AC Amplifier gain. Thus, if we increase the AC Amplifier gain to 20, we'll get five volts out of the Memory for each volt of input signal. Then we'll use a 5X attenuator in the feedback network to keep the proper relationship across the Sampling Gate. It's the 5 volts that goes on into the Vertical Amplifier to drive the crt, of course.

Editor's Note: Authorship of this article can hardly be attributed to any one person. Rather, it is the result of the joint efforts of the people who comprise the Tektronix Field Training group. Paul Thompson of this group is responsible for the literary efforts and the basic discussion is adapted from a seminar originated by the Field Training people and conducted by their Bob Sadilek.

NEW FIELD MODIFICATION KITS

TYPE 502 VERTICAL-SIGNAL-OUT MOD KIT

This modification provides a rear panel, direct-coupled signal out from each vertical amplifier. Output level is approximately 2 volts for each centimeter of crt deflection. Output impedance is 200 Ω. Installation time is approximately 3 hours* for instruments below serial number 1667 and approximately 2 hours for instruments above serial number 1666.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-284. Price $18.50.

TYPE 507 SILICON RECTIFIER MOD KIT—For Type 507 instruments with serial numbers 101 through 211,

and;

TYPE 575 SILICON RECTIFIER MOD KIT—For Type 575 instruments with serial numbers 101 through 4919.

These modification kits replace the original selenium-rectifier stacks of their respective instruments with a silicon-rectifier assembly. Silicon rectifiers provide better reliability and longer life. Approximate installation times are 1 hour* for the Type 507 and approximately 45 minutes* for the Type 575.

Order through your local Tektronix Field Engineer or Field Office. Specify:

For the Type 507—Tektronix part number 040-259. Price $25.00.

Or,

For the Type 575—Tektronix part number 040-223. Price $29.75.

TYPE RM503 AND TYPE RM504 REAR VERTICAL AND HORIZONTAL INPUT MOD KITS

Two separate modification kits—one for the Type RM503 and one for the Type RM504—supply coax-cable assemblies for adding Vertical and Horizontal Inputs to the rear panels of these instruments. These rear-panel inputs parallel the front-panel inputs and introduce an added input capacitance. Because of this additional capacitance, standard passive probes, when used with these modified instruments, cannot be compensated.

Installation requires approximately 45 minutes* for the RM503 and approximately 30 minutes* for the RM504.

Order through your local Tektronix Field Engineer or Field Office. Specify:

For the Type RM503, all serial numbers; Tektronix part number 040-243. Price is $16.00.

Or,

For the Type RM504, all serial numbers; Tektronix part number 040-272. Price is $9.00.

TYPE 575 INCREASED COLLECTOR VOLTS MOD KIT

Installation of this modification converts the Type 575 (all serial numbers) to the Type 575MOD122C which provides the following features:

a. A maximum Collector Sweep voltage of 400 volts (instead of 200 volts), rated at 0.5 amperes maximum.
b. Three (3) more sensitivities (50, 100, and 200 volt per division) on the HORIZONTAL VOLTS/DIV. switch.
c. A ± 1.5 kv supply for checking peak inverse voltage of rectifiers. The high voltage is accessible at the Collector Test terminals and the supply current is limited by an internal impedance of 1.8 megohms.

Note: The output voltage (Collector Terminal voltage) of the 1.5 kv supply varies directly with the line voltage and inversely with the load current (i.e., at 117 v [235 v] line voltage and zero load current of 1 ma, the output voltage is zero).

This modification requires installation of a new front panel (furnished in the kit). When ordering the modification kit, please give the serial number of the instrument in which it is to be installed. We will stamp the new front panel with the serial number of your instrument before shipping the modification kit to you.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-276. Price is $200.00.

* Quoted installation times are for first time installations by a trained technician familiar with Tektronix instruments.

MISSING INSTRUMENTS

During the week end of June 30th, 1962, a Type 503 Oscilloscope, serial number 973, was apparently stolen from the Chemistry Department at Carnegie Institute of Technology. This instrument disappeared during the week end and a check of authorized personnel failed to reveal its presence. The Chemistry Department would like to hear from anyone with information regarding this instrument. Their address is Carnegie Institute of Technology, Pittsburgh 13, Ohio. Telephone number is area code 412, MAyflower 1-2600.

Pennon Electronics, 7500 South Garfield Avenue, Bell Gardens, California reports the loss of two oscilloscopes: a Type 503, serial number 291; and a Type 511AD, serial number 5106. These instruments which disappeared about the middle of June '62 are believed to have been stolen. Pennon Electronics asks that anyone with information on these instruments, please contact them at the above address.

Herbert Gunther, New York Representative for the Control Data Corporation called our Long Island Field Office to report a missing Type 317 Oscilloscope, Tektronix serial number not available. However, a tag on the front panel of the instrument says "CONTROL DATA SN 1883-7363".

Mr. Gunther believes this instrument may have been stolen. He asks that anyone with information on this scope either contact him at 160 Rockaway Parkway, Valley Stream, New York City, New York—telephone VA 5-8852, or report their information to the Control Data Corporation, 8100 34th Avenue, Minneapolis, Minnesota.

USED INSTRUMENTS WANTED

1 Type 535 or Type 545	Dr. J. F. McNall Phoenix Engrg. & Computer 7464 Hubbard Avenue Middleton, Wisconsin
1 Type 515 or Type 310	Tom Hall Geotechnical Corp. P. O. Box 28277 Dallas 28, Texas
1 Type 570 Vacuum-Tube Curve Tracer	Stan Mahurin c/o Marine Radio Service Berth 73 San Pedro, Calif.

USED INSTRUMENTS FOR SALE

1 Type 127 Power Supply (for Type A to Z Plug-Ins), s/n 462	Robert Malta George A. Philbrick Researches, Inc. 172 Clarendon Street Boston, Massachusetts
1 Type 317, s/n 314, with Type 123 Preamplifier, s/n 1054	M. H. Schaffner Columbus Bank Note Co. 40 East Spring Street Columbus 15, Ohio Phone: 224-2117
1 Type 536, s/n 104	General Electric Co. D. Dowell/G. Bedore 13430 Black Canyon Hwy. Phoenix, Arizona
1 Type 513D	William Johnson 31 Waverly Road Wyncote, Penn. Phone: TUrner 4-9837
1 Type 310	Arthur Sommers 1875 S. Taylor Road Cleveland Heights, Ohio Phone: area code 216, FA 1-2277
1 Type 514D	Chuck Phillips Tektronix, Inc. 11681 San Vincente Blvd. West Los Angeles 49, Calif. Phone: GR 3-1105 BR 2-1563
1 Type 514AD	Engineering Associates 434 Patterson Road Dayton 19, Ohio Attn: C. C. Littell, Jr.
1 Type 517A with a Type 500A Scope-mobile. Both in good condition. Asking $2250.00	A. Lincoln Mekelburg Decisions, Inc. 142 Second Street Fall River, Mass.

SERVICE HINTS

CONDUCTED OSCILLATOR RIPPLE IN TYPE 503/TYPE 504 OSCILLOSCOPES

Appearance of convertor-oscillator ripple at the input of a Type 503 or Type 504, when connected to a low-impedance signal source, has been traced to a conducted ground-loop via the power-cord third wire.

Type 503's with serial numbers above 1385 and Type 504's with serial numbers above 480 have a factory installed modification to eliminate this ground loop.

For instruments already in the field, Tektronix Field Engineer Frank Elardo worked out a simple field modification to correct this condition. Simply move the ground (green) wire of the power cord from its original installation point — the ceramic strip by C652 — to the small hole in the chassis behind V692 (5642). Use a 4-40 self tapping screw (Tektronix No. 213-035) and a No. 4 solder lug (Tektronix No. 210-201). In some early instruments this point was used for grounding C692 A/B and a new screw will not be required.

To determine whether conducted interference is causing ground-loop problems, disconnect the power-cord ground wire by using a three-to-two wire adapter. If the adapter eliminates the interference, then the ground-relocation modification described here should be performed.

REMOVING PAPER CAPACITOR COVERS

Removing the glued-on paper covers installed over the chassis-mounted electrolytic capacitors in some Tektronix instruments can be quite a chore. Tektronix Field Maintenance Engineer Udo Lindemeyer offers a novel approach to the solution of this problem. Using a hypodermic syringe, Udo injects about two cc's of acetone between the paper cover and the capacitor can. He makes the injection about the middle of the capacitor-cover assembly. In about ten minutes, the acetone softens the glue and the cover slips off easily. Some covers, however, may be glued at the top. In these instances it is necessary to invert the instrument and repeat the injection. Udo suggests that to get through the tough hide of the cover, try cutting the hypodermic needle down to about two centimeters and resharpening it.

TIPS FOR TUBE TAPPERS

Tektronix District Manager Harvey Worth reports that during environment tests, one of his customers found that tapping a tube with a pencil created up to 400 G's. They also found that the tapped tube had only 1/5 the life expectancy of a tube of the same type that was not tapped.

We suggest that a less destructive way of testing tubes for microphonics is to use a tool formed from a piece of ¼" plastic or phenolic rod. By means of a file or grinding wheel shape the rod as shown in Figure 1. When testing tubes for microphonics, gently saw the serrated edge of the tool back and forth over the tips of the tubes while observing the effects.

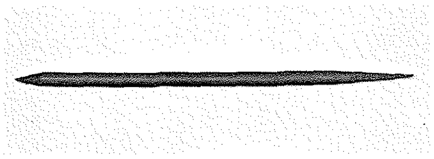


Figure 1

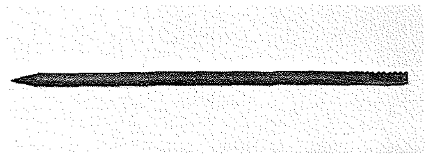


Figure 2

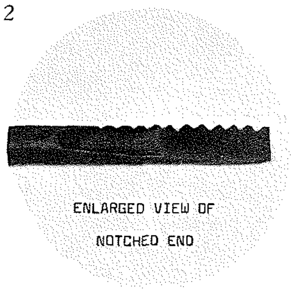


Figure 3

You'll also find that this tool makes a handy aid to hold wires and components in place while soldering. In addition, it makes a dandy non-conducting probe to poke around in an instrument when looking for loose leads or damaged components.

EFFECTIVE AIR-FILTER CLEANING AGENT

Tektronix Field Engineer Duncan Doane sent us the following information: A customer demonstrated the effectiveness of a new (to me) cleansing agent for cleansing the aluminum air filter on Tektronix instruments. He sprayed it on a filter choked with dirt, then merely held the filter under the hot water faucet. The filter came out sparkling! This customer buys the agent in gallon cans and transfers it to a window-cleaner type spray bottle, the name: Grease Off, Garden Products Corporation, Two Rivers, Wisconsin. The customer says it is available in Los Angeles at: Harvey's Butchers and Packers Supplies, 4506 S. Western Avenue, Phone: AXminister 4-8718. Price is $3.85 per gallon.

TRACE BOWING, POOR REGISTRATION AND COMPRESSION

Tektronix Field Engineer Tom Smith received a complaint of bowing, poor registration and compression in a new T502 crt. Investigation revealed about 2 mm of bowing when the trace was positioned to the perimeter of the crt.

Using a soft rag saturated with Anstac "M"*, Tom wiped the face of the crt and the graticule to remove the static charge and then dried them with a soft cloth. Following this action, Tom checked the crt display with a special geometry graticule and found the crt to be good in all respects.

* Anstac "M" is a product of the Chemical Development Corporation, Danverse, Massachusetts. We have found it effective in

Service Scope

USEFUL INFORMATION FOR
USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

removing the static charges which sometimes build up on crt's and graticules. We recommend it also for removing dirt, grease and finger marks from these components.

6U8A TUBES NOT SATISFACTORY AS REPLACEMENT FOR 6BL8 TUBE

Chassis identification and instruction manuals for several Tektronix instruments (Type 503, 504 Oscilloscopes; Type 67 Time Base Plug-In) have indicated that the type 6U8A tube may be substituted for the type 6BL8/ECF80 originally supplied in the sweep generator circuit (V160 in Type 503 or Type 504, V161 or V145 in Type 67).

Recent tests indicate, however, that the percentage of presently available 6U8A's that will operate satisfactorily in these circuits is extremely low. Tektronix no longer recommends this substitution, and references to it on chassis and in manuals will be deleted.

REMINDING YOU —

. . . that your Tektronix Field Engineer is your best possible source of information pertaining to oscilloscopes, their purchase, use, maintenance and repair.

. . . that you should apply Filter Coat (Tek no. 006-580. Price $1.00/pint) to the filter element after cleaning.

. . . that you *should not* apply oil to the air filter element.

. . . that you should oil the fan motor each time you clean the air filter.

. . . that to obtain accurate and reliable measurements when using an attenuator probe, you must compensate the probe to the oscilloscope. (See oscilloscope instruction manual).

TEKTRONIX, INC.

Tektronix, Inc., an Oregon Corporation, Home Office & Factory, P.O. Box 500, Beaverton, Oregon
Telephone: MItchell 4-0161 TWX—503-291-6805 Telex: 036-636 Cable: TEKTRONIX

FIELD ENGINEERING OFFICES

ARIZONA	• Phoenix... 7000 E. Camelback Road, Scottsdale...TWX: 602-949-0102	WHitney 6-4273
		Tucson Area: Enterprise 383
CALIFORNIA	San Diego... 3045 Rosecrans Street, San Diego 10...TWX: 714-276-4265	ACademy 2-0384
Los Angeles Area	*Encino*... 17418 Ventura Blvd., Encino...TWX: 213-783-3434	STate 8-5170
		From Los Angeles telephones call: TRiangle 3-6868
	• *Orange*... 1722 E. Rose Avenue, Orange...TWX: 714-633-2542	633-3450
	Pasadena... 1194 East Walnut Street, Pasadena...TWX: 213-449-1151	449-2164
		From Los Angeles telephones call: 681-0201
	• *West L.A.* ... 11681 San Vicente Blvd., West Los Angeles 49...TWX: 213-490-3958	GRanite 3-1105
		From Los Angeles telephones call: BRadshaw 2-1563
San Francisco Bay Area	*Lafayette*... 3530 Golden Gate Way, Lafayette....TWX: 415-281-5262	YEllowstone 5-6101
		From Oakland, Berkeley, Richmond, Albany and San Leandro: CLifford 4-5353
	• *Palo Alto*... 3944 Fabian Way, Palo Alto...TWX: 415-492-9458	DAvenport 6-8500
COLORADO	Denver... 2120 South Ash Street, Denver 22...TWX: 303-292-1702	SKyline 7-1249, 7-1240
		Salt Lake Area: Zenith 381
FLORIDA	• Orlando... 205 East Colonial Drive, Orlando...TWX: 305-275-1734 (also serves Puerto Rico)	GArden 5-3483
GEORGIA	• Atlanta... 467 Armour Circle, N.E., Atlanta 9...TWX: 404-527-1029	873-5708
		Huntsville, Alabama Area: WX2000
HAWAII	• Kentron Hawaii, Ltd., 1140 Waimanu Street, Honolulu 14...Telex: MHU 0093	Phone: 53975
ILLINOIS	• Chicago... 400 Higgins Road, Park Ridge...TWX: 312-823-3639	TAlcott 5-6666
INDIANA	Indianapolis... 3937 North Keystone Avenue, Indianapolis 5...TWX: 317-634-0156	LIberty 6-2408, 6-2409
KANSAS	Kansas City... 5920 Nall, Mission...TWX: 913-552-7309	HEdrick 2-1003
		St. Louis Area: ENterprise 6510
MARYLAND	• Baltimore... 724 York Road, Towson 4...TWX: 301-828-7054	VAlley 5-9000
MASSACHUSETTS	• Boston... 442 Marrett Road, Lexington 73...TWX: 617-862-2249	VOlunteer 2-7570
MICHIGAN	• Detroit... 27310 Southfield Road, Lathrup Village...TWX: 313-357-4618	ELgin 7-0040
MINNESOTA	Minneapolis... 3307 Vera Cruz Ave. North, Suite 102, Minneapolis 22...TWX: 612-292-4133	533-2727
NEW MEXICO	• Albuquerque... 509 San Mateo Blvd., N.E., Albuquerque...TWX: 505-243-8433	268-3373
		Southern New Mexico Area: Enterprise 678
NEW YORK	Buffalo... 961 Maryvale Drive, Buffalo 25...TWX: 716-770-1565	NF 3-7861
	• Endicott... 3214 Watson Blvd., Endwell...TWX: 607-262-0277	PIoneer 8-8291
	• Poughkeepsie... 8 Raymond Ave., Poughkeepsie...TWX: 914-452-7738	GRover 1-3620
	• Syracuse... East Molloy Road & Pickard Drive, P.O. Box 155, Syracuse 11 TWX: 315-477-1195	GLenview 4-2426
New York City Area	• *New York City and Long Island*... 840 Willis Avenue, Albertson, L. I. TWX: 516-248-9249	PIoneer 7-4830
	• *Northern N. J.* ... 400 Chestnut Street, Union, New Jersey...TWX: 201-687-6177	MUrdock 8-2222
	Westchester County, Western Conn., Hudson River Valley...144 Morgan Street, Stamford, Connecticut TWX: 203-327-9538	DAvis 5-3817
NORTH CAROLINA	• Greensboro... 1838 Banking Street, Greensboro...TWX: 919-292-1064	274-4647
OHIO	Cleveland... 1503 Brookpark Road, Cleveland 9...TWX: 216-749-6426	FLorida 1-8414
	Dayton... 3601 South Dixie Drive, Dayton 39...TWX: 513-944-0448	AXminster 3-4175
OREGON	• Portland... 4020 S.W. 114th Avenue, Beaverton...TWX: 503-291-6805	MItchell 4-9169
PENNSYLVANIA	• Philadelphia... 126 Presidential Blvd. North, Bala-Cynwyd...TWX: 215-667-3935	TEnnyson 9-3111
	Pittsburgh...3834 Northern Pike, Monroeville...TWX: 412-372-4620	ELectric 1-3345
TEXAS	• Dallas... 6211 Denton Drive, P.O. Box 35726, Dallas 35...TWX: 214-899-8364	FLeetwood 7-9128
	Houston... 2605 Westgrove Lane, Houston 27...TWX: 713-571-2291	MOhawk 7-8301, 7-8302
WASHINGTON	Seattle... 236 S.W. 153rd St., Seattle 66...TWX: 206-998-0618	CHerry 3-2494
WASHINGTON, D.C.	• Washington, D.C. ... 4205 Evergreen Lane, Annandale, Virginia...TWX: 703-256-8902	256-6700
		Norfolk, Portsmouth, and Hampton, Virginia Area: Enterprise 741

TEKTRONIX CANADA LTD.

QUEBEC	Montreal... 3285 Cavendish Blvd., Suite 160, Montreal 28...Telex: 01-2867	HUnter 9-9707
ONTARIO	• Toronto... 4A Finch Ave. West, Willowdale...Telex: 02-2776	Toronto, 225-1138

• ALSO REPAIR CENTER

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 16 PRINTED IN U.S.A OCTOBER 1962

OSCILLOSCOPE PHOTOGRAPHY AND FILM STORAGE

It's smart business to check the expiration date of the film you are using when you engage in oscilloscope photography. Those who attempt to photograph waveform phenomena that tax the writing rate of the oscilloscope and, or, the film should give an attentive ear to this advice. All film, packet or individual roll, carries a definite date stamped on the box. For best results, film should be used before this date.

Also, all sensitized photographic materials are perishable and can sustain damage if not properly stored. The following information appeared originally in the "POLAROID POINTERS", a pamphlet published by the Customers Service department of the Polaroid Corporation. It should be helpful to those who attempt to keep a supply of film on hand.

Storage and the Effects of Temperature: Excellent pictures can be obtained over a wide temperature range. From near freezing to 100° F, the camera and rolls give good results. However, since all sensitized photographic materials are perishable and can be damaged by high temperature and high relative humidity, care should be taken to handle and store the film as recommended below, with as much protection as possible against heat and moisture and away from X-rays, radioactive materials, and chemical fumes.

Protection Before Using: The wrappers in which all Polaroid Land* picture rolls are packaged will provide ample protection to withstand, through the expiration date printed on the box, normal handling in the humidities encountered in most places in the U.S.A. This wrapper does not provide protection against heat and therefore Polaroid Land picture rolls (and any sensitized photographic material, for that matter) should not be stored or left near radiators, hot pipes or other unventilated areas where the temperature may climb. The glove compartment, trunk and back deck of automobiles may reach very high temperatures (in excess of 200°F) in the hot sun. Excessive heat may damage the film, resulting in fogged (or flat and gray) pictures or a collection of developing reagent on the positive print.

If you are in the habit of keeping a number of picture rolls on hand during the summer heat or in tropical areas, it is good practice to store your picture rolls (unopened) in the refrigerator. Wherever possible, store the film under these conditions:

For Storage Up to—	Keep Temperature Below—
2 months	70°F
6 months	55°F
9 months	50°F

Generally speaking, there is no low temperature limit for storing Polaroid Land film, and this means that it can be frozen (or stored in a deepfreeze) for long periods of time. However, before using film that has been stored below 60°F, it must be brought back to room temperature before opening the foil wrapper.

If the foil wrapper on a tray of 4x5 packets has been broken, and only a few packets are to be stored under refrigeration, wrap the packets in a good brand of aluminum foil—a sandwich-type wrapping with the ends firmly closed.

Protection After Opening: Once the moisture-vapor-barrier wrapper is opened, the picture roll loses its protection against moisture. Under humid or high temperature conditions, use the roll as soon as practicable and do not allow the roll to remain in the camera longer than necessary. Protect your loaded camera and picture rolls from direct sunlight as the temperature inside the camera or the carrying case may rise extremely high even when the weather is temperate. On long trips through high temperature regions an insulated container will provide protection to your film.

All type 4x5 film packets can be damaged by exposure to humidity over 75% R.H. at 75°F or above. To provide protection, each box of 12 packets includes a polyethylene bag. After removing the foil wrap from the box, the tray of packets should be immediately inserted in the bag and the end of the bag folded over several times to seal out moisture. When humidity is high, packets should be developed within 15 minutes after removing them from the polyethylene bag.

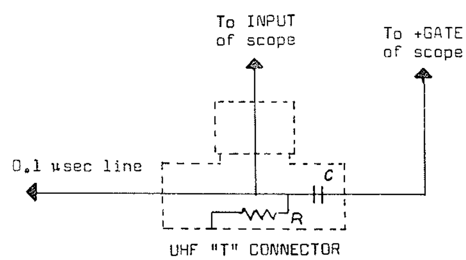
Once the protective wrapper is removed, care should be taken to keep the film away from formaldehyde, industrial gases, motor exhausts, solvents, mercury and radiation in any form.

*Polaroid is a registered trade-mark of the Polaroid Corporation

LOCATING TROUBLE IN TV COAXIAL CABLES

John Unruh, Jr., Tektronix Field Engineer with our Orange, California Field Office, calls on a company which uses a Tektronix Type 317 Oscilloscope to locate trouble in a coaxial cable system. This company picks up a TV signal on a nearby mountain top and relays it into subscribers' homes via this coaxial-cable system. Occasionaly a trouble such as an open circuit, short circuit or connectors with water in them will develop. When this happens they can, with the aid of the Type 317, determine within a few feet (and sometimes precisely) the area of the cable within which the trouble lies. This customer happens to use a Type 317. However, any Tektronix oscilloscope with a passband of 10 mc (or better) will also accomplish this purpose. In fact, the faster the risetime of the oscilloscope the more precisely you can pinpoint the difficulty.

For this application, you connect the + GATE of the oscilloscope to the INPUT through a differentiating circuit (see Figure 1). An UHF "T" connector makes a convenient housing for this circuit. The other



C = is selected for best pulse shape

R = is as close to the Z of the cable as possible

Figure 1

end of the "T" connector you connect to a cable with a predetermined delay time (John's customer uses a length of cable with a 0.1 microsec delay time). With this hook-up, by free running the oscilloscope sweep, you produce a pulse on the crt screen. When the cable you wish to check is connected to the 0.1 microsec cable, any irregularities are immediately visible on the screen. Should the cable be open, then a positive reflection will show on the screen sometime after the initial pulse. A short in the cable will show as a negative reflection. Connectors used to couple sections of cables together will appear as a small "bump" similar to a termination bump. Any connectors making a poor connection or ones with water in them will also appear as a bump but will show considerable more + or — amplitude than those produced by normal connectors.

To determine the distance to the defective portion of the cable, you merely determine the time between the initial pulse and the reflected pulse, being sure to measure in microseconds from the start of the rise of each pulse. From this total-time-between-pulses, subtract the 0.1 microsec of the small length of cable used to connect the output of the "T" connector to the cable under test. Multiply the remainder by the multiplying factor for the type of cable under test and you have the distance to the fault in feet.

John's customer uses the following chart:

CABLE TYPE	PROPAGATION FACTOR	MULTIPLYING FACTOR
Solid Poly	.66	325
Foam Poly	.82	404
½" Styro	.89	439
¾" Styro	.90	443

The multiplying factor of a given cable is determined by multiplying the figure for the speed of light (983.5 ft. per μsec) down one foot of the cable by the propagation factor of the cable and dividing by two since the pulse must travel twice the distance to the fault before showing up as an echo. John says that according to his figures the multiplying figure for solid poly should be closer to 320. However, his customer has been using this chart for sometime and hasn't been too far off yet.

When the cable under test is less than 30 or 40 feet, then an additional hundred feet should be inserted. Otherwise, the reflection returns so fast it rides on the top of the initial pulse.

This method is currently being used on cables with lengths up to 2,000 feet. Reportedly, it may be used on lengths upwards of a mile provided the cable is of a low loss type.

THAT OLD BUGABOO "CATHODE INTERFACE"

Tektronix Canada, Ltd. Field Engineer Gordon Dickson (Montreal) called on a customer to find him struggling with the transient response of a Type 545 Oscilloscope. The customer stated that he had spent two days in sporadic attempts to bring the vertical response of the instrument within specifications. He claimed that each time he endeavored to touch up the high frequency peaking and the delay line, the transient response showed a change from the last time he had worked on it.

Immediately suspecting the cause of the difficulty, Gordon connected the instrument to its power source through a variable-voltage transformer. A quick check confirmed his suspicions. The customer had been battling a condition that no amount of tweaking and adjusting would overcome—cathode interface. Cathode interface is a condition that can develop in the vertical-amplifier tubes of any oscilloscope—some tubes being more offensive than others. It will cause degeneration of all but high frequency signal components . . . leaving an overshoot on the leading edge of fast-rise (0.2 μsec or less) squarewaves.

At Gordon's suggestion, the customer replaced the offending tubes and then easily recalibrated the vertical amplifier to bring transient response of the instrument within specifications.

In the August 1960 issue of SERVICE SCOPE we published an article that dealt at some length on this problem of cathode interface. Those who maintain a back-issue file of SERVICE SCOPE may wish to review that article. The title—*"Does The Square Wave Response of Your Scope Look Like This."*

If you do not maintain a back-issue file of SERVICE SCOPE you can obtain a copy of the August 1960 issue by contacting your Tektronix Field Engineer or local Field office.

OSCILLOSCOPE LITERATURE RACK

A DO-IT-YOURSELF PROJECT

This idea for a literature-holding rack (see Figure 1 and 2) comes to us from one of our readers, Anthony J. Kalilich of the NASA in Cleveland, Ohio. Tony uses this rack to hold manuals for easy, ready reference during instrument calibration. He and other engineers at NASA also use it to hold their reference data during various tests. Having this material off the bench but still handily available, tends to minimize the time spent searching under papers and manuals for tools or components. This in turn contributes to a more efficient utilization of the engineer or technician's time.

Fabrication of the rack requires only about 15 minutes of time and most laboratories or maintenance facilities will contain the necessary materials. Suggested materials are two 10/32 female banana jacks and two 30" lengths of buss wire or copper-clad welding rod. The diameter of the buss wire or welding rod should be such that it will fit into the female end of the banana jacks. About ¾" from one end of each wire or rod length make a 90° bend. Insert the end of the ¾" section into a banana jack and solder it to the jack. Now insert the two banana jacks into the two top graticule stud bolts of your Tektronix (5"crt) oscilloscope and bend the wire or rod as shown in Figure 1. Solder the two wires or rods together at the two points where they cross. The degree of the angle thus formed by each wire or rod is not critical. However, for appearances sake they should match. If you solder the wires or rods together so that the distance between the two points of the two V's is approximately 18½", the rack will accommodate an opened Tektronix instrument manual as shown in Figure 2.

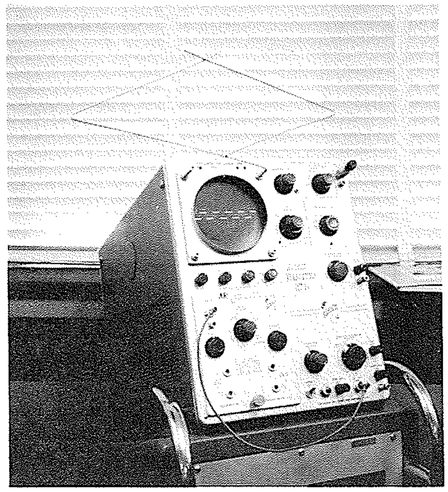


Figure 1

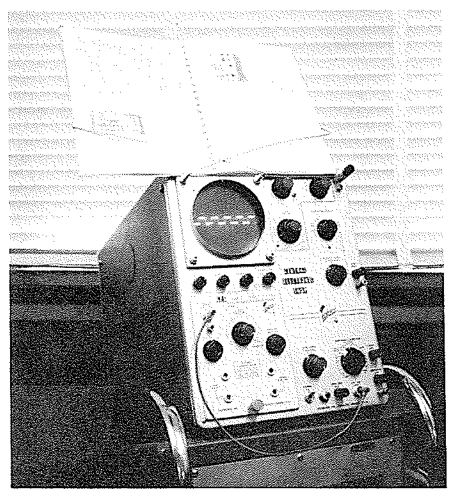


Figure 2

That's all there is to it . We thought it was quite simple and with only the pictures as a guide.

USED INSTRUMENTS FOR SALE

Type 524D Oscilloscope, s/n 179. Asking $500. Gene Phelps, KPTV, 735 S.W. 20th Place, Portland, Oregon. Phone: CApitol 2-9921.

Type 310A Oscilloscope, s/n 7142. Price $575. Dr. Leonard Rose, 2311 N.W. Northrup Street, Portland 10, Oregon.

Type 310 Oscilloscope, s/n 3350. Mr. La Douceur, American Motor Corp., 14250 Plymouth Road, Detroit 32, Michigan.

Type CA Plug-In Unit. Deictron Electronics Corp., 850 Shepherd Avenue, Brooklyn 8, New York. Phone: NI 9-8110.

Type 105 Square Wave Generator, s/n 5875. Price: $325. Type 110 Pulse Generator and Trigger Takeoff, s/n 600. Price: $525. Type 113 Delay Cable, s/n 294. Price: $150. Type N Plug-In Unit, s/n 683. Price: $475. Bernard H. Shuman, General Manager, Morris Cooper Corp., 3832 Terrace Street, Philadelphia 28, Pa.

Type 122 Preamplifier, s/n 3289. Colonel Hoxie, Lind Instruments, 2294 Mora Drive, Mountain View, California. Phone: 968-0083.

Type 180 Time-Mark Generator, s/n 207. Landy Garman, National Aeronautical Corp., Commerce Drive, Fort Washington, Pennsylvania. Phone: MI 6-2900, xtn. 41.

Type 517A Oscilloscope, s/n 622. Sam Cooper, Rutherford Electronics, 8944 Lindblade Avenue, Culver City, California. Phone: UP 0-7393.

Type 551 Oscilloscope, s/n 369. Type 535 Oscilloscope, s/n 1173. Type 53C Plug-In Unit, s/n 1143. Engineering Dept., Richard D. Brew & Co., 90 Airport Road, Concord, New Hampshire.

Type 533 Oscilloscope, s/n 515. Price: $775. Type 53/54E Plug-In Unit, s/n 2090. Price: $125.
Type 53/54C Plug-In Unit, s/n 20261. Price: $175. Type RM181 Time-Mark Generator, s/n 1034. Has a crystal oven. Price: $195. Type 500A Scope-mobile. Price: $70. Cradle Mount for rack mounting a Type 533 scope. Price: $20. Miscellaneous small accessories including probes, connectors, and other small items will be included with the appropriate units. Joseph M. Edelman, M. D., 4550 North Boulevard, 204 Medical Center, Baton Rouge 6, Louisiana.

1 Type 517 Oscilloscope, s/n 161. Price: $1500. Needs work. Armond Piscopo, 1546 Slater Street, Toledo 12, Ohio.

USED INSTRUMENTS WANTED

1 Type 124 Television Adapter. Purchasing Agent, Owen-Illinois Technical Center, 1700 N. Westwood, Toledo, Ohio.

1 Type 575 Transistor Curve Tracer. L. Bachhuber, Appleton Mills Co., 614 S. Oneida Street, Appleton, Wisconsin. Phone: REgent 4-9876.

2 Type 535 or Type 545 Oscilloscopes. J. R. Halchak, E. G. & G., Inc., 160 Brookline Ave., Boston 15, Mass.

1 Type 531 and 1 Type 533 Oscilloscopes. Harry Applebay, 902 West Pedragosa, Santa Barbara, Calif.

1 Type 310 or 310A Oscilloscope. Steve Karapti, National Aeronautical Corp., Commerce Drive, Fort Washington, Penn.

1 Type 541 Oscilloscope and 1 Type CA Plug-In. Joe Gaon, 64-50 229th Street, Bayside, N. Y.

1 Type 531A, Type 533A, Type 541A or Type 543A Oscilloscope. A. R. Shelby, President, Production Electronics, Inc., 525 Lehigh Avenue, Union, New Jersey.

1 Type 515A Oscilloscope. John Harshbarger, Systems Research Laboratories, Inc., 500 Woods Drive, Dayton 32, Ohio. Phone: CH 4-4051.

1 Type 531A Oscilloscope with a Plug-In Preamplifier (Type CA preferred). 1 Type 516 Oscilloscope. 1 Type 524AD Oscilloscope. Charles Hanavich, 712 Grandview Drive, Alexandria, Virginia.

MISSING INSTRUMENTS

Our Long Island Field Office advises us that a Type 533 Oscilloscope, serial number 1202, and a Type CA Plug-In Unit (serial number not available) are missing from the Alternating Gradient Synchrotron at Brookhaven National Laboratory, Upton, New York. These instruments are the property of the United States Government and unauthorized possession of them is a federal offense. Officials consider this a serious matter and the Federal Bureau of Investigation has been called in on the case.

Persons with information on the above instrument should contact Mr. Herb Lutz at the Brookhaven National Laboratory. Telephone number is: area code 516, number 924-6262, extension 2193. Or, you may contact the nearest Federal Bureau of Investigation office.

Mr. Sternberg, with the Department of Entomology at the University of Illinois in Urbana, Illinois, reports that his Type 502 Oscilloscope, serial number 901, disappeared on August 6, 1962. This instrument was not in working condition. Suspected trouble was a crt or high voltage problem. All instrument repair centers and technicians are asked to be on the alert should a Type 502 with these symptoms of trouble be presented for repair.

Mr. Sternberg would appreciate hearing from persons with information regarding this instrument. They may contact him at the address given above.

The Deer Valley Park plant of General Electric Company asks that our readers keep an eye out for a Type 535A Oscilloscope, serial number 27884 and two Type CA Plug-In Units, serial numbers 41577 and 45244. These instruments have disappeared from this facility and they would like very much to recover them. Direct any information you may have on the whereabouts of these instruments to the General Electric Company, 13430 North Black Canyon Highway, Phoenix, Arizona. Attention: C. H. Worlock, Mgr., Product Service Administration.

NEW FIELD MODIFICATION KITS

TYPE 180 TIME-MARK GENERATOR CRYSTAL OVEN MOD KIT—For Type 180 instruments with serial number 951 to 5000 inclusive.

This modification installs a temperature-stabilized crystal oven in the Type 180. Frequency-stability characteristics will be improved to three (3) part per million over a 24 hour period. Time required for installation is approximately one and one-half hours*.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-285. Price: $49.50.

A previously announced Crystal Oven Mod Kit installs a temperature stabilized crystal oven in Type 180 Time-Mark Generators with serial numbers below 951. For this modification order Tektronix part number 040-252. Price: $50.75.

TYPE 532 AND TYPE RM32 OSCILLOSCOPES CHOPPED-TRANSIENT BLANKING MOD KIT. All serial numbers.

Installation of this modification adds blanking to the crt cathode to eliminate switching transients when using the Type 53/54C, 53C, CA, or M Plug-In Units in the CHOPPED Mode. Time required for installation is approximately two and one-half hours*.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-283. Price: $70.00.

TYPE 517 AND TYPE 517A THERMAL PROTECTION MOD KIT—For serial numbers 101 through 1739.

When installed, this modification provides thermal cutouts for both the Indicator and Power Supply units. In instruments wired for normal line voltages (i.e. 105 to 125 v), should the chassis temperature reach approximately 137° F, the cutout will turn the affected unit off. The fan will continue to operate as an aid to cooling the unit to a safe operating temperature. In those instruments wired for 210 to 250 v line voltages, the cutouts will operate in the same manner with one exception—the fan will not operate during the cooling off period. Time required for installation is approximately two and one-half hours*.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-291. Price: $58.00.

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

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USEFUL INFORMATION FOR
USERS OF TEKTRONIX INSTRUMENTS

CRT SCREW ALIGNMENT MOD KIT

This modification provides a more satisfactory means for adjusting the crt alignment. A new bracket, with rotator and clamp assembly, replaces the old support bracket and clamp assembly at the base of the crt. This new assembly features a finger-operated screw adjustment for easy and precise rotation of the crt. Another feature is an adjustment to minimize parallax between the phosphor surface and the graticule. Time required for installation is approximately 30 minutes*.

Order through your Tektronix Field Engineer or Field Office. Specify for the following instruments Tektronix part number 040-292. Price: $4.75.

SCOPE TYPE	SERIAL NUMBER
531/531A	5001-20409
532	5001-6519
533	101-1469
535/535A	5001-21349
536	101-1089
541/541A	5001-20469
543	101-1249
545/545A	5001-22059

For these following instruments, specify Tektronix part number 040-293. Price: $4.75.

SCOPE TYPE	SERIAL NUMBER
RM31/RM31A	101-1059
RM32	101-330
RM33	101-139
RM35/RM35A	101-1229
RM41/RM41A	101-1029
RM43	101-111
RM45/RM45A	101-1199

TYPE 127 SILICON RECTIFIER MOD KIT—For Type 127 Preamplifier Power Supplies.

This modification replaces the selenium rectifiers used in the Type 127 with silicon diodes. Silicon diodes offer greater reliability and longer life. Time required for installation is approximately one and one-half hours*.

Two kits, each restricted to a certain serial number range, are offered. In ordering, care must be exercised to be sure that you order the kit for the serial-number range in which your instrument's serial number falls.

Order through your Tektronix Field Engineer or Field Office. For instruments with serial numbers 101 through 358, specify Tektronix part number 040-217. Price: $29.50. For instruments with serial numbers 359 and up, specify Tektronix part number 040-282. Price: $34.00.

*Quoted installation times are for first-time installations by a trained technician familiar with Tektronix instruments.

DON'T LET THIS HAPPEN TO YOU

One of the prime purposes of the Tektronix Field Office and its Field Engineers is to help customers select the instruments best suited to their present and future needs. To prepare himself for this task, the Field Engineer spends at least six months in training—at the factory—and returns periodically for further training and indoctrination on new instruments.

The following incident illustrates what can happen when a customer, not completely familiar with Tektronix instruments, places an order without availing himself of a Tektronix Field Engineer's counsel and advice.

A certain company makes solenoid-operated, fast-response valves for a special application. These valves must open or close within several milliseconds of the application of current to the solenoid.

One of this company's customers suggested that this response time can be measured with a Tektronix Type 551 Dual-Beam, Dual-Plug-In Oscilloscope. The company ordered one, regrettably not through the Tektronix Field Office that should serve them.

When the instrument was delivered, they found that they did not have an end-use instrument—they had not ordered Plug-Ins.

Duncan Doane, of our Encino, California Field Office, was the Tektronix Field Engineer finally called on for help. When he determined the company's actual application, he informed them that a less sophisticated oscilloscope could do the job for them and at a considerable savings. He offered to take back the Type 551 and replace it with a less expensive oscilloscope.

Possibly to show their appreciation for Tektronix efforts to be agreeable and fair, they declined the offer. However, they did ask Dunc if he would advise them on what they must do to make the measurement.

Here was a natural for the Tektronix Type Q Transducer and Strain Gage Plug-In Unit and Dunc so advised them. They will use a Stratham P-27 pressure transducer with it. To fill in the other vertical plug-in compartment of the Type 551, Dunc suggested a Type A Plug-In unit to monitor the current build up through the solenoid. They will use the drop-in-potential method across a series resistor.

Remember, your Tektronix Field Engineer can be your best source of help—before, during, and after delivery of your Tektronix instruments.

SERVICE HINTS

VERTICAL DRIFT IN TYPE 503 OSCILLOSCOPES

The flange-mounted electrolytic capacitors C652 and C654 affect the output voltage of the —12, +100 and +250 volt supplies in the Type 503. These supplies are only indirectly regulated. In cases of vertical drift, not attributable to tubes, try cinching down the flange-mounting screws of these capacitors.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 17 PRINTED IN U.S.A. DECEMBER 1962

NEW TRIGGER-CIRCUIT ADJUSTMENT METHOD

By Paul Thompson
Tektronix Field Training Department

We present here a new method of adjusting the trigger circuits in the Tektronix Type 530/540 and Type 530A/540A Series Oscilloscopes having a PRESET position for the STABILITY control. It is fast, simple and accurate and requires a minimum of equipment (a screwdriver, and one or two jumper leads). Normally it does not require any "adjust this while tweaking that for minimum this." It also provides a check on the tubes in the circuit. Try it; we think you'll become a convert.

This method also works on the Type 316, s/n's 1298 and up; Types RM16 and RS 16, s/n's 900 and up; Type 317, s/n's 900 and up; Type 516, 551, 555, all s/n's; and Type 515A, s/n's 5309 and up. It will not work on a trigger circuit which has no Trig. Sens. adjustment.

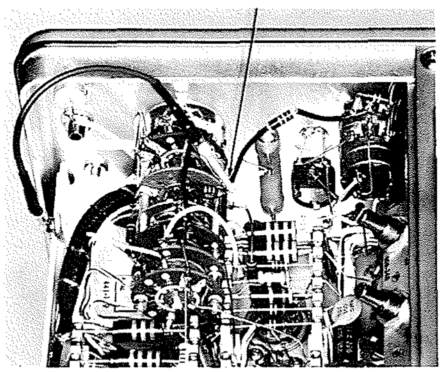
In the procedure that follows, the completely capitalized terminology refers to controls or switches located on the front panel of the instrument. Terminology with only the first letter of each word capitalized refers to adjustment controls located within the instrument.

1. Set the PRESET ADJUST by the standard method. (Set the TRIGGERING MODE to AUTO and the TIME /CM switch to .1 millisec. Set the STABILITY to the PRESET position. Set the PRESET ADJUST control halfway between the points where the trace first appears and where it brightens.) Position this trace to the vertical center of the graticule, you'll need it there later. Leave the STABILITY control in the PRESET position for the rest of this procedure.

2. Set the trigger controls to EXT., either + or —, and AC. Ground the junction of the two resistors in the time base trigger circuit as indicated in the following chart:

Oscilloscope Type	Resistors
530/540 Series	R16 and R17
530A/540A Series	R19 and R20
551	R19 and R20
555	R19 and R20
316	R426 and R427
317	R426 and R427
515A	R24 and R25
516	R20 and R21

3. Turn the TRIGGERING LEVEL control fully clockwise. You may or may not get a trace on the crt screen.



In the figure above the arrow points to the junction of the two resistors and shows the grounding jumper referred to in step 2. (Instrument: Type 533A. Resistors: R19 and R20).

4. Set the Trig. Level Centering adjustment to the center of the region which makes a trace appear on the screen. (If you can't get a trace by manipulating the Trig. Level Centering adjustment, the trigger Schmitt circuit is not working properly.)

5. Turn the TRIGGER SLOPE switch (TRIGGER SELECTOR on some instruments) between + EXT. and — EXT. and readjust the Trig. Level Centering adjustment, if necessary, to get a trace in both the + and — positions. If you can't, the trigger amplifier circuit is not operating properly (probable cause; a gassy tube).

6. Set the triggering controls to INT., either + or —, and DC. The trace will probably disappear.

7. Set the Int. Trig. DC Level adjustment to the center of the region which makes the trace appear on the screen. This region will probably be very narrow.

8. Remove the grounding strap you connected in step 2, and position the TRIGGERING LEVEL control until the trace reappears. The white spot on the knob should then be at or very near the top (opposite the "O" on the front panel). If it is not, loosen the Allen set screw in the knob and position the knob properly.

9. Turn the Trig. Sens. adjustment counterclockwise until the trace just disappears and then about 45 degrees further counterclockwise. This will provide adequate triggering capabilities for most uses and will probably put the scope within factory triggering specifications. If you want to make sure, go on to steps 10 and 11.

10. Set the triggering controls to EXT., either + or —, and AC. Set the AMPLITUDE CALIBRATOR to .2 volts and connect the CAL. OUT to the vertical INPUT. Set the VOLTS/CM switch to .1 or .05.

11. Turn the Trig. Sens. adjustment counterclockwise until the trace disappears and then clockwise just far enough to get proper triggering in both the + and — EXT. positions. If the scope won't trigger in both the + and — positions, touch up the Trig. Level Centering adjustment until it does.

Theory: In step 3, you are setting the trigger Schmitt to free run when the dc voltage on its input grid matches its inherent hysteresis level. In step 4, you are setting this hysteresis level to match the dc level of the trigger-amplifier output plate with both grids at zero volts. In step 5, you are checking the trigger-amplifier tube for gas under much more rigorous conditions than would ever be present in normal scope use (one grid to ground through 1 meg, the other grid to ground through 47 ohms). In step 7, you are setting the Int. Trig. DC Level adjustment to the point where the vertical amplifier places zero volts on the trigger-amplifier grid when the trace is centered on the screen. In step 11, you are adjusting the circuit so that it will trigger on 0.2 volt external but not on much less than that. (The hysteresis gap closes as the Schmitt tube ages; if the Trig. Sens. is set too sensitive, you may be adjusting it again next week.)

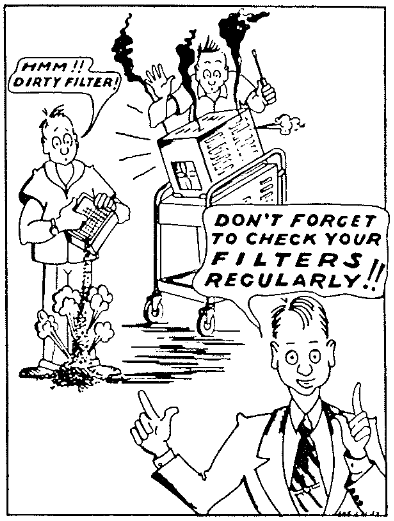
GREASE-OFF

In the August '62 issue of Service Scope we referred to an air-filter cleaning agent called "Grease-Off", a product of the Garden Products Company of Two Rivers, Wisconsin. Several customers have written to us or our Field Offices asking for a more complete address for this concern. Here it is:

Garden Products Company
3914 Monroe Street
Two Rivers, Wisconsin

According to Gordon Allison, District Manager at our West Los Angeles Field Office, the West Coast source of supply for Grease-Off is the American Geophysical and Instrument Company, 16440 South Western Avenue, Gardena, California — Phone 321-2634. Also, according to Gordon, we were misinformed as to the price of Grease-Off. Correct price is $6.85 per gallon not $3.85 per gallon as we stated.

REMINDING YOU



. . . that you should not operate your Tektronix forced-air-ventilation instruments, for extended periods, with the side panels removed. The panels contain and conduct the flow of air for maximum cooling efficiency. Damage from overheating can occur if the instrument operates for extended periods of time with the side panels removed.

. . . that to ensure an adequate flow of ventilating air, we recommend a clearance of approximately one foot (sides, top and rear) for the instrument.

. . . that instruments with dirty air filters cost you money by causing more down time, more maintenance problems, more need for replacement parts and a shorter life expectancy for the instrument.

. . . that you should clean air filters (see your instrument's instruction manual or the October '59 issue of SERVICE SCOPE) at least every 500 hours of operation—more often under difficult environmental conditions.

MORE ABOUT PIN POINTING INFORMATION ON POLAROID PRINTS

In an article in the June issue of Service Scope, we described a method for pin pointing information on Polaroid Land Camera prints. We neglected to state that the system works well only after the print's surface has dried a couple of minutes or more after development, and before the preservative coating is applied.

Quite a few of our readers called this oversight to our attention. One of them, Mr. William R. Hayes, manager of the Electrical Laboratory at Joslyn Manufacturing and Supply Company, offered an alternate method of adding notes to Polaroid prints.

Here, in Mr. Hayes' own words, is his suggestion: "—For some years now our laboratory has used a faster and simpler method of adding notes to Polaroid prints that takes advantage of the softness of the print's surface just after development. It is so soft in fact, that it is easily scratched; so we scratch out our notes. It is still soft enough to scratch for perhaps an hour after development. If the print has been coated or if it is a long time after development, the surface can be scratched easily by first wetting it with the print coater.

The success of this method however, lies in the nature of the point used to scribe the emulsion. A pin is too sharp and will dig up the surface. A sharpened pencil is too rounded. Something between these is best. Some experimentation with a whetstone and a metal point is necessary. We have made a number of scribes by pointing the head end of a 6-32 stainless screw and inserting the other end into a threaded ¼" plastic rod about 6 inches long.

These handy instruments have increased our efficiency and accuracy in data recording by immediately scribing sweep times, sensitivities, serial numbers and circuit information on the face of the oscillograms."

Tektronix Field Engineer Earl Williams with our Field Information group suggests a third method: In this method you apply Snopake to selected portions of the Polaroid print. Snopake is a fast-drying correction fluid used in Xerography work. It dries quickly to furnish a snow white surface upon which you may write the required information. Be sure that the preservative coating has been applied to the Polaroid print and allowed to dry thoroughly before using Snopake.

Snopake is readily available through your local business-stationery and office-supplies outlet.

FOR YOUR INFORMATION

Recently we sent to our Field Offices reprints of the booklet "Fundamentals of Selecting and Using Oscilloscopes." This booklet contains two articles, "Appraising Oscilloscope Specifications and Performance" and "Factors Affecting the Validity of Oscilloscope Measurements" which appeared originally in *Electrical Design News*. John Mulvey, Manager of the Field Information group in the Field Engineering Department of Tektronix, Inc., authored the articles.

"Appraising Oscilloscope Specifications and Performance" intends to clarify the significance of many of the technical terms used to describe oscilloscopes. People who, being responsible for buying or recommending such instruments, feel the need for a better understanding of the relative importance of different features will find this article informative.

"Factors Affecting the Validity of Oscilloscope Measurements," the second article in the booklet, discusses some common limitation and application pitfalls which apply to cathode-ray oscilloscopes. Some easily made performance checks are also included.

Another item of the booklet is a ready-reference chart giving the basic specifications of most Tektronix oscilloscopes.

To obtain a copy of this booklet, contact your local Tektronix Field Engineer or Field Office and ask for "Fundamentals of Selecting and Using Oscilloscopes." If you do not know your local Tektronix Field Engineer or the address of the nearest Field Office, direct your inquiries to: Editor, SERVICE SCOPE, Tektronix, Inc., P. O. Box 500, Beaverton, Oregon. We'll send you the needed names and addresses and see that you receive a copy of the booklet.

We recently received word from our Phoenix Field Office that a Type 310A Oscilloscope, s/n 10023, belonging to U. S. Semcor is missing. Mr. Porter of U. S. Semcor has asked that we request our readers to be on the lookout for this instrument. If you have any information regarding this Type 310A, please contact Mr. Porter. His address is: U. S. Semcor, 3504 West Osborn, Phoenix, Arizona.

* * *

The Physics Department of the College of William and Mary notifies us that a Type 503, s/n 000230, disappeared from the college last May and is now presumed to have been stolen.

Dr. Melvin A. Pittman, Chairman of the Department of Physics, will appreciate it if anyone with information on the whereabouts of this instrument will contact him or Mr. John H. Long, Assistant Professor, Department of Physics. Address your information to either man at the College of William and Mary, Williamsburg, Virginia.

USED INSTRUMENTS WANTED

1 Type 545 Oscilloscope and 1 Type CA Plug-In Unit. George J. Kominiak, 195 Preakness Avenue, Paterson 2, New Jersey.

* * *

1 Type 502 Oscilloscope. Ken MacIntosh, Lectour, Inc., 4912 Cordell Avenue, Bethesda 14, Maryland. Telephone OLiver 2-4477.

* * *

USED INSTRUMENTS FOR SALE

1 Type 511 Oscilloscope (s/n not given). J. Greenspan, Process and Instruments Corporation, 15 Stone Avenue, Brooklyn 33, New York.

* * *

For sale or trade 1 Type 105 Square-Wave Generator, s/n 4348. Would consider trade for good Frequency Meter to cover Marine to Business Radio Band. Dan J. Mooney, Communications Equipment Company, P.O. Box 35, Handsboro, Mississippi.

* * *

1 Type 503 Oscilloscope, s/n not given but instrument is less than one year old and in "mint condition." Asking $540.00. Bernie Markam, Cabinart Inc., 35 Geyser Street, Haledon, New Jersey.

* * *

1 Type 105 Square Wave Generator, s/n 2970, Autoelectronics, Inc., Attention: Allan Sicks, 6207 Braemore Road, Indianapolis 20, Indiana. Telephone CL 3-6100.

* * *

1 Type 541 Oscilloscope, s/n not given. Al Browdy, KCOP TV, 915 La Brea, Los Angeles 38, California. Telephone OL 6-6050, Ext. 305.

* * *

1 Type 517 Oscilloscope, s/n not given. Mr. Osborne, 153-13 Northern Boulevard, Flushing, New York.

* * *

1 Type 502, MOD 407 Oscilloscope, s/n 5531, complete with accessories and polarized viewer. Instrument has been used less than six months. Asking $825.00. Bob Briggs, Geosonic, Inc., Box 22166, Houston 27, Texas. Telephone: Sunset 2-2250.

* * *

2 Type 581 Oscilloscopes, s/n's 163 and 167. 2 Type 80 Plug-In Preamplifiers, s/n's not given. 1 Type 517A, s/n 1680, with a Type 500A Scopemobile. John Ivimey, 595 5th Avenue, New York 17, New York. Telephone: PLaza 2-1144.

* * *

1 Type 515A Oscilloscope, s/n 3979. Webster Enterprises, 795 Marin Drive, Mill Valley, California.

* * *

1 Type 512 Oscilloscope, s/n 3317. Ken Goodman, Chief Engineer, Engineered Electronics, P. O. Box 659, Santa Ana, California.

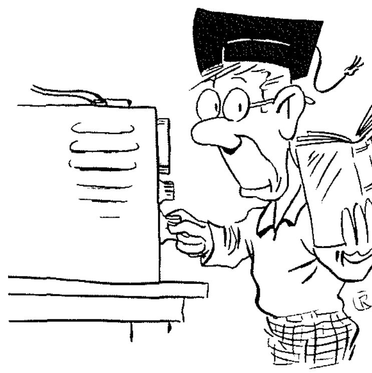
* * *

1 Type 561 Oscilloscope, s/n 646; 1 Type 72 Dual-Trace Amplifier, s/n 409; 1 Type 67 Time-Base Unit, s/n 719, and 1 Type 201 Scopemobile. Henry Petheridge, Electronics, Inc., 2440 Maryland Avenue, Willow Grove Industrial Park, Willow Grove, Penna. Telephone: OL 9-6666.

* * *

1 Type 72 Dual-Trace Plug-In Amplifier (no serial number given). Price: $200.00. Dr. Dick Tuttle, Masonic Research Laboratory, Utica, New York. Telephone: RE 5-2217.

"TYPICAL OSCILLOSCOPE CIRCUITRY"



". . . Manipulation of the front panel controls of an oscilloscope can be learned by rote. To use the instrument to its fullest capabilities a knowledge of oscilloscope circuitry is essential . . ." These words help to introduce the reader to a new book, "Typical Oscilloscope Circuitry," published by Tektronix Incorporated.

"The purpose of this book," as the preface explains, "is to provide a basic understanding of the functioning of those fundamental circuits that appear most often in Tektronix instruments. It is aimed at the man who maintains and calibrates instruments. But a knowledge of the information that is in this book will also help the instrument user to appreciate the characteristics, performance and limitations of his instrument. . . The treatment throughout is essentially nonmathematical. Some of the most elementary ideas of algebra and trigonometry (sine waves) are used. A few calculus symbols appear but these are applied only graphically and no knowledge of calculus operation is needed. The purpose of using these calculus symbols is one of brevity. . ."

We think you will find that the order of subject presentation plus the clear, concise wording of the subject explanations accomplishes the stated purpose of this book and with a minimum of confusion for the reader.

Price of the book is $5.00. Copies may be ordered through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 070-253.

SERVICE HINTS

SERVICING HIGH-VOLTAGE POWER SUPPLIES

Ron Bell, Tektronix Field Engineer with our Pittsburgh Field Office, uses this trick quite frequently when trouble-shooting the high-voltage power supply of Tektronix oscilloscopes: He removes the cover from the high-voltage supply and inspects the filaments of the type 5642 tubes. Should he find the filaments of one tube glowing brighter than the others, he replaces that tube on suspicion.

The type 5642 tube has a direct heated cathode. The filament or heater wires are coated with an emitting material and this material acts as the cathode for the tube. Over a period of time sublimation of this material takes place and the cathode emits fewer and fewer electrons, finally reaching a point where electron emission is too low for the tube to function properly. This low emission is one of most common causes of faulty performance in these high voltage power supplies.

Ron claims that it takes only a few minutes to whip off the cover and replace a faulty tube and it can save hours of frustration in trying to trouble-shoot with a meter.

Other difficulties can develop in the power supply that will cause the filaments of one or more of the 5642 tubes to glow unnaturally. A replaced 5642 tube whose filaments continue to glow too brightly indicates the need for a more thorough investigation of the high voltage supply. Also, reoccurrence of unnatural filament brightness in replaced 5642's after only a relatively short period of operation (50 to 100 hours) suggests the need for this more comprehensive investigation.

TYPE 60 AMPLIFIER—INSTRUCTION MANUAL CORRECTION

Starting with serial number 432, the Type 60 Plug-In was modified to operate V434 and V444 from the regulated dc-filament supply, and to delete HUM BALANCE control R493.

Information concerning the modification was inadvertently omitted from the Type 60 Instruction Manual until serial number 480, when the omission was discovered and the manual corrected.

Owners of Type 60 Plug-In above serial number 432 whose manuals do not agree with the instruments circuitry may order updated schematics. Tektronix number for the schematic is 061-374. Order through your nearest Tektronix Field Office or overseas representative. There is no charge for one or two copies.

TYPE 502MOD104 OSCILLOSCOPE—INCREASING NEON LIFE

You can extend the life expectancy of the "READY" neon in this instrument by removing the strap, located between the neon and ground on the SINGLE SWEEP toggle switch, and installing a 27 k, ½ watt, 10% resistor mounted between the neon and the detent plate of the TRIGGER SELECTOR switch.

TYPE 504 AND TYPE RM504 OSCILLOSCOPE—DECREASING TUBE SELECTION

You can decrease the necessity of tube selection for V24 in these instruments by making the following changes:

(1). Remove R26, a 100 k ½ watt, 10% resistor and replace it with a 120 k, ½ watt, 1% precision resistor.

(2). Remove R28, a 33 k, 1 watt, 10% resistor and replace it with a 33 k, 1 watt, 1% precision resistor.

This modification applies to Type 504 instruments with serial numbers below 530 and Type RM504 instruments with serial numbers below 550. Instruments with higher serial numbers have this modification incorporated at the factory.

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

USERS OF TEKTRONIX INSTRUMENTS
USEFUL INFORMATION FOR
Service Scope

QUESTIONS FROM THE FIELD

Q. I've had some trouble with a Type 507 arcing at the crt anode connector. How can I correct this?

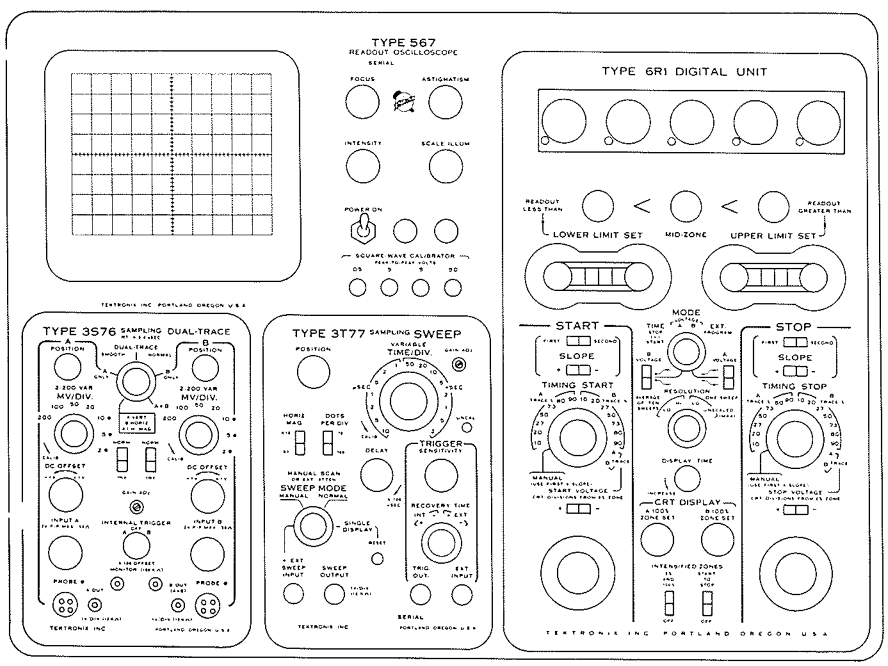
A. Sometimes a conductive coating on the crt glass and anode button will cause the arcing you describe. Try scrubbing the anode button and surrounding glass area with alcohol or acetone. Check the length of the anode brush and trim the brush if it bows. Twist the brush to prevent loose strands.

In rare cases the crt may be rotated far enough for arcing to occur between button and shield. We've been able to cure this problem with Corona Dope (General Cement No. 47-2 or equivalent). Apply the dope to the inside of the shield. Paint a band about 1.5 inches wide overlapping the seam between the light cap and the crt shield. Apply two coats.

Q. When viewing 1-μsec time markers from the output of the Type 181 Time-Mark Generator, while triggering the scope externally with 100-μsec markers from the front panel binding post of the Type 181, we have a spurious pulse of less intensity than the main pulse. How can we get rid of this spurious pulse?

A. The pulse is actually very regular, but appears spurious when the sweep is triggered at a repetition rate higher than 1 kc. Every 10th 100-μsec pulse is loaded by the 1-msec multi, which shifts the time position of every 10th 100-μsec mark slightly with respect to the others. When an occasional sweep is started by the "spurious" 100-μsec marker, faster pulses will be out of relationship with the majority and will appear to be spurious. The condition is normal in the Type 181, but can be improved by putting a 12 pf capacitor across R170, a 22 k, ½ w, 10% comp. resistor.

TYPE 567 TEST SET-UP CHART



DATA: This is a Type 567 Test Set-Up Chart. It provides a ready means of recording instrument control settings for any given test or production set up. A facsimile of the trace resulting from the set up can be drawn on the chart graticule or a picture of the waveform attached to the chart. In the "DATA" space, where this message to you is printed, special instructions or pertinent information concerning the test or production set up can be recorded.

Besides the Type 567 Digital Readout Oscilloscope, Test Set-Up Charts are also available for the following instruments: Type 502, Type 503, Type 545A (with CA, R, or Z Plug-In Units), Type 570 and Type 575 Oscilloscopes.

Your Tektronix Field Engineer will be glad to give you more detailed information on these Test Set-Up Charts. Why not call him right now?

TEK 001-826D — TEKTRONIX, INC.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 18 FEBRUARY 1963

PRINTED IN U.S.A

INTRODUCTION TO OPERATIONAL AMPLIFIERS

Prepared by
Tektronix Field Information Department

Part 1.

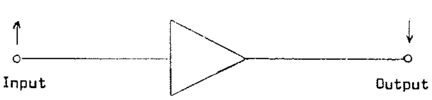
Functionally speaking, an operational amplifier is a device which, by means of negative feedback, is capable of processing a signal with a high degree of accuracy limited primarily only by the tolerances in the values of the passive elements used in the input and feedback networks.

Electronically, an operational amplifier is simply a high-gain amplifier designed to remain stable with large amounts of negative feedback from output to input.

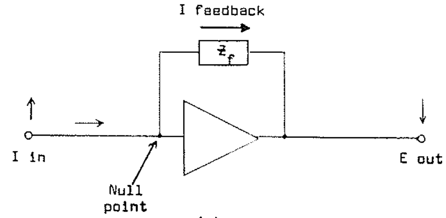
General-purpose operational amplifiers, useful for linear amplifications with precise values of gain, and for accurate integration and differentiation operations, have low output impedance and are DC-coupled, with the output DC level at ground potential.

The primary functions of the operational amplifier are achieved by means of negative feedback from the output to the input. This requires that the output be inverted (180° out of phase) with respect to the input. The conventional symbol for the operational amplifier is the triangle shown in Figure 1-a. The output is the apex of the triangle; the input is the side opposite the output. Negative feedback, through a resistor, capacitor, inductor, network or nonlinear impedance, designated "Z_f" is applied from the output to the input as shown in Figure 1-b. The input to which negative feedback is applied is generally termed "-input"* or "grid" (in the case of vacuum-tube operational amplifiers).

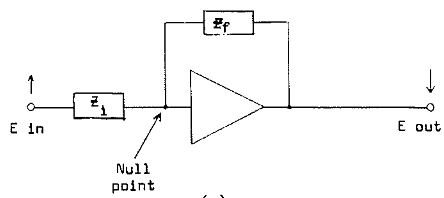
* The operational amplifiers of the Tektronix Type O Operational Amplifier also provide access to a non-inverting input. Uses of this "+input" or "+grid" are discussed later.



(a)



(b)



(c)

Figure 1. Conventional Operational Amplifier Symbols.

(a) The input is to the base of the triangular symbol, the output is from the apex opposite. The —input and output are out-of-phase (arrows).

(b) Feedback element Z_f provides the negaative feedback to permit high-accuracy operations. The amplifier seeks a null at the input by providing feedback current through Z_f equal and opposite to the input current I_{in}. Output voltage is whatever is necessary to provide required balancing current through Z_f.

(c) Input element Z_i converts a voltage signal (E_{in}) to current, which is balanced by current through Z_f.

Operational Amplifier Seeks Voltage Null at —Input

An operational amplifier, using negative feedback, functions in the manner of a self-balancing bridge, providing through the feedback element whatever current is necessary to hold the —input at null (ground potential). See Figure 1-b. The output signal is a function of this current and the impedance of the feedback element.

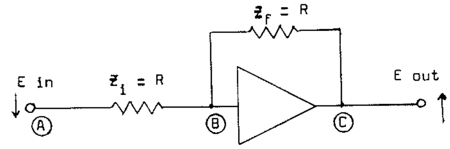
The —input, held to ground potential by the feedback current, appears as a very low impedance to any signal source. Using resistive feedback, for instance, the input appears to be the resistance of the feedback element, divided by the open-circuit gain of the operational amplifier.

If current is applied to the —input, it would tend to develop voltage across the impedance of feedback element, and move the —input away from ground potential. The output, however, swings in the opposite direction, providing current to balance the input current and hold the —input at ground. If the impedance of the feedback element is high, the output voltage must become quite high to provide enough current to balance even a small input current.

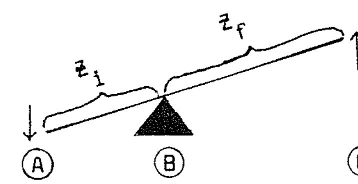
Input Element Z_i Converts Input Signal to Current

Since we more often have to deal with voltage rather than current signals, an additional element is used in most operational amplifier applications, designated "Z_i" (input impedance). This is an impedance placed in series with the —input, converting into *current* that parameter of the input signal which we want to appear as voltage at the output (Figure 1-c).

If Z_i and Z_f are both resistors (Figure 2), the operational amplifier becomes a simple voltage amplifier, the gain of which is $-Z_f/Z_i$.



(a)



(b)

Figure 2

(a) Operational amplifier using resistors for both Z_i and Z_f becomes fixed-gain linear amplifier. Gain is $\frac{-Z_f}{Z_i}$.

(b) "See-Saw" operation of operational amplifier. System appears to pivot about a fulcrum (the null point B) whose "location" is determined by Z_f/Z_i.

Let's examine the mechanism by which this works. Referring again to Figure 2, we apply a voltage to point A, causing current to flow through Z_i. Were it not for the operational amplifier, this current would also flow through Z_f and to ground through the low impedance at point C, making Z_i and Z_f a voltage divider, and raising the voltage at point B. However, the operational amplifier operates to hold the voltage at point B (the —input) at ground potential. To do this, it must supply at point C a voltage which will cause a current to flow through Z_f which will just balance the current flowing through Z_i. When point B is thus held at ground potential, the voltage across Z_i is obviously equal to the applied voltage at A.

Output Voltage is Input Current X Impedance of Z_f

The current through Z_i is equal to the applied voltage at A divided by the impedance (in this case, resistance) of Z_i, or E_{in}/Z_i. This same value of current must flow through Z_f in order to keep point B at ground. The voltage at point C, then, must be E_{in}/Z_i (which is the value of the current in Z_f) multiplied by Z_f. The output is inverted (of opposite polarity) from the input, so we say that $E_{out} = (-E_{in})\left(\frac{Z_f}{Z_i}\right)$, and the voltage gain of this amplifier configuration is seen to be $\frac{-Z_f}{Z_i}$.

See-Saw Operation

As indicated in Figure 2-b, the operational amplifier with resistive input and feedback elements acts in see-saw fashion, the amplifier moving the output end of the see-saw in response to any motion of the input end, causing the system to pivot about an imaginary fulcrum, which is the "sensing point" (—input). The distance from the near end to the sensing point or fulcrum corresponds to the Z_i or input resistor, and the distance from the fulcrum to the far end corresponds to Z_f. The motion of the far end depends on the motion of the near end and the ratio of the two distances. This analogy suggests that the operational amplifier may be used to solve dynamic problems in mechanical engineering, and so it can. One of the principal uses of operational amplifiers has been in the rapid solution of complex mechanical or hydraulic problems by means of electronic analogs of mechanical or hydraulic systems: operational amplifiers are the basic components of an analog computer.

As may be expected, simple linear voltage amplification by precise gain factors is, though useful, not by any means the limit of the operational amplifier's capabilities.

Capacitor as Z_i Senses Rate-of-Change

Remembering that an operational amplifier with a resistor as a feedback element responds with an output voltage equal to the product of the input current and the feedback resistance, let's consider what happens if a capacitor is used instead of a resistor as Z_i (Figure 3).

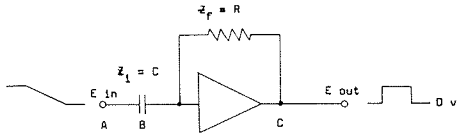


Figure 3.
Operational Amplifier as Differentiator. Output is proportional to *rate-of-change* of input voltage. $E_{out} = \frac{-dE_{in}}{dt} \times RC$.

The current through a capacitor is proportional to the *rate-of-change* of the voltage across the capacitor. A steady state DC voltage across a capacitor (assuming an "ideal" capacitor) passes no current through the capacitor, so no balancing current need be furnished by the output to hold the —input of the operational amplifier at ground. The output voltage then, is zero.

If the voltage at the input is changed, however, the *change* causes a current to flow through capacitor Z_i. The *amount* of current that flows is directly proportional to the capacitance of Z_i times the *rate of change* of the input voltage.

Let's assume that the potential at point A is +100 v DC, and that we change it smoothly to +95 v DC in five seconds. This represents a rate of change of one volt per second, the change taking place over a period of five seconds. If the value of Z_i is 1 μf, then, a current of —1 microampere will flow through Z_i for those 5 seconds.

The operational amplifier will cause an equal and opposite current to flow in Z_f. If we select a value of 1 megohm for Z_f, the one microampere current necessary to balance the circuit will require +1 v to appear at the output of the operational amplifier, during the time that 1 μa current flows through the capacitor.

This operation is *differentiation*: sensing the *rate-of-change* of an input voltage, and providing an output voltage proportional to that rate of change.

The actual relationship of output to input is this: $E_{out} = -\left(\frac{dE_{in}}{dt}\right)(RC)$, where the expression $\frac{dE_{in}}{dt}$ indicates the rate of change (in volts per second) of the input signal at any given instant, and R and C are Z_f and Z_i respectively.

In our example, we used a constant rate of change, and obtained a constant voltage level out. Had the rate been less even, the output signal would have demonstrated this dramatically with wide variations in amplitude. The differentiator senses both the rate and direction of change, and is very useful in detecting small variations of slope or discontinuities in waveforms.

Differentiator Has Rising Sine Wave Response Characteristic

In responding to sine-waves, the differentiator has a rising characteristic directly proportional to frequency, within its own bandwidth limitations (see Figure 7). The output voltage is equal to (E_{in}) $(2\pi fRC)$, and the output waveform is shifted in phase by —90° from the input (the phase shift across the capacitor is actually +90°, but the output is inverted, shifting it another 180°).

Capacitor as Z_f Senses Input Amplitude and Duration

If we interchange the resistor and capacitor used for differentiation, and use a resistor for Z_i and a capacitor for Z_f (Figure 4) we obtain, as might be expected, the exact opposite characteristics from those obtained above. While in differentiation we obtained an output voltage proportional to the rate of change of the input, by swapping the resistor and capacitor, the output signal becomes a rate of change which is proportional to the input voltage.

This characteristic allows us to use the operational amplifier for integration, since the instantaneous value of output voltage at any time is a measure of both the amplitude and duration (up to that time) of the input signal — to be exact, a sum of all the amplitudes, multiplied by their durations, of the input waveform since the start of the measurement.

Here's how integration works: Let's assume the conditions of Figure 4 ($Z_i = 1$ meg, $Z_f = 1\ \mu f$), and an input signal level of zero volts. No current flows through Z_i, so the operational amplifier needs to supply no balancing current through Z_f. Suppose now we apply a DC voltage of —1 v to Z_i. This will cause a current of —1 μa to flow in Z_i, and the operational amplifier will seek to provide a balancing current through Z_f. To obtain a steady current of 1 μa through 1 μf, the operational amplifier will have to provide a continually rising voltage at the output, the rate of rise required being 1 volt per second. It will continue to provide this rate of rise until the input voltage is changed or the amplifier reaches its swing limit ("bottoms out"), or approaches its open-loop gain.

Now, this rate-of-rise, though helpful in understanding the mechanism by which the operational amplifier performs integration, is not the "answer" we seek from an integrator. The significant characteristics is the exact voltage level at a certain time, or after a certain interval.

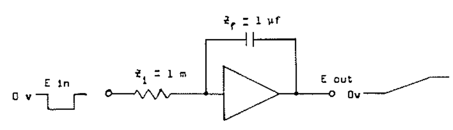


Figure 4.

Operational Amplifier as Integrator. Output *rate of change* is proportional to input voltage. $\frac{dE_{out}}{dt} = \frac{-E_{in}}{RC}$, or $E_{out} = \frac{-1}{RC} \int E_{in}\, dt$. RC in the example here is 1 second. Output, then, is 1 volt per second per volt input, and—most important—the output level at anytime is *one volt per volt-second input*.

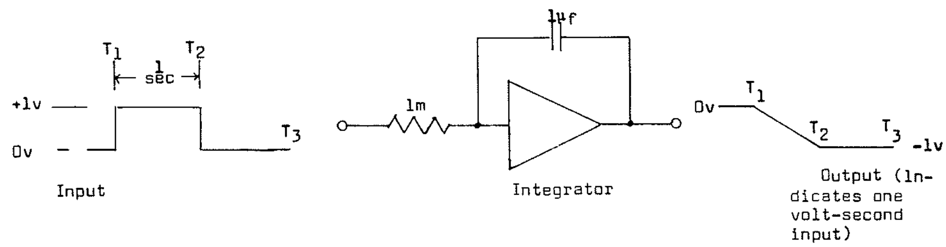


Figure 5.
Simple case of integrating 1-volt-second pulse. Integrator does not improve measurement accuracy in so simple a case.

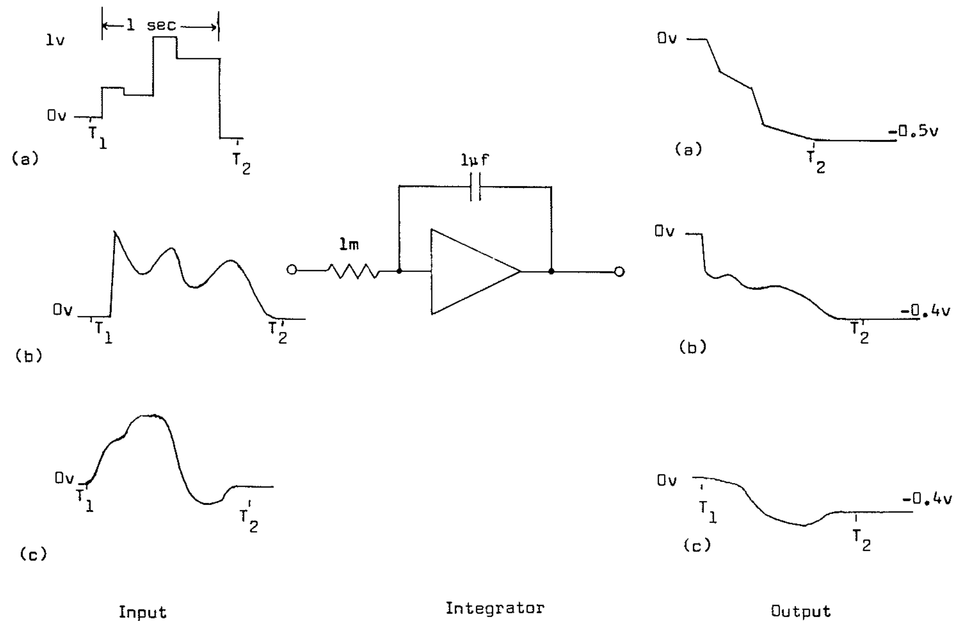


Figure 6.
Integrating more complex waveforms to determine "area under the curve" between T_1 and T_2. Note that in (c) the negative portion of the input waveform *reduces* the net integral.

Integrator Holds Final Level Until Reset

Before the amplifier reaches its output limit, suppose we remove the input voltage to Z_i. The output does not return to ground, but remains at the level it reached just before the signal was removed. The rate of rise has stopped because the necessity for providing $+1\ \mu a$ through Z_f to maintain the null at the —input has been removed. With an ideal capacitor and amplifier, the output voltage would remain at the last level reached indefinitely, until an input signal of the opposite polarity were applied to Z_i, and a negative-going rate of change at the output were required to maintain the null at the —input.

If the positive input signal is greater than our original —1 volt, it will take less time for the output voltage to reach zero than it originally took to rise. If the positive signal is smaller, it will take more time.

The absolute output level of the integrator at the end of some interval is the sum of the products of all the voltages applied to Z_i since the output was at zero, times the durations of these voltages, that sum divided by —RC.

Interpreting Answers Obtained From Integrator

The mathematical expression for the output level reached in a given interval of time $(T_2 - T_1)$ is as follows:

$$E_{out} = \left(\frac{-1}{RC}\right) \int_{T_1}^{T_2} E_{in}\ dt$$

The integral sign indicates that the value to be used is the *sum* of all of the products (E_{in} X dt) shown, between the limits (T_1, T_2) noted. The expression "dt" indicates infinitely small increments of time.

It is not necessary, however, to understand and be able to manipulate expressions in integral calculus to understand and make use of an operational amplifier integrator.

The integrator provides a voltage output proportional to the net number of volt-seconds applied to the input. If the total volt-seconds of one polarity is equalled by those of the opposite polarity, the output level at the end of the selected interval will be zero. Let's look at some examples.

Simple Example of Data From Integrator

First, we'll assume the signal we want to integrate is a simple one-volt positive pulse of one second duration (Figure 5). The sum of all voltages times durations between T_1 and T_2 is one volt-second. Using 1 megohm and 1 microfarad for Z_i and Z_f, the operational amplifier output will fall at the rate of one volt per second $\left(\frac{-E_{in}}{RC}\right)$ for one second, reaching —1 v when the pulse ends, and remaining at that level.

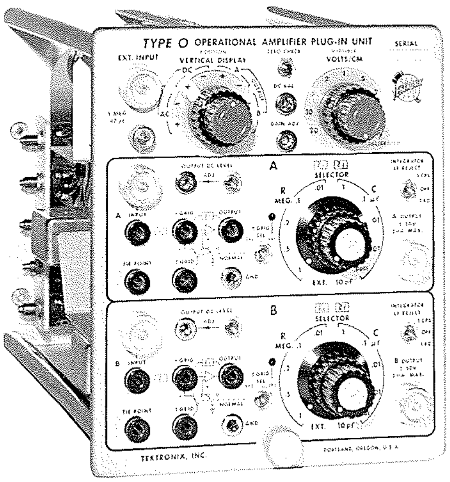
In reading this output level at T_2 we know that the input signal has amounted to 1 volt-second during the interval T_1 to T_2. Note also that a later observation, at T_3, gives the same answer, since E_{in} has been 0 between T_2 and T_3.

More Complex Cases

Now, take the more complicated case of the waveform in Figure 6-a. Its four voltage levels, of different duration, cause the integrator output to fall at four different rates, reaching a final level representing the total number of volt-seconds contained in the waveform. It should be apparent now that the integrator can measure the total volt-seconds contained in even the very complex waveform of Figure 6-b — something that would be difficult to measure by direct observation of the waveform. This type of operation is often referred to as "taking the area under the curve," since the area underneath a waveform plotted against time (i.e., the area bounded by T_1, T_2, the waveform and the line representing 0 volts) is the number of volt-seconds involved. Note, too, that we needn't wait for T_2 to obtain a reading: the instantaneous value of E_{out} at *any time* is proportional to the input volt-seconds up to that time.

Using Different Values of R and C

In the cases we've used for illustration, RC was 1 ($10^6 \times 10^{-6}$), and the numerical value of the output voltage at the end of the integrating interval was the number of volt-seconds in the input waveform. Using other values of R and C requires some additional calculation. To find the actual input volt-seconds, multiply the output voltage by (—RC). Example: R is 200 k, C is .01 μf and the output voltage after the selected interval is —2.5 volts. Multiplying —2.5 by $(-2 \times 10^5 \times 1 \times 10^{-8})$ gives us 5×10^{-3}, or 5 millivolt-seconds, positive polarity. Note that because of the polarity-reversal in the amplifier, we multiply by (—RC), to obtain the proper sign in the answer.



Measuring Ampere-Seconds (Coulombs)

To measure ampere-seconds, Z_i is omitted, and the current source is applied directly to the —input. The output level reached in a given time $(T_2 - T_1)$ is $\frac{-1}{C}\int_{T_1}^{T_2} I_{in}\,dt$.

Integrator Response to + and — Signals

If a waveform to be integrated contains both positive and negative polarity portions during the integrating interval, the output will be proportional to the *difference* between the volt-seconds of each polarity, the integrator being an averaging device. If it's desired to add the two polarities instead of allowing them to be subtracted, it is necessary to precede the integrator with an "absolute-value amplifier" (full wave rectifier) which inverts one of the polarities.

Necessity to "Reset" Integrator After T_2

The "integrating interval" (T_1 to T_2) has been mentioned several times. Because we frequently deal with repetitive signals; and continued integration of a waveform which is not perfectly symmetrical with respect to zero volts will eventually drive the operational amplifier to its output voltage limit, it's desirable to have some way of returning the output to zero at or after T_2, the end of the desired interval.

For slow work, a pushbutton which can be used to discharge Z_f manually is usually sufficient. Other circuits which may be used to perform this function automatically are shown in the applications section of the Type O-unit manual. Where the integrating interval is quite short, RC networks may be placed around Z_f to return the output level to 0 v through a time constant much longer (e.g., 100X) than the integrating interval.

In the Type O Unit, the "Integrator LF Reject" switch-positions perform this function whenever Z_f is set to a capacitive value.

Since the LF Reject circuit operates continually to return the integrator output to zero, it is necessary not only to keep the integrating interval short with respect to the LF Reject time-constant, but also to measure E_o before it has had a chance to decay, whenever these circuits are used. The value of resistors used in the circuit will also limit the maximum output obtainable for any given amplitude input (Max $\frac{E_{out}}{E_{in}} = \frac{R_r}{Z_i}$, where R_r is the resistance of the LF Reject circuit.

Reset or LF Reject Imperative When $Z_f = C$ is Small

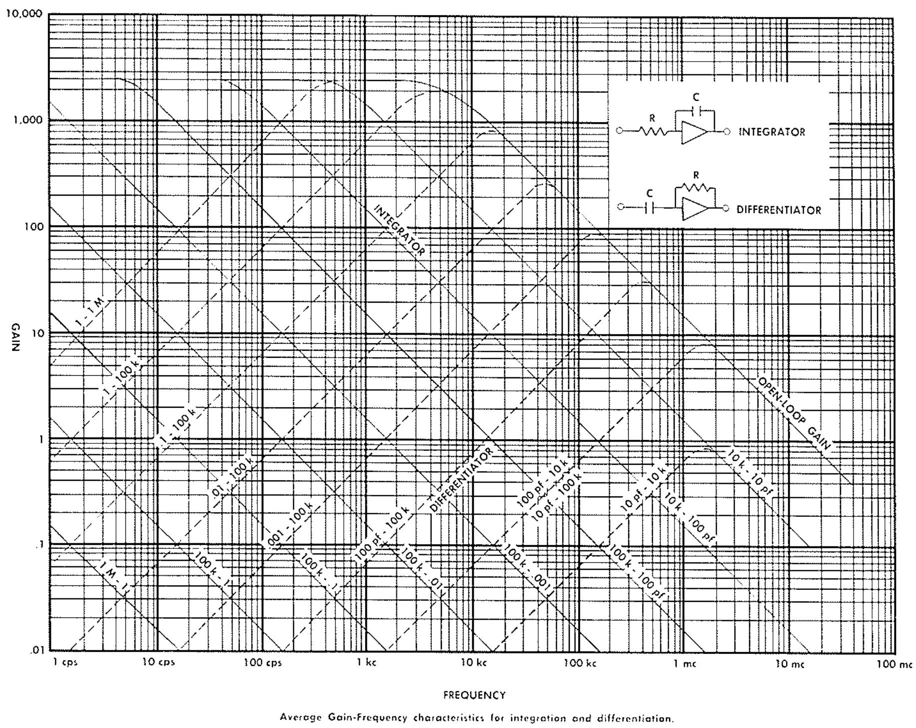
Use of resetting or LF reject circuits is usually imperative when small values of C are used for Z_f, since the small amount of grid current which flows in the —input grid even in the absence of an input signal is sufficient to cause a relatively rapid rise in output voltage as the operational amplifier tries to hold the —input null with balancing current through Z_f.

Response of Integrator to Sine Waves

For sine waves, the gain of the integrator varies inversely with frequency, the actual gain being $\frac{-1}{2\pi\, fRC}$, except as limited by the open-loop gain (at low frequencies) and the open-loop gain-bandwidth product at high frequencies (see Figure 7). At low frequencies, the gain becomes less than the formula would indicate, the effect becoming noticeable at the point where the formula indicates a gain of approximately 1/3 the open loop gain. At high frequencies, the error becomes significant above approximately 1/10 of the open-loop gain-bandwidth product. Except as limited above, the integrator shifts the phase of the input sine wave by +90°.

Editor's note: The second (and concluding) part of this article will appear in the April '63 issue of SERVICE SCOPE. This second part will discourse on the + input, a feature of some operational amplifiers. It will also discuss limitations of operational amplifiers, chief of which are:

1. *Open-loop Gain*
2. *Gain-bandwidth product.*
3. *Grid current (primarily of concern during integration).*
4. *Output-current and voltage capability.*
5. *Signal-source impedance.*



Average Gain-Frequency characteristics for integration and differentiation.

Figure 7.

ANODE-CONNECTOR ARCING IN THE TYPE 507 OSCILLOSCOPE

In the December '62 issue of SERVICE SCOPE we suggested a cure for arcing at the anode connector in the Type 507 Oscilloscope. In a good many instances this cure proved effective. However, under difficult environmental conditions, arcing may persist. Humidity, altitude, temperature and other atmospheric conditions can contribute to the proclivity of the Type 507 toward arcing. This tendency stems from the 20 kv present at the anode connector of this instrument.

Happily, we can now offer a more effective solution to this problem. A new anode connector, developed recently by our Instrument Manufacturing Staff Engineers, exhibits a remarkable ability to resist arcing. Tested under severe environmental conditions this connector, in almost every instance, eliminated or drastically reduced anode-connector arcing.

Type 507's with serial numbers above 418 have this new anode connector installed at the factory. Type 507's with serial numbers 418 and under will readily accept it. A word of caution here: The silicon rubber cover of the new connector, although highly resistant to arcing is a very easily damaged material. It is quite tender, and care must be exercised when installing and connecting the connector. Avoid the use of sharp pointed or edged tools. A hole through the silicon rubber covering destroys the effectiveness of the connector.

The Tektronix part number for this new connector is 131-238. Price is $2.50. Order through your local Tektronix Field Office or Field Engineer.

SERVICE HINTS

DIODE REPLACEMENT IN TYPE 503, RM503, 504 AND RM504 OSCILLOSCOPES

Do not use "off-the-shelf" diodes when replacing the rectifier diodes (D652, D662, D672 and D682) in the power supplies of these instruments. If you will refer to the power supply schematic for any of these instruments you will notice that V620 (a 6DQ6A tube), the primary of transformer T620, and part of the secondary of T620 form an Armstrong oscillator circuit to drive T620 at about 25 kc. Recovery time, therefore, becomes an important consideration in selecting these rectifier diodes.

Not all types of power diodes nor all the diodes of any one type have the short recovery time required in this application. Diodes must be checked and only those with the required short recovery time selected. Tektronix part numbers 153-007 and 153-008 are such selected diodes. You may order these from your local Tektronix Field Office or Field Engineer. For D652 specify part number 153-008 and for D662, D672 or D682 specify part number 153-007.

TYPE 321 OSCILLOSCOPE SWEEP FAILURE AT 10/MSEC AND SLOWER SWEEP RANGES

"No Sweep" at the 10 msec/cm and slower sweep ranges in the Type 321 Oscilloscope generally indicates failure of holdoff capacitor C180A, a 2 μf, 25 volt electrolytic capacitor. Investigation indicates that a certain brand of capacitor which we formerly used in this application will not give reliable service in this circuit. Should you experience a failure of C180A in your Type 321 Oscilloscope, replace it with a Sprague 2 μf, 25 volt electrolytic capacitor — Tektronix part number 290-121.

TYPE 575 TRANSISTOR CHARACTERISTIC-CURVE TRACER AND LONG-LEAD TRANSISTORS

A confusing failure can occur when using the Type 575 Transistor-Curve Tracer to check long-lead transistors. The trouble may appear to be a failure of the base step generator in the Type 575. If you encounter this difficulty, check the long-lead transistor receptacle before you blame the Type 575. Occasionally the receptacle will open up internally at the emitter connection and cause the Type 575 to exhibit symptoms indicating failure of the base step generator.

TYPE 585 OSCILLOSCOPE FUSE FAILURE

Experience in the field reveals that, in some areas, operators of the Type 585 Oscilloscopes are experiencing excessive fuse failure; particularly when using the Type 82 Dual-Trace or Type 84 Test Plug-In Units.

Prior to the advent of these two plug-in units, the Type 585 used a 6 amp fast-blow fuse. The current demands of the two newcomers are a bit higher than those of previously designed plug-in units intended for use with the Type 585. At start-up time or at high line voltage a Type 585/82 (or 84) combination can draw enough current to exceed the limitations of the 6 amp fast-blow fuse. However, the design of the Type 585 is such that you may safely substitute a 7 amp slow-blow fuse for the original 6 amp fuse. This will minimize the chances of interruption due to fuse failure.

TYPE 585 Oscilloscope with serial numbers above 4108 are equipped with a 7 amp slow-blow fuse at the factory.

USED INSTRUMENTS FOR SALE

1 Type 514D Oscilloscope, s/n 1135. In excellent condition. Lawrence Gevins, Electronic Instruments for Research, 4135 Hayward Avenue, Baltimore, Maryland.

* * *

1 RM31A Oscilloscope, s/n 1807. Harry Buckalter, Applied Systems Corporation, 925 East Meadow Drive, Palo Alto, California.

* * *

1 Type 517A Oscilloscope, s/n not given but instrument is said to be one year old. Jim Shaw, Amelco, Inc., 12964 Panama Street, Los Angeles 66, California.

* * *

1 Type 535 Oscilloscope, s/n 368. Earl Dahlin, Tally Register Corporation, 1310 Mercer Street, Seattle, Washington.

* * *

1 Type 561 Oscilloscope, s/n 577. Fred Proctor, Proctor and Associates, Box 471, Bellevue, Washington.

* * *

1 Type 503 Oscilloscope, s/n not given but instrument is approximately two years old. Dr. Siegfried Lindena, Electrosolids, 12740 San Fernando Road North, Sylmar, Calif.

* * *

1 Type 524D Oscilloscope, s/n 1799. Has just had a complete overhaul. Joel Naive, 2758 Bordeaux, La Jolla, California. Phone: GL 4-1314.

* * *

1 Type 502 Oscilloscope, s/n 3146. M. Lipshutz, Cofax Electronics, 537 Commerce Street, Franklin Lakes, New Jersey. Phone: FE. 7-6177.

* * *

1 Type M Plug-In Preamplifier, s/n 206. Used very little. Dr. Ralph Waniek, Advanced Kinetics, 1231 Victoria Street, Costa Mesa, California.

* * *

1 Type 53/54C Plug-In Preamplifier, s/n 20261. Price: $175.00. 1 Type RM181 Time-Mark Generator with crystal oven, s/n 1034. Price: $195.00. 1 Tektronix Cradle Mount for rack mounting a Type 503 Oscilloscope. Price: $20.00. Joseph M. Edelman, M.D., 4550 North Boulevard, 204 Medical Center, Baton Rouge 6, Louisiana.

1 Type 535A Oscilloscope with a Type CA Plug-In Preamplifier, s/n not given but owner says instrument is in new condition. Ross Farmer, 3675 Westwood Boulevard, Los Angeles 34, California. Phone: VErmont 8-4753.

* * *

1 Type 514AD Oscilloscope, s/n not given. Engineering Associates, 434 Patterson Road, Dayton 19, Ohio. Attn: C. C. Littell, Jr.

* * *

1 Type 53/54H Plug-In Preamplifier, s/n 1198. Blake Lloyd, Engineer, Engineering Test Department, Metcom, Inc., 76 Lafayette Street, Salem, Massachusetts.

* * *

1 Type E Plug-In Preamplifier, s/n 003376. Used about one year. Bertram Wellman, Instrumentation Laboratory, Dartmouth Medical School, Hanover, New Hampshire.

* * *

1 Type M Plug-In Preamplifier, s/n 206, (very low mileage). Dr. Ralph Waniek, Advanced Kinetics, 1231 Victoria Street, Costa Mesa, California.

Intercontinental Electronics, located on Shames Drive in Westbury, New York, has asked us to report their Type 524D Oscilloscope, serial number 651, as missing and presumably stolen. They ask that anyone with information regarding this instrument contact them, either by mail at the above address or by telephone. Their phone number is 334-8300 in Westbury, New York.

* * *

The Wisconsin Air National Guard, either through theft or misplacement, suffered the loss of a Type 545A Oscilloscope, serial number 10661, and a Type 53/54K Plug-In Preamplifier, serial number 7048. These instruments disappeared from the air base on November 30, 1962.

Information concerning this oscilloscope and plug-in should be directed to Major Paul H. Poberezny, Chief of Maintenance, Wisconsin Air National Guard, General Mitchell Field, 4840 South Howell Avenue, Milwaukee 7, Wisconsin, Attn: BMO.

USED INSTRUMENTS WANTED

1 Type 310 or Type 310A Oscilloscope. Leo L. Stachowski, P. O. Box 703, Newark, Ohio.

* * *

1 — 3" or 5" oscilloscope. Must have a triggered sweep. Condition of instrument not important, except that it must be repairable. Will pay up to $300.00 for the right instrument. Contact: John M. Hicks, 329 South Avenue, Pittsburgh, Pennsylvania.

* * *

1 Type 524D Oscilloscope. T. Jorgenson, KXLY Television, West 315 Sprague Avenue, Spokane 4, Washington.

* * *

1 Type 310A Oscilloscope. Joe Marie, Bronson Instruments, 1643 Lee Road, Room 9, Cleveland 18, Ohio. Phone: 216-321-9339.

* * *

1 Type 503 or Type 504 Oscilloscope. Dr. James Nicol, Cyronetics Corporation, Northwest Industrial Park, Burlington, Massachusetts.

6AG7 TUBE PROBLEMS

Recent reports from our Field Engineers contain a number of complaints regarding 6AG7 tubes. Drift, compression, microphonics, interface and hum are the offensive characteristics complained against. These complaints are supported and reinforced in the regular reports of our plant calibration personnel. Because of this, we requested an evaluation of 6AG7 tubes by our Material Evaluation Group. The results indicate that the greatest problems are drift and compression, which appear to be related and the result of the same defect—a weak or inactive cathode.

Fortunately, heating the cathode will in most cases activate (or reactivate) it. This heating of the cathode is done by raising the filament voltage to 18 volts for a period of about 30 seconds, with the other tube elements floating or the tube biased below cutoff. After the tube cools to normal temperature it is ready for use. Some tubes may require two or more such treatments.

The heating or reactivation of the cathode can be readily accomplished on the Tektronix Type 570 Characteristic Curve Tracer. Here is the recommended procedure for this application:

Procedure for Reactivating 6AG7 Cathodes

Set up the Type 570 as follows:

I. Plate Sweep Block
   A. PEAK VOLTS to 200 v
   B. SERIES LOAD to 300 Ω

II. Operating Voltage Block
   A. HEATER to 6.3 v
      1. VARIABLE (red knob) to 10 o'clock (will be adjusted later)
   B. + DC to 200 v
      1. VARIABLE (red knob) to 12 o'clock (will be adjusted later)
   C. —DC, counter clockwise

III. POWER
   A. MAINto OFF
   B. TEST to OFF

IV. TEST POSITION to OFF

V. Voltmeter Block
   A. RANGE DC VOLTS to 350
   B. INDICATION to +DC

VI. Grid Step Generator Block
   A. STEPS/SEC to left 120
      1. STEPS/FAMILY (red knob) to 12 o'clock
   B. VOLTS/STEP to .5
      1. START ADJUST (red knob), counter clockwise.

VII. CRT Display Block
   A. VERTICAL MA/DIV. (black) to 5
      1. Red knob to plate
   B. HORIZONTAL VOLTS/DIV (black) to 20
      1. Red knob to plate
   C. POSITIONING
      1. VERTICAL to mid range
      2. HORIZONTAL to mid range

VIII. Install 8-pin octal-socket adapter plate
   A. Patch pins 1 & 5 to "K" on test panel
   B. Patch pins 2 & 7 to HEATER jacks
   C. Patch pin 4 to GRID A jack
   D. Patch pin 6 to +DC jack
   E. Patch pin 8 to "P" jack

IX. Install 6AG7 tube and turn on MAIN POWER. Position crt spot to lower left hand corner of graticule.
   A. Turn on TEST POWER switch and note a horizontal trace of about 10 divisions.
   B. Switch TEST POSITION switch to GRID A and note a family of curves (see Figure 1).

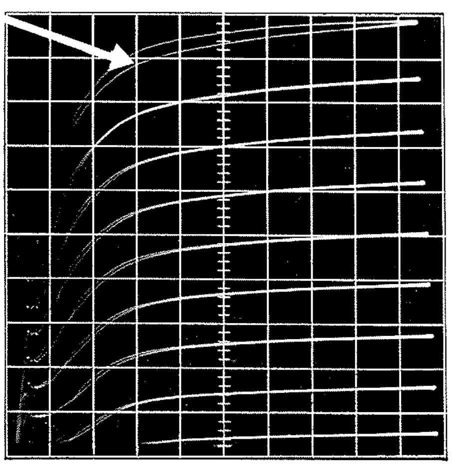


Figure 1
6AG7's with weak or inactive cathodes will show excessive retrace lines (see arrow) on the top member of a family of curves.

   C. Switch the INDICATION control to HTR and adjust the VARIABLE (concentric with the HEATER control and located in the Operating Voltages Block) to give an 80% reading on the Type 570's Volts-DC-and-Heater-Volts meter. Switch the INDICATION control back to +DC and adjust the VARIABLE (concentric to the +DC control and located in the Operating Voltages Block) to give a reading of 150 v on the 350 v scale of the Type 570's Volts-DC-and-Heater-Volts meter.

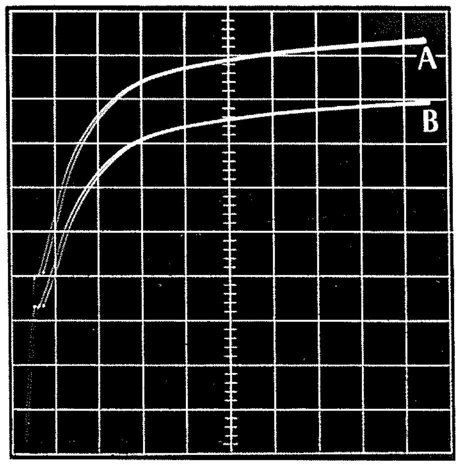


Figure 2
Waveform photo (double exposure) showing the E_p — I_g curve of a 6AG7 with a weak or inactive cathode; (A) at the instant after depressing the ZERO BIAS button and (B) at the point of maximum deflection change during depression of the button.

   D. While observing the top curve push the ZERO BIAS button and observe the deflection change (if any). If this change is greater than one minor division on the graticule, proceed as follows:
      1. Set TEST POSITION switch to OFF.
      2. Set POWER, TEST switch to OFF.
      3. Disconnect the leads from +DC and "P" (on test panel).
      4. Reset POWER, TEST switch to ON and turn HEATER control to 25 and leave there for 25 seconds (reactiviating time).
      5. Turn HEATER control back to 6.3 and wait 15 seconds.
      6. Set POWER, MAIN switch to OFF and reconnect leads disconnected in Step 3 above.
      7. Set both POWER switches, MAIN and TEST, to ON.

8. Set TEST POSITION switch to GRID A. After warm up make check again as in Step IX, D. There should be no change in plate current now. However, if there still is a change, repeat Steps 1 through 8 above and this time increase the reactivating time to 45 seconds. If, after this second attempt, the tube still exhibits an excessive deflection change when the ZERO BIAS button is depressed, it is probably beyond redemption and should be discarded.

In Part 4 of D, under Step IX, of this procedure the load on the filament transformer of the Type 570 is sufficient to drop the heater voltage applied to the 6AG7 to about 17.5 volts. Because of this load we recommend that only one 6AG7 be processed at a time.

THE TYPE 130 L-C METER AND THE S-30 DELTA STANDARDS

Some *Questions and Answers*

Question: In measuring the inductance of a coil with a Type 130 L-C Meter, I can increase inductance by inserting a core into the coil, but only up to a point, then the meter indication suddenly drops to zero. What is wrong?

Answer: Core losses. Many types of cores are suitable only for low frequency use, and show considerable loss (low Q) at the 120-140 kc measurement frequency of the Type 130 L-C. Core loss shows up as effective series resistance. The Type 130 L-C manual (Tektronix part number 070-231, page 2-4) provides correction tables for L measurements with *known* series resistance up to 40 ohms. When series resistance reaches about 75 ohms, the Q of the entire variable oscillator tank circuit has dropped to a level beneath that required to sustain oscillation, and the meter circuit—unable to follow a "difference" frequency of 140 kc—ceases to function. Therefore, do not rely on the Type 130 to measure coils which owe most of their inductance to their cores, particularly where the core material is intended for low-frequency use. The Type 130 is intended primarily for measuring coils having high Q at 120-140 kc.

Question: I understand that a S-30 Delta Standards can be "certified," traceable to N.B.S. Is this right?

Answer: Yes. On an order for a new S-30, simply request a certificate of traceable calibration. There is no extra charge; but, allow extra time.

Question: Why can't L15 (300 μh) in the S-30 be measured on a bridge?

Answer: Actually, L15 could be calibrated on a bridge *if* you had a bridge which operated at 120-140 kc. Most bridges at 1 kc, however, and most "Q" meters don't provide drive frequencies below 1 Mc. Since L15 has a powdered-iron core, its inductance at 120-140 kc will not be quite the same as its inductance at 1 kc or 1 Mc. In addition, shunt capacitance across L15, representing perhaps 1/3 of 1% of L15's admittance at 140 kc, will throw a measurement at 1 Mc off by about 20%.

Question: How does the "Inductance Standardizer," mentioned in the Type 130 L-C manual, work? Isn't it "circular calibration" to use the Type 130 to check its own standard?

Answer: The Type 130 L-C is used only as a frequency source and null indicator for adjustment of L15 in the S-30. The actual scale calibration of the Type 130 is not important. What is important is that the Type 130's fixed oscillator be within frequency tolerance ($\pm$ $\frac{1}{2}$ kc or $\pm$ 0.35%).

The inductance standardizer circuit consists of two circuits: a capacitor which is resonant at 140 kc with 300 μh, and a resistor which has the same resistance as the series-resonant circuit of 4310 pf and L15 where they are resonant at 140 kc.

The Type 130 is first adjusted so that the variable oscillator produces just 140 kc (zero beat with the fixed oscillator) in the 300 μh position when looking into a circuit which appears to be a (nearly) pure resistance of 7.5 ohms at 140 kc.

The Type 130 is then connected to the series circuit of 4310 pf and L15. If this circuit is resonant at 140 kc, the Type 130 meter reads "zero."

If L15's value is too high, the series circuit presents an inductive reactance to the Type 130, forcing the variable oscillator frequency down and causing the meter to read upscale. If L15's value is too low, the inductance standardizer appears as a capacitive reactance (negative inductance) in series with the inductance of the variable oscillator tank coil, forcing the variable oscillator frequency up. Since the meter circuitry reads only the "difference" between the fixed and variable oscillator frequencies, without regard to which is higher, an increase in variable oscillator frequency also reads upscale on the meter.

The 100 to 400 μh inductor across the input to the inductance standardizer is there to complete the oscillator's dc grid return, which is blocked by the 4310 pf capacitor. Since it is in the circuit both during the zeroing operation and during L15 standardization, its small reactive effect across the 7.5 ohm circuit (its reactance is 90-350 ohms at 140 kc) has no material effect on the operation. A low-value resistor here would swamp the null, so an inductor is used.

Question: The 130 L-C manual says to use 2% components in constructing the inductance standardizer. Will a standardizer, so constructed, be adequate to hold 1% calibration of L15?

Answer: No! 2% components will assure calibration to only within about 3%. The 4310 pf capacitor should be made up of stable, low-loss units (such as silvered micas) bridged out to $\pm\frac{1}{2}$%, or closer at 1 kc or—preferably—140 kc. Tolerance on the 7.5 ohm resistor is not critcal. The inductor can be any convenient value between 100 and 400 μh.

Question: I'm piping the multivibrator output from the Type 130 L-C into a highly accurate frequency counter in order to obtain 0.01% resolution and 0.1% accuracy. The Type 130 seems to drift considerably with temperature and line voltage. Can I put a 140 kc crystal into the fixed oscillator circuit?

Answer: You can, but you'll wish you hadn't. The two oscillators (fixed and variable) in the Type 130 use identical transformers and component types so they will be self-compensating. Tie one of them down "solid" and you increase thermal sensitivity and drift by a factor of seven or more.

We designed the Type 130 L-C as a 3% device. With *careful*—and we repeat, *careful*—calibration it will give 1% (of full scale) accuracy. No part of its circuitry is so far overdesigned as to permit reliance on it to provide greater accuracy than the meter gives. We do not represent the Type 130 L-C to operate except as a self-contained "system."

Question: I'm experiencing some difficulty in measuring capacitance in a small relay assembly on my bench. Even though I keep it away from all metal objects, "guard" all unwanted contacts and use the P93C probe, I obtain two different C readings between points X and Y, depending upon which side I ground. What's going on?

Answer: The surface of your bench may be slightly conductive, thus forming a grounded capacitor "plate" which will have more capacitance to the larger or less isolated contact. Try slipping your Type 130 L-C manual under the relay. If this improves your measurements, you may want to build an insulated platform on which to make your more critical measurements; or, you might consider putting the relay into a guarded enclosure.

A CORRECTION

Ye Olde Editor misquoted the author, Paul Thompson, twice in the article "New Trigger-Circuit Adjustment Method," which appeared in the December issue of SERVICE SCOPE. In step 3 of the article, "TRIGGER LEVEL control" should read "TRIGGER SENSITIVITY control." In step 10 the second sentence should read "Set the AMPLITUDE CALIBRATOR to .2 VOLTS and connect the CAL. OUT to the EXT. TRIG. input and to the vertical INPUT."

If you tried this method and ran into trouble, give it another whirl. These corrections will probably clear up the difficulty.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

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Beaverton, Oregon

Tektronix Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

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INTRODUCTION TO OPERATIONAL AMPLIFIERS

Prepared by
Tektronix Field Information Department

Part 2

Use of The +Input

Many operational amplifiers (including those in the Tektronix Type O unit) provide access to a non-inverting input, referred to as the +grid or +input. A positive-going signal injected at this point produces a positive-going signal at the output. Conventional identification of + and — inputs is shown in Figure 8.

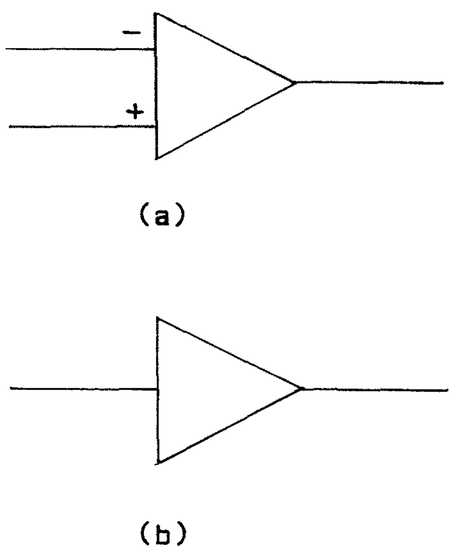


Figure 8

Identification (a) of + and — inputs of an operational amplifier. If only one input is shown (b), it is always assumed to be the —input.

If the output is connected directly to the —input, the operational amplifier becomes a non-inverting gain-of-one voltage amplifier for a signal applied to the +grid, with very high input impedance and very low output impedance.

Non-Inverting Amplifier With Gain > 1

With less than 100% negative feedback (Figure 9), obtained by putting the —input on a voltage divider between the output and ground, gains of greater than one may be realized, the actual gain being $\frac{R_i + R_f}{R_i}$ or 2 where $R_i = R_f$.

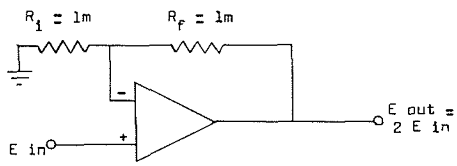


Figure 9

Gain of Two Using +Input. Very high input resistance ($>10^9\ \Omega$) for signals on the order of 1 v amplitude is possible. Other values of gain may be obtained using different ratios of R_i and R_f.

Feedback applied to the +input from the output is positive feedback, which tends to raise the input impedance of the +input toward infinity as the amplitude of the feedback approaches the amplitude of the input signal. If the loop gain (feedback amplitude compared to signal amplitude) exceeds 1 for any frequency, the amplifier becomes unstable (negative input resistance) and will oscillate at that frequency. If the loop gain exceeds 1 at DC, the amplifier will swing to its output voltage limit and stay there. The +input is useful for applications combining positive and negative feedback, and for use of the operational amplifier as an oscillator, waveform generator or multivibrator. The +input may also be used to provide a balanced or differential input, in which the operational amplifier responds only to the instantaneous *difference* between the signals applied to the + and — inputs. Other uses are suggested in the applications section of the Tektronix Type O Operational-Amplifier instruction manual.

Operational Amplifier Limitations

In performing linear operations with an operational amplifier, it is necessary to recognize and allow for the limitations of the amplifier and technique used, to obtain accurate results. The chief limitations are:

1. Open-loop gain.
2. Gain-bandwidth product.
3. Grid current (chiefly of concern during integration).
4. Output current and voltage capability.
5. Signal source impedance.

1. *Open Loop Gain*

The accuracy of all operations is ultimately limited by the open-loop gain of the amplifier, which determines how closely the amplifier is capable of holding the —input null. An amplifier with infinite gain would provide a null of exactly 0 volts, and the impedance at the —input (using feedback) would be exactly 0 ohms.

With finite gain, the —input does not quite null, and does not appear as 0 ohms. With an open-loop gain of A*, the —input moves $\frac{1}{A}$ times the output voltage swing, and appears as an impedance which is $\frac{Z_f}{1 - A}$. If this voltage swing of $\frac{E_{out}}{A}$ is a significant fraction of the input signal E_{in}, or if the impedance $\frac{Z_f}{1 - A}$ is a significant fraction of Z_i, there will be a definite output signal error in addition to the error introduced by the tolerances of

*Common usage in the analog computer field assigns a *negative number* to the open-loop gain between the —input and output (and a positive number to the gain from the +input). Therefore, in calculating values from formulas involving A and the —input, it is necessary to keep in mind that *A is a negative number*, and the expression "1 — A" for instance, when A is —2500, equals +2501, not —2499.

One simplification has been made in this article. Closed-loop gain, commonly expressed as $\frac{-Z_f}{Z_i}\left[\frac{1}{1 - \frac{1}{A}\left(1 + \frac{Z_f}{Z_i}\right)}\right]$ has been reduced to: $\frac{-Z_f}{Z_i}\left[\frac{A}{A - 1 - \frac{Z_f}{Z_i}}\right]$. It may also be written $\frac{-Z_f}{Z_i}\left[\frac{1}{1 - \frac{1 + Z_f/Z_i}{A}}\right]$, if this seems to indicate the effect of A on accuracy more clearly.

Z_i and Z_f. The exact value of this error is $1 - \frac{A}{A - 1 - \frac{Z_f}{Z_i}}$. So long as $\frac{Z_f}{Z_i}$ is small and A is large, the error is not serious. For instance, using the O-Unit's operational amplifiers (at low frequencies where A = —2500) in the simple fixed-gain amplifier mode with resistors for Z_i and Z_f, we see that the error for the gain of 1 ($Z_i = Z_f$) is only $1 - \frac{2500}{2502}$, or less than 0.1%. For a gain of 100, however, the error becomes $1 - \frac{2500}{2601}$, or almost 4%. (A gain-correcting resistor is automatically shunted across Z_i in the O-Unit when the internal Z_i resistor is set to 10 k and Z_f to 0.5 or 1.0 meg.

Using external components, similar precautions should be observed when high gain is required).

Approximate Error Calculation Using C for Z_i or Z_f

Since it is not easy to assign a single impedance value in the error formula for Z_i or Z_f when one of them is a capacitor, it is convenient to use the ratio E_{out}/E_{in}, representing the actually obtained voltage gain, to compute the approximate error. The error ε is found by this formula:

$$\varepsilon = 1 - \left[\frac{\frac{E_{out}}{E_{in}} - A}{1 - A} \right]$$

, or, more simply,

$$\varepsilon = \frac{1 - \frac{E_{out}}{E_{in}}}{1 - A}$$

, where A, as before, is the open-loop gain, and E_{out}/E_{in} is the actually obtained voltage gain (Don't forget — both A and E_{out}/E_{in} are *negative numbers*). Example: where A is —1000 and the observed E_{out}/E_{in} is —50, the error has been 51/1001 or 5.095%. The output "—50" represents, then, 94.905% of the correct value, and the correct value is —50/0.94905, or almost —52.7.

For convenience, you may want to rearrange the terms as shown below, to determine how large an output signal to allow, for a given input and an arbitrarily selected maximum error:

$$\frac{\text{Max } E_{out}}{E_{in}} = 1 - \varepsilon \ (1 - A)$$

Using the Tektronix Type O Operational Amplifier for integration, for instance, to keep error due to amplifier gain below 1%, the output voltage during or at the end of the integrating interval should not exceed the average value of the signal being integrated by more than a factor of 1 — (.01 x 2501), or —24, for low frequencies. The same limitation should be observed during differentiation.

The minimum open loop gain required by an operational amplifier to operate within a given error even at "zero" Z_f/Z_i is

$$A = \frac{(\varepsilon - 1)}{\varepsilon}$$

, where ε is the error expressed as a decimal fraction (.01 = 1%, 0.1 = 10%, etc.).

Where Z_f/Z_i is a finite number, the minimum open-loop gain required for a given maximum error is:

$$A = \frac{(\varepsilon - 1)\ (1 + Z_f/Z_i)}{\varepsilon}$$

The application of these formulas will be most useful in observing gain-bandwidth limitations, discussed below.

2A. Gain-Bandwidth Product:

The gain-factor A varies with frequency, and it's important to know what the effective value of A is for the frequencies or signal frequency components being used. In the Type O, the gain factor A is constant (—2500) only to about 1 kc, dropping off to —1000 at about 15 kc, and reaching a value of —1 at approximately 15 Mc.

The error introduced by the gain factor, then, becomes greater with frequency, and for accurate measurements the allowable ratio of E_{out} to E_{in} must be reduced as higher-frequency information is processed.

Although the drop in gain at high frequencies in the open-loop bandwidth characteristic follows the same pattern as that of an integrator, it must be remembered that this response is obtained *without* input and feedback elements. The effect of this rolloff will *add* to the effect of the integrating components, altering their effect.

At a frequency approximately 1/10 of the open-loop gain-bandwidth product, the open-loop gain will be insufficient (on the order of 10 or so) to provide accuracy better than 9% even at "zero" closed loop gain, or 16.7% when Z_f/Z_i is 1, (i.e., $E_{out} \approx E_{in}$). Above 1/10 of the open-loop gain-bandwidth product, answers will be only approximate, although the data will be useful for frequencies as high as 1/3 of the open-loop gain-bandwidth product. For high-frequency work, then, the nominal values of Z_f and Z_i are usually trimmed to compensate for gain-factor error and improve functional accuracy.

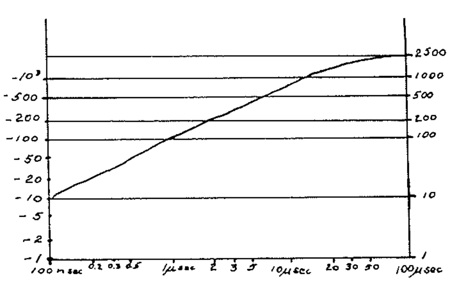


Figure 10 (a)

Variation in open-loop gain after application of signal, for O-Unit.

2B. Gain-versus-Time Factor — Complex Waveshapes:

In working with pulse and complex waveforms, open-loop gain in terms of frequency is not too useful. Instead, the open-loop risetime characteristic, Figure 10 (a), may be used to determine the time after the start of a signal at which the A-factor has reached a sufficiently high level to permit the desired accuracy.

Figure 10 (b) shows the A-factor required to support a given accuracy at a given attempted or "virtual" gain (Z_f/Z_i).

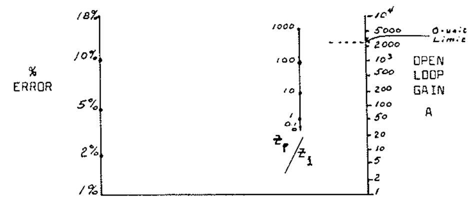


Figure 10 (b)

Nomograph for determining A-FACTOR, ERROR and Z_f/Z_i. Given any two factors, the third may be found. (Lay straightedge across chart.)

"Virtual gain" (roughly, E_{out}/E_{in}) in the case of integration or differentiation is the ratio between the RC time constant chosen and the time interval involved in the operation.

In the case of integration, virtual gain G_v will be $G_v = \frac{-t}{RC}$, where t is the integrating interval — i.e., that span of time during which the integral continues to increase. The larger the values of integrating components, the smaller the virtual gain.

In the case of differentiation, the virtual gain will be: $G_v = \frac{-RC}{t}$, where t is that span of time during which the input signal has its steepest slope. The larger the values of differentiating components, the higher the virtual gain.

As can be seen from Figure 10 (b), holding virtual gain to a value of one or so is a good general rule of thumb for accurate measurements.

NOTE: It should be kept in mind that the values of the internal 10 pf and 100 pf Z_f and Z_i components of the O-Unit have been adjusted under *dynamic conditions*, to compensate partially for the time-dependent errors indicated in Figure 10 (a). For greatest measurement accuracy, standard waveforms involving a similar time interval and virtual gain as the signal to be measured should be used to determine the probable measurement error, or to trim the values of external components to provide direct readings for the particular waveform to be measured (comparison method). However, correction of this sort can be optimized for only a limited range of waveforms, and cannot extend the operating range of the system indefinitely.

3. *Grid Current*:

During integration, any grid-current flowing in the —input will be integrated along with the current through E_{in}, except when this current is bucked out through a DC path from output to input (in the Type O Unit, "Integrator LF Reject" circuits are provided for this purpose).

The amount of grid-current flowing in the —input circuit may be determined by switching out any "LF Reject" circuit and measuring the length of time it takes the output signal to rise or fall 1 v with a capacitor as Z_f (no signal input). The grid current I_g is found by the formula $I_g = \frac{C}{t}$, where t is the time (in seconds) required for the output to move one volt. A grid current (electron current) at the —input of 300 picoamp is normal.

It is not usually practical to try to adjust a wide band operational amplifier for "zero" input current, since this condition is not as stable as is a fixed value of grid-current appropriate to the input tube type and amplifier design. In low-frequency operational amplifiers using electrometer tubes as input elements, extremely low values of input grid current can be obtained with good stability. In wide-band units, higher values must be tolerated.

Once the grid current has been set to a known value, its effect on a given integrating operation can be computed. So long as the value of I_g is very small compared to the average value of the current through Z_i during the integrating interval, the effect of I_g can be largely ignored.

4. *Output Current and Voltage Limits*:

Any operational amplifier is limited in the amount of current and voltage it can deliver to its feedback network and any external load with good linearity. If these limits are exceeded during any part of an operation, the accuracy of that part of the operation, at least, will be impaired.

In the case of the Type O Unit, maximum output is ±50 v and ±5 ma. At high speeds, the maximum rate-of-change at the output will be limited by the available current, and should not exceed 20 v per μsec, when loaded by the O-Unit's oscilloscope preamplifier (47 pf) and 10 pf of other loading (e.g., Z_f).

5. *Input Signal Source Impedance*:

A part of Z_i, the input element of the operational amplifier circuit, is the source impedance of the signal being processed. Linear operations using precision input and feedback components will be accurate only if the source impedance of the signal is very small compared to the impedance of the input component, or the value of the input or feedback component is trimmed to allow for the impedance of the signal source.

Where trimming of components is not practical, or the signal source impedance is not resistive and linear, the usual practice is to process the signal first through a gain-of-one, high input-impedance, low-output-impedance amplifier, such as that shown in Figure 11, to obtain a low-impedance signal source for the desired operation. In the case shown, the output impedance of the first amplifier is *too* low, making it capable of overdriving the second. A current-limiting resistor helps keep down noise as well as prevent overdriving.

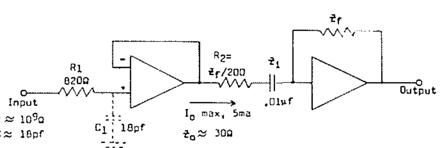


Figure 11

Operational amplifier connected as gain-of-one, non-inverting amplifier to drive low-input-impedance differentiator from high impedance signal source. If output current capability is 5 ma (as in the O-Unit), driver amplifier will reproduce faithfully an input rate-of-change as high as 0.5 v/μsec into 0.01 μf, several orders of magnitude in excess of the amount necessary to obtain usable output from the differentiator. Component R_i combines with the input C of the first operational amplifier to compensate its response in this mode. R_2 limits the current to the second operational amplifier to prevent overdriving, and reduces noise components possibly introduced by first amplifier.

Shunt Impedance Across —Input

Though we tend to think of the —input or —grid as a "virtual ground", and that impedances between this point and ground will have a negligible effect on the performance of the operational amplifier, this is only partially true. The true impedance of this point is $Z_f/1 - A$, and that instead of holding a perfect voltage null (as would be the case if A were infinite), its voltage excursions actually amount to E_{out}/A.

So long as A is large and Z_f has a fairly low value, an impedance across the —input which is large compared to Z_f or Z_i will have little effect on performance. However, in high-frequency work, where the effective value of A is low, more and more care must be exercised to assure that shunt impedances — particularly capacitive reactance, which becomes lower with increasing frequency — do not interfere with the operation (Figure 12).

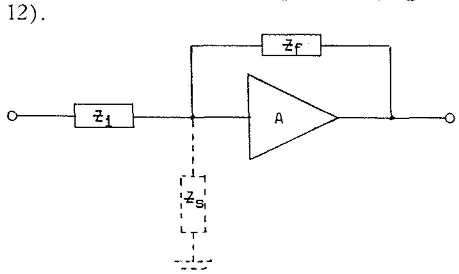


Figure 12 (a)

Shunt Impedance across —input. Where Z_s is large compared to Z_i and Z_f, and open-loop gain A is high, effect of Z_s is negligible.

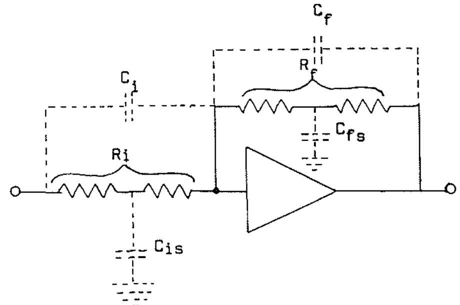


Figure 12 (b)

Where Z_i or Z_f is a resistor, and particularly if a large (>100 k) value, more serious errors may be caused by capacitance from the resistor body (highest impedance point) to ground, and, in the case of R_i during integration, end-to-end capacitance of R_i. Time constants involved in shunt capacitance C_{fs} and C_{is} are approximately RC/4.

The general expression for the closed loop gain of an operational amplifier

$$\frac{E_{out}}{E_{in}} = \frac{-Z_f}{Z_i}\left[\frac{A}{A - 1 - \frac{Z_f}{Z_i}}\right]$$

may be modified as follows to show the effect of shunt impedance Z_s across the —grid:

$$\frac{E_{out}}{E_{in}} = \frac{-Z_f}{Z_i}\left[\frac{A}{A - 1 - \frac{Z_f}{Z_i} - \frac{Z_f}{Z_s}}\right]$$

keeping in mind that A is a negative number. As you can see, unless Z_s is very high compared to Z_f, its effect on accuracy may become comparable to that of Z_f/Z_i.

The terms in the above equation can be rearranged to show the effect of Z_s as related to Z_i:

$$\frac{E_{out}}{E_{in}} = \frac{-Z_f}{Z_i}\left[\frac{A}{A - 1 - \frac{Z_f}{Z_i}\left(\frac{Z_s + Z_i}{Z_s}\right)}\right]$$

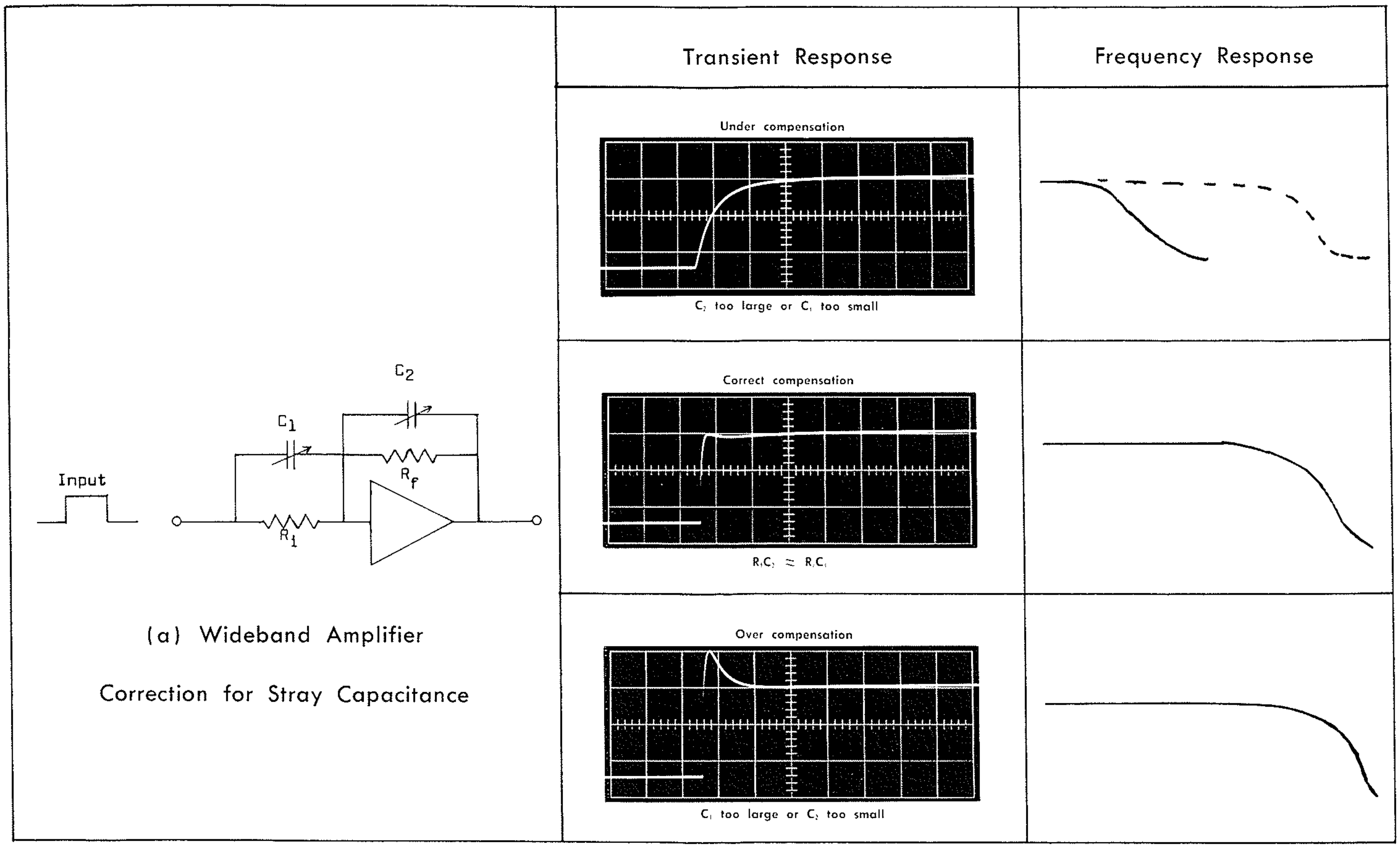
Correcting For The Effects of Stray C

In high-speed work, the accuracy of operations will be affected by Cs during the start of an operation when the effective value of A is low, and also by the end-to-end and distributed capacitance to ground of the resistors used for Z_i and Z_f (Figure 12b).

To correct for strays and the variation in A, the 100 pf and 10 pf values of Z_i and Z_f in the Type O operational amplifiers are factory adjusted under dynamic conditions, and no external compensation of these components is generally required. If it is intended to use values in this range externally, they should be padded or trimmed as necessary under conditions similar to those of the contemplated measurements.

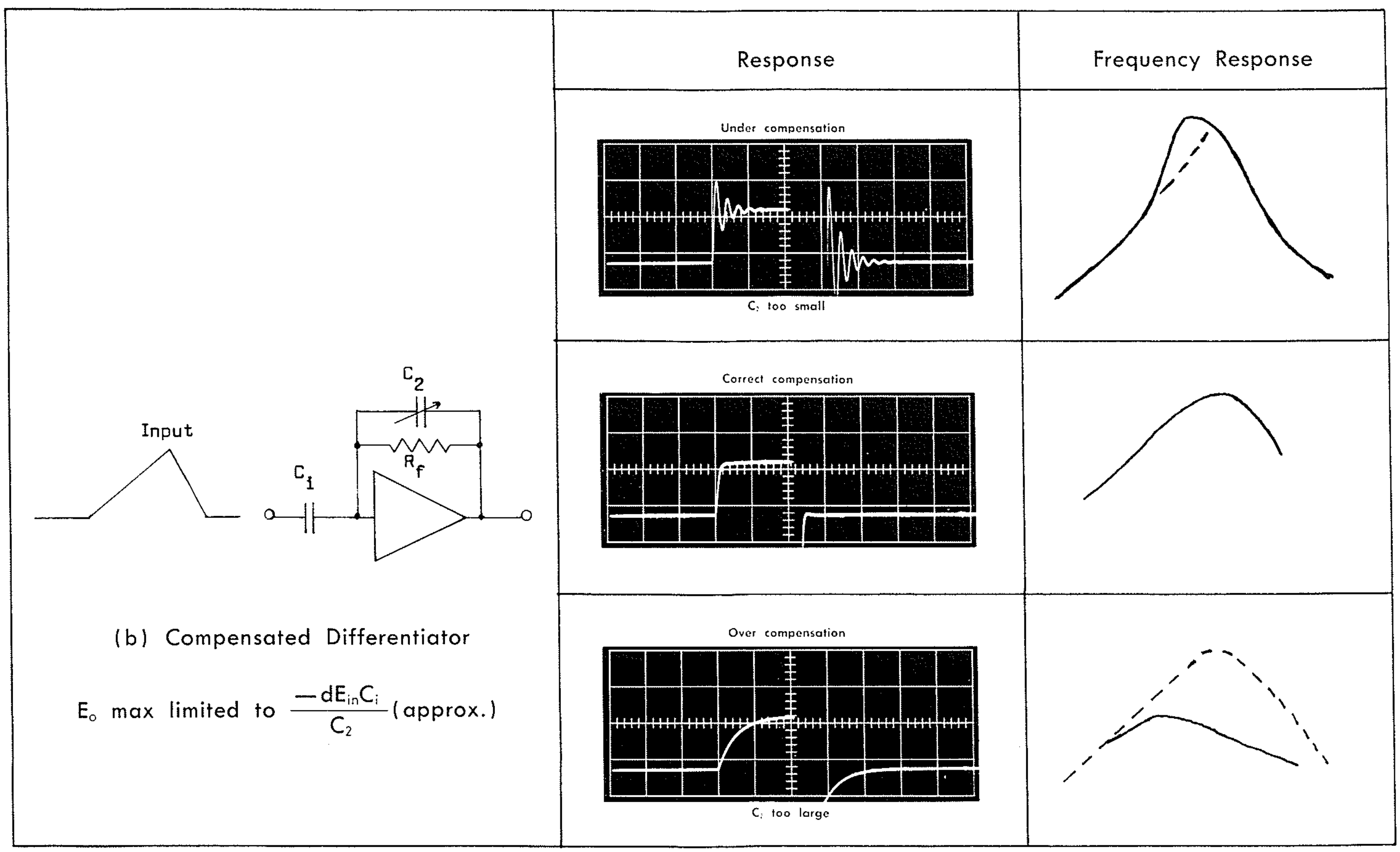
The resistors used as Z_i and Z_f, however, can be given only partial compensation internally, since the optimum value of compensation varies with the application. For this reason, it is usually necessary in dealing with short-duration or high-frequency

Figure 13



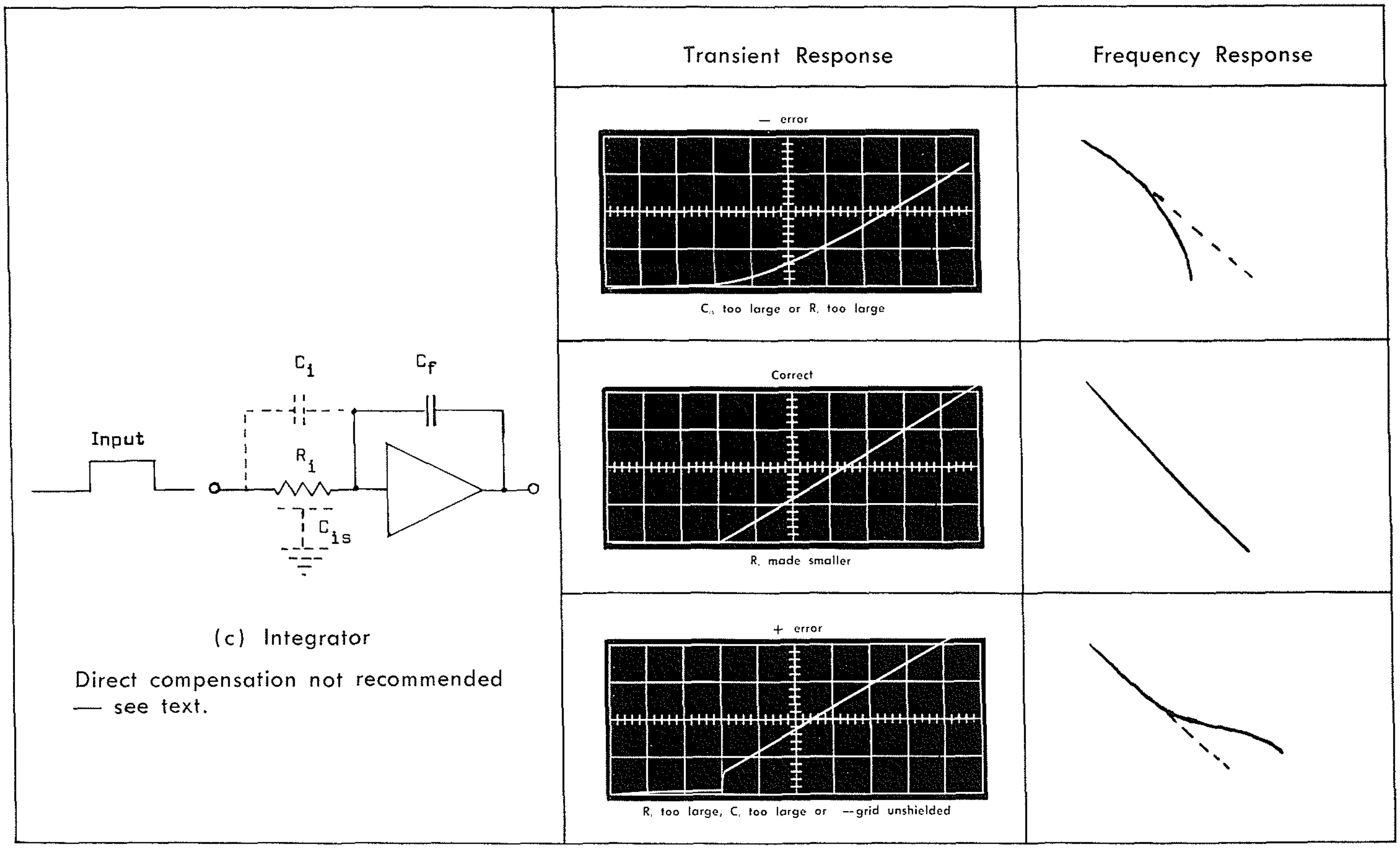
(a) Wideband Amplifier

Correction for Stray Capacitance



(b) Compensated Differentiator

E_o max limited to $\frac{-dE_{in}C_i}{C_2}$ (approx.)



signals to add external compensation to R_f or R_i when these components are used in amplification and differentiation.

Figure 13 illustrates the corrections necessary to improve operational accuracy for each of the three basic operations.

Note, however, that except in the case of straight amplification (Figure 13a), the compensation itself introduces possible errors which must be recognized and allowed for in interpretation of results.

Compensated Amplifier

In the case of amplification, selecting small values of capacitance (on the order of 2-25 pf) for C_1 and C_2, the closed-loop risetime can be made to approach the slope of the open-loop risetime (Figure 9), providing a gain-bandwidth product about equal to the open-loop gain-bandwidth product. Without compensation, the amplifier may typically achieve only 1/20 of this figure.

Compensated Differentiator

Without compensation, the differentiator (Figure 13b) may respond to a sudden change in dE_{in}/dt by overshoot, followed by sinusoidal ringing, due to the fact that excess output voltage must be developed to charge via R_f the input capacitance and the distributed stray capacitance of R_f itself, as well as provide the current needed to obtain a null at the —input. As soon as the strays are charged, however, the excess current through R_f upsets the null, and the output must swing in the opposite direction to re-establish the null and discharge the capacitance associated with R_f — hence the ringing. A small capacitance across R_f provides the current needed to establish the null at the start of the waveform without having to develop excess voltage across R_f.

Differentiator Compensation Limits Initial Accuracy

The presence of this capacitance, however, limits the output voltage maximum to approximately $\frac{-dE_{in}\,C_i}{C_2}$. After an abrupt change in the input waveform, then, when dE_{in} is small, but $\frac{dE_{in}}{dt}$ X RC may be quite large, the output voltage limitation of $\frac{-dE_{in}\,C_i}{C_2}$ may result in a significant error. The solution in this case is to select a larger value of C_i and smaller values for R_f and C_2 (keeping the $R_f\,C_i$ time constant the same) to minimize the error, and keep its duration as short as possible.

Integrator Compensation Rarely Needed

Failure of the integrator to start integrating at the proper rate at the beginning of a fast-rise pulse or after a sharp step in the input waveform is usually due largely to the distributed stray capacitance to ground in R_i. This is infrequent; more commonly the error is in the opposite direction because of excessive capacitance coupling of the input waveform around R_i into the —grid directly, producing a step of approximately $\frac{-dE_{in}\,C_{in}}{C_f}$. The first (—error) waveform in Figure 13c was obtained by deliberately putting a ground plane near the center of a 9 megohm R_i and carefully shielding the —grid. Removing the ground plane and shield produced the third (+error) waveform, using the same input signal (a rectangular pulse) and components.

Normally, the "undercompensated" effect would only occur when R_i is composed of several resistors in series, or when a high-value potentiometer is used as, or in series with, R_i.

The solution usually is to select a smaller value for R_i and a larger one for C_f, to maintain the same time-constant. Normally, if a signal source is capable of driving a large value of R_i with capacitive compensation, it is also capable of driving a smaller value of R_i without compensation.

Theoretically — as when a potentiometer is used in conjunction with R_i — it is possible to compensate the RC losses in R_i by shunting R_i with a series RC network of the proper time-constant, or by using a small value of R in series with C_f. In practice, these added components usually add nearly as many stray-C problems as they cure, and "compensation" of this sort is not recommended. Compensating with simple capacitance across R_i produces a "step" error at any abrupt transition, and usually an error of greater magnitude than the one to be corrected.

If R_i is a single component, an environmental "guard" driven by the input signal (e.g., a short piece of wire soldered to the input end of R_i and dressed near the body of the resistor) can make some correction, but its use requires more complete shielding of the —grid and the —grid end of R_i.

Using "Standard" Waveforms For Comparison

The use of standard waveforms (pulses and ramps) with known parameters, is of considerable help in adjusting compensation and assuring best accuracy for critical measurements near the limits of the instrument's capabilities. For many purposes, such "standard" waveforms may be obtained by attenuation of the oscilloscope gate and sawtooth output waveforms. Selection of time and amplitude parameters close to those of waveforms to be measured will give best assurance against possible system errors.

Editor's note: This concludes the article "Introduction to Operational Amplifiers". If you missed Part 1, which appeared in the February 1963 issue of Service Scope, you can obtain a copy of that issue by contacting your local Tektronix Field Office or Field Engineer.

BROCHURE FOR TYPE O OPERATIONAL AMPLIFIER PLUG-IN UNIT

We have a four-page brochure giving the specifications, basic characteristics and operations of the Type O Operational Amplifier Plug-In Unit. It also contains typical applications and operation information.

These brochures are available through your local Tektronix Field Office or Field Engineer.

USED INSTRUMENTS FOR SALE

2 CA Plug-In Units, s/n's 13443 and 13444. Instruments are one year old and have been used less than fifty hours. Asking price is $230.00 each. Also, 1 Type 72 Plug-In Unit, s/n 474. Asking price is $200.00. Dr. Vernon J. Wulff, Masonic Medical Research Lab., Bleecker Street, Utica 2, New York.

1 Type 517 High-Speed Oscilloscope with power supply and Scopemobile, s/n 789. 1 Type 180-S1, s/n 666. This Time-Mark Generator has a temperature-stabilized crystal oven installed. R. G. Lee, Litton Industries, U. S. Engineering Company Division, 13536 Saticoy Street, Van Nuys, California.

2 Type 517 High-Speed Oscilloscopes, s/n's 388 and 1523. Open for bid. Contact: Hal Boven, Advanced Communications, 16799 Schoenborn Street, Sepulveda, California. Telephone: EM 2-0761.

USED INSTRUMENTS WANTED

1 Type 535A or Type 545A Oscilloscope with a Type CA Plug-In Unit. Buyer wishes to remain anonymous. Please direct your replies to: Tektronix, Inc., 442 Marret Road, Lexington 73, Massachusetts.

1 Type 315D Oscilloscope. Scott M. Overstreet, Sylvania EDL, Box 205, Mountain View, California.

1 Type 310 or Type 524 Oscilloscope. E. H. Frazier, Phillips Petroleum Company, 241 Valley Drive, Idaho Falls, Idaho.

1 Type 500 Series Oscilloscope (prefer a low serial numbered instrument). William Lindinsky, 1623 South 50th Avenue. Cicer 50, Illinois. Telephone: SP 2-0100, ext. 638 or 652-8449 (home).

ITA Electronics reports a Type 503 Oscilloscope, s/n 002236 as missing. Anyone with information regarding the whereabouts of this instrument should contact Stan Freidman, ITA Electronics, Inc., 130 East Baltimore Avenue, Lansdowne, Pennsylvania. Telephone number is CL 9-8200.

Someone who believes in doing his scope-lifting in an easy manner walked off with a Type 533A Oscilloscope, s/n 1131 and a Type A Plug-In Unit, s/n unknown. These instruments which belong to Fullerton Jr. College were sitting on a scope cart (we just can't bring ourselves to mention the make — competitor, you know) and the culprit or culprits just wheeled the whole setup off. Officials at Fullerton Jr. College, which is located in Fullerton, California would appreciate hearing from anyone who has information on the location of these instruments.

While Ted Anderson, Field Engineer with our Denver Field Office, gave a talk to a night class at the Salt Lake Trade Technical Institute in Salt Lake City, Utah, car prowlers broke into his car and made off with a C12 Camera (s/n 1807) and carrying case. Considerable other equipment including three demonstrator oscilloscopes was in the car. However, a careful check showed that the thieves had taken only what they apparently considered luggage. If you should come across a C12 Camera bearing the above serial number, please notify your local Tektronix Field Office or Field Engineer.

The Precision Instrument Company of 3170 Porter Drive in Palo Alto, California has asked our help in locating a missing and presumably stolen instrument. It is a Type 67 Plug-In unit, serial number 298, asset number 671. Persons with information regarding this plug-in should contact Dan Marquess at the above address or telephone him at DA 1-5615, ext. 311.

STOLEN SCOPE RECOVERED

Recently a man brought an oscilloscope requiring extensive repairs to one of our Repair Centers. He left the instrument saying he would call in for our quote on the estimated repair charge.

The Maintenance Engineer in the process of making the estimate, checked the instrument's serial number (a normal procedure at our Repair Centers) and discovered the oscilloscope had been reported stolen way back in December of 1958.

Our Repair Center called the original owner to determine if the oscilloscope had been recovered and resold in the interim. No such luck! It was still unrecovered and considered stolen as far as he was concerned. Our Maintenance Engineer then called the police.

In the meantime our "customer" called the Repair Center to learn the estimated repair charge. On being informed of the amount, he decided it was too much (we purposely quoted an excessively high figure), and said he was sending someone over to pick up the instrument. The police converged on our office, and when the man arrived, they picked him up along with the instrument and carted both off to the police station.

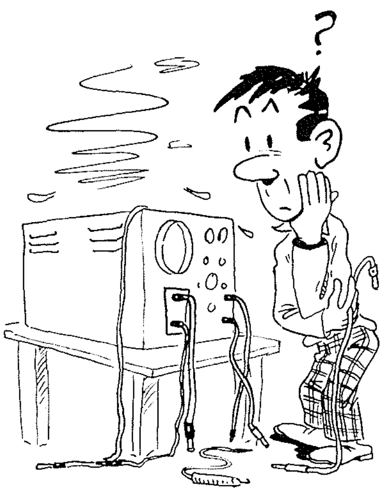
Subsequent investigation by the police revealed other stolen electronic equipment on the premises of the would-be owner of the stolen oscilloscope.

The pleasant aspect of the whole affair is that the rightful owner recovered his scope. He even sent it back to us for the needed repairs.

fer to go no farther than to say that the 6BL8 tube can be used in these circuits with no apparent disadvantages.

As this pleased owner remarked, "Maybe, if Tektronix instruments weren't so reliable, we'd get a stolen instrument back in less than three years."

DOUBLING SENSITIVITY WITH ALGEBRAIC ADDED



Five Tektronix Plug-In Units include as one of their characteristics the ADDED, ADDED ALGEBRAICALLY or A + B mode of operation. These units are the Type CA, Type 3A1, Type 3A72, Type 3S76 and the Type 4S1.

Some operators may overlook the fact that by placing both the A and B channels POLARITY switches in the same position (both + or both —) and connecting separate but identical probes from the channel INPUTS to the test point on the circuit under investigation you can double the sensitivity of these Plug-In Units. We're assuming here, of course, that the circuit under investigation can stand the additional loading caused by the second probe.

Don't make the mistake of trying to use only one probe and patching the two INPUTS together. It just won't work. When you do this you in effect parallel the input resistor of channel A with the input resistor of channel B and thus reduce the input resistance of both channel A and channel B by one half. This reduced input resistance will attenuate the incoming signal by approximately 50% aand you're right back where you started.

SERVICE HINTS

TYPE 72 PLUG-IN UNITS FOR X-Y APPLICATIONS

Type 72 Plug-Ins with serial numbers below 1780 require a minor modification if you wish to obtain properly "paired" X-Y displays when using two Type 72's with Channel A of the right-hand plug-in plotted against Channel A of the left-hand plug-in, etc.

You accomplish the modification by installing a 15 k, ½ watt, 10% resistor paralleled by a 150 pf capacitor between pin 8 of V593A and pin 18 of the interconnecting socket in each Type 72. The two multivibrators — already synchronized via pins 3 and 4 — are now "phase-locked" to turn off Channels A together. If the Type 72's are to be used in a Type 561 Oscilloscope below serial number 580, be sure the cable mod kit 040-267 has been installed in the Type 561. This modification provides a coax between pins 18 of the right and left-hand interconnecting socket.

When using the Type 72's for X-Y applications, set the left-hand Type 72 to the CHOPPED mode and the right-hand unit to the ALTERNATE mode of operation.

TYPE 162 WAVEFORM GENERATORS

If your Type 162 tends to free run in the GATED or MANUAL modes, try replacing R5, a 9.1 k, 1 w, 5% resistor with an 8.2 k, 1 w, 5% resistor. R5 is located in the plate lead (pin 5) of V1 (a type 12AU7 tube) in the regenerative trigger circuit of the Type 162.

FIELD MODIFICATION KITS

TYPE 561A AND TYPE 561A-MOD210C OSCILLOSCOPES

This modification improves the reliability of these instruments by:

1. Providing protection for the clamping and coupling diodes (D838 and D839).
2. Reducing the possibility of crt filament damage when measuring the instrument's high voltage.
3. Supplying protection for the blocking oscillator transistor in the Type 3A74 Plug-In Unit.
4. Removing diode D852.
5. Circuit changes to improve high-voltage regulation.

The mod is applicable (with some exceptions) to Type 561A and Type 561A-MOD-210C instruments with serial numbers from 5000 to 5789. Some instruments in this serial-number range were modified at the factory. Before ordering this kit, check with your local Tektronix Field Engineer to see if your instrument is one of these.

Order from your local Tektronix Field Office or Field Engineer. Specify Tektronix part number 040-305. Price: $3.65.

TYPE 531, TYPE 531A, TYPE 535 AND TYPE 535A OSCILLOSCOPES — SILICON RECTIFIERS FOR DC-FILAMENT SUPPLY

This modification replaces the selenium rectifier, SR650, (in the dc filament supply) with silicon diodes which offer better reliability and longer life.

It is applicable to Type 531 and Type 531A instruments with serial numbers 593 to 7600, Type 535 and Type 535A instruments with serial numbers 1059 to 8627, and instruments of these types (with earlier serial numbers) that have had mod 040-097 installed.

Order from your local Tektronix Field Office or Field Engineer. Specify Tektronix part number 040-299. Price: $7.50.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

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TRANSISTORS IN DEGENERATIVE FEEDBACK COMBINATIONS

By
Jack Rogers and Norm Winningstad
Project Engineers for Tektronix, Inc.

"Gain" in the vernacular of electronics is a loose term; generally understood (unless otherwise stated) to mean "voltage gain." Another common meaning is "power gain" and another, though less common meaning is "current gain." If we generalize "gain" to "transfer," we can then include "voltage-to-current" gain (transadmittance), and "current-to-voltage" gain (transimpedance). These symbols will then apply: T_v (voltage transfer or "gain" e_o/e_{in}); T_i (current transfer or gain", i_o/i_{in}); T_y (transadmittance or voltage-to-current "gain", i_o/e_{in}); T_z (transimpedance or current-to-voltage "gain", e_o/i_{in}); and T_p (power "gain").

For example, an amplifier whose transfer is $T_z = 10^6$ is a transimpedance type of amplifier. It requires a current input and gives a voltage output, the value of which is determined by multiplying the input current by 10^6.

Table 1 summarizes the four possible ways to arrange voltages and currents as inputs and outputs for these three-port devices.

A practical example of the considerations in Table 1 is in the case of a low voltage source remotely located from a voltage sensitive load. A preamplifier is desirable at the source before transmitting the signal to the output amplifier. Here one could use a *voltage* preamplifier and a *voltage* output amplifier: (e_L is the transmission line voltage) $T_{v1} \times T_{v2} = e_L/e_{in} \times e_o/e_L = e_o/e_{in}$. Or, one could also use a *transadmittance* preamplifier and a *transimpedance* output amplifier: (i_L is the line current) $T_y \times T_z = i_L/e_{in} \times e_o/i_L = e_o/e_{in}$. Which system is best—$T_{v1} \times T_{v2}$ or $T_y \times T_z$? Figure 1 illustrates the above problem.

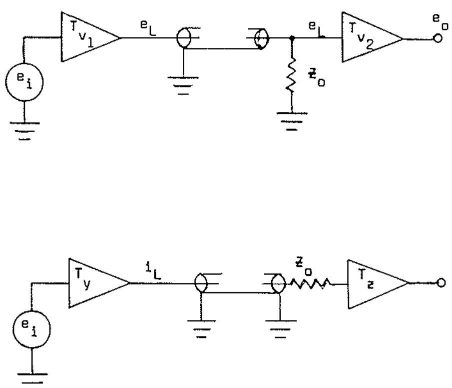


FIGURE 1

Input		Output		Name
Signal	Impedance	Signal	Impedance	And Symbol
Voltage	High	Voltage	Low	Voltage Gain $e_o/e_{in} = T_V$
Current	Low	Current	High	Current Gain $i_o/i_{in} = T_i$
Voltage	High	Current	High	Transadmittance $i_o/_{in} = T_Y$
Current	Low	Voltage	Low	Transimpedance $e_o/i_n = T_Z$

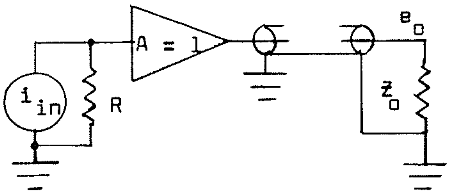
TABLE 1

Although either will do the job well, first-order signal-to-noise ratio or power consumption may be important. If the transmission line suffers mainly from magnetically-induced noise voltages, then the $T_y \times T_z$ combination will prove best — the high output impedance of the transadmittance preamplifier will not allow the magnetically-induced voltages to produce a current which could affect the current-sensitive input of the transimpedance output amplifier. If, on the other hand, the transmission line suffers mainly from electrostatically-induced noise currents, then the $T_{v1} \times T_{v2}$ combination will prove best — the low output impedance of the voltage preamplifier will not allow the induced currents to develop a voltage which would effect the voltage-sensitive input of the output voltage amplifier.

Another example is a remotely located current source of pulses which must be amplified with reasonable fidelity. Here the capacity of a transmission line usually requires a terminated mode of operation to avoid both reflections and capacitive loading. A large resistor (compared to Z_o) at the current source and a gain-of-one line driver would work. However, it would require large amounts of power to drive the line termination to the large output voltage. A better method would be to use a low input impedance amplifier (such as the transimpedance or the current amplifier types) with an appropriate series resistor to terminate the cable and use the large resistor in the output feedback position. This reduces the power requirements considerably and places the amplifier back at the load. The signal-to-noise ratio is considerably better than if the cable were simply terminated at the load, and then a voltage or transadmittance amplifier was used. Figure 2 illustrates four cases.

In considering transistors as degenerative feedback "singles"—that is, a single transistor used to perform transfer with either internal or external feedback—Table II summarizes the four useful possibilities.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.



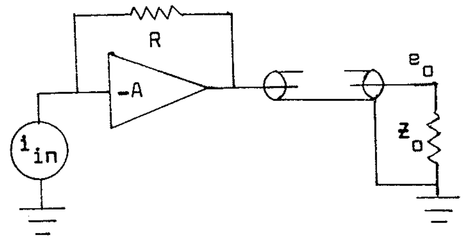
Z_o is less than R, A is greater than R_o/Z_o except in (a)

$e_o = i_{in} R$ $\qquad P_o = i_{in}^2 R \times \frac{R}{Z_o}$

$P_i = i_{in}^2 R$ $\qquad T_p = \frac{R}{Z_o}$

Output power requirement large, good signal/noise

(a)

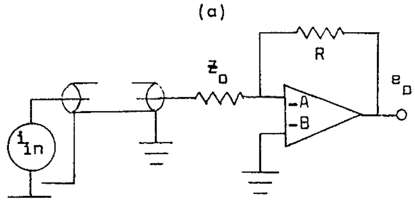


$e_o = -i_{in}^2 R$ $\qquad P_o = i_{in} R \frac{R}{Z_o} + 1$

$P_{in} \approx 0$ $\qquad T_p \approx \infty$

Output power requirement largest, good signal/noise

(b)

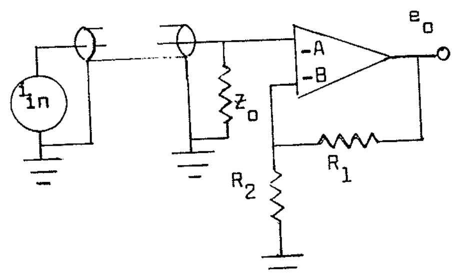


$e_o = -i_{in}^2 R$ $\qquad P_o = i_{in}^2 R$

$P_o = i_{in}^2 R$ $\qquad T_p = \frac{R}{Z_o}$

Lower power output required, reasonable signal/noise with currents to 10^{-6} amps and nega-cycle bandwidth.

(c)



$R_1 + R_2 = R$, $R_2 = Z_o$, $R_1 = R + Z_o$,

$e_o = i_{in} R$ $\qquad P_o = i_{in}^2 R$

$P_{in} = i_{in}^2 Z_o$ $\qquad T_p = \frac{R}{Z_o}$

Same power as (c), but signal/noise difficult with small current.

(d)

FIGURE 2

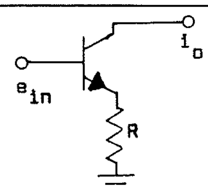
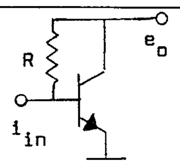
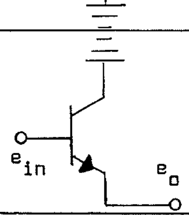
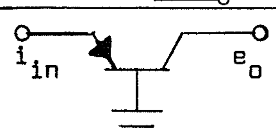
Circuit Example	Transfer	Good	Bad
	Transadmittance (1) $T_Y = \frac{-1}{R}$ High input Z Low output Z	High output Z High input Z	Transfer $\propto$ dependent
	Transimpedance (2) $T_Z = -R$ Low input Z Low output Z	Low input Z	Loop gain strongly load dependent with $R_L < R$.
	Voltage gain (3) $T_V \approx 1$ High input Z Low output Z	Low output Z High input Z	Input impedance load dependent
	Current Gain (4) $T_i \approx 1$ Low input Z High output Z	Low input Z High output Z	Transfer $\propto$ dependent

TABLE II

Transistors considered as degenerative feedback pairs are more numerous and more flexible, in that current and voltage gains may be greater than 1. Table III lists all possibilities in descending order or usefulness, by type (voltage, current, admittance, or impedance transfer).

Note that T_i can be converted to a T_z by the use of a known load resistor. Similarly a T_y can be converted to a T_v. Then, T_i can be converted to T_y, and T_z to a T_v by placing a known resistor in series at the input (source Z assumed to be low). Again, a T_v converts to a T_y and a T_z to a T_i when a known resistor is placed in series with the output (load Z assumed low). And finally, a T_v converts to a T_z and a T_y to a T_i when a known resistor is placed in shunt with the input (source Z assumed high). Table IV presents the above information in chart form.

Going beyond transistor pairs is difficult, if high loop gains are desired. This is due to Nyquist troubles mainly associated with the transistors themselves. The most easily successful transistor triplets involve the addition of an emitter follower to one of the existing listed pairs. Usually the emitter follower is added to example 1, 3, 8, 9, or 10 (Table III) to lower the output impedance; or, added to the input of 2, 3, or 12 to increase the input impedance (also provides temperature compensation for 2 and 12).

We hate to be old fashioned, but we are compelled for completeness to point out that the foregoing applies also to (you should pardon the expression) "vacuum tube"* amplifiers.

* Flemming Valves

REMINDING YOU

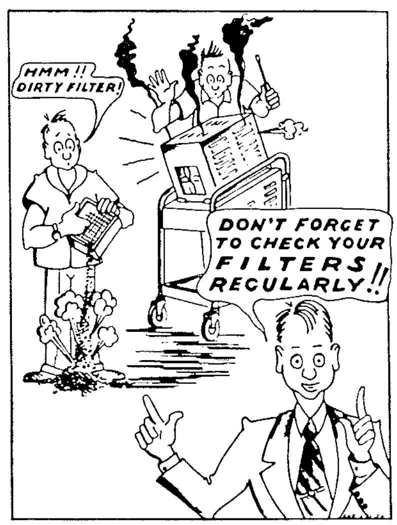


TABLE III

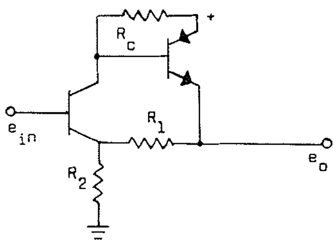
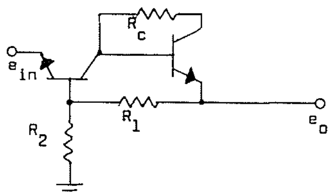
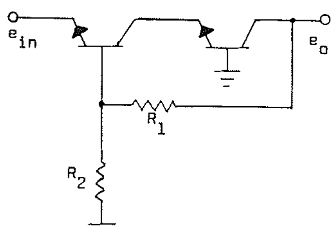
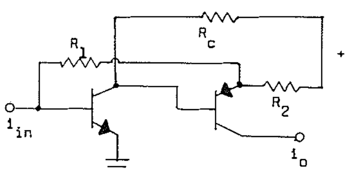
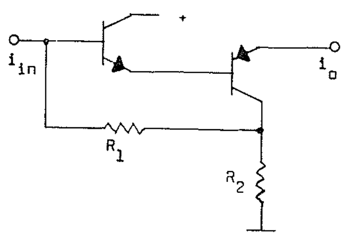
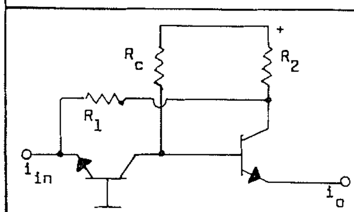
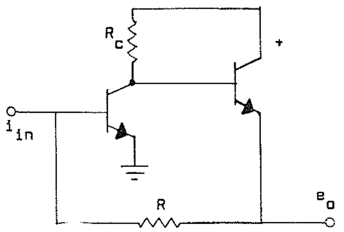
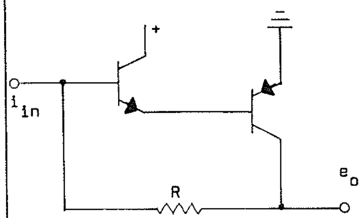
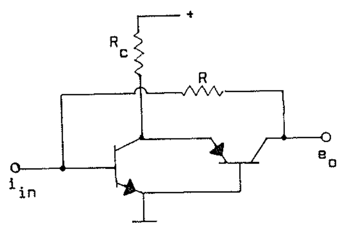
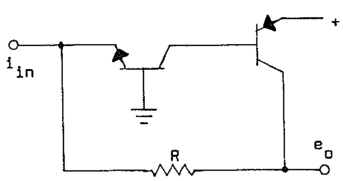
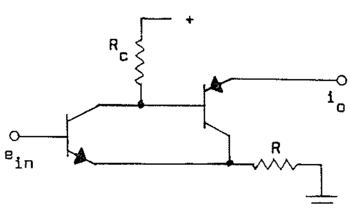
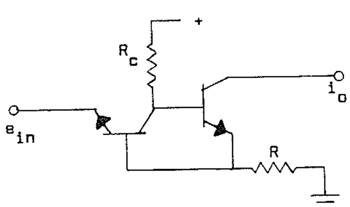
TRANSFER	CIRCUIT EXAMPLE	GOOD POINTS	BAD POINTS	USUALLY USEFUL
Voltage Gain $T_L = \frac{R_1 + R_2}{R_2}$ High input Z Low output Z		(1) High input Z. Open circuit gain predictability.	Output Z could be lower. Loop gain strongly load dependent when $R_L < R_1 + R^2$.	Yes
		(2) Output Z low.	Input Z a bit low.	Output
		(3)	Input Z a bit low. Loop gain strongly load dependent when $R_L < R_1 + R_2$.	No
Current Gain $T_i = \frac{R_1 + R_2}{R_2}$ Low input Z High output Z		(4) Low input Z High output Z	Transfer $\propto$ dependent.	Yes
		(5) Temp. Compensated	Loop gain load dependent (likes low Z load). Input Z bit high. Output Z bit low.	Low Z load, Large $R_1//R_2$
		(6)	Output Z a bit low. Loop loaded by emitter. Loop gain load dependent.	No

TABLE III Continued

		(7) Low input Z. Low output Z. Open circuit gain predictability.		Yes
		(8) Temperature comp.	Loop gain strongly load dependent when $R_L < R$. Output Z a bit high.	Input
Transimpedance $T_Z = -R$ Low input Z Low output Z		(9)	Poor loop gain. Output Z bit high. Input Z not low enough. D. C. awkward.	No
		(10)	Loop loaded by input emitter, low loop gain.	No
Transadmittance $T_Y = -\frac{1}{R}$ High input Z High output Z		(11) High input Z	Output Z bit low; transfer $\propto$ dependent. Loop gain dependent — likes low Z load.	Input
		(12) High output Z	Input Z bit low, transfer $\propto$ dependent.	Output

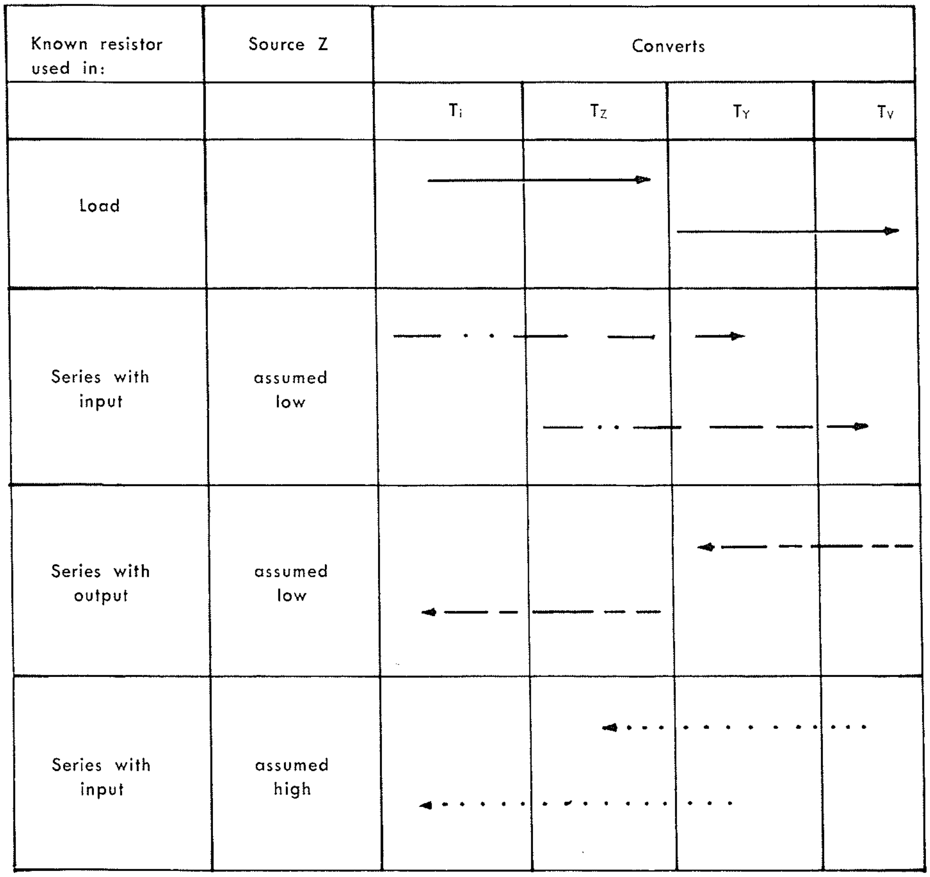


TABLE IV

MISSING INSTRUMENTS

Apparently those sly and slippery individuals who use the "midnight requisition" to "purchase" their oscilloscopes are on a buying (?) strike.

Since our April issue of Service Scope, we've received only one report of a missing instrument. That report concerned a Type 310A, s/n 013798, apparently stolen from an automobile belonging to a service representative of the General Electric Company, X-ray Department.

The instrument disappeared early in April and the apparent theft occurred in the immediate Chicago area.

The General Electric people have requested that we ask our readers to be on the alert for this instrument. Information you may have regarding this scope should be relayed to Mr. R. M. Landis, General Electric Company, X-Ray Department, 1061 W. Jackson Blvd., Chicago, Illinois.

USED INSTRUMENTS FOR SALE

One Type 570 Electron Tube Curve Tracer, s/n 5303. New condition. Reasonably priced. Fred Pack, Technical Materiel Corp., 700 Fenimore Road, Mamaroneck, New York.
The Univac Division of the Sperry Rand Corporation at 311 Turner Street in Utica, New York, offers the following instruments for sale:

- 2 — 315D Oscilloscopes
- 4 — 512 Oscilloscopes
- 1 — 514 Oscilloscopes
- 11 — 531 Oscilloscopes
- 1 — 532 Oscilloscopes
- 7 — 533 Oscilloscopes
- 19 — Preamplifiers consisting of an assortment of Type 53C, Type 53/54C and a few Type CA Plug-In Units.

All instruments will be repaired and recalibrated before shipment to any buyer. Contact Art Ebberhart at the above address for serial number ranges and prices.

One (1) Tektronix oscilloscope, model RM15, s/n 106 — brand new. In original Tektronix packing case — never uncrated or placed in service. Has been in storage since 1957. Address inquiries to Schlumberger Well Surveying Corporation, P. O. Box 2175, Houston 1, Texas. Attention: Purchasing-Surplus.

1 Type 517 Oscilloscope complete, s/n 789. Also, 1 Type 513 Oscilloscope. StuartEx Enterprises, 7626 Lexington Avenue, Los Angeles 46, California. Telephone OL 6-9940.

1 Type 502 Oscilloscope, s/n 6635. Approximately one year old. William Simpson, Sound and Audio Electronics, 1902 Euclid Avenue, Cleveland 15, Ohio. Telephone 861-3907.

1 Type 512 Oscilloscope, s/n 578. Recently reconditioned. Set spare matched amplifier tubes included. A. C. Wall, 36 Beach Drive, Norton, Connecticut. Telephone 203-655-4218.

1 Type 53/54K Plug-In Unit, s/n 867. Very good condition. B. Stapler, Columbia Technical Corporation, Woodside, New York. Telephone YE 2-0800.

1 Type 535A Oscilloscope, 1 Type CA and 1 Type D Plug-In Units. All instruments are less than one year old. Tom Summers, 407 Harvard S. E., Albuquerque, New Mexico.

1 Type 515A, s/n 5477. Phil Fullerton, Electramatic, Inc., 3324 Hiawatha Avenue, Minneapolis 6, Minnesota. Telephone PA 1-5074.

1 Type 517A Oscilloscope, s/n 1106. Will sell or trade for other Tektronix equipment. Electronic Laboratory Supply Company, 7208 Germantown Avenue, Philadelphia 19, Pennsylvania. Telephone: Area Code 215, CH 8-2700.

1 Type 190 Constant-Amplitude Signal Generator, s/n 5116. 1 Type 108 Fast-Rise Mercury Pulser, s/n 251. 1 Type 107 Square-Wave Generator, s/n 106. Harry Bishop, Bishop Enterprises, Inc., P. O. Box 236, Westminister, Colorado.

1 Type 513D Oscilloscope, s/n 1584. Asking price $350.00. Thomas L. Dinsmore, Buyer, Thomas A. Edison Research Laboratory, Division of McGraw-Edison Company, West Orange, New Jersey. Telephone REdwood 6-1000.

1 Type 517A Oscilloscope, s/n 1047. George Moore, 542 Hurt Road, Smyrna, Georgia.

1 Type 561A Oscilloscope (round-face crt), 1 each Type 63, Type 67 and Type 75 Plug-In Unit. Serial numbers not given. Dave Rutland, 2185 Alisos Drive, Montecito, California. Telephone WO 9-3657.

USED INSTRUMENTS WANTED

1 Type 512 Oscilloscope. Walter R. Nass, Consulting Engineer, Route 3, Box 505, Escondido, California. Telephone SHerwood 5-7437.

1 Type 514 or Type 514D Oscilloscope. Prefer one or the other of these scopes but will consider a Type 310A. M. Perez & Sons, 6475 Main Street, Long Hill, Connecticut.

1 Type 317 Oscilloscope. Don Costello, 8279 West Winnemac, Chicago, Illinois.

1 Type 515 or Type 515A Oscilloscope, any condition, price commensurate thereto. G. Summers, 1511 LeVee, Dallas 7, Texas.

1 Type 514 Oscilloscope. Condition not important. Kenneth H. King, 16210 May Creek Road, Renton, Washington.

1 Type 535 or Type 545 Oscilloscope, Ronald Silver, 2576 East Wren Road, Salt Lake City 17, Utah. Telephone CR 7-1697.

1 Type 515 or a similar 10 Mc Oscilloscope. David Fraser, Dyna Sciences Corporation, Fort Washington, Pennsylvania. Telephone MI 6-6247.

NEW FIELD MODIFICATION KITS

TYPE 661 OSCILLOSCOPE DELAYED-PULSE GENERATOR IMPROVEMENTS KIT — For Type 661 Oscilloscopes with s/n's 101 to 361 inc.

This modification reduces to a minimum radiation of the pulse (produced by the Delayed-Pulse Generator) into the vertical circuitry after the signal delay. This radiated pulse causes disturbances in the time region from approximately 100 nsec before the step output of the Delayed-Pulse Generator up to the step.

The modification adds a shield to the rear of the DELAYED-PULSE connector and utilizes a torroid transformer to isolate the tunnel diode pulse from the delay line and bias circuit.

The modification also improves the delayed pulse risetime of those instruments using a 1N3130 tunnel diode in the D992 position by incorporating changes that permit the use of a TD 1081 tunnel diode in the D992 position.

Please note: this mod kit does *not* include a TD 1081 tunnel diode. This diode (Tek part number 152-099) must be ordered separately if your instrument does not already have one.

If your instrument has a serial number 271 or higher, it will have a factory-installed TD 1081 in the D992 position. If your instrument is in the 101-to-270 serial number range, and has had the tunnel diode in the D992 position replaced since the instrument was delivered, it may have been replaced with a TD 1081. A visual check will determine this for you. If the tunnel diode in this position is a 1N3130, it will measure about 0.020" in thickness. If it is a TD 1081 it will measure about 0.050" in thickness.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-307. Price: $25.20.

Remember, if you need the TD 1081 tunnel diode you will also have to order it. Specify Tektronix part number 152-099. Price: $21.00.

TYPE M PLUG-IN UNIT 'A' SIGNAL-OUT IMPROVEMENT — For Type M Plug-In Units with s/n's 101 to 2759 inc.

This modification replaces transistor Q5344 and its related circuitry with a temperature-stabilized dual-transistor comparator circuit. This replacement effects improvements in the 'A' Signal Out circuit as follows:

(a) Stabilizes the 'A' Signal Out dc level to reduce temperature variations and changes which result from transferring the unit from one oscilloscope to another.

(b) Reduces chopping transients appearing at the 'A' Signal Out connector.

(c) Improves bandpass.

(d) Changes the range of the DC BAL control to allow compensation for low-bias Nu Vistors.

Order through your local Tektronix Field Office or Field Engineer. Specify Tektronix part number 040-308. Price: $22.40.

TYPE O PLUG-IN UNIT OPERATIONAL AMPLIFIER IMPROVEMENTS — For Type O Plug-In Units with s/n's 101 to 813 inc.

This modification incorporates several refinements in the operational amplifiers of the Type O Plug-In Unit. The modification and its instructions are divided into four sections (A, B, C, & D). Any part of the modification may be performed separately. Benefits of the modification are:

1. Sections A and B improve the temperature-sensitive drift characteristics of the 'A' and 'B' amplifiers.
2. Section C improves the cross-talk characteristics by relocating several wires and changing the decoupling arrangement.
3. Section D increases the accuracy of the output amplifier when Z_f is set at 10 pf and the INTEGRATOR L.F. REJECT is set to OFF.
   Note: This section applies only to the instruments with serial numbers 101 to 318 with the exception of a few instruments in this serial number range that were modified at the factory. Consult your Tektronix Field Engineer if you are not sure of your instruments status.

Order through your local Tektronix Field Office or Field Engineer. Specify Tektronix part number 040-301. Price $44.20.

TYPE 507 OSCILLOSCOPE CRT FILAMENT ISOLATION TRANSFORMER —For Type 507 Oscilloscopes with s/n's 101 to 427 inc.

This modification installs a special oil-filled isolation transformer (T702) between the crt filament and the filament transformer (T701). This eliminates the possibility of breakdown in the crt-filament winding of transformer T701.

Order through your local Tektronix Field Office or Field Engineer. Specify Tektronix part number 040-304. Price $43.10.

TYPE 581 AND TYPE 585 OSCILLOSCOPES REGULATED DC FILAMENTS MOD KIT — For Type 581 Oscilloscopes with s/n's 101 to 1331 inc. and Type 585 Oscilloscopes with s/n's 101 to 3763 inc.

Installation of this modification materially reduces variations in vertical gain due to changes in line voltage. The modification makes the following improvements in the instrument:

(a) Changes the vertical-amplifier filament supply from elevated 6 volts ac to regulated 12.6 volts dc.

(b) Rewires the filaments into a series parallel arrangement.

(c) Increases the filter capacitance in the 12.6 volt and 100 volt supplies.

(d) Adds fuses between the vertical amplifier and the 100, 225 and 350 volt supplies to protect components in the event of tube shorts.

(e) Increases the decoupling to the —150 and +350 volt supplies and the screen of the Miller-Runup tube (V161). This helps to prevent abberations (caused by high current pulses from the sweep generator) in the displayed waveform.

Order through your local Tektronix Field Office or Field Engineer. Specify Tektronix part number 040-303. Price $39.05

TYPE 519 OSCILLOSCOPE MAXIMUM INTENSITY MOD KIT — For Type 519 Oscilloscopes with s/n's 101 to 383 inc.

This modification adds a Maximum-Intensity potentiometer to the high-voltage circuit and limits the range of the front-panel INTENSITY control. This lessens the chance of accidentally burning the crt phosphor because of a too-high INTENSITY-control setting. It also helps to prolong the life of the crt cathode.

In addition, the modification adds several other refinements such as: eliminating oscillations of the neon voltage regulator, assuring the start of neon ionization in complete darkness and improving the regulation of the high voltage supply.

Order through your local Tektronix Field Office or Field Engineer. Specify Tektronix part number 040-302. Price is $6.35.

SUBSTITUTING 6BL8'S FOR 6U8'S

In the August 1962 issue of SERVICE SCOPE, we stated that the 6U8 tubes were no longer recommmended as a satisfactory replacement for 6BL8 tubes in the Type 503 and Type 504 Oscilloscopes and the Type 67 Plug-In Units. That statement is still valid. However, several of our customers after reading the statement raised the question, "Wouldn't 6BL8 tubes make a more satisfactory replacement for 6U8 tubes located in the trigger, trigger pickoff and delay-pickoff circuits of the Type 530 and 540 Series Oscilloscopes?"

To determine the answer, we asked our Manufacturing Staff Engineering Department to run some tests using 6BL8 tubes in place of 6U8's in the circuits in question. The tests revealed that in each application the 6BL8's showed no apparent short comings. While they have a lower output rating than the 6U8 tube, they operate well within their ratings in all the Type 530/540 series instruments except the Type 532.

In the trigger amplifier circuit of the Type 532, a 6BL8 tube must operate at cutoff because of the higher operating bias of the triode section. As a result, output is insufficient to allow correct triggering on 1 cm of signal with the TRIGGERING LEVEL control set to 0. Also, these tubes fail to operate satisfactorily in the trigger multi circuit of the Type 532; with normal adjustment of the Trigger Sensitivity and the TRIGGER MODE switch in the AUTO position, the multi will not free run in the absence of a signal.

In all other Type 530/540 Series instruments the 6BL8 tubes perform satisfactorily. Trigger output was slightly greater and the trigger circuits set up very well.

The Manufacturing Staff Engineer also tested the E80CF tube (Telefunken and Amperex). They, too, gave satisfactory performances in these circuits. Life tests were not conducted for either the 6BL8 or E80CF tubes.

Our conclusion is that despite the slight gain in trigger output (about 6 to 10%), we do not feel that the advantage gained is great enough to recommend wholesale replacement of the 6U8 tubes in the trigger circuits of the Type 530/540 Series Oscilloscopes. We prefer to go no farther than to say that 6BL8 and E80CF tubes can be used in these circuits with no apparent disadvantages.

HIGH REP-RATE BURSTS FROM MULTIPLES OF TYPE 111 PULSE GENERATORS

In some applications, two or more closely-spaced pulses will prove nearly as useful as pulses from a high-rep-rate generator. Two or more Type 111 Pretrigger Pulse Generators will, when coupled together, supply such closely-spaced pulses. They will also supply many other pulse trains. The pulses may be, as desired, of either positive or negative polarity and of various spacings and widths. Such pulses are useful in many forms of logic testing.

Tektronix Field Engineer Jim Johnson has used three Type 111's to provide a means of testing high speed scalers.

Figure 1 shows a suggested setup for three Type 111 Pulse Generators. In this example, unit number 1 acts as a master unit to set the rep rate of the bursts and to provide one of the pulses. The RANGE switch in the Pulse Generator block of the other Type 111's should be set to EXT TRIG. The VARIABLE control in the Trigger To Pulse Time Difference block allows you to space the pulses in the bursts. Output polarity and pulse widths may be different for each Type 111.

Norm Winningstad, of our Instrument Engineering group, suggests the matching network shown in Figure 2 for reflection-free mixing of any number of Z_o transmission lines. Any one of the branches may be used as an output.

The maximum transfer ($\propto$ max) between input and output occurs when r becomes infinite. Then for N branches:

$$R = \frac{N-2}{N} Z_o$$

$$\propto \text{max} = \frac{1}{N-1}$$

If less transfer than $\propto$ max is desired, r becomes finite and R increases from values given above — impedance matching is retained. If $\propto$ is the desired transfer (i.e., $E_{out}/E_{in} = \propto$. $\propto < \propto$ max) then:

$$R = \frac{1-\propto}{1+\propto} Z_o$$

$$r = \frac{1-(R/Z_o)^2}{2+N\left(\frac{R}{Z_o}-1\right)} Z_o$$

Two small limitations exist in this setup:

1. The more channels used, the smaller the output pulse.
2. When combining positive and negative pulses, there could be inter-triggering via the pulse output connector of each network. If, for instance, a negative pulse of 5 volts or so reaches a Type 111 set to a positive polarity, it could force the emitter of the avalanche transistor down enough to cause it to avalanche. Generally, though, a network with $\propto$ of 0.3 or less should eliminate this problem.

If you wish, you can connect all the pulses together in an unmatched network using GR874 "T's". If you get involved in inter-triggering from alternate plus polarities, use 5-to-1 attenuators—but, beware of reflections.

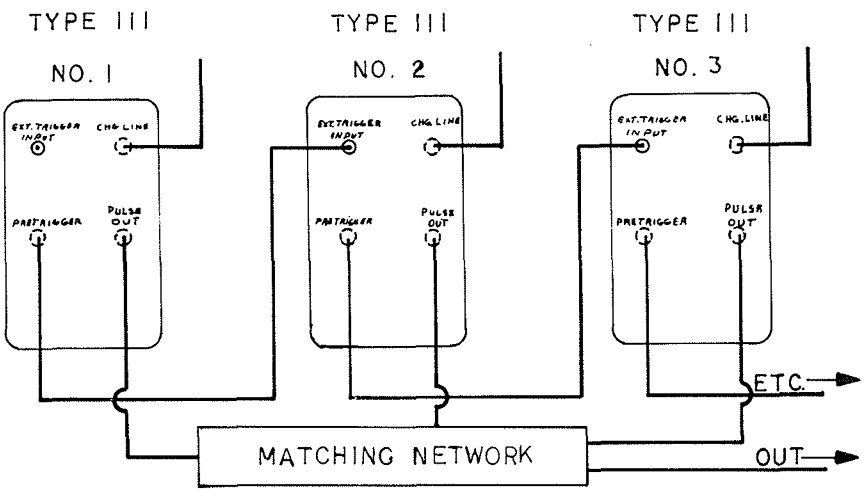


FIGURE 1

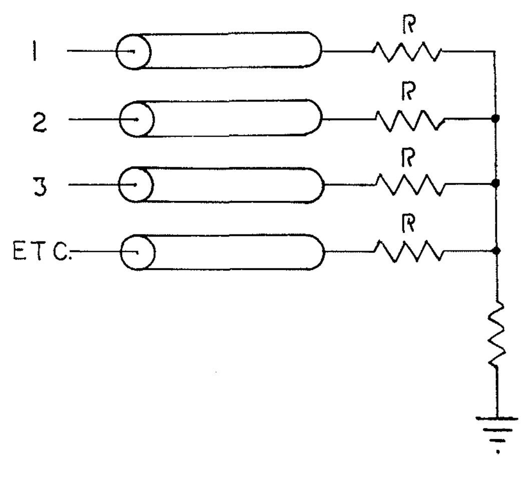


FIGURE 2

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

TEKTRONIX

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 21 AUGUST 1963

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NOISE—SOME BASIC DATA

At any given state of the art, any increase in the gain or bandwidth of an amplifier inevitably means more *noise*. Some of the limitations are absolute, based on the nature of current-flow; some are only relative to the quietness of available components.

Noise limitations apply not only to oscilloscope inputs, of course, but also to the circuits to be examined with the oscilloscope.

Random (as opposed to systematic) noise is almost always specified in rms terms. Being random, it is capable of analysis only in statistical terms. Instantaneous amplitudes (determining peak-to-peak values) under a given set of circumstances are distributed on a probability curve. The probability of any given rms noise level having all of its peaks between two limits varies with the time-limits set. (If you stand around long enough, you may get struck by lightning.)

It is possible to approximate the rms/peak-to-peak ratio for wideband noise. Normally, 90% or more of the peaks will fall within 3X the rms value of the noise. On an oscilloscope, this represents the main "body" of a noisy trace observed at a relatively slow time/cm rate.

Noise power adds directly; noise voltage vectorially. One milliwatt of noise plus one milliwatt of noise is two milliwatts of noise. One millivolt of noise plus one millivolt of noise is 1.414 millivolts of noise (square root of the sum of the squares).

Noise generally may be broken down into two types: Broadband "white" noise (so-called because of the analogy to white light) in which the power is evenly distributed throughout the frequency spectrum, and low-frequency noise (referred to by some as "pink" noise) in which the power varies inversely with the frequency. All resistances, tubes and semiconductors exhibit both types of noise to some extent.

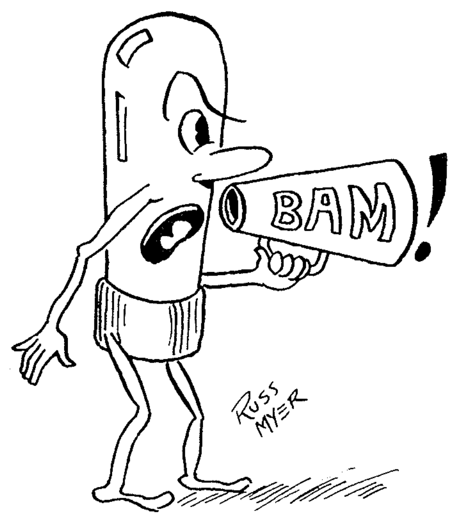
The noise discussed here is more or less inherent in electronic components—not that due to manufacturing defects or to deterioration or damage (as, gas in tubes or moisture in transistors), or that due to external interference (e.g., atmospheric noise or RFI).

RESISTANCE NOISE

ABSOLUTE: At any given temperature, any resistance or resistive component of an impedance generates random wideband noise due to thermal agitation of electrons. The noise *power* generated is proportional to resistance, temperature and bandwidth of the circuit; the observed value may be limited by the bandwidth of the measuring instrument.

RELATIVE: Current flowing in a resistor (particularly a carbon resistor) produces a low-frequency noise called "excess noise" or "current noise." The amount varies widely with the type and construction of the resistor. This low-frequency noise is generally measurable only in the region below 100 kc, and the noise power varies inversely with frequency.

TUBE NOISE



WIDEBAND TUBE NOISE: This "shot noise"—so-called because the effect of pouring electrons from cathode to plate is analogous to the noise of pouring buckshot into a barrel—is a combination of the effects of cathode temperature and resistance and the fact that current flow, being a flow of many discrete charges, is subject to random fluctuation: the number of electrons reaching the plate at any given instant for any given average current is a matter of statistical probability. The flow of grid current is likewise subject to random fluctuation; the resulting output noise and frequency distortion depends on the impedance into which the grid "looks."

"FLICKER": While the wideband noise in tubes is fairly predictable from tube parameters, low-frequency noise, commonly called flicker or 1/f noise, is highly unpredictable. Not much is known about controlling it in tube manufacture. The power distribution of flicker noise varies inversely with frequency, and is predominant over broadband noise below 1-10 kc. It is usually quite a serious limitation to vacuum-tube amplifier performance below 50 cps. The ultimate low-frequency flicker we call drift.

TRANSISTOR NOISE

ABSOLUTE: Electrons crossing any semiconductor "barrier" generate wideband noise. The noise is proportional to the current and to the circuit bandwidth.

RELATIVE: Low-frequency flicker noise is generated in transistors as well as in vacuum tubes, but transistor manufacturers seem to have had more luck in controlling it. The 6 db per octave rise of low-frequency noise over wideband noise may start as low as 1 kc in commonly available types today.

The following information should aid in determining noise values stemming from the causes under discussion here.

RESISTANCE NOISE

Thermal or "Johnson" noise *power* is proportional to temperature, resistance and bandwidth. The rms noise *voltage* is proportional, then, to the *square root* of these factors:

$$E_{rms} = 2\sqrt{1.38 \times 10^{-23}\ TRf}$$

where T is the temperature in degrees Kelvin (absolute), R is the resistance or resistive component of an impedance, and f is the effective bandwidth of the system. The constant shown is Boltzman's constant expressed in meter-kilogram-second units (joules/degree Kelvin).

 Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

A simpler formula for use at room temperature (25° C = 77° F) is:

$$E_{rms} = \sqrt{1.65 \times 10^{-20}\ Rf}$$

The values obtained will be essentially the same (±10%) from −15° C to +65° C (5° to 150° F).

Technically, the effective bandwidth f is narrow, sharply defined, and may be located anywhere in the frequency spectrum. Practically, it is convenient to use −3 db bandwidths in calculation, on the assumption that the total of the (attenuated) noise outside the −3 db points is about equal to the rolled-off noise inside the −3 db points which is weighted at 100%.

A one-megohm resistance at room temperature generates about 130 μv of rms noise over a 1 mc bandwidth. However, when the resistance is shunted by a capacitance of, say 10 pf, the noise output above 16 kc will be rolled off at 6 db/octave. We can then approximate the noise level by calling f 16 kc, giving us a value of 16 μv rms for the noise voltage, or about 50 μv peak-to-peak over a short span of time—say, a few hundred msec.

A resistance of 50 ohms generates about 28 μv rms over a one Gc bandwidth.

Because resistor noise is typical of all broadband noise, white noise levels are often specified as "equivalent noise resistance," which allows specification of noise in terms applicable to any bandwidth. The temperature assumed for "equivalent noise resistance," is 25° C, and for any particular bandwidth, the rms voltage can be calculated from the formula above.

CURRENT NOISE

Composition and deposited carbon resistors—to a greater extent than wirewound or the better grade of metal-film resistors—generate low-frequency noise proportional to the applied voltage. This noise is governed primarily by *current density;* a noisier-than-normal resistor is assumed to have localized bottlenecks of high current density. In most resistors, this current noise, "excess noise" or "1/f noise" as it is variously called, is about equal to thermal noise at 100 kc or so and is negligible above about 1 mc. The noise power of current varies inversely with frequency.

The absolute value for composition resistors is usually specified in terms established by the National Bureau of Standards—microvolts rms per applied volt for one frequency decade. Typically, the values will fall between 0.1 μv and 10 μv per applied volt in a frequency decade, but poor manufacturing techniques and quality control can produce much larger figures. For estimating purposes, 1 μv/v in a decade, or 2.24 μv rms per applied volt for the 5 decades from 1 cps to 100 kc, can be used for resistors of good quality. Note that for several decades, we multiply by the square root of the number of decades, since it's the *power* not the voltage, which varies as 1/f.

TUBE NOISE

WIDEBAND NOISE (SHOT-EFFECT)

TRIODES: The various factors affecting the wideband noise in a triode (grid grounded) are approximated by the formula:

$$I_{rms} = 2\sqrt{1.38 \times 10^{-23}\ T_c K G_m f}$$

Where T_c is the cathode temperature (in degrees Kelvin), K is a tube merit factor between 0.64 and 1.28, f is the bandwidth, and I_{rms} is the noise *current* in the plate circuit. Assuming a cathode temperature of 1000° K and a merit factor of 1.0, the formula becomes:

$$I_{rms} = \sqrt{5.5 \times 10^{-20}\ G_m f}$$

Relating this to the input, we get

$$E_{rms} = 2.34 \times 10^{-10}\sqrt{\frac{f}{G_m}}$$

For a 6DJ8 operated at a current of 10 ma and 100 v on the plate (giving a G_m of about 9,000), the grounded-grid equivalent input noise over a 1 mc bandwidth would be about 2.5 μv rms.

A quicker approximation for the grounded-grid noise level in triodes gives the equivalent wideband "noise resistance" at the grid:

$$R_{eg} = \frac{3}{G_m} \quad \text{(some sources say } 2.5/G_m\text{)}$$

For the 6DJ8 in the case above, R_{eg} becomes 333 ohms. To convert equivalent noise resistance into volts, insert the resistance and desired bandwidth figures into the simplified formula for 25° C thermal noise. The figure comes out about 2.4 μv rms for the example above, close to the value obtained before.

If—as is usually the case in high-impedance input stages—the grid is not grounded, grid current developing a voltage across the input resistance adds another noise factor. The noise component of the grid current amounts to:

$$I_{rms} = \sqrt{2 \times 1.6 \times 10^{-19}\ I_g\ f}$$

where the constant 1.6×10^{-19} is the charge (coulombs) of an electron, I_g is the steady-state grid-current, and f is the bandwidth. If the grid looks into an impedance of R and C in parallel, grid-current noise for any small bandwidth Δf at a center frequency F is:

$$E_{rms} = R\sqrt{\frac{3.2 \times 10^{-19}\ I_g \Delta f}{1 + R^2\ (2\pi FC)^2}}$$

The total noise can be approximated as was done for thermal noise by equating f with the −3 db bandwidth $1/(2\pi RC)$, and ignoring the term in the denominator, which approaches the value of 1.0 below −3 db frequency. Now,

$$E_{rms} \approx \sqrt{\frac{3.2 \times 10^{-19}\ I_g R}{2\pi C}}$$

Taking a 6DJ8 with a 10 nanoamp grid current, a grid resistor of 1 megohm and shunt capacitance amounting to 50 pf, we obtain a value of approximately 3.2 μv for rms noise due to grid current. This noise will be primarily in the dc-to-3 kc region. Of course, if we connect a low-impedance signal source to the grid, this noise will, to a great extent, disappear.

PENTODES: In pentodes, the wideband shot-effect noise in the plate circuit is complicated by the random variation in the division of cathode current between screen and plate—so-called "partition noise." In this case, it is easiest to calculate "equivalent noise resistance" first, and go on from there to total noise for a given bandwidth.

$$R_{eg} = \frac{I_b}{I_k}\left(\frac{3}{G_m} + \frac{20\ I_s}{G_m^2}\right)$$

where I_b is plate current, I_k is cathode current, I_s is screen current and R_{eg} is the equivalent noise "resistance" at the grid.

If we consider the Tektronix Type 502's input stage (6AU6's) as a typical pentode application for low-noise operation ($I_k \approx$ 720 μa, $I_b \approx$ 430 μa, $I_s \approx$ 430 μa, G_m about 1100), expectable wideband noise resistance would be about 4500 ohms per side. Or, adding push-pull noise components vectorially, about 3.8 μv rms over 100 kc passband of the oscilloscope. Needless to say, the Type 502's actual noise performance is not this good, primarily because of low-frequency noise which almost completely masks the broadband noise.

LOW-FREQUENCY (FLICKER) NOISE

Because researchers into noise have been occupied primarily with getting answers for the communications industry—which is mostly concerned with tuned RF amplifiers when working with microvolt signals—not much has been done about identifying the causes and cures for low-frequency flicker noise in tubes. This noise is most serious at frequencies below 1 kc and in tubes with oxide coated cathodes. Flicker noise, like current noise in resistors, varies inversely with frequency, and is quite serious in high-sensitivity dc-coupled amplifiers. It is believed to be related to variations in the conductivity of the cathode coating, to thermal agitation and migration of cathode material and areas of emission activity, with consequent shifts in the configuration of the space charge, and to interface resistance between the cathode coating and sleeve, among other hypothetical causes. One investigator, noting excessive noise in a direct-heated cathode with very small filament diameter, concluded that at least some of the noise was due to high-velocity gas ions, speeding from plate to cathode, being captured *in orbit* around the cathode (like little satellites), crashing into freshly emitted electrons and generally creating a nuisance. This seems quite plausible—*collision* of gas ions with the cathode is a common source of noise. Some researchers have found the flicker noise to vary as the square of the cathode current. However, variations among tube types and even among samples of the same tube types are so great that no consistent theory has been developed to explain all the phenomena. Flicker noise in vacuum-tube circuits operated down to 10 cps or below will commonly be three to four times the value of the broadband shot noise and other contributing factors (plate and cathode resistors, etc.). For instance, resistor noise and broadband tube noise account for about 5 μv rms in the front end of the Type 502—corresponding to perhaps 15 μv peak-to-peak.

The observed peak-to-peak value is about 40 μv, with 20 μv seen in exceptional cases.

Since there is no standardized method of measuring or specifying low-frequency tube noise, it's pretty much up to the user to select circuits and tube types and then hope the tube manufacturer keeps his product consistent.

In general, because wideband equivalent noise varies inversely with G_m and both low and high-frequency noise increases with increasing current, the best candidate for a low-noise tube type is one which offers the best transconductance at the lowest cathode current.

TRANSISTOR NOISE

WIDEBAND SHOT NOISE: A fixed minimum wideband noise value for any semiconductor carrying a given value of current is:

$$I_{rms} = \sqrt{3.2 \times 10^{-19}\ I_f}\ *$$

where I is the dc collector current and f is the bandwidth. The constant this time is twice the charge of an electron (1.6×10^{-19} coulomb). In a transistor operated at 1 ma collector current, then, the minimum wideband noise over a 1 mc bandwidth would be about 18 nanoamperes rms, at the collector. With a 1 k collector load, 18 na becomes about 50-60 μv peak-to-peak.

To convert to equivalent input-noise current, divide the output noise current by beta. As is evident from the above (all other things being equal), the only way to avoid this limitation for low-noise performance is to seek transistor designs which offer highest values of beta for a given collector current, but without increased leakage or other noise-source problems.

LOW-FREQUENCY NOISE: As with vacuum tubes, the low-frequency flicker noise in transistors is not mathematically predictable. It frequently is unspecified, even for so-called "low-noise" transistor types. A few years ago, it was exceptional for a transistor's low-frequency noise to be less than broadband noise below 10 kc. Today, "turnover" points as low as 100 cps may be obtained. Below the turnover point, the flicker noise increases at 6 db/octave. Turnover is that point below which low-frequency noise exceeds the broadband value.

TRANSISTOR SPECIFICATIONS: Even though circuit considerations have a great effect on transistor noise, transistor manufacturers have made more effort to assign numbers to noise levels than have tube manufacturers. However, in the absence of industry standards, the methods of measurement and specification are not uniform, and numbers are often hard to interpret.

Aside from the basic collector current noise mentioned above, noise-current in the collector circuit increases with increasing collector voltage (leakage current noise at the reverse-biased collector-base junction), and with increasing emitter current (surface phenomena at the forward-biased base-emitter junction). Base driving impedance affects these two noise "generators" oppositely; for any given set of voltage and current conditions, there is an optimum base driving impedance for lowest noise, generally between 300 ohms and 3 k. Transistor noise specifications are often based on very low voltage and current settings, plus optimum driving impedance. A collector voltage of 2 v, current of 500 μa and perhaps 1 k driving impedance are typical numbers for "spec" noise levels.

A commonly used spec is "Noise Figure" (NF). This is defined as the ratio of the signal-to-noise ration at the collector to the "available" signal-to-noise ratio at the base, and is normally expressed in db. Usually, it does *not* include flicker noise.

The "available" signal-to-noise is noise of that optimum driving resistance. If a transistor exhibits lowest noise when driven by a very high impedance, its noise figure may be very good but its actual noise contribution quite high. It's important to know the "R_{opt}" when evaluating a specification.

The noise figure NF is calculated as $10 \log \frac{R_{opt} + R_{equiv}}{R_{opt}}$ where R_{opt} is the optimum driving impedance and R_{equiv} is the equivalent input noise resistance of the transistor itself. So to find out the actual transistor noise level R_{equiv}, we work this formula:

$$R_{equiv} = R_{opt}\ (\text{antilog}\ \frac{NF}{10})\ - R_{opt}$$

or

$$R_{equiv} = R_{opt}\ (\text{antilog}\ \frac{NF}{10}\ - 1)$$

Here is an example (from the General Electric handbook, 6th edition). General Electric Type 2N123. At 5 v and 1 ma, NF is 1.94 db with a driving resistance of 720 ohms.

$$R_{equiv} = 720\ (\text{antilog}\ 0.194 - 1)$$
$$= 720\ (1.56 - 1)$$
$$= 420\ \Omega$$

For a 1 mc bandwidth, then, the transistor will contribute about 2.55 μv of rms noise. However, the base driving resistance brings up the total equivalent input noise to about 4.3 μv rms. A lower value driving impedance might (depending on the transistor) provide lower total input noise.

Noise figures specified in "microvolts per square root cycle" ($\mu v/\sqrt{f}$) or "nanoamperes per square root cycle" ($nA/\sqrt{f}$) may refer to measurements taken on a Quan-Tech transistor noise analyzer over a *one cycle* bandwidth centered at 100 cps, 1 kc or 10 kc, and must be multiplied by the square root of the intended bandwidth before becoming meaningful. Even so, they are not too useful, referring only to open-circuit and short-circuit base conditions. Additional calculation (μv/nA) yields the R_{opt} driving impedance and the noise figure for the conditions specified.

Noise figures specified in "db below 1 μv" or the equivalent are of little use without the conditions being specified. One abridged specification sheet, for instance, describes a 2N207B transistor as having a noise level of "2db below 1μv." The full specification sheet reveals that this performance was measured over a 2700 cycle bandwidth of 300-3000 cps at a collector current of 500 μa.

Noise specifications at best are only a general guide, and in-circuit evaluation with transistors, as with tubes, is the only way as yet to evaluate the limits of achievable performance, especially with regard to low-frequency noise.

In conclusion then, the very nature of an oscilloscope—a "search" tool capable of responding to random or unpredictable waveforms—demands that it respond to noise in the circuit being "searched". Thus, the signal to noise ratio in the circuit being investigated imposes one absolute limitation on usable sensitivity and bandwidth. Only to the extent that one can *predict* the nature of the signal he wishes to measure and also delineate the characteristic of rejectable, non-significant signals, can substantial improvements in sensitivity and bandwidth be made at any given state of the art. (Compare the cost and complexity of obtaining a gain of 10^6 at 1 mc by means of a dc-coupled amplifier and by means of a little ac-dc radio, and then consider their comparative signal-to-noise ratios.)

Advancement of the state of the oscilloscope art depends upon improvements in the performance of components and an abilty to discover and apply those circuit techniques which allow an approach to the absolute limitations imposed by the nature of electron flow. Two possible techniques that may help to overcome these limitations are cyrogenics to reduce thermal noise and micro-circuitry to reduce noise associated with current (the smaller the L's and C's the less current required to achieve a given bandwidth). At this time, however, material gains in sensitivity with wide bandwidth and at high impedance by these techniques appear to be still far in the future.

* This same relationship is true of tubes in "plate saturation" when the noise-modifying space charge is depleted, and in general of any current flowing across a "barrier."

SINGLE-SHOT MULTIVIBRATOR CIRCUITS

One of the characteristics common to most single-shot multivibrator circuits is their sensitivity to the rate of rise of the trigger signal as well as to the amplitude of the signal. For this reason, the single-shot multivibrator tends to become increasingly difficult to trigger as the rate of rise of the trigger signal decreases. (Trigger risetime becomes slower for constant amplitude triggers.)

Finally, there is often a rise rate which is so slow that the circuit cannot be triggered even with triggers of very high amplitude. In vacuum tube single-shot multivibrators, this effect is produced by either the input coupling time constant (Hi-pass) or the timing network itself failing to couple sufficient signal to initiate regeneration.

In tunnel-diode single-shot multivibrators it is usually an L/R network that determines the timing (duration) of the multi. It is also this network which "robs" trigger current away from the tunnel diode if the rate of rise of the trigger is too small.

To avoid this problem, both in tube-transistor circuits or tunnel-diode circuits, a Schmitt trigger circuit is sometimes used.

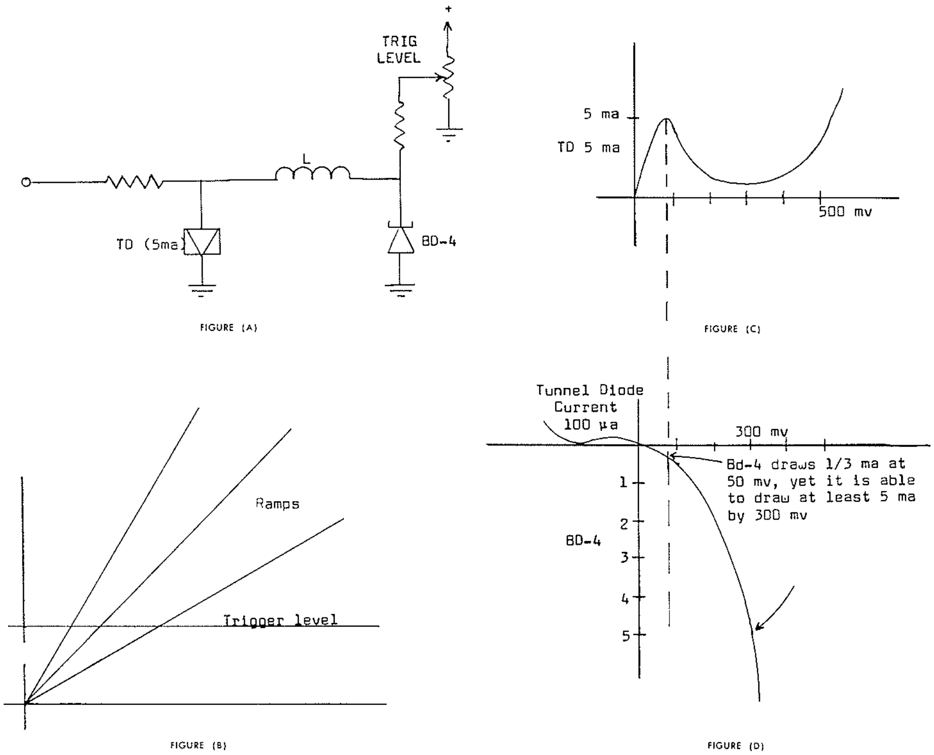


FIGURE 1

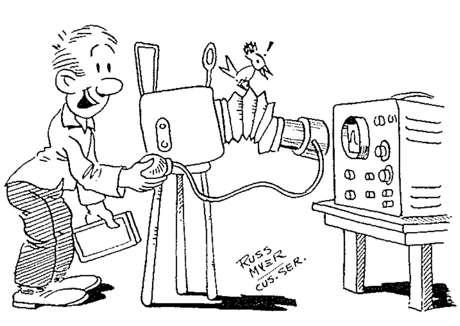
These, however, are not generally as sensitive as the single-shot multivibrator. Another (and we believe, better) solution that is useful in tunnel-diode applications, makes use of a "Back-Diode" to hold the timing circuit (L/R) disconnected and then connect it to perform its normal function after the regeneration of the main tunnel diode has occurred — the normal function here being that of switching the multi after a certain time interval.

Figure 1 shows a typical application. The requirement here is to pick off from ramps, having a wide variety of slopes, a pulse corresponding to the time the ramp crosses a certain voltage.

Since the back-diode (BD-4) takes no more than 0.33 ma (out of 5) at the trigger voltage (50 mv), it will not affect the firing level by any more than this over a wide range of trigger slopes. The ability to guarantee switching depends upon the current drawn at the valley of the tunnel diode (TD) by the BD. The BD-4 draws at least 5 ma by this voltage, and since switching would be assured even if it were only to draw 1 ma (Iv), the circuit is safely mono-stable.

This circuit has proven useful in several applications involving triggers of varying slopes. The combination of a 20 ma tunnel diode with a 1 ma Back-Diode (BD-1) is also useful.

OPTIMUM WRITING-RATE TECHNIQUES FOR OSCILLOSCOPE PHOTOGRAPHY



A competent technician should be able to provide satisfactory Polaroid* pictures of single-shot traces on an oscilloscope at the maximum speed and amplitudes for which the trace can be resolved.

There are a number of critical factors in an oscilloscope recording system which are under the control of an operator. It is necessary to employ to the optimum each of these factors for best results. P31 or P2 phosphor can be used successfully; P11 is not as effective because the phosphor cannot be prefogged. The trace must be properly focused; keep critical portion of display centered on the crt, where the system writing rate is highest. Display a pattern traversing the screen at an angle of about 45°, at a repetition rate (60 cycles or less) just rapid enough to permit focusing while observing the trace through the viewing channel or a light-tight viewing hood. Adjust the intensity to just below the point where a stationary spot appears, then focus for the finest trace. Reduce the intensity as necessary to maintain good focus.

A Tektronix C-19 camera with the fastest lens (f/1.5) and a 2-to-1 image reduction is preferred. Use the widest lens aperture but be sure the *camera* is precisely focused; at widest aperture opening the depth of the field is less than a millimeter. It is sometimes worthwhile to take a shot of a slow trace to prove out the optical focus.

If Type 47 Polaroid film is used, it should be prefogged to where the background is dark grey, rather than black. To prefog Type 47 film: Swing the camera away from the scope, tape a sheet of bond paper across the front of the camera, and shine a 60-watt lamp toward the paper from a distance of three feet. Expose the film at f/16 for 1/50 second. If the fog level is too high, increase the distance from the lamp, or decrease the time to 1/100 second. It would be well to try one or two shots to get an optimum degree of fog. Use the same technique with Type 410, but reduce the exposure to 1/100 second.

Polascope* Type 410 should be used if available. After loading the camera, develop an unexposed picture to determine the condition of the film. If the film is fresh, and has been properly stored, the print will be a definite black. Fresh film should be prefogged as directed above. If the film is not fresh, the unexposed print will be mottled grey, and prefogging will not provide further gain, however, the speed of a stale film may be as fast as that of prefogged fresh film.

For high speed traces you will need to get additional light gain by "prefogging" the P2 phosphor. This procedure provides an excitation bias for the phosphor. With the camera in place on the scope and everything ready for the exposure, open the viewing-tunnel door and shine a 60-watt lamp into the viewing tunnel in a manner that will expose the phosphor area to be occupied by the trace. The lamp should be about three feet away from the tunnel, and held for a few seconds. Then close the viewing-tunnel door, wait for about 15 seconds (for P2), open the shutter and trigger the scope in the usual manner. If you use P31 phosphor, wait only about two seconds before taking the shot.

In general, use:

Smallest f stop (widest aperture opening).
Low amplitude display; one or two cm.
A 45° trace to focus beam.
Fresh film.
Type 410 film.
Prefogged film.
20-second development.
Centered display.
High intensity, but sharp trace.
Trace carefully focused at low repetition rate.
Precise camera focus.

*Polaroid and Polascope are registered trade marks of the Polaroid Corporation.

? LARGER INPUT CAPACITORS FOR THE TYPE 503 AND TYPE 504 OSCILLOSCOPES ?

The Type 503 and Type 504 Oscilloscopes use 0.022 µf capacitors in their input circuits. From time to time we receive inquiries about the installation of 0.1 µf capacitors in these circuits. While 0.1 µf capacitors in these positions may be an advantage in some cases, people making such a request should consider the information that follows. It may help them to reach the right decision.

Usually the basis for such a request is extension of low-frequency measurement accuracy. We offer here a timely reminder: A 10X probe will accomplish almost the same purpose as will the 0.1 µf input capacitors! Simply using a 10X probe extends the low-frequency 3 db point down by a factor of 10. The Type 503's 22 msec time constant becomes 220 msec (—3 db at 0.7 cps) when you attach a P6000, P6006, or P6017 probe. A word of caution though; don't assume this also applies to a 100X probe! The P6002, 100X probe, for instance, because of the divider circuit used, does not extend the time constant by 100, but only about 10%.

The 0.022 µf capacitors used in the Type 503 and Type 504 Oscilloscopes offer these advantages:

1. Lower leakage: For any given style of capacitor, the leakage specification is given in "megohm-microfarads", which says that as capacitance goes up, leakage resistance goes down. An input capacitor leakage resistance of 100,000 megohms will cause a trace displacement of 1 mv (in the Type 503, up to 1 cm) per 100 v applied. The 0.022 µf capacitor gives us a leakage, lower by a factor of 4, than the leakage we would get in the same capacitor in the 0.1 µf size.
2. Amplifier protection: AC-coupling is normally used when measuring small signals riding on high DC voltages. When the input is connected to a high DC voltage, the amplifier receives a severe overload signal, the duration of which is determined by the input coupling time constant. The shorter this time constant, the better reliability we get out of the amplifier.
3. Greater operator convenience: With a 0.022 µf input capacitor, when you overdrive the amplifier the trace will return to the crt screen in less than a quarter of the time required with an 0.1 µf input capacitor.

In terms of low-frequency measurement accuracy Table 1 compares the error introduced by the capacitor for 0.1 µf and 0.022 µf inputs, with and without 10X probes. Since capacitor values are typically ± 5% to ± 20%, the same order of variation should be expected in the frequencies shown in the table.

The lower section of the table shows the pulse or square wave width for a given amount of tilt for the same four cases.

If you really need 0.1 µf input capacitors, Tektronix-made Mylars are probably the best bet in what we have available. These capacitors carry a nominal 10% tolerance. Tektronix part number is 285-556. To preserve the original balance specifications in the Type 503, pairs should be selected for 5% match. For even better differential performance at low frequencies, these capacitors are available already matched in pairs to within 1% of each other under Tektronix part number 295-054 pair.

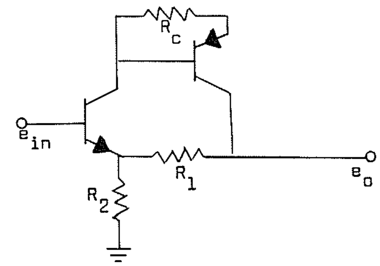
	0.022 µf		0.1 µf	
Measurement Error due to Capacitor	From Signal Source < 1 k	With 10X Probe	From Signal Source < 1 k	With 10X Probe
1%	50 cps	5 cps	11 cps	1.1 cps
2%	35 cps	3.5 cps	7.8 cps	.78 cps
3%	30 cps	3 cps	6.4 cps	.64 cps
5%	22 cps	2.2 cps	4.8 cps	.48 cps
10%	15 cps	1.5 cps	3.3 cps	.33 cps
20%	10 cps	1 cps	2.1 cps	.21 cps
30%	7.2 cps	0.72 cps	1.6 cps	.16 cps
	(above) Frequency for given error (below) Pulse width for given tilt			
Tilt				
10%	2.2 msec	22 msec	10 msec	100 msec
5%	1.1 msec	11 msec	5 msec	50 msec
2%	0.4 msec	4.4 msec	2 msec	20 msec
1%	0.2 msec	2.2 msec	1 msec	10 msec

TABLE 1

OUR APOLOGIES

In the last (June '63) issue of Service Scope several errors occurred that are serious enough to warrant our calling them to the attention of our readers.

In the article "Transistors in Degenerative Feedback Combinations," on page one, paragraph three, the phrase "three-port devices" should read "three-terminal devices." On page two, Figure 2(a) the statement "Z_o is less than R, A is greater than R_o/Z_o except in (a)" applies to all four diagrams in Figure 2. Therefore, it should be included as part of the caption for Figure 2. Next, in part (b), Figure 2, "$e_o = -i_{in}^2 R$" should read "$e_o = -i_{in} R$" and "$P_o = i_{in} R\left[\frac{R}{Z_o} + 1\right]$" should read "$P_o = i_{in}^2 R\left[\frac{R}{Z_o} + 1\right]$". Also in Figure 2, but in part (c), "$e_o = i_{in}^2 R$" should read "$e_o = i_{in} R$." Then on page two but in Table 11, under the column headed "Transfer" and in the "Impedance" box, "Low output Z" should read "High output Z." Turning now to page three, Table III, the first circuit shown here contains a "funny" looking transistor—one with two emitters. Correct this by removing the emitter on the lower leg of the upper transistor and placing it on the lower leg of the lower or "e_{in}" transistor as shown in the diagram below.



Finally, in the article "High Rep-Rate Bursts from Multiples of Type III Pulse-Rate Generators," we neglected to identify the resistor to ground in Figure 2, page seven. This resistor should be identified with a lower case "r".

Fairness compels me to confess that I must bear the responsibility for the errors which marred these two fine articles. The errors were not present in the authors' original manuscripts.

Please accept my sincere apologies,

The Editor.

A MEASUREMENT TECHNIQUE USING A Z UNIT WITH 1000 MEGOHM INPUT

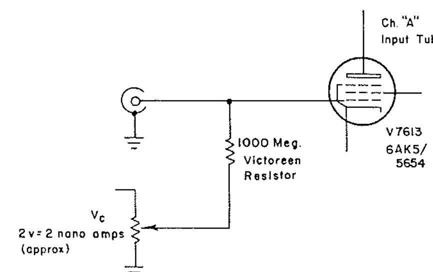
Charlie Rhodes, Tektronix project Engineer, contributes a technique for making measurements not ordinarily possible with an oscilloscope because of circuit loading by the usual 1 or 10 meg input resistor. This technique requires the use of a modified Type Z Plug-In Unit in a Type 530, Type 530A, Type 540, Type 540A, Type 550, or Type 580-Series Oscilloscope.

The Type Z Unit is modified to give an input resistance of 1000 megohms by installing a 1000 megohm resistor between the A input grid and the slider on the Z Unit's Comparison Voltage potentiometer. Disconnect everything between the A input grid and the A channel UHF input connector. Use a stiff piece of wire and route it in the air to bring input signals directly to the grid (pin 1) of V7613, a 6AK5/5654 tube. Set the VAR. ATTEN. control to A ONLY.

The input resistance is now, of course, 1000 megohms. The usual 2 nanoamps of grid current are supplied by adjusting Comparison Voltage to about —2 volts; the trace is on screen and quite stable.

A current of 50 picoamps through 1000 megohms resistance equals 50 mv or 1 cm deflection. Input sensitivity is 50 picoamps/cm. Extremely high values of leakage resistance can, therefore, be measured dynamically.

Capacitor-type inputs such as sonar transducers, strain gauges, etc., are potential applications.



Schematic showing the Type Z Unit input modified to give an input resistance of 1000 megohms.

USED INSTRUMENTS FOR SALE

1 Type 531A Oscilloscope, s/n 9199 and a Type CA Plug-In Unit, s/n 30886. F. C. Shidel, 4620 Ethel Avenue, Sherman Oaks, California.

2 Type 525 Television Waveform Monitors, s/n's 1204 and 1216. Price: $750.00 each. Information on these instruments can be obtained through Dean Butts, Tektronix, Inc., 11681 San Vicente Boulevard, Los Angeles 49, California. Phone: GR 3-1105 or BR 2-1563.

1 Type 502 Oscilloscope, s/n 6890. Kaiser Foundation Hospital, 4900 Sunset Boulevard, Los Angeles 27, California. This instrument has seen very little, if any, use.

1 Type 560 Oscilloscope, s/n 229 and 2 Plug-In Units—a Type 60, s/n 372, and a Type 67, s/n 189. These instruments are in new condition. Contact: David Hammel, 5 Devon Court, Riverton, New Jersey. Phone: Area Code 609, 829-1561.

1 Type 561A Oscilloscope, s/n 7177, approximately 4 months old. Will discount 15% from the purchase price of $399.50. Contact: Dr. von der Groeben, Stanford Medical Center, Department of Cardiology, Palo Alto, California.

1 Type 545A Oscilloscope and 1 Type CA Plug-In Unit. Instruments are about two years old. Louis G. Fields, Starling Corporation, 2047 Sawtelle Boulevard, Los Angeles 25, California. Phone BR 2-7131.

2 Plug-In Units for Type 530, Type 540, Type 550, or Type 580-Series Oscilloscopes —one 53/54K, s/n 5455, and one 53/54G, s/n 1923. Thorobred Photo Service, Inc., 7618 Sepulveda Boulevard, Van Nuys, California.

1 Type 502 Oscilloscope, s/n 004162, (Purchased in 1962). Boris Stefanov, 5628 Harold Way, #8, Los Angeles 28, California. Phone: NO 3-8011.

1 Type 541A Oscilloscope, s/n 7099, and 1 Type 53/54G Wide Band Differential Plug-In Unit, s/n 2969. Contact: R. Rechter, 11611 Chenault Street, #219, Los Angeles 49, California. Phone 648-4132 or evenings 472-1418.

1 Type G Plug-In Unit (only 8 months old.) Industrial Dynamics Company, 3423 S. LaCienega Boulevard, Los Angeles 16, California. Attn: Ed Wagner. Phone VE 7-3330.

1 Type 541A Oscilloscope, s/n 7763; 1 Type CA Plug-In Unit, s/n 2199; 1 Type 53/54K Plug-In Unit, s/n 988; and 1 Scopemobile (model not given). Contact: Philips Applied Research, 1640 21st Street, Santa Monica, California.

Richard D. Brew and Company, Incorporated offer the following Tektronix equipment:

1 Type 180 Time-Mark Generator, s/n 756

1 Type 180S1 Time-Mark Generator, s/n 1033

2 Type 121 Wide-Band Amplifiers, s/n 2701 and 2703

1 Type 127 Preamplifier Power Supply, s/n 413

1 Type 551 Dual-Beam Oscilloscope, s/n 369

1 Type 511AD Oscilloscope, s/n 1547

All this equipment is in good working condition and will meet Tektronix manual specifications. Contact Samuel A. Oliva, Electronic Division, Richard D. Brew and Company Incorporated, Concord, New Hampshire. Phone: Area Code 603, 225-6605.

1 Type 512, s/n 1691, in very good condition. Electronic Engineering Company, 1601 Chestnut Avenue, Santa Ana, California. Attn: A. Harman, Purchasing 1 Agent. Phone: KI 7-5501.

1 Type 317 Oscilloscope— $650.00, and 1 Type 105 Square-Wave Generator—$325.00. Both instruments were purchased in 1960, but never used. J. George Rakonitz, 565 Willow Road, Menlo Park, California.

1 Type 517 Oscilloscope, s/n 738. Wyle Laboratory, 128 Maryland Avenue, El Segundo, California, Attn: Ray Prasta.

1 Type 570 Electron Tube Curve Tracer, s/n 5231. F. Andrews, Canadian Marconi Company, 90 Trenton Avenue, Montreal, Quebec, Canada. Phone RE 8-9441.

1 Type 532 Oscilloscope, s/n 5100; 1 Type 53G Plug-In Unit, s/n 100; and 1 cart. S. P. Dobisz, N.J.E. Corporation, 20 Boright Avenue, Kenilworth, New Jersey.

1 Type 511A Oscilloscope. Make us an offer! Chief Engineer WPIX-TV, 220 E. 42nd Street, New York, 17, New York. Phone: MU 2-6500.

4 Type FM122 Low-Level Preamplifiers, s/n's 6923, 6924, 6925, and 6926; and 1 Type FM125 Power Supply, s/n 1076. These instruments are practically new. They have seen only about one hour service and are in "original-equipment" condition except for holes drilled in the back panel to accommodate input and output connectors. Please direct your inquiries to John West, Tektronix, Inc., 442 Marrett Road, Lexington, Massachusetts. Telephone number is VOlunteer 2-7570.

MISSING INSTRUMENTS

The "grey market" for oscilloscopes has evidently sailed out of the doldrums and is *stealing* along at a good clip. Since the July issue of Service Scope, in which we had only one "lost" instrument to report, we have received notices of six presumably stolen instruments.

Our Long Island Field Office reports a C-12 Oscilloscope Camera and carrying case disappeared from the Presbyterian Hospital. Mr. Sheridan, Chief of Security of the hospital, gives the serial number of this camera as 1474. The camera and case belong to the College of Physicians and Surgeons of Columbia University Radiology Research Lab and was purchased on an Atomic Energy Commission grant.

Information regarding the whereabouts of this camera should be telephoned to Mr. Sheridan at 212-579-2145 or Dr. William Gross at 212-579-3545.

Field Engineer Bill Lewis with our Chicago Field Office lost two oscilloscopes plus plug-ins to car prowlers in the Des Plaines, Illinois, area. While Bill was assisting a customer to repair an instrument, thieves damaged a vent window, unlocked the car door and removed a Type 535A Oscilloscope, s/n 27138, with a Type CA Plug-In Unit, s/n 46850; and a Type 561A Oscilloscope, s/n 5984, with two Plug-In Units; a Type 3A75, s/n 415, and a Type 3B3, s/n 147.

Information regarding these instruments should be relayed to your Tektronix Field Engineer or local field office.

A Type 545 Oscilloscope, s/n 35888, along with a few other instruments totaling $4,000 was removed from the laboratory of the Puget Sound Bridge and Dry Dock in Seattle, Washington. This loss occurred around the last of January of this year, but the information did not reach your editor until just recently. Ernie Hiser, Supervisor with the Puget Sound Bridge and Dry Dock company would appreciate hearing from anyone with information regarding these missing instruments.

A Type 317 Oscilloscope, s/n 1848, was apparently stolen from a motel in Kankakee, Indiana. This instrument is the property of the Shell Oil Co., 8500 North Michigan Road, Indianapolis 8, Indiana. Mr. George Axmann, telephone number AX 1-7440, ext. 62 is the man to contact if you have information regarding this instrument.

Western Scientific of 1200 W. Olympic Boulevard in Los Angeles suffered the loss of two Tektronix instruments recently. A Type 107 Square Wave Generator, s/n 2298, and a Type 180A, s/n 9164, were apparently stolen out of one of their trucks. Western Scientific will appreciate any assistance our readers can give them in helping to locate these instruments.

A very brief message from our Lathrup Village Field Office states succinctly that a Type 310A, s/n 017915, disappeared from the Toledo Scale Company's premises in Pomona, California. Despite the terseness of the message, we are sure the Toledo Scale people will appreciate any information you have that will help them locate their oscilloscope.

USED INSTRUMENTS WANTED

1 Type 310 Oscilloscope. Please contact Mr. Griffin, Filmotype Corporation, 7500 McCormick Blvd., Skokie, Illinois. Phone: OR 5-7210, Area Code 312.

1 Type 514/AD or Type 531 Oscilloscope. Frank Stabile, 1560 Brande Avenue, Anaheim, California. Phone: PR 4-5934.

1 Type 515A or Type 317 Oscilloscope. William Skidmore, 10756 Willworth Avenue, Los Angeles 24, California. Phone: GRanite 3-0403.

1 Type 515A Oscilloscope. Joe DeMichael, 12 New Haven Avenue, Derby, Connecticut. Phone: RE 5-5253.

1 Type 502 Oscilloscope. Oliver W. Osborne, American Geophysical & Instrument Co., 16440 S. Western Avenue, Gardena, California. Phone: FAculty 1-2634.

1 Type 515 Oscilloscope. Tom Burroughs, 557 Riford Road, Glen Ellyn, Illinois. Phone: 727-3441.

1 Type 515 or 514AD Oscilloscope. Instrument need not be in working condition but should be in good mechanical condition and electrically repairable. Contact: Chuck Keating, 23 S. E. 81st Street, Portland, Oregon, Phone: ALpine 3-9780.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

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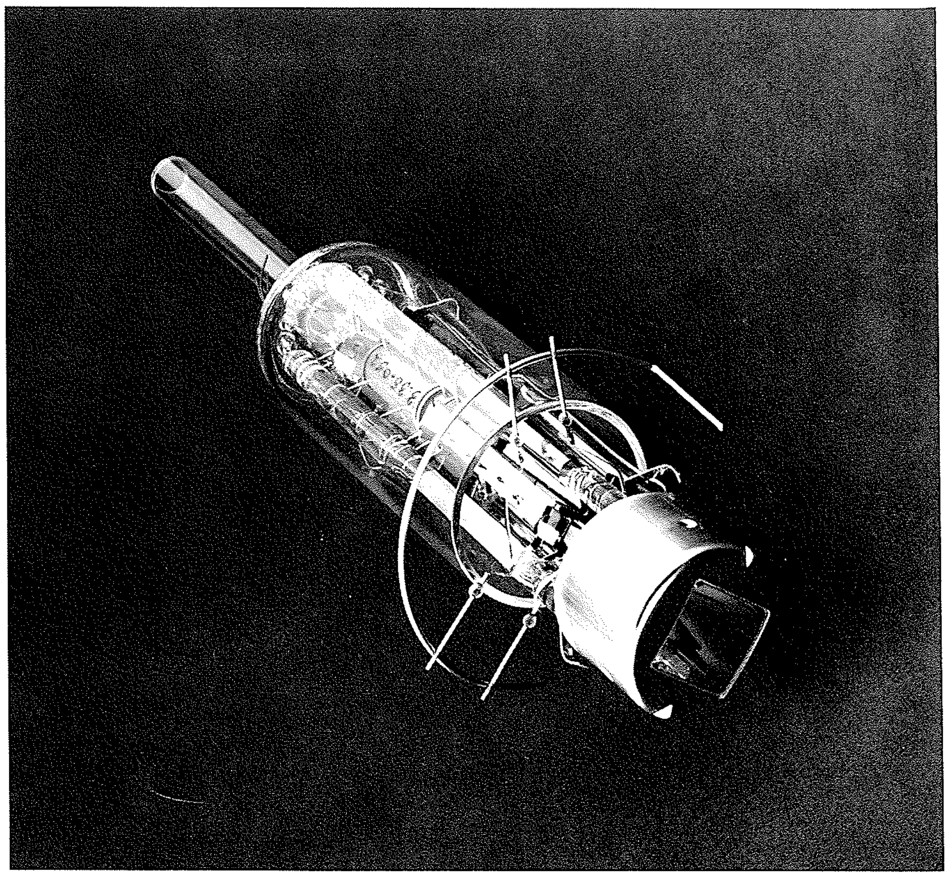
CRT-Design Review

Mesh and Frame-Grid Characteristics

By Geoff Gass
Tektronix Staff Field Engineer



FRAME-GRID GUN ASSEMBLY READY FOR SEALING INTO THE CRT ENVELOPE

Mesh and frame-grid crt's have come into fairly wide usage in the oscilloscope industry in the last few years. The author outlines the theory of their operation and the advantages and disadvantages from the oscilloscope user's point of view.

The idea of interposing an electrostatic shield between the post-deflection accelerator and the deflection plates of a crt has been around for sometime, as a means of increasing deflection sensitivity of a high-accelerating-potential crt. The British were among the earliest users of "mesh" crt's in general-purpose laboratory oscilloscopes. One manufacturer (Marconi) has employed mesh tubes for several years now, producing instruments with 10 kv acceleration, yet having deflection amplifiers no more complex than might be required for a 4 kv conventional pda (post-deflection-accelerator) crt.

In the past two years, several American manufacturers also have begun to use mesh design— particularly in crt's for wideband instruments where amplifier gain and voltage swing are at a premium. The recently introduced Tektronix Type 647 Oscilloscope uses a highly-developed frame-grid design crt. This crt, housed in a very-compact and rugged instrument, provides 50 Mc performance with 14 kv acceleration.

The mesh or frame-grid is not, however, a magic cure-all for oscilloscope bandwidth, sensitivity, and scan (picture size) problems. Its use in any given situation depends on the particular instrument-performance compromises that are allowable.

In general, the bad effects of the mesh are larger spot-size, lower writing rate, and a shadow-pattern that can be seen on the phosphor when the spot is defocused. The good effects are high sensitivity (for a given tube length and accelerating potential), less edge-defocus, and the possibility of using post-deflection acceleration in a rectangular crt — which has not as yet become practical in the conventional tube types. The mesh also allows the designer to obtain a fairly high level of performance in a relatively *short* crt, making for instrument compactness.

How it Works

The mesh or frame-grid is an electrostatic shield, just beyond the deflection plates in a crt, which performs two functions: It acts as a shield to prevent the post-deflection accelerating fields from reaching into the deflection plate structure and compressing the deflection (Figure 1), and it also acts as a field-*forming* electrode to give a positive curvature to the accelerating fields (Figure 2), which may be used to cause an effective *expansion* or *magnification* of the deflection. The first of these effects results in a sensitivity increased by a factor of about two with a 10 kv tube, since the compression effect in the conventional tube is of this order. The expansion effect is determined by the curvature and placement of the mesh and the shaping of the accelerating field between the mesh and the phosphor. Achievement of 10% to 40% deflection magnification is possible from this latter effect.

The entire concept is quite simple (in theory). An electron beam will always be accelerated in the direction of the highest potential *gradient*. In the conventional pda crt, the accelerating field of the post accelerator (helix) reaches down well into the deflection structure; if the equipotential contours are plotted, it becomes immediately apparent that, because of the deformation of the field by the presence of the deflection plates, the highest gradient (shortest distance between equipotential lines) for a deflected beam is not in the direction of the original deflection, but at an angle tending back toward the center of the screen.

Near the deflection plates, where the beam has low energy, it is most easily bent by the curvature of the accelerating field. Out near the phosphor, where — because the voltage gradient of the helix stops about an inch short of the phosphor — the contours are bent in a way to have a magnifying effect on the beam, the beam already has so much energy that the incremental magnifying effect is negligible. The net effect in the conventional tube is *compression* — a linear compression if the tube is properly constructed, not the nonlinear sort of compression for which a tube would be rejected.

In the mesh-type crt, the mesh serves to *shape* the accelerating field so that the greatest accelerating potential gradient beyond the mesh is pretty much in line with the angle of deflection. Thus, the beam is accelerated in the same direction as it has been deflected. If the field lines just outside the mesh have a radius of curvature shorter than the distance from the mesh to the effective center of deflection in a given plane, the deflection will be magnified in that plane. If the radius of curvature is longer, there will be compression, though not as much as in a conventional tube.

It is possible to shape the mesh and helix in such a way that the post-deflection accelerating field has almost no effect on deflection sensitivity, the deflected beam entering the acceleration field at nearly a right angle to the equipotential lines for all angles of deflection. In a case like this a scope could be equipped with a front panel "+Hi volts" knob, and the post accelerator varied at will. However, there are other problems outlined below which make this less than practical.

Since to obtain optimum performance a very high-gradient accelerating field must be used with a mesh-type tube, it is possible to compress the accelerating helix into a very short distance . . . such as the round portion of the neck of a rectangular-faceplate crt, leaving the forward rectangular portion of the crt a "free-fall" area, where there is no further acceleration (the faceplate and interior of the crt are maintained at the maximum acceleration voltage).

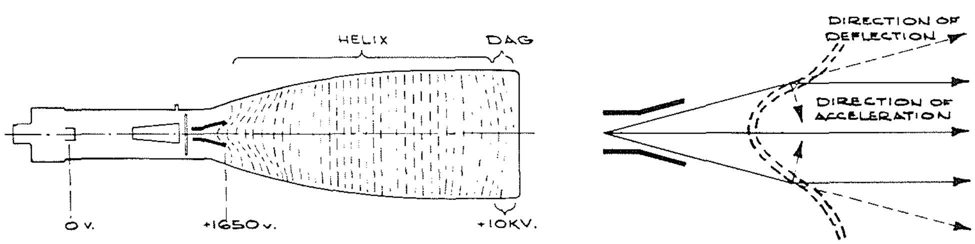


FIGURE 1. CONVENTIONAL PDA CRT.

Curvature of equipotential lines of accelerating field near deflection structure reduces effective deflection by refracting beam. Beam tends to cross equipotential line at 90° angle. Actual refraction effect depends on energy (acceleration) of the beam before it reaches the "line". Thus, the "positive" curvature at the phosphor (caused by the "fringing" of the helix field here) has little magnifying effect; curvature at plates has large compression effect.

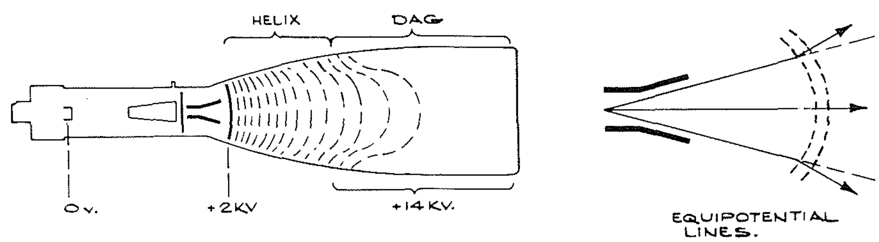


FIGURE 2. MESH-TYPE CRT.

Very strong accelerating field gradient may be used, since mesh prevents accelerating field from penetrating deflection area. Depending on radius of mesh and equipotential line curvature, magnification of deflection may be obtained. Magnification occurs when radius of mesh and field curvature is less than distance from mesh to center of deflection.

Mesh versus Frame-Grid

The post-acceleration screen may be made by either of two techniques, known as mesh and frame grid.

The mesh — though it is more often an electro-formed foil structure than an actual wire gauze — has conductors running in both planes. Its chief advantage is that it may be curved in both planes, spherically or with unequal curvature as described, to obtain the desired acceleration field curvature. It also is capable of dissipating more readily the heat generated by interception of the beam. Its chief disadvantage is that it does intercept more (40 to 50% in a typical 500 lines/inch structure) of the beam current, and it defocuses the spot in both the X and Y axes.

The frame-grid has conductors running in one direction only. Its chief advantage is substantially less beam intercept for a given spacing (around 15% in a typical 500 lines/inch structure) and spot defocusing in one axis only. Its chief disadvantage is that it can be curved in one plane only, requiring special techniques to obtain optimum deflection sensitivity in both planes.

Limitations

As mentioned before, the mesh idea is not a cure-all. For all of its advantages in gaining deflection amplifier simplicity and low power for wide-band, wide-scan, high-performance scopes, the mesh tube suffers from some basic limitations which require accepting some fairly serious compromises in its use. Primarily, the limitations relate to spot size and writing rate.

The chief purpose (other than the psychological one) in providing a high-potential post-deflection accelerator is to put beam *power* into the spot. To the extent that the tube designer can increase beam power (kv x μa) faster than he increases spot size (area), he increases both visual and photographic writing rate . . . at least over a nominal range.

The mesh not only intercepts 15 to 50 percent of the available beam current, as

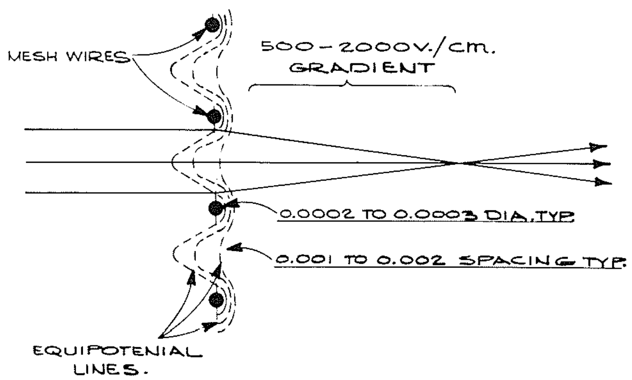


FIGURE 3. ACCELERATION FIELD OF THE MESH STRUCTURE.

Small beam-defocusing lenses form at each mesh aperture. The larger the aperture or the higher the field gradient, the worse the defocusing. The effect is exaggerated and simplified here; typically, beam may cover 15-20 apertures; spot size will increase by a factor of 2 in perhaps 8" throw. Frame-grid causes this type of defocusing in one axis only.

mentioned above, but it also provides a larger spot (under the same general conditions) than the conventional pda tube, for two reasons:

(1) Lack of compression: The same compressing effect the post-accelerator field had on the deflection, it also had on the spot size. Reduce this compression effect, and the spot grows larger*.

(2) Accelerating fields penetrating the mesh: The spacing of the wires or conductors of the mesh is made very close, for two reasons: (a) The mesh itself tends to throw a shadow pattern on the screen, so this pattern should be made as fine as possible; and (b) the larger the holes in the mesh, the deeper the accelerating fields may penetrate through the mesh into the deflection area. The effect of this penetration (Figure 3) is defocusing of the spot by accelerating different parts of the beam in different directions. The closer the spacing of the conductors of the mesh, the less penetration a given gradient field will have, and hence the less defocusing of the spot. Unfortunately, at just the point where the spacing is correct for 0% defocusing, the beam intercept by the mesh is 100%, and there's no spot. So some compromise between beam intercept, mesh spacing, and accelerating field gradient must be arrived at which will provide usable spot size and writing rate.

* To this extent, adding the mesh has about the same effect as *lengthening* the crt in the area beyond the deflection plates. A "long-throw" crt has greater effective deflection sensitivity, a larger spot, and poorer writing rate than a "short-throw" crt, other parameters held equal. Most of both the good *and* bad effects, then, of a mesh tube can be achieved in a long-throw crt, provided that length is no problem.

Compromise operating conditions: Because of the spot size and writing rate problems, it is pointless simply to add a mesh to an existing crt design so as to be able to advertise a high accelerating potential. With all other parameters held equal, adding a mesh to a crt, increasing its deflection sensitivity by a factor of (say) 3, will cause on the order of a 4 times increase in spot size and an even greater reduction in writing rate.

To recover the original desirable crt characteristics, it is generally necessary to do three things:

(1) Increase gun voltage (cathode-to-deflection-plates) for a better "original" spot size.

(2) Increase cathode "loading" (milliamperes per cm^2 of usable cathode area) by increasing the effective G_m or changing the cutoff voltage of the crt, so that more beam current is available.

(3) Increase the post acceleration potential, to increase the number of watts per cm^2 delivered to the spot on the phosphor.

By the optimum utilization of these three techniques together, a mesh crt design with overall performance comparable to that of a conventional design can be obtained, together with the mesh tube's advantages of possible short length, high sensitivity, and adaptability to rectangular (space-saving) format. But none of the mesh tube's apparent advantages can be individually maximized without severe sacrifices in one or more of the normally desirable characteristics of writing rate, spot size, good geometry, and low power supply (heater and accelerator) requirements.

Miscellaneous Characteristics

Flare: Deflection-plate bounce in a mesh-type crt produces much more *even* illumination of the phosphor than in a conventional tube, because of the scattering effect the mesh has on electrons arriving from odd angles. The flare characteristics is sometimes useful for pre-fogging the phosphor and film for photography.

Shadow Pattern: Figure 3 shows how the mesh tends to defocus the spot by producing a convergence and crossover short of the screen. This applies, of course, to a spot which is properly focused. By changing focus, the beam can be caused to enter the mesh at the diverging angle which will just compensate for the lens effect of the mesh apertures, putting the convergence out to the plane of the phosphor. The result is a large, defocused spot containing a fairly well-focused image of the mesh.

ANALYZING SYSTEM MECHANICS AND IMPROVING MECHANICAL DESIGN WITH **CATHODE-RAY OSCILLOSCOPES**

"Oscilloscopes are versatile engineering tools for shock and vibration analysis, bearing and lubrication studies, and virtually every other area of mechanical research and development. They are basically electronic graph-drawing instruments capable of handling and displaying events or signals one billion times too fast for display on meters, recorders and similar mechanical devices.

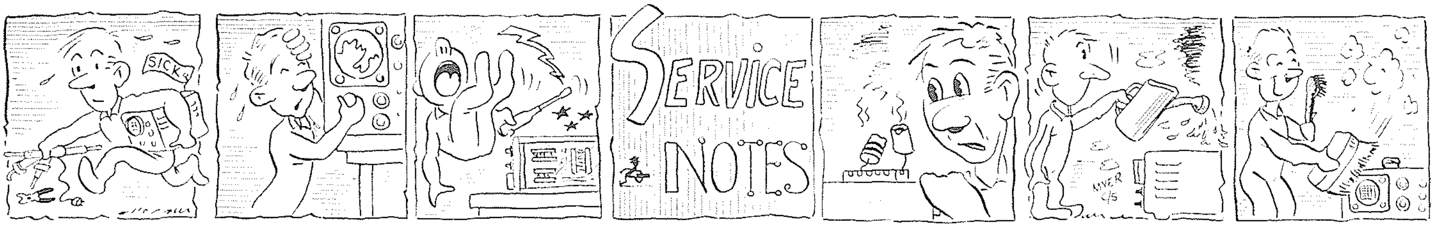
The commercial availability of transducers for conversion of mechanical, thermal, optical and chemical phenomena into electrical signals has extended the utility of the oscilloscope well beyond the electrical industry. This article analyzes the relationship between an incident and a system response in terms of mechanical engineering problems, the available measuring tools, the information needed for planning and evaluating data, and gives an indication of system costs and some practical examples of oscilloscope measurements".

In this manner, Will Marsh, Tektronix Staff Engineer and author of the article "Analyzing System Mechanics and Improving Mechanical Design with Cathode-Ray Oscilloscopes" introduces his subject to readers of "Machine Design". The article appeared in the June 6, 1963 issue of that magazine.

People in the mechanical industry are becoming increasingly aware of the possibilities of an oscilloscope as a means of obtaining precise (and sometimes otherwise unobtainable) information. For such forward thinking people, Will's article carries a special appeal.

Reprints are available from your Tektronix Field Engineer of local Field Office (see list of Tektronix Field Offices on page 7 of this Service Scope).

(*REPRINT AVAILABLE*)



TYPE 3A74 FOUR-TRACE AMPLIFIER UNIT — GRID-TO-PLATE SHORT

A grid-to-plate short can develop in V533B (a 6DJ8 tube) in the Type 3A74 Unit and cause considerable damage to the unit by taking out several diodes, resistors and transistors. Replacing R593, a 1 k, ½ w, 10% resistor (in the plate circuit of V533B) with a 10 k, ½ w, 10% resistor will limit the average plate current to 30 ma.

This information applies to all Type 3A74 units presently in the field. Serial number of the unit in which the factory-installed mod became effective will be announced later.

TYPE 561 and RM561 OSCILLOSCOPES — INTERMITTENT INTENSITY MODULATION

Some Type 561 and Type RM561 Oscilloscopes can develop an intermittent-intensity-modulation problem. The problem stems from R842, a 12 meg, 2 w, precision resistor in the crt high-voltage-divider string. When R842 goes out completely, the operator will have no control over the intensity; the beam will be full on. R842 is rated at 2 kv. At turn-on time the voltage across R842 goes up to 2.5 kv and some of these resistors just can't stand it. Replacing R842 with a Pyrofilm, 12 meg, 2 w, precision resistor will overcome this problem. The Pyrofilms carry the same Tektronix part number (310-568) as the originally installed resistor, but are rated at 5 kv.

This information applies to Type 561's below s/n 1165 and Type RM561's below s/n 230.

WELWYN RESISTORS — Handle With Care

Welwyn precision resistors can be easily damaged if they are handled with pliers. Puncture of the moisture-resistant lacquer and pressure on the resistance element and ceramic substrate from holding the resistor body with pliers have been identified as the cause of a number of failures. It's a good idea to avoid holding any brand of carbon film resistors by the body with pliers.

TYPE 3S76 DUAL-TRACE SAMPLING UNIT

The 0.1 μf, 200 volt discap used in four locations (C1073, C2073, C2277 and C2279) in early Type 3S76 Dual-Trace Sampling Units has developed a reliability problem. These discaps show a tendency to short out. When they do, damage to the high-voltage supplies can occur — sometimes to a considerable extent.

None of the other presently available discaps of this value and rating will fit physically, so we've changed the values. C1073 and C2073 now use a 0.02 μf, 500 volt discap (Tektronix part number 283-006); C2277 and C2279 now use a 0.001 μf, 200 volt discap (Tektronix part number 283-067).

This information applies to Type 3S76 Units with s/n's below 409 with some exceptions. A physical check of C1073, C2073, C2277 and C2279 will help to determine if your instrument is one of these exceptions.

LOW-FREQUENCY COMPENSATION — DON'T OVERDO IT!

A slight misadjustment of the low-frequency compensation in a Type L, Type ML or Type B Plug-In Unit or a Type 310, Type 310A, Type 316 or Type 317 Oscilloscope may cause a low-frequency *boost* of as much as 3 db at about 5 cps when a probe is used.

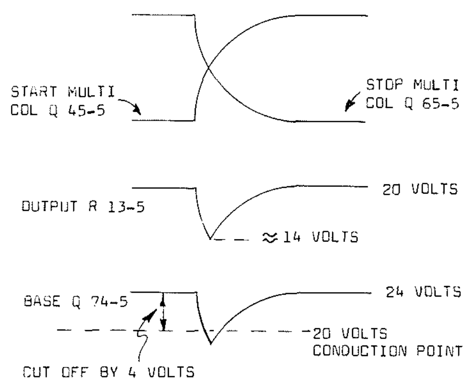
The problem is this: There are *two* capacitors in the circuit — the input coupling capacitor and the preamplifier coupling capacitor. The LF Comp. or LF Adj. controls are intended to compensate only for the second (preamplifier) time constant so the response will be substantially the same as in the regular AC-coupled positions. If the compensation is adjusted so as to partially correct the *input* time constant as well, the use of a probe (which increases the input time constant) will result in low-frequency boost. A good procedure is to use a strap to short out the input-coupling capacitor while adjusting the LF compensation. Then remove the strap and double-check the result by observing a 50 cps square wave using a 10X probe. Set the VOLTS/DIV. control in the most sensitive position and the INPUT control in the AC position. There should be no upward tilt to the waveform, though the flat-top may be somewhat bowed. This bowing represents a small, but not critical, boost at low frequencies. Those interested in accurate low-frequency measurements should be careful to verify the exact roll-off and LF boost characteristics of the particular oscilloscope used, if AC coupling is required.

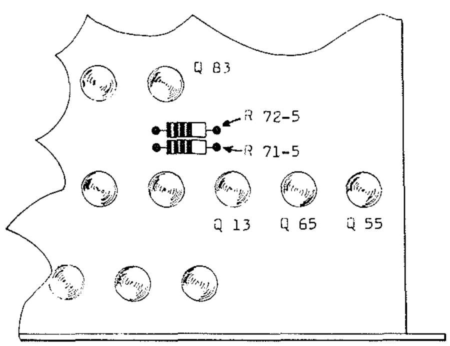
The square-wave adjustment as outlined is probably the best approach; however, we still experience a rise at approximately 5 cps when doing it this way. Those interested in low-frequency sine-wave response, may want to adjust accordingly.

The two plate-load decoupling electrolytics (LF boost circuit) in the X10 amplifier also act to complicate the multiplier time constant.

Many persons prefer the simplicity of using a 10X probe in the first place. This is all right, but the "straight-in" (no probe) operation should be double-checked afterwards.

TYPE 6R1 DIGITAL UNIT —SPURIOUS COUNT





MASTER GATE BOARD

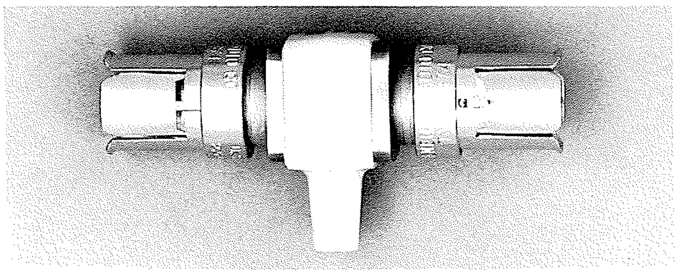
Type 6R1's employing a Model 2A, Series 5, Master Gate circuit board will produce a spurious (one extra) count during the reset phase of the Start and Stop multivibrators. This shows up when making voltage measurements with either a Type 3S76 Dual-Trace Sampling Unit or a Type 3S3 Sampling-Probe Dual-Trace Unit in the vertical plug-in compartment of the Type 567 Digital Readout Oscilloscope. It is most apparent when the MV/DIV control of these units is in any (except the most sensitive) "5" position.

To check for this problem, apply a waveform to the A or the B INPUT of the Type 3S76 (or Type 3S3) unit in the Type 567 and set the unit's MV/DIV control to a "5" position. Set the RESOLUTION control of the 6R1 to AVERAGE OF 10 SWEEPS — HI. Depending upon the INPUT (A or B) to which you applied the waveform, reverse the polarity of the A VOLTAGE or the B VOLTAGE switch of the 6R1. The Nixie tubes should then read 0000 — if they do not, the Master Gate is producing a spurious count.

To correct this condition, — and we suggest here that you refer to the Master Gate schematic in the Type 6R1 manual — replace R72, a 1 meg, ½ w, 5% resistor with a 470 k, ½ w, 5% resistor (Tektronix part number 301-474).

This problem stems from the fact that the Start multivibrator does not completely reset before the Stop multivibrator and produces a 6 volt negative pulse across the R13 resistor. The transistor Q74 is reverse biased by about 4 volts which is not enough to stop the 6 volt pulse. Changing the R72 resistor from 1 meg to 470 k raises the bias of Q74 to 9 volts enabling it to effectively block the 6 volt pulse and thus overcome the problem.

VP-1 50-OHM PICKOFF "T"



The VP-1 is a 50-ohm coaxial tee with GR fittings on each end and a plastic center collar. The collar is formed to provide a branch for insertion of P6034 10X or P6035 100X low-capacity, miniature passive probes.

The VP-1 is designed for use with a Type 4S1, Type 4S2 or Type 3S76 Pulse-Sampling Plug-In Unit as a means of access to a 50-ohm system with minimum disturbance of the 50-ohm environment. The reflection coefficient with either probe in use is less than 2% (capacitive) and without a probe, 2 to 3% (inductive) as seen on a Type 4S1.

Some of the more obvious uses of the VP-1 are as a trigger takeoff and inspection of signals within a 50-ohm system.

SC-87 DRI-FILM EFFECTIVE IN RETARDING METAL-ION MIGRATION

Recent tests indicate that treatment of (new) ceramic strips with General Electric SC-87 Dri-Film will retard metal-ion migration by a factor of 6 or more under conditions of high humidity and atmospheric contamination such as some customers must contend with in their laboratories.

Our Manufacturing Staff Engineers evaluated sample strips in a high humidity atmosphere containing hydrogen sulfide, using no treatment (control group), using silicone grease, and using SC-87. Only one failure was noted in 18 days in five 11-notch strips using SC-87. Three failures (e.g., 1/16 amp fuses blown at 360 v) occurred in the three silicone-grease treated samples; five failures in the five untreated samples, in the first seven days. The one failure on the 18th day in the SC-87 group was easily cured by wiping off a track of black sulfide between notches with a dry cotton swab. The dramatic success of the SC-87 was demonstrated by the fact that the average notch-to-notch resistance of the SC-87 treated strips was significantly higher after the test than that of the untreated strips *before* the test.

Accordingly, we suggest that a customer planning to use a new instrument in a corrosive atmosphere under high humidity, treat the strips with SC-87 prior to use.

There are some precautions to observe:

(1) SC-87 forms its protective film by combining with atmospheric moisture and changing its chemical composition. During this process, it gives off hydrochloric acid. Therefore, the work area where it's applied should be well ventilated, and the treated instrument should be allowed to sit for about 24 hours before turning on. This allows the reaction to complete itself. Precautions should be taken *not* to get SC-87 or its fumes on the skin or in the eyes.

(2) The treatment will be most effective only on a *new* instrument. Where metal-ion migration has already attacked an instrument, the affected area between strip notches can be cleaned in many cases using soap and water (e.g., tooth paste) abrasive, if rinsed well. The strips should be clean and dry before application of the Dri-Film.

(3) The SC-87 should not be allowed to flow onto or into pots, variable capacitors, or switches.

To treat a scope, simply brush the SC-87 along the tops of the ceramic strips. It will flow down between the notches to form a quite durable film after the reaction is complete. The reaction will tend to discolor the tinning of the ceramic strip notches, but will have no other deleterious effects.

SC-87 is available through General Electric Silicone Products Department distribution offices in most major cities.

NEW FIELD MODIFICATION KITS

TYPE 132 and TYPE 133 PLUG-IN UNIT POWER SUPPLIES — SPLIT-PHASE FAN MOTORS

This modification will reduce ac noise apparent when using these power supplies with Type Q Plug-In Units. It replaces the original induction-type fan motor with a split-phase (capacitor start-run) fan motor. The modification applies to Type 132's with serial numbers 101 to 940 and Type 133's with serial numbers 101 to 440.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-310. Price $13.15.

TYPE Z PLUG-IN UNIT — HOOK REDUCTION

This modification reduces "hook" distortion of the signal and improves turret-attenuator reliability. It replaces the AC-DC switches, PUSH-TO-DISCONNECT SIGNAL switches and the input-tube sockets with components made of material with less tendency to impart hook to the signal. It also replaces plastic tubing with Teflon tubing, adds ground springs to ground the turret-attenuator contacts on each side of the contacts in use and provides a different type of turret-attenuator switching contact.

The modification applies to Type Z units with serial numbers 101 to 3563.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-313. Price $29.00.

TYPE 581 AND TYPE 585 OSCILLOSCOPES* — IMPROVED TUNNEL DIODE TRIGGER

This modification extends the triggering range of these instruments out to 100 Mc or more. It installs an improved tunnel diode circuit and TRIGGERING SOURCE switch. The new switch incorporates three new (for the Type 580 Series) triggering modes — INT and EXT HY SYNC and INT AC LF REJ. The INT and EXT HF SYNC modes accept and trigger stably on signals above approximately 100 Mc. The INT AC LF REJ mode affords stable triggering on signals above 15 kc that contain low-frequency noise or line-frequency pickup. It also prevents trace dimming when operating multi-trace plug-ins in the ALTERNATE mode.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-322. Price: $65.00.

*NOTE: This modification replaces Tunnel Diode Modification Kits, Tektronix part numbers 040-242 and 040-270. It applies to Type 581 instruments, serial numbers 101 to 510 and Type 585 instruments, serial numbers 101 to 1070, that have *not* — we repeat, have *not* — previously been modified by the installation of kits 040-242 or 040-270.

If your instrument is in these respective serial-number ranges (and has had modification kit 040-242 or 040-270 installed), you may update it by installing a Triggering Source Switch and Improved TD Trigger Modification Kit, Tektronix part number 040-323, which is described elsewhere in this column.

TYPE 581 AND TYPE 585 OSCILLOSCOPES — IMPROVED VERTICAL OUTPUT TUBES

This modification will decrease compression in the vertical-amplifier output stage. It replaces V1284, a dual-tetrode 7699 tube, with two single-pentode 7788 tubes. It also replaces the crt support-bracket assembly.

The modification applies to Type 581's with Serial numbers 101 to 1500 and Type 585's with serial numbers 101 to 5000. However, on the following instruments, a Vertical Amplifier Standardization modification kit, Tektronix part number 040-275, must first be installed: Type 581, serial numbers 101 to 949 and Type 585, serial numbers 101 to 2584.

Order through your Tektronix Field Engineer or local Field Office, Specify Tektronix part number 040-324. Price $64.05.

TYPE 581 AND TYPE 585 OSCILLOSCOPES — TRIGGERING SOURCE SWITCH AND IMPROVED TD TRIGGER

The benefits and changes offered by this modification kit are the same as those described above for the Improved Tunnel Diode Trigger Modification Kit.

It was designed for Type 581 Oscilloscopes with serial numbers 510 to 1500 and for Type 585 Oscilloscopes with serial numbers 1071 to 5000. These instruments will not accept the Improved Tunnel Diode Trigger Modification Kit.

The Triggering-Source-Switch-and-Improved-TD-Trigger modification kit is intended also for Type 581's, s/n's 101 to 510 and Type 585's, s/n's 101 to 1070 that have had either the 050-242 or the 040-270 Tunnel Diode modification kit installed.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-323. Price: $60.00.

TYPE 5T1 TIMING UNIT — TIME EXPANDER AND GENERAL IMPROVEMENTS

This modification improves the Type 5T1, serial numbers 101 to 996, so as to nearly correspond to the performance of the more recent 5T1A. It does this by replacing the Fast Ramp board with a new one which provides improved linearity of the Fast Ramp waveform, and, by the addition of several new features which are: a TIME EXPANDER control, two new positions ("1000" and "TIMED") for the SAMPLES/CM control, a front-panel screwdriver-adjusted potentiometer and a TIMED POSITION control.

The TIME EXPANDER control is incorporated into a switch assembly in which it is concentric with the SWEEP MODE control. The TIME EXPANDER supplies X1, X10, X20, X50 and X100 "magnification" which does not affect the number of samples per centimeter.

The SAMPLES/CM control with its two added positions, "1000" and "TIMED", is incorporated into a new switch assembly in which it is concentric with the new TIMED POSITION control. This new assembly replaces the old assembly in which the SAMPLES/CM control was concentric with the TIME DELAY (N SEC) control — now obsolete. The "1000" of the SAMPLES/CM control provides greater display resolution. The "TIMED" position provides slow scan for use with Y-T recorders, and, the new front-panel screwdriver-adjusted potentiometer supplies a means of adjusting the TIMED scan speed between the approximate limits of 5 to 8 sec/cm.

The new TIME POSITION control provides the variable time delay for time positioning the signal display when the TIME EXPANDER control is in the X1 position. In the other expanded positions, the TIME POSITION control moves the time "window" anywhere within the original range displayed in the X1 position.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-311. Price: $152.00.

Three Type D High-Gain DC Differential Units, s/n's 19681, 19682, and 19683, shipped by Tektronix, Inc., Beaverton, Oregon, apparently never arrived at their destination. They were new instruments destined for the George C. Marshall Space Flight Center in Huntsville, Alabama. The Receiving Department at the Flight Center has no record of their arrival.

Tektronix, Inc. would appreciate hearing from anyone with information on the whereabouts of these instruments. Information can be reported to any Tektronix Field Office or to Jim Leep, Customer Service Department, Tektronix, Inc., P. O. Box 500, Beaverton, Oregon. Telephone: MItchell 4-0161.

The Electronic Industries Association reports the loss of a Type Z Plug-In Unit, serial number 374. This instrument was lost in a shipment and Mr. G. F. Hohn, Manager of EIA in Newark, New Jersey asks that any information regarding its present location be directed to him. The street address is 32 Green Street. Telephone: MArket 3-7245.

Two Type 503 Oscilloscopes, serial numbers 1467 and 1882, were reported stolen from the International Rectifier Corporation in Los Angeles, California.

Anyone with information on the whereabouts of these instruments should contact Detective Hotchkiss of the West Los Angeles Detective Bureau, Los Angeles Police Department, Los Angeles, California. The Police Report number is 63-507176.

A Type 310A Oscilloscope, serial number 014069, IBM number 892740, disappeared from Clarkson College in Potsdam, New York. This instrument, which disappeared sometime in April of this year, may show up in the Albany, New York area.

Mr. Harry Mang of the International Business Machine Corporation at 1512 Genesee Street in Utica, New York, would appreciate hearing from anyone with information on the whereabouts of this instrument.

Here is another Type 310 Oscilloscope reported as stolen. This one by the International Business Machine Corporation in New Orleans. Serial number of this instrument is 3098. It disappeared from the automobile of one of their Engineers on July 12, 1963. The supposed theft occurred in the New Orleans area.

Information regarding the location of this instrument should be passed on to Mr. Lou Russell, IBM Corporation, 2640 Canal Street, New Orleans, Louisiana. Telephone: 504-523-2011.

The convenient portability of the Type 310 makes this oscilloscope the preferred choice of many legitimate operators. It apparently also offers an irresistable appeal to those unwelcome human parasites who "borrow" or appropriate an oscilloscope without the owner's consent.

At any rate, still another Type 310A, serial number 013632, has come up missing. This one disappeared from the Naval Air Station at North Island. Any information regarding this instrument should be forwarded to the O & R Security Officer, Naval Air Station, North Island, San Diego 35, California. Telephone: 714-435-6611.

USED INSTRUMENTS FOR SALE

1 Type 561A, s/n 6255, 1 Type 67 Time Base Unit, s/n 2932, 1 Type 3A1 Dual-Trace Unit, s/n 1218 and 2 probes. Total price: $800.00. Equipment has seen 661 hours of service. Mr. Jenkins, Don Lee Electronics, Vallejo, California. Telephone: MI 2-8983.

1 Type 533 Oscilloscope, s/n 1783 and 1 Type 53C/54C Plug-In Unit, s/n 20259. Williams and Associates, 4971 Jackson Street, Denver, Colorado.

1 Type 503 Oscilloscope, s/n 478. Howell Runion, 2525 North Pershing Avenue, Stockton, California. Telephone: HO 2-8808.

1 Type 561 Oscilloscope, s/n 648; 1 Type 63 Differential Amplifier Unit, s/n 508; 1 Type 75 Amplifier Unit, s/n 355; 1 Type 67 Time-Base Unit, s/n 988 and 1 Type 203 Scope-Mobile® Cart. Original price of this complete outfit was $1004.50. Will sell for 10% off original price. Mr. Ben Ambrosio, BFA Products, 5711 Melvin Ave., Tarzana, California. Phone: DI 3-3346.

USED INSTRUMENTS WANTED

1 Type 531, Type 533, Type 515, or Type 316 Oscilloscope. Harvey Minsk, Southeastern Engineering Service, 1356 Carolyn Drive, N. E., Atlanta 6, Georgia.

1 Type 515 or Type 516 Oscilloscope. Ray Dakin, Correlated Data Systems, 1007 Airway, Glendale 1, California.

1 Type 121 Wide Band Preamplifier. Responses to this ad should be directed to George Lodge, Tektronix, Inc., 3601 South Dixie Drive, Dayton 39, Ohio.

1 Type 575 Transistor Curve-Tracer Oscilloscope. Tennelec Instrument Company, Inc., Box 964 Oak Ridge, Tennessee.

1 Type 531 or Type 533 Oscilloscope and a CA Plug-In Unit or,
1 Type 516 Oscilloscope. Contact Dick Martin, P. O. Box 5824, Tucson, Arizona.

TEKTRONIX, INC.

Tektronix, Inc., an Oregon Corporation, Home Office & Factory, P. O. Box 500, Beaverton, Oregon 97005
Telephone: MItchell 4-0161 TWX—503-291-6805 Telex: 036-691 Cable: TEKTRONIX

FIELD ENGINEERING OFFICES

ALABAMA	Huntsville... 3322 South Memorial Parkway, Suite 102, Huntsville...Telex 05-9422.. Telephone: (205)881-2912
ARIZONA	Phoenix... 7000 E. Camelback Road, Scottsdale...Telex 031-701 .... Telephone: (602)946-4273 Tucson Area: Enterprise 383
CALIFORNIA	San Diego... 3045 Rosecrans Street, San Diego 10...Telex 039-825 .... Telephone: (714)222-0384
Los Angeles Area	*Encino*... 17418 Ventura Blvd., Encino...Telex 06-74395 .... Telephone: (213)788-5170 From Los Angeles telephones call: 873-6868 Island of Oahu, Hawaii Area: ENterprise 5-700
	• *Orange*... 1722 E. Rose Avenue, Orange...Telex 06-78812 .... Telephone: (714)633-3450
	Pasadena... 1194 East Walnut Street, Pasadena...TWX: 213-449-1151...Telex 06-74397 .... Telephone (213)449-2164 From Los Angeles telephones call: 681-0201
	• *West L.A.*... 11681 San Vicente Blvd., West Los Angeles 49...Telex 06-74396 .... Telephone: (213)GRanite 3-1105 From Los Angeles telephones call: BRadshaw 2-1563
San Francisco Bay Area	*Walnut Creek*... 1709 Mt. Diablo Blvd., Walnut Creek... Telex 033-644 .... Telephone: (415) 935-6101 From Oakland, Berkeley, Richmond, Albany and San Leandro: 254-5353
	• *Palo Alto*... 3944 Fabian Way, Palo Alto...Telex 033-911 .... Telephone: (415)326-8500
COLORADO	Denver... 2120 South Ash Street, Denver 22....Telex 045-662 .... Telephone: (303)757-1249 Salt Lake Area: Zenith 381
FLORIDA	• Orlando... 205 East Colonial Drive, Orlando...Telex 056-515 .... Telephone: (305)GArden 5-3483 (also serves Puerto Rico)
GEORGIA	• Atlanta... 467 Armour Circle, N.E., Atlanta 24...Telex 05-42233 .... Telephone: (404)873-5708
ILLINOIS	• Chicago... 400 Higgins Road, Park Ridge...Telex 02-53374 .... Telephone: (312)825-6666
INDIANA	Indianapolis... 3937 North Keystone Avenue, Indianapolis 5...Telex 027-348 .. Telephone: (317)LIberty 6-2408
KANSAS	Kansas City... 5920 Nall, Mission...Telex 04-2321 .... Telephone: (913)HEdrick 2-1003 St. Louis Area: ENterprise 6510
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MASSACHUSETTS	• Boston... 442 Marrett Road, Lexington 73...Telex 094-6301........... Telephone: (617)VOlunteer 2-7570
MICHIGAN	• Detroit... 27310 Southfield Road, Lathrup Village...Telex 023-400 ....Telephone: (313)ELgin 7-0040
MINNESOTA	Minneapolis... 3307 Vera Cruz Ave. North, Suite 102, Minneapolis...Telex 029-699..Telephone: (612)533-2727
NEW MEXICO	• Albuquerque... 509 San Mateo Blvd., N.E., Albuquerque...Telex 074-621 .... Telephone: (505)268-3373 Southern New Mexico Area: Enterprise 678
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	• *Northern N. J.*... 400 Chestnut Street, Union, New Jersey...Telex 01-26344 ...... Telephone: (201)688-2222
	Westchester County, Western Conn., Hudson River Valley...144 Morgan Street, Stamford, Connecticut Telex 096-5917 ...... Telephone: (203)DAvis 5-3817
NORTH CAROLINA	• Greensboro... 1838 Banking Street, Greensboro .... Telex 057-417 .... Telephone: (919)274-4647
OHIO	Cleveland... 1503 Brookpark Road, Cleveland 9...Telex 098-5217 .... Telephone: (216)351-8414
	Dayton... 3601 South Dixie Drive, Dayton 39...Telex 02-8825 .... Telephone: (513)293-4175
OREGON	• Portland... 4020 S.W. 114th Avenue, Beaverton...Telex 036-691 .... Telephone: (503)MItchell 4-9169
PENNSYLVANIA	• Philadelphia... 126 Presidential Blvd. North, Bala-Cynwyd...Telex 083-4218 . Telephone: (215)TEnnyson 9-3111
	Pittsburgh... 3834 Northern Pike, Monroeville...Telex 086-761 .... Telephone: (412)351-3345
TEXAS	• Dallas... 6211 Denton Drive, P.O. Box 35726, Dallas 35...Telex 073-2217 . Telephone: (214)FLeetwood 7-9127
	Houston... 2605 Westgrove Lane, Houston 27...Telex 077-494 .... Telephone: (713)MOhawk 7-8301 Austin Area: ENterprise 3093 New Orleans, Louisiana Area: WX 3093
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WASHINGTON, D.C.	• Washington, D.C.... 4205 Evergreen Lane, Annandale, Virginia...TWX: 703-256-8902...Telex 089-515....... Telephone: (703) 256-6700 Norfolk, Portsmouth, and Hampton, Virginia Area: Enterprise 741

Area Code Numbers are in parenthesis preceding telephone number.

TEKTRONIX CANADA LTD.

QUEBEC	Montreal... 3285 Cavendish Blvd., Suite 160, Montreal 28...Telex: 01-2867 ...... Telephone: (514)489-9707
ONTARIO	• Toronto... 4A Finch Ave. West, Willowdale...Telex: 02-2776 .... Telephone: Toronto (416)225-1138

• ALSO REPAIR CENTER

Tektronix Ltd., P. O. Box 36, St. Peter Port, Guernsey, Channel Islands; Telephone: Central 3411, Telex: 41193, or Cable: TEKTRONIX GUERNSEY.

Tektronix Overseas Distributors in 27 countries.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

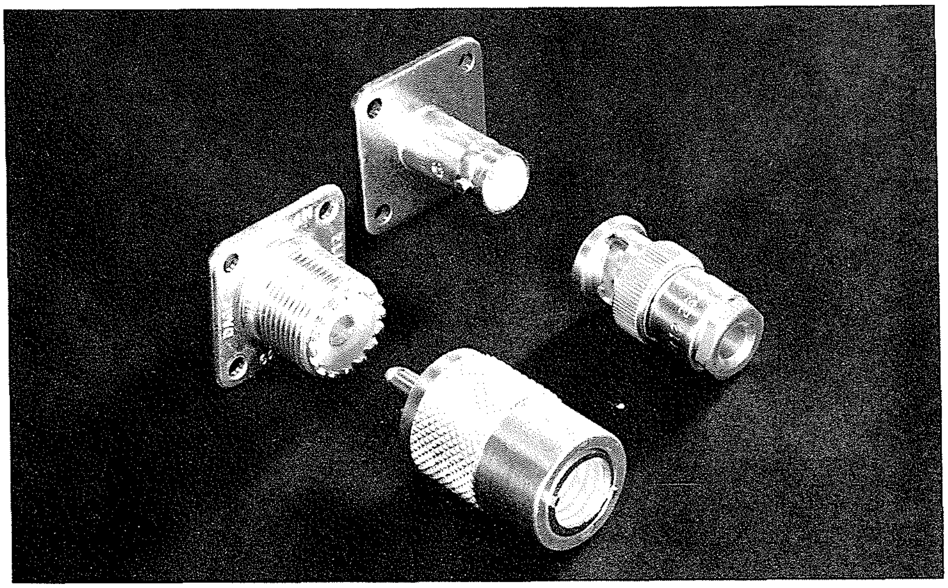
Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 23 DECEMBER 1963

PRINTED IN U.S.A

UHF TO BNC CONVERSION



Recently, Tektronix, Inc. made the decision to convert all Tektronix instruments having UHF connectors to BNC connectors and, also, that Tektronix instruments of future design will employ BNC connectors.

The decision to convert the Tektronix product line to BNC connectors was based on the following facts:

1. BNC connectors offer lower input capacitance — an extremely important consideration in some applications.
2. BNC connectors have the requirements demanded by high-frequency instruments for good performance.
3. BNC connectors require less panel space and provide more finger room. Growing panel-density problems dictate their use.
4. BNC connectors are employed by the majority of manufacturers producing instruments used in conjunction with oscilloscopes.
5. BNC connectors are quicker and easier to connect and disconnect.

First, because it is not desirable to perpetuate the compatability of problems of hybrid systems (main frames, plug-ins, probes, etc.) having non-matching connectors, and, second, because it would be more costly for us (and, therefore, our customers) to maintain production on both UHF and BNC connectors, we feel we should make a complete conversion from UHF to BNC connectors.

We include here a visible comparison of the new BNC accessories and their UHF counterparts.

Included are:

- Panel Connectors
- Binding Post Adapters
- Terminations
- Attenuators
- Minimum Loss Networks
- Input RC Standardizers
- Cable Assemblies
- N-Unit Calibration Adapters

For purposes of quick identification, the UHF connector has visible threads; the BNC connector is smooth except for two little bumps that serve as guide pins.

Where BNC counterparts are not available, it may be necessary to use one of the two BNC-to-UHF adapters — BNC female to UHF male, or UHF female to BNC male.

The hexagonal-case attenuators and terminations with BNC connectors, Tektronix Part Number 010-314 to 010-320 inclusive, are being discontinued and replaced by those in the new cylindrical plastic case as illustrated under "Attenuators". The six digit numbers under each illustration are Tektronix part numbers.

Also included is a chart of the probes currently manufactured by Tektronix, Inc. It lists the probes by type number and cable length, gives the Tektronix part number for the BNC and/or UHF versions, and indicates the function for which the probe is designed.

The P6025 and P6032 Cathode-Follower probes and the P6026 Passive and P6034 and P6035 Low-Capacity, Miniature Passive probes are not listed on this chart. They are designed and intended primarily for use with Tektronix sampling systems and are supplied with GR connectors only.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

PANEL CONNECTORS

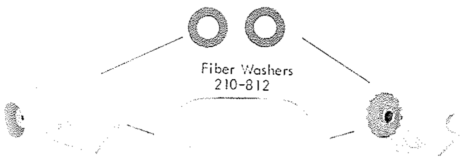
BNC | UHF

131-277

131-051

131-278

131-038



131-279

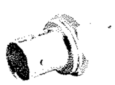
Nylon Insulator
406-244

131-064

131-274

Insulated connectors. Includes mounting hardware.

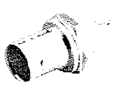
131-320



131-126

Single-hole, 1/2 inch mount. Includes mounting hardware.

131-081

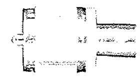


131-106
Single-hole 3/8 inch mount. Includes hardware.

No UHF Counterpart

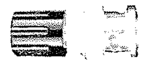
ADAPTERS

BNC | UHF



103-015
BNC Female to UHF Male

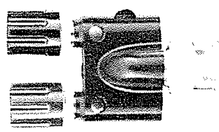
103-032
UHF Female to BNC Male



103-033

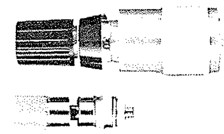
Binding Post Adapter Single

013-004



103-035

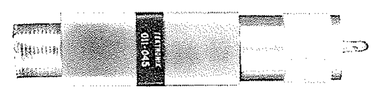
Binding Post Adapter Double



013-009

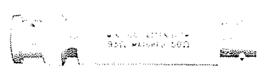
ATTENUATORS

BNC | UHF



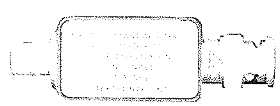
BNC		UHF
011-059	50 Ω, 10X	011-031
011-060	50 Ω, 5X	011-032
011-061	75 Ω, 10X	011-033
011-062	93 Ω, 10X	011-035

MINIMUM LOSS NETWORKS



BNC		UHF
011-057	50 Ω-75 Ω	011-041
011-058	50 Ω-93 Ω	011-042

INPUT RC STANDARDIZERS



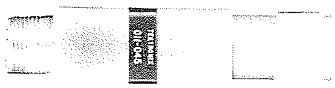
BNC		UHF
011-065	1 M X 12 pf	None
*011-073	1 M X 15 pf	None
011-066	1 M X 20 pf	011-022
011-067	1 M X 24 pf	011-029
011-068	1 M X 47 pf	011-030

*Used with later Types 82 and 86 that have 50 v/cm position.

TERMINATIONS

BNC

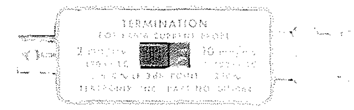
UHF



011-049
011-055
011-056

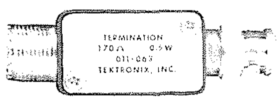
50Ω
75Ω
93Ω

011-045
011-046
011-047



P6016 Current Probe Termination
011-064

Same shape as BNC termination at left, but with UHF connectors.
011-028



170-Ω Termination
011-063

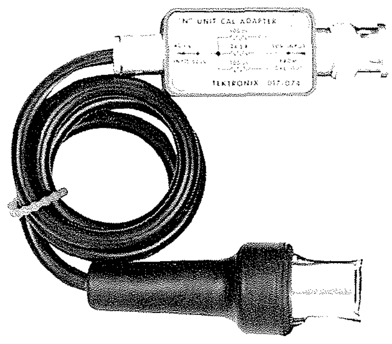
Use with P170CF Probe on scopes other than 517A

Same shape as UHF termination at top of page.
011-048

CABLE ASSEMBLIES, 42-inch
MALE CONNECTORS

BNC		UHF
012-057	50 Ω	012-001
012-074	75 Ω	012-002
012-075	95 Ω	012-003

N-UNIT CAL ADAPTER



017-074 For amplitude calibration of N units. 017-010

PROBE	ATTEN.	CABLE LENGTH	BNC PART NUMBER	UHF PART NUMBER	FUNCTION
P6006*	10X	3.5′	010-127	010-125	General Purpose
		6′	010-160	010-158	General Purpose
		9′	010-146	010-142	General Purpose
		12′	010-148	010-144	General Purpose
P6007**	100X	3.5′	010-150	010-134	General Purpose
		6′	010-165	010-162	General Purpose
		9′	010-152	010-136	General Purpose
		12′	010-154	010-138	General Purpose
P6027	1X	3.5′		010-070	General Purpose
		6′		010-071	General Purpose
		9′		010-072	General Purpose
		12′		010-073	General Purpose
P6028	1X	3.5′	010-074		General Purpose
		6′	010-075		General Purpose
		9′	010-076		General Purpose
		12′	010-077		General Purpose
P6023	10X	3.5′	010-167	010-065	Designed for use with Differential Amplifiers.
P6008	10X	3.5′	010-129		Type 82 and Type 86 Plug-In Units
P6009	100X	9′	010-140		Type 82 and Type 86 Plug-In Units
P170CF	2X	3.5′		010-101	Cathode Follower Probe
P500CF	10X	3.5′		010-109	Cathode Follower Probe
P6013	1000X	10′		010-106	High Voltage Probe
P6015	1000X	10′		010-132	High Voltage Probe
P6016		3.5′	010-037		AC Current Probe

* Replaces P6000, P6003, P6017 and P6018 General-Purpose Probes.

** Replaces P6002 and P6005 General-Purpose Probes.

A CORRECTION

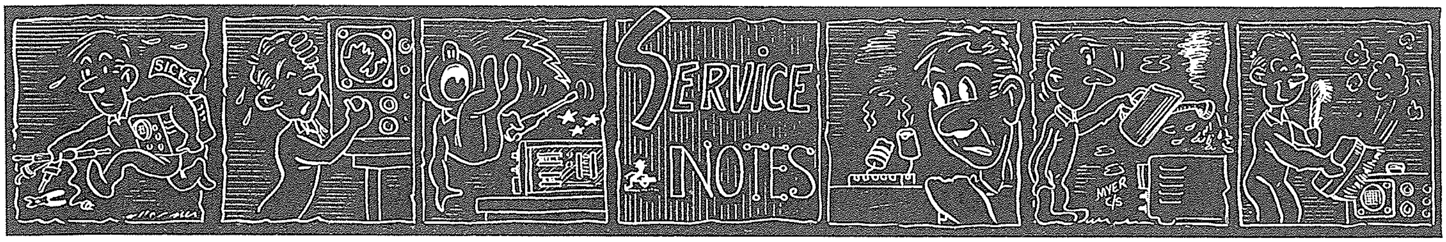
We wish to thank Mr. J. K. Grierson of the Research and Development Laboratories of the Northern Electric Company, Ltd. in Ottawa, Ontario for calling our attention to an error in the article "Noise — Some Basic Data" in the August, 1963, issue of Service Scope.

On page 1 under "Resistance Noise" we stated: "Thermal or 'Johnson' noise power is proportional to temperature, resistance and bandwidth. The rms noise *voltage* is proportional, then, to the *square root* of these factors".

We should have said: "Thermal or 'Johnson' noise power is directly proportional to bandwidth and temperature; for a given power level, voltage is proportional to the square root of resistance. The rms noise voltage, then, is proportional to the square root of the factors bandwidth, temperature and resistance".

We hope this correction will clear up the confusion our mis-statement may have caused our readers.

There is also a typographical error in this article. On page two, column three, about the middle of the column, I_s should be given as "290 μa" — not "430 μa". [$I_s + I_b$ must (approximately) equal I_k].



TYPE 561 AND TYPE RM561 OSCILLOSCOPES — INTERMITTENT INTENSITY MODULATION PROBLEM

In the October, 1963 issue of Service Scope we stated that some Type 561 and Type RM561 Oscilloscopes can develop an intensity modulation problem. That statement is still valid — but the cure we offered is not!

Although the Pyrofilm resistor we recommended performed very well during the tests we conducted to find a replacement, it has since proven just as susceptible to failure as the original resistor.

A more satisfactory replacement for R842 in these instruments is a series string of four 2 w, 10% composition resistors — two of 2.7 megohms and two of 3.3 megohms — totaling 12 megohms. The high-voltage environment and limited available space of R842 require a special arrangement and careful wiring of these resistors into a series string. These resistors, properly arranged and wired and with instructions for installation are available as a kit. For Type 561 Oscilloscopes specify Tektronix Part Number 050-118; for Type RM561 Oscilloscopes specify Tektronix Part Number 050-147.

TYPE 561A, TYPE RM561A, TYPE 564, TYPE 565 AND TYPE RM565 OSCILLOSCOPES — INTERMITTENT INTENSITY MODULATION PROBLEM

The above instruments can also develop the same intermittent-intensity-modulation problem that plagues the Type 561 and Type RM561 Oscilloscopes. The offending resistor in all these instruments is R842 in the high voltage circuit. When R842 goes out completely, the operator will have no control over the intensity; the beam will be full on.

The Tektronix replacement part number for R842 in the Type 561A and Type 564, all serial numbers is 050-118; in the Type RM561A, serial numbers below 5610, it is 050-147; and in the Type 565, serial numbers below 470 and Type RM565, serial numbers below 350, it is 050-146.

TYPE 519 OSCILLOSCOPE—TRIGGER JITTER

In certain cases of trigger jitter in the Type 519 Oscilloscope the cause can be traced to poor wire dress of the High-Voltage Anode lead near the Sweep Time/CM switch. Try dressing the lead away from the switch. With a little experimentation you may cure the problem.

TYPE 502A OSCILLOSCOPE — FAILURE OF DIODE D126

The failure of diode D126 in the time-base generator circuit of the Type 502A Oscilloscope is most generally caused by inductive kickback from the high-voltage transformer, T801. The cure for this problem is:

1. Replace R137, a 100 Ω, ½ w, 10% resistor, located between pins 6 and 2 of V135 (a 6AN8 tube in the time-base generator circuit) with a 47 k, ½ w, 10% resistor (Tektronix Part Number 302-473).
2. Add an 8 pf, 500 v capacitor (Tektronix Part Number 281-503) between pins 6 and 2 of V135.

Designate the new capacitor C137 and make the necessary changes and additions to your Type 502A's instruction manual.

TYPE 515A AND OTHER OSCILLOSCOPES — FAN BLADE ARCING

Occasionally a combination of high insulation leakage resistance in a fan motor and fan mounts plus a certain spacing between fan blade and filter will induce intermittent arcing between the blade and filter. Static electricity buildup on the motor and fan blade causes the arcing. The phenomena has been seen on the Type 515A; it may occur in other instruments.

Its most noticeable effect is to cause misfire of a single-sweep. The occurrence is, however, too rare to be noticed with a repetitive sweep.

One cure is to change the spacing between the fan blade and the filter. A better cure is to bypass one of the rubber shockmounts with a short length of flexible wire braid.

TEKTRONIX 5″ OSCILLOSCOPES — POLARIZED LIGHT FILTER

A polarized light filter is available for use with Tektronix Oscilloscopes with 5″ crt's. The filter is punched for use with nearly all 5″ round crt's. A little trimming may be necessary for installation on the Type 503 or Type 504 Oscilloscopes.

To mount the polarized light filter, remove the four graticule-cover nuts. Dismount the graticule cover but leave the graticule in place over the crt. Mount the polarized light filter on the graticule studs, remount the graticule cover and replace the four graticule nuts.

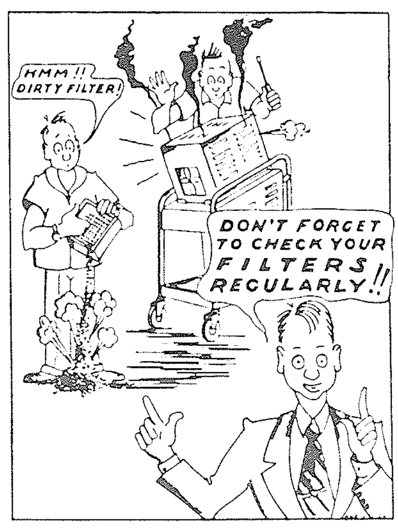
Though it lacks the non-glare feature of the polarized *viewer,* the light filter can do a good job of increasing trace contrast with minimum light loss wherever space or other considerations preclude the use of the polarized viewer.

The Tektronix Part Number of the Polarized Light Filter is 378-539.

TYPE 82 AND TYPE 86 PLUG-IN UNITS — USING THE P170CF CATHODE FOLLOWER PROBE

With one of the above units in a Type 580 Series Oscilloscope the P170CF Cathode-Follower probe will give a 6 nsec risetime and about 60 mc bandwidth when terminated with a 170 Ω termination (Tektronix Part Number 011-048). You'll need a UHF-to-BNC adapter (Tektronix Part Number 103-032) to connect the termination to the Type 82 or Type 86 input. There is some overshoot, generally under 5%.

REMINDING YOU



NEW FIELD MODIFICATION KITS

TYPE 503, TYPE 504, TYPE 560, TYPE 561, TYPE 561A, AND TYPE 564 OSCILLOSCOPES — CRADLE MOUNT

This modification is applicable to any of the above instruments, all serial numbers. It provides a means of rack mounting these instruments in a standard 19-inch relay rack. Modified instruments require 15¾" of rack height. Order from your Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 040-321. Price: $45.00

TYPE 555 OSCILLOSCOPE — ADDITIONAL TRIGGER SOURCES

This modification provides the Type 555 Oscilloscope with additional triggering sources when the Type 21A and Type 22A Sweep Plug-In Units are used. It permits direct triggering from the Type J Plug-In Unit when that unit is operating in the CHOPPED or ALTERNATE modes. Triggered in this manner, the Type 555 will display input signals in true time or phase relationship. The modification applies to Type 555 Oscilloscopes with serial numbers 101 through 6999. Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 040-328. Price: $1.10

TYPE M PLUG-IN UNIT — IMPROVED CHANNEL SWITCHING

This modification improves the performance of the Type M Plug-In Unit's channel switching circuit by:

1. Improving the timing of the chopped blanking to minimize the switching transients visible on the crt display.
2. Insuring that the blocking oscillator will stop in the CHOPPED mode with only one channel in the ON position; or will operate with only two channels in the ON position, as the temperature varies.
3. Increasing the blocking-oscillator switching rate to 1 mc to insure that it will trigger properly in all instruments.
4. Increasing the ring-counter shut-off currents to prevent possible one-channel lock-up.
5. Replacing the +12.6-volt supply zener diode (D5390) with a series zener diode combination totaling +13.6 volts (±2%) to increase the supply voltage and improve stability when the Type M Unit is used in the Type 581 or Type 585 Oscilloscopes.

This modification applies only to Type M Units, serial numbers 101 through 824, that *have not* had Field Modification Kit 040-294 installed. Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 040-333. Price: $14.75.

Special Note: Type M Units with serial numbers 101 through 824 that *have had* Field Modification Kit 040-294 installed may be up-dated by installation of Field Modification Kit 040-334 which is described below.

TYPE M PLUG-IN UNIT — IMPROVED CHANNEL SWITCHING

This modification improves the performance of the channel switching in Type M Plug-In Units not covered by Field Modification Kit 040-333 described elsewhere in this column. It is applicable to Type M Units, serial numbers 825 through 3479; and Type M Units, serial numbers 101 through 824, that have had Field Modification Kit 040-294 installed.

The improvement in performance is accomplished by:

1. Increasing the ring-counter shut-off currents to prevent possible one-channel lock-up.
2. Decreasing the value of R6356 to give a higher chopping rate in the CHOPPED mode and a faster recovery in the ALTERNATE mode.
3. Replacing the +12.6 volt supply zener diode (D5390)) with a series zener diode combination totaling +13.6 volts (±2%) to increase the supply voltage and improve stability when the Type M Unit is used in the Type 581 or Type 585 Oscilloscopes.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 040-334. Price: $18.85

TYPE 561 OSCILLOSCOPES — 3B1 AND 3B3 COMPATIBILITY

This modification permits the Type 3B1 and Type 3B3 Plug-In Units to be used with the Type 561 Oscilloscopes and utilize their trace-intensifying feature.

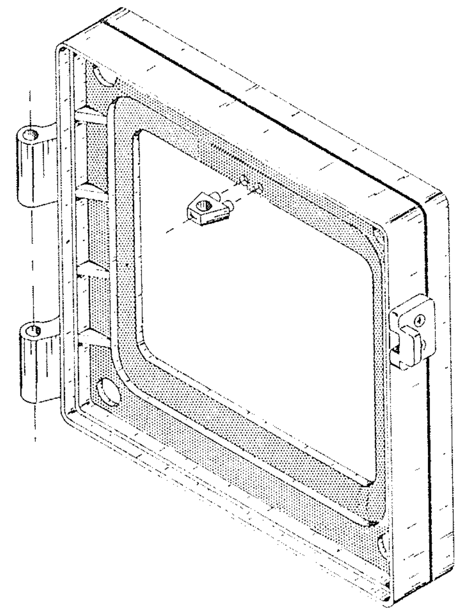
The High Voltage circuit is replaced by a new assembly which has separate secondary windings for the crt grid and cathode. This permits insertion of intensifying pulses on the crt grid and/or chopped blanking (or external) pulses on the cathode.

A crt CATHODE SELECTOR switch is added to permit selection of CHOPPED BLANKING or CRT CATHODE inputs.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 040-320. Price: $43.40.

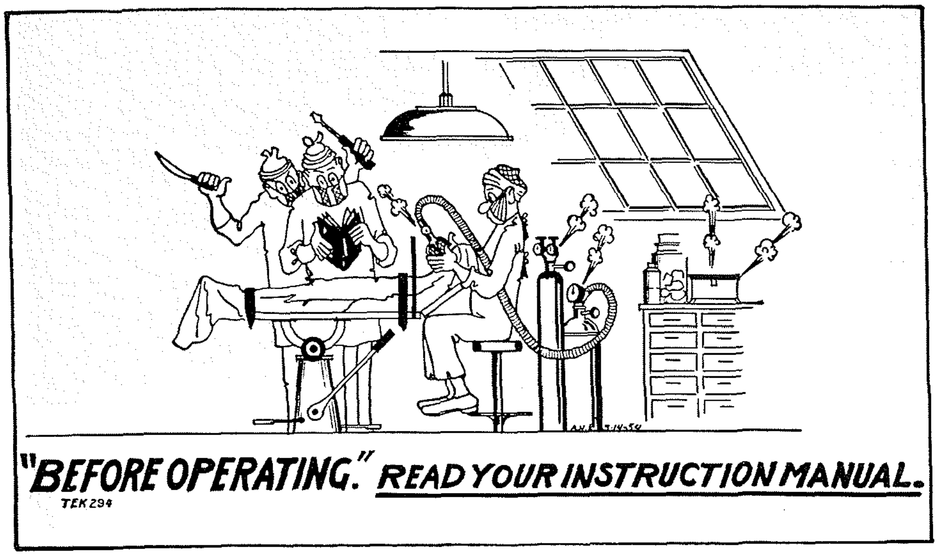
Special Note: As a further improvement in the performance of the Type 561 Oscilloscope with the Type 3B1 or Type 3B3 Plug-In Units, we suggest the installation of two previously-announced field modification kits. They are: Field Modification Kit 040-267 for Type 561 Oscilloscopes, serial numbers 102 through 578 (with some exceptions—see your Tektronix Field Engineer before ordering). This modification improves stability and reduces ripple in the −12.2 volt supply. And, Field Modification Kit 040-288 for Type 561 Oscilloscopes, all serial numbers. This modification improves regulation and reduces ripple in the −100 volt supply.

CAMERA-MOUNTING BEZEL FOR TEKTRONIX 5"-ROUND-CRT OSCILLOSCOPES* — MOUNT FOR RECTANGULAR POLARIZED VIEWER



This modification is applicable to Tektronix camera-mounting bezels for Tektronix 5"-round-crt oscilloscopes*. It installs a plastic mount which permits the use of a Tektronix rectangular polarized viewer (Part Number 016-039) when the camera is not in photographic position. Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 040-338. Price: $0.35

Note: Camera-mounting bezels (for Tektronix 5"-round-crt oscilloscopes*) with this modification already installed are available. In circumstances where one Tektronix camera must serve several oscilloscopes of this type, we suggest the installation of this bezel on each oscilloscope. This



eliminates the need to remove and reinstall a bezel each time the camera is moved from one oscilloscope to another and allows the use of a rectangular polarized viewer except when the camera is in the photographic position. Order through Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 016-226. Price: $15.00

* Not applicable to bezels supplied with Type 519 Oscilloscopes.

TYPE 3B1 PLUG-IN UNITS — VARIABLE-TIME/DIV SHAFT AND COUPLER

This modification replaces the VARIABLE TIME/DIV shaft and coupler. The new shaft prevents damage to the shaft coupling if the knob is bumped. The modification applies to Type 3B1 Plug-In Units with serial numbers 101 through 1400. Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 040-340. Price: $0.50.

TYPE 561A OSCILLOSCOPES — SILICONE RUBBER CRT LEADS

This modification replaces the high voltage leads to the crt cathode and control grid with silicone-rubber insulated leads. Silicone rubber — highly resistant to environmental conditions that cause a rapid deterioration in conventional rubber insulation — tends to prevent insulation breakdown and subsequent arcing.

This modification is applicable to Type 561A Oscilloscopes with serial numbers 101 through 8159, with these exceptions: Serial numbers 5766, 7691, 7692, 7695, 7696, 7699, 7750, 7751, 7752, 7753, 7860 through 7894, 7920 through 7954, and 7980 through 8014.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 040-341. Price $0.65.

TYPE 530 SERIES, TYPE 530A SERIES, TYPE 540 SERIES AND TYPE 540A SERIES OSCILLOSCOPES — EXTERNAL-TRIGGER DECOUPLING

This modification eliminates the possibility of a large voltage spike appearing at the TRIGGER INPUT connector when the TRIGGERING MODE control is rotated from INT to EXT triggering positions.

A decoupling network is added to the INT position of the oscilloscope's Trigger Selector (TRIGGERING MODE/TRIGGER SLOPE) switch. The Type 535A, Type RM35A, Type 545A and Type RM45A Oscilloscopes have two time base generators — TIME BASE A and TIME BASE B — and each time base has its own Trigger Selector switch. On these instruments, a decoupling network is added to the INT position on each of the Trigger Selector switches.

This modification is applicable to the following oscilloscopes:

Type	Serial Numbers
531A	20001 through 25079
533	301 through 3000
533A	3001 through 4694
535A	20001 through 31259
541A	22899
543	301 through 3000
543A	3001 through 4489
545A	20001 through 38829
RM31A	1001 through 2439
RM33	101 through 1000
RM33A	1001 through 1249
RM35A	1001
RM41A	1001
RM43	101 through 1000
RM43A	1001
RM45A	1001 through 3839

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 040-326. Price: $1.50.

TYPE 515, TYPE 515A, TYPE RM15, TYPE RM15-209C, AND TYPE 516 OSCILLOSCOPES — EXTERNAL-TRIGGER DECOUPLING

This modification eliminates the possibility of a large voltage spike appearing at the TRIGGER INPUT connector when the TRIGGER SELECTOR control is switched from INT to EXT triggering positions.

A decoupling network is added to the INT position of the TRIGGER SELECTOR switch.

This modification is applicable to the following oscilloscopes:

Type	Serial Numbers
515	101 through 1000
515A	1001 through 2869
RM15	101 through 2869
RM15-209C	101 through 2869
516	101 through 1958

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 040-329. Price $1.80.

TYPE 519 OSCILLOSCOPE — FUSE PROTECTION

This modification installs a 15 ampere fuse (F651) to protect the Regulated Heater supply from cable burnouts caused by the shorting of capacitor C650. It is applicable to Type 519 Oscilloscopes, serial numbers 101 through 521, with these exceptions: Serial numbers 458, 471, 487, 493, and 501 through 520.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 040-348. Price: $N/C

TYPE 128 PROBE POWER SUPPLIES — SILICON RECTIFIER

This modification replaces the selenium rectifier (SR650), used in the probe filament supply, with silicon diodes which offer better reliability and longer life. It is applicable to Type 128 Probe Power Supplies with serial numbers 101 through 714 and serial numbers 718 and 719. Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix Part Number 040-327. Price: $7.25.

USED INSTRUMENTS WANTED

1 Type 516 Oscilloscope. Edward C. Regan, 6331 Templeton, Huntington Park California. Telephone LU 1-8348.

1 Type 561 and Plug-Ins. John Davis, 8029 Quentin Street, Hyattsville, Maryland.

1 Type 561A or will consider a Type 561 Oscilloscope. C. J. Hire, Advanced Engineer, Therm-O-Disc, Inc., Mansfield, Ohio. Telephone LA 2-4311.

1 Type 531 or Type 531A Oscilloscope in any condition. Henry Steigers, Rt. 2, Box 787, Puyallup, Washington. Telephone TH 5-9729.

1 Type 524 Oscilloscope or 1 Type 535 Oscilloscope with a Type L Plug-In Unit. Tom Landers, 84 Flower Street, Hartford 5, Connecticut.

USED INSTRUMENTS FOR SALE

1 Type 551 Oscilloscope, s/n 515; 1 Type 53/54C Dual-Trace Plug-In; 2 Type D High-Gain Differential Plug-Ins. Dr. B. Libet or Gus Winston, U. C. Medical Center, 2nd and Parnassus, San Francisco, California. Telephone MO 4-3600, Ext. 735.

1 Type 551 Oscilloscope, s/n 4281; 1 Type CA Dual-Trace Plug-In Unit, s/n 45892; 1 Type L Plug-In Unit, s/n 14151. These instruments are about 17 months old. Contact Mr. Stanley, Jerguson Gage and Valve Company, Adams Street, Burlington, Massachusetts.

1 Type 541 Oscilloscope; 1 Type CA Dual-Trace Plug-In Unit; 1 Type 53/54K Fast-Rise Plug-In Unit and a Type 500/53A Scopemobile® (no serial numbers given). These instruments were overhauled by Tektronix in November of 1962. Price complete $1100.00. Bob Haskins, Phillips Applied Research, 1640 21st Street, Santa Monica, California. Telephone CL 1-1642.

2 Type 555 Oscilloscopes and Power Supplies; 1 Type CA Plug-In Unit; 2 Type L Plug-In Units and 1 Type G Plug-In Unit (no serial numbers given). All instruments are in A-1 condition, completely recalibrated, etc. by Tektronix. Contact Mr. Dean DeLue, Molectro Corporation, 2950 Ysidro Way, Santa Clara, California. Telephone 245-4320.

1 Type 517A Oscilloscope, s/n 1508, with Power Supply; 500A Scopemobile; P170-CF Cathode-Follower Probe and B170A Attenuator. Address inquiries to Pearl Horwitz Meckelburg, Decisions, Inc., 142 Second Street, Fall River, Massachusetts. Telephone Area Code 617 OS 2-7448.

4 Type 512 Oscilloscopes; 4 Type 514AD Oscilloscopes; 1 Type 524D Oscilloscope; 1 Type 315D Oscilloscope; and 5 Scopemobiles (older type). All instruments will be repaired and recalibrated before shipment to buyers. Details as to prices and serial numbers may be obtained by contacting Mr. Art Eberhardt, Univac Division of Sperry-Rand Corporation, 311 Turner Street, Utica, New York.

1 Type 321 Oscilloscope, s/n 1473. Mr. R. Klein, 651 Ambleside Road, Des Plaines, Illinois.

1 Type 502 (no serial number given) with a 500A Scopemobile. Price $800.00. Contact Bernie Borane, Arizona Journal, Phoenix, Arizona.

1 Type 543 Oscilloscope, s/n 624 and 1 Type CA Plug-In Unit, s/n 2083. Instruments are approximately 5 years old and in good condition. Price $1000.00. Contact Mr. Dwight Lord, Rutherford Electronics. Telephone Area Code 213 UP 0-7393.

Bob Wells, Texas Crystal Company, 4117 West Jefferson, Los Angeles, California has a Type 502 Oscilloscope he would like to trade for a Type 531 or Type 541 Oscilloscope. His telephone number is 731-2258.

In May of this year, a Type 310A, s/n 13137, disappeared from the Vandenberg Air Force Base in California. This instrument carries Air Force Tag #441921 and is believed to have been stolen.

Information regarding the whereabouts of this Type 310A should be forwarded to Bill Davies, Arma Division, A. Bosch Arma Corporation, P. O. Box 1585, Vandenberg Air Force Base, California. The Telephone number is 866-1611, extension 6925 or 7242.

The Marine Radio Service in San Pedro, California also suffered the loss of an oscilloscope in May of this year. This was a Type 321, s/n 1895 and it, like the 310A above, is believed to have been stolen. Marine Radio Service would appreciate hearing from anyone with information on the whereabouts of this Type 321.

Here's another report of a Type 310 stolen from a car. Instruments left in automobiles seem to offer an exceptional attraction to car prowlers. A good move before *locking* an instrument in a car is to conceal it from covetous eyes by some kind of a covering—coat, blanket, paper, etc.

The s/n of this stolen 310 is 4893. Donald Brasnan of the Univac Division of Sperry-Rand Corporation says it was removed from the car of one of their service personnel at 63rd and Western in Chicago, Illinois, on the evening of Monday, October 21, 1963.

Mr. Brasnan asks anyone with information on this missing Type 310 to please contact him at 440 N. Michigan in Chicago, Illinois.

In another car prowl a Type 133 Plug-In Unit Power Supply, s/n 209, and a Type E Plug-In Unit, s/n 4721 were removed from a car in the Manhattan section of New York City. These instruments belong to the Geophysics Department of Rensselaer Polytechnic Institute in Troy, New York.

Anyone with information regarding these instruments is asked to please contact the Tektronix Field Office at 12 Raymond Avenue in Poughkeepsie, New York or the Geophysics Department of Rensselaer Polytechnic Institute in Troy, New York.

A Type 72 Dual-Trace Plug-In Unit, s/n 276, is missing from the Tektronix Field Office in Baltimore, Maryland. This is a Tektronix-owned instrument and we would appreciate having anyone with information on the location of this instrument contacting either their local Tektronix Field Office or our Field Office in Baltimore. The address of the Baltimore Office is 1045 Taylor Avenue, Towson 4, Maryland. Their telephone number is Area Code 301 825-9000.

The University of Minnesota is missing a Type 531 Oscilloscope, s/n 5199, and a Type 53/54C Dual-Trace Plug-In Unit, s/n 18622. These instruments disappeared from the Electrical Engineering Department. Information concerning the whereabouts of these instruments should be directed to Al Larson, Electrical Engineering Department, University of Minnesota, Minneapolis, Minnesota 55414. Telephone Number 373-2494.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 24 PRINTED IN U.S.A FEBRUARY 1964

CURRENT MEASURING TECHNIQUES

By Willem B. Velsink
Project Manager, Accessory Design Group,
Tektronix Instrument Engineering Department

Introduction

Modern technology requires measurement capabilities in the fractional nanosecond (10^{-9} second) area. Diodes with switching times well under 100 picoseconds (10^{-12} second) and transistors with f_t (cut off frequency) of over 1000 Mc are presently available.

The sampling oscilloscope provides an excellent tool for the observation of these phenomena provided the signals are presented in a 50 Ω characteristic impedance system. However, it is very seldom that one can load a circuit with 50 Ω either in parallel or in series without disturbing it beyond use. Therefore, one has to provide means to extract the voltage and current waveforms from the circuit without disturbing the circuit to any great extent. The output of this device should present, to the sampling oscilloscope, an undistorted signal on a 50 Ω level.

In the case of voltage measurements, a good high frequency resistor (Ref. 1) may be selected. Provided it is placed in a proper environment, this type of series probe will perform rather well up to 1000 Mc. For the current waveforms, however, the solution is more complicated. Conventional current monitoring devices are restricted to relatively low frequencies either by basic limitations or by stray parameters. For example, the Hall potential in a Hall device is established in approximately 10^{-14} second. However, its inherent stray capacity and flux-linkage patterns prohibits its economical use above a few Mc.

The conventional current transformer with laminated core (Ref. 2) is useful up to a few kc. The tape wound version extends the frequency response and phase correlation to approximately 100 kc.

If the design of a current transformer is based on a TEM (Transverse Electromagnetic Mode) approach however, the basic frequency limitations are overcome and fractional nanosecond speeds can be achieved.

The TEM Current Transformer

A single turn circular winding is inserted in the space between the inner and outer conductor of a coaxial transmission line of impedance Z_0 (Figure 1). For simplicity only half of the lengthwise section is represented. The H (magnetic) field will terminate in a current sheath J in the circular winding.

(Curl H $= \frac{\partial D}{\partial t} + J$ since $\frac{\partial D}{\partial t} = 0$ inside the winding ∴ curl H = J.)

Also, since H is proportional to I, then $\oint J = I$ and a current I will flow in Z_1 for a single turn winding. At X_3 the current I in the single turn winding will

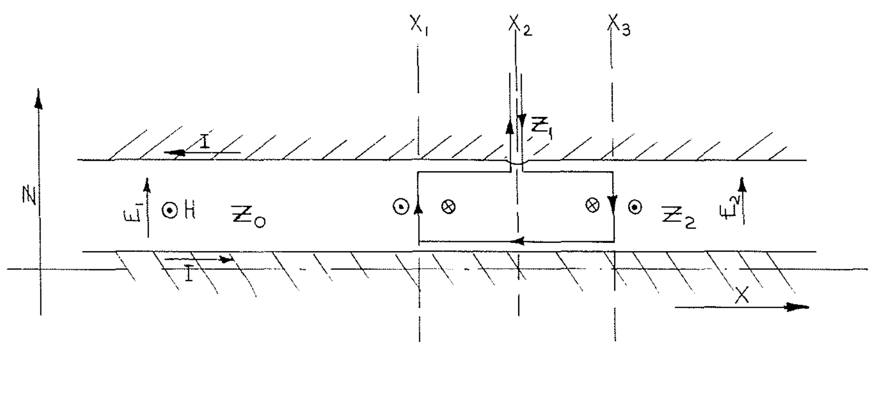


Figure 1. A single-turn winding inserted in the space between the inner and outer conductor of a coaxial transmission line of impedance Z_0.

regenerate H in equal magnitude and according to the principle of super-position $E_2 = E_1 - IZ_1$.

$$Z_o = \frac{E_1}{I} \; ; \; Z_2 = \frac{E_1 - IZ_1}{I} = Z_o - Z_1$$

indicating that the impedance Z_1 is effectively placed in series with Z_o. (Therefore, to maintain a first order matching, the ratio of the diameters of the inner and outer conductor past X_3 in the X direction should be reduced to be equal to Z_2.) A second order capacitive reflection occurs because the E field in going from X_1 to X_3 is confined between the inner conductor and the winding and between the outer conductor and the winding.

Neglecting the winding transit time, for an "n" turn winding $\oint J = I$ would still hold; however, I will be a current I/n per turn. The current through Z_1 is I/n and the series voltage drop reflected in the original E field is $\frac{\frac{I}{n}}{n} = \frac{I}{n^2}$

Therefore, $Z_2 =$

$$\frac{E_1 - \frac{I}{n^2} Z_1}{I} = Z_o - \frac{Z_1}{n^2}$$

The reflected impedance is proportional to $1/n^2$, similar to the conventional transformer. A true mathematical derivation of these results amounts to a double boundary value problem (Ref. 3 and 4) and is quite involved. However, this is not essential to achieve a basic understanding of the functioning of a TEM transformer.

Up to this point we really have not solved all basic limitations of the transformer, yet the preceding is essential for the understanding of the methods involved in solving them.

Outline of Limitations of Conventional TEM Transformer

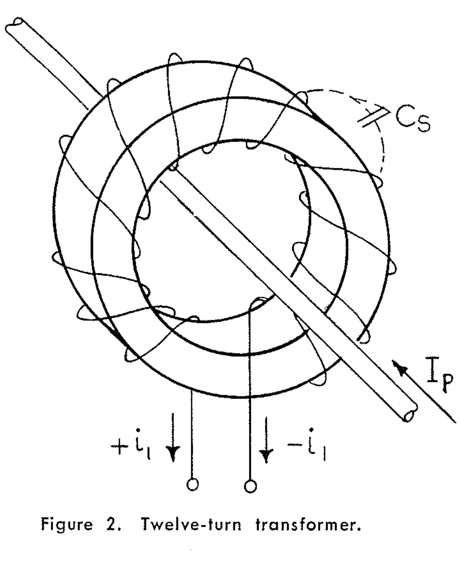


Figure 2. Twelve-turn transformer.

We have a transformer with one primary and n secondary turns (Figure 2). If we introduce a current step I in the primary winding, we will introduce a current step i_n at the *same* time and of equal magnitude in all n turns. The step i_n introduced in a particular turn will propagate in a transmission-line mode around the core in both directions and so will all steps in every turn. The resulting output waveforms at the secondary terminals of the transformer will, therefore, look like Figure 3 indicating a "push-pull" mode output.

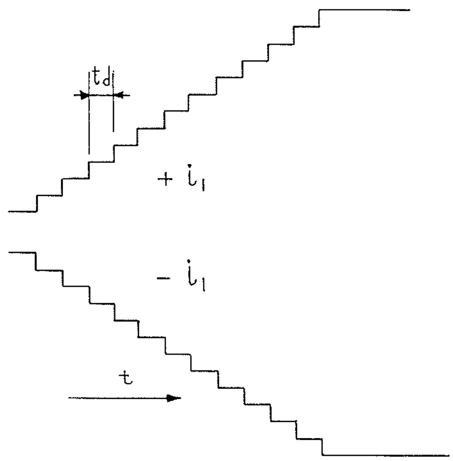


Figure 3. Output of twelve-turn transformer.

Here, then, we have the first basic limitation: the risetime of the output waveform will be approximately n times td, where td is the delay of one winding.

The second limitation of the conventional current transformer is the fact that there is a certain amount of stray capacitance (C_s) and inductance (L_s). This will form a distributed L-C circuit that will resonate at a frequency below $\frac{0.35}{n \times td}$ (equivalent 3-db point due to the first limitation) and, therefore, give a poor transient response especially when n is large.

Transmission Line Addition Technique

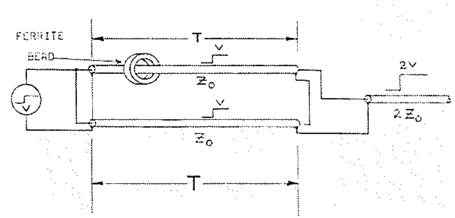


Figure 4. A step V, placed simultaneously on two Z_o cables, adds the two steps to a 2V step into a $2Z_o$ cable.

In Figure 4, if a step V is placed simultaneously on the two Z_o cables, one can add these two steps to a 2 V step into a 2 Z_o cable, as shown. However, this will work only for a time equivalent to the double delay time (2T) in one Z_o cable because after that the generator will be shorted. One can extend this time span by placing an impedance in the short circuit loop — here done by means of a ferrite core (Refs. 6 and 7).

Solution to First Order Limitations

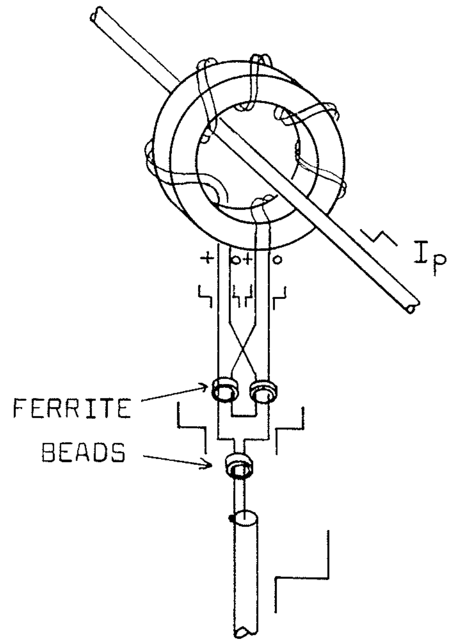
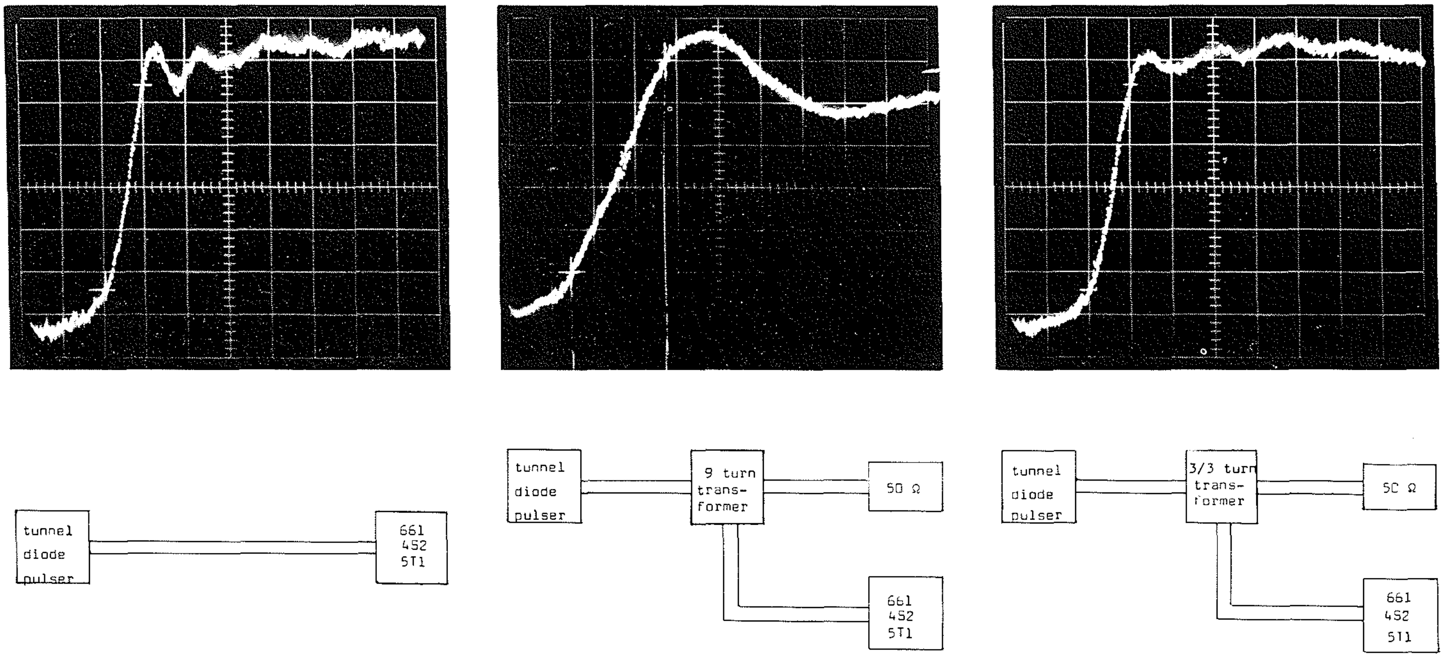


Figure 5. Twelve-turn bifilar winding.

In Figure 5, rather than wind an n turn single winding transformer, two windings each having $\frac{n}{2}$ turns have been wound bifilar, as shown. The four output voltages are then added and supply one single ended signal. The addition is performed with the transmission line addition technique. However, for practical reasons the wires are kept very short and, therefore, the double delay time (2T) is short. One depends mainly on the isolation provided by ferrite beads placed in the short circuit loop. Leads should be kept to the same length to assure time-coincident addition of the signals. By doing this we have achieved two improvements (Figure 6):

(a) The risetime of the output pulse, due to limitation one, has been reduced from n x td to n/2 x td. (This is not exact because the turns in this case will be slightly longer; therefore, td will be slightly greater. However, this effect is small.)



(a) Pulse direct to 4S2.

(b) Pulse coupled to 4S2 via a straight nine-turn transformer on a ½" dia. by ¼" core.

(c) Pulse coupled to 4S2 via 3 x 3-turn transformer on a ½" dia. by ¼" core [same core as used in (b)].

Figure 6. System used to obtain these waveform pictures: Tunnel diode pulser (≈30 psec risetime), Type 661 Sampling Oscilloscope with a Type 4S2 Dual-Trace Sampling Unit and a Type 5T1 Timing Unit, and a Type C-19 Camera. Sweep Time/cm: 0.2 nsec.

(b) The transient response, due to limitation two, has been improved due to the fact that the stray capacitance has been reduced since the two windings at every point on the core move in the same manner voltage-wise [fr (resonant frequency) proportional to $1/\sqrt{c}$] while the inductance and resistance stay essentially the same.

Note that at DC the two windings are in series. The output voltage is the same as that of a conventional n turn transformer. One can use multiple turns through the isolation beads to obtain a large time constant. Note also that one is not limited to 2 windings of n/2 turns per winding. One can use n windings of 1 turn per winding (as long as n/a is greater than 1 and a real number). The limitation is n windings of 1 turn per winding and there the risetime is equivalent to 1 x td or the total propagation time around the core, whichever is greater (Figure 7).

One can build a transformer with a large number of turns to get a long time constant, but at the same time one can get a very fast risetime and good transient response, as will be explained later.

Core Material

Unless a core with a permeability >1 is inserted inside the windings, the transformer action is limited to the double transit time

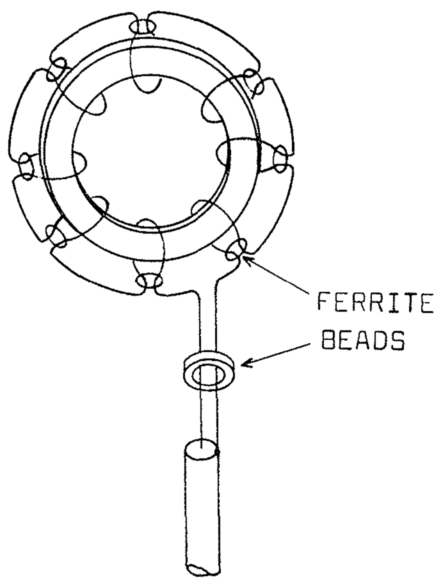


Figure 7. Eight-turn multifilar winding.

of the winding. To extend this time usually for high frequency applications a ferrite core material (Ref. 5) is used. Ferrites are sintered materials, generally of a basically spinel crystalline structure consisting of $MOFe_2O_3$ where M can be of any of the following elements: Co, Ni, Mn, Cu, Mg, Zn, Cd.

Generally the low permeability ferrites have a high resistivity and the high permeability ferrites a low resistivity. Therefore, the high permeability ferrites have higher loss than the low permeability versions. Some typical high frequency ferrite materials are:

		Permeability	*Rho* (Ω *cm*)
Ferroxcube	104	200-250	$>10^5$
	102	250-400	400-600
	101	300-700	250-450
Kearfott	MN30	4,000-6,000	300
	MN60	5,000-10,000	250

The Design of a TEM Current Transformer

In order to design a high speed current transformer, one has to consider several factors; transformer ratio, risetime, low frequency time constant, space available, impedance level, etc. The lumped constant equivalent circuit is represented in Figure 8. Here $R_1 = R_o n^2$; $L = L_o n^2$

R_o is assumed to be a constant proportional to the core losses and expressed in ohms/turn². In practice, however, one might have to use a different R_o for high frequency (and low frequency) calculations depending on material and bandwidth. The values given by the ferrite manufacturers generally refer to the low-frequency losses of the material. They have no consistent

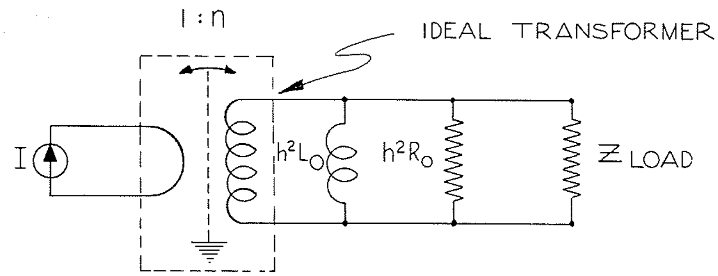


Figure 8. Lumped-constant equivalent circuit of a current transformer.

correlation with the frequency values of R_o. Therefore, these need to be measured for individual materials. Values vary from 20 Ω/n^2 to >500 Ω/n^2 depending on core material and dimensions.

L_o is a constant proportional to the permeability of the core, the cross section and the magnetic length. For a cylindrical core with outer diameter D, inner diameter d and length t, the inductance/turn² can be estimated by: $L_o = 0.2\ \mu t \ln D/d \times 10^{-8}$ $\mu H/n^2$

Z_{in} = the transformed impedance.

The low frequency cut-off is determined by the L/R time constant.

The response will be 3-db down if:
$\omega L = 2\pi fL = R$, where R is the total resistance R_p in parallel with L.

$$R_p = \frac{n^2 R_o R_L}{n^2 R_o + R_L}$$

$$f_{3db} = \frac{R_p}{2\pi L} = \frac{R_p}{2\pi n^2\ L_o}$$

At this point there will be a 45° phase shift through the transformer.

If accuracy of 1% is required in the transfer ratio, the low frequency response will be limited to a higher frequency. It can be readily verified that:

$$f_{1\%} = \frac{R_p}{.282\pi L_o n^2}$$

The phase shift will be approximately 8.1° at this frequency. If a maximum phase shift of 1° is required the lower frequency response should be limited to a still higher frequency. By performing the necessary calculations one finds:

$$f_{\theta=1^\circ} = \frac{R_p}{.0349\pi L_o n^2}$$

As a practical example, a transformer with a low frequency 3-db point of 10 kc will have a 1% amplitude accuracy above 70 kc and less than 1° phase shift above 570 kc.

From the low frequency point of view it is desirable to have a large number of turns to make L and R_l large. As previously shown, this limits the risetime.

By splitting the winding into several multifilar turns, as previously outlined, one can maintain the risetime for high speed operation and still have a large L and long time constant since at low frequencies the turns appear in series. The transformer may be used for current measuring purposes as well as for matching two points of different impedance levels. In either case, the transmission line will have a voltage waveform as well since the characteristic impedance is always greater than zero. In order to prevent capacitive coupling of the voltage waveform, the transformer has to be well shielded by a ground plane between the center conductor and the transformer. A perfect shield is not feasible, since this would amount to a shorted turn on the transformer. However, satisfactory shielding can practically be achieved by leaving a narrow gap in the shield.

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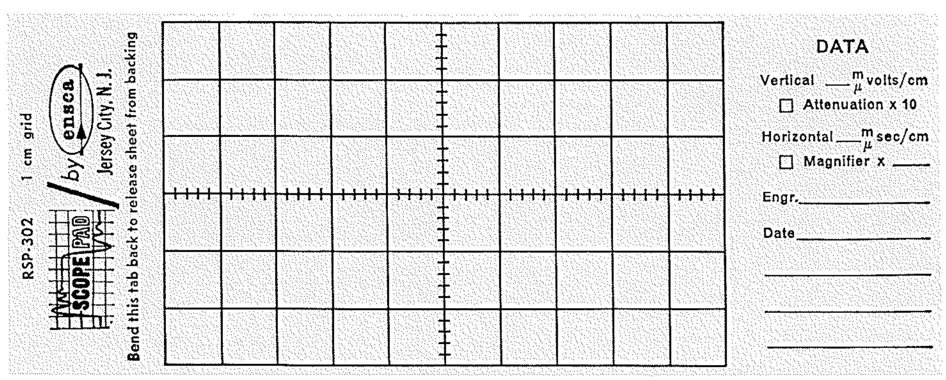
7. Lewis - Wells, MILLIMICROSECOND PULSE TECHNIQUES, Pergamon Press

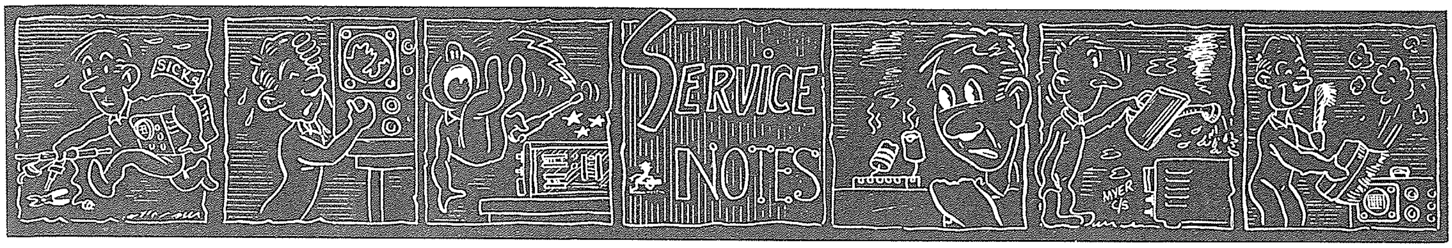
RECORDING WAVEFORMS WITHOUT A CAMERA

If you wanted to make a record of a repetitive waveform displayed on the crt of an oscilloscope and you didn't have a camera, you could stand back with easel and pen, hold up your thumb in Rembrandt-style and sketch away. Or, you could place a sheet of translucent paper over the face of the crt and trace the waveform. The difficulty here, of course, is trying to hold the paper firmly in place and at the same time make the tracing.

One solution to this problem is to use a sheet of "Scope Pad". This is a unique product manufactured and distributed by Ensca, Inc., P. O. Box 253, New York, New York 10023.

"Scope Pad" consists of twenty, translucent, adhesive-backed sheets ruled with a graticule-line grid. At the side of each sheet are spaces for time and amplitude data.





SHORTING PROBLEMS DURING TROUBLE SHOOTING

Chuck Miller of our Field Training group calls our attention to a serious problem that can exist when attempting to trouble-shoot an instrument incorporating high-density (tightly-notched) ceramic strips—see Figure 1.

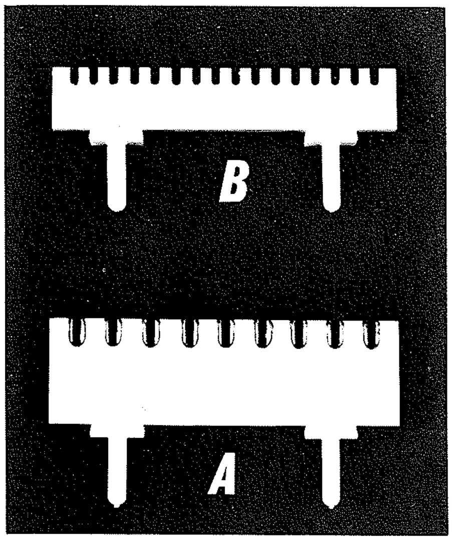


Figure 1. These two ceramic strips are the same length. The conventional strip (a) contains 9 notches, the high-density strip (b) contains 16 notches.

If, in this trouble-shooting, the probe employed uses a large tip—the old-style double-pincher tip for example—the danger exists of shorting out components and possibly destroying expensive transistors, diodes, etc.

A way to minimize this problem is to use the newer and thinner pincher tip (Tektronix Part Number 013-071—see Figure 2). This blade-like, single-pincher tip offers a greater margin of safety against the shorting out of components in crowded areas and the improved pincher tip has greater holding ability. The thin blade design causes a minimum of component displacement during trouble-shooting and facilitates checking difficult-to-reach test points.

This newer pincher tip is designed to be used with the following Tektronix probes:

P6000	P6004	P6008	P6023
P6001	P6005	P6009	P6027
P6002	P6006	P6017	P6028
P6003	P6007	P6022	

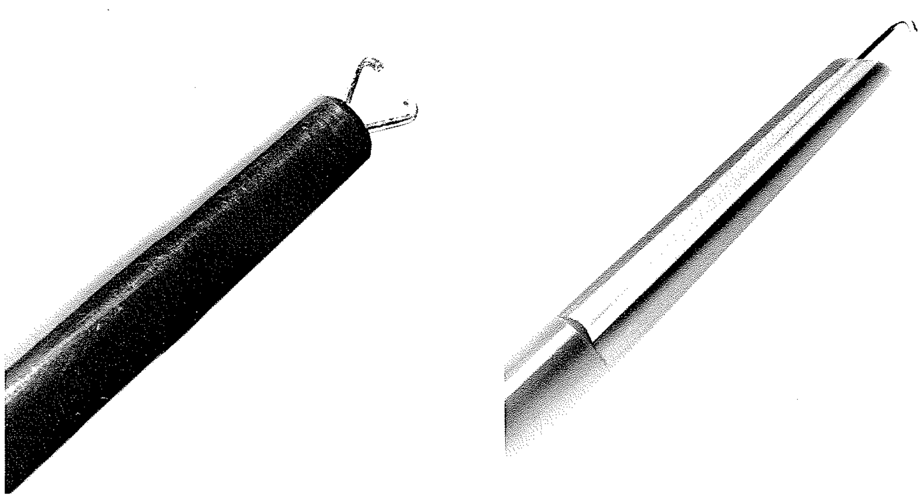


Figure 2. A comparison of the older double-pincher tip (left) and the new thin-blade, single-pincher tip (right). Both shown with pincher extended.

TYPE 575 TRANSISTOR CURVE TRACER — PEAK-VOLTS AUTO-TRANSFORMER IMPROVEMENT

Here is a service that if performed on the Peak-Volts autotransformer (T701 in the collector-sweep schematic) will improve its operation at low collector voltage when the HORIZONTAL VOLTS/DIV control is set to the 0.01 collector-volts position.

Prior to this service the PEAK VOLTS control will not turn down past around 5 cm of volts with the HORIZONTAL VOLTS/DIV control in the 0.01 position. After the service it will turn down to 2 cm of volts and the operation down to and up from this position will be very smooth.

The service consists of lowering the minimum voltage output of the autotransformer, T701. To do this, loosen the screw holding the rotational limit stops and adjust the stops so that counter-clockwise rotation can be made down to the last one or two windings. *Care must be exercised not to allow the contact to run off the end of the windings* as damage could result.

PLASTIC LIGHT SHIELD FOR RECTANGULAR CRT's

A plastic light shield, similar to that used in Tektronix instruments with 5″ round crt's, is available for Tektronix instruments with 5″ rectangular crt's.

The shield is designed to block any entrance of light onto the phosphor via the space between the crt shield and the front panel. Light escaping through this space can prove bothersome in some oscilloscope photography applications.

Designed specifically for the Type RM-561, the shield is equally useful in other Tektronix instruments employing a rectangular glass crt—the Type 567, Type RM567, Type 527, Type RM527 and the Type 561A MOD210C or 210E. This shield is not needed with the ceramic crt since light is shielded by the ceramic envelope and rubber boot.

Tektronix part number of the new light shield is 337-586. Order through your local Tektronix Field Office or your Tektronix Field Engineer.

POWER CONNECTOR BREAKAGE—PREVENTIVE MAINTENANCE

Breakage of the 3-wire power connector on instruments employing a detachable 3-conductor power cord can occur when the instruments are tilted or lifted from the front with the power cord connected.

This breakage can be prevented by recessing the power connector as shown in Figure 3.

Parts needed:

Qty.	Item	Tektronix Part No.
1	aluminum spacer	361-012
2	1¼", 6-32 screw	211-545
2	6-32 Keps nut	210-457

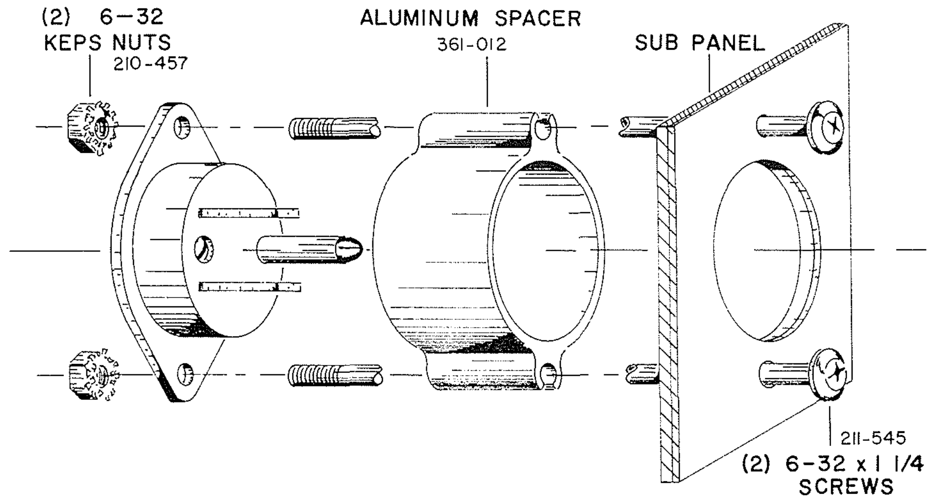


Fig. 3. Pictured instructions for recessing the 3-wire connector on instruments using a detachable, 3-conductor power cord.

TYPE 527 AND TYPE RM527 WAVEFORM MONITOR—VOLTAGE STRESS ON 6EW6 TUBES DURING TURN-ON

When the Type 527 or Type RM527 Waveform Monitor is first turned on, V444 and V544 (6EW6 tubes in the two-stage, push-pull input amplifier) are subjected to quite a voltage stress. This stress can cause excessive cathode deterioration which, in turn, will cause the tube to become gassy. Under this condition the input amplifier will not perform properly and the 6EW6 tubes in the input amplifier are doomed to early failure.

A simple modification to overcome this problem consists of replacing the 0.01 μf/47 k RC network in the grid circuit of both V444 and V544 with a 1N3605 diode (Tektronix Part Number 152-141)—See Figure 4. After the modification, R440, the 47 ohm parasitic resistor will connect directly from the rear wafer of the RESPONSE switch to pin 1 of V444 and the new diode will connect between pin 1 and 2 of V444. Be sure the cathode of the diode connects to pin 2. Repeat these changes in the grid circuit of V544 and the modification is complete.

Gassy 6EW6 tubes in the V444 and V544 positions cause hook and tilt in the displayed waveform. This malfunction is most apparent when viewing the vertical blanking pulse portion of the transmitted composite-video signal. To determine whether the fault is in the transmitted signal or in the Waveform Monitor, position the vertical-blanking-pulse waveform near either the top or bottom of the crt. This increases the current through either V444 or V544, and if they are gassy the hook and tilt will be much more pronounced.

If there is no appreciable change in hook or tilt, V444 and V544 are probably all right and the difficulty is most likely in the transmitted signal.

Type 527's with serial numbers above 744 and Type RM527's with serial numbers above 1189 have this modification installed at the factory. Also, the following serially numbered instruments were modified out of sequence:

Type 527:

645	724 through 726
646	739
674	

Type RM527:

730 through 732	1066
889	1071 through 1074
908	1097
980	1116
997	1121
1020	1122
1035	1138 through 1141
1036	1143 through 1145
1038	1147 through 1159
1042	1162 through 1188

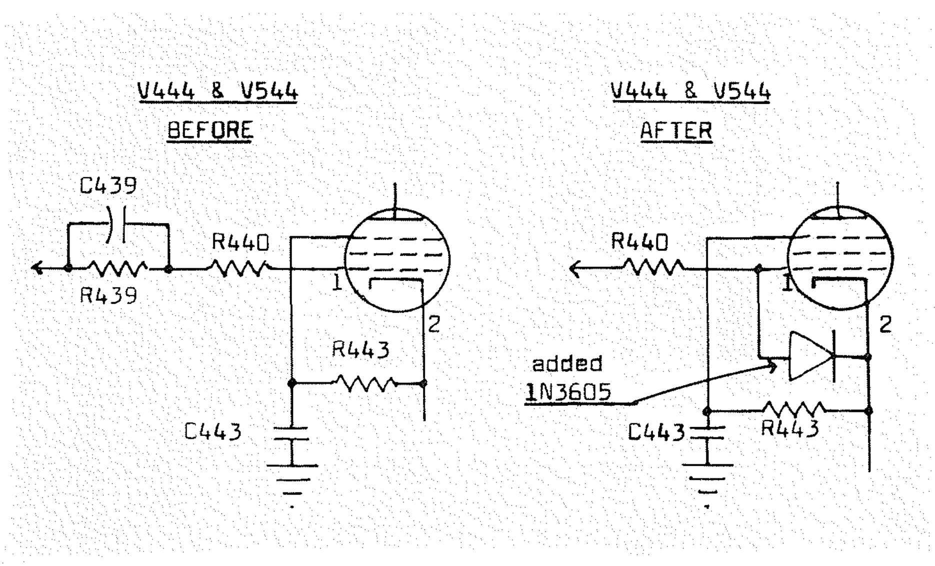


Figure 4. "Before" and "After" schematic for replacing the 0.01 μf/47 k RC network, in the grid circuit of both V444 and V544, with 1N3605 diodes.

USED INSTRUMENTS FOR SALE

1 Type 513D Oscilloscope, s/n 1672 with new crt. Ray Case, 8146 Matilija, Panorama City, California, phone 780-0322. Price: $350.

1 Type 317 Oscilloscope, s/n 346. Instrument like new. Will sacrifice for $500. Mr. Rising, 53 Hundreds Circle, Wellesley Hills, Massachusetts. Telephone: Area Code 617, 235-0385.

1 Type 535 Oscilloscope, s/n 6095 with a Type 53/54C Plug-In Unit, s/n 9668. Price: $1200. R. L. Bennett, Todd-AO Corporation, 1021 Seward Street, Hollywood, California. Phone: HO 3-1136.

1 Type 511AD Oscilloscope, s/n 4718 with P510 Attenuator Probe. Recently repaired, modified and recalibrated at Tektronix Repair Center. R. J. France, Control Science Corporation, 5150 Duke Street, Alexandria, Virginia.

1 Type 502 Oscilloscope, s/n 4211 and 2 Type 122 Preamplifiers, s/n's 5494 and 5495. Instruments have seen little use. C. R. Smith, President, Capital Sales Ltd., P. O. Box 266, Fredericton, New Brunswick.

1 Type 81 Plug-In Adapter (for use with Type 580 Series Oscilloscopes). New, never used. Dalmo Victor, Belmont, California, Attention: Mr. Wells.

1 Type 532 Oscilloscope, s/n 5100; 1 Type 53G Plug-In Unit, s/n 100 and 1 cart. Mr. Richardson, N.J.E. Corporation, 20 Boright Avenue, Kenilworth, New Jersey.

1 Type 67 Plug-In Unit, s/n 2596. Never used. In original packing. Mr. Leo Katz, Electronics Laboratory, Notre Dame Hospital, 1560 Sherbrooke Street East, Montreal 24, Quebec, Canada. Telephone 525-6363 — Local 576.

1 Type 190A, s/n 6048; and 1 Type 190B, s/n 6952 Constant-Amplitude Signal Generators. A. Samuelson, Electric Service Systems, 5555 Old Highway 5, Minneapolis 24, Minnesota. Telephone: 941-2200.

1 Type 517, s/n 508, High Speed Oscilloscope. For sale, lease or rent. Recently overhauled by Tektronix, Inc. Michael J. Haddad, Surface-Air Electronics, 138 Nevada Street, El Segundo, California. Telephone SP2-1469.

1 Type 82 Plug-In Unit, s/n 2307. Joel Backer, Magnetic Research Corporation, 3160 West El Segundo Boulevard, Hawthorne, California. Telephone: OS 5-1171.

1 Type 513D Oscilloscope, s/n 691. Price: $450. Donald Fleischer, 503 Tennis Avenue, Ambler, Pennsylvania. Telephone: MI 6-0580.

1 Type 502 MOD104 Oscilloscope, s/n 2840. Dr. Peckham, Eye Research Foundation, 8710 Old Georgetown Road, Bethesda, Maryland. Phone: 301-656-1527.

USED INSTRUMENTS WANTED

1 Type 310 Oscilloscope. E. C. Webb, Lakewood Manufacturing, 25100 Detroit, Westlake, Ohio. Telephone: Area 216-TR1-5000.

1 Type 321 Oscilloscope, John Sumner, 728 N. Sawtelle, Tucson, Arizona.

1 Type 515 or Type 515A Oscilloscope. William Macoughtry, Code 536, NASA, Goddard Space Flight Center, Greenbelt, Maryland.

1 Type 524AD Oscilloscope. H. Holland, H. W. H. Electronic Service, 7217 Gulf Boulevard, St. Petersburg Beach, Florida.

1 Type 310, 316 or 515 Oscilloscope. $225 maximum. George Reeves, 4273 W. Oak Avenue, Fullerton, California.

Mr. John Bowser of the Smith Corona Corporation at 301 N. Michigan Street, Chicago, Illinois, reports the theft of a Type 310A Oscilloscope, s/n 17926. The instrument disappeared from the car of one of their servicemen while it was parked in the back of their office building. Mr. Bowser would appreciate hearing from any of our readers who have any information on the whereabouts of this instrument.

Another car prowl, this one also in Chicago, produced a Type 516 MOD 108B for the vandals. Serial number of this instrument is 1930 and it is the property of the General Electric Company, 840 S. Canal Street, Chicago, Illinois. The theft occurred on Tuesday, November 26, 1963, while the car was parked outside their building. Information on the location of this instrument should be relayed to Mr. O. Nickerson of the General Electric Company at the address noted above.

This last report of a missing instrument concerns one that disappeared on January 1, 1963 and has just been called to our attention.

This oscilloscope, a Type 310A, s/n 012960, belongs to Huyck Systems located on Wolf Hill Road in Huntington, Long Island, New York.

Mr. Al Richert of Huyck Systems tells us that the oscilloscope was at Lockheed in Burbank, California at the time of its disappearance and he asks our readers in that area to be on the lookout for it.

Mr. Richert is the man to contact if you have any information about this oscilloscope.

Service Scope

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USERS OF TEKTRONIX INSTRUMENTS

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Beaverton, Oregon

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USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 25 PRINTED IN U.S.A APRIL 1964

TELEVISION AND SINE-SQUARED TESTING

by Joseph E. Nelson
Tektronix Product Information Department

Electronic people, other than those engaged in television work, should also find this article of interest. Where there is a necessity for good resolution of phase characteristics, the sine-squared testing technique offers great potential in the evaluation of broad-band amplifier performance.

Editor's note — The major North American television networks now transmit a sine-squared signal for network-testing purposes. Test methods employing this signal easily detect small abnormalities in the linear-transmission performance of television links. Abnormalities that, although they greatly affect the quality of the television picture, are difficult to evaluate using conventional steady-state methods of signal testing.

When a television camera scans a vertical white line against a black background, the camera output resembles a sine-squared pulse. This pulse contains frequency components that extend toward the upper bandwidth of the TV system. For faithful reproduction of a televised picture, the entire TV system should be capable of passing this pulse without undue distortion or change in width or shape.

Since the reproduced condition of this pulse depends on the quality of the TV system, i.e., transient response, envelope and phase delay, it became apparent that a synthetically generated pulse of this type would make an ideal test signal. Thus the sine-squared pulse was born.

To make this type of test more complete, a low-frequency signal, the $\sin^2$ bar, was joined with the $\sin^2$ pulse to form a composite signal that can test the entire frequency spectrum of a TV system.

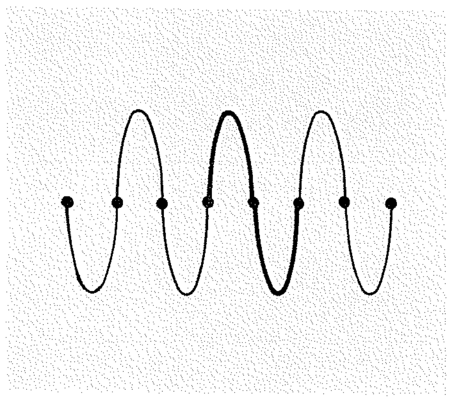


Figure 1. Sine wave with a single cycle indicated by the heavier line.

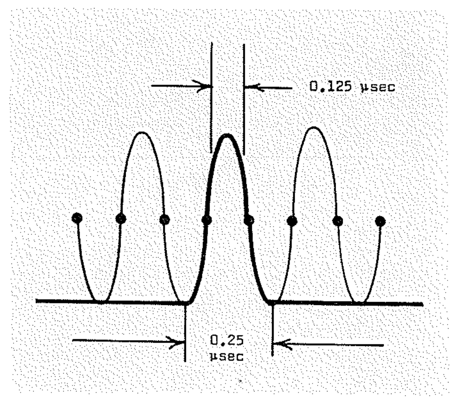


Figure 2. The single cycle of Figure 1 with the base line moved to the bottom.

This composite signal, now available from commercial sine-squared generators, can be used in a number of ways. The test signal can be coupled directly into a camera, link amplifier, or transmitter, and the output examined on an oscilloscope. Or, during non-viewing hours of a TV network, the composite signal can be transmitted on each horizontal line of the camera scan, received at network affiliate stations, and examined for distortion. An additional method, used by all major networks, is to transmit the composite test signal during regular viewing hours but only include it in a single horizontal line during the vertical blanking period. With this latter method, the condition of the entire system can be constantly monitored throughout the transmission period. Since the test signal occurs on a single line during vertical blanking, an oscilloscope capable of displaying this line is necessary. The Tektronix Special-Model Type 527 or Special-Model Type RM527 TV Monitor can be used for this purpose.

$\sin^2$ Pulse and Bar

One can perhaps best visualize the shape of the $\sin^2$ pulse by thinking of a sine wave with the base line moved to the bottom (see Figure 1 and 2). The pulse width of the test pulse is made to be one-half of the period of one cycle of the upper cutoff frequency of the TV system. Thus the pulse width when used with a 4 megacycle system is 0.125 microsecond. This time (0.125 μsec) is designated by a capital T. A $\sin^2$ pulse with a width of 0.125 μsec is 6 db down at 4 megacycles and contains practically zero energy at 8 megacycles. For routine tests a $\sin^2$ pulse with a width of 2T (0.250 μsec) can be used. A $\sin^2$ T pulse is shown in Figure 3.

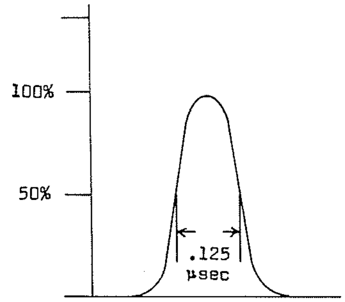


Figure 3. Sin^2 T pulse.

The $\sin^2$ bar, also called a white window, is a combination of a square-wave and a $\sin^2$ pulse. The risetime and falltime is the same as an integrated $\sin^2$ pulse while the flat-top is similar to a square-wave. Pulse width of the bar signal is 25 microseconds which is 0.4 H. (H is the time-length of one horizontal line, 63.5 μsec). The bar signal is shown in Figure 4.

The composite test signal, with typical time spacings is shown in Fig. 5.

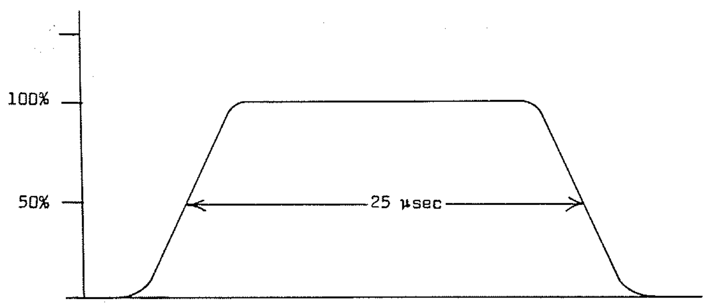


Figure 4. Sin^2 bar, a combination of a sin^2 pulse and a square wave.

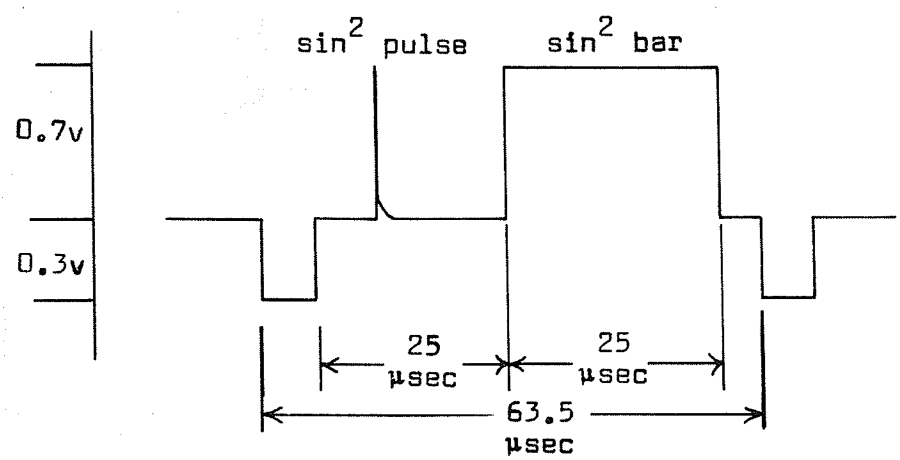


Figure 5. Composite test signal with typical time spacings.

The Oscilloscope and $\sin^2$

The type of oscilloscope needed to examine the sine-square signal depends on the type of transmission. For example, within the studio, where a sine-square generator supplies the test signal continuously a triggered oscilloscope such as the Tektronix Type 524 with adjustable time-base can be used. However, when the test signal is present only on a single line of each frame, some method of selecting and examining this line must be used. The line selector feature of the Tektronix Special-Model Type 527 or Type RM527 allows the operator to select and examine any line within the television frame. Briefly, the line selector uses the principle of a delayed trigger. A trigger circuit phantastron is started by the vertical sync pulse of the received signal. The phantastron is mixed with each horizontal sync pulse of the signal and presented to a comparator. The voltage on the opposite side of the comparator can be adjusted to make the comparator switch on any one of the field horizontal sync pulses. The output of the comparator is a trigger pulse that starts the sweep in the oscilloscope.

When a single line that contains the $\sin^2$ pulse and bar is selected, the Type 527 sweep is set to 0.125 H/CM, and since the bar signal is 0.4H, it will occupy 3.2 horizontal centimeters. After the bar signal has been examined, the sweep control is switched to 0.005 H/CM and the $\sin^2$ pulse examined in detail.

Typical $\sin^2$ Response to Distortion

The change in shape and size of the composite $\sin^2$ test signal is a direct indication of the kind of distortion a system produces. Here are several examples of these changes.

1. Low-frequency distortion. This type of distortion has its greatest effect on the $\sin^2$ bar while little change is seen in the $\sin^2$ pulse. Depending on the time-constant of the circuit involved, the bar will show: undershoot, overshoot, or horizontal tilt. For example, a short time-constant undershoot is a leading-edge roll-off, as shown in Figure 6-a; while a long time-constant overshoot is a negative tilt (drop in amplitude from leading to trailing edge), as shown in Figure 6-b.

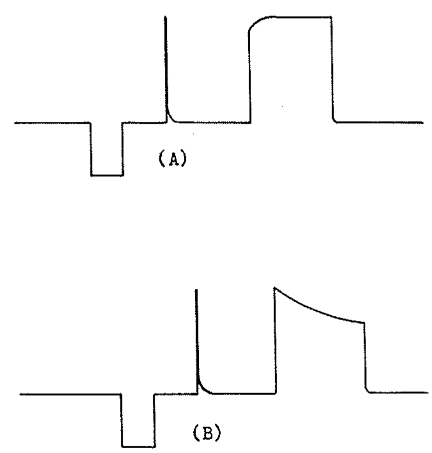


Figure 6. Sin^2 test signal showing: (a) short time constant undershoot, (b) long time constant overshoot.

2. Frequency Response irregularities. When the frequency response is not flat across the bandwidth of the system, we get dips and bumps. These dips and bumps on the test signal are actually ringing that is related to the frequency

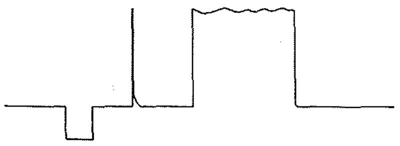


Figure 7. Sin^2 test signal with dips and bumps caused by frequency response irregularities.

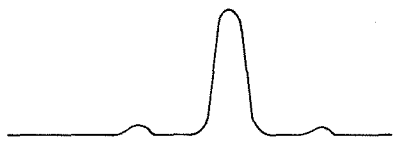


Figure 8. Sin^2 pulse showing a leading and a trailing reflection or echo.

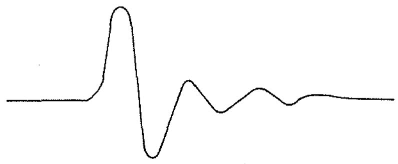


Figure 9. Sin^2 pulse showing distortion caused by high frequency roll off: reduced height, increased width, and decaying ringing.

irregularity (Figure 7). Once again the change in the test signal depends on the frequency.

3. Reflections. Since the sin^2 test signal can be transmitted (during the vertical blanking interval), the nature of reflections caused by multi-path signals can be measured. (See Figure 8.)

4. High-frequency roll-off (Figure 9). The most significant change caused by reduced bandwidth is the amplitude of the sin^2 pulse. And with this reduced amplitude, the pulse width increases since the area of the pulse represents a dc component that remains constant. From the appearance of the pulse, you can estimate the shape of the roll-off curve. For example, a slow roll-off produces a large reduction in amplitude with little, if any, ringing; while a rapid roll-off (almost a cutoff) affects the amplitude less, but does show considerable ringing.

CAPTURING POWER-LINE TRANSIENTS

by Ron Bell
Tektronix Field Engineer

Power-equipment engineers frequently find it necessary to measure transients on sixty-cycle power lines. The need arises, for example, when working with solid-state power-control equipment. Large voltage transients, introduced through the power line, can cause equipment malfunction or even semi-conductor failures. Circuit-breaker testing, where the sudden closure or opening of a circuit marks the beginning of a test, is another situation requiring transient measurements. In these circumstances, it is common for the engineer to display the transient on an oscilloscope; photographing the results for analysis.

But it is not always easy to photograph the transients.

The power-line waveform with simulated transients, shown in Figure 1, will serve to explain the operating problems. Notice first that transient A exceeds the peak line voltage; whereas transient B does not. Notice also that transient A is a positive-going impulse and transient B is negative going.

Photographing transient A would be rel-

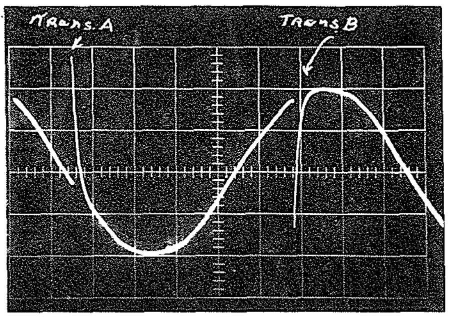


Figure 1. Power-line waveform with simulated transients.

atively easy. The oscilloscope triggering circuits could be adjusted to initiate a sweep (1) during a positive-going slope and (2) when the instantaneous voltage exceeds the peak-line voltage. If, however, the transient occurred later in the cycle, the instantaneous transient voltage would not exceed the instantaneous power-line voltage. As a result, condition (2) would prevent sweep triggering. Adjusting the trigger circuits for a lower triggering level would result in power-line waveform triggering.

To differentiate between transient voltages and the power-line waveform, the sixty-cycle component can be rejected from the trigger circuits. This is accomplished by operating in the AC LF-REJECT mode. In this mode, the triggering circuits respond to the transients as though they started at zero volts, regardless of when they occur during the power-line cycle.

Using the AC LF REJECT mode, transient B could be photographed by adjusting the trigger circuits for triggering during a negative slope. Obviously, it is rare that the polarity of a transient is known beforehand. In short, for any one setting of the triggering controls, we can display either transient A or B, but not both. If transients of both polarities are to be displayed, it is necessary that the triggering circuits respond to both concurrently.

This article describes a modification to permit triggering on plus and minus slopes concurrently. The circuit information applies specifically to the 530A-, 540A- and 550-series oscilloscopes. In general the circuit modification can be applied to other instruments (except those with solid-state triggering circuits) with only minor changes.

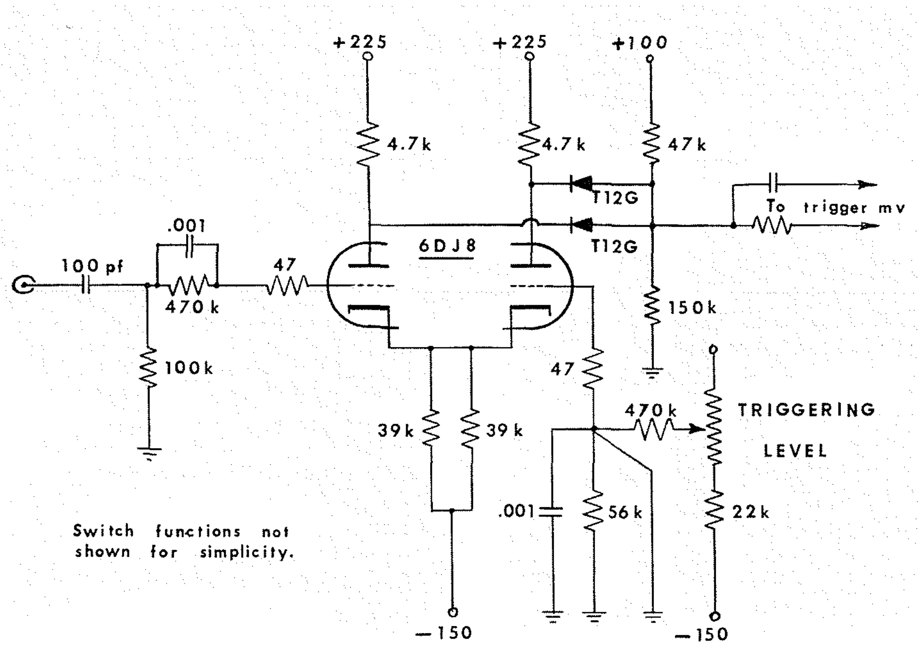


Figure 2. Modified Trigger-Amplifier Circuit of a Type 530 or Type 540 Series Oscilloscope.

The modified-circuit diagram is shown in Figure 2. Notice that the only additional parts required are two T-12G diodes, a 150 k resistor and a 47 k resistor. Notice also that the 47 pf capacitor normally connected across the plate-load resistor of the left-hand triode has been removed and that the grid of the right-hand triode is grounded.

Circuit operation is almost self-explanatory. The two T12G diodes are normally back-biased between the center-tap of the voltage divider and the quiescent triode plate voltages. The sixty-cycle power-line waveform (and, of course, the transient) is connected to the input connector.

The time constant of the 100 pf coupling capacitor and the 100 K input resistor is short enough to effectively block the sixty-cycle component; while at the same time, allowing fast-changing transient voltages to pass through to the input grid. The two triodes are operating as a paraphase inverter. If the input transient is positive-going, it will cause the left-hand plate voltage to go down. Similarly, if the input transient is negative-going, it will cause the right-hand plate to go down.

A negative-going voltage on either triode plate will cause the associated diode to go into conduction. When one of the diodes conducts, a negative-going voltage appears at the common-anode point. This negative-going voltage is coupled to the trigger multivibrator which, in turn, triggers the time-base generator.

Trigger sensitivity of the modified circuit is less than normal. Unmodified, the triggering circuit will respond to 0.1 volts or less. This circuit requires approximately 1.5 volts. For simplicity, the right-hand triode grid is grounded. Because of imbalance in the triodes and tolerance in the plate-load resistors, it is unlikely that the plate voltages will be equal. To avoid the possibility of no-signal diode conduction, the diode anode voltages are lower than necessary. This means the triggering voltage must overcome this back-bias before triggering can occur. This should not be a handicap, however, since ample triggering voltages are usually available in power-line testing.

Near-normal sensitivities can be realized by replacing the 150 k resistor in the divider with a 220 k resistor. It will be necessary to check the plate voltages for imbalance. Removing the ground from the right-hand triode grid will permit using the TRIGGERING LEVEL control to achieve perfect balance. Of course, the operator must be careful not to disturb this control once adjusted.

To adjust the circuits for correct operation, set the front-panel controls as follows:

TIME/CM	2 μsec
5X MAGNIFIER	Off
STABILITY	Preset
TRIGGERING LEVEL	0
VOLTS/CM	1
CALIBRATOR	5
TRIGGERING MODE	AC LF-REJECT
TRIGGER SLOPE	+ Int.

Connect the Calibrator output to the plug-in input. Starting with the Trig. Level Centering Control turned fully clockwise, turn it counter-clockwise for a display

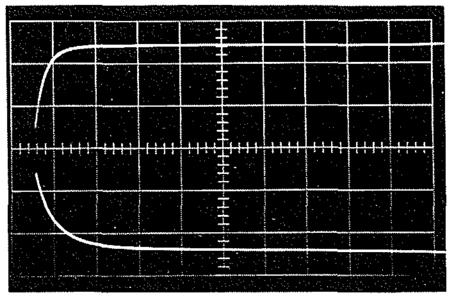
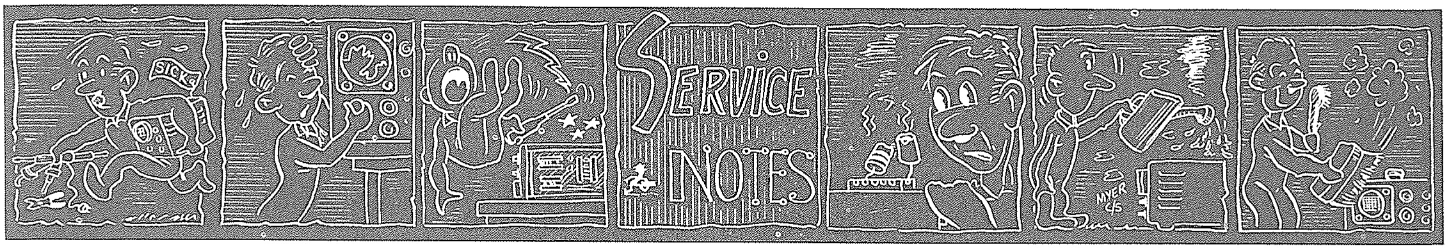


Figure 3. Initial display during adjustment procedure. The vertical deflection factor is 1 volt/cm. The sweep rate is 2 μsec/cm.

similar to Figure 3. Next, reduce the vertical deflection with the Volts/CM controls until either the upper or lower trace disappears. Turn the Trig. Level Centering Control CCW to restore the display. Continue to reduce the vertical deflection while adjusting the Trigger Level Centering Control until the two traces are separated by 1 cm or less.

To verify your adjustments, connect the calibrator output to the External Trigger Input connector. Set the Trigger Slope Switch to + Ext. You should be able to obtain displays similar to Figure 3 over a range of input voltages from 2 to 10 volts.

Details on how this modification might be installed in an oscilloscope are left to the inventiveness of the reader. Certainly, consideration should be given to how frequently it might be used. In those situations where this mode of operation would be used often, a permanent switch function would seem most convenient. On the other hand, for occasional "one-shot" applications, it might be simpler to "tack-in" the components as needed. On those instruments having an operator's manual compartment in the right-hand side panel, one shouldn't overlook the possibility of mounting a chassis directly underneath the compartment for easy access through the trapdoor.



CERAMIC STRIP BREAKAGE TRACED TO EXCESS SOLDER

The newer high-density (tightly-notched) ceramic strips will sometimes break if the notches are over-filled with solder. The shrinking of the solder as it cools can cause stresses severe enough to crack the strip. The shrinking solder tries to pull the two ends of the strip together.

One should take care when soldering these strips to use just enough solder to cover the wires. The resulting connection will be just as electrically sound as when the notch is filled.

The use of Enthoven *silver-bearing* solder (instead of Divco), coupled with the use of solder in judicious amounts reduces the hazard of breakage to a minimum. Enthoven solder possesses a higher "creep-rate", i.e., it relaxes more quickly after hardening. Both Enthoven and Divco solder tend to cold-flow and relieve the tension, the Enthoven immediately, the Divco more slowly. Enthoven solder is identified by a star-shaped rosin core; Divco has a round core.

A recent change in the material used in the manufacture of our high-density ceramic strips should further alleviate this breakage problem. This new material offers increased flexural strength, tensile strength and compressive strength. It also has a lower thermal expansion which helps in thermal shock. An empirical test which we developed for checking thermal shock, consists of excessive loading of silver or solder in the notches. Under these test conditions, the new porcelain material displays a pronounced superiority over the old material.

NEW NE-23 NEONS VERSUS THE OLDER NE-2 NEONS

From time to time a problem arises within an instrument because a NE-2 neon refuses to immediately ionize upon application of voltage. Previously, all neons exhibited a touchiness about environmental conditions — sensitivity to temperature changes, light, radiation, etc. A new neon, the NE-23, offers a good solution to this problem. A tiny dot of radioactive material, added to the glass envelope during manufacture, guarantees the immediate ionization of the neon gas.

Modifications now in progress will change, wherever possible, the neons in instruments manufactured by Tektronix, Inc. to the new NE-23's. For the present, certain circuits will continue to use NE-2's for a specified voltage drop. As selected NE-23's become available for these circuits they will replace the NE-2 neons.

BLADE-TYPE ALIGNMENT TOOL IMPROVEMENT

Our thanks to Bob Nagler, Field Mainland, USAF with the PME Lab. in Ramstein AB, Germany, who offers this suggestion:

"When using blade-type alignment tools it is often difficult to position the blade to fit the slot since the blade cannot be seen from the top. To remedy this trouble, modify the tool as follows: Scribe a line across the top of the handle of the blade-type tool to indicate the position of the blade. The scribed line may be filled with paint to give better visibility."

We tried Sgt. Holland's suggestion (see Figure 1) and liked the result.

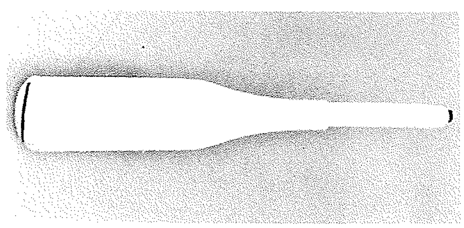


Figure 1. Scribed line on handle indicates position of blade.

TYPE 2B67 TIME-BASE UNIT—COMPROMISE SETTING OF STABILITY CONTROL CRITICAL

With the MODE control of the Type 2B67 Time Base Unit in the SINGLE SWEEP position, current drawn through R126 (a 220 k resistor) can cause the setting of the STABILITY control to become quite critical.

R126 functions to keep Q124 (a 2N2043 transistor) turned off when the sweep is "armed" and the READY light on (ready to be triggered). It may pull the plate of V135A (½ of a 6DJ8 tube) enough positive while in this condition to shift the triggerable range of the multivibrator considerably. In a typical instrument, the STABILITY control may offer a compromise setting (for operation in both NORM and SINGLE SWEEP modes) with a range of only about 0.5 volt.

The 220-k value of R126 was selected to prevent Q124 from turning itself on with collector-base leakage which, according to the manufacturer's spec sheet, can be 500 μamp at 71°C. However, experience in the field with this instrument indicates a much smaller typical value of leakage—so much so that most of the current from R126 simply goes to upset the sweep-gating multivibrator's hysteresis range.

Check the quiescent (READY) value of plate voltage at pin 1 of V135A. If plate voltage changes by more than about 5 volts as the MODE control is moved from NORM to SINGLE SWEEP, try changing R126 to a value between 470 k and 1 M. This will usually help considerably in making the compromise setting of the STABILITY control easier to find and more stable.

Our thanks to Bob Nagler, Field Maintenance Representative of the Toronto Field Office of Tektronix Canada, Ltd. for pointing up this problem and offering a solution.

TYPE 6R1 AND TYPE 6R1A DIGITAL UNIT CAUTION

Ben Franklin, or somebody, once said, "A word to the wise is sufficient". The word this time is: Always turn off the power when removing or replacing circuit cards in the Type 6R1 or Type 6R1A Digital Unit of a Type 567 Digital Readout Oscilloscope.

Failure to do so may cause destruction of some transistors and other components both in the replacement and other circuit cards of the Digital Unit.

Plugging a circuit card into the Digital Unit with the power on can cause the 2B67 Time Base Unit in the SINGLE voltage-carrying contacts in the connector to introduce voltage to the board's circuit (or circuits) a momentary instant before other contacts in the connector mate to establish a return-voltage path.

When this occurs, the momentary delay may cause a surge of power or generate a transient that exceeds the dissipation capabilities of certain transistors or other components in the Digital Unit's plug-in circuit cards.

TYPE 580 SERIES OSCILLOSCOPES—DIRECT CONNECTION TO CRT VERTICAL PLATES

Several circuit changes plus the construction of a balun will allow direct connection of signals to the vertical deflection plates of the crt in Type 580 Series Oscilloscopes. Input impedance is about 50 ohms (47½ ohms actual) and sensitivity is about 5 volts per centimeter depending on the crt. Risetime is essentially that of the crt deflection structure—about 1 nanosecond. Low-frequency cutoff L/R-risetime constant varies with signal amplitude from about 20 microseconds a centimeter step amplitude, to about 30 microseconds at ½ centimeter amplitude.

Returning the oscilloscope to normal operation will require rewiring the vertical output system to the original circuit.

Figure 2 shows the new vertical output circuit. Figure 3 shows the input connector, cables, balun and 107 ohm resistors. The cable from the input connector, through the balun and to the one deflection plate and the cable from the input connector to the other deflection plate *must be the same length, and as short as possible* (for minimum cable loss).

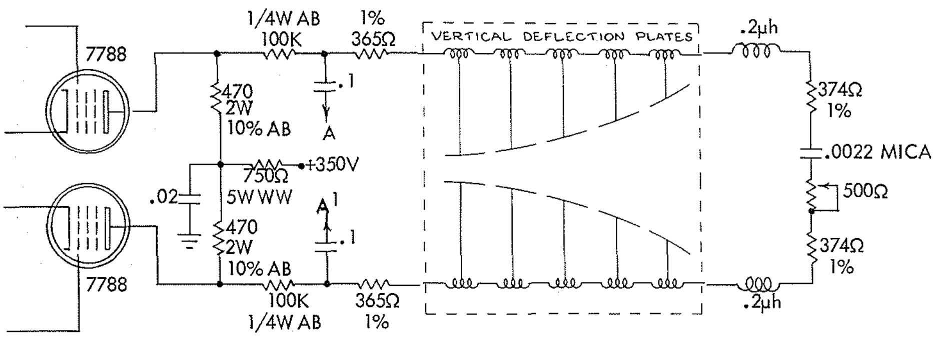


Figure 2. Type 580 Series Oscilloscope — Vertical-output circuit for direct connection to crt vertical plates.

To construct the balun, first construct the transition by severing one of the pieces of 93 Ω cable at mid-point and reconnecting the severed pieces as shown in the "Transition detail" of Figure 3. Next, place the transition within the 101 ferrite core and pass each end of the cable through the core four times as shown in Figure 3. Each pass of the cable through the core constitutes a turn and each side of the transition is considered ½ a turn.

Parts required:

Qty.	Item	Tektronix Part No.
1	500 Ω pot.	311-056
1	0.0022 μfd Mica cap.	283-530
2	374 Ω, 1%, ½ w, Prec. res.	323-152
2	365 Ω, 1%, ⅛ w, Prec. res.	321-151
2	0.1 μf, Cer. Cap.	283-008
2	0.2 μf fixed coil	108-008
2	100 k, ¼ w, comp. res.	316-104
2	470 Ω, 2 w, comp. res.	305-471
1	750 Ω, 5 w, WW, res.	308-067
1	0.02 μf, Cer. cap.	283-004
1	GR connector	none
1	Ferrite core, 101	276-519
2	107 Ω, comp. res.	
2	pc's. 93 Ω cable of equal length	none

The 500 Ω pot installed in this modification takes the place of R1293 in the normal circuitry. Consult the "Adjust Vertical System High-Frequency Compensations" section of your Type 580 Series instruction manual for instructions on the function of this pot.

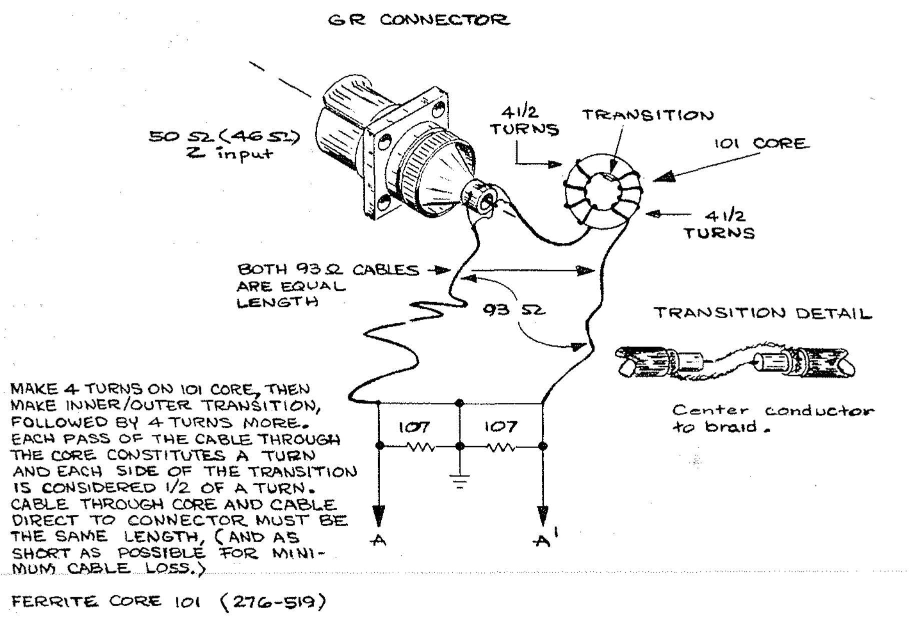
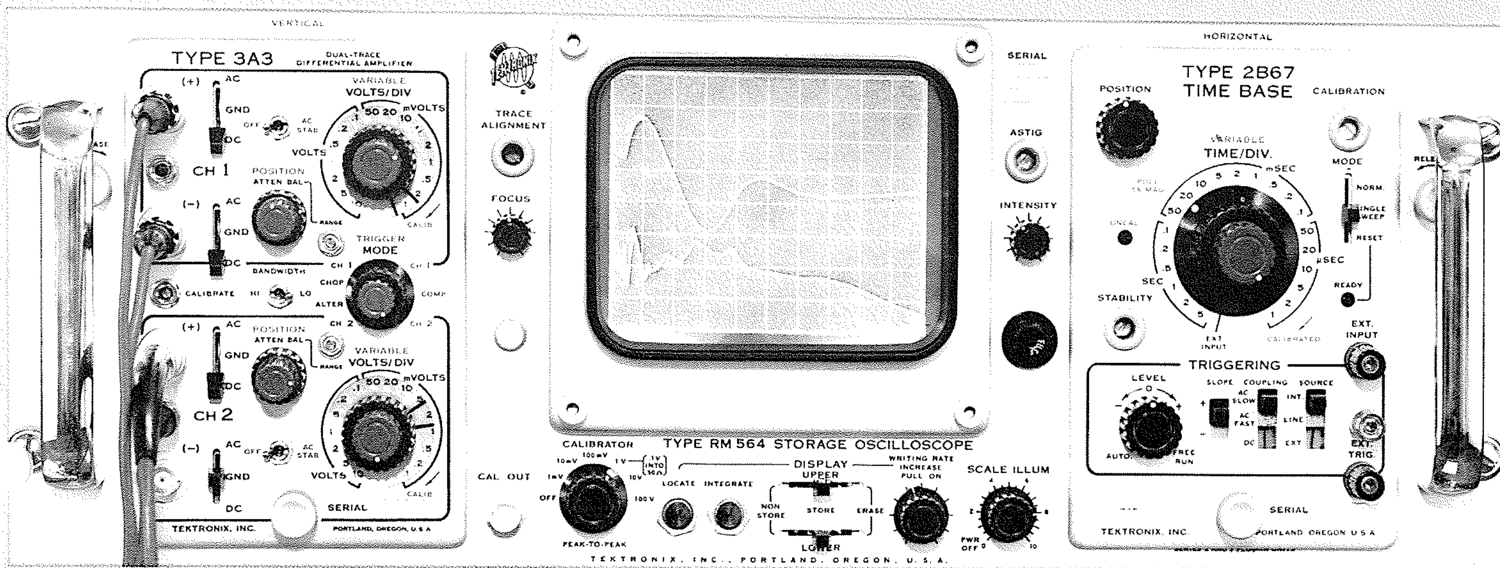


Figure 3. Connector detail for direct connection to crt vertical plates — Type 580 Series Oscilloscope.

PRESENTING THE TEKTRONIX

TYPE RM564

RACK-MOUNT STORAGE OSCILLOSCOPE



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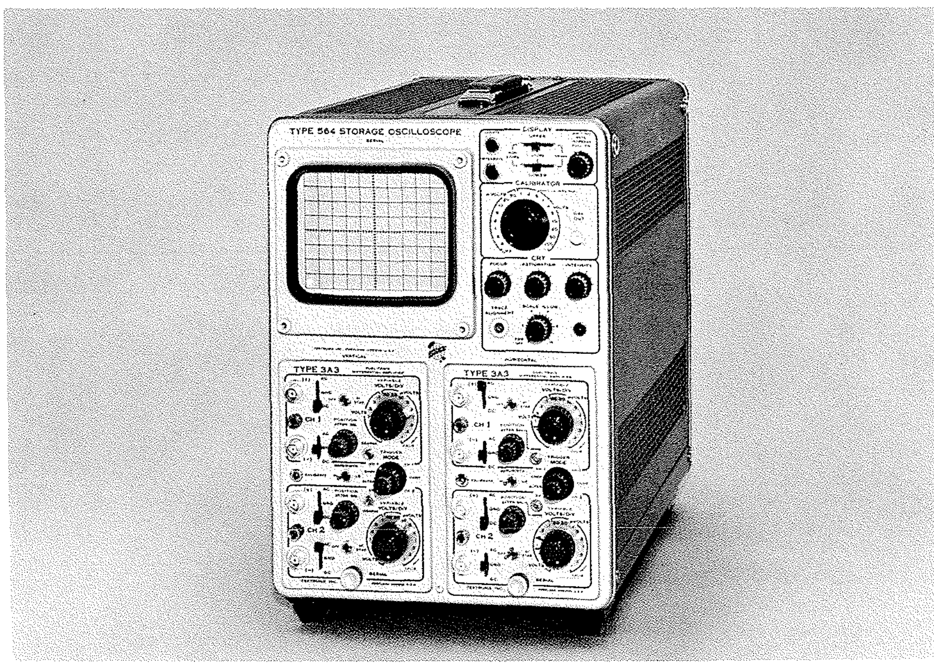
NUMBER 26 PRINTED IN U.S.A JUNE 1964

FREQUENCY COMPARISONS USING ROULETTE PATTERNS

Roulette patterns, because they retain their shape under conditions of slight oscillator frequency drift, offer a considerable advantage over the use of Lissajous figures in making frequency comparisons.



Type 564 Storage Oscilloscope with two Type 3A3 Dual-Trace Differential Plug-In Units, one in the vertical and one in the horizontal amplifier compartments.

High-ratio frequency comparisons by use of Lissajous figures are often difficult to observe. Any slight oscillator frequency drift causes the Lissajous figure to change shape. The display appears to rotate in a plane perpendicular to the face of the cathode-ray tube. Since the front and back portions of the figure are not separated, interpretation of the pattern becomes increasingly difficult as the frequency ratio increases.

Roulettes are much easier to interpret than are Lissajous figures because slight oscillator frequency drifts cause a pattern rotation in the plane of the crt screen without a change in pattern shape. Roulettes are readily displayed with oscilloscopes having differential inputs on both the horizontal and vertical amplifiers.

Several Tektronix Oscilloscopes and Oscilloscope/Plug-In combinations lend themselves to this application. The reference chart which appears elsewhere in this article lists these oscilloscopes and oscilloscope/plug-in combinations. It also gives their sensitivity and bandpass capabilities.

The waveforms illustrating this article were photographed using a Type 564 Storage Oscilloscope with two Type 3A3 Dual-Trace, Differential Plug-In Units—one in the vertical and one in the horizontal plug-in compartments. The storage feature of the Type 564 Oscilloscope makes this instrument the ideal choice for this application. As mentioned before, a slight drift in oscillator frequency will cause a rotation of the displayed roulette pattern. The rotation will be in the plane of the crt. The operator, by employing the Storage mode of Display, can "stop" this rotation for ease in counting the points of the roulette pattern. This count, which will be explained later, is a necessary part of the application procedure.

As for the other oscilloscope and oscilloscope/plug-in combinations listed on the reference chart, the best way to "stop" the roulette-pattern rotation on these instruments is to use an oscilloscope camera and photograph the display.

"Stopping" the roulette pattern's rotation is not, however, a necessary part of the application. One can usually control the drift in oscillator frequency to a point where the roulette pattern remains stable enough for an accurate point count.

How to set up roulette patterns

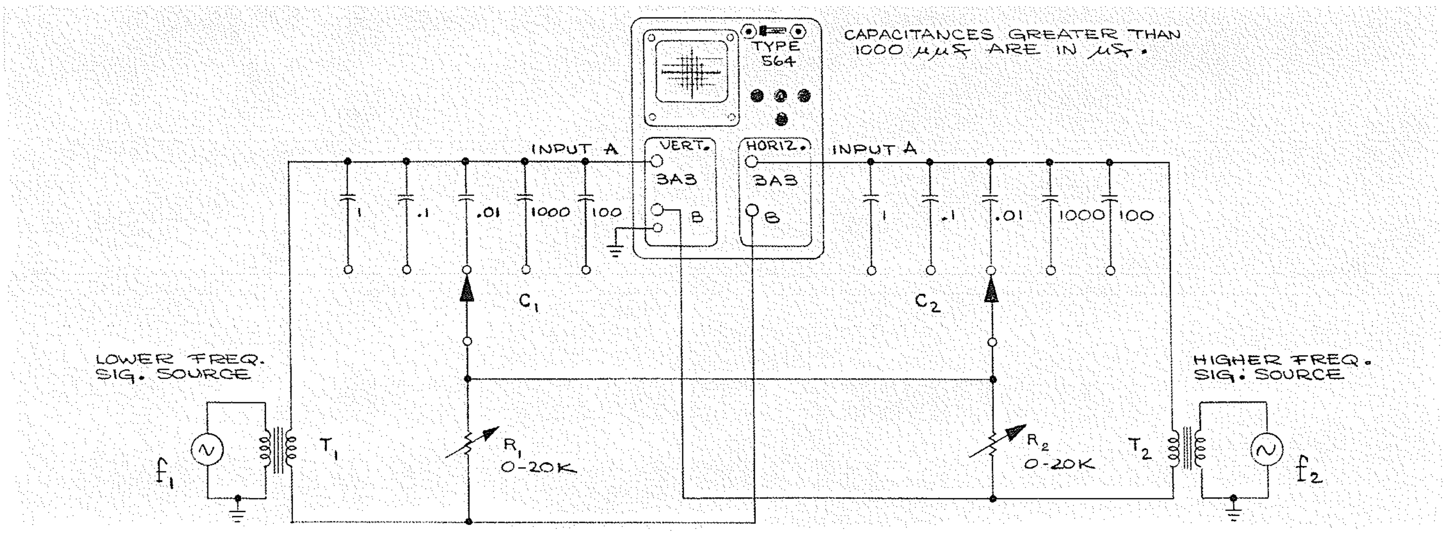


Fig. 1. Circuitry For Displaying Roulette Patterns.

Fig. 1 shows the circuit used in displaying roulette patterns. Transformers T_1 and T_2 provide isolation so that both of the signal sources can be operated with a common ground connection. In many applications either one or both of the transformers can be omitted, provided hum problems are not encountered. If isolation transformers are not used, the signal sources should be operated without a common ground connection. For convenience, we will discuss the display of roulette patterns at audio frequencies. You can use any signal source within the frequency range of your oscilloscope, however, stable radio-frequency displays are usually limited to crystal-controlled frequency sources. The circuit adjustment procedure is as follows:

1. Turn on the equipment and allow a few minutes for warm-up.
2. Using appropriate settings, adjust the plug-in units' V/CM controls to provide equal sensitivities for both the VERTICAL and HORIZONTAL channels. Should later readjustment be necessary, keep the sensitivities equal.
3. Set the output amplitude of both frequency sources to zero.
4. Advance the amplitude control on the higher-frequency generator until an elliptical trace appears on the crt screen. Adjust R_2 and C_2 until the ellipse becomes a circular shape. Return the output amplitude of the higher-frequency generator to zero.
5. Advance the amplitude control on the lower-frequency generator until an elliptical trace appears on the crt screen. Adjust R_1 and C_1 until the ellipse becomes a circular shape.
6. Readvance the amplitude control on the higher-frequency oscillator to obtain the desired roulette. Adjust the frequency of either oscillator for a stationary pattern.

Typical patterns for a 15:2 frequency ratio are shown in Fig. 2. The patterns differ only in that the output amplitude of the higher-frequency generator is greater in Fig. 2b.

To determine the frequency ratio, count the total number of points on the circumference of the pattern (17 points in Fig. 2a). Call this number N_1. Next, determine the number of points passed over in tracing from one point to another along the figure. For instance, in tracing from point 1 to point 3 in Fig. 2a, only one point (point 2) is crossed. Add one to this number and call it N_2. The ratio of the two frequencies is given by:

$$\frac{f_2}{f_1} = \frac{N_1 - N_2}{N_2} = \frac{(17 - 2)}{2} = 15{:}2 \text{ for Fig. 2a.}$$

When no points are crossed in moving from one point to another along the trace, the ratio of frequencies is a whole number (an integer), and the ratio is simply one less than the total number of points on the pattern circumference. Fig. 3 shows a 21 point pattern indicating a 20:1 frequency ratio.

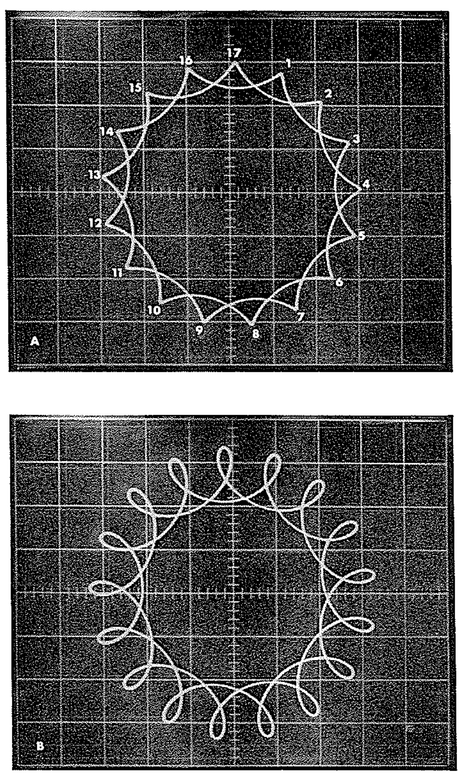


Fig. 2. Typical roulettes for a 15:2 frequency ratio.

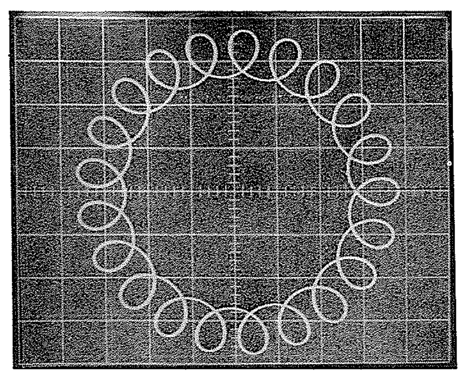


Fig. 3. Roulette pattern for a frequency ratio of 20:1.

Theory

The operation of the circuit of Fig. 1 is best understood by the application of superposition theory. We first determine the crt trace deflections produced by the signal sources operating separately, then we add the resultant deflections vectorially. Fig. 4a shows the circuit of Fig. 1 redrawn and slightly revised. Here, we have replaced the cathode-ray oscilloscope with the crt deflection plates corresponding to the amplifier input connectors. In addition, we have replaced the higher-frequency oscillator by its internal impedance Z_2. The impedances Xc_2, R_2 and Z_2 can usually be neglected when compared to the oscilloscope input resistances (1 megohm). Neglecting these impedances, we get the simplified equivalent circuit of Fig. 4b. If the magnitude of Xc_1 equals R_1 at the frequency f_1, a circular trace appears on the crt screen. If generator f_2 is restored and generator f_1 is replaced by its internal impedance, the analysis outlined above may be repeated. With both f_1 and f_2 in operation, the actual deflection of the electron beam is the vector sum of the positions due to each of the frequency sources acting separately.

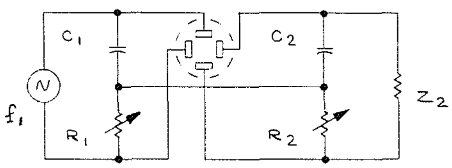


Fig. 4a. Equivalent circuit of Fig. 1, with the higher-frequency generator replaced by its internal impedance.

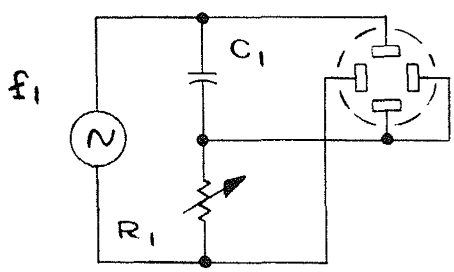


Fig. 4b. Further simplification of Fig. 4a.

The graphical addition of the deflections due to each of the frequency sources acting separately is not difficult. Assume, for example, a 3:2 frequency ratio. Assume, also, that the frequency sources, when applied individually, produce circles C and D as shown in Fig. 5. The numbers on the perimeter of the circles represent the hypothetical position of the beam on each circle at corresponding instants of time. By taking the vector sum of the displacements from the center, as indicated in Fig. 5, the actual position of the spot on the screen can be determined. The locus of many such determinations is the desired roulette. Fig. 6 shows the same pattern displayed on the crt screen.

Roulettes can be analyzed by geometrical analogy. The pattern of Fig. 2a is generated by a point on the surface of a cylinder rolling on the inside of another cylinder. Curves of this type are called hypocycloids. If you interchange one pair of RC elements in the circuit of Fig. 1, the patterns will be turned inside out. This is equivalent to having the generating circle roll on the outside of another cylinder. In this case, the point on the surface of the rolling cylinder generates a special form of inverted roulette called an epicycloid.

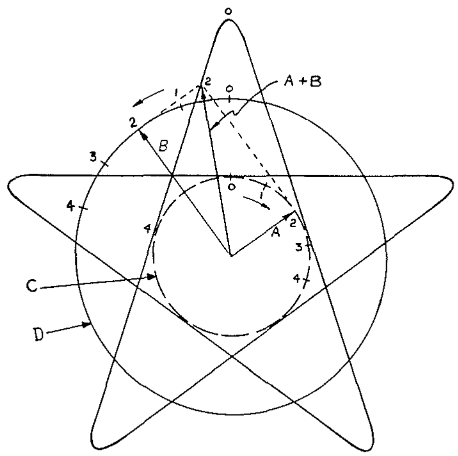


Fig. 5. Graphical construction of a roulette pattern for a frequency ratio of 3:2.

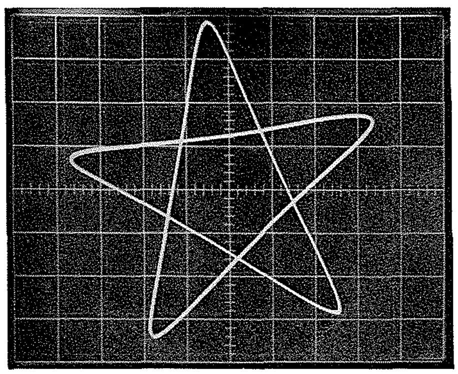


Fig. 6. Roulette pattern for a 3:2 frequency ratio.

Drift Measurements

When the ratio of the oscillator frequencies is not exactly integral (or fractional), the pattern rotates on the crt screen. The number of complete pattern rotations per second is proportional to the number of cycles per second that the lower-frequency oscillator differs from the frequency that gives an exact integral ratio. If the oscillator frequencies are initially adjusted for a stationary pattern, any subsequent rotation is a direct measure of the total frequency drift between the two oscillators. This method of measuring drift is best suited to oscillators that have very small drift rates.

You will usually find that it is easier to count the number of points passing a particular graticule line per second rather than to count the whole number of pattern rotations. The drift expressed in cycles per second of the lower-frequency oscillator is given by:

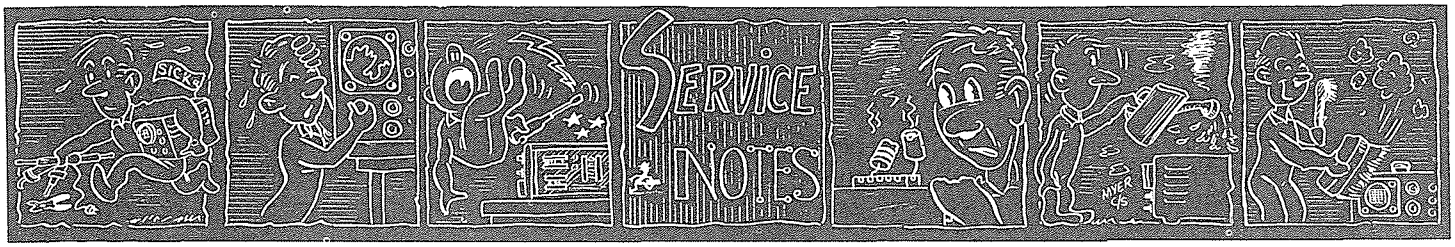
$$\text{Drift} = \frac{(N_2)\ (\text{No. of points per second passing a grat. line})}{(N_1)}$$

where N_2 and N_1 are as defined previously.

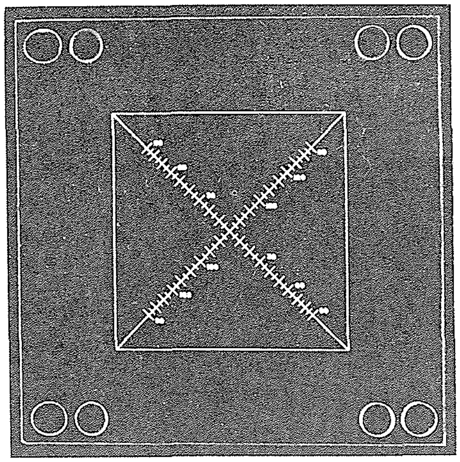
The equivalent drift of the higher-frequency oscillator can be determined by multiplying the equivalent drift of the lower-frequency oscillator by the frequency ratio.

OSCILLOSCOPE TYPE	AMPLIFIER UNIT (plug-in type)	SENSITIVITY	PASSBAND (at 3db down)
502A or RM502A		100 µv/cm	dc to 50 kc
		200 µv/cm	dc to 100 kc
		1 mv/cm	dc to 200 kc
		50 mv/cm	dc to 400 kc
		2 v/cm	dc to 1 mc
503 or RM503		1 mv/cm	dc to 450 kc
536	2-Type CA	0.05 v/cm	dc to 10 mc
	2-Type D	1 mv/cm	dc to 300 kc
		50 mv/cm	dc to 2 mc
	2-Type E	0.05 mv/cm	0.06 cps to 20 kc
		0.1 mv/cm	0.06 cps to 40 kc
		0.2 mv/cm	0.06 cps to 50 kc
		0.5 mv/cm	0.06 cps to 60 kc
	2-Type G	0.05 v/cm	dc to 10 mc
	2-Type Z	50 mv/cm	dc to 9 mc
561A RM561A 564 RM564	2-Type 2A61	0.01 mv/div	0.06 cps to 100 kc
		0.1 mv/div	0.06 cps to 300 kc
	2-Type 2A63	1 mv/div	dc to 300 kc
	2-Type 3A3	100 µv/div	dc to 500 kc

Reference chart of Tektronix Oscilloscopes and Oscilloscope/Plug-In Unit Combinations having vertical and horizontal amplifiers with differential inputs.



LISSAJOUS PHASE-MEASUREMENT GRATICULE



The 8 x 8 cm phase-measurement graticule (Tektronix part number 331-057), originally designed for use with the Type 536 X-Y Oscilloscope, will work equally well with the Type 661 Sampling Oscilloscope and the Type 504 X-Y Oscilloscope. This special graticule (see Figure 1) is useful in measuring phase differences from lissajous displays.

REPLACING CABLES CONTAINING COLOR-CODED WIRES

Here's a time saver when replacing cables containing color-coded wires. When you remove the old cable, cut the wires about ½ inch from their solder points. If you do this you then have the color codes to go by when installing the new cable.

Jim Hartley, Field Maintenance Engineer with our Orange Field Repair Center, offered this suggestion with the comment that he finds it saves a lot of time over other methods.

FILM-PACK BACK FOR TEKTRONIX CAMERAS

A new Film-Pack camera back adapts all Tektronix Trace-Recording Cameras to use Polaroid's® two recently introduced plastic film packs—3000 speed/Type 107 and Pola Color®/Type 108.

These new plastic film packs offer several advantages over the older roll-type film.

1. They load easier and faster—just slide the plastic pack in place, pull a tab and you're ready to shoot the first picture.
2. They allow you to shoot pictures faster—the exposed film develops the picture outside the camera (black and white in ten seconds, color in 50 seconds). You are free to keep shooting—no waiting for the picture to develop. This can be a big help when a rapid sequence of pictures is needed.
3. Unlike the roll-type film, the new film pack produces flat prints with no bothersome curl to straighten out.

The new Film-Pack camera back interchanges with either the Roll-Film back or the Graflok back. No tools required. Order through your local Tektronix Field Office, Field Engineer or Representative. Specify Tektronix part number 122-671.

TYPE 3B1 TIME BASE UNIT—DELAYED SWEEP TRIGGERS BEFORE END OF DELAY

A large external trigger can sometimes override the lockout circuit and trigger a delayed sweep before expiration of the delay period when the controls of the Type 3B1 are set as follows: MODE to DLY'D, TRIG.; SOURCE (DELAYED SWEEP TRIGGERING) to EXT.

It usually takes a trigger signal of about 20 volts in the non-attenuated external trigger (± 15 volts) range to cause this to happen.

An easy cure is to replace R202, a 680 Ω, ¼ w, 5% resistor with a 1 k, ¼ w, 5% resistor (Tektronix part number 315-102).

This information applies to Type 3B1's with serial numbers *below* 2777. Instruments above this number have the change implemented at the factory.

TYPE 525 TELEVISION WAVEFORM MONITOR AND TYPE 526 COLOR-TELEVISION VECTORSCOPE — 6DB6 VACUUM TUBES REPLACED BY 6HZ6 TUBES

Manufacturers of the 6DB6 Vacuum tube have discontinued its manufacture. The 6DB6 was used in the V310 location of the Type 525 and the V14, V24, V304, V314, and V354 locations of the Type 526. As a replacement we recommend the 6HZ6 tube. It has characteristics similar to the discontinued 6DB6 and may be used as a direct replacement in the locations mentioned above. No modification required.

TYPE 517A, TYPE 517, AND TYPE 555 OSCILLOSCOPES — ADJUSTING THE 6.3 VOLT REGULATED HEATER SUPPLY

Setting the Reg. Htr. Adj. control of these instruments requires the use of an ac voltmeter having an iron-vane or dynamometer-type movement and a range of zero to 10 volts rms. A meter employing a d'Arsonval-Type movement—a vtvm, for instance—will not give the required accuracy for this measurement. In measuring ac voltage the accuracy of a meter with a d'Arsonval-type movement is predicated on the ac voltage waveform being a pure sine wave.

The Type 517, Type 517A and Type 555 Oscilloscopes incorporate a saturable reactor in their regulated-heater circuits. The ac-voltage waveform in passing through this saturable reactor undergoes alteration to the extent that it is no longer a pure sine wave. Therefore, the actual value of the regulated heater supply in these instruments, if set to 6.3 volts with a voltmeter of the d'Arsonval-movement type, will be 7.3 volts—1 volt too high.

This excess of 1 volt of filament power will considerably shorten the life expectancy of tubes and seriously degrade the instruments' reliability.

TEKTRONIX CIRCUIT COMPUTER

The Tektronix Circuit Computer, a circular slide-rule device, computes directly problems involving resistance, inductance, capacitance, frequency and time. Its primary design objective is to provide a means of quick computation of time values from other circuit dimensions.

With slide-rule ease the engineer or technician can compute:

1. Capacitive Reactance
2. Inductive Reactance
3. Resonance
4. RC Time Constant and Resistance
5. L/R Time Constant and Reactance

6. Filter Cut-off Frequency

7. Risetime

The computer consists of three circular decks—containing seven accurate scales—and a hairline indicator. Each scale is clearly identified and the scale graduations—jet black on pure white—stand out in vivid contrast and help to provide easily-read answers.

The computer is constructed of laminated plastic—light weight but durable. Mylar laminations over the three decks protect the printed information from wear and assure its remaining clearly legible under even the most strenuous use.

Overall diameter of the computer is 7¾″.

An 8½″ by 11″ booklet which accompanies the computer presents, in clearly-written and easily-understood steps, instructions for its use. The booklet also contains a short discussion of Risetime and Time Constant.

These computers are available through your Tektronix Field Engineer or local Field Office. The Tektronix Part Number for the computer is 003-023.

IDENTIFYING POLAROID PRINTS

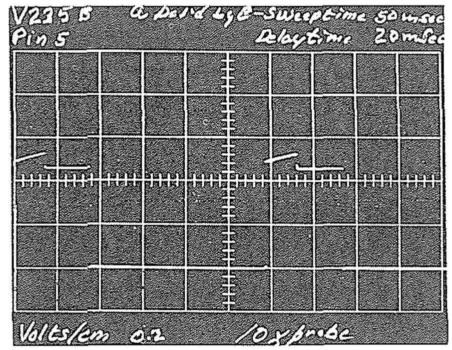


Figure 1. Information noted on Polaroid print with a hot soldering iron.

Ken Steele of the Hartman Electric Company in Mansfield, Ohio volunteers the information that a hot, 25 watt soldering iron employing a ⅛″ round tip supplies a convenient way of writing information on Polaroid* prints. Using the iron like a pencil, you just write on the black portion of the print. The information stands out in brilliant white (see Figure 1).

Following Mr. Steele's lead we experimented a bit further and learned that the pencil-type soldering irons in the 15 watt class work equally well and are a bit easier to write with.

Service Scope issues #17, December, 1962; and #13, June, 1962, contain additional suggestions for identifying information on Polaroid prints.

* Polaroid is a registered trademark of the Polaroid Corporation.

NUVISTOR PULLER

Here is a simple-to-make tool that facilitates the removal of Nuvistors from their sockets. Take a large alligator-clip cover and cut it off about an inch from the small end. Discard the large end and "presto" you have a Nuvistor puller.

Pliers, of course, should never be used to remove Nuvistors from sockets.

NEW FIELD MODIFICATION KITS

TYPE 541 AND TYPE 545 OSCILLOSCOPES — VERTICAL AMPLIFIER TUBES

This modification replaces the checked 6CB6 tubes in the distributed amplifier stage with Type 8136 tubes. The 8136 tubes deliver greater reliability, give higher gain and experience only negligible cathode interface over a long period of time.

The modification also changes: R1142, screen resistor in the vertical amplifier circuit, to 820 Ω (2 w, 10%) to provide a more suitable bias for the 8136 tubes; and R1021 and R1024, plate resistors in the input amplifier, to 500 Ω (½ w, 1%) to compensate for the increased gain delivered by the 8136 tubes.

This modification applies to Type 541's, serial numbers 101 through 6474; and Type 545's, serial numbers 101 through 9291.

Order through your local Tektronix Field Representative or Field Office. Specify Tektronix part number 040-360.

TYPE 564 STORAGE OSCILLOSCOPES —REMOTE ERASE FEATURE

This modification provides an external Remote-Erase feature for the Type 564 Storage Oscilloscope.

It installs a circuit assembly which contains two monostable multivibrators — one for the Upper display area and one for the Lower display area. When activated from either the front panel Erase controls or the Remote-Source Erase controls these multis erase their respective display areas. The Remote-Source Erase control can be any switch contact that can short a wire from the Type 564 to ground or any equipment that can provide a negative-going 5-to-10 volt pulse for the multi of each display area.

The external connections are brought out to a four-contact connector on the rear of the Type 564 and a mating connector is included to permit attachment of the Remote-Erase control.

This modification applies to Type 564 Storage Oscilloscopes, all serial numbers. Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-352.

TYPE 502A DUAL-BEAM OSCILLOSCOPE—VERTICAL SIGNAL OUT

This modification provides a rear-panel, direct-coupled Vertical Signal Out from each of the Type 502A's two vertical amplifiers. Output level is approximately 2 volts per centimeter of crt deflection, with an output impedance of approximately 200 ohms.

The modification replaces the 6AU6 Trigger-Pickoff tube (V493) and seven-pin socket with a 6DJ8 tube and a nine-pin socket. This new tube combines a Trigger-Pickoff cathode follower (CF) and a Vertical Output CF in a single tube.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-335.

TYPE 567 AND TYPE RM567 DIGITAL-READOUT OSCILLOSCOPES — POWER SUPPLY IMPROVEMENTS

This modification incorporates several refinements in the power supplies of the Type 567 and Type RM567 Digital-Readout Oscilloscopes.

1. It replaces the 1 w, 10 Ω fuse resistors R600, R660 and R661 with 2 w, 10 Ω fuse resistors and parallels the 1 w, 10 Ω fuse resistor R680 with an additional 1 w, 10 Ω fuse resistor (R681). This increase in wattage rating assures a longer resistor life.

2. It adds a potentiometer and a suitable divider network to the —12.2 volt supply. This provides a means for accurately adjusting the voltage of this supply.

3. It adds a 100 μf capacitor (C633) from the base of the transistor Q634 to ground to reduce ripple in the —12.2 supply.

4. It adds potentiometers and suitable divider networks to the +125-volt and +300-volt supplies to provide a means for more accurately adjusting these supplies.

This modification applies to Type 567's with serial numbers 101 through 407 and Type RM567's with serial numbers 101 through 149 with the following exceptions:

Type 567, serial numbers:

183	333	354	375	394
206	334	355	384	395
286	341	367	391	397
291	342	368	392	401
320	346	369	393	404

Type RM567, serial numbers:

129	136	141
131	137	144
134	138	147
135	140	148

These instruments had this modification installed at the factory.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-319.

TYPE 67 TIME-BASE UNIT—SWEEP LOCKOUT FOR SINGLE SWEEP OPERATION

This modification adds a sweep lockout feature to the Type 67 Time-Base Unit to allow the electron beam to sweep once after receiving a triggering pulse. The lockout circuitry then prevents any subsequent trigger pulse from activating the sweep until the operator resets or "arms" the sweep circuit by depressing the lever arm of the MODE switch. This feature allows the viewing of "one shot" (non-repetitive) phenomena. A front-panel READY light indicates when the sweep is armed and ready to fire on the next trigger pulse.

The modification adds a sweep-lockout transistor circuit and installs a new front panel and a MODE switch. It is applicable to Type 67 Time-Base Units, all serial numbers.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-318.

TYPE 3A1 DUAL-TRACE UNIT — INCREASED VERTICAL DEFLECTION

Installation of this modification increases the linear vertical deflection of the early Type 3A1's. It adds a linear hybrid amplifier to obtain this increase.

The following chart lists the oscilloscopes compatible with the Type 3A1 and notes the vertical scan before and after modification.

Instrument Type	Vertical Scan Area Before	Vertical Scan Area After
561* RM561* 567* RM567*	±2 cm (4 cm overall)	±3 cm (6 cm overall)
561A RM561A 564 RM564 565 RM565	±3 cm (6 cm overall)	±4 cm (8 cm overall)

* When used in these instruments it may be necessary, in some cases, to increase the internal 0.01 v/div and 0.02 v/div gain settings of the Type 3A1 to provide adequate front panel "Calib" control range for instruments with low-sensitivity crt's.

The modification also offers improved linearity by increasing the plate voltage of V364 and V374 (8233 tubes in the output amplifier) by 10 volts, and better stabilization of the correct voltage level at the cathode of the Trigger Pickoff cathode follower (V383A) by changing the values of resistors R381 and R382 in the grid circuit of this tube.

The modification applies to Type 3A1's, serial numbers 101 through 4327.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-349.

TYPE 581 AND TYPE 585 OSCILLOSCOPES — IMPROVED VERTICAL-AMPLIFIER STANDARDIZATION

This modification is a combination of Field Modification Kits 040-275 and 040-324. *It should not be used if either of these kits has previously been installed.*

The modification standardizes the vertical amplifiers of the Type 581 and Type 585 for use with the Type 82 Dual-Trace Unit, Type 86 Unit, or any future Type 580-Series plug-in units by improving the impedance matching between the delay line and the termination networks. This improvement also enhances the transient response of the Vertical Amplifier.

Another benefit of the modification is decreased compression on the Vertical Amplifier output stage. V1284, a dual-tetrode 7699 tube, is replaced with two single-pentode 7788 tubes. The crt support bracket is also replaced.

Finally, the modification adapts the Type 80 Plug-In Units (serial numbers 101 through 3386) and the P80 Probe for use in the "standardized" Type 581 and Type 585 Oscilloscopes.

The modification applies to Type 581's, serial numbers 101 through 949 and Type 585's, serial numbers 101 through 2584.

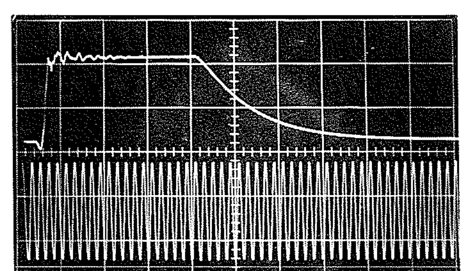
Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-364.

AUTOMATIC DISPLAY SWITCHING

Featured In The Type 547 Oscilloscope

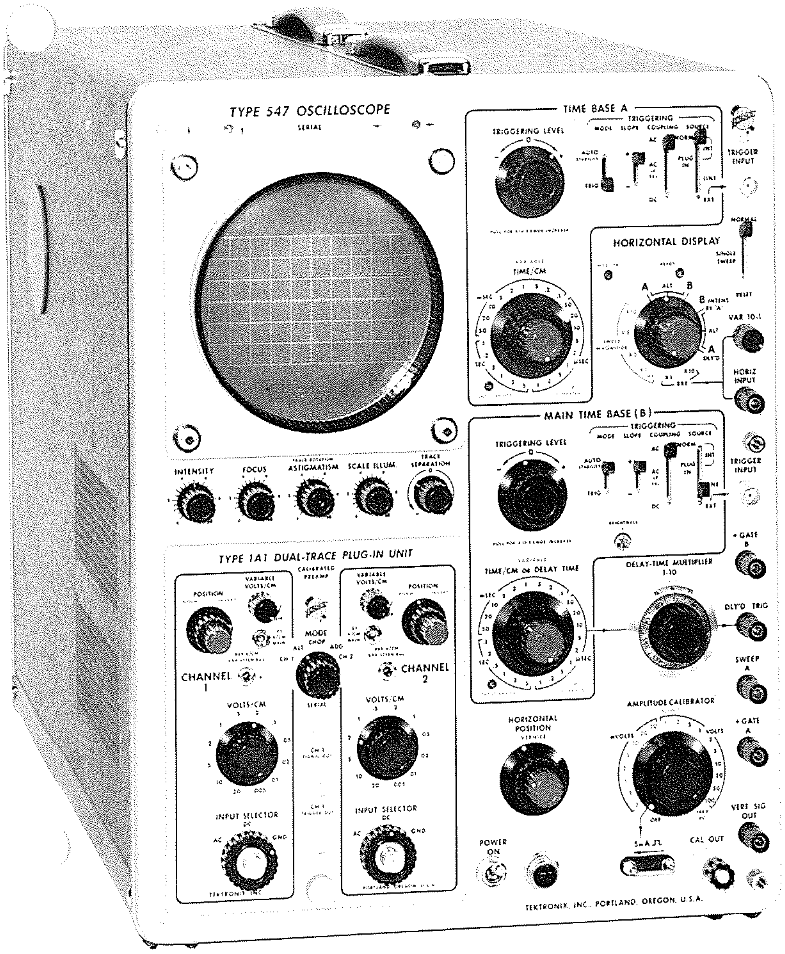
Electronic switching between 2 wide-range time bases allows an alternate presentation of the same signal at 2 different sweep rates. Gallium Arsenide diodes in the switching circuit provide fast switching between time bases, and insure that only the desired time base is displayed at one time.

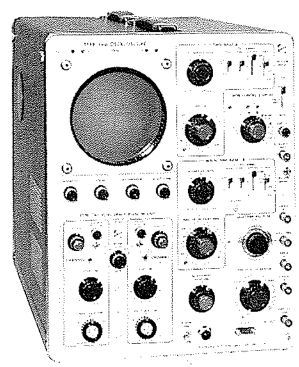
Two different signals can be alternately displayed at the same or different sweep rates with a dual-trace unit such as the new Type 1A1. In many applications, this dual-scope operation provides the equivalent of two oscilloscopes, and at a considerable savings. Since a single-gun tube is used, beam registration and geometry problems of dual-gun tubes are avoided. Dual displays are viewed with accuracy of the single-beam construction. Also, the full 6 x 10-cm screen area can be used to display signals on either time base. A trace separation control operates in conjunction with the normal vertical positioning to allow full control of dual displays.



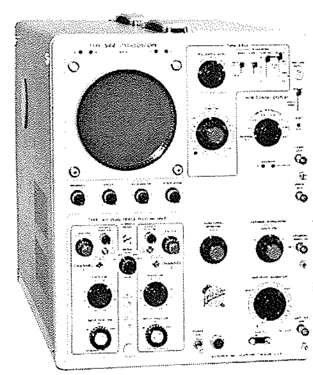
Dual-Scope Operation—independent control of each signal with Channel 1 of the Type 1A1 Dual-Trace Unit locked to Time Base A, and Channel 2 locked to Time Base B.

A NEW GENERATION OF TEKTRONIX OSCILLOSCOPES TYPE 540-SERIES





TYPE 546



TYPE 544

BRIGHT 6 x 10-CM DISPLAYS

ILLUMINATED NO-PARALLAX GRATICULE

SMALL SPOT SIZE, UNIFORM FOCUS

COMPLETELY NEW VERTICAL AMPLIFIER

FULL-PASSBAND TRIGGERING

WIDE SELECTION OF VERTICAL PLUG-INS

MAJOR CHARACTERISTICS

OSCILLOSCOPE	PASSBAND Ⓐ	SWEEP RANGE	SWEEP DELAY	SWEEP MAGNIFIER
Type 543B	DC to 33 MC	0.1 µsec/cm to 5 sec/cm in 24 calibrated steps, variable uncalibrated from 0.1 µsec to ≈ 12 sec/cm.	None	2, 5, 10, 20, 50, 100X
Type 545B			1 µsec to 10 sec	5X
Type 544	DC to 50 MC		None	2, 5, 10, 20, 50, 100X
Type 546			0.1 µsec to 50 sec.	2, 5, 10X
Type 547		Same characteristics as Type 546 plus Automatic Display Switching.		

Ⓐ Passband with Type 1A1 or 1A2 Dual-Trace Plug-In Units at 50 mv/cm sensitivity. Passband of the Type 1A1 at 5 mv/cm sensitivity is dc to 28 Mc with Type 547, 546, or 544, dc to 23 Mc with Type 543B and 545B.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Service Scope

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NUMBER 27 PRINTED IN U.S.A AUGUST 1964

THE CATHODE FOLLOWER

Because both its input-grid capacitance and its output-impedance are small, the cathode-follower circuit lends itself to many uses in electronics. This article discusses these and other useful characteristics of cathode-follower circuits.

Part I

The cathode follower is a circuit related to the familiar plate-loaded amplifier. In the plate-loaded amplifier the load resistance R_L is connected in the plate lead to the tube. But in the cathode follower, shown in Fig. 1, the load resistance R_k is connected in the cathode lead to the tube. Useful characteristics of the cathode follower include these:

1. The grid-input capacitance is small.

2. And the internal output impedance is small.

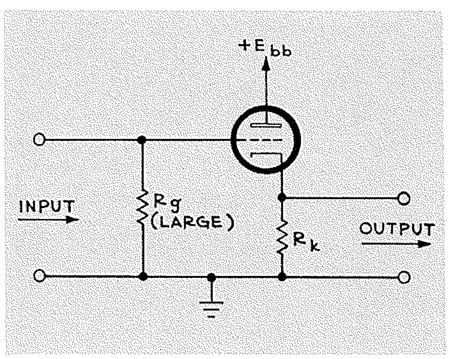


Fig. 1 — Basic cathode-follower circuit. Here the load resistor R_k is connected in the cathode circuit, rather than in the plate circuit as in the plate-loaded amplifier.

In this article we shall take up these and other cathode-follower characteristics in more detail. But first, let's consider some cases where we can take advantage of the two characteristics we have mentioned above.

Need for a device having a small input capacitance. Suppose we apply an input signal to a device whose input capacitance is C_{in}. And suppose that the source of the signal voltage has an internal output impedance (resistance) R_o (see Fig. 2). For simplicity, assume that C_{in} and R_o are the only impedances present in the source or in the circuit connected to the source. Then the time constant of the source-and-input circuit will be R_oC_{in}.

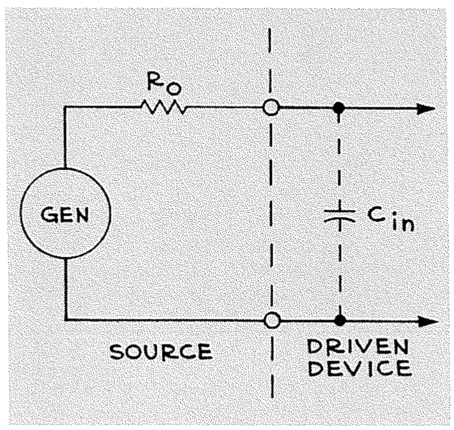


Fig. 2 — Here a signal source has an internal impedance R_o. The source drives a circuit whose input capacitance is C_{in}. If the time constant R_oC_{in} of this arrangement is small, then the risetime of the combination is short. One way to keep the time constant small is to make C_{in} very small. Then the risetime is short even if R_o is relatively large.

If we can keep the input capacitance C_{in} very small, then the time constant R_oC_{in} will be small — even though R_o might be quite large. And consequently the risetime of the R_oC_{in} circuit will be short.

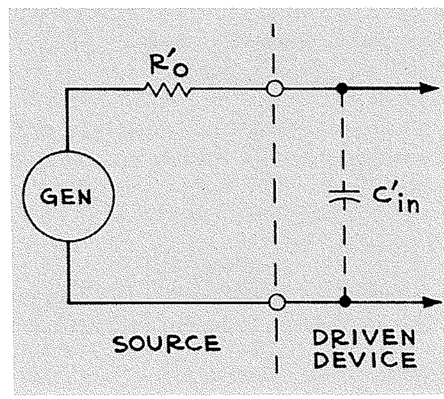


Fig. 3 — Here a second signal source whose internal impedance is R'_o drives a circuit whose input capacitance is C'_{in}. One way to keep the time constant $R'_oC'_{in}$ short is to make R'_o very small. Then the risetime is short even if C'_{in} is relatively large.

The input capacitance C_{in} of a cathode follower is small, for reasons that will be explained later. Consequently the cathode follower has the advantage that we can connect the cathode-follower input circuit to a signal source without greatly lengthening the risetime of the source itself.

Need for a device having a small internal output impedance. Suppose a signal source has an output impedance (resistance) R'_o that is very small. Imagine that we use this signal source to apply a signal voltage to another device whose input capacitance is C'_{in} (See Fig. 3). For simplicity, assume that C'_{in} and R'_o are the only impedance present in the source or in the circuit connected to the source. Then the time constant of the source-and-input circuit will be $R'_oC'_{in}$.

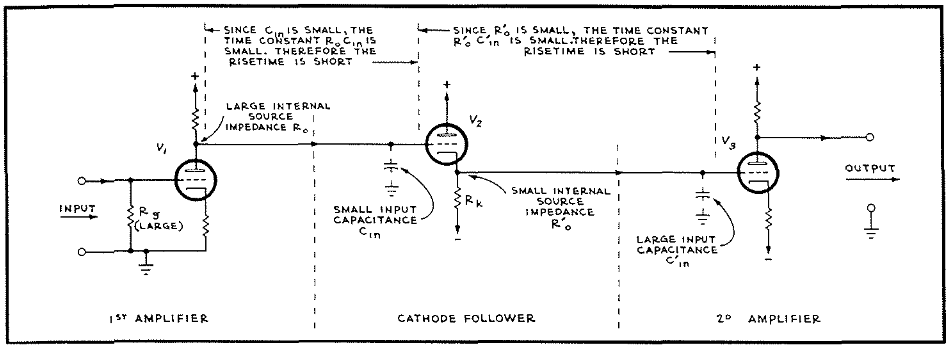


Fig. 4 — Here we want to apply a signal from the plate circuit of V_1 (representing a relatively large impedance R_o) to the grid circuit of V_3 (representing a relatively large capacitance C'_{in}). If we couple the plate of V_1 directly to the grid of V_3, the corresponding coupling-circuit time constant is a large value $R_oC'_{in}$. But if we insert the cathode follower V_2 as shown, we now have two coupling-circuit time constants in cascade. The first time constant is R_oC_{in}, where C_{in} is the very small input capacitance to the cathode-follower; thus, as indicated in Fig. 2, this first time constant is relatively small. The second time constant is $R'_oC'_{in}$, where R'_o is the very small output impedance of the cathode follower; thus, as indicated in Fig. 3, this second time constant is relatively small. By inserting the cathode follower we thus break up a large time constant $R_oC'_{in}$ into two much smaller time constants R_oC_{in} and $R'_oC'_{in}$. In this way we use the cathode follower to improve the coupling-circuit risetime.

If we can keep the source impedance R'_o very small, then the time constant $R'_oC'_{in}$ will be small — even though C'_{in} might be quite large. And consequently the risetime of the $R'_oC'_{in}$ circuit will be short.

The internal output impedance of a cathode follower is small, for reasons that will be explained later. Consequently the cathode follower has the advantage that we can use the cathode follower to drive a device that has appreciable input capacitance while still achieving a short risetime. As an example, we might use a cathode follower to drive a coaxial transmission line — where the capacitive effect of the line is appreciable — and still preserve a short-risetime characteristic.

Figure 4 shows an application that utilizes the advantages of both the small input capacitance and the small output impedance of the cathode follower. We desire to couple a rapidly changing signal from the plate of V_1 to the grid of V_3. In Fig. 4, we apply the output signal from the plate of V_1 to the grid of the cathode follower V_2. The internal source impedance of the amplifier stage that includes V_1 is ordinarily rather large. But the input capacitance of the cathode follower V_2 is small, so that we end up with only a short risetime T_{R1} associated with the circuit that couples the plate of V_1 to the grid of V_2. Now, the input capacitance of the amplifier stage that includes V_3 is ordinarily rather large. But we drive the grid of V_3 from the low-impedance output circuit of the cathode follower V_2. Thus we end up with only a short risetime T_{R2} associated with the circuit that couples the output of V_2 to the grid of V_3. The effective risetime of the cathode-follower coupling system between V_1 and V_3 will, by the equation $T_R = (T_{R1}^2 + T_{R2}^2)^{1/2}$, be shorter than the sum of the two individual risetimes T_{R1} and T_{R2}.

We see, then, that we can often shorten the risetime of an interstage-coupling system by inserting a cathode follower between one stage and the next.

Polarity of output signal from a cathode follower. Let us now consider some factors that tell us how a cathode follower actually operates.

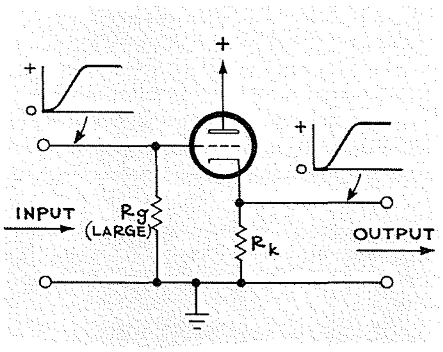


Fig. 5 — Illustrating that the polarity of the cathode-follower output-signal voltage is the same as that of the input-signal voltage — in contrast to the polarity reversal that occurs in the plate-loaded amplifier.

If we apply to the cathode-follower circuit of Fig. 5 a grid-input signal that makes the grid more positive, the cathode-to-plate electron flow will increase. Therefore the voltage drop across the cathode resistor R_k will increase, so that the voltage at the cathode of the tube will be farther removed from the potential of the grounded negative terminal of the power supply. That is, the voltage at the cathode output terminal of the cathode-follower stage will become more positive. Thus, in contrast to the action in the plate-loaded amplifier, *the polarity of the output signal from the cathode follower is the same as the polarity of the input signal:*

Output impedance. The internal output impedance of a cathode-follower stage is comparatively small (usually from less than 100 ohms to perhaps 200 or 300 ohms). This range of values represents impedances that are considerably smaller than the typical output impedances we would expect from plate-loaded amplifiers (from a few hundred to several thousand ohms).

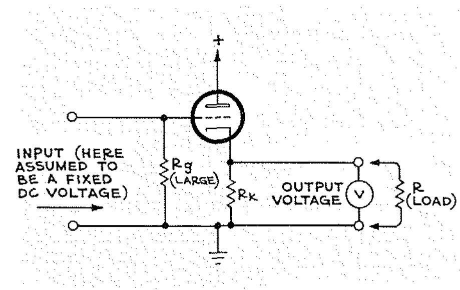


Fig. 6 — Illustrating that the internal output impedance of a cathode follower is small. A given cathode current makes the voltmeter V show a certain dc output voltage (the IR voltage drop across R_k). If we connect the external load R, we thereby reduce the total resistance in the cathode output circuit. Thus we might at first expect the voltmeter to show a sharply reduced output-circuit IR voltage drop. But this voltage drop is also the negative dc grid-to-cathode bias voltage — so that the tube allows a greater cathode current to flow. Therefore the new output voltage is the IR voltage drop produced by a larger current in a smaller total resistance. As a result, this new output voltage isn't much less than the original voltmeter reading. The fact that the output voltage changes only a little when we connect the load R shows that the internal source impedance of the cathode follower is small.

To see why the internal output impedance of a cathode follower is small, suppose we connect an external load resistor R across the output terminals of the cathode follower as shown in Fig. 6. Let the input grid-to-ground voltage be held constant. When we connect the external load resistor R, we effectively reduce the resistance in the cathode circuit. Suppose first that cathode current remains constant. Then the voltage drop across the cathode resistance decreases. Therefore, the grid-to-cathode voltage becomes less negative. But this actually allows more cathode current to flow. Thus the voltage drop across the paralleled cathode resistor and external load resistor tends to increase again to almost its original value. In effect, then, *the voltage across the output terminals doesn't depend greatly upon the amount of external load resistance we connect to these terminals.* This statement is equivalent to saying that a cathode follower is a source that has a small internal impedance.

The actual internal source impedance of a cathode-follower stage is not simply the value of the cathode resistor R_k. Instead, it consists of a parallel combination of R_k shunted by the internal impedance of the tube. We can see that this statement applies if we look at Fig. 7. Note that the power supply represents a short circuit to signal variations. Thus the signal output impedance of the cathode-follower stage, looking back into the output terminals, is made up of the tube impedance in parallel with the cathode resistor R_k.

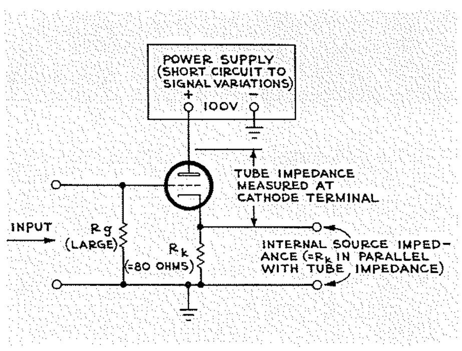


Fig. 7 — The internal source impedance of a cathode-follower stage includes the cathode resistor R_k. But for a varying signal, the cathode-to-plate dynamic impedance of the tube is connected (through the power supply) in parallel with R_k. This tube impedance is roughly $1/g_m$, and is therefore often quite low. For example, if the tube has the characteristic curve of Fig. 8, its cathode-to-plate impedance is about 80 ohms. With such a tube, the cathode-follower stage of Fig. 7 would have an internal source impedance of only about 40 ohms.

The impedance of the tube itself, at its cathode terminal, can be shown to be approximately $1/g_m$ (where g_m is the mutual conductance of the tube in mhos). But the value of g_m of a given tube depends upon the operating point at which the tube works. Suppose, for example, that we use a tube whose plate current-grid voltage characteristics is that shown in Fig. 8. For this particular tube, the operating point is that shown as point A in Fig. 8 when the tube is used as indicated in Fig. 7. The slope of the tangent line to the characteristic curve at the operating point A shows that g_m is 12,500 micromhos (= 0.0125 mho). Then the impedance of the tube, at its cathode terminal, is approximately 1/0.0125 = 80 ohms. Since the cathode resistor is also 80 ohms, the effective internal impedance of the cathode-follower stage of Fig. 7 is about 40 ohms.

Voltage Gain. In a plate-coupled amplifier stage, the varying output signal voltage may well be several times the varying input signal voltage. That is, a plate-coupled amplifier stage may have a voltage gain of several times.

But the voltage gain of the cathode follower cannot be as great as unity. In other words,

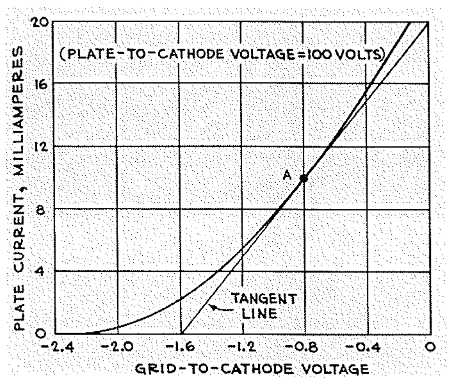


Fig. 8 — Assume that this curve represents the plate current-grid voltage characteristics of the tube in Fig. 7. Then we can use this curve to find the approximate internal impedance of the tube itself, measured at the cathode pin. First note that the 80-ohm cathode resistor R_k in Fig. 7 establishes the tube operating point as point A in Fig. 8. (To check this, observe that a current of 10 milliamperes in 80 ohms produces an 0.8-volt drop — the grid-to-cathode bias corresponding to point A). Next, to find the mutual conductance of the tube at operating point A, we draw a straight tangent line to the curve at point A. We see that the tangent line intercepts a base interval corresponding to 1.6 volts and a vertical interval corresponding to 20 milliamperes (0.02 ampere). Thus, at operating point A, the mutual conductance g_m is 0.02/1.6 = 0.0125 mho. Since the tube internal impedance at the cathode pin is approximately $1/g_m$, the tube whose characteristic curve is shown in Fig. 8 has an internal source impedance of about 1/0.0125 = 80 ohms.

the varying output signal voltage cannot be as great as the varying input signal voltage. This result springs from the fact that the cathode electron flow for a given plate voltage is controlled essentially by the grid-to-cathode voltage. Suppose, for example, that an input grid-to-ground signal-voltage change of +2 volts *could* change the electron flow sufficiently to vary the cathode-to-ground voltage by +2 volts (corresponding to a voltage gain of unity). But this change would involve no net change in grid-to-cathode voltage; therefore there would be no net change in electron flow — an absurdity. Thus the voltage gain of the cathode follower cannot be as great as unity.

Clearly, then the cathode follower is not useful directly in providing voltage gain. But as we have seen, the cathode follower can be very useful in improving the risetime characteristics of circuits that actually do produce voltage gain.

The voltage gain of a cathode-follower stage depends both upon the characteristics of the tube and upon the value of the cathode resistor R_k. When R_k is equal to the internal output impedance of the tube itself (approximately $1/g_m$, where g_m is in mhos), the gain of the stage is approximately one-half. Thus, with values shown in Fig. 7, we realize an output of about one-half volt for each volt of input grid-to-ground signal. If we use greater values of R_k, we can make the gain of the stage appreciably greater. We can make the voltage gain reach values between 0.9 and 0.99 by using large values of R_k.

Since the output signal from a cathode follower has the same polarity as the input signal, and since the output signal can be made almost as large as the input signal, we can consider that the output signal approximately duplicates the input signal. Hence the name *cathode follower.*

Part 2 of this article will appear in the October, 1964 issue of Service Scope.

The material for this article was taken from the book "Typical Oscilloscope Circuitry", published by Tektronix, Inc. The complete text is available from your Tektronix Field Engineer or Representative.

SOLDERING OF TEKTRONIX ETCHED CIRCUIT BOARDS

An Explanation and Technique
by Verne McAdams
Tektronix Manufacturing Staff Engineer

Soldering is an alloying process between two metals. In its molten state, solder chemically dissolves some of the metal with which it comes into contact. However, the metals to be soldered, are, more often than not, covered with a thin film of oxide that the solder cannot dissolve. A flux must be used to remove this oxide film from the area to be soldered. The solder used in most electronic work contains this flux as a center core which has a lower melting point than solder itself. The flux in its molten state cleans the metal and holds the oxides suspended in solution. The molten solder can then make contact with the cleaned metal and the solvent action of solder on metal can take place.

The soldering process then is the following:

1. The cored flux melts first and removes the oxide film on the metal to be soldered.
2. The solder melts, floating the lighter flux and the impurities suspended in it to the surface.
3. The solder dissolves some of the metal in the connection.
4. The solder cools and fuses with the metal.

To do a proper soldering job the following must be done:

1. The connection itself must become hot enough for the rosin to melt and clean the metal.
2. The cored solder must be applied directly to the heated connection so that the flux, which melts at a lower temperature than the solder, will melt first and clean the connection by the time the solder has melted. (If the solder is applied to the soldering-iron tip, the flux, being lighter, will float on top of the solder. It will be unable to reach the connection and clean it.)
3. A good easy flow of heat from the soldering-iron tip to the connection must be obtained by a clean, well-tinned soldering-iron tip. A thin film of molten solder will transfer heat rapidly.

In soldering techniques for etched circuit boards, the basic principles for soldering prevail. We are now interested in the difference in the soldering of etched circuit boards and normal soldering.

The first consideration of soldering to etched circuit boards is the limitations of the substrate of the boards. The Tektronix etched circuit boards have a substrate of fiber-glass epoxy, which has a temperature limitation of 530° F for not more than 5 minutes. Hotter temperatures reduce the time in inverse relationship; the hotter the temperature, the less time the boards will stand it before damage. (As an indication of damage, white flakes will first appear in the surface of the board. These white flakes indicate a decomposition of the fiber-glass epoxy substrate).

A second consideration is the soldering-iron-tip temperature, which is determined by the type of soldering iron and soldering-iron tip used. The wattage of the soldering iron and the configuration of the soldering-iron tip combined with the speed of soldering will determine the ultimate tip temperature as well as the working-tip temperature. Since we are here primarily concerned with the working tip temperature, the soldering iron and tip should be chosen so that the working tip temperature will at no time exceed the limitations of heat set forth above.

A third consideration in soldering of etched circuit boards is the type of solder used. The best type for use on the Tektronix etched circuit boards is a "eutectic"-type cored-wire solder of size #20 AWG, composed of 63% tin and 37% lead (as designated in FED. SPECS. QQ-S-571c as Sn63) with a central core of activated rosin flux (Divco X-25, or equivalent).

The fourth consideration is the technique of repair — repair in this case consisting of replacement of components. The Tektronix etched circuit boards consist of straight-through connections (no crimped connections) gold plated to facilitate soldering. Carelessness in reheating the solder connections for the removal and replacement of components is the only difficulty to be guarded against here. Caution must be taken not to overheat the substrate and this can best be accomplished with deft hands and by small applications of heat. If the removal or replacement is not accomplished in the first few seconds of heat application, avoid transferring too much heat to the substrate by *going to another connection or waiting a few minutes before reheating the connection.* Giving the connection these few minutes to cool will allow the heat to dissipate and help to avoid overheating the substrate. Heat dissipates quite slowly from some of the smaller connections and too long an application of the soldering iron will result in the overheating of the substrate.

Repair on the older phenolic-copper laminate boards is similar to that on the newer gold-plated fiber-glass epoxy boards with a cautionary remark that the problems of heat limitation applies even more so on the *older* boards. Their ultimate heat limitation is much lower than that of the newer boards and the copper laminate is glued to the board instead of being bonded to the substrate as in the case in the fiber-glass epoxy boards.

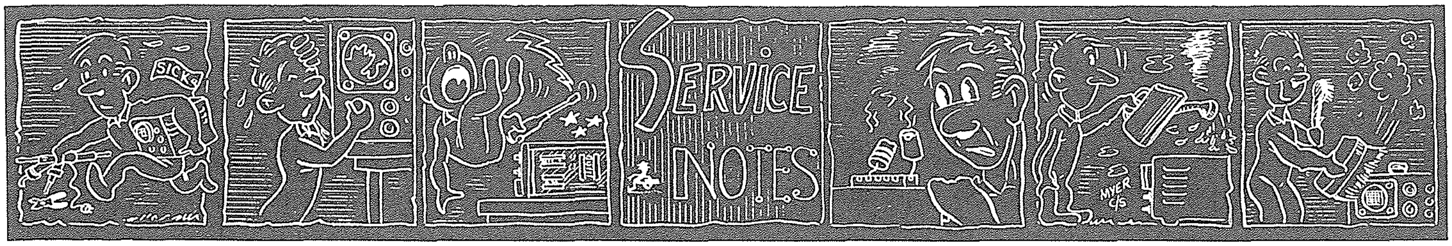
Some things to be considered in order to obtain a low working-tip temperature are:

1. At slow soldering speeds, a 25-watt iron and a ⅛" tip.
2. At medium soldering speeds, a 40-watt iron and a 3/16" tip.
3. At fast soldering speeds, a 50- or 60-watt iron and a ¼" tip.

A recommendation for soldering tips is that they be made of copper and have a chisel or bevel shape.

There are two areas on an etched circuit board which might require different soldering techniques. One is the large copper area used as a common connection in contrast to the smaller spot connections. The larger areas will absorb heat much more rapidly than the smaller spot connection. This may necessitate a hotter iron and a larger tip for these areas than the smaller spot connections.

With these cautions and recommendations in mind you should encounter no trouble when soldering Tektronix etched circuit boards.



TYPE 551 OSCILLOSCOPES — CRT REPLACEMENT

The Type 551 (T57) crt (cathode ray tube), original equipment in Type 551 Oscilloscopes, s/n's 101 to 2031, has been discontinued. An improved crt, T5511, is offered as a replacement. This new crt is designed for use with a Horizontal Beam Registration control — an adjustment that allows you to compensate for stray fields to make the starting times of both beams coincide. For Type 551's with serial numbers below 2032 you will need to install a parts modification kit (Tektronix Part Number 050-026) in order to use the new T5511 crt. We will supply the modification kit at *no charge*. Please note that the T551 (T57) crt can no longer be supplied!

Although Type 551 Oscilloscopes before serial number 216 have a Horizontal Beam Registration control, the parts replacement modification kit 050-026 *must be installed.*

When necessary to order a replacement for your T551 (T57) crt, please order Parts Replacement Mod Kit 050-026 *plus* the T5511 crt with desired phosphor. See below:

Old crt	Tektronix Part No.	New crt	Tektronix Part No.
T551(T57)-P1	154-186	T5511-P1	154-186
T551(T57)-P2	154-160	T5511-P2	154-160
T551(T57)-P5	154-210	T5511-P5	154-210
T551(T57)-P7	154-189	T5511-P7	154-189
T551(T57)-P11	154-143	T5511-P11	154-143

TYPE E PLUG-IN UNIT — HIGH FREQUENCY OSCILLATION

The Type E Plug-In Unit, when used in a Type 547 Oscilloscope, tends to oscillate at about 200 Mc. You can overcome this tendency by adding one ferrite bead (Tektronix Part Number 276-532) on each signal output lead at pins 1 and 3 of the interconnecting plug. This Service Note applies to Type E instruments with serial numbers below 6490. Instruments with higher serial numbers have the ferrite beads installed at the factory.

TYPE 21A AND TYPE 22A TIME BASE UNITS — TRIGGER IMPROVEMENT

A recent production modification greatly improves triggering stability of the Type 21A and Type 22A Time Base Units. It also makes adjustment of TD BIAS and LOCKOUT LEVEL less critical. The modification is quite simple and can be installed in Type 21A's with serial numbers below 8398 and Type 22A's with serial numbers below 8400.

The modification consists of changing D40, a Type BD-1 diode in the Time Base trigger circuit, to a Type TD-2 diode (Tektronix Part Number 152-081) and R126, a 100 k, ½ w, 10% resistor in the Lockout multivibrator circuit, to a 47 k, ½ w, 10% resistor (Tektronix Part Number 302-473). Changing this resistor brings the nominal setting of the LOCKOUT LEVEL control to the center range of its adjustment.

After the modification, the TD BIAS and LOCKOUT LEVEL controls are set according to instructions in the Type 555 Instruction manual. The benefits of the modification are that one setting gives reliability of trigger and equal response to both sine waves and pulses.

TYPE 564 AND TYPE RM564 OSCILLOSCOPES — SOME PRECAUTIONARY MEASURES

Here are some precautionary measures which, if observed, will prolong the useful life of the storage screen in the Type 564 and Type RM564 Oscilloscopes.

First and foremost, take great care in the degree of writing-gun intensity you use. High writing-beam current can cause permanent damage to the storage target. Always use the minimum beam intensity required to produce a clear well-defined display. Special care should be taken during warm up or when using slow rates or sampling displays.

Use caution when storing fast-changing portions of a waveform. Beam current could then be too great on the slow-changing portions of the waveform.

Avoid repeated use of the same area of the screen for storing displays. Distributing the use will allow the storage target to "age" uniformly and will prolong the effective life of the storage tube.

Turn the intensity control to minimum when changing plug-in units. An undeflected spot on the crt screen can burn the storage target even at normal intensity.

Do not leave a display on the crt screen (either writing or stored) when the display is not needed.

Do not leave the DISPLAY switches at STORE when the storage mode is not needed.

"Negative images" (dark waveform images that appear as a darker background light level when the DISPLAY switch is at STORE) result from writing or storing a waveform in one position on the screen for a relatively long period of time. Negative images will usually disappear in a short time, but may cause a temporary decrease in writing speed of the affected areas.

"Bright burns" (bright waveform images that will not erase completely) are caused by excessive intensity of the writing-gun beam. Severe burns may remain indefinitely; a mild case which may only show when the writing speed enhancement circuit is used (Type 564, s/n 2000 and up, or RM-564), will slowly fade to normal over a period of a few days normal use.

"Dark burns" (spots or lines on the screen that will neither write nor store) result from destructive burning of the storage target by the writing-gun beam. Replacement of the storage tube will be required if dark burns impair operation of the instrument.

TEKTRONIX CIRCUIT COMPUTER — AN ADDITIONAL USE

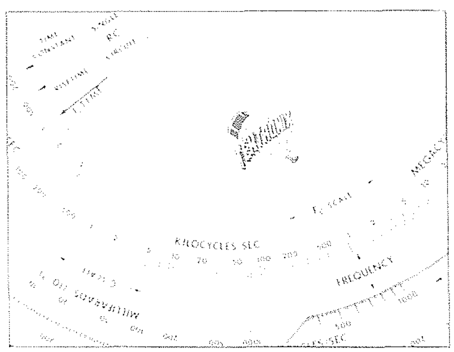


Figure 1. Shows location of new F_c TIME arrow on the top deck of the Tektronix Circuit Computer.

In this column of the June, 1964, issue of Service Scope, we describe the Tektronix Circuit Computer (Part Number 003-023), a circular slide-rule type of device.

Since then, Nelson R. Drew, K3RGH, of 906 7th Street in Laurel, Maryland, has written us telling about an additional use for this computer. By the addition of another "Time" arrow to the top deck of the computer you can read time as a reciprocal of frequency — in other words, solve the equation $T = \frac{1}{f}$.

You determine the location of the new arrow by positioning the top deck of the computer so that the 1-megacycle marker of the F_c scale is aligned with the FREQUENCY marker on the middle deck. Then, reading through the top-deck cut out, locate the 1-microsecond marker on the middle deck. Then, on the top deck opposite this 1-microsecond marker, scribe a short radial line to form the new "Time" arrow. Label this new arrow "F_c TIME". See Figure 1. Your computer will now solve the equation $T = \frac{1}{f}$. Example: Set F_c Scale to 5 megacycles; read 200 nanoseconds (through the top-deck cut out) opposite the new "F_c Time" arrow.

Our hearty thanks to Mr. Drew for his suggestion of a new use for the circuit computer.

THIN-BLADE, SINGLE-PINCHER PROBE TIP — INDEXING FOR PINCHER-TIP ORIENTATION

Indexing the barrel back near the finger flange identifies orientation of the pincher-tip hook (see Service Scope, issue 24, February, 1964) and so simplifies the probe removal when the tip is buried in a maze of wires. Red nail polish or lacquer shows up well on the plastic, see Figure 2.

H. I. Wilson of 40 Hillside Road, Beacon, New York, sent in this suggestion. Thank you, Mr. Wilson, for sharing your idea with our readers.

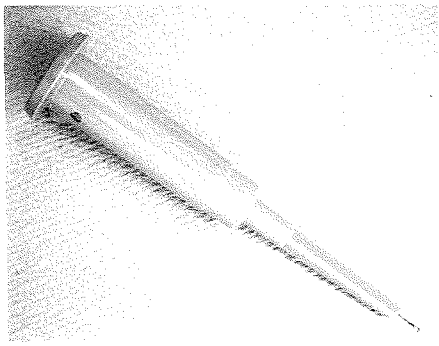


Figure 2. Adding a dot of red lacquer identifies orientation of pincher-tip hook.

PLUG-IN EXTENSION 013-055 — SUPPORT FOR EXTENSION

Here's another do-it-yourself project. Figure 3 shows a support that fits into the plug-in compartment of a Type 530, Type 540, Type 550 or Type 580 Series Oscilloscope. When using a Plug-In Extension (Tektronix Part Number 013-055), this support holds and aligns the outboard end of the extension so that a plug-in can be quickly and easily changed or installed. We made the one shown here (see Figure 3) from a one-inch thick piece of pine board.

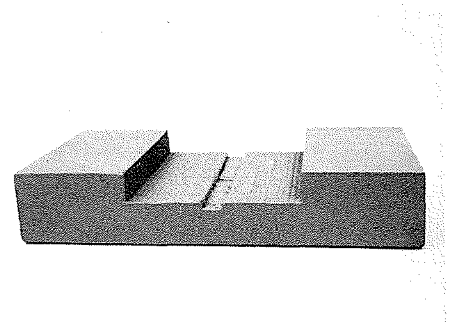


Figure 3. An easily-made support for the Tektronix Plug-In Extension (013-055).

The width of the support is 3 inches and the length is 5½ inches. The cut out portion of the support measures 2 7/16 inches wide by 7/16 of an inch deep. The narrow groove in the bottom of the cutout is 3/16 of an inch wide and 1/16 inch deep.

The support should fit snugly in the oscilloscope plug-in compartment and the plug-in extension should be a press fit into the cutout section of the support so that support and extension will stay in place when exchanging plug-ins.

Our thanks for this suggestion go to Mr. Ed Davis of Raytheon, HASCO, Ft. Bliss, Texas.

NEW FIELD MODIFICATION KITS

TYPE 131 CURRENT AMPLIFIER — UHF CONNECTOR

This modification supplies a special replacement UHF connector that will more perfectly fit a wider tolerance range of Type 131 housings. It helps to overcome and prevent the problem of the connector working loose.

Order through your local Tektronix Engineer, Field Office or Representative. Specify Tektronix Part Number 040-373.

TYPE 561 AND TYPE 561A OSCILLOSCOPES — POWER SUPPLY IMPROVEMENTS

This modification installs a means for accurately adjusting power supply voltages. It adds potentiometers to the divider network in the comparator circuits of the —12.2, +125, and +300-volt supplies. Installation involves the drilling of two holes and mounting a potentiometer assembly on the rear of the horizontal plug-in housing and changing several components in the —12.2, +125 and +300-volt supplies. A 10-Ω fuse resistor is added to limit surge currents and protect the +300-volt supply.

The modification is applicable to Type 561 Oscilloscopes, s/n's 101 through 5000; and Type 561A Oscilloscopes, s/n's 5001 through 6634. Order through your local Tektronix Field Engineer, Field Office or Representative. Specify Tektronix Part Number 040-347.

TYPE 502 OSCILLOSCOPE — INTENSITY BALANCE CONTROL

This modification moves the Intensity Balance control to the front panel. It allows a more precise control of trace brightness — a useful feature in dual-trace photography.

A new front panel overlay makes room for the new control and supplies graduated markings for all five crt controls. Order through your local Tektronix Field Engineer, Field Office or Representative. Specify Tektronix Part Number 040-350.

TYPE 527 AND TYPE RM527 WAVEFORM MONITORS — VERTICAL AMPLIFIER AND TRIGGER IMPROVEMENT

Installation of this modification brings four improvements to the Type 527 and Type RM527 instruments.

1. It improves triggering at low-level input signals by changing V24 (a 6EW6 tube in the Trigger amplifier) to a 6EJ7 tube. This 6EJ7 tube gives increased trigger gain.

2. It ac couples the Internal Sync amplifier tube (V14) to isolate the Internal Snyc signal from the DC Restorer feedback loop. This minimizes trace disappearance and distortion that may occur at low-level input signals.

3. It adds diodes between the grid and cathodes of V444 and V544 and from the cathode of V413 to ground. This gives warm up protection for the Vertical Amplifier tubes by limiting the positive grid-to-cathode potentials and eliminates the possibility of waveform distortion from damaged tubes.

4. It changes the time constant of the Gate Multi (V595). This minimizes Vertical DC-Restorer shift in the presence of color burst so that video will not occur during restoration time.

The modification applies to Type 527's s/n's 151 through 744 and Type RM527's*, s/n's 151 through 1189. Order through your local Tektronix Field Engineer, Field Office or Representative. Specify Tektronix Part Number 040-362.

*A few instruments in the following serial number ranges were modified at the factory: Type 527, s/n's 645 to 744; Type RM527, s/n's 730 to 1189. Consult your Tektronix Field Engineer or Representative before ordering if your instruments fall in these serial number ranges.

DC-TO-50 MC, 10 MV/CM

NEW SOLID STATE OSCILLOSCOPES

TYPE 647
RM647

COMPACT HIGH-PERFORMANCE INSTRUMENTS CAPABLE OF ACCURATE MEASUREMENTS IN SEVERE ENVIRONMENTS (−30°C TO +65°C).

EVEN GREATER ACCURACY PLUS AN EXTRA MARGIN OF DEPENDABILITY IN NORMAL ENVIRONMENTS (0°C TO +40°C).

The Type 647 And Type RM647 Offer These "Most Wanted" Features In A Ruggedized Oscilloscope:

DC-To-50 MC Dual-Trace Capability

Choice Of Horizontal Plug-Ins:

Calibrated Sweep Delay, Or

Wide-Range Magnification

Bright 6 x 10 cm No-Parallax Displays

Low Power Requirements

Ease Of Maintenance

All In A Compact Easily-Handled Package.

For more information contact the distributor in your country.

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THE CATHODE FOLLOWER

A continuation of the discussion on the cathode-follower circuit. Part 1 of this discussion, which appeared in the August, 1964, issue of Service Scope, covered the need for a device having a small input capacitance and a device having a small internal output impedance — two prime characteristics of the cathode-follower circuit. Also covered, were the polarity of the output signal and the voltage gain of the circuit.

Part 2

Input capacitance. The input capacitance of a cathode follower consists essentially of the effects of (1) the grid-to-cathode capacitance of the tube and (2) the grid-to-plate capacitance of the tube (see Fig. 9).

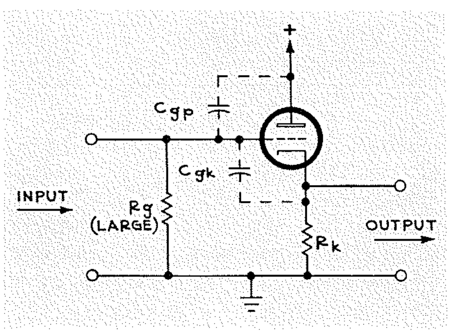


Fig. 9 — Illustrating that the input capacitance of a cathode-follower stage is small. If we apply a given grid-input voltage change, this input signal causes the cathode output voltage to change in the same direction. Since the voltage gain of the stage is commonly between 0.5 and 0.99, the new grid-to-cathode voltage (*with* the input signal applied) isn't much different from the original grid-to-cathode bias voltage that existed before we applied the signal. Since we haven't changed the voltage across the grid-to-cathode capacitance C_{gk} very much, this capacitance hasn't required much charging current. And therefore C_{gk} causes relatively little loading effect on the source. (As far as the grid-to-plate capacitance C_{gp} is concerned, C_{gp} acts simply as a shunting grid-to-ground capacitance since the positive power supply acts as a short circuit to signal variations.) The resulting total input capacitance is considerably less than for a plate-loaded amplifier using a similar tube.

To observe the effect of the grid-to-cathode capacitance C_{gk}, suppose that C_{gk} is 2 picofarads, and that the voltage gain of the stage is 0.9. If we apply an input signal-voltage change of +1 volt to the grid of the tube, then the cathode output voltage changes by +0.9 volt. Thus we change the voltage across C_{gk} by 0.1 volt — thereby changing the charge stored in C_{gk}. But this 0.1 volt change across the 2-picofarad capacitance C_{gp} alters the charge in coulombs exactly as much as a 1-volt change (the actual input signal) across a capacitance of only 0.2 picofarad. Therefore the actual grid-to-cathode capacitance (2 picofarads) loads the source only as much as if C_{gk} were a grid-to-ground capacitance of only 0.2 picofarad.

The grid-to-plate capacitance C_{gp} in Fig. 9 presents a simple shunt capacitance across the input terminals, since the power supply is a short circuit to signal variations.

Thus, as far as the signal source is concerned, *the input terminals of the cathode follower represent a capacitance equal to a fraction of the rated grid-to-cathode capacitance of the tube — plus the rated grid-to-plate capacitance.* The input capacitance of a plate-loaded amplifier is ordinarily considerably greater than the input capacitance of the cathode follower. We can make the effective input capacitance of the cathode follower even smaller by increasing R_k so that the voltage gain of the stage approaches unity.

Cathode-follower probes. Suppose we are using an oscilloscope to look at a waveform developed by a certain source. The vertical-input circuit of the oscilloscope causes a certain amount of resistive and capacitive loading on the source. Unless the internal impedance of the source is low, this loading might (1) distort the waveform, or (2) reduce the amplitude of the waveform, or both.

We can use a voltage-divider probe to reduce the loading and thus reduce the waveform distortion. But the voltage-divider probe also *attenuates* the signal we want to display. Consequently, if the signal is already small, the voltage-divider probe can attenuate the signal to a point where it no longer produces a useful display. Therefore the voltage-divider probe might not fill the bill when we need to look at a small waveform from a high-impedance source.

What we need for such purposes is a probe that (1) loads the source only lightly, but still (2) has a voltage gain as close as possible to unity. We can make such a probe by placing a cathode follower inside the probe body. The small input capacitance of the cathode follower puts only a light load on the source. But the voltage gain in the cathode follower can readily be between 0.5 and unity.

In Table 1, we compare the loading effects and the voltage gains that we might get (1) when we use a typical voltage-divider probe, and (2) when we use a typical cathode-follower probe.

TABLE 1

	Loading effect	Voltage gain
Typical voltage-divider probe	10 megohms 11.5 picofarads	0.1 (10X attenuation)
Typical cathode follower probe	40 megohms 4 picofarads	0.8 - 0.85

From this comparison, we might at first imagine that we should forget about the voltage-divider probe and simply use the cathode-follower probe for all our waveform observations. But there are some other considerations, including these:

1. A cathode-follower probe can readily be oveloaded by large input signals. This overloading causes waveform distortion. (For example, one type of cathode-follower probe introduces about 3 percent amplitude distortion when the input voltage exceeds about 5 volts. Some other cathode-follower probes can accommodate only much smaller input voltages.)

2. Attenuators are available that can be attached to the nose of the cathode-follower probe, for signals larger than those the probe can handle directly. (These attenuators affect both the input impedance and the frequency response of the probe.)

3. If an uninformed worker uses a cathode-follower probe in such a way that the probe is overloaded — as discussed above — he can get readings or waveforms that are very misleading.

4. Suppose we connect the cathode-follower-probe input to a waveform source whose internal impedance is inductive at some frequency. Then the cathode-follower-probe input impedance drops — perhaps sufficiently to change the amplitude or shape of the displayed waveform. If the Q of the source-and-probe circuit is high, the probe-input impedance can actually become negative at some frequency so that the cathode-follower-probe circuit oscillates.

5. The cathode-follower probe costs significantly more than the voltage-divider probe. Furthermore, the cathode-follower probe requires a stable, low-ripple power supply that is external to the probe. (Probe power supplies are available. Some oscilloscope types include probe-power connections.)

6. If the tube needs replacing in a cathode-follower probe, the new tube should be carefully selected and installed at the factory or by a technician trained in such work.

If you think a cathode-follower probe will help you, ask your Tektronix Field Engineer or Representative to help you select the probe and apply it to your work.

A method of increasing apparent input resistance. In order to reduce the loading on the signal source, we often want to make the resistive component of the input impedance of a stage very large. To accomplish this result, we might make the grid resistor R_g very large. But tube manufacturers often specify a maximum value of R_g that we should not exceed. This maximum value of R_g is based principally on grid-current considerations. A typical recommended maximum value for R_g is 1 megohm.

When we use a cathode resistor to obtain the negative grid-to-cathode bias voltage — as in the case of cathode followers and of many plate-loaded amplifiers — the upper limit for R_g is not so critical. (The tendency for grid current in R_g to make the dc plate current unstable is largely balanced out, since a change in plate current causes a change of bias voltage developed across the cathode resistor — and this bias-voltage change is in a direction that tends to bring the plate current back to its original value.) However, even with cathode-resistor bias, we cannot expect the tube to operate reliably in every case when we use indiscriminately large values of grid resistance R_g.

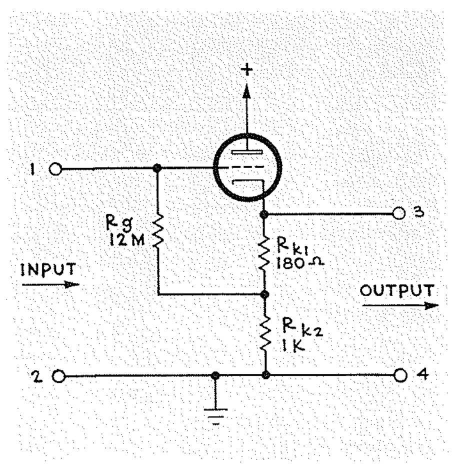


Fig. 10 — Means of increasing the apparent value of the grid resistor R_g in a cathode follower, to reduce the shunt loading effect on the signal source. R_{k1} and R_{k2} act as a voltage divider, applying most of the output-signal voltage to the lower terminal of the grid-return resistor R_g. Since the output-signal voltage at the cathode terminal is nearly as great as the input-signal voltage, only a small part of the signal voltage appears across R_g. In Fig. 10, the resulting signal current in R_g is so small that this 12-megohm resistor appears to the input-signal source as if it were a 40-ohm resistance between the input terminals.

A circuit like that of Fig. 10 can make the apparent grid-input-circuit resistance of a cathode follower very large — considerably larger than the actual value of R_g. In the figure, the actual value of R_g is 12 megohms. But the apparent resistance seen by a source that drives the grid circuit is about 40 megohms. Let us see how the circuit of Fig. 10 accomplishes this increase in apparent input resistance.

Suppose, for example, that we apply an input signal voltage of +1 volt to terminals 1 and 2 of the circuit of Fig. 10. Assume that the gain of the cathode follower is, say, 0.83. Then the output signal voltage that appears across terminals 3 and 4 will be 0.83 volt. Because of the voltage-divider action of the series cathode resistors R_{k1} and R_{k2}, only a part of this output-signal voltage will appear at the junction of R_{k1} and R_{k2}. In fact, since $R_{k1} = 180$ ohms and $R_{k2} = 1{,}000$ ohms, the signal voltage at the junction of these two resistors will be 1,000/1,180 times the output-signal voltage of 0.83 volt. Thus the signal voltage at the junction of R_{k1} and R_{k2} is about 0.7 volt.

Since the signal voltage at the lower end of R_g is 0.7 volt, and the signal voltage at the upper end of R_g is 1 volt, the signal voltage across R_g is only 0.3 volt. The resulting signal current in R_g is, by Ohm's law, equal to 0.3/12,000,000 ampere, or 0.025 microampere.

Thus the input circuit takes a signal current of 0.025 microampere when the source signal voltage is 1 volt. By Ohm's law, the apparent resistance of the input circuit is 1/0.000,000,025 ohms or 40 megohms. This increase in apparent grid-input-circuit resistance occurs simply because we connected the lower end of R_g to the junction of the two series cathode resistors rather than to ground. We should note, however, that there is a certain sacrifice in the voltage gain as compared to the gain we would get with the lower end of R_g grounded.

The circuit of Fig. 10 is actually used in some cathode-follower probes.

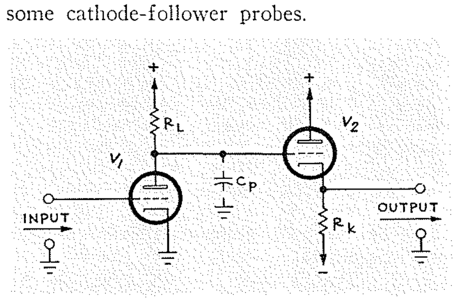


Fig. 11 — Here a plate-loaded amplifier V_1 drives the input of a cathode follower V_2. The plate-to-ground capacitance of V_1 (plus the small input capacitance of V_2) is represented by C_p. The risetime of the coupling circuit between V_1 and V_2 is determined by the time constant $R_L C_p$.

Bootstrap capacitor. Fig. 11 shows a plate-loaded amplifier V_1 that supplies a varying signal voltage to the grid-input circuit of a cathode-follower tube V_2. There

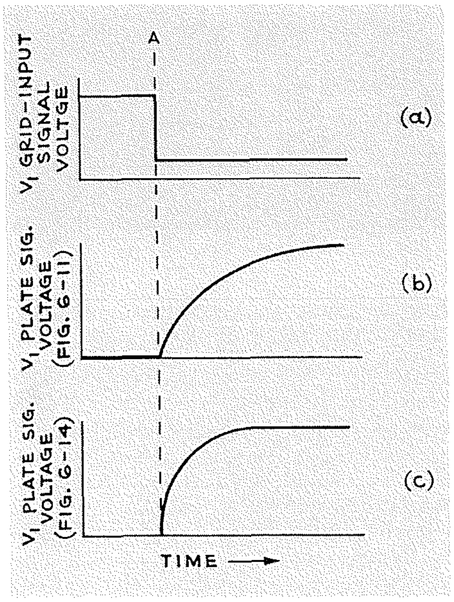


Fig. 12 — (a) An example of a grid-input signal voltage that we can apply to V_1 in Fig. 11 to observe the effect upon the output signal of the time constant R_L C_p in Fig. 11.

(b) V_1 plate signal voltage applied to the grid of V_2 in Fig. 11 when we apply to the grid of V_1 the waveform of diagram (a).

(c) Faster response of the coupling circuit between V_1 and V_2 to the input signal of diagram (a), achieved by the hypothetical method of Fig. 13 or by the practical method of Fig. 14.

will exist an unavoidable shunt capacitance C_p at the plate of the amplifier tube V_1. And the RC circuit composed of the plate-load resistor R_L and the shunt capacitance C_p might cause the risetime of the circuit to be longer than we can tolerate.

If, for example, we apply a negative-going input-voltage step (instant A, Fig. 12) to the grid of V_1, the plate current will be abruptly reduced. And the signal voltage at the plate of V_1 will rise according to a curve like Fig. 12b.

We can use peaking or compensating circuits to shorten the risetime. But another approach to shortening the risetime is shown in Fig. 13. Here the upper end of the plate-load resistor R_L is connected to the movable contact of a variable voltage divider R. Suppose we could provide some way by which the movable contact would automatically move toward the positive end of R when the signal voltage at the plate of V_1 tended to rise. If we could make this provision, then the stored charge in C_p would be more quickly removed so that the signal voltage at the plate of V_1 could rise more rapidly.

We cannot, of course, provide the mechanical arrangement just suggested—except possibly for signals that change quite slowly. But a system that operates in somewhat the same way can be arranged electronically, as follows:

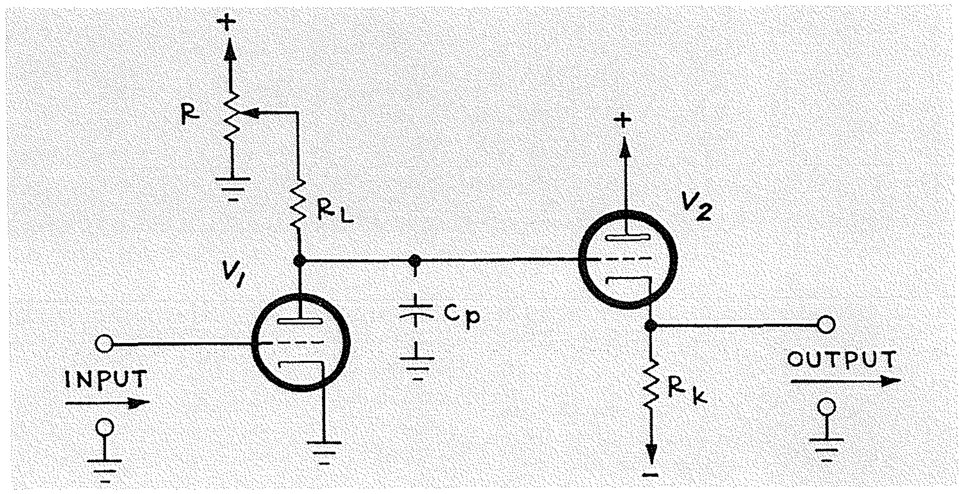


Fig. 13 — A hypothetical way to improve the speed of the response of the coupling circuit between V_1 and V_2 in Fig. 11. Here we apply the waveform of Fig. 12a to the grid of V_1. And we assume that we can provide some way by which a voltage rise at the plate of V_1 moves the variable contact on R upward. The resulting voltage rise at the upper end of R_L helps to charge C_p while the input waveform changes. Thus the voltage at the plate of V_1 can change more rapidly, as indicated in Fig. 12c.

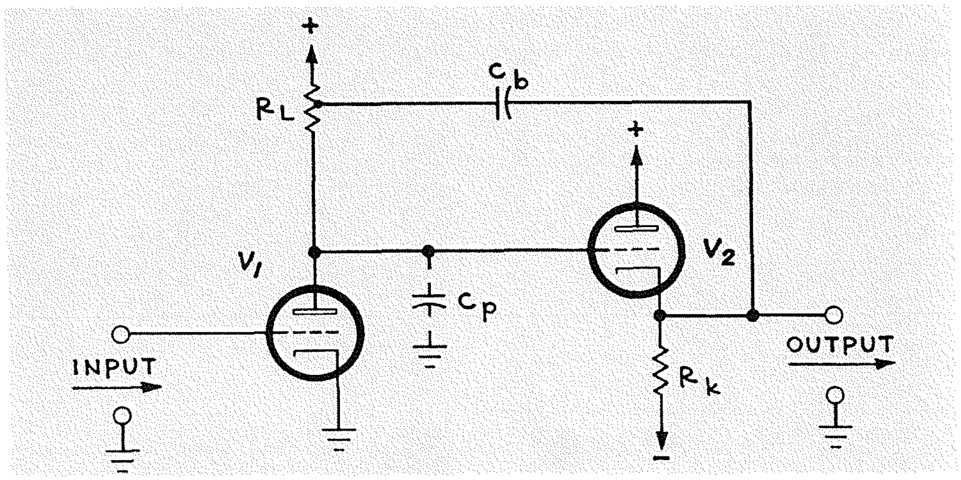


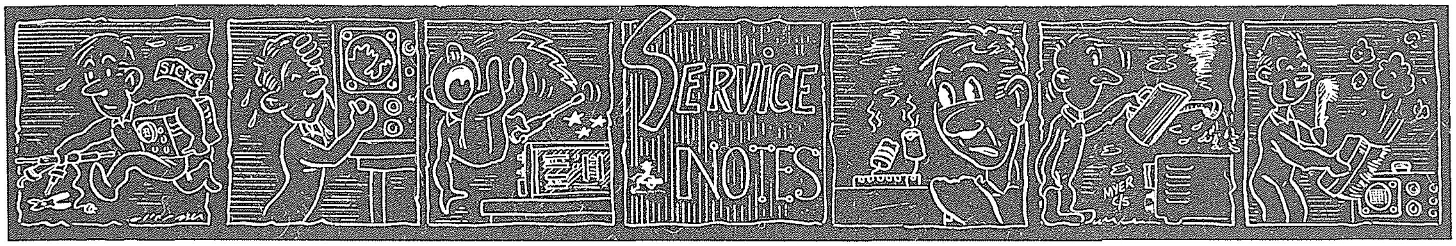
Fig. 14 — A practical way to achieve the result we considered in Fig. 13. Here the V_1 grid-input signal of Fig. 12a makes the voltage at the plate of V_1 rise. By cathode-follower action, V_2 couples this voltage rise to the cathode of V_2. The bootstrap capacitor C_b applies this voltage rise to the tap on the plate-load resistor R_L, helping to change C_p more rapidly. Therefore, in response to the input waveform of Fig. 12a, the voltage at the plate of V_1 can change relatively rapidly as indicated in Fig. 12c.

Fig. 14 shows a small capacitance C_b connected between the cathode output terminal of the cathode follower V_2 and a tap on the plate-load resistor R_L. When the signal output voltage at the plate of V_1 begins to rise, this voltage rise is applied to the grid of V_2. And the signal-voltage rise appears only slightly diminished at the cathode output terminal of V_2. The same signal-voltage rise is coupled through C_b to the tap on R_L, so that the voltage at the tap rises more rapidly than it would if the circuit through C_b were absent. Thus electrons are drawn away from C_b more rapidly than they would if C_b were absent. The action continues during the plate-voltage rise of V_1 — each increase in plate voltage causing a corresponding rise in voltage at the tap on R_L so that electrons can be drawn rapidly away from C_b. The corresponding output-voltage waveform at the plate of V_1 is therefore like that of Fig. 12c.

In thus improving the risetime of the response to a step-voltage input, we have also made the circuit of Fig. 14 capable of responding to other rapidly changing waveforms. Inasmuch as this improvement is actually intended to affect only waveforms that change rapidly, we make C_b small enough that its coupling action is negligible for slowly changing waveforms. We can refer to C_b as a *bootstrap* capacitor. It is, in general, necessary to select the value of C_b and the tap point on R_L so that optimum results are obtained.

The End

The material for this article was taken from the book "Typical Oscilloscope Circuitry", published by Tektronix, Inc. The complete text is available from your Tektronix Field Engineer or Representative. The price in the U.S.A. is $5.00.



TYPE 1A1 DUAL-TRACE PLUG-IN UNIT — OUTPUT-AMPLIFIER CARD IMPROVEMENTS

Depending upon the model of Output-Amplifier card in your Type 1A1, there are up to five improvements you can incorporate into the instrument. The Output-Amplifier cards affected by the improvements are models 2, 3 and 4. Cards with model numbers 5 and up have all the improvements installed at the factory. Model numbers are silk screened on the cards near the tube socket for the V464 NU-Vistor.

Installation of the improvements require the removal of the Output-Amplifier card. These are of the plug-in type and easily removed by first removing the securing rod. Next, un-plug the ground lead and the leads which individually plug into the card. Now un-plug the card itself from the Bendix connector.

Page 5-6 of the Type 1A1 Instruction Manual features a large photograph of the component side of the Output-Amplifier. Each component on this card is identified with its circuit number. Consulting this photo will aid you in physically locating the components replaced, changed or removed in making the improvements.

The first improvement is applicable to Output-Amplifier cards with model numbers 2, 3, and 4. It reduces the failure rate of the diodes D454, D453, D452, D451, D424, D423, D422 and D421 by replacing the original GaAs point-contact diodes with the Type 6153 Silicon Diodes (Tektronix Part Number 152-153). To do this, remove the original diodes from the card by lifting them from their clips. Next, using a 15 or 25 watt soldering iron heat each clip and lift it from the card. This will expose four soldering points (two per clip) for each diode position. Install a 6153 replacement diode in each position orienting the diode and soldering the axial leads in their locations as shown in Figure 1.

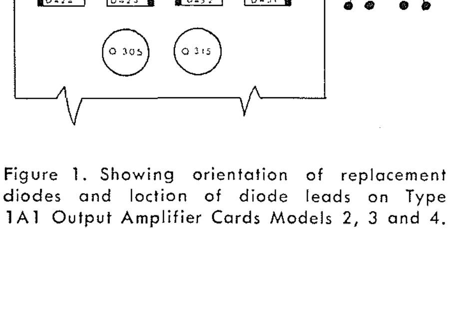


Figure 1. Showing orientation of replacement diodes and loction of diode leads on Type 1A1 Output Amplifier Cards Models 2, 3 and 4.

The second improvement is applicable to models 2 and 3 Output-Amplifier cards. It prevents the alternate-trace blocking oscillator from intermittently running twice on a sync pulse. The improvement adds a Type 6075 Germanium Diode (Tektronix Part Number 152-075) across the collector winding of T330. Circuit designation of this new diode is D330, see Figure 2. Figure 3 shows the physical location of D330 on the rear (soldered) side of the Output-Amplifier card.

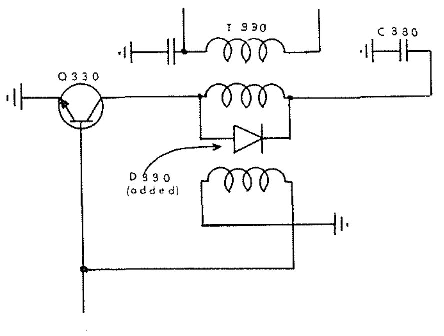


Figure 2. Partial schematic showing circuit location of the added Type 6055 Germanium diode (D330) across the collector windings of T330.

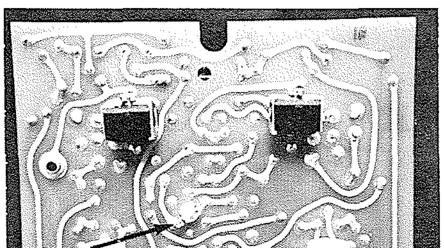


Figure 3. Partial view of Output Amplifier Card (rear or soldered side.) Arrow shows the physical location of the added Type 6055 Germanium diode (D330) and points to the anode end of the diode.

The third, fourth, and fifth improvements are applicable to the model 2 Output-Amplifier card. These improvements reduce abberations on the Chopped waveform, reduce field failure of Q353 and assure ALTERNATE trace operation in all units.

To Reduce Abberations on Chopped Waveform install a new 150 pf ceramic capacitor (Tektronix Part Number 281-524) in parallel with R343. Designate this new capacitor C344. Replace C491, a 0.001 μf capacitor located from pin 10 of V243 to ground, with a 0.1 μf ceramic capacitor (Tektronix Part Number 283-057) and add a 3/8 inch piece of #18 varglas to the lead at pin 10. V243 is located on a bracket directly behind the front sub-panel on the Channel 2 side of the Type 1A1. Install a new 0.1μf ceramic capacitor (Tektronix Part Number 283-057) from pin 21 of the Output Amplifier card's Bendix connector to the ground lug under R495, a 470 ohm, wire wound resistor, located on the rear frame plate of the Type 1A1. Designate this new capacitor C494. Remove and discard C260*, a 0.001 μf capacitor, located between pin X of the Channel 2 Input-Amplifier card's Bendix connector and a solder lug on the bracket supporting the rear end of this Bendix connector.

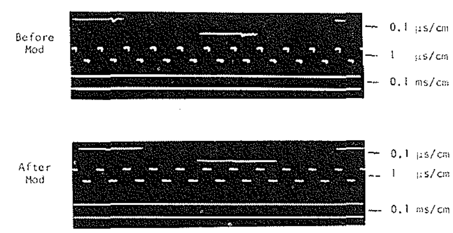


Figure 4 shows waveforms from a Type 1A1 in Chopped Mode before and after the improvement.

To Reduce Field Failure of Q353

On the rear wafer of the MODE switch locate a contact with a green-on-white wire and a second contact with a red-on-white wire. Install a 2.7 megohm*, ½ w, 10% resistor (Tektronix Part Number 302-275) between these two contacts. Designate this resistor R360.

To Insure ALTERNATE trace operation in all units

Replace C303 and C304, 0.001 μf capacitors, with 0.05 μf ceramic capacitors (Tektronix Part Number 283-010). Replace C306 and C316, 22 pf capacitors, with 47 pf, ceramic capacitors (Tektronix Part Number

281-518). Replace D303, a 6075 diode, with a 1N3605 diode (Tektronix Part Number 152-141). Replace Q305 and Q315, 2N964 transistors, with a pair of selected 2N964 transistors (Tektronix Part Number 153-530). These last two transistors are selected for a minimum Beta of 80 at 10 ma I_c.

Correct the schematics and parts list in your Type 1A1 Instruction Manual to conform to the improvements you have just made.

*Some Type 1A1 instruments in the field may have had these starred components removed or installed at the factory. If your instrument falls in this category, ignore these portions of the improvement procedure.

TYPE 180A FREQUENCY DOUBLER—MARKING TURN-AROUND

The Type 180A Frequency Doubler (Tektronix Part Number 015-013) — used for obtaining 100 Mc from the 50 Mc output of the Type 180A Time-Mark Generator — is intended to be coupled directly to the Type 180A, not at the end of a cable. The schematic on the case of the Frequency Doubler has confused some operators. The schematic markings implied that the female UHF connector was the input and the male connector the output. This interpretation is wrong. The *male connector* is the *input.* It connects directly to the 50 Mc Sine Wave output (a female UHF connector) of the Type 180A Time-Mark Generator.

TYPE 4S1, 4S2 and 4S3 DUAL-TRACE SAMPLING UNITS — "SLASH"-REDUCTION MODIFICATION INFORMATION

Here is a very simple solution to a problem that a few operators find troublesome. The problem occurs when using a Type 4S1, Type 4S2 or Type 4S3 to look at fast signals recurring at a very low rep rate. In this situation, there is such a long waiting period between samples that the Miller Memory usually drifts away from the level it was set to by the preceding sample before it is reset by a new sample. This creates vertically elongated "slashes" instead of dots. The addition of a 25 k potentiometer (Tektronix Part Number 311-390) in series with the plate of V1133A in the Memory circuit of these plug-ins will give you an adjustment with which you can virtually eliminate the tendency to drift and slash. Figure 5 shows a schematic of the new circuit.

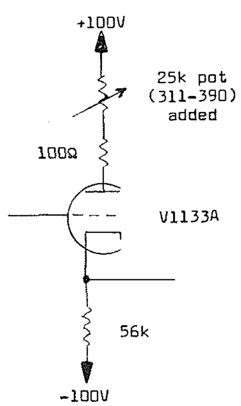


Figure 5. Partial schematic showing the addition of the 25 k potentiometer to the plate circuit of V1133A.

Please note that the Types 4S1, 4S2 and 4S3 are dual-trace instruments. As such they have two input channels and each channel has its own Memory card. For single trace operation you need modify only the Memory card of the input channel you intend to use. For dual-trace operation you should modify the Memory cards of both channels.

The potentiometer may be installed on the lip of the Memory card chassis alongside the Smoothing Balance potentiometer. It will require the drilling of a ¼-inch hole. A nearby vacant slot in a ceramic strip simplifies rerouting the +100-volt supply lead through the new potentiometer before connecting it to the plate (pin 6) of V1133A via the 100-Ω suppressor resistor.

To adjust the pot, first be sure the DC-offset control for the channel used is set to zero volts. Monitor the voltage with a voltmeter at the monitoring jacks. Observe that adjustment of the potentiometer can reverse the direction of the spot (up or down) as well as the rate at which it drifts each time a free-running sweep is stopped. Set it so the spot remains in the same position as the trace each time the sweep is stopped from free-running.

There is some interaction with the Smoothing Balance Control so you may have to work back and forth between these controls a couple of times.

NE-23 NEONS RADIOACTIVE MATERIAL — A CORRECTION

In this column of the April, 1964, Service Scope we stated that the new NE-23 Neon lamps contained a tiny bit of radioactive material added to the glass envelope during manufacture. Mr. Charles Dougherty, Applications Engineer with the Miniature Lamp Department of General Electric Company, tells us that radioactive material is *not* added to the glass envelope. They do, however, add a radioactive gas with the neon mixture. This accomplishes the purpose which we cited as the reason for adding radioactive material to the glass — that of assuring immediate ionization of the neon gas. In addition, it minimizes dark effect in these neons.

To answer any question that you may have in regard to danger from this radioactive gas, Mr. Dougherty assures us that it offers no hazard to service people or users of equipment containing NE-23 neons.

TYPE 541, 545, RM41 and RM45 OSCILLOSCOPES — MODIFICATION TO PERMIT THE USE OF TYPE T543 CRT

A simple modification will permit the use of either the Type T54 (original equipment) crt or the Type T543 (used in Type 543 Oscilloscopes) in all Type 541, 545, RM41 and RM45 Oscilloscopes. Both the T54 and the T543 crt employ etched deflection plates. There are, however, two possible advantages in converting to the Type T543 crt. One is, facilities that use both the Type 543 instrument and other instruments in the older Type 540 Series (541, 545, RM41 and RM45) will need stock only one type of replacement crt — the Type T543. The other advantage is that the Type T543 crt reduces the effect of intensity change as a result of Astigmatism control changes.

Please note that this modification does not apply to the recently announced Type 544, Type 546 and Type 547, or to the Type 540A Series and Type 540B Series Oscilloscopes.

To make the modification:

1. Remove the crt from the instrument.

2. Disassemble the crt socket by removing the two screws.

3. Short pins 11 and 12 of the crt socket together. One method is to notch the rib between the ribs and short them with a piece of #22 bare wire; another, to use an external loop.

Steps 4, 6 and 7 apply to the following instruments only:

Type 541, s/n 101 - 6928, inclusive
545, s/n 101 - 11328, inclusive
RM41, s/n 101 - 135, inclusive
RM45, s/n 101 - 192, inclusive

4. Run a lead through hole #8 in the crt socket insert and solder it to pin #8. We suggest using a 9-inch length of #22 stranded wire, color-coded: white-orange-green-brown, which denotes the supply voltage to which the lead will be connected.

5. Re-assembly the crt socket.

6. Remove the high-voltage shield on the top left side of the instrument.

7. Run the free end of lead (Step 4) through a vacant hole in the high-voltage chassis (just above the crt socket) and solder it to the +350 volt point (white-orange-green-brown lead) on the rear ceramic strip.

8. Replace the high-voltage shield and install the crt.

Correct your Instruction Manual parts list and schematic as required.

Refer to your Instruction Manual and recalibrate your instrument as required.

SCOPE PADS BY ENSCA, INC. — ADDRESS INFORMATION

In the February, 1964, issue of Service Scope we told our readers about a product called "Scope Pad" distributed by Ensca, Inc., P.O. Box 253, New York, New York 10023 (Zip Code).

We are now informed that the address should include "Ansonia Station" following the P.O. box number.

Several of our readers complained to us that inquiries to Ensca using the address as originally given were returned to them as undeliverable. Using the corrected address should solve these readers' problem. This Editor has contacted Ensca several times using the correct address.

Mr. Sidney, Sales Manager for Ensca, Inc., stresses the need to include the Zip Code in the address. New York postal people are becoming very emphatic about the inclusion of Zip Code Numbers.

NEW FIELD MODIFICATION KITS

TYPE 3T77 SAMPLING PLUG-IN UNIT — IMPROVED SINE-WAVE TRIGGERING

This modification improves the display stability when triggering on high-frequency sine waves.

A change in the trigger circuit supplies a means of switching to a "lock-on" type of triggered operation when displaying high-frequency sine waves. This eliminates the drift in recovery time and the subsequent display break-up.

A new front-panel RECOVERY control with a push-pull switch replaces the old RECOVERY control. Pulling the switch to the ON position activates the RECOVERY control to synchronize the circuit on sine waves above approximately 30 Mc. Pushed in, the RECOVERY control activates the circuit to trigger on signals below 30 Mc.

This modification is applicable to Type 3T77 Sampling Units with serial numbers 126 through 839.

Order through your local Tektronix Field Engineer, Representative or Field Office. Specify Tektronix Part Number 040-372.

TYPE 6R1 DIGITAL PLUG-IN UNIT — PEAK-TO-PEAK MEMORY AND IMPROVED COMPARATOR CARDS

This modification replaces the original Memory and Signal Comparator cards with new and improved cards. The new cards offer switch selection of Peak-to-Peak or Average Memory, switch selection of Fast or Slow charging rate, increased 100%-Zone adjustment and improved long term stability.

This modification also decouples the —12.2 volt supply to the Comparator Card. Installation requires changing some of the associated circuitry and includes some changes in the Vertical Input circuits to the Timing Start and Timing Stop switches.

This modification is applicable to Type 6R1 instruments with serial numbers 126 through 994. Please note, however, that instruments below serial number 695 must have the Series M Master Gate Card Modification (Tektronix Part Number 040-342) installed before this modification is performed.

Tektronix part number for the Peak-To-Peak Memory and Improved Comparator Card Modification Kit is 040-369. Order through your local Tektronix Field Engineer, Representative or Field Office.

TYPE 581 AND TYPE 585 OSCILLOSCOPES — SILICON RECTIFIER

This modification replaces the original selenium rectifier assembly with a silicon diode rectifier assembly. This new rectifier offers better reliability and longer life.

The modification also adds a fuse in series with one of the AC leads for protection from damage caused by an overload or component short.

This modification is applicable to Type 581 instruments with serial numbers 101 through 1300 and Type 585 instruments with serial numbers 101 through 3762*. Please note that this modification does not apply to instruments that have had the modification kit "Regulated DC Filaments in the Vertical Amplifier" installed.

Order through your local Tektronix Field Engineer, Representative or Field Office. Specify Tektronix Part Number 040-387.

*Some instruments within this serial number range were factory modified. A visual check of your instrument will determine if it is one of these.

TYPE 321 OSCILLOSCOPE — VERTICAL LINEARITY IMPROVEMENT

This modification gives the Type 321 improved vertical linearity, minimum AC-DC gain change and reduced DC shift.

The improvement in the vertical linearity is accomplished by electrically relocating the POSITION control to the Input Amplifier emitter circuit, by reducing post accelerator voltage and by thermally balancing the Input Amplifier. The input protection neon is moved from the +45-volt supply to ground. This reduces the small "dark current" in the neon that tends to introduce dc shift.

The modification is applicable to Type 321 Oscilloscopes with serial numbers 101 through 4267. However, instruments in the serial number range 101 through 719 should have the Nuvistor Modification Kit (Tektronix Part Number 040-309) installed before the Vertical Linearity Improvement Modification Kit (Tektronix Part Number 040-377) is installed.

Order through your local Tektronix Field Engineer, Representative or Field Office. Specify Tektronix Part Number 040-377.

RELAY RACK CRADLE ASSEMBLY

This modification provides a rear support cradle for mounting the listed instruments in a backless relay rack by means of slide-out tracks. The slide-out tracks, which must be ordered separately, allow the instrument to be pulled out of the rack like a drawer and locked in one of seven positions; horizontal, or 45°, 90°, or 105° above and below horizontal.

The modification is applicable to instruments in the following list. The list also gives the slide-out tracks required for mounting the instrument in a backless relay rack.

Instrument	Serial Number	Slide-out Track Tek. Part No.
Type 127	309-up	351-006 (1 each)
Type RM15	101-up	351-006 (1 each)
Type 526	101-up	351-010 (1 each) and 351-011 (1 each)
Type RM561	101-up	351-050 (1 each)
Type RM561A	101 to 105	351-050 (1 each)
Type RM561A	5001-up	351-050 (1 each)
Type RM564	100-up	351-050 (1 each)
Type RM647	100-up	351-006 (1 each)

Order through your local Tektronix Field Engineer, Representative or Field Office. Specify Tektronix Part Number 040-344.

TYPE 121 PREAMPLIFIERS — SILICON RECTIFIER

This modification replaces the original selenium rectifier with a silicon-diode rectifier. The silicon-diode rectifier offers better reliability and longer life.

The modification applies to Type 121 instruments with serial numbers 101 and up.

Order through your local Tektronix Field Engineer, Representative or Field Office. Specify Tektronix Part Number 040-381.

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SIMPLIFYING TRANSISTOR LINEAR-AMPLIFIER ANALYSIS

By Larry Reierson, Instructor, Tektronix Product-Manufacturing Training Department, in collaboration with Ron Olson, Design Engineer, Tektronix Instrument Engineering Department

The complicated characteristic-family parameters for transistors are more useful for design purposes than for analysis. The best analytical tool is one that provides a means of quickly doing an adequate job of circuit analysis for trouble-shooting or evaluation purposes. This article suggests such a tool.

When a person thinks of a transistor amplifier, he usually thinks of a transistor in a circuit, behaving in some manner that depends on a set of measurements that have been made on the device. These measurements may be called h-parameter, r-parameter, or any of many other characteristic families. Each has its advantages, but they all have common disadvantages to the technician. They are complicated in nature and involve numerous variables. They are a means of measuring a transistor's charateristics, but say little about the circuit which uses that transistor. Published parameters are very general and, for a given type, will vary widely from one unit to another.

Designers have these variations in mind when they design a linear amplifier circuit and some type of feedback is usually employed in order to make the circuit as independent of the transistor characteristics as is practical. Transistor parameters may vary 50% or more without appreciably altering the gain or linearity of a well designed amplifier.

As we will show later transistor parameters are more useful as a guide by which to judge the relative merits of one transistor against another than as an analytical tool. They also give the student of solid state theory some measurable quantities to identify, in order to grasp some of the more difficult concepts involved in semiconductor action.

The parameter families are more useful for design purposes than for analysis. The best analytical tool provides a means of quickly doing an adequate job of circuit analysis for trouble-shooting or evaluation purposes.

The approach we are about to present eliminates the use of published data, except for Beta. This by no means implies that the other parameters are not useful. It does say, however that it isn't necessary to apply all you know about transistors to get a general understanding of how an amplifier works. Anyone with a basic knowledge of transistor characteristics and of Ohm's law, will have no trouble applying this approach to transistor amplifiers.

Keep in mind that our approach is very general and is not intended for use where extreme accuracy is desired. You can expect an accuracy that varies no more than 10 to 20 percent from the true circuit values—depending upon how familiar you are with the transistor being used.

If a transistor is considered to be two PN junctions connected together, and if we then consider *only* the junction formed between emitter and base, we find that the E-I plot of that junction is roughly that shown in Figure 1. Line 1 on the graph is the plot of the Base-to-Emitter Voltage -vs- Base Current, and line 2 is the plot of Base-to-Emitter Voltage -vs- Emitter Current. If the slopes of the curves are measured at a

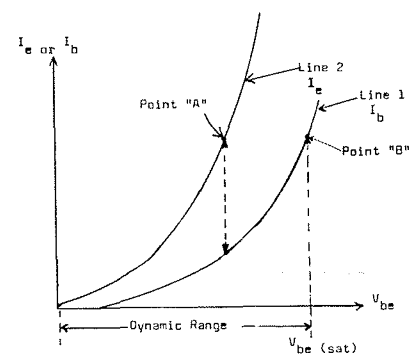


Figure 1 — Voltage -vs- current graph of the Base-to-emitter characteristics of a transistor. Line 1 is the plot of base current (I_b) -vs- Base-to-emitter voltage (V_{be}). Line 2 is the plot of emitter current (I_e) -vs- Base-to-emitter voltage (V_{be}). Point "A" indicates a typical operating point on the characteristic. With a common V_{be}, the ratio of I_e, to I_b at point "A" is: $I_e/I_b = \beta + 1$. Point "B" indicates the point at which the transistor goes into saturation. The area between $V_{be} = 0v$ and $V_{be\ sat}$ is the dynamic operating range of the device. The resistance represented by line 2 at any given point is approximately $0.026/I_e$. The resistance represented by line 1 at any given point is approximately $0.026/I_b$. Line 2 represents the resistance $1/gm$ and line 1 represents $1/gm\ (\beta + 1)$.

common point in voltage (Point "A") there will be a considerable difference in the two. The slope of these curves is actually a plot of the dynamic resistance of the junction. The resistance shown by line 1 is approximately $(\beta+1)$ times that shown by line 2 for any point on the curve between the origin and point "β". If we can by some means determine the value of resistance represented by one line, and if we know β, then we can find the resistance represented by the other line.

The slope of line 2 at any point between the origin and point "β" is approximately equal to:

$\frac{0.026}{I_e}$ where I_e is the DC current at the point selected. (The value $0.026/I_e$ is justified in the basic physics of the device, and no further explanation is offered.)

To simplify the powers of ten involved, remember that the resistance shown by line 2 is:

$$\frac{26}{I_e \text{ expressed in ma.}}$$

(If $I_e = 10$ ma, then $r_{(\text{line } 2)} = \frac{26}{10} = 2.6\,\Omega$)

Now consider what this has to do with transistor circuits. Note that the slope of line 2 on the graph is:

$$\frac{\Delta V_{be}}{\Delta I_e}$$

(For a transistor in a common base configuration the slope represents:

$$\frac{\Delta E_{in}}{\Delta I_{in}}$$

which is input resistance.)

Assuming the transistor has a very high β, the input current (ΔI_e) will be approximately equal to the output current (ΔI_c). Then we can say that line 2 closely approximates the plot of:

$$\frac{\Delta E_{in}}{\Delta I_{out}}$$

In vacuum tube theory, $\frac{\Delta E_{in}}{\Delta I_{out}}$ is called 1/gm, so lets's just call the resistance represented by line 2 of Figure 1 by the same name — 1/gm.

All we've said so far is that the impedance looking into the emitter of a transistor is approximately equal to 1/gm of the device, and can be calculated by:

$$\frac{1}{gm} = \frac{26}{\text{DC value of emitter current in ma.}}$$

In series with 1/gm is a small resistance, R_{EB}, that is made up of the ohmic resistance of the leads and the semiconductor material. R_{EB} usually amounts to about $2\,\Omega$ to $5\,\Omega$. (For power transistors the value of R_{EB} may be as low as a few tenths of an ohm, while some special purpose and low performance types may have R_{EB}'s as large as $25\,\Omega$. The value of $2\,\Omega$ to $5\,\Omega$ fits most modern, high-performance, medium-power transistors.) For very low values of I_e, R_{EB} can be neglected since 1/gm will be fairly high. However, if the transistor is operating at several ma of emitter current, R_{EB} becomes an appreciable part of the total resistance from emitter to base, and must be added to 1/gm.

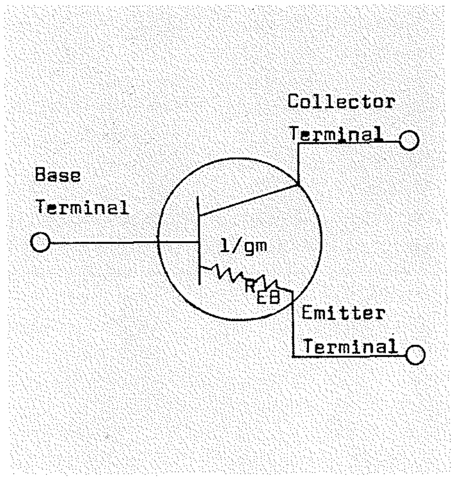


Figure 2 — Schematic equivalent of the emitter circuit of a transistor. 1/gm is the dynamic resistance of the junction due to carrier action and R_{EB} is the DC resistance in the leads and ohmic contacts of the leads within the transistor case.

Figure 2 shows what the transistor looks like between emitter and base. The sum of R_{EB} + 1/gm is an operating characteristic of the device we shall call "transresistance". The notation for transresistance is r_{tr}.

An example of the application of this idea to circuit analysis can be seen by referring to the diagram in Figure 3 (a).

Assume the DC operating point has been solved for.

Since the driving voltage is on the base, the drive will be impressed across the transresistance of the device. Now, if we ignore the small error due to base current, (assume $i_c = i_e$) we have the relationship:

$$(1)\quad \frac{v_{in}}{r_{tr}} = \frac{v_{out}}{R_L}$$

From the relationship in (1) we obtain:

$$(2)\quad A_v = \frac{v_{out}}{v_{in}} = \frac{R_L}{r_{tr}}$$

The equivalent of the circuit in Figure 3 (a) is shown in Figure 3 (b).

For degenerative circuits, such as that shown in Figure 3 (c), the input voltage is developed across the transresistance and R_e in series. (The equivalent of the degenerative circuit is shown in Figure 3 (d).) The formula for voltage gain in this circuit is:

$$(3)\quad A_v = \frac{R_L}{r_{tr} + R_e}$$

When R_e is large with respect to r_{tr}, the gain is simply:

$$(4)\quad A_v = \frac{R_L}{R_e}$$

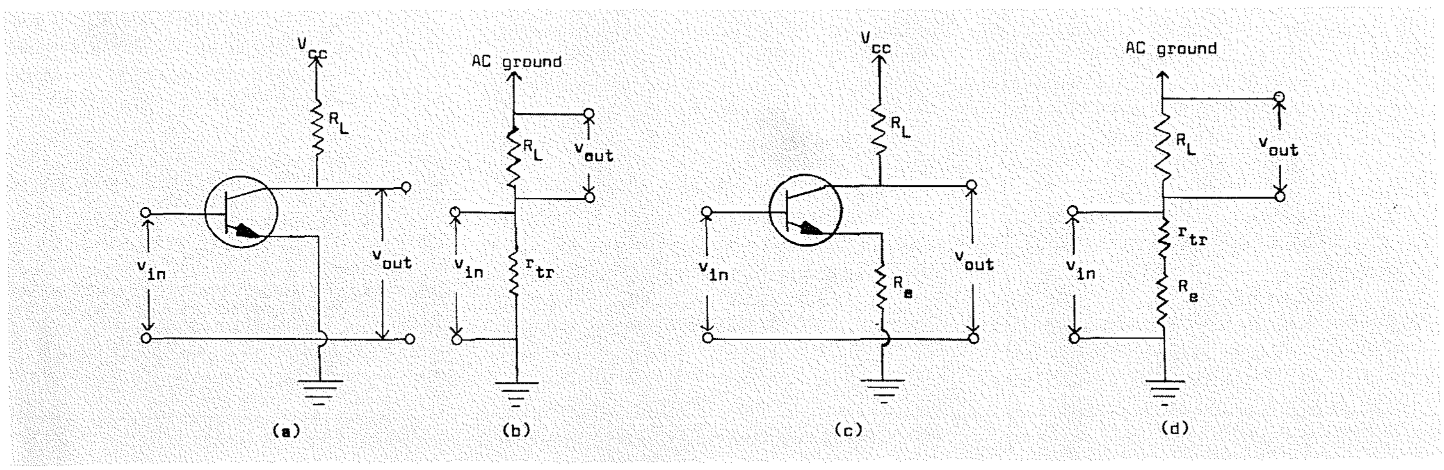


Figure 3 — (a) Common emitter voltage amplifier showing location of input and output terminals. (b) Equivalent circuit of 3(a) shows v_{in} impressed acorss r_{tr}. That voltage causes current through R_L that is approximately equal to the current through r_{tr}. Hence: $v_{out}/V_{in} = A_v = R_L/r_{tr}$. (c) Common emitter amplifier using degeneration in the emitter. (d) Equivalent circuit of 3(c) showing R_e in series with r_{tr} in the signal path. Voltage gain for this current: $A_v = R_L/r_{tr} + R_e$.

The above approach works very well for any configuration of amplifier, whether common base, common emitter or common collector. It also applies very well to paraphase and push-pull amplifiers, as long as the concept of transresistance is used to represent the resistance seen when looking into the emitter of the transistor. Of course the approach must be modified and added to, if it is to be applied at or near the frequency limits of the amplifier. Those modifications are beyond the intent of this writing and will be saved for a later discussion.

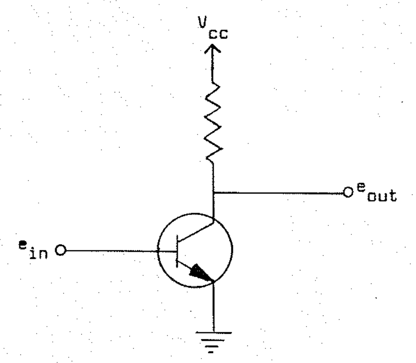


Figure 4 — Amplifier used as an example of the application of transresistance compared to h-parameters. The DC operating point is assumed to be set at $I_e = 5$ ma; $V_{ce} = 2.5$ v. The transistor is a 2N2475.

An example of how the foregoing method can be applied to amplifier analysis and how it compares to the h-parameter approach follows:

Figure 4 is a common emitter amplifier that uses a 2N2475 transistor. Table 1 gives the h-parameters for the transistor as measured on a Tektronix Type 575 Transistor Curve-Tracer.

TYPE 2N2475 TRANSISTOR	
I_e	5 ma
V_{ce}	2.5 ma
h_{ie}	1.4 k
h_{re}	1×10^{-4}
h_{fe}	180
h_{oe}	300 µv

Table 1 — List of the h-parameters for the Type 2N2475 transistor at $I_e = 5$ ma; $V_{ce} = 2.5$ v.

In this example we will determine voltage gain (A_v) and input resistance (r_{in}) using both the h-parameter method and the approach just described.

The solution using h-parameter follows:

$$(5)\ A_v = \frac{hfe\ R_L}{\Delta\ h_e R_L + h_{ie}}$$

$\Delta\ h_e$ is defined as:

$$(6)\ \Delta\ h_e = (hie)\ (hoe) - (hre)\ (hfe)$$

For the parameter in this example:

$$\Delta h_e = (1.4)\ (10^3\Omega)\ (3)\ (10^{-4}\text{mho}) - (180)\ (10^{-4})$$
$$= 0.42 - 0.018$$
$$= 0.402$$

Inserting circuit values in equation (5) yields:

$$A_v = \frac{(180)\ (100\ \Omega)}{(0.402)\ (100\ \Omega) + 1400\ \mu}$$
$$= 12.5$$

To find the input resistance:

$$(7)\ r_{in} = \frac{hie + \Delta\ h_e\ R_L}{1 + hoe\ R_L}$$

Putting in circuit values:

$$r_{in} = \frac{1400\ \Omega + (0.402)\ (100\ \Omega)}{1 + (3)\ (10^{-4}\text{mho})\ (100\ \Omega)}$$
$$= 1.4\ k\Omega$$

Now let us solve for the same quantities using transresistance.

As we have shown:

$$(8)\ r_{tr} = 1/gm + R_{EB}$$

and:

$$(9)\ 1/gm = \frac{26}{I_e \text{ in ma.}}$$

R_{EB} is typically $2\ \Omega$ to $5\ \Omega$ for this type of transistor. For this example we will use $R_{EB} = 3\ \Omega$.

Therefore, for this circuit:

$$r_{tr} = \frac{26}{5\ \text{ma}} + 3\ \Omega$$
$$= 8.2\ \Omega$$

From equation 2:

$$A_v = \frac{R_L}{r_{tr}}$$

For this example:

$$A_v = \frac{100\ \Omega}{8.2\ \Omega}$$
$$= 12.2$$

To find input resistance using transresistance it must first be shown that any impedance that appears in the emitter of a transistor will be seen as that impedance multiplied by (β +1) when measured from the base. Transresistance appears in the emitter of the transistor—therefore:

$$(10)\ r_{in} = r_{tr}\ (\beta + 1)$$

For this example:

$$r_{in} = (8.2\ \Omega)\ (181)$$
$$= 1.4\ k\Omega$$

Comparing the two approaches we see that h-parameters give us:

$$A_v = 12.5$$
$$r_{in} = 1.4\ k\Omega$$

and the transresistance approach yields:

$$A_v = 12.2$$
$$r_{in} = 1.48\ k\Omega$$

As this shows, the results are very nearly the same regardless of the method used. The advantage of the transresistance method is that it didn't require the use of a set of parameters. Instead it was necessary only to know the beta of the transistor and to make one calculation. If R_{EB} had been assumed to be either of the two extreme values, the results would have still been within 20% of the answer given by h-parameters.

If we now take the same transistor and place it in a circuit such as the one in Figure 5, the voltage gain will be shown by equation 3.

$$A_v = \frac{R_L}{r_{tr} + R_e}$$

If we assume the DC operating point to be the same as that of the previous example, the voltage gain will be:

(Figure 5)

$$A_v = \frac{100\ \Omega}{8.2\ \Omega + 5\ \Omega}$$
$$= 7.6$$

The input resistance to this amplifier is now:

$$(11)\ r_{in} = (R_e + r_{tr})\ (\beta + 1)$$
$$= (13.2\ \Omega)\ (181)$$
$$= 2.38\ k\Omega$$

Note that the addition of R_e would require modification of the DC levels around the circuit in order to maintain the same DC operating point for the transistor.

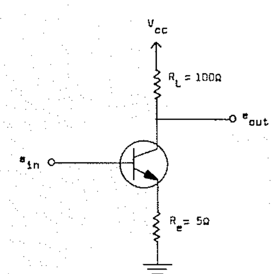


Figure 5 — Amplifier with the same type transistor set at the same operating point as that in Figure 4. This circuit has R_e added to reduce the voltage gain and increase the input resistance.

TYPE 530/540 SERIES OSCILLOSCOPES—
SIMPLIFIED MAIN SWEEP TRIGGER ADJUSTMENTS

By Sandy Sanford, Field Engineer with Tektronix
Product Information Department.

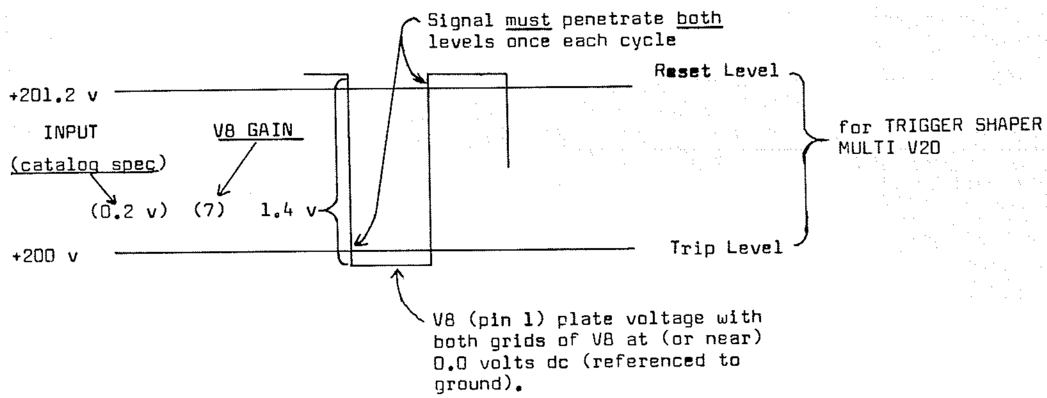


Figure 1. Graphic illustration of the three basic requirements of the trigger system; points a, b and c of this article.

Here is a systematic step-by-step adjustment procedure which will increase the length of time between necessary recalibrations of the MAIN SWEEP trigger circuits. As you work your way through these adjustments, any defective component or bad tube will be noticed—making your troubleshooting easy.

By using this system you will satisfy three basic requirements of the trigger system:

a. Right-hand plate of V8 must not move up or down when grids of V8 are interchanged by turning the SLOPE switch.

b. Trip voltage level of the bistable multivibrator, V20, must be set to a few millivolts above the plate voltage of V8 as found above.

c. Width of the bistable multi hysteresis gap (difference in volts between the "trip" level and the "reset" level) must be set to about 1.2 volts.

In general, procedure set down here can be used to adjust similar trigger systems in many Tektronix oscilloscopes. The specifications will turn out to be different but the basic functions performed by each trigger system will be about the same.

I. Preset the front panel controls as follows:
- A. Sweep TIME/CM — 1 msec
- B. STABILITY control — Triggerable range (free-run less 10 degrees).
- C. TRIGGER SLOPE — +EXT.
- D. TRIGGERING MODE — DC.

II. Set TRIGGERING LEVEL:
- A. Connect 20,000 ohms/volt meter (first on 6 v range — then on 12 v range) across plates of trigger amplifier, pins 1 and 6 of V8.
- B. Turn TRIGGERING LEVEL control until meter reads "O".
- C. Change SLOPE switch to —EXT.
- D. Meter will read up scale or down scale. (If meter reads down scale, reverse the leads.)
- E. Voltage reading (on 12 v range):
  1. Turn TRIGGERING LEVEL control to ½ previous voltage reading.
  2. Now, moving from +EXT to —EXT should cause no change in voltage reading.
- F. Verify that white dot on TRIGGERING LEVEL knob is opposite the engraved Zero on the panel. If not, correct by loosening knob.

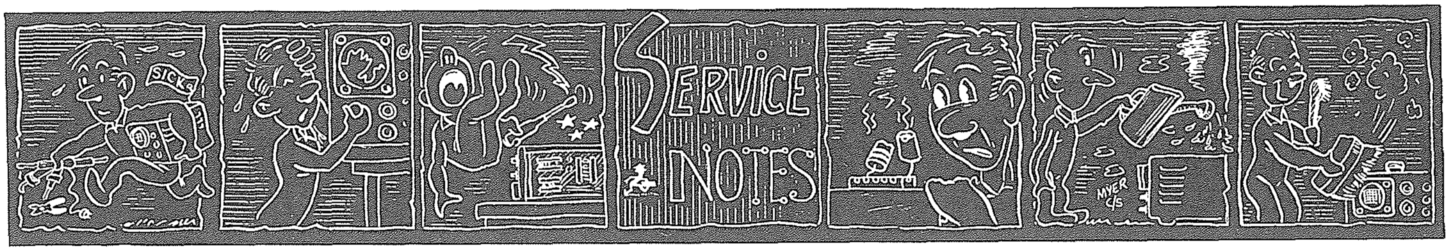
III. Check for grid current:
- A. With TRIGGER SLOPE +EXT
  1. Short EXT TRIGGER INPUT to ground (use 47-Ω resistor).
  2. Meter should move less than 100 mv (0.100).
- B. With TRIGGER SLOPE —EXT:
  1. Check for grid current as above.
  2. Replace tube if grid current is too high.

IV. INTERNAL TRIGGER DC LEVEL ADJ:
- A. Tie the vertical amplifier input to ground.
- B. Move spot to center of crt with HORIZONTAL POSITION control. Vertically position the spot or trace to the horizontal center-line of graticule.
- C. Set TRIGGER SLOPE to +INT.
- D. Turn INT. TRIG. DC LEVEL ADJ. pot until meter indicates voltage obtained in step II, E, 2.
  Note: Shifting from +INT to —INT to +EXT to —EXT should cause no change in meter voltage reading.

V. TRIGGER LEVEL CENTERING:
- A. Turn TRIGGER SENSITIVITY pot to mid-range.
- B. Turn TRIGGER LEVEL CENTERING pot:
  1. Clockwise to reset the Schmitt circuit (V20).
  2. Slowly counter-clockwise till Schmitt circuit has just triggered (this is indicated by one stroke of the sweep generator).
- C. If more than one stroke occurs, or if the Schmitt circuit triggers for both clockwise and counter-clockwise rotation of the TRIGGER LEVEL CENTERING POT, turn the TRIGGER SENSITIVITY pot 15° or 20° counter-clockwise from mid-range and recheck TRIGGER LEVEL CENTERING. The Schmitt circuit tube may need to be replaced.
- D. Remove meter leads.

VI. TRIGGER SENSITIVITY:
- A. Connect 200 mv calibrator square wave to VERTICAL INPUT *and* to EXT TRIGGER input.
- B. Set vertical VOLTS/CM switch for a 2 cm display.
- C. Reduce ac input (oscilloscope's line voltage) to 105 volts—or to a line voltage which just keeps all regulated power supplies functioning.
- D. Adjust TRIGGER LEVEL control slightly; system should trigger smoothly on 200 mv EXT. Square wave.
- E. Check that the trigger system will *not* trigger continuously on 100 mv—even with very careful adjustment of the TRIGGERING LEVEL control.
  Note: If oscilloscope triggers on 100 mv, turn TRIGGER SENSITIVITY counterclockwise 15° to 20° and recheck. Return oscilloscope's line voltage to 117 volts and again check the TRIGGER circuit for proper operation.

VII. PRESET STABILITY:
Follow procedure given in Instruction Manual.



TYPE 526 VECTORSCOPES — QUADRATURE PHASE DRIFT

Some Type 526 Vectorscopes have exhibited quadrature-phase-drift problems. The seat of the trouble seems to be L264, a 15-to-27 μh coil in the quadrature phasing circuit. In some environments this coil will absorb moisture during the periods the instrument is not in operation. The effect of L264 on the circuit will vary according to the amount of moisture absorbed and drift will occur as the heat from the instrument drives moisture from the coil during periods of operation.

Installation of a newly-designed moisture-resistant coil in the L264 position will help to correct this difficulty. For Type 526 instruments with serial numbers 101 through 511, with the exceptions of numbers 439, 477 and 492, specify Tektronix part number 050-210. For instruments with serial number 512 and up (and also serial numbers 439, 477 and 492) specify Tektronix part number 114-163. Order the new coil through your Tektronix Field Engineer or local Field Office.

TYPE 317 OSCILLOSCOPE — 120 CYCLE RIPPLE

Sometimes a Type 317 Oscilloscope will exhibit 120 cycles of ripple on the trace when the VOLTS/DIV switch is in the 10, 20, or 50 mv AC position. This may be due to a ground loop between C154 (a 500 μfd, ETM capacitor in the preamplifier circuit) and ground. Placing a short jumper between C154 and the front panel reduces the amount of ripple. By lifting the can of C154 above ground at its grounding strap and then running a separate ground from C154 to the shield of the Vertical Volts/Div switch you will completely eliminate the problem.

TYPE 545 OSCILLOSCOPE — POWER SUPPLY REGULATION

Do you have a stubborn problem of 60 cycle ripple in the 100-volt supply of your Type 545 Oscilloscope yet everything seems to check out as normal? If you do, try separating the common cathode and filament ground of V742, a 6AU6 tube in the low voltage power supply. Re-connect the filament lead to a separate ground lug of the tube socket. Sometimes, when the cathode and filament of this tube share the same ground lug, oxidation will occur between the ground lug and the chassis and allow the filament to modulate the cathode.

TYPE 502 OSCILLOSCOPE — LOW FREQUENCY DISTORTION

The recalibration instructions in the Type 502 Instruction Manual, under step 29 (Feedback Bal. Adj.), Figure 6-10 shows a typical low-frequency square-wave distortion. A simple modification will eliminate this distortion.

The distortion comes from the trigger pick-off cathode follower tube (V493) in the Upper and Lower-Beam Vertical amplifiers. Being single-ended, V493 produces a small change in current through the decoupling resistors R685 (or R686) when a signal is applied to the vertical amplifier. This change in current affects the nominal +100 volts enough to cause the distortion.

The modification returns the plates of V493 directly to the +100 volt supply (rather than through the decoupling network) and eliminates the difficulty.

Here are the instructions for making the modification:

Note: Follow this same procedure for both the Upper and Lower Beam Vertical Amplifiers.

1. Locate the two 1% resistors soldered to pin 1 of V493. (To make wiring easier, temporarily unsolder these resistors from pin 1 of V493 and bend them back out of the way.)
2. Unsolder the white-brown and the white-brown-black-brown wires from pin 5 of V493.
3. Unsolder the bare wire soldered to pin 2 of V493 and cut it off where it connects to pin 6.
4. Solder the two wires unsoldered in Step 2, to pin 2 of V493.
5. Solder one end of a length of #24 white-brown stranded wire to pin 5 of V493. Dress it along the underside of the cable leading to the +100 volt decoupling circuit (R685 and C685 or R686 and C686).
6. Solder the other end of the #24 white-brown stranded wire to the +100 volt supply at the rear of R685 or R686.
7. Resolder the two resistors unsoldered in Step 1.
8. Correct the schematic in your manual to conform to the work you have just done.
9. Refer to your Instruction Manual for the proper procedure and readjust the Feedback-Bal-Adj. Disregard Figure 6-10 in the manual.

P6038 DIRECT SAMPLING PROBE — REPAIR INFORMATION

The probe head of the P6038 Direct Sampling Probe (specifically designed for use with the Type 3S3 and 4S3 Sampling Plug-Ins) contains some rather delicate parts. These parts are critically arranged with some tolerances as close as 0.005 inches. Even the replacement of the diodes must be done with care and a jeweler's touch lest the diode clips be sprung. We suggest that P6038 probes in need of repair be returned to the factory via your local Tektronix Field Office. Here at the factory we have the necessary alignment jigs and special techniques to do a quick and efficient repair job.

AN INEXPENSIVE SURPLUS-SOLDER REMOVER

Art Baier, Maintenance Technician with the Tektronix Canada Ltd's Toronto Service Center, offers the following suggestion: Take a three or four inch length of ⅛" Teflon tubing and insert it in an ear syringe. This combination makes a useful tool for removing unwanted or excessive solder from connections and solder holes. It is particularly useful when replacing components on etched circuit boards. The tool can be used to either suck or blow the unwanted solder away from the connection. The heat resistance of the Teflon tubing is such that it will not melt from the soldering iron heat.

POTENTIAL CRT PROBLEM

The PME Lab at Ent Air Force Base in Colorado Springs, Colorado, reports a potential problem when using other than Tektronix crt's in Tektronix instruments. In the General Atronic's crt for the Type 545 Oscilloscope, pins 8 and 9 are shorted internally. If this crt is installed in the Type 545A Oscilloscope, there is a good chance of burning up the Astigmatism control—which they did!

The people at the PME Lab suggested that a note here in SERVICE SCOPE might prevent other Air Force Bases from making a similar mistake.

TYPE 310 AND TYPE 310A OSCILLOSCOPES — TRIGGER PROBLEM

If your Type 310 or 310A Oscilloscope reveals a lack of trigger capability after about ten minutes of operation, try replacing C671. This is a 0.01 μfd, 400 v, PT capacitor in the +300-volt circuit of the low-voltage supply. When it becomes leaky it can cause the difficulty described here. The replacement capacitor should be of the same value *and of Mylar or Di-Film construction.* The recommended replacement is Tektronix part number 285-511. Order through your Tektronix Field Engineer or local Field Office.

TYPE 527 TELEVISION WAVEFORM MONITOR — APPARENT DOUBLE TRIGGERING

Rick Ennis, Tektronix Field Engineer with our Greensboro, North Carolina, Field Office, calls our attention to a situation in which a Type 527 will appear to be double triggering. One of Rick's customers was interested in vertical-interval testing. However, when they attempted to monitor the signals with the DISPLAY switch in the VIT position, the Type 527 appeared to be double-triggering. They could not see the standard one or two interval test signals. Instead they noticed either two or four interval test signals. What they were seeing was the half-line interlace since the Type 527 was triggering at the field rate. To one not aware of this situation it does appear that the Type 527 is double-triggering. Much time can be wasted trying to correct the situation. As Rick explained, the indication was not double-triggering but in effect a meaure of the interlace.

To view the VIT signal you should go to the TWO FIELD position and set the MAGNIFIER to X25. This will show a single vertical-interval test signal.

NEW FIELD MODIFICATION KITS

TYPE 533, TYPE RM533, TYPE 543, AND TYPE RM543 OSCILLOSCOPE—SILICON RECTIFIER

This modification replaces the selenium rectifier SR752, used in the V152 heater supply, with silicon-diode rectifiers. The new rectifiers offer longer life and greater reliability. There is a difference in the voltage drop across the silicon rectifier and the selenium rectifier it replaces. To compensate for this difference a resistor is added in series with the silicon diodes.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-389.

NOTE: You may replace the remaining selenium rectifiers with silicon rectifiers in the above instruments by ordering Modification Kit 040-240.

TYPE 81 PLUG-IN ADAPTERS — GENERAL IMPROVEMENTS

This modification enhances the performance of the Type 81 Plug-In Adapter by:

1. Improving the transient response.
2. Decoupling power supply aberrations from the plug-in units.
3. Eliminating parasitic oscillations in the Type 581 or Type 585.
4. Eliminating the 75-volt supply oscillations which occur when using certain plug-ins.
5. Changing several components in the Vertical Amplifier.
6. Adding decoupling to the plug-in power supplies.
7. Changing two transistor types.
8. Elevating the plug-in filament supply.
9. Increasing the amplitude of the Alternate-Trace Sync pulse.

The modification applies to Type 81 Plug-In Adapters with serial number 101 through 4092.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-371.

TYPE RM647 OSCILLOSCOPE—RACK-MOUNT REAR SUPPORT

This modification supplies a rear support for the Type RM647, making it capable of withstanding 4G's of vibration. To complete the installation, the instrument must be fastened to the front rack rails with the RELEASE knobs and four screws.

This kit replaces Rackmount Rear Support Kit part number 016-065.

Please note, if the instrument is mounted in a backless rack using Relay Rack Cradle Assembly 040-344; or, if slide-out extensions are used, the instrument will not meet the 4G-vibration specification.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-394.

TYPE RM565 AND TYPE RM567 OSCILLOSCOPES — RELAY RACK CRADLE ASSEMBLY

This modification provides a rear-support cradle for mounting a Type RM565 or Type RM567 instrument in a backless relay rack on slide-out tracks. The slide-out track assemblies *are not* included in the modification. They must be ordered separately as follows:

Instrument	Quantity	Part Number
RM565 and RM567	1 pair	351-055

The slide-out tracks allow an instrument to be pulled out of the rack like a drawer. When pulled out, the instrument can be locked in any one of seven positions: horizontal, or 45°, 90°, or 105° above and below the horizontal.

The modification kit includes a detailed drawing giving all dimensions necessary to design a relay rack to support these instruments.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-346.

SOME CORRECTIONS

In the April, 1964 SERVICE SCOPE, the schematic on page 4 contains an error. The voltage to which the plate loads of 6DJ8 are returned is shown as +225 volts. If this were true, the T12G diodes would be held at about 74 volts and quiescently the 6DJ8 plates would be at about 205 volts. On receipt of a trigger large enough to cut off one half of the 6DJ8, the other plate would fall to about 185 volts. This would leave the diode back-biased by more than 100 volts and no signal could reach the trigger multivibrator. We don't believe the diode would like it much, either.

The voltage to which the plate loads of the 6DJ8 should be returned is 100 volts. Quiescently, then, the plate will sit at about 80 volts back-biasing the diode by some 5 volts. A trigger signal can then cause one plate to fall to nearly 60 volts allowing up to a 10-volt signal to reach the multivibrator —or had you already figured this out for yourself?!

In the October, 1964 SERVICE SCOPE, a typographical error occurred twice in the "Cathode Follower" article. On page 3, center column, the sentence "Thus electrons are drawn away from C_b more rapidly than they would if C_b were absent". The first C_b in this sentence should read C_p.

Reading on further (next sentence) "The action continues during the plate-voltage rise of V_1—each increase in plate voltage causing a corresponding rise in voltage at the tap of R_L so that electrons can be drawn rapidly away from C_b". Here, again, C_b should be changed to C_p. This is the capacitance which we are interested in changing terminal voltage on in a short period of time.

TEKTRONIX CANADA LTD. ANNOUNCES

A new uniform F.O.B.-DESTINATION price policy.

Because we are interested in our customers and the ease with which they may do business with us, Tektronix Canada Ltd. will absorb the p.o.e. (point-of-entry)-to-destination freight tariffs on Tektronix instruments purchased by our Canadian customers.

Prior to now, instrument prices were quoted f.o.b. point of entry (Toronto, Montreal or Vancouver) with the customer responsible for the expense of delivery from there to his location. Thus, the total cost of an instrument laid down at the customer's location could be at considerable variance with the quoted price.

The new price policy offers you, the customer, several distinct advantages:

You will find your purchase and budget planning problems considerably eased in so far as Tektronix instruments are concerned.

You will, with the quoted price, know the total cost of obtaining that instrument — no longer will you need concern yourself with bothersome insurance rates and difficult-to-figure freight charges.

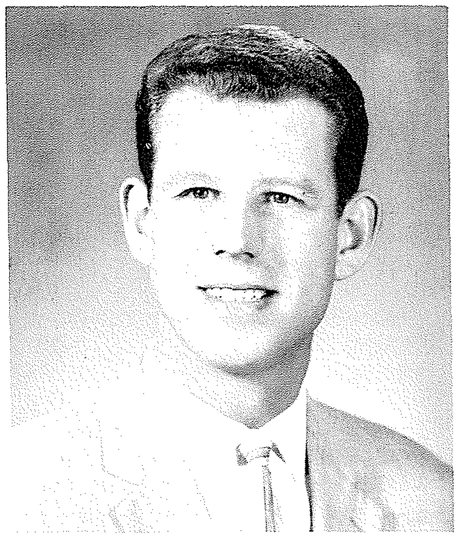
You will be relieved of the necessity to initiate and process possible claims for instruments damaged in transit. Although Tektronix has in the past volunteered to assist customers in this regard, it has until now remained an irksome chore that was primarily the customer's responsibility. Now, should you be unfortunate and receive a Tektronix instrument damaged in shipment you need only to notify Tektronix Canada Ltd., and the carrier handling the shipment. Then, hold for their inspection the carton and packing material in which the instrument was shipped. Tektronix guarantees delivery of a completely satisfactory and damage-free instrument.

In making this announcement we have saved the most important news until the last. A steadily increasing volume of Tektronix instruments shipped to Canada now allows us to route our freight to Canadian points-of-entry on a consolidated basis — and at some saving in expense. This saving we are passing on to you by making the F.O.B.-DESTINATION price policy available without an increase in instrument prices.

TEKTRONIX CANADA LTD. REPRESENTS ROHDE AND SCHWARZ IN CANADA

You can now enjoy for your Rohde and Schwarz instruments the same high degree of service, assistance and back-up support that you expect for your Tektronix instruments. On October 1, 1964 Tektronix Canada Ltd. assumed the responsibility for the sales and servicing of Rohde and Schwarz products in Canada.

Rohde and Schwarz, a West Germany-based electronic instrument manufacturer, enjoys an excellent worldwide reputation. Typical products are signal generators, impedance measuring devices, frequency standards, etc. These products, which so nicely complement the Tektronix line of instruments, will allow your Tektronix Canada Ltd. Field Representative to more completely serve your electronic-instrument needs.



Melle Zegel

The Tektronix Canada Ltd. policy of continuing assistance with any problem involving oscilloscopes — selection, operation, application, maintenance or modification — has been extended to include Rohde and Schwarz instruments.

Melle Zegel, who recently joined Tektronix Canada Ltd., brings with him a vast fund of information and a comprehensive knowledge of Rohde and Schwarz instruments. Melle recently spent six months at their factory in Munich familiarizing himself with new instruments and attending their service and training school. The benefit of Melle's information and experience is available through your local Tektronix Field Representative. Please consult Melle and your Tektronix Field Representative whenever there is a need. They and Tektronix Canada Ltd. welcome every opportunity to assist you.

Service Scope

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USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

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SOME BASIC SAMPLING CONCEPTS REVIEWED

Patrick B. Gee

Tektronix Field Maintenance Engineer

Editor's Notes

The basic concepts reviewed in this article apply to all sampling instruments. The information, however, as it is presented here was developed around the calibration of the Tektronix Type 4S1 Dual-Trace Sampling Unit. It is directed principally toward those who, when exposed to sampling techniques, feel the need for a bit more support. By developing a fuller understanding of these important features of fundamental concern, the author hopes to supply this support and to dispel the needless fear of sampling that seems to hover in the minds of some.

This article has been prepared for those involved in the calibration of the Tektronix Sampling Units, with the Type 4S1 Dual-Trace Sampling Unit being used as an example. It is intended to dissolve a few ordinary misgivings about approaching the unit and to outline an orderly and effective method of system diagnosis and treatment. You should make an effort to thoroughly understand what each adjustment accomplishes. Once you attain this objective, you will no longer need to rely on detailed instructions to calibrate the instrument. You should find it possible to perform all the necessary adjustments on a Type 4S1 in a very few minutes. Performing all the checks that insure the instrument meets original specifications may, however, take an hour or more.

	RISETIME	SAMPLING EFFICIENCY	LOOP GAIN	DOT TRANSIENT RESP.	NOISE	SCALING DRIFT	ATTENUATOR BALANCE	BRIDGE DYNAMIC RANGE
SNAP-OFF CURRENT	X	X		X	X			
MEMORY GATE WIDTH			X	X	X			
"A" BRIDGE VOLTS	A	A		A	A	A		A
"B" BRIDGE VOLTS	B	B		B	B	B		B
AC AMP GAIN (A)	A		A	A	A			
AC AMP GAIN (B)	B		B	B	B			
"A" BRIDGE BALANCE							A	A
"B" BRIDGE BALANCE							B	B
"A" SMOOTHING			A	A	A			
"B" SMOOTHING			B	B	B			
"A" SMOOTHING BAL							A	
"B" SMOOTHING BAL							B	
"A" DC OFFSET							A	A
"B" DC OFFSET							B	B

TABLE I

Excellent performance should not be expected from random adjustments. Rather, an orderly and systematic approach must be taken to restore the Type 4S1 to its proper characteristics. Adjustment is neither a difficult nor an extremely simple thing to do. A few adjustments, because they have an effect on several different characteristics (all of which we wish to hold within specified limits), confound the recalibration. The chart (see Table 1) shows the adjustments that have an effect on several different characteristics. Your principal objective should be to first diagnose the ills by knowing the symptoms, select the most suitable remedy, and *then* perform the operation you have selected.

Let's review some basic sampling concepts with the intent of learning what characteristics are changed by each adjustment within the sampling "head". First of all we should have a good understanding about *sampling efficiency* which is a measure of signal transfer across the bridge diodes sampling gate. Consider the diagram shown in Figure 1. Our purpose in opening the sampling gate is to permit the sampling capacitance (C_1) to "see" the input signal for a small period of time, the duration of the sample being a limiting factor of system risetime. (Instrument risetime can be no faster than the length of time the sampling gate is open.) We know that it invariably takes some time to fully charge a capacitor because the source and current path have impedance. The pre-amplifier input capacitance (frequently called the sampling capacitance) in the Type 4S1 will charge to

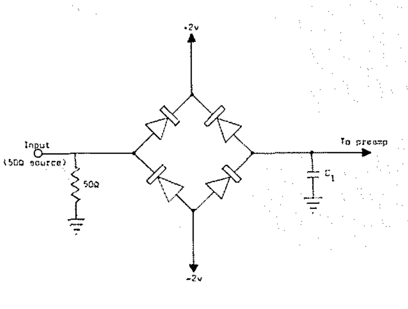


Figure 1. Schematic of a simplified sampling-bridge gate.

only about 25% of the difference in voltage across the sampling gate in 0.35 nanoseconds. This percentage is referred to as the sampling efficiency.

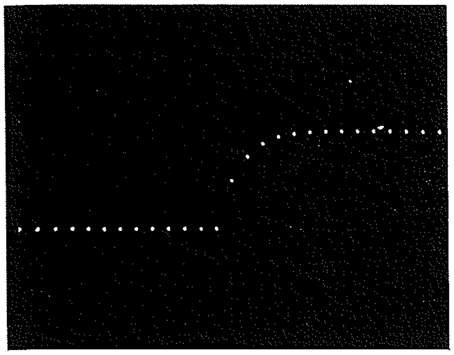


Figure 2. Waveform of the exponential increase in the sampling-capacitance charge with each successive sample, when very few samples/division are taken.

Since this capacitance will not be discharged between samples, we would expect the charge to increase exponentially with each successive sample as shown in Figure 2. Our system would then reconstruct a pulse with severe rolloff even from an infinitely fast step function if very few samples per division were taken. The rolloff would become less obvious, of course, if more samples per division of horizontal deflection were taken. For example, if 10 samples were required to fully charge the sampling capacitance, the rolloff would be evident for 1 division at 10 samples per division. But with 100 samples per division the rolloff would take place in less than one-tenth of a division and would be less apparent.

But let's suppose that the oscilloscope operator should choose to decrease the time required to complete a display of low rep-rate signals. He may do this by reducing the number of samples taken per trace (fewer samples/div). Since under these circumstances a fast rising step function may go from zero volts to its maximum voltage between samples, we must somehow cause the sampling capacitance to become
FULLY CHARGED TO THE ERROR VOLTAGE

ACROSS

the gate with only one sample. The method used here is to amplify the change in voltage on the sampling capacitance and add the amplifier voltage to this capacitance between samples in such a way that it has a voltage equal to the input signal voltage at the instant when last sampled. In other words, the amplifiers and attenuators in the entire loop should cause the sampling capacitance to charge to the level it was exponentially headed for during the preceding sample.

Refer to Figure 3 and assume a one-volt step signal applied to the input of this system. The system we may assume has a sampling efficiency of 25%. The sampling capacitance would therefore charge to 0.25 volts on the first sample. Between samples we could amplify the charge with an amplifier having a gain of four and feed back this one-volt signal level to the sampling capacitance for a period of time that permits full transfer of the charge. We then end up with the required one volt across the sampling capacitance. Now we can change the number of samples per division and the transient response of the observed waveform should remain the same. We could say, then, that our "dot transient response" is correct since we have a gain of exactly one through the entire loop when referred to the input signal. (Remember, though, that this required *a gain of four* when referred to the charge on the sampling capacitance.)

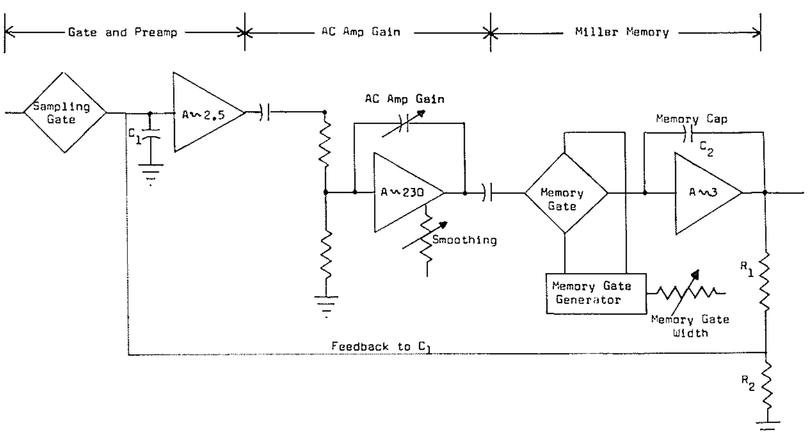


Figure 3. Tektronix slide-back, feed-back sampling system.

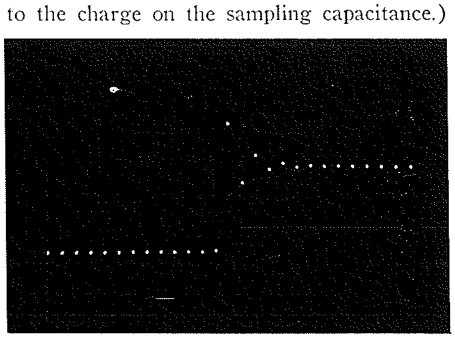


Figure 4. Waveform of overshoot due to the product of sampling efficiency and the amplified feed-back signal being greater than unity.

Obviously then, anything that we do within the sampling loop that changes either sampling efficiency or gain within the loop will also change dot transient response. In other words, *dot transient response is a function of both sampling efficiency and loop gain.*

Suppose that the product of sampling efficiency and the amplified feedback signal were to equal more than unity. Our presentation would then appear to have overshoot and/or ringing as shown in Figure 4. This is just as undesirable as the rolled-off presentation shown in Figure 2.

The four-diode sampling gate performs a few functions which require further explanation. During quiescent conditions the gate is closed so that the signal cannot pass through. To do this, we back-bias the gate with a positive and negative dc voltage of approximately two volts. The dynamic range of the gate is limited by the magnitude of this holdoff bias (BRIDGE VOLTS); a signal greater than two volts might overcome the holdoff bias and improperly charge the sampling capacitance. A trigger pulse from the timing unit initiates the generation of the strobe pulse (to open the sampling gate) and the memory gate pulse (to open the memory gate). The amplitude of the narrow strobe pulse must be sufficient to rise above the holdoff bias for a period of time T, thus forward biasing the bridge diode gate as shown in Figure 5. An increase of strobe amplitude will usually cause an increase in sampling efficiency because the sampling capacitance has longer exposure to the input signal and therefore can charge to a

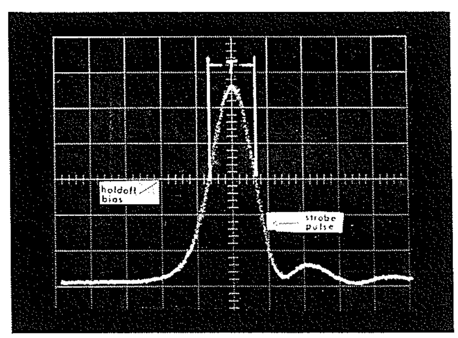


Fig. 5. The narrow strobe pulse rises above holdoff bias for a period of time "T" to forward bias the bridge-diode gate.

higher voltage. Also, a higher strobe amplitude will cause the diodes to exhibit a lower impedance during the sampling interval. The gain required through the amplifiers and feedback attenuators to yield a loop gain of unity (correct dot transient response) is the reciprocal of sampling efficiency, so we would need to reduce loop gain to compensate for an increase in sampling efficiency if we were to maintain proper dot transient response. Note that a reduction of BRIDGE VOLTS (keeping strobe amplitude constant) could cause a similar change in sampling efficiency.

A few words are in order concerning the generation of strobe pulses. A trigger pulse from the 5T1A timing unit causes the normally forward-biased snap-off diode to become reverse biased by a reverse current of high and relatively constant amplitude. A peculiar characteristic of the snap-off diode is that this large reverse current ends very abruptly (within a few picoseconds) and the snap-off diode becomes a very high impedance. The reverse current that was flowing down the 50-Ω shorted transmission (clip) line in trying to continue to flow, produces a voltage pulse of short duration that overcomes the back bias on the sampling gate and causes the diodes to conduct. When all the bridge diodes are conducting, they represent a low impedance path for the input signal to get to the input preamplifier. When the voltage pulse is reflected (after about 0.35 nanoseconds) due to current traveling in the shorted clip-line, the sampling gate is returned to its reverse-bias condition thus locking out the input signal once again. The combined snap-off diode and clip-line action produces a very fast rising and falling pulse of a very short controlled duration. Amplitude of reverse current in the clip-line is determined by the stored charge in the diode which is a function of forward SNAP-OFF CURRENT. Reverse current must be sufficient in magnitude so that the voltage created while it travels in the 50-Ω clip line is more than enough to overcome the holdoff bias on the sampling gate.

Let's refer again to Figure 3 and review some of the primary objectives here which are: (1) charge C_1 to the amplitude of the input signal as much as possible during the useable period of the strobe pulse to increase sampling efficiency, (2) feed back an amplified version of this signal between samples to charge C_1 to the full level of the input signal, (3) simultaneously charge C_2 to a value proportional to the input signal level and permit C_2 to retain this charge long enough for us to observe low rep-rate signals.

The voltage on the Memory Capacitor is proportional to the input signal and is used to drive the scope's vertical amplifier. To deflect the dot a given distance with a larger signal at the input requires attenuation of the larger signal before it is applied to the Memory. In other words, the Memory output signal will normally always be proportional to the deflection it causes. Stray capacitance and other factors prohibit using a switched attenuator at the input connector for reducing the deflection sensitivity. It is more feasible to use an attenuator at the pre-amplifier output to limit the signal coupled to the high gain ac amplifier and also prevent overdriving this stage. But we must maintain loop gain close to unity. This requires a second attenuator in the feedback path from the Memory Capacitor to the pre-amplifier input capacitance—one that will track with the ac amplifier attenuator. This will increase the feedback applied to the sampling capacitance as the ac amplifier signal is decreased (as referred to the signal applied to the 4S1 input connector) with less sensitive settings. R_1 and R_2 make up the second attenuator. (Attenuation is reduced here when it is increased between amplifiers with both attenuators operated by the same control knob). The resistor divider ratio of this pair determines the basic calibration of the sampling loop.

Another diode gate precedes the Memory stage. When the fast, narrow strobe pulse is generated, a relatively wide (250-350 nanosecond) pulse is also generated to open the memory gate. The paramount functions of the memory gate circuits are to: (1) control the in-phase feedback to the sampling capacitance and prevent the memory from responding to this regenerative feedback signal, (2) insure maximum coupling of the amplified error signal to C_2, and (3) limit memory capacitor discharge between samples. (Leakage of the charge in this capacitor causes vertical deflection of the dots between samples and is called Memory Slash.) It limits the maximum permissible time between samples for a useful display. This leakage is caused by Memory Amplifier grid current or diode gate leakage.

A cursory analysis of the system as shown in Figure 3 reveals that the following controls all have a direct effect on dot transient response:

1. Those that control *sampling efficiency* are
   a. SNAP-OFF CURRENT—common to both sampling gates
   b. BRIDGE VOLTS—one for each sampling gate
2. Those that control *loop gain* are
   a. AC AMPLIFIER GAIN—one for each sampling gate
   b. MEMORY GATE WIDTH—common to both memories
   c. SMOOTHING—a front panel control for each ac amplifier

The primary purpose of the SMOOTHING control is to reduce random noise by reducing gain of the ac amplifier. Since this is within the feedback loop, it necessarily follows that dot transient response will be effected corresponding to the amount of smoothing used, but may not be apparent when using lots of samples.

Your preparation for recalibration and/or repair should include the following additional presets on the Type 4S1:

MV/CM SWITCH	200
VARIABLE	Calibrated
VERTICAL POSITIONING	Midrange (dot to 12 o'clock)
SMOOTHING	Normal (Maximum loop gain)
DC OFFSET	Adjust for zero volts ±100 mv at the DC OFFSET MONITOR jack

With a free-running sweep, both traces should be well within the central graticule area of a properly adjusted instrument. Severity of imbalance is often indicated in this display and your observations here may help in the diagnosis. If the presentation looks other than normal, first perform steps 3 and 4 of the recalibration guide which follows this article and then start back with step number 1.

Several methods, each having its own merits, may be used to show dot transient response error. A most useful method is to apply a step-function to the input and use a sweep speed that will display no more than two or three samples on the leading edge of the pulse (low vertical dot density) at 100 or more samples per division. Should the pulse shape or transient response change when switching from 100 to 10 or fewer samples, *then dot transient response is not correct.* Quite often in using only 10 samples/div an important part of the trace may be missing and the overshoot or undershoot that appeared with 100 samples/div will not be displayed because it occured between dots in the presentation. Therefore, when operating at few samples/div you may need to relocate the dots along different portions of the trace or "slide" them back and forth to simulate a solid trace by rotating either the TIME POSITION or VARIABLE TIME/CM control. (The slow sweep speed required for low vertical dot density usually places the beginning of the pulse towards the left edge of the crt. Using the VARIABLE TIME/CM control is generally more desirable for this situation since it moves the trace to the right, towards the center of the screen.)

Another method requires a generator of the mercury-pulser variety (Tektronix Type 109 or Type 110) with a small charge line on one side of the switch and no charge line on the other side. Here the sampling gate is opening on the two inputs alternately. The sampling capacitance most of the time must alternately charge from the amplitude extremes between the voltage at the top of the pulse input and the zero volts from the other input. Response with each sample is manifested in the display. Proper DTR (dot transient response) would give a presentation that should look like Figure 6a. Low loop gain would give a presentation that should look like Figure 6b, and exces-

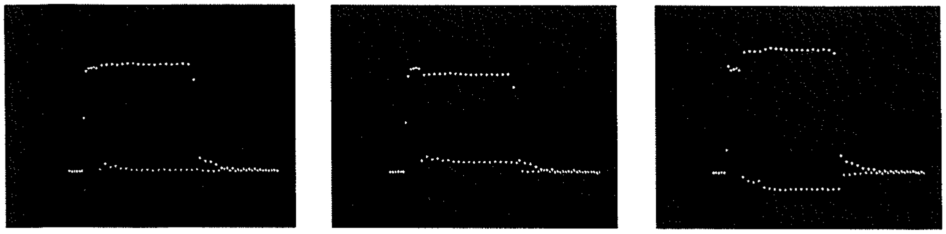


Fig. 6. Waveforms of: (a) correct DTR, (b) low loop gain, (c) excessive loop gain, using a small charge line on one side of the switch and none on the other.

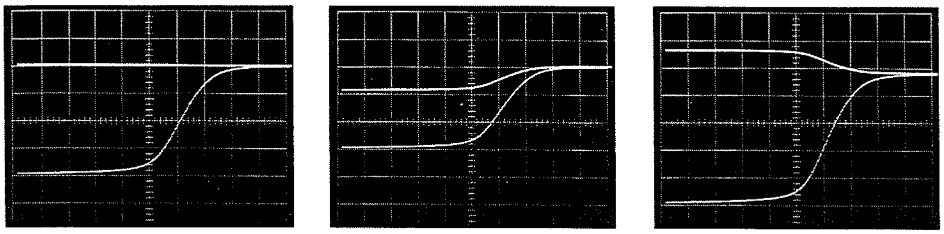


Figure 7. Waveforms of: (a) correct DTR, (b) low loop gain, (c) excessive loop gain, with the 5T1A set up for + INTERNAL triggering at a sweep speed of about 2 NSEC/CM and using a TU-5 Pulser/Adapter operated by a 25-kc square wave from a Type 105 Square-Wave Generator to drive the Type 4S1.

sive loop gain would give a presentation that should look like Figure 6c.

Low repetition rates inherent with mercury-pulsers are sufficiently annoying to warrant investigating other ways of obtaining a similar "twosies" type of display. One such way follows, but requires dc internal triggering: Using a Type 5T1A Timing Plug-In Unit set up for + INTERNAL triggering at a sweep speed of about 2 NSEC/CM, obtain a normal display of the leading edge of a pulse from a Tektronix Type TU-5 Pulser operated by a 25 kc square wave from the Tektronix Type 105 Square Wave Generator. Switching the 4S1 triggering switch from ac to dc trigger coupling should produce a display similar to those shown in Figure 7. Here the trigger circuit is alternately responding to the leading edge and pulse top. Triggering on the pulse top occurs because the pulse top is still more positive than the THRESHOLD setting after trigger recovery takes place making the Type 5T1A ready to trigger again whenever the THRESHOLD level is exceeded. Pulse amplitude after the next recovery cycle will be below the THRESHOLD level which will prevent the trigger circuit from responding until the next positive excursion through the THRESHOLD level setting. The sampling capacitance must therefore charge to the pulse amplitude extremes during the first few centimeters of display with each successive sample.

The chart shown in Table 1 is another useful tool during recalibration. Use it to increase your understanding of the interaction between the various amplifiers and controls.

TYPE 4S1 RECALIBRATION GUIDE

Field recalibration is usually a relatively simple process if previous calibration settings have not since been misadjusted. The following method may be used to perform routine recalibration. This is *not* a complete recalibration procedure, but should serve as a useful reference in conjunction with the regular recalibration procedure in the instruction manuals.

1. Adjust MEMORY GATE WIDTH for maximum loop gain (i.e., maximum overshoot when observing DTR—dot transient response).

NOTE: Before adjusting SNAP-OFF CURRENT or BRIDGE VOLTS, first determine which adjustments need to be made by application of the following concepts:

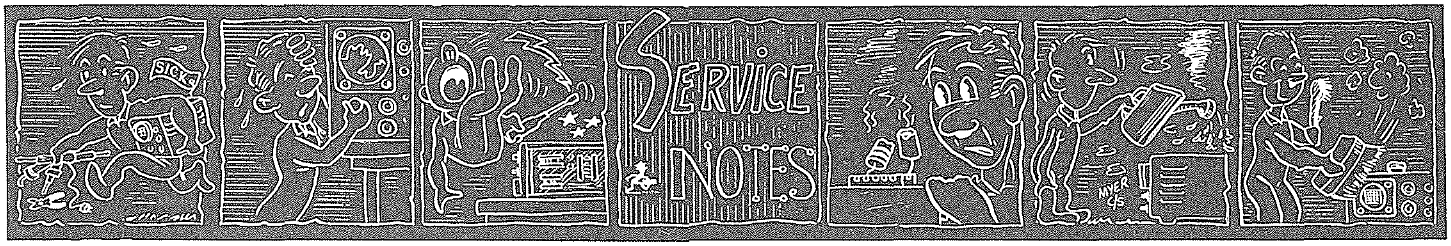
2. *Check* DTR on both channels.
   a. If the same DTR error exists on both channels, adjust SNAP-OFF CURRENT for correct DTR on both channels.
   b. If Channel A DTR is poor and Channel B DTR is good, adjust Channel A BRIDGE VOLTS for proper DTR on Channel A.
   c. If Channel B is poor and Channel A is good, adjust Channel B BRIDGE VOLTS for proper DTR on Channel B.
   d. If both channels exhibit DTR errors in opposite directions (one showing too much loop gain and the other showing insufficient loop gain), perform the following steps:
      (1) Adjust BRIDGE VOLTS on both channels to maximum clockwise positions.
      (2) Adjust SNAP-OFF CURRENT for proper DTR on the channel that has the highest loop gain as indicated by the most overshoot when samples/cm is changed.
      (3) Adjust BRIDGE VOLTS on the *other* channel for proper DTR.
3. Adjust BRIDGE BALANCE on both channels so that the trace remains on the screen throughout MV/CM settings. (DC OFFSET must be zero volts). Be sure not to brush the DC OFFSET control as you rotate MV/CM.
4. Adjust SMOOTHING BALANCE for no trace shift while rotating SMOOTHING—both channels.
5. Apply a known amplitude to B Channel and adjust B GAIN ADJUST for proper deflection.
6. Apply a known amplitude to A Channel and adjust A-B BALANCE (on the front panel) for proper deflection.
7. Adjust INVERTER ZERO on both channels for less than 2 mm trace shift when switching from NORMAL to INVERTED (DC OFFSET MUST BE ZERO).

This completes the adjustments for the Type 4S1, leaving only a series of checks that should be performed to insure that the instrument is functioning properly. The most important considerations include:

a. RISETIME—less than 0.35 nanoseconds computed.
b. NOISE—less than 1 mv (consider 90% of the dots).
c. BASELINE SHIFT—less than 3 mv base-line shift between 50 cps and 100 kc rep-rates. (This is a shift of the dc reference level or base-line with changes of rep-rate. It may come from several sources including improper adjustments, and is usually greatest between 90 kc to 100 kc. Scaling drift is checked by observing a trace with no signal applied and triggering the sweep from 10 cps to 100 kc using a Type 111 Pulse Generator or equivalent.)
d. MEMORY SLASH—less than ½ cm vertical trace slash at 10 cps.
e. OVERSHOOT or UNDERSHOOT—3% maximum.
f. DOT TRANSIENT RESPONSE—correct for both positive and negative going signals of less than ±½ v in amplitude.

If risetime is adequate but noise and/or scaling drift are excessive, decrease BRIDGE VOLTS and readjust SNAP-OFF CURRENT for proper dot transient response, then repeat steps 2, 3 and 4 above. Make sure that BRIDGE VOLTS is at least 2 volts above and below ground for your final setting.

NOTE—Refer to your instruction manual or recalibration procedure for other checks to be performed.



TYPE 575 TRANSISTOR CURVE TRACER — NOISE ON HORIZONTAL AND VERTICAL ATTENUATOR SWITCHES

Under extreme environmental conditions, foreign material can build up on switch contacts and cause excessive electrical noise. This noise can be particularly objectionable.

The application of a *thin* film of Cramolin cleaner and lubricant (Tektronix part number 006-197) will solve this problem. Usage of Cramolin will result in approximately 40 times improvement in reducing noise and wear, over a dry switch.

Cramolin should be applied with a small artist-type camel-hair brush. Just a drop placed on the brush and then applied to the switch contacts and rotor will give good results. After application, rotate the switch back and forth through its range several times. This aids the cleaning and lubrication action. Avoid the use of excessive amounts of Cramolin. Anything more than a thin film will only detract from the neatness of your work and will neither hasten nor aid the cleaning and lubricating action.

Cramolin may be obtained through your local Tektronix Field Engineer, Representative, Field Office or Distributor.

TEKTRONIX INSTRUMENTS WITH FORCED-AIR VENTILATION — FAN MOTOR SALVAGE

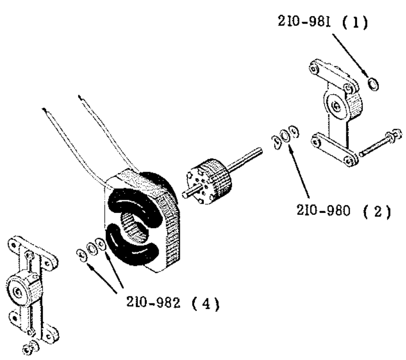


Figure 4. Exploded drawing of fan motor, part number 147-001.

Many Tektronix instruments employing forced-air ventilation use the same type fan motor. Tektronix part number for this motor is 147-001. When these motors begin to display signs of wear (normally after extended periods of service) they may be salvaged to give many more hours of use. Indications of wear can be a noisy motor, and/or excessive end play of the motor shaft. (You should note here that a bent or out of balance fan blade can vibrate and give the appearance of a noisy motor. Check your fan blade before finally assessing the cause of noise.)

The cause of noise or shaft end play in a 147-001 motor is wear on the seven washers shown in Figure 4. To replace the washers shown in this exploded drawing you will need:

Qty.	Part #	
2 each	210-980	steel washers
4 each	210-982	beryllium washers
1 each	210-981	fiber washer

These parts may be ordered through your local Tektronix Field Engineer, Representative, Field Office or Distributor.

The Mechanical parts list in the Instruction Manual for your instrument gives the Tektronix part number for the fan motor. We remind you, the information given here applies only to instruments using fan motors part numbered 147-001.

TYPE 661 SAMPLING OSCILLOSCOPE — DELAYED PULSE MODIFICATION

Here is a do-it-yourself modification that will protect the Tunnel diode D992 (in the Delayed Pulse circuit) from excessive current during the warm-up time of V694 and V814. The modification routes the current supply through relay K601 until the instrument is warmed up, at which time normal supply current is restored. This modification applies to Type 661 instruments serial numbers 101 through 2219.

The following instructions should aid in rewiring the relay:

IMPORTANT: Use silver-bearing solder when soldering to ceramic strips.

( ) 1. Unsolder from relay K601:

( ) white-violet wire

( ) sleeving-covered wire

( ) gray-red-red wire

( ) 2. Replace the sleeving-covered wire with a piece of wire and sleeving that is ⅛" longer.

( ) 3. Solder the new sleeving-covered wire and the white-violet wire to the terminals shown in Figure 1.

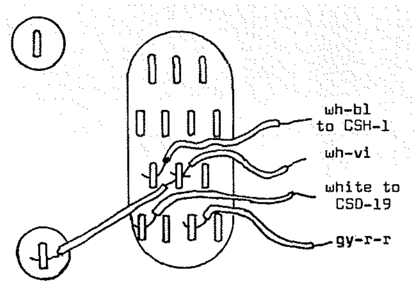


Figure 1. Diagram showing solder terminals on relay K601.

( ) Solder the gray-red-red wire to the terminal shown in Figure 1.

( ) 4. Solder a 10" piece of #22 white-black wire and a 6" piece of white wire to the terminals shown in Figure 1.

( ) 5. Solder the other end of the white-black wire to CSH-1 (locate in Figure 2).

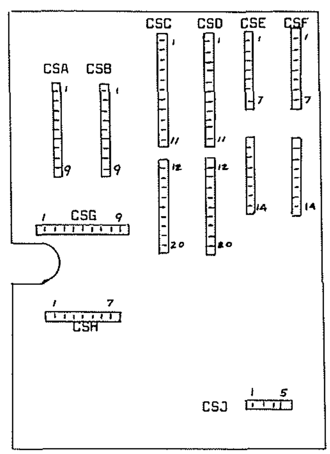


Figure 2. Diagram showing layout of ceramic strip terminals referred to in Delayed Pulse Modification.

( ) 6. Solder the other end of the white wire to CSD-19 (locate in Figure 2). This completes the modification.

( ) 7. Check wiring for accuracy and change Interconnecting Sockets diagram in the Type 661 Instruction Manual to agree with Figure 3.

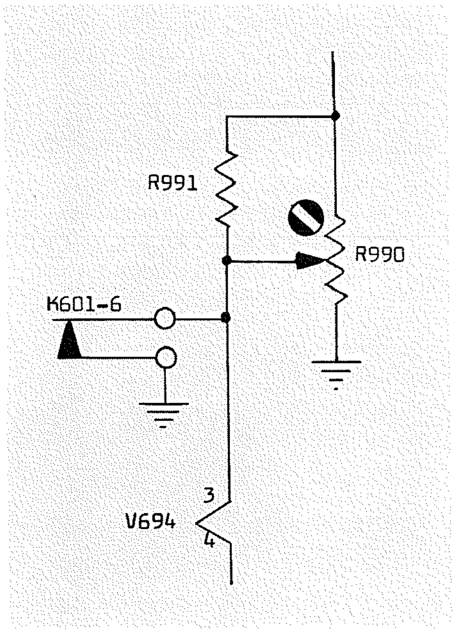


Figure 3. Schematic of K601 relay after performing Delayed Pulse Modification.

TYPE 575 TRANSISTOR CURVE TRACER—VIEWING FIELD EFFECT TRANSISTORS' CURVES

Normally, a Type 575 Transistor Curve Tracer is limited in displaying a family of curves for an FET (field effect transistor). When the STEP SELECTOR control of the Type 575's Base Step Generator is set to the maximum (200 ma) position it will not completely cutoff the FET.

A simple modification is to place a 10 k, ½ w, 1% precision resistor between the base and emitter terminals of the Type 575 and then set the Base Step Generators STEP SELECTOR control to 0.05 ma. This gives an IR drop between the gate and source terminals of the FET of 0.5 volts per step. This is sufficient to view the complete family of curves from zero to cutoff.

TYPE 530, TYPE 530A, TYPE 540, TYPE 540A, TYPE 540B, TYPE 550, TYPE 585 AND TYPE 585A OSCILLOSCOPES — EXCESSIVE DELAY BEFORE CRT BEAM COMES ON

Time-delay relays used in the above oscilloscopes delay their operation for approximately 45 seconds after the power switch is turned on. This brief delay allows the tubes to warm up to near their operating temperature before the dc operating voltages are applied. At the end of this delay period the cathode-ray beam should appear on the face of the crt.

A more lengthy delay (two or more minutes — or up to 30 minutes in aggravated cases) can very often be traced to low emission by one or both of the 5642 tubes in the crt grid supply and the crt high-voltage cathode supply. Or, it may be due to low emission in the crt itself.

To determine if the 5642 tubes are at fault, remove the ground strap from the crt-cathode connector located on the rear panel of the oscilloscope. Patch a cord from the calibrator output to the crt-cathode connector and feed in 10 volts of calibrator signal. With the sweep free running you should now see a modulated trace on the face of the crt. Advance the calibrator control through the 20, 50, and 100 volts positions. If the modulated trace remains on the crt face the 5642 tubes are most probably functioning properly.

To check for low emission in the crt, remove the calibrator signal from the crt-cathode connector and reconnect the ground strap. Adjust the FOCUS and ASTIGMATISM controls for largest diameter spot. With the sweep turned off, adjust the INTENSITY control to where the de-focused spot on the crt face has a very slight halo. Remove the left-hand side panel from the oscilloscope. Then, with the tip of a magnetized screw driver, touch the base of the crt near where it joins the glass neck. While moving the tip of the screw driver around the available circumference of the crt base, check for dark areas within the defocused spot on the crt face. If dark areas are observed the crt is suffering from low emission.

If either the 5642's or the crt are low in emission they should be replaced.

TYPE CA PLUG-IN UNIT — LACK OF DUAL-TRACE DURING WARM UP

Type CA Plug-In Units, serial numbers 101 through 34790, may exhibit a lack of dual trace during the period when the instrument is warming up. The problem is caused by V3382. This 6AL5 tube in the switching circuitry has its cathodes returned to the —150 volt supply through a 1.8 meg resistor in the oscilloscope via pin 16 of the interconnecting plug. The 1.8 meg resistor provides a current source for the 6AL5 that tends to balance the multivibrator plates (V3375) in the CA unit; both halves saturate and prevent multivibrator action.

A 330 k, ¼ w, 10%, composition resistor (Tektronix part number 316-334) added between pin 5 of V3382 and +225 volts will cure the problem.

NEW FIELD MODIFICATION KITS

TYPE 111 PRETRIGGER PULSE GENERATORS—PULSE WAVEFORM IMPROVEMENTS

This modification reduces overshoot, ringing, and other aberrations in the pulse waveform. It also improves the risetime of the negative pulse.

Primarily, the modification consists of replacing the Avalanche transistor (Q84) and reworking the associated circuitry on the etched circuit board. New "transition pieces" are used to connect the Charge Line and Output Polarity coaxial cables to the board.

Parts Replacement Kit 050-216 is also included to replace the OUTPUT POLARITY switch and Charge Line cable.

This modification applies to Type 111 instruments with serial numbers below 800. Order through your Tektronix Field Engineer, Field Representative, Field Office or Distributor. Specify Tektronix Part Number 040-392.

TYPE 4S2 DUAL-TRACE SAMPLING UNITS—TRANSIENT RESPONSE IMPROVEMENTS

This modification improves the transient response and reduces ringing on fast-rise signals in the Type 4S2:

1. Replacing Gate (bridge) diodes with closer-matched and lower-capacitance diodes.
2. Making the sampling bridge compensation networks adjustable.
3. Substituting 200 Ω resistors for the ferrite beads between sampling bridge and Nuvistor grid.
4. Terminating the strobe pulse lines with 100 Ω resistors.
5. Adding grid-bias balancing potentiometers for each Nuvistor.
6. Decoupling the —100 and +300 voltages to the Sampler and Gate-Generator circuits.

This modification applies to Type 4S2 instruments with serial numbers below 301.

Order through your local Tektronix Field Engineer, Field Representative, Field Office or Distributor. Specify Tektronix part number 040-379.

TYPE 53/54C AND TYPE CA DUAL-TRACE PLUG-IN UNITS—SLAVE TO AUTOMATIC DISPLAY SWITCHING

This modification allows Channels A and B of either Type 53/54C, serial numbers 3710-up, or Type CA, serial numbers 101 through 64009, to be slaved to the respective sweeps of the Type 547 Oscilloscope, when the Type 547 is operated in A ALT B mode. The modification does not change the operation of the Type 53/54C or Type CA when operated in any other instrument.

Order through your local Tektronix Field Engineer, Field Representative, Field Office or Distributor. Specify Tektronix part number 040-391.

RELAY RACK CRADLE ASSEMBLY

Three new Field Modification Kits provide a rear support cradle for installing rack-mounted instruments in a backless relay rack by the use of slide-out tracks. The slide-out tracks are not included in the modification kits and must be ordered separately.

Slide-out tracks allow the instrument to be pulled out like a drawer. When pulled out, the instrument can be locked in one of seven positions: horizontal, or 45°, 90°, or 105° above and below horizontal.

Order through your local Tektronix Field Engineer, Field Representative, Field Office or Distributor from the following information.

Field Modification Kit, Tektronix part number 040-344, applies to the following instruments:

Type 127	serial numbers	309 - up
Type RM15	serial numbers	101 - up
Type 526	serial numbers	101 - up
Type RM561	serial numbers	101 - up
Type RM561A	serial numbers	5000 - up
Type RM564	serial numbers	100 - up
Type RM647	serial numbers	100 - up

Order slide-out track assemblies separately, as follows:

Types 127, RM15, and RM647	1 ea. 351-006
Types RM561, RM561A, RM564	1 ea. 351-050
Type 526	1 ea. 351-001 1 ea. 351-011

Field Modification Kit, Tektronix part number 040-346, applies to the following instruments:

Type RM565 serial numbers 101 - up
Type RM567 serial numbers 101 - up

Order slide-out track assemblies, Tektronix part number 351-055 (1 pr.), separately for these instruments.

Field Modification Kit, Tektronix part number 040-345 applies to the following instruments:

Type RM16 serial numbers 101 - up
Type RM17 serial numbers 101 - up

Order slide-out track assemblies, Tektronix part number 351-083 (1 pr.), separately for these instruments.

TYPE 3T77 SAMPLING PLUG-IN UNITS, S/N'S 840 TO 1999 — IMPROVED SINE-WAVE TRIGGERING

This modification imparts a greater stability to the display during triggering on high-frequency sine waves. A trigger-circuit change allows switching to a lock-on type of operation when displaying high-frequency sine waves and eliminates display break-up caused by drift in recovery time.

A new push-pull Recovery control replaces the old control.

Pulling the control to the ON position synchronizes the circuit on sine waves above approximately 30 Mc. With the control pushed in the instrument triggers on signals below 30 Mc. Order through your local Tektronix Field Engineer, Field Office or Representative. Specify Tektronix Part Number 040-366.

SCOPEMOBILE® CART ADAPTER

This modification adapts the Type 202, Type 202-1, Type 202-2 and Type 204 Scopemobile carts for use with a Type 502 or Type 502A Oscilloscope. Two adapter plates fasten to the Scopemobile cart and prevent the oscilloscope from shifting sideways. Order through your local Tektronix Field Engineer, Field Office or Representative. Specify Tektronix Part Number 040-365.

TYPE 502 AND TYPE 502A OSCILLOSCOPES—SAWTOOTH AND +GATE OUT

This modification installs two UHF output connectors (one for the direct coupled Sawtooth and one for the +Gate Out waveforms) on the rear panel of the Type 502 or Type 502A Oscilloscopes. The +Gate Out waveform is 40 volts and of the same duration as the +150-volt Sawtooth waveform. The waveforms are dc coupled to the connector via a dual cathode-follower assembly which mounts on the Time/CM switch bracket.

Order through your local Tektronix Field Engineer, Field Office or Representative. Specify Tektronix Part Number 040-312.

TYPE 502 OSCILLOSCOPE—SILICON RECTIFIER

This modification replaces the selenium rectifier (SR642) used in the Type 502 with silicon rectifiers which offer more reliability and longer life. Order through your local Tektronix Field Engineer, Field Office or Representative. Specify Tektronix Part Number 040-383.

TYPE 108 FAST-RISE MERCURY PULSER — SILICON RECTIFIER

This modification replaces the original selenium rectifiers (SR3A,B) with silicon rectifiers which offer more reliability and longer life.

The modification is applicable to all Type 108 Mercury Pulsers.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-388.

TYPE 527 WAVEFORM MONITOR—LINE SELECTOR

This modification installs a prewired Video Output-Amplifier chassis in the Type 527 to allow a picture monitor to be connected directly to the Type 527 and to display the signal, being displayed on the Type 527, on the picture monitor.

The modification also installs a prewired Line-Selector chassis circuit for detailed observation of any one TV line in a frame. A Field-Shift circuit provides line selection from either the odd or the even field. A Line-Intensification circuit rapidly identifies the line being observed and the selected line is intensified on the picture monitor via the Video-Output connector of the Type 527 Waveform Monitor.

Order through your local Tektronix Field Engineer, Field Office or Representative.

Specify for:

Type	S/n's	Tektronix Part Number
527	151-579	040-356
RM527	151-979	040-354
527	580 and up	040-359
RM527	980 and up	040-358

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Service Scope

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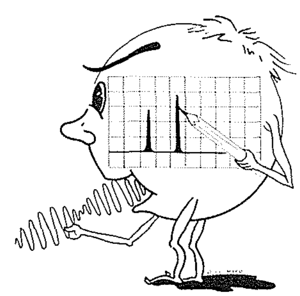


GETTING ACQUAINTED WITH SPECTRUM ANALYZERS

by Russ Myer
Tektronix Advertising Dept.

This article forms a conceptual basis for the understanding of Spectrum Analysis, thus preparing the reader for the several advanced works available on the subject written on the Engineering level.

Part I

WHAT IS A SPECTRUM ANALYZER?

At any given moment, there is an incredible amount of activity within that portion of the Electromagnetic Spectrum that we call the Radio Frequency Bands. These bands range in frequency from about 15 kc to 750,000 Mc.

Assume you have a special radio receiver capable of tuning over this entire range. At the lower end, you'll find maritime ship-to-shore, aircraft point-to-point, high-powered government and commercial transoceanic signals. Tuning higher in frequency, within the familiar 540-to-1600 kc broadcast band, dozens of commercial radio stations compete for your attention. Above these, you'll find more ship-to-shore, and, confined to relatively small portions of the spectrum, thousands of "ham" radio operators pursue their electronic endeavors. Also, interspaced throughout this short-wave band, you will hear much air-ground activity, government point-to-point, many foreign broadcast stations, the Voice of America (and Moscow!), police radio broadcast stations, and some experimental work.

Still higher in frequency, you'll find television stations, starting at 54 Mc, FM stations above 88 Mc and more television above 174 Mc. The area above 400 Mc, once considered experimental, produces myriad signals: microwave, telemetry and others.

These radio transmissions take various electronic configurations, ranging from single-frequency carriers to complex signals produced by changing these carriers in amplitude, frequency and phase.

Regardless of the shape of these signals and how they were produced, or "modulated", each one can be separated into individual sine waves. Each sine wave represents a single frequency. To examine the composition and quality of a signal, you would find it very helpful to extract each individual sine wave that it contains and display it alone on an oscilloscope. Seeing all the sine waves in a "group" picture, each standing alone, would enable you to analyze the complex signal. The instrument that performs this task for you is called a Spectrum Analyzer.

To use an example of a familiar but complex waveform which could be reduced to individual sine waves for analysis, consider an AM radio station. A broadcast transmitter radiates a single carrier frequency from its antenna. Intelligence (speech, music, tones, etc.) is superimposed on this carrier, varying its amplitude at an audio rate. Assume the station is transmitting a 1000-cycle test tone. The carrier frequency of the station is 1 Mc. This carrier is combined in the final stage of the transmitter with the 1000-cycle tone. The antenna, however, through the process of "modulation", is broadcasting not two, but *three* signals. Viewed on a conventional scope, the signal might look like figure 1a.

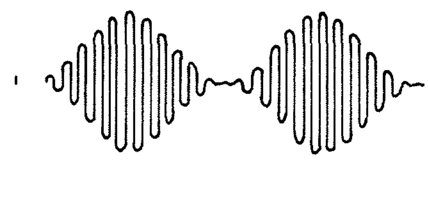


Figure 1a. Conventional oscilloscope display of 1000 kc carrier modulated by a 1000 cps tone.

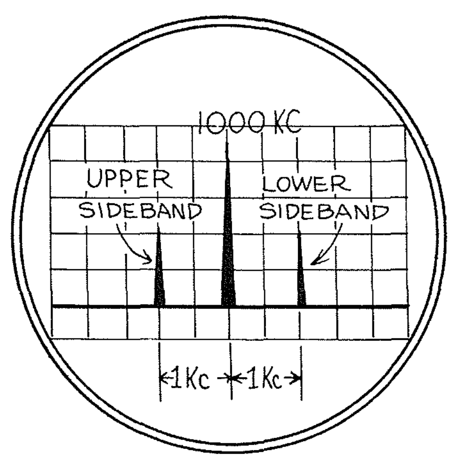
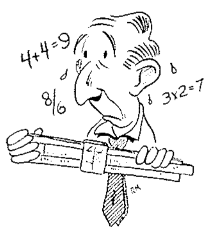


Figure 1b. Display of same signal using Spectrum Analyzer.

Electrically, the carrier is still occupying the 1-Mc spot in the spectrum. Exactly 1000 cycles below this frequency, however, at 999 kc, you will find a new signal, called the "lower sideband". 1000 cycles above the 1-Mc spot, at 1,001 kc, you'll find another signal, identical to the one at 999 kc, called the "upper sideband". The separation is exactly equal to the modulating frequency — the 1000 cycle tone. The Spectrum Analyzer is capable of displaying these three frequencies, individually, on the screen of a cathode-ray tube. Thus, the component frequencies may be individually studied, or "analyzed". Figure 1b shows how the Spectrum Analyzer would display them.



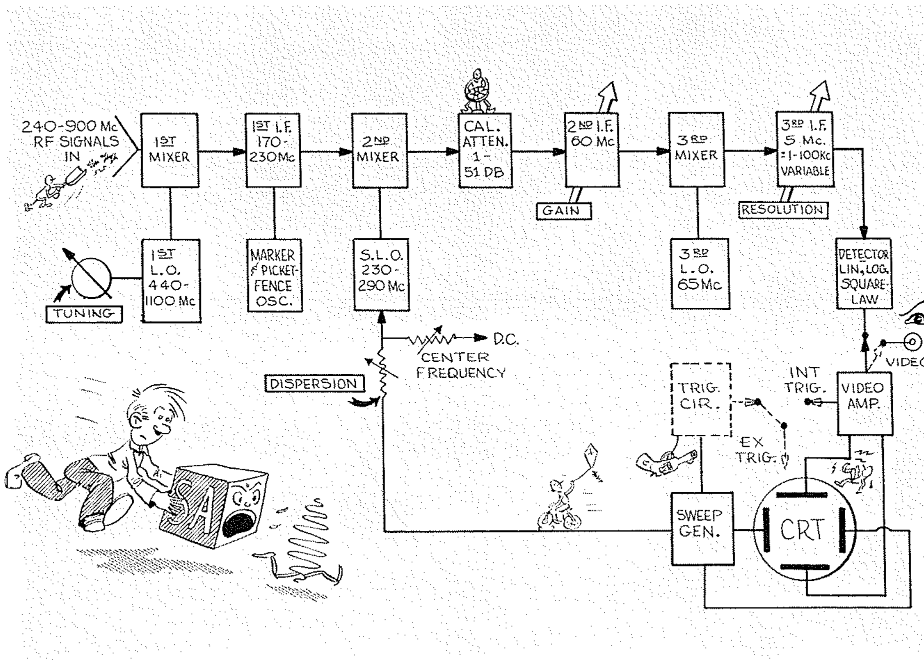
There is nothing difficult about the overall operation of the analyzer. The signals which we will use as examples, however, must be followed in detail through the different sections shown in the block diagram. To understand the conversion of input signals to signals of lower frequencies, you will find it helpful to perform the simple arithmetical computations dealing with the mixer and i.f. (intermediate frequency) sections.

There are several ways that a signal can be broken down into component sine waves. One method is to introduce the signal to a stack of filters, the inputs of which are paralleled. Each filter is tuned, in successsion, to a slightly different frequency than the others. The output of each filter will contain only that portion of the input which corresponds to the frequency it was tuned to. The drawback here is that for most complex signals, you would need hundreds of filters — a costly mechanical burden. Too, it is difficult to design filters with narrow bandwidths to produce good resolution between closely-related signal components.

The prism is also a simple spectrum analyzer. It takes the visible portion of the electromagnetic spectrum and breaks it up into its component frequencies, each representing a familiar color. There are chemical analogies, also, such as the chemist's ability to reduce complex compounds into their individual ingredients. The Tektronix Spectrum Analyzer performs an analysis by purely electronic means.

HETERODYNING

To continue our discussion of the analyzer, we will review, briefly, the principle of heterodyning. Years ago, Armstrong and his colleagues created the "superhet" receiver. They discovered that it was possible to feed two separate single-frequency signals into a non-linear device, usually a vacuum tube, and get *four* signals out! Using suitable filters, they found that besides the two original frequencies, they had a 3rd



Block diagram of typical Tektronix Plug-In Spectrum Analyzer.

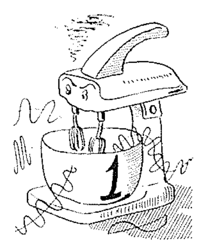
frequency that was equal to the mathematical difference of the input signals. Also, they found a 4th frequency in the output — one equal to the sum of the two original signals. They applied this principle to the superheterodyne receiver, like one you probably have in your home today. The following example illustrates this concept, so necessary to the understanding of Spectrum Analyzers.

Tune in a radio station that has, let us say, a carrier frequency of 1080 kc. This frequency enters the front end of your radio and into a "mixer" tube. A local oscillator in your set, which follows the main tuning, generates a frequency of 1535 kc. This oscillator frequency also is fed into the mixer tube. In the output of this tube, as in the days of Armstrong, you have the two original frequencies *plus* the two new frequencies mentioned before: 2615 kc and 455 kc. The latter, 455 kc, is the one accepted by the tuned circuits of the intermediate-frequency stages of your receiver.

As we tune across the band, we simultaneously tune the local oscillator to a frequency exactly 455 kc above the frequency of the station tuned in. Thus, a highly-efficient i.f. stage can be designed which is responsive to a single frequency — the 455-kc difference between the local oscillator and the frequency present at the front end.

HOW THE ANALYZER WORKS

Tektronix Spectrum Analyzers, built as plug-in accessories for existing oscilloscopes, cover various frequency ranges. Currently, these cover frequencies from 1 Mc to 10.4 Gc (Gigacycles). One of these, the Type L-20, will analyze frequencies from 10 Mc to 4 Gc, in 5 bands. We will consider the range of frequencies covered by band 2 of the Type L-20, roughly 230 Mc to 900 Mc.



Refer to the block diagram of the analyzer. Incoming signals are introduced directly into the first mixer. As in your radio receiver, there is a local oscillator associated with the mixer. This oscillator is tuned by the front-panel control which also rotates the tuning dial indicating the frequency of the incoming signal. It tunes through a frequency range of 440 Mc to 1100 Mc. The output of the mixer is fed into the first i.f. stage. This stage is fixed-tuned to 200 Mc.

Therefore, any input signal that will mix with the local-oscillator frequency in the mixer stage and produce a difference frequency of 200 Mc will pass through the 1st i.f. For example, when the local oscillator (abbreviated L.O.) is tuned to its lowest frequency, 440 Mc (the main tuning dial reading 240 Mc), an input signal of 240 Mc will "beat" with this frequency in the mixer and produce the desired i.f. output of 200 Mc. Tuning the L.O. to 600 Mc means that there has to be an input signal of 400-Mc to produce a 200-Mc difference. The highest setting of the L.O., 1100 Mc, allows a signal of 900 Mc to produce the 200-Mc difference and appear in the first i.f. You will see that *any* signal tuned in from 240 Mc to 1100 Mc will produce the same 200-Mc difference.

The first i.f. is tuned to a center frequency of 200 Mc. The bandwidth of this circuit is fixed at 60 Mc. Therefore, any signals 30 Mc above or below the 200 Mc difference frequency will also pass through the i.f. This is important to the operation of the Spectrum Analyzer.

We will now follow 3 input signals through the analyzer. Their frequencies are: 280 Mc, 300 Mc, and 320 Mc. Assume you have set the tuning dial on 300 Mc, calling it the "Center Frequency". Actually, you have tuned the L.O. to 500 Mc. This produces a 200-Mc difference between the L.O. and the 300-Mc center frequency. This 200-Mc "beat" frequency falls in the middle of the i.f. tuned circuit. The input frequency of 280 Mc also is beating with the established L.O. frequency of 500 Mc. It produces an output from the mixer stage of 220 Mc. This falls within the 60 Mc bandpass of the i.f. stage. The input of 320-Mc also produces a frequency (180 Mc) that falls within the bandpass of the i.f. stage. You will see, therefore, that at the output of the first i.f. stage, all three input signals are present. They have the same 20-Mc separation but are reduced in frequency. Although converted in frequency, their relationship to one another has not been changed. It is important to realize one difference, however: The 180-Mc i.f. signal represents the *highest-frequency* input signal, 320 Mc. The 220-Mc i.f. signal represents the lowest-frequency (280 Mc) input signal. In other words, there is a reversal of relative frequency.

The three signals at the output of the first i.f. stage are now fed into a second mixer. See block diagram. This mixer is also associated with a local oscillator, and the output is fed into a 2nd i.f. stage. This stage is actually tuned to 59 Mc, but to simplify our example, consider that it is tuned to 60 Mc. The 2nd local oscillator is also tuned and covers a frequency range of 230 Mc to 290 Mc. The tuning is accomplished by electronic means, however. The oscillator frequency is "swept" through this frequency range by the application of an external sawtooth.

The inputs to the 2nd mixer stage always exist within the range of 170 Mc to 230 Mc. No other signals can get through the first i.f. Note that the 2nd local oscillator (Swept Local Oscillator — S.L.O.) sweeps through a range of 60 Mc — the band-width of the 1st i.f. Therefore, any signal from 170 Mc to 230 Mc, when combined with the 230-Mc to 290-Mc "sweep" of the S.L.O. will produce a 60-Mc difference frequency. The 2nd i.f. has a relatively narrow bandwidth and is sensitive only to this 60-Mc difference.

To illustrate how a swept oscillator produces the 60-Mc i.f. frequency, consider the 3 input signals to the 2nd mixer stage. The S.L.O. begins its normal sweep, starting at 230 Mc. To produce the desired i.f. frequency of 60 Mc there would have to be a 170-Mc signal present at the 2nd detector input. There is none, thus no i.f. frequency is produced. The S.L.O. continues its sweep and passes through the frequency of 240 Mc. This mixes with the 180-Mc input and produces the 60-Mc i.f. frequency. As it sweeps through 260 Mc and 280 Mc, it mixes with the other two inputs and also produces the 60-Mc i.f. frequency.

Thus, by using a local oscillator that sweeps a certain range of frequencies, input signals to the mixer can be made to enter the 2nd i.f. stage *one by one*, separated in time. *This is the important thing to remember about the operation of the analyzer.*

Skipping the 3rd mixer and i.f. for a moment, assume you have fed the output of the 2nd i.f. into a detector. As the signals appear one by one at the output of the 2nd i.f., they are rectified, giving positive pulses which will cause vertical deflection on the face of a crt. In our typical spectrum analyzer, the sawtooth that causes the the S.L.O. to sweep through its frequency range is the same one that drives the horizontal circuits of the oscilloscope in which it is used. Thus, you will observe the three input signals on the crt, with the horizontal axis representing frequency. Study the following example, referring to Fig. 2.

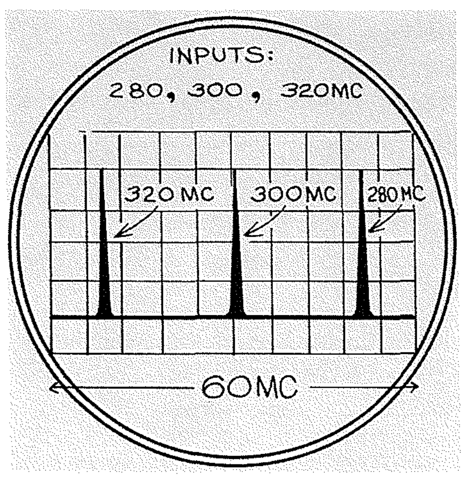
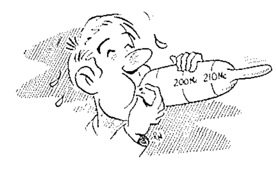


Figure 2. Crt display of output of 2nd i.f. (detected). Each cm = 6 Mc. Note that frequency is read from right to left on Spectrum Analyzer displays.

The crt spot begins its sweep at the 0 centimeter mark at the left-hand side of the graticule. The S.L.O., in step with the crt spot, is now at the low-end of its frequency range, or 230 Mc. No output is observed, as discussed above; the spot is not deflected vertically. The S.L.O. sweeps through a range of 60 Mc. Thus, a complete sweep of the horizontal represents 60 Mc also, and each major graticule line represents 6 Mc (assuming a normal 10-cm scan, of course). When the beam reaches a point 1.4 cm from the left-hand side, the S.L.O. is sweeping through 240 Mc. This produces an output corresponding to the 180-Mc input signal and the crt beam is deflected vertically. The beam then passes through the 5-cm mark at which time the S.L.O. passes through its mid-range, or 260 Mc. At this time, the crt beam is deflected again, indicating the 200-Mc input signal on the crt. Likewise, the 220-Mc signal is displayed at the 8.6-cm graticule line. The sweep is repetitive in normal operation and the result is a display similar to Figure 2. Note that the highest-frequency signal appears on the left-hand side. Frequency is read from *right to left.*



The previous example considered the S.-L.O sweeping through a 60-Mc range. This affords a "look" at a 60-Mc piece of the electromagnetic spectrum. The S.L.O. was set at maximum *dispersion* (range of frequencies swept by S.L.O.). The portion of the spectrum under analysis can also be narrowed. This is accomplished by decreasing the dispersion. If we set the dispersion at 20 Mc, the S.L.O. will sweep from 250 Mc to 270 Mc. Note that its center frequency is *still* 260 Mc, as before. Figure 3 shows the display obtained on the simplified spectrum analyzer, using this dispersion.

When the S.L.O. begins its sweep at the dispersion setting of 250 Mc, the 180-Mc signal at the input of the 2nd mixer is heterodyned to a frequency of 70 Mc. This falls outside of the bandpass of the 2nd

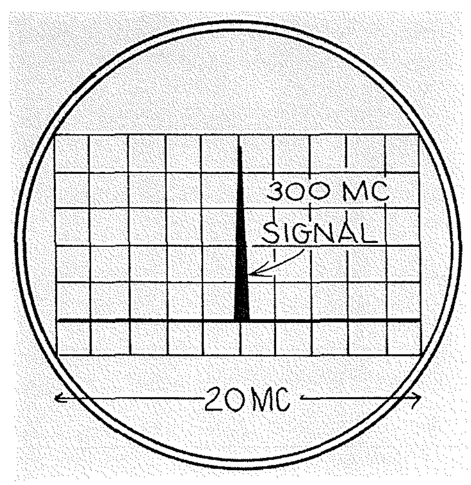


Figure 3. Dispersion, or bandwidth, set at 20 Mc. Each cm = 2 Mc.

i.f., which is tuned to 60 Mc. The 200-Mc signal produces a 50-Mc difference and is not accepted by the 2nd i.f., either. The 220-Mc signal produces an even lower beat; 30 Mc, which is well outside the bandpass of the i.f. As the S.L.O. passes through 260 Mc, the 200-Mc signal from the 1st i.f. produces the 60-Mc beat signal which is accepted by the 2nd i.f. The S.L.O. sweeps to 270 Mc and the same arithmetic proves that no other signal is displayed. Thus, of the original three signals, only one is displayed. The other two fall outside the area "scanned" by the S.L.O. In effect, we have narrowed the "window", through which we observe a portion of the spectrum, in order to take a closer look at it. (A good analogy would be a zoom movie camera that closes in on a subject.) As the dispersion of the S.L.O. is narrowed to sweep a smaller range of frequencies, we "close in" on the center portion of the output of the first i.f. As the observed portion still fills the entire horizontal sweep of the oscilloscope, the signal is spread out more. This gives better resolution in the case of closely-associated sine waves.

Figure 4 represents a display with the dispersion set at 10 Mc. Note that an upper and a lower side-band are beginning to emerge. Although at first we could not see them, these sidebands were associated with the 200-Mc signal all along. With a wide dispersion, the resolution was so poor, they all blended together. The following circuitry of the analyzer can spread, or resolve, these signals even more.

A front-panel vernier labeled "Center Frequency", controls a dc voltage to the S.L.O. This provides a slight shift of the S.L.O. center frequency. This is useful

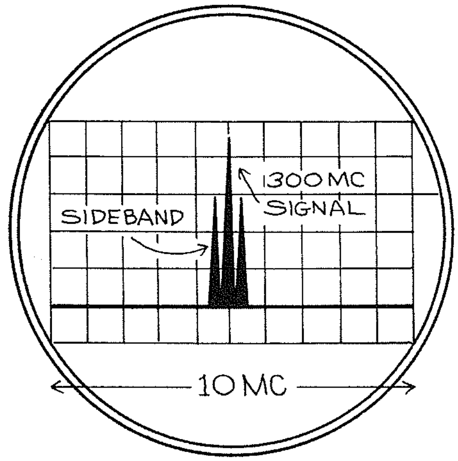


Figure 4. Dispersion set at 10 Mc. Note emergence of sidebands.

for lining up the display with a desired graticule line for subsequent measurement.

Because of the wide range of possible input voltages, a 1 to 51-db attenuator network is inserted between the 2nd mixer and the second i.f. In addition, the second i.f. also has a "Variable Gain" control on the front-panel.

A THIRD I.F. IS ADDED

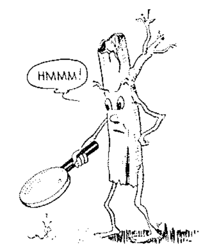
The output of the 60-Mc 2nd i.f. is still too broad for resolution of closely-associated signals. So we convert a 3rd time! A 3rd L.O., operating at a fixed frequency of 65 Mc, beats in the 3rd mixer with the 60-Mc output and produces an i.f. frequency of 5 Mc. This signal is fed into the 3rd i.f. which is fixed-tuned to 5 Mc. This i.f. has variable bandwidth and can be changed from 1 kc to 100 kc. Therefore, we can vary the resolution by changing the actual bandwidth of the i.f. stage. The output of the 3rd i.f. is fed to the detector.

THE DETECTOR CIRCUIT

All signals appearing at the input of the detector circuit are both positive and negative. We have no need to display the entire signal because one-half of it would simply mirror the other. So the signals are detected, or rectified, and passed on to a video amplifier.

The detector circuit provides three different outputs: LINEAR, LOARITHMIC, AND SQUARE-LAW. We'll consider each in turn.

The LINEAR output increases proportionally as the input increases. In other words, if an input voltage to the detector causes a crt deflection of 4 cm, doubling the input will cause a crt deflection of 8 cm.



The LOGARITHMIC output reflects a decrease in the gain of the detector circuit as the input is increased. This has the effect of compressing the larger input signals and increasing the dynamic range of the detector input. The output is proportional to the log of the input signal to the detector. The crt vertical deflection increases as the *square* root of the input voltage. This is equal to the db gain of the display. Increasing the input amplitude by a factor of 4 only doubles the height of the vertical display.

(Part 2, which concludes this article, will appear in the forthcoming June, 1965 issue of SERVICE SCOPE.)

TEKTRONIX PART-NUMBERING SYSTEM EXPANDED

We, at Tektronix, Inc., recently expanded our part-numbering system from six to nine-digit numbers. Several factors necessitated this change. One factor given major consideration was our desire to give ever more effective support to our customers. The expanded part-numbering system will work to that end.

What we've done is merely to expand the existing part number. The change won't require much getting used to on the part of the customer. (For example, parts categories will remain as they are.)

If a customer's original purchase order used six-digit numbers, here's how he can check his parts against the new numbering system:

Here is the familiar Tektronix part number as our customers know it:

524-268

All we've done is move the description digits (the three digits following the hyphen) one place to the right:

524- 268

Drop in a zero:

524-**0**268

and add a two-digit suffix:

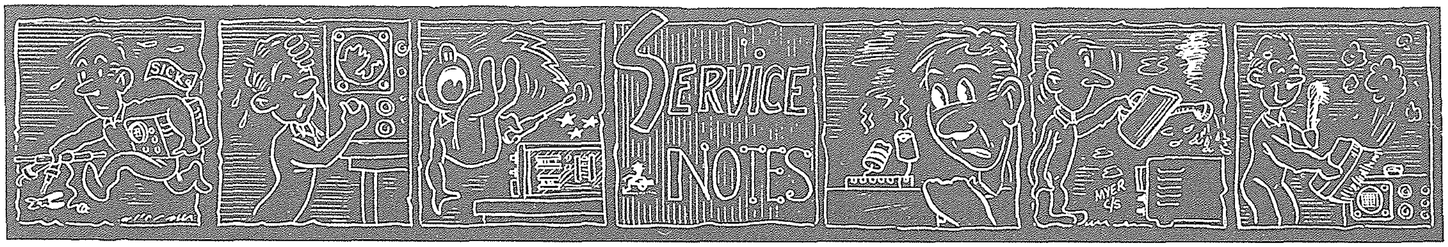
524-**0**268-**00**

That's all there is to it.

This method will work for all Tektronix six-digit part numbers except those few having an alphabetical suffix — 154-058A for example. For help in converting these to the new nine-digit part numbers, please consult your local Tektronix Field Office, Field Engineer or Representative.

During the transition period to our new system, the numbers on the parts customers receive may not jibe with those on the invoice we send. When this happens, by just applying the above simple steps in reverse the customer will find it was the same old part number all the time.

We hope this information helps. In the meantime, we appreciate our customers' cooperation and thank them for their patience while we make this necessary change.



SILICONE GREASE FOR TRANSISTOR HEAT-SINK USE

The need for the use of silicone grease in mounting heat-sinked transistors is apparently not well known.

The maximum power which may be dissipated in a transistor is limited by its junction temperature, T_J. An important factor in determining junction temperature is the ability to conduct heat away from it. There are several "thermal resistances" to be considered in series with heat transfer from junction to ambient air.* Figure 1

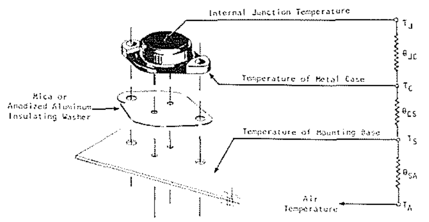


Figure 1. Electrical analog of heat path in a heat-sinked transistor. Θ_{jc} = Thermal resistance of junction to case bond. (Controlled by manufacturing process only.) Θ_{cs} = Thermal resistance of mounting. (Silicone grease can improve surface contact between transistor and mounting surface.) Θ_{sa} = Thermal resistance of "heat sink" or mounting base. (Usually a designed in factor after other elements have been optimized.)

shows an electrical analogy of these separate "resistances". One of these Θ_{cs}, is the thermal resistance from case to heat sink and is influenced by the method of mounting. If a mica insulating washer is used dry, the junction temperature rise per watt of power dissipated is about 1.0°C due to Θ_{cs} *alone*. This is mainly due to irregularities in the surface resulting in dead air spaces which do not readily transfer heat. See Figure 2. One way to over-

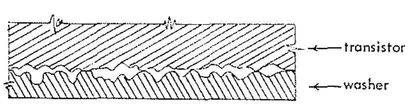


Figure 2. How a magnified cross-section view of the surface might look.

come this difficulty is to fill the dead air spaces with a substance superior to dead air in thermal conduction. Nearly anything is better than dead air, but silicone grease has the advantage of being a good electrical insulator while readily conducting heat. The use of ordinary silicone grease (like Dow-Corning DC-4) can reduce the above mentioned 1.0°C rise per watt of power to about half, and some of the new types of grease bearing metallic oxides claim reductions to the area of 0.1°C/w. As an example, this would mean a difference of 22.5°C in the junction temperature of a power transistor dissipating 25 watts.

Of the many readily available silicone dielectric compounds, we recommend Dow Corning Type 4 or Type 5 Silicone Compound for heat-sink use in current Tektronix instruments. These types of silicone grease we know will meet the thermal conductivity requirements and temperature range requirements of our "environmental" instruments.

As previously mentioned, there are some other types of silicone greases containing metallic oxides which increase thermal conductivity. However, we haven't fully tested the special metal oxide-bearing "Silicone Heat Sink Compounds" so we are not sure that they will meet our environmental temperature range requirements. This is, the ability to retain the desired fluid consistency from the lowest (storage) to the highest temperature range that any of our instruments are specified to operate over; and, the range of temperatures that could occur at the point in the instrument where the grease is used.

A practical general rule is to use silicone grease whenever replacing *any* heat-sink-mounted transistor. Apply a thin film of silicone grease between the transistor case and the heat sink. The error, if any, in the amount used should be on the generous side. (The excess that squeezes out when the mounting bolts are tightened can be neatly wiped off.)

If a mica or other type electrically-insulating washer is used between the transistor and heat sink, apply a thin film of grease to both sides of the insulating washer as well.

In some cases (such as the Type 547 Oscilloscope Vertical-Amplifier output transistors), the transistor is electrically insulated from the chassis by a white beryllium oxide disk. If you remove the heat-sink disk, you should also apply silicone grease where the disk contacts the chassis.

The Dow Corning Type 4 Silicone Compound is available in 2 oz. and 8 oz. tubes through electrical and electronic supply houses.

*For a more complete analysis of thermal characteristics, see "MOTOROLA POWER TRANSISTOR HANDBOOK", copyright 1961.

A CORRECTION

In the article "Some Basic Sampling Concepts Reviewed" which appeared in the February, 1965 issue of SERVICE SCOPE, one line is missing.

On page two at the bottom of column one, the line " . . . fully charged to the error voltage across . . . " should be added. Properly corrected the sentence, which begins five lines up from the bottom and in the center of the column, should read: "Since under these circumstances a fast rising step function may go from zero volts to its maximum voltage between samples, we must somehow cause the sampling capacitance to become fully charged to the error voltage across the gate with one sample".

The type was set correctly but somehow in the mechanics of production this line was lost in the shuffle.

Our sincere apologies to the author and our readers for this omission from an otherwise excellent article.

The Editor.

C12, C13, C19 and C27 TRACE-RECORDING CAMERAS—CLEANING AGENT FOR FOCUS PLATE

Any of the liquid dishwashing detergents (Joy, Vel, Lux, Swan, etc.) performs effectively as a cleaning agent for the focus-plate assembly supplied with these cameras. Used in fairly concentrated form, these readily-available detergents will easily remove oily residues as well as ordinary dust and dirt.

As a rule of thumb, you should avoid most all organic solvents such as Fotocal, Socal, flux remover, trichlor, etc. These agents will attack either the Plexiglass plate or the silk-screening. One which you can use without harm, however, is DuPont Freon TF. This is available locally from your chemical supply house.

TYPE 262 PROGRAMMER — RESISTOR KITS

The Type 262 Programmer Instruction manual, on page 2-8, tells how to place the No-Go Limits on a program card by soldering resistors to the NO-GO LIMITS terminals. On this same page Table 2-1 lists the required resistor values and the corresponding numbers.

The resistor values listed are available in a kit. Each kit contains a total of 176 resistors. These are ¼ w, 1%, precision (Std Mil-Bel) resistors in the following quantities and values:

Quantity	Value	Number
36	887 Ω	0
25	1.58 k	1
20	2.26 k	2
20	3.01 k	3
10	3.83 k	4
25	4.64 k	5
10	5.49 k	6
10	6.34 k	7
10	7.15 k	8
10	8.06 k	9

These kits are available through your Tektronix Field Engineer, Representative, local Field Office or Distributor. Ask for Tektronix part number 016-0056-00.

TYPE 3T77 SAMPLING SWEEP UNIT AND TYPE 3S76 DUAL-TRACE SAMPLING UNIT — TRIGGER-TO-VERTICAL KICKBACK

Sometimes, when a Type 3S76 Dual-Trace Sampling Unit is set to trigger internally from either A or B Channel, a certain amount of sweep gating voltage from the Type 3T77 Sampling Sweep Unit gets coupled into the vertical channel.

This voltage will appear on the displayed waveform. You can detect the aberrations with the sweep free running at 5 nanoseconds per division and sensitivity set at 2 mv per division. Their amplitude is affected by what might be connected to the input and is least with no signal applied.

An additional decoupling capacitor placed between the base of Q14 (the trigger input isolator in the Type 3T77) and ground will usually reduce the amplitude of the aberrations to a negligible amount. We recommend a 500 pf capacitor (Tektronix part number 283-0025-00). Solder the capacitor in place without leads (if possible) right at the point where the base lead of Q14 transistor socket emerges from the socket. A word of caution here. Too long leads on the capacitor or a sloppy soldering job will aggravate rather than relieve the difficulty. Perform your work carefully, neatly and with a critical eye.

BEER-CAN OPENER WEARS TWO HATS—The so-called "church key" type beer-can opener makes a handy tool for removing the large copper-clad staples used to close and secure the cartons in which Tektronix instruments are shipped. A carelessly used pliers or screw-driver employed to remove these staples can eject them with sufficient force to endanger the eyes or appearance of surrounding personnel. The bottle-top opening end of the ubiquitous beer-can opener works almost as well as a commercial staple-removing tool. It eliminates the hazard of flying staples and—the price recommends it. Our thanks to Rick Le Forge, Field Engineer with our Van Nuys Field Office, for passing on this information.

NEW FIELD MODIFICATION KITS

TYPE 5T1 TIMING UNITS — TIME-EXPANDER AND GENERAL IMPROVEMENTS

This modification improves the performance and versatility of the Type 5T1, s/n's 101 through 996, to nearly correspond with that of the Type 5T1A. The modification adds to the SAMPLES/CM switch a '1000' position for greater display resolution; and, a TIMED slow-scan position for use with a Y-T recorder. A new front-panel, screw-driver adjusted potentiometer adjusts the TIMED scan speed between the limits of 5 to 8 sec/cm (approx.).

The modification adds a TIME-EXPANDER control which provides X1, X10, X20, X50 and X100 sweep 'magnification' but does not affect the number of samples per centimeter.

A TIME-POSITION control replaces the old TIME-DELAY control. This new control supplies a variable time-delay for positioning the signal display when the TIME-EXPANDER switch is in the X1 position. In the expanded positions, the TIME-POSITION control moves the time 'window' anywhere within the original range displayed in the X1 position of the TIME-EXPANDER switch.

A new Fast-Ramp board with improved linearity for the Fast-Ramp waveform replaces the original Fast-Ramp board.

Order through your local Tektronix Field Engineer, Field Representative, Field Office or Distributor. Specify Tektronix part number 040-0311-00.

TYPE 5T1 AND TYPE 5T1A TIMING UNITS — IMPROVED SINE-WAVE TRIGGERING

By providing a high-frequency mode of operation, this modification reduces jitter and improves stability when triggering on high-frequency sine waves. The operating procedure for the instrument is not altered. To synchronize on high frequencies, the THRESHOLD control is simply advanced into the free-running portion of its range. Both positive and negative trigger circuits are modified for improved performance.

This modification applies to Type 5T1 Units, s/n's 101 through 996 and Type 5T1A Units, s/n's 997 through 2089. Order through your local Tektronix Field Engineer, Field Representative, Field Office or Distributor. Specify Tektronix part number 040-0390-00.

TYPE 2A61 DIFFERENTIAL PLUG-IN UNIT — INCREASED DYNAMIC RANGE

This modification replaces C437, a 13000 μf capacitor, and its protective diodes, D437 and D438, with a larger non-polarized capacitor. It also adds tube shields to V484 and V584 to prevent negative feedback caused by capacitor-tube coupling. The net result is an increase in the range of the Type 2A61's dynamic "window" from ±90 mv to better than ±300 mv. The improvement is in the 0.01, MV/DIV through the 0.5-MV/DIV attenuator positions.

(Please note: The increased value of C437 increases the time constant of the circuit to a dc input.)

This modification is applicable to Type 2A61 Units, s/n's 100 through 986. Order through your local Tektronix Field Engineer, Field Representative, Field Office or Distributor. Specify Tektronix part number 040-0361-00.

TYPE 2A61 DIFFERENTIAL PLUG-IN UNITS—NOISE AND DRIFT REDUCTION

This modification minimizes drift and reduces low-frequency noise and microphonics when the plug-in is used in the differential mode.

By replacing the floating preamplifier chassis with one that utilizes nuvistors in special, heat-stabilizing shields, and changing the circuitry to permit greater stability of the DIFF BAL control, the modification accomplishes its purpose.

This modification applies to Type 2A61 Units, s/n's 100 through 986. Order through your local Tektronix Field Engineer, Field Representative, Field Office or Distributor. Specify Tektronix part number 040-0397-00.

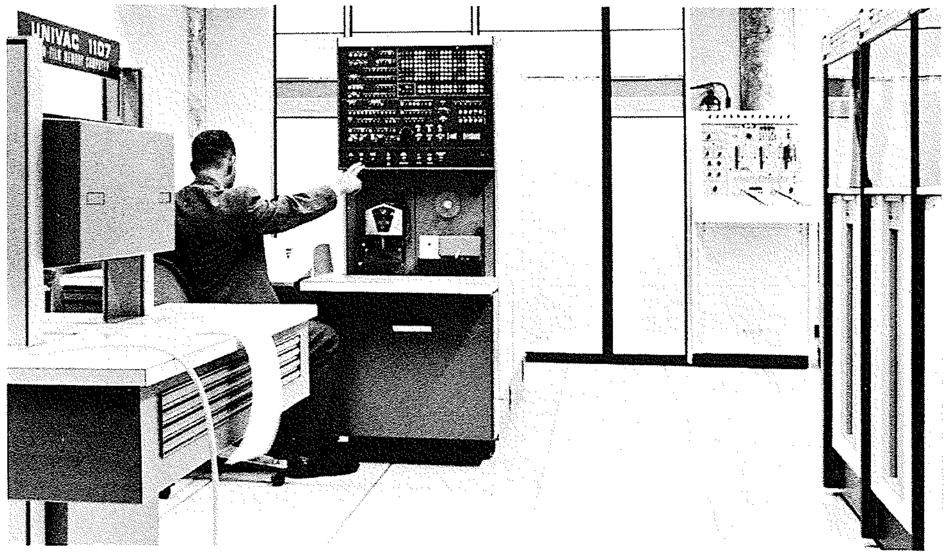
TORONTO TRAFFIC CONTROL SYSTEM USES TEKTRONIX OSCILLOSCOPE

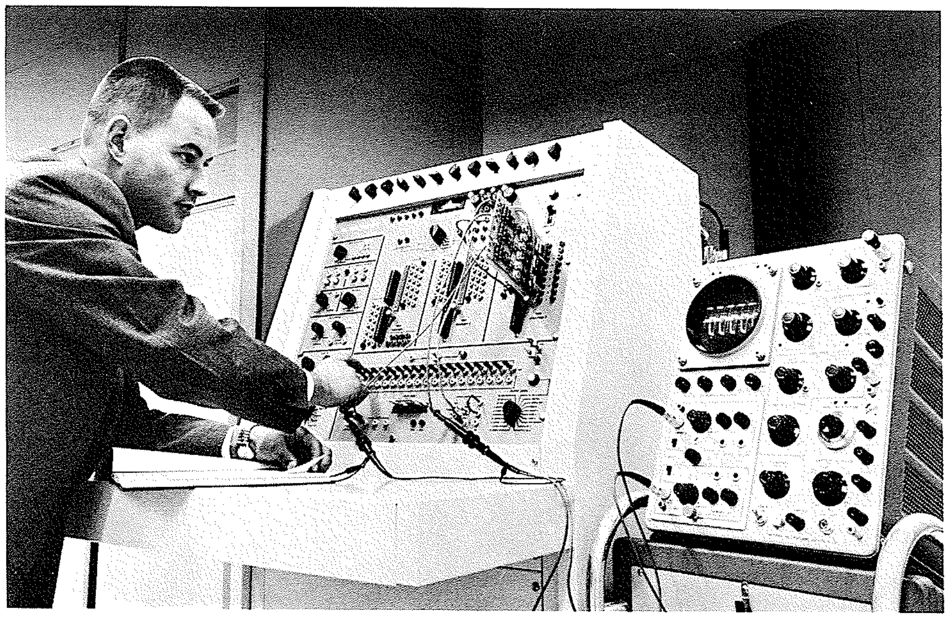
At the new Traffic-Control Center in Toronto, Canada, a Tektronix Oscilloscope aids the engineer in preventive maintenance. This new automatic traffic-control installa-ation uses thousands of printed circuit cards in the UNIVAC 1107 Thin-Film Memory Computer.

In the larger photo on this page, an engineer observes waveform displays on a Tektronix Oscilloscope. The waveforms are from a printed circuit board undergoing tests in the card analyzer shown to the left of the oscilloscope. This is a preventive maintenance test accomplished quickly and reliably with a card analyzer and Tektronix Oscilloscope. The tests give the engineer added assurance of computer proficiency in daily work of traffic simulation and analysis.

The smaller photo, taken at City Hall in Toronto, shows the UNIVAC 1107 Computer (left), the special-purpose Traffic Control Computer (center), and the card analyzer featured in the larger photo (right). Here the engineer is checking the console of the control computer which accumulates data at high speeds from traffic-detector sensors in metropolitan Toronto's new traffic-control system.

The computer-based system, which was designed by the UNIVAC Division of Sperry Rand Corporation, continously and automatically analyzes movement of vehicles within a controlled area of intersections. It will, sometime in 1965, control traffic flow at over 1000 intersections.





GRATICULE SWITCHING A PROBLEM? TRY THIS

Mr. Edward G. Morgis, Maintenance supervisor at Trans Canada Telemeter, offers a suggestion that will interest oscilloscope users who must interchangeably use graticules scribed as regular rasters and in Percentage of Modulation.

Mr. Morgis uses a 6 x 10-cm graticule (Tektronix part number 331-0037-00) and a TV graticule (Tektronix part number 331-0009-00) sandwiched in between the green filter and the bezel. He positions the two graticule lights so that one lights the front graticule, the other the rear graticule.

He replaces the scale-illumination potentiometer with a 75-ohm wire-wound potentiometer. By electrically placing the potentiometer between the two graticule lights with the center tap connected to 6.3 volts, the control acts like a "fader". Full rotation to either end of the control will illuminate one graticule leaving the other invisible.

Naturally, illumination of either graticule by only one light will not afford as even a raster as using both. Also, some increase in parallax will be apparent when using the front graticule. But if your work requires you to change graticules often, these negative features may be a minor consideration compared to the convenience Mr. Morgis' modification affords.

USED INSTRUMENTS FOR SALE

The University of Alberta Hospital in Edmonton, Alberta offers the following instruments for sale:

1—Type 551 Oscilloscope, s/n 002951
1—Type CA Plug-In Unit, s/n 026921
1—Type Q Plug-In Unit, sn 00525

Equipment is in very good condition. Contact: Mr. R. M. Allen, Asst. Purchasing Agent. Telephone: 439-5911.

TO OUR READERS

Do you have an item of local origin or interest that you would like to see in Service Scope? If you have send the information to Mr. E. C. von Clemm, General Manager, Tektronix Canada Ltd., 5050 Sorel Street, Room 12, Montreal 9, Quebec.

Items, in general, should relate to oscilloscopes and associated instruments. Ways and means that you have found helpful in using and maintaining your instruments may aid someone else to do a better job. Unique applications are often interesting, also.

We can not guarantee that all items received will be used in Service Scope. We can assure that all items will be thoughtfully considered and those that we feel have a broad appeal will be used. The decision as to which articles meet these objectives must be the responsibility and perogative of the editor.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

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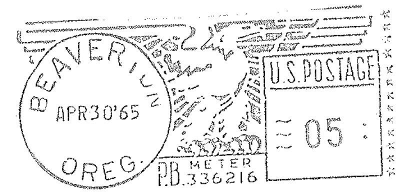

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Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

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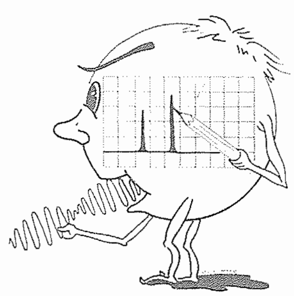


GETTING ACQUAINTED WITH SPECTRUM ANALYZERS

by Russ Myer
Tektronix Advertising Dept.

This is the second and concluding half of an article intended to form a conceptual basis for the understanding of Spectrum Analysis. The first half of the article appeared in the April, 1965 issue of SERVICE SCOPE.

Editors Note:

Part 1 of this article, presented the author's thoughts on Spectrum Analysis to as far as the detector circuit of a spectrum analyzer. Part 1 concluded with a short explanation of two of the detector circuit's three outputs—the linear output and the logarithmic output.

Here in the June, 1965 issue of SERVICE SCOPE, Part 2 begins with a brief review of decibels. This is intended to give the reader a better understanding of the logarithmic output.

We suggest that a refresher reading of Part 1 *before* continuing on to Part 2 will allow the reader to more readily associate himself with the author's thoughts presented here in the second half of the article.

Part II

DECIBELS

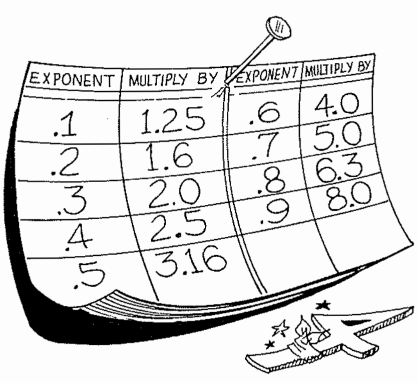
To give you a better understanding of the logarithmic output, let's briefly review decibels.

A decibel is one-tenth of a bel. A bel is the same thing as a power of ten. Thus: 50 db is equal to 5 bels. This is the same as 10 to the 5th power, or 10^5.

If we increase the power level of a signal by 60 db, we increase it 10^6 times—a gain of 1,000,000. Increasing a one-watt signal by 60 db increases it to one million watts!

Remember that db merely expresses the difference between two power levels. By itself, it means nothing, nor does it represent any actual quantity of power. If the example above were 1 micro-watt, a 60 db gain would bring the power up to 1 watt. So the same 60 db expressed a difference of almost 1 million watts in the first example and only 1 watt in the second!

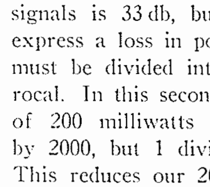
Gains of whole bels, 1, 2, 3, etc. . . . can easily be calculated in the head. 1 bel (10 db), for example, means a power gain of 10^1, or ten. 2 bels, (20 db), means a power gain of 10^2, or one hundred. And so on.



EXPONENT	MULTIPLY BY	EXPONENT	MULTIPLY BY
.1	1.25	.6	4.0
.2	1.6	.7	5.0
.3	2.0	.8	6.3
.4	2.5	.9	8.0
.5	3.16		

Figure 5. Fractional Exponent Multipliers.

Unfortunately, gain is not always expressed in even numbers of bels. What about a gain of 33 db? This is a gain of 3.3 bels, or $10^{3.3}$. Reviewing math, this means 10^3 times $10^{.3}$. 10^3 is easy: 1000. What about $10^{.3}$? For this, you'll have to refer to the table of fractional exponents. See Fig. 5. From the table, you'll see that 0.3 corresponds to 2. So 10^3, or 1000, is multiplied by 2. A 33 db gain, therefore, is equal to a gain of two thousand.



Assume that an amplifier has an input of 200 milliwatts. The gain is 33 db. The output, in watts, would be 400 watts. ($0.2 \times 10^{3.3}$)

Db's are also used to express a loss. We can still consider, in the case of our example, that the difference between two signals is 33 db, but as we now desire to express a loss in power, the figure of 2000 must be divided into 1 to obtain its reciprocal. In this second case, our initial power of 200 milliwatts must be multiplied not by 2000, but 1 divided by 2000, or 0.0005. This reduces our 200 milliwatts to 100 microwatts.

To express a difference in voltage levels, more commonly used in oscilloscope work, the number of bels used as exponents, is divided by 2. Example: a voltage gain of 44 db gives an exponent of $10^{4.4}$. Dividing the exponent by 2 gives a new number: $10^{2.2}$. This is $10^2 \times 10^{.2}$, or 100×1.6, or 160. Increasing any voltage level (RMS) by a factor of 160 produces an increase in power of about 25,000 times. This is proved by the relationship $E^2/R(160^2)$.

The power formula, $P = E^2/R$ indicates that power increases as the square of the voltage (resistance remaining the same, of course). The oscilloscope is a voltage-operated device; therefore, increasing a vertical signal by a factor of 2 requires a signal 4 times the power of the original.

So much for decibels. Let us return now to the detector circuit and its 3rd or SQUARE-LAW output.

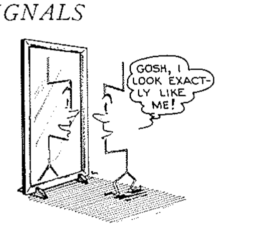
To expand vertical signals, the analyzer's detector is operated in the SQUARE-LAW mode. In this manner, the output voltage is the *square* of the input voltage. Doubling the input causes the output to increase *four* times. Tripling the input causes the output to increase 9-fold!

The advantage of this circuit can easily be seen. Input signals of nearly the same amplitude are expanded and can be measured more accurately on the crt. Also, the crt now measures relative input *power*. Doubling the input power doubles the vertical deflection. Thus, the square-law mode causes the output to behave exactly the opposite of the logarithmic mode.

THE VIDEO AMPLIFIER

The detector circuit is followed by the Video Amplifier. Signals are fed into the amplifier and applied, push-pull, to the crt vertical-deflection plates. To increase the versatility of the spectrum analyzer, video signals can be fed directly into the amplifier, by-passing the i.f. and detector portions of the instrument. This allows an oscilloscope display of ordinary time-based signals.

IMAGES AND OTHER SPURIOUS SIGNALS



Until now, we have assumed that only the signals appearing in the area of the center frequency are presented on the crt display. Unfortunately, this is not always the case. Other signals also sneak through the analyzer and are displayed.

Assume you have set the tuning dial at 300 Mc to observe a signal of that frequency on the crt. Since 300 Mc is the center-frequency signal, it will appear at the center graticule line. Assume further that along with the 300-Mc input, another signal with a frequency of 700 Mc is present at the input.

Since the first L.O. operates 200 Mc higher than the desired input signal, it will be oscillating at 500 Mc. This frequency beats with the 300-Mc input to produce the 200-Mc difference which is allowed to pass through the 1st i.f.

But . . . . the difference between the 500-Mc L.O. and the 700-Mc input is *also* 200 Mc! So, it too is introduced into the 1st i.f. and, as you would expect, appears on the crt — exactly super-imposed on the 300-Mc signal at the center graticule line. Now, set the dial slightly to either side of the 300-Mc center frequency. This causes the signals to move from the center graticule area. However, each signal goes in the *opposite* direction!! A little arithmetic will prove why.

Moving the L.O. to 530 Mc, for example, (tuning dial reading 330 Mc, of course) produces a beat of 230 Mc for the desired input signal of 300 Mc. As the output of the 2nd i.f. is swept through its range of 170 Mc to 230 Mc, it's obvious that the true signal now will appear on the extreme right of the crt. The L.O. frequency of 530 Mc also beats with the 700-Mc input and produces a difference frequency, or beat frequency, of 170 Mc. This causes it to appear to the extreme left of the crt.

This illustrates an important rule: Tuning the L.O. (main tuning dial) to a higher frequency causes the true signal to move to the right of the crt; unwanted signals move to the left. These undesired responses are called "images," or "spurious" responses.

As signals above and below the center frequency of the 1st L.O. can produce beat frequencies, either of the two could be called the "true" signal, depending upon how we labeled the tuning dial. We simply choose to call signals below the frequency of the L.O. *true responses* and all signals above it, the image signals. The i.f., of course, doesn't know the difference.

Another type of spurious response that shows up on the crt is caused by input signals that fall within the bandpass of the first i.f Any input signal falling within the range of 170 Mc to 230 Mc will be displayed. This is called *i.f. feedthrough*. This type of spurious signal is the easiest to identify. Moving the tuning dial either direction does not shift the display on the crt. This is because the 1st L.O. does not beat with any input signal to produce the response.

Figure 6 shows two unknown signals on the crt of the scope. Note their positions on the graticule. The dispersion is set at 50 Mc. Thus, each graticule line represents 5 Mc. First attending to signal A, move it to the center graticule line. This will determine the center frequency of the signal as read on the tuning dial. Assume that

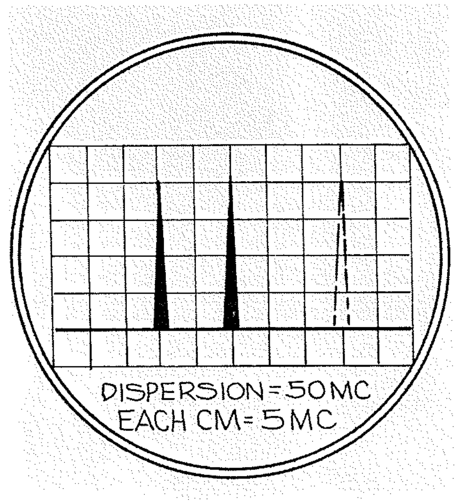
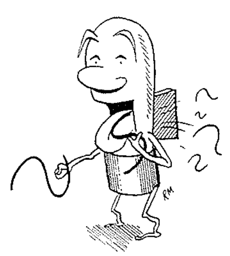


Figure 6. Display after shifting image to center of graticule. This illustrates how two signals, separated by 390 Mc, show up only 10 Mc apart on the crt.

it was necessary to tune the dial higher in frequency. The signal moved higher in frequency, also (towards the left). This identifies signal A as a spurious, or image, response. Reading the tuning dial gives us a figure of 205 Mc. We know the L.O. is operating 200 Mc above the tuning-dial reading, so it must be oscillating at 405 Mc. The image, therefore, is 200 Mc above that, or 605 Mc!

Signal B was moved to the right (down in frequency) to be located at the center graticule line. The tuning dial would now read 215 Mc, which is the frequency of the true input signal.

HARMONIC SPURII



When the operation of the Spectrum Analyzer is considered, remember that any complex waveform is the algebraic sum of a number of pure sine waves. The analyzer permits the display of these individual sine waves on an oscilloscope. The horizontal sweep represents some continuous frequency range.

Any sine wave passed through a nonlinear device, such as a tube or a transistor, will be accompained in the output by a new set of frequencies called *harmonics*. These frequencies will be exact multiples of the original, but of decreasing amplitude. The second harmonic, for example, of a 200-Mc signal, is 400 Mc; the 3rd, 600 Mc, etc.

Here is where we can get into trouble with our typical spectrum analyzer. Originally, we spoke of all the signals present at the output of the first mixer: the original L.O. frequency, the original input signal, the sum of the two, and the difference, which was the one selected for i.f. amplification. We also learned that any signal

170-Mc to 230-Mc *higher* than the L.O. frequency would also produce a beat that fell within the bandpass of the first i.f. And, finally, there was i.f. feedthrough.

But, unfortunately, there are other spurii which can show up on the crt screen.

The mixer will produce harmonics of its two input signals, (original signal and L.O.) which are present in the output. Harmonics of the L.O. are of particular interest to us now. For example, assume the L.O. could be set at 300 Mc to show a 100-Mc input signal on the crt. The second harmonic of the L.O. is 600 Mc. If there were a 400-Mc signal of equal strength at the input of the analyzer, it, too, would produce a 200-Mc difference and be displayed on the crt! Because of the decreased amplitude of the harmonic, however, the crt presentation would be less than that of a true-response presentation. (Bear in mind, however, that the 400-Mc signal could have a signal strength several times that of the true signal and show up as a larger amplitude presentation than the true one).

Also, an 800-Mc signal, if present at the input, would beat with the 2nd harmonic of the L.O. and produce the 200-Mc i.f. difference signal. Likewise, the 3rd harmonic of the L.O. — 900 Mc — could beat with a 700-Mc input, or a 1,100-Mc input and produce the 200-Mc i.f. frequency!

Fortunately, these harmonic-caused spurii can be easily recognized. Increasing the L.O. frequency by 100 Mc, for example, increases the 2nd harmonic by 200 Mc, and the 3rd by 300 Mc. Thus, harmonic spurii move across the screen faster than true response or images.

Assume inputs of 700, 400 and 100 Mc. The L.O. is set at 300 Mc to display the 100-Mc signal at the center of the crt. The dispersion is set at 10 Mc, each centimeter representing 1 Mc on the crt. At the center of the crt, only one signal is observed. Actually, three signals are present — the true signal which is L.O. minus the input frequency of 100 Mc, 2 x L.O. minus the input frequency of 400 Mc and 3 x L.O. minus the input frequency of 700 Mc. All these differences are exactly 200 Mc! See Figure 7.

Tuning the L.O. up 1 Mc in frequency will shift the true signal, 100-Mc, exactly 1 division to the right (remember that tuning higher in frequency shifts true signals towards the minus-frequency or right hand side of the crt). The 1-Mc shift upward caused the 2nd harmonic to increase 2 Mc, and this moved the 400-Mc input *two* divisions to the right! The 3rd harmonic increased by 3 Mc, and the 700-Mc signal appeared three divisions to the right of center. Assuming inputs of equal signal strength, the 2nd harmonic signal would be less than the amplitude of the true response and the 3rd harmonic signal amplitude would be

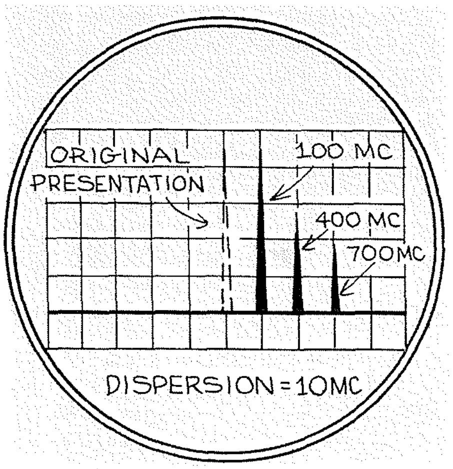


Figure 7. Display showing effects of moving tuning dial up 1 Mc to recognize and separate spurii from true response.

less than the second. Observe that, unlike images, moving the L.O. up in frequency causes these harmonic spurii to move in the same direction as true responses.

MARKER OSCILLATOR

A feature of the spectrum analyzer is the Marker Oscillator. It generates a 200-Mc signal which is fed into the 1st i.f. of the analyzer. You can use it to determine relative frequency or frequency difference of signals observed on the crt.

You'll remember that the center frequency of the 1st i.f. is 200 Mc. The marker frequency of 200 Mc is injected into the i.f. and will exist at the center of the bandpass of the i.f. You can say, therefore, that the 200-Mc marker indicates the center frequency of the i.f. and is displayed at the center graticule line of the crt. The marker appears as a spike, or "pip", much like the time marks used to calibrate oscilloscopes.

A front-panel control, the "Frequency-Difference Control," allows the marker to be tuned to either side of its 200-Mc mid-range, usually plus or minus 30 Mc (170 Mc to 230 Mc). Figure 8 gives an example of the use of the marker.

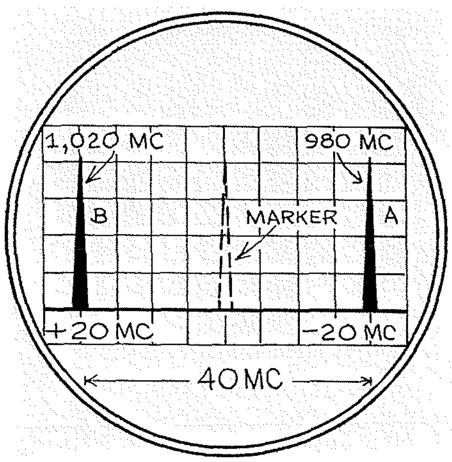
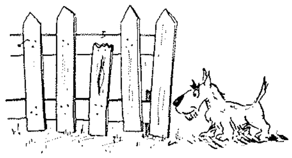


Figure 8. Dispersion is 50 Mc. Each cm = 5 Mc. Marker reads frequency difference.

First, line up the marker "pip" and the signal at "A". The control reads —20 Mc. Moving the marker over to signal "B" and lining them up, the control reads +20 Mc. The frequency difference is 40 Mc and that is the frequency difference between signals "A" and "B". Assume the main-tuning dial is tuned to 1,000 Mc. The dispersion is set at 50 Mc. Each graticule mark now represents 5 Mc. No signal appears at the center graticule line, which represents the center frequency. Therefore, no input at 1000 Mc is present at the input of the analyzer. However, there is a signal 4 graticule lines to the left of the center one. This signal is 20 Mc less than the 200-Mc center frequency, or 180 Mc, and corresponds to an original input of 1,020 Mc. The signal on the right, "B", is 20 Mc greater than 200 Mc and is produced by an input of 980 Mc. Remember to read frequency from right to left!

As we have seen previously, spurious inputs will also produce similar signals on the crt. An input of 1,380 Mc will produce a signal similar to "A" and an input of 1,420 Mc will produce one similar to "B". Note that in the case of these and any images, frequency is read from left to right, in the normal fashion. You can, of course, identify true signals by shifting the main-tuning dial and observing which way the signals move on the crt.



The marker-oscillator output can be frequency - modulated, also. Two modulating frequencies are available on this typical analyzer: 1 Mc and 100 kc. When modulated, the 200-Mc marker signal now becomes a complex waveform which the analyzer will break down into individual sine-wave components (which is what our analyzer does to all complex waveforms!). These are displayed on the crt as pips, spaced equally apart. These pips extend to the right and left of the marker center-frequency displayed on the crt. The separation between the pips is equal to the modulating frequency that caused them. In other words, with a dispersion of 10 Mc and the marker set on 200 Mc, a modulating frequency of 1 Mc will create a "pip" at each graticule line. These pips are called the *"picket fence."*

VERTICAL AMPLITUDE MEASUREMENTS

Look at the graphical view of the bandwidth of the 1st i.f. (Figure 9). The center frequency is 200 Mc. The bandwidth limits are 170 Mc to 230 Mc and is expressed in db variation, usually ±3 db. The figure shows that the flat portion of the curve can vary between minus 3 db and plus 3 db. This is a 6-db variation! Per-

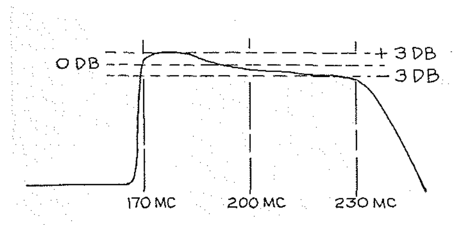


Figure 9. Bandwidth of 1st i.f., reproduced on crt by sweeping constant input signal over 60 Mc range. Note that despite constant input, there is a 6 db variation between 170 Mc and 230 Mc.

haps at the 170-Mc point, the response is +3 db. At the 230-Mc point, it could be —3 db. A single, constant-input signal, swept from 170 to 230 Mc, will produce an output to the detector that varies between +3 db and —3 db. Obviously, this same signal viewed on the crt would assume a varying vertical deflection at different points along the horizontal axis although the input had not changed at all. Therefore, it is important that all measurements using the Spectrum Analyzer be made with the signal under measurement lined up at the center graticule line. Thus, a constant output from the detector is assured.

To measure relative differences in amplitude of signals displayed on the crt, we use the calibrated attenuator of the analyzer.

Assume you have a crt display of two signals of different amplitudes. The detector is in the linear mode. The largest signal is reduced, with the attenuator, to the original amplitude of the second signal. The difference is noted on the attenuator. This is the relative difference. For signals of greatly different amplitude, the log mode of detection may be used. If the input signals were nearly the same amplitude, the square-law detection mode could be used.

This discussion has presented the overall operation of a typical Tektronix Spectrum Analyzer. Although the company's product line features several different models covering other portions of the electromagnetic spectrum, some of which operate a little differently than explained here, they all do one basic thing. They break down complex waveforms and display them on an oscilloscope as individual sine waves on a frequency time base.

The End

The Author wishes to acknowledge the help received from pertinent articles and material supplied by the following Tektronix personnel: Arnold Frisch, Project Manager, and Morris Engelson, Design Engineer of the Spectrum Analyzer group in the Instrument Engineering Department, Fred Davey, Education and Training Program Director, and Fred Beville Field Engineer; also the assistance of others who aided in the editing of this material . . . Russ Myer

About the Author—

Russ Myer received his training in basic electronics at the Venezuela Communication School in Caracas, Venezuela.

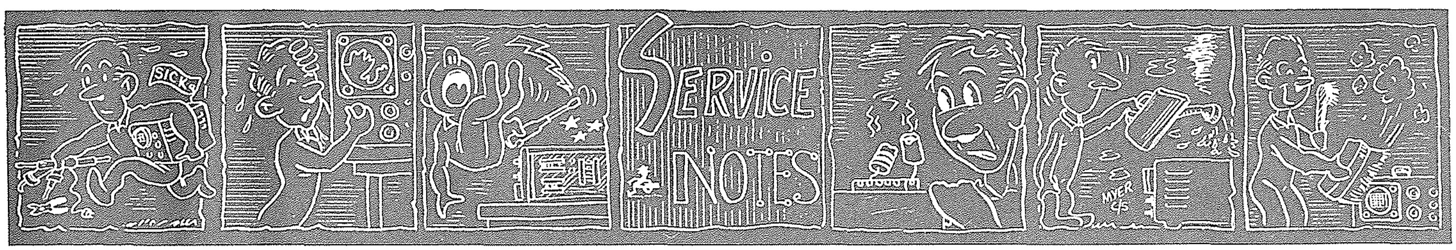
He later took service with the U.S. Federal Aviation Agency and during his tenure studied electronic engineering at their University of the Air in Oklahoma City, Oklahoma.

He followed this with a stint as teacher of electronics at Port Arthur College in Port Arthur, Texas.

Russ has also had five years of experience as a broadcast engineer, holding the position of chief engineer at each of the several stations employing him.

He came to Tektronix, Inc. in April of 1962 and worked in the Test and Calibration and Customers Service departments before transferring, recently, to the Advertising Dept. as a technical writer.

The Editor.



TYPE L-20 PLUG-IN-UNIT SPECTRUM ANALYZER—APPLICATIONS ABOVE ITS SPECIFIED FREQUENCY RANGE

The Type L-20 Spectrum Analyzer's specified upper frequency is 4 Gc. You can, however, use the instrument for applications up to 12 Kmc, at reduced sensitivities. You will need to compute the dial setting for any input frequency from a knowledge of the local oscillator frequency; and, you can compute the local oscillator frequency from the dial setting on Band 2 (fundamental operation) using this equation:

$$\frac{F_{rf} + 200}{n} = F_d + 200$$

Where

F_{rf} = Input signal rf frequency

200 = IF Frequency

n = harmonic number of local oscillator,

Band 2 Dial Reading	n = 5 Kmc	sens —dbm	n = 6 sens —80 dbm Kmc	n = 7 sens —75 dbm Kmc	n = 8 sens —70 dbm Kmc	n = 9 sens —66 dbm Kmc	n = 10 sens —63 dbm Kmc	n = 11 sens —60 dbm Kmc
230	1.95	—85	2.38	2.81	3.24	3.67	4.10	4.53
240	2.00	—85	2.44	2.88	3.32	3.76	4.20	4.64
250	2.05	—85	2.50	2.95	3.40	3.85	4.30	4.75
260	2.10	—85	2.56	3.02	3.48	3.94	4.40	4.86
270	2.15	—85	2.62	3.09	3.56	4.03	4.50	4.97
280	2.20	—85	2.68	3.16	3.64	4.12	4.60	5.08
290	2.25	—85	2.74	3.23	3.72	4.21	4.70	5.19
300	2.30	—85	2.80	3.30	3.80	4.30	4.80	5.30
320	2.40	—85	2.92	3.44	3.96	4.48	5.00	5.52
340	2.50	—85	3.04	3.58	4.12	4.66	5.20	5.74
360	2.60	—85	3.16	3.72	4.28	4.84	5.40	5.96
380	2.70	—85	3.28	3.86	4.44	5.02	5.60	6.18
400	2.80	—85	3.40	4.00	4.60	5.20	5.80	6.40
450	3.05	—85	3.70	4.35	5.00	5.65	6.30	6.95
500	3.30	—85	4.00	4.70	5.40	6.10	6.80	7.50
550	3.55	—85	4.30	5.05	5.80	6.55	7.30	8.05
600	3.80	—85	4.60	5.40	6.20	7.00	7.80	8.60
650	4.05	—85	4.90	5.75	6.60	7.45	8.30	9.15
700	4.30	—85	5.20	6.10	7.00	7.90	8.80	9.70
750	4.55	—85	5.50	6.45	7.40	8.35	9.30	10.25
800	4.80	—85	5.80	6.80	7.80	8.80	9.80	10.80
850	5.05	—85	6.10	7.15	8.20	9.25	10.30	11.35
900	5.30	—85	6.40	7.50	8.60	9.70	10.80	11.90

Chart 1. Chart for determining the value for n in the equation $\frac{F_{rf} + 200}{n} = F_d + 200$.

for F_{rf} between 4 Kmc and 12 Kmc is 5 to 11 (for Type L-20)

F_d = Band 2 dial settings

Sensitivities are estimated—we make no production measurements, *nor do we guarantee performance in this frequency range.* Engineering tests do, however, indicate that the Type L-20 exceeds the estimated sensitivities in most cases.

NOTE: You should always operate at the lowest harmonic possible so as to achieve best sensitivity. Also, on Chart 1 below, those numbers to the right and below the mid-chart line do not appear on the dial of the Type L-20 Spectrum Analyzer. Those numbers above and to the left of the mid-chart line do appear on the dial at a low order of harmonic.

TYPE 545B AND TYPE RM545B OSCILLOSCOPES—IMPROVED VERTICAL AMPLIFIER HF RESPONSE

You can improve the high frequency response of the Type 545B (s/n's 101-1079) and the Type RM545B (s/n's 101-219) Oscilloscopes by replacing C551, a fixed 7.5 pf capacitor, with a 5-25 pf variable capacitor (Tektronix part number 281-0075-00). C551 is located on the lower Vertical Amplifier chassis. You will need to rearrange the components on the ceramic strips to accommodate the larger replacement

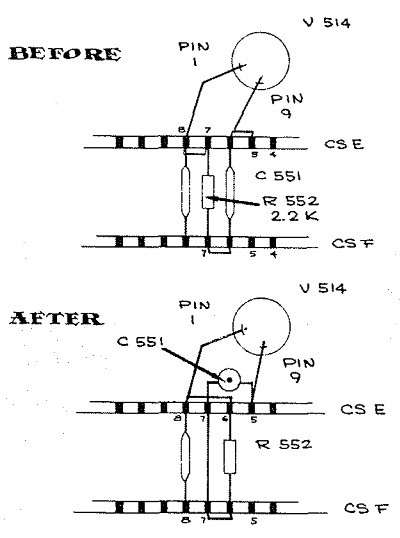


Figure 1. "Before" and "After" sketch showing the placement of components on the ceramic strips when making the modification to improve the vertical amplifier high frequency response in the Type 545B and Type RM545B Oscilloscopes.

capacitor. Figure 1 shows a "BEFORE" and "AFTER" sketch of this modification.

Remove C551 from the ceramic strips, located on the lower Vertical Amplifier, just above the two TA1938 transistors Q513 and Q523. Follow the BEFORE and AFTER drawings and rewire the ceramic strips to accommodate the new C555 capacitor. Refer to your Instruction Manual's Calibration section and recheck the Vertical Adjustment, adding C551 to the procedure as necessary. Don't neglect to change the parts list and schematic values in your Instruction Manual to agree with the new capacitor.

TYPE 2B67 TIME-BASE UNIT—RASTER

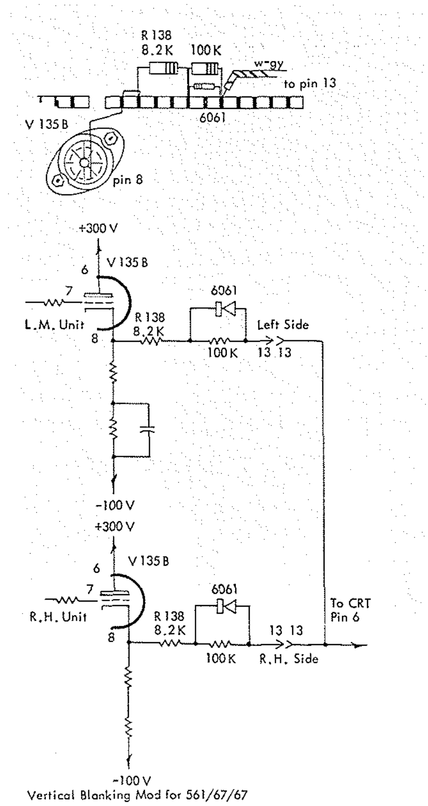


Figure 2. Partial schematic and sketch of component placement on the involved ceramic strips when making the vertical blanking modification to the Type 2B67 Time-Base Unit.

When two Type 2B67 Time-Base Units are used for raster applications in a Type 561A or Type 564 Oscilloscopes the left-hand unit will not blank the vertical retrace. A slight modification to the two Type 2B67's will allow the left-hand 2B67 to blank the vertical retrace. Figure 2 shows the circuit modification in schematic form. With this circuit, if either time base says "off" the beam turns off. That way it's off during each retrace of the horizontal and off during vertical retrace, too. This circuit works well with moderately slow sweeps. It *will not* work at very fast sweeps; there just isn't enough current in the Type 2B67 system to pull these plates around very rapidly.

There are four steps involved in the modification and here they are:

1. On the bottom ceramic strip of each of the two 2B67's, remove the white-grey lead from the end of R138 (8.2 k) resistor and move it two notches to the rear.
2. Connect a 100 k, ½ w resistor (Tektronix part number 302-0104-00) between the 8.2 k resistor (R138) and the white-grey wire moved in Step 1.
3. Shunt the 100 k resistor installed in Step 2 with a 6061 diode (Tektronix part number 152-0061-00). Connect the cathode end of the diode to the junction of the 8.2 k and 100 k resistors.
4. On the Type 561A (or Type 564) Oscilloscope, run a lead from pin 13 of the right-hand interconnecting socket to pin 13 of the left-hand interconnecting socket.

That's all there is to it.

TYPE 545B AND TYPE RM545B OSCILLOSCOPES — ELIMINATING TIME-BASE 'B' TRIGGER JITTER

In some of these instruments, trigger jitter may be apparent when Time-Base 'B' is triggered with the MODE switch in the —EXT position. Should this be objectionable, replacing R92, a 22 k, 1 w, 5% resistor, with a 20 k, 1 w, 5% resistor, (Tektronix part number 303-0203-00) will eliminate the jitter.

R92 is located on the 'B' sweep chassis between the center two ceramic strips, with one end connected to L424, a 225 μh inductor, which is directly over V424, a 6AU6 tube. Be sure to note the changed value for R92 in your Instruction Manual's part list and schematic when you make this modification.

TYPE Q TRANSDUCER & STRAIN GAGE PLUG-IN UNIT—POSSIBLE TEMPERATURE/GAIN PROBLEM

Some Type Q Units within the serial number range of 101 through 1629 will exhibit a temperature/gain problem. The problem manifests itself as a change in gain with a change in temperature and is most likely to occur during warm up of the Q Unit. It can result in a significant measurement error. Two 0.02 μf discaps in the amplifier cause the instability. Replacing these with 0.022 μf, 200 v, PTM capacitors (Tektronix part number 285-0566-00) will assure stable operation during and after warm up.

With the Q unit turned upside down on the bench and the front panel facing you, C5724 and C5755 are located on the four-notch ceramic strips directly behind the front panel and under the μ STRAIN/DIV. switch.

After making this modification, correct the parts list and schematic in your Type Q Unit Instruction Manual to agree with the work you have done.

TYPE 519 OSCILLOSCOPE — POSSIBLE SHORT DAMAGE IN HV SUPPLY

Accidentally grounding the HV supply of the Type 519 Oscilloscope (s/n's below 560) may cause C841, an 0.01 μf-500 v capacitor, to short. This short will, in turn, damage V800, the 6AU5 oscillator tube in the HV circuit.

Replacing C841 with a capacitor having a higher voltage rating will protect against this damage. The replacement should be an 0.01 μf, 1 kv capacitor (Tektronix part number 283-0013-00). C841 is located in the HV supply between pin 7 of V814 (a 12AU7 error-signal-amplifier tube) and ground—consult the CRT CIRCUIT schematic in your Type 519 manual. Be sure to note the changed value for C841 in the schematic and parts list of your manual.

TYPE 519 OSCILLOSCOPE — REPLACEMENT CAPACITOR COVER

Installation of a new type capacitor cover on C655 will offer more protection against arcing of this capacitor in the Type 519 Oscilloscope. C655 is a 2 x 1000 μf, 450 v, EMF capacitor in the 6.3-v crt-heater circuit of the Type 519's power supply. Under the proper atmospheric conditions and at 4000 foot elevations, pins 16, 17 and 26 of T601 and the can of C655 may arc to ground. Should this occur, the two dioodes, D655 and D656 may be destroyed and 601 damaged. Normal age deterioration of the original capacitor cover will enhance the possibilities of this arcing.

The new capacitor cover (Tektronix part number 200-0293-00) is molded of a recently available plastic, highly resistant to age deterioration and with very effective insulating abilities.

TYPE 160A POWER SUPPLY—EXCESSIVE RIPPLE ON +225-SUPPLY

Under conditions of high-load demand at the output and a low-line supply at its power source the Type 160A Power Supply (s/n's 101 through 9049) may exhibit ripple on the +225-v supply that exceeds specifications. Changing R33 from a 1 meg to a 1.5 meg ½ w, 10% resistor will assure that ripple on the +225-v supply remains within specifications. R33 is located on the Type 160A chassis between pin 5 of V33 (a 6AU6 tube) and pin 2 of V35 (a 6080 tube). Tektronix part number for the 1.5 meg resistor is 302-0155-00. After you make the replacement, note the changed value for R33 in the parts list and on the schematic of your Type 160A's Instruction Manual.

REPRINTS AVAILABLE

Reprints of two articles written by Tektronix personnel and which appeared in technical magazines recently are available.

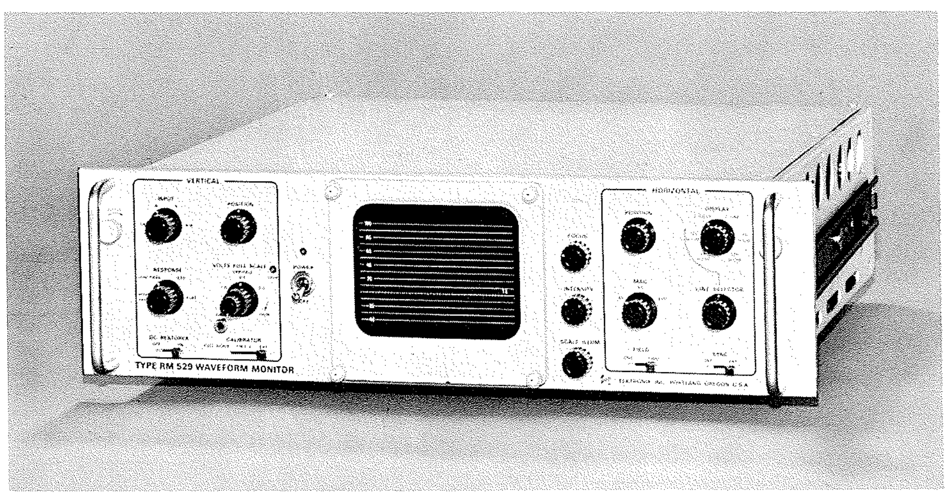
The March, 1965 issue of THE MICROWAVE JOURNAL contained an article on spectrum analyzers. Title of the article is "Oscilloscope Plug-In Spectrum Analyzers". Three Tektronix design engineers, Arnold Frisch, Project Manager, and Larry Weiss and Morris Engelson, Design Engineers with the Spectrum Analyzer group in our Instrument Engineering Department, collaborated to produce this article. It deals primarily with the plug-in type of spectrum analyzers designed for use with the Tektronix Type 530, 540, 550 and 580 Oscilloscopes.

Following a brief rundown on the principles of a spectrum analyzer's performance, the article explains how the plug-in analyzer uses to advantage certain oscilloscope characteristics; such as, the calibrated sweep, the expanded sweep, intensity modulation and (as in the case of the Type 555 Oscilloscope) dual beam presentation.

The January, 1965 issue of ELECTRO-TECHNOLOGY carried an article on sampling oscilloscopes entitled "Nanosecond Measurements with a Sampling Oscilloscope". The author is H. Allen Zimmerman, Project Engineer with the Tektronix, Inc. Instrument Design Department. This article describes the sampling process and discusses the usefulness and versatility of a sampling oscilloscope.

Reprints of either or both of these articles can be obtained from your local Tektronix Field Office, Field Engineer, Field Representative or Distributor.

A NEW TELEVISION WAVEFORM MONITOR THE TEKTRONIX TYPE RM529



The Tektronix Type RM529 is a new television waveform monitor with capabilities for precise measurement of Vertical Interval Test Signals (VIT).

VIT signals have been in use in Europe and Canada for the past ten years. Their use on the North American continent was pioneered by the Canadian Broadcasting Corporation. The United States government authorized the use of VIT signals in that country as far back as 1956. They have, however, only recently come into common use there.

The Type RM529 is designed for use with the 525/50 line scanning rate used in the United States and here in Canada. This instrument can be obtained (on special order) with minor modifications to the sweep and vertical amplifiers that adapt it to other systems currently in use, including 405/50, 819/50 or high-resolution closed circuit systems. Tektronix, Inc. also produces a television waveform monitor, the Type RM529 MOD 158E, that is designed specifically for the CCIR system. This instrument is of interest, primarily to television authorities, engineers and technicians in areas other than the North American continent.

The wide bandwidth of the Type RM529—flat to 8 MHz—assures excellent waveform fidelity and makes the instrument ideally suited for sine-squared testing.

A new highly efficient 12.7 cm aluminized mono-accelerator crt operating at an increased accelerating potential, assures brighter waveform displays in line-selector operation. Viewing area is 7 x 10 cm.

The electrical design of the instruments incorporates the best of both solid state and vacuum tube circuitry, thus assuring extra high reliability and longer component life. Except for the two power transistors all 45 transistors are socket mounted to enhance serviceability. The two power transistors are bolted to the heat sink on the rear panel of the instrument. Vacuum tubes (there are only seven in the instrument) have been used in but a few circuits, and then, only when they offered superior performance or better reliability over presently available semiconductor devices. Total power consumption is only 80 watts and this low power consumption precludes the need for a fan. The result is cleaner operation and complete freedom from mechanical noise.

The design of the Type RM529 is compact. The instrument fits in a standard 19" rack and requires only 5¼" of vertical rack space. It is designed for mounting with the Conrac picture monitor, or other commercial picture monitors in a standard console or relay rack installation.

A positive field selector is incorporated in the Type RM529 and is ideal for monitoring VIT signals.

A video signal is composed of frames (complete pictures) ,occurring at a 30 Hz rate. Each frame is divided into two fields —Field One and Field Two. Each field contains 262½ lines, making up a complete frame of 525 horizontal lines. The two fields interlace; that is, Field One lines occur between those of Field Two. Close inspection shows that a full line of video precedes Field One; while only noe-half line of video precedes Field Two. These two identifying features occur *immediately* before the vertical blanking pulse which precedes the field in question. (See Figure 1,

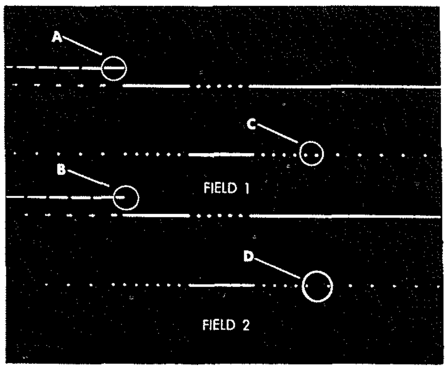


Figure 1. shows the differences between Field One and Field Two. (Double exposure photograph)

point a and b.) Careful inspection of the vertical-blanking pulse reveals another difference between Field One and Field Two—a difference in the time relationship between the last equalizing pulse and the first horizontal-sync pulse. (See Figure 1, points c and d.) This difference enables electronic circuits to identify individual fields.

A prime feature of the Type RM529 is the ability to distinguish between Field One and Field Two. Through the use of appropriate delay circuitry to interrogate the vertical blanking interval, the Type RM529 can generate a trigger which *positively* locks the Field Trigger Generator to Field One or to Field Two. Hence, triggers initiating a sweep at the start of either Field One or Field Two can be selected with a front-panel switch. *After a noise transient or temporary loss of video, this circuit will always return to the proper field.*

By introducing a delay between these triggers and the start of the sawtooth, *any* line of the TV raster can be inspected individually. Horizontal magnification allows more detailed inspection of the signal on the line selected.

Bright waveform displays are another important feature of the Type RM529. A single line displayed at a frame rate is inherently dim. The Line Selector circuitry in the Type RM529 furnishes a brightening pulse to the crt grid (ac-coupled). This feature makes it unnecessary for the operator to re-adjust the intensity control in line-selector operation. It also limits the normal intensity range, thus preventing accidental burning of the crt phosphor; particularly in the event of sweep circuit failure. The net result is waveforms—exceptionally bright and sharp—that are clearly viewed or photographed.

The Type RM529 has four vertical-amplifier-response positions: high pass, low pass, IEEE and flat.

The high-pass or chroma position is often used to remove low-frequency components from the staircase. With these removed, amplitude of the 3.58 MHz modulation is more easily measured and differential gain determined. Adequate reserve gain exists to expand the subcarrier signal for accurate measurements.

The low-pass position is used to attenuate the high-frequency bursts on the multiburst signal when making axis-shift measurements. It will limit the 0.5 MHz-modulation to approximately 20% of the original amplitude. Modulation is scarcely detectable on the 2-MHz portion of the burst and negligible at the higher frequencies. (This response position is also useful when it is necessary to observe a waveform in the presence of extreme amounts of white noise.)

The IEEE position is the standard response designated by the broadcast industry in Canada and the U.S.A. for making amplitude measurements. It removes the chrominance signal from video containing color information, and eliminates high frequency noise which is often present.

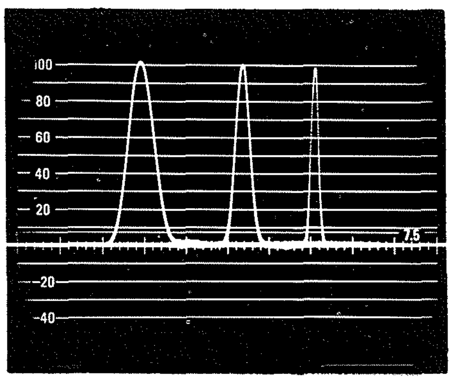


Figure 2. 2T Signal. Multiple exposure. Left: 2T. Center: T. Right: ½T Sine².

The flat response position is usually used when making measurements with multiburst and sine² pulses. It will not significantly attenuate a T pulse and it provides good reproduction of the 50 nsec ½ T pulse, see Figure 2. This position is also useful for making signal-to-noise-ratio measurements because it readily passes all white noise present in the system. A calibrated 14 db increase in sensitivity over the 1.0 v full-scale calibrated sensitivity is provided for such purposes.

DC RESTORATION

A dc restorer on-off switch is incorporated in the Type RM529 to facilitate its use as a modulation monitor. In normal use, the dc restorer serves the function of clamping the video signal to a reference level so that it will not change position with varying average voltage level (brightness). The dc restorer normally clamps to the back porch of the video signal. Black level is usually set to 7.5 IEEE units above the back porch, and the white level to 100 units. The bottom of the sync tip is normally set to —40 IEEE units. Studio signals are usually measured at the 1 v level and 1 v equals 140 IEEE units in normal signal.

When the dc restorer is turned off, the input capacitor of the Type RM529 may be shorted out. All following stages are dc-coupled, making it possible to use the Type RM529 in conjunction with a diode detector for % of modulation measurements. Signals which are not video, such as found in tape recorders, may also be measured. DC coupling is also useful for measuring hum and bounce in the video system. With the dc restorer disabled, and the input of the Type RM529 ac-coupled (normal), the low frequency 3-db down point is approximately 0.32 Hz.

Both the back porch (blanking level) and the sync tip represents stable reference levels in the video signal. Back-porch clamping has in the past been objectionable because it interfered with color burst. Design considerations in the Type RM529 make this objection invalid. Back-porch clamping has the advantage that there is a more direct relationship between the blanking level (back porch) and picture black level than there is to the sync tip level. (A simple modification of the Type RM529 circuitry will adapt the instrument for sync-tip clamping. This modification is described in the Type RM529 Instruction Manual.)

Change in blanking level due to the presence of color burst is well under 1%. No aberrations to the color burst are caused by the clamping circuit.

Tektronix, Inc.
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USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

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INTRODUCTION TO OSCILLOSCOPE DIFFERENTIAL AMPLIFIERS

by
Joseph E. Nelson
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This article describes oscilloscope differential amplifiers in terms of their application to measurements. Characteristics such as common-mode rejection ratio, voltage range, and frequency range are explained, and typical figures are given. In addition, the effect of probes and filters as well as the importance of source impedance are discussed and pointed up as factors that can affect measurement capability.

What Is It?

The word "differential" in the amplifier name can be misleading. To some it suggests a relationship to differential calculus while others think of a differentiating network. It is neither of these, but simply a *difference* amplifier. By definition: An oscilloscope differential amplifier is a device that amplifies and displays the voltage difference that exists at *every* instant between signals applied to its two inputs.

With this definition as a departure point, one can get some idea of the oscilloscope display that will result from a variety of input signals. For example, two pulses that differ in both amplitude and coincidence that are applied to a differential amplifier will cause the oscilloscope display to be a complex waveform that represents the instantaneous difference between the two pulses. On the other hand, two signals that are *identical* in every respect will cause no output on the CRT screen (limitations to this statement will be described under *Common-Mode Rejection*).

Several examples of input waveforms as applied to a differential amplifier and the resultant output waveforms are shown in Figures 1, 2 and 3.

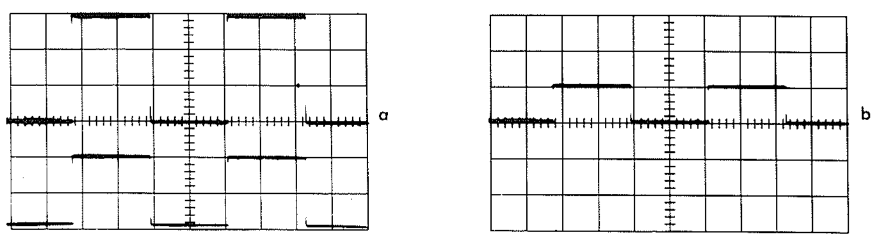


Figure 1. a, Input signals of different amplitude (same phase) applied to a differential amplifier. b, The resultant ouput signal.

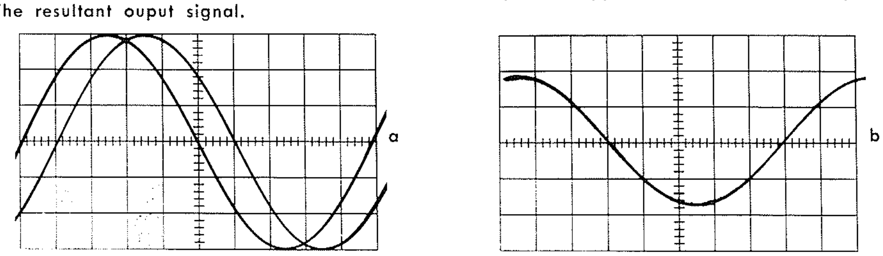


Figure 2. a, Two signals of equal amplitude but of different phase (approx. 35°) applied to a differential amplifier. b, The resultant signal seen on the crt.

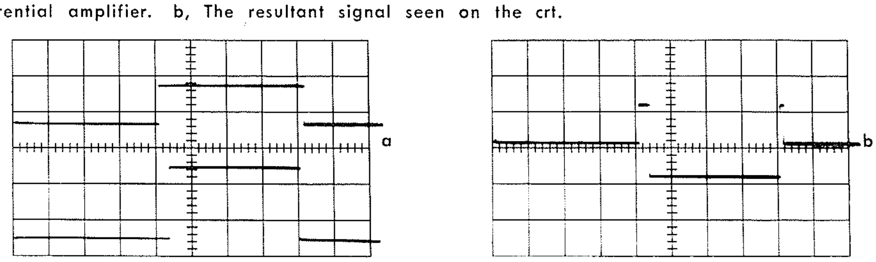


Figure 3. a, Two square waves of different amplitude and coincidental applied to a differential amplifier. b, the difference waveform seen on the crt.

Common-Mode Rejection

The definition of the term differential amplifier implies a rejection of equal amplitude, coincident signals. This implication is correct. However, the degree of rejection depends primarily on the symmetry of the amplifier inputs. Unfortunately, the design and construction of two exactly symmetrical inputs to a differential amplifier cannot be accomplished in practice. Small differences in resistor and capacitor values result in deviations from the theoretical input attenuation ratio. In addition, the capacitance of active elements may not remain the same for each input and this can cause a difference voltage, especially at the higher frequencies. The net result of these variations in component values is an unbalance that causes a *difference* signal, even though the amplifier is driven by identical input signals. The amount of difference signal that one can expect from a particular amplifier is documented with a mathematical relationship that is called the common-mode rejection ratio (CMRR). This ratio and associated terms are defined as follows:

Common-Mode: Refers to signals that are identical with respect to both amplitude and time. Also used to identify the respective parts of two signals that are identical with respect to amplitude and time.

Common-Mode Rejection: The ability of a differential amplifier to reject common-mode signals.

Common-Mode Rejection Ratio (CMRR): The ratio between the amplitude of the common-mode input signal to the difference input signal which would produce the same deflection on the CRT screen.

NOTE: Since the differential amplifier in this discussion (and throughout this article) is part of an oscilloscope, the output signal used to calculate the CMRR is measured in the usual way from the CRT screen and volts-per-division switch setting.

Thus, a differential amplifier that produces a .005-volt output when driven by 5.0 volts of common-mode signal has a CMRR of 5/.005 or 1000:1.

Measurements made with a differential amplifier should contain an allowance for the output voltage that is due to common-mode signal. For example, if an amplifier with a CMRR of 1000:1 is used to measure the difference between two similar five-volt signals, the output seen on the oscilloscope screen is the result of two voltages: (1) the *actual* difference between the input signals, and (2) the difference voltage that results from the common-mode signal. Because of this combination, the actual difference voltage cannot be *exactly* measured. Therefore, the voltage measured on the CRT screen should include a tolerance that is equal to the computed, or measured, output voltage due to the common-mode signal.

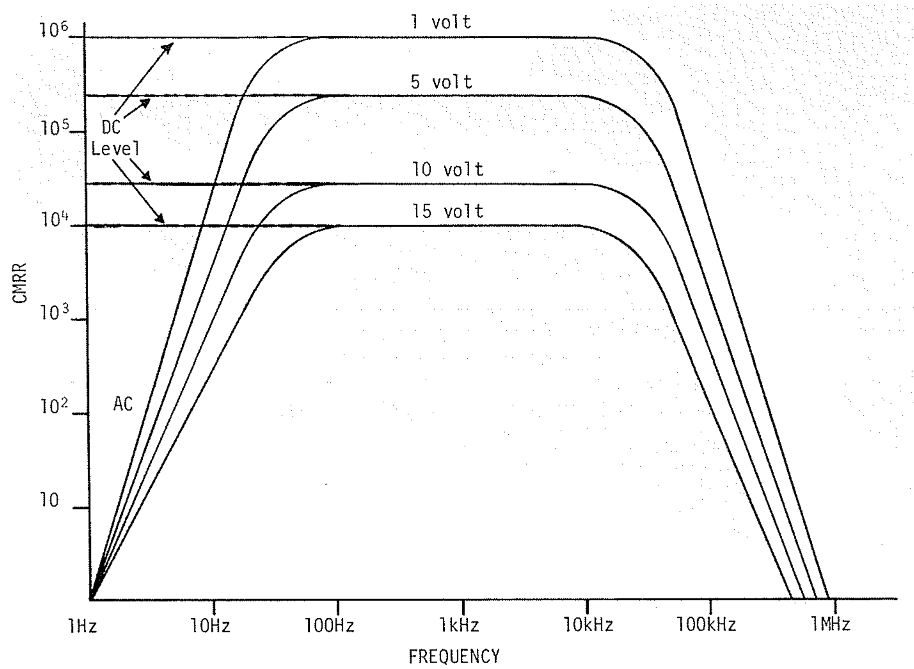


Figure 4. The common-mode rejection ratio related to frequency, voltage level, and input coupling of a typical differential amplifier.

COMMON-MODE REJECTION[1]
0.1 MV/CM to 10 MV/CM[2]

	Referred to Input Connectors: DC-Coupled Input	Referred to Input Connectors: AC-Coupled Input With Low-Z Source	Referred to Input of Properly Adjusted P6023 Probes: DC-Coupled Input	Referred to Input of Properly Adjusted P6023 Probes: AC-Coupled Input With Low-Z Source
DC to 100 kHz	50,000:1			
500 kHz	1,000:1	1,000:1		
DC to 10 Hz			50,000:1	
15 Hz		500:1		
60 Hz		2,000:1		
100 Hz			10,000:1	
1 to 10 kHz			1,000:1	1,000:1
100 kHz		50,000:1	500:1	500:1
20 MV/CM to 10 V/CM[3]				
DC to 1 kHz	10,000:1			
DC to 100 kHz	1,000:1			
500 kHz	500:1	500:1		
15 Hz		500:1		
60 Hz		2,000:1		

1 For ground-referenced sine-wave common-mode signals.
2 With 10 volts peak-to-peak or less in common mode at input connectors.
3 With common-mode amplitude at input connectors of 100 volts peak-to-peak or less from 20 mv/cm to 0.1 v/cm, and with 600 volts peak-to-peak or less from 0.2 v/cm to 10 v/cm.

These common-mode signals will not overdrive the amplifier:
0.1 mv/cm to 10 mv/cm, ±20 v from gnd (40 v pk-to-pk ac)
20 mv/cm to 0.1 v/cm, ±200 v from gnd (400 v pk-to-pk ac)
0.2 v/cm to 10 v/cm, ±600 v from gnd (1200 v pk-to-pk ac)

Figure 5. Chart for the Tektronix Type 3A3 Differential-Amplifier Unit that outlines the parameters under which certain common-mode rejection ratios can be achieved.

In the above example, the CMRR of 1000:1 means that the common-mode portion of the five-volt signals will cause an output of 5.0 volt/1000 or .005 volt. If a voltage of, say .015 was measured on the CRT screen, it should be noted as .015 ±.005 volt.

Amplitude, Frequency and Input Coupling

To this point, no mention has been made of common-mode rejection in terms of amplitude, frequency, or type of input coupling. The importance of these factors is graphically illustrated in Figures 4 and 5. From these figures one can formulate some general rules as to expected changes in common-mode rejection when amplitude, frequency or input coupling are changed.

1. The specified common-mode rejection becomes *lower* as the common-mode signal amplitude is *increased*.
2. The specified common-mode rejection becomes *lower* as the input attenuators (within the amplifier) are switched into the amplifier input circuit.
3. The specified common-mode rejection becomes *lower* as the frequency of the common-mode signal increases. (Exception: with AC-coupled input the CMRR can become higher as frequency is increased within the 1 Hz to 100 Hz range).
4. Generally, the addition of components such as probes, attenuators, or even extra cable to the amplifier inputs will lower the *apparent* common-mode rejection. (Note: the actual CMRR of the instrument cannot be changed by added external components.)

Where precise quantitative data is needed, one should measure the CMRR of the instrument at the specific frequency or repetition rate and amplitude of the signals being used and use this measured CMRR as a tolerance figure in difference measurements.

Amplitude and Common-Mode Rejection

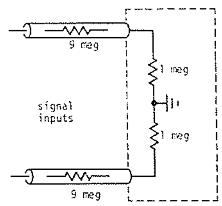
In the text to follow, the term maximum *common-mode input voltage* means the maximum voltage that will not overdrive the amplifier. This should not be confused with the *maximum non-destructive input voltage* which is related to the breakdown limits of the amplifier components.

Figure 4 shows that the CMRR decreases as the input voltage increases. If the voltage applied to the input is raised beyond the maximum common-mode input voltage specified for the amplifier, at some point the input circuit will be overdriven and the common-mode rejection ratio becomes meaningless. Once this occurs, further increase of the common-mode voltage will cause a disproportionate increase in the amplitude of the CRT display.

This discussion of input voltage also applies to pulses and square-waves as well as sine-waves. But because these waveforms contain components of many frequencies, it is difficult to predict the shape of the resultant waveform that a differential amplifier may display.

Probes and Common-Mode Rejection

Attenuator probes extend the usable voltage range of a differential amplifier by reducing the input signals to a level that is below the *maximum common-mode input voltage*. In doing this, however, the probes



Probe	Tolerance	CMRR (Apparent)
A	+1%	50:1
B	-1%	50:1
C	+2%	25:1
D	-2%	25:1
E	+3%	16:1
F	-3%	16:1

Figure 6. Simplified input circuit and table that shows the change in CMRR (apparent) due to X10 probes that are within 1, 2, and 3% of their attenuation value.

may cause a reduction in the *apparent* CMRR due to component value differences within the probes. For example, Figure 6 illustrates the change in CMRR (apparent) due to X10 probes that are within 1, 2, and 3% of their attenuation value. Bear in mind that the reduction in apparent CMRR can also be caused by different values of the input resistor. Also, probes with cables of different length may introduce enough signal delay between them to cause a difference voltage at the inputs. A good rule, especially with probes, is to try to make conditions at both inputs identical.

A typical test was run on four Tektronix Type 6006 probes to illustrate what might be expected in practice. The differential amplifier was a Tektronix Type 3A3 Dual-Trace Differential Amplifier in a Tektronix Type 561A Oscilloscope and the source voltage was from a Tektronix Type 190B Sine-Wave Generator set at 1 kHz.

	CMRR
Probes 1 and 2	56:1
Probes 1 and 3	40:1
Probes 2 and 3	68:1
Probes 4 and 1	8:1
Probes 4 and 2	7:1
Probes 4 and 3	8:1

This test pointed out two additional features of probe use: (1) by reversing the probe connections to the amplifier inputs the CMRR was changed. For instance, when probes 1 and 2 were reversed, the CMRR changed from 56:1, as shown above, to 46:1; and (2) the test showed probe number 4 to be defective, as indicated by the low CMRR (8:1).

In measurements where attenuator probes must be used because of voltage levels, and at the same time a high (above 1000:1) CMRR must also be achieved, the Tektronix Type P6023 Probe is suggested. This is a X10 low capacitance probe with variable attenuator ratio that is adjustable over a ±2.5% range. As pointed out earlier in Figure 5, these probes, when used with a Tektronix Type 3A3 Differential-Amplifier Unit, can be adjusted for CMRR's of 50,000 at certain frequencies.

Filters and Common-Mode Rejection

Some differential amplifiers use filters, but this technique is not considered to be common-mode rejection since difference signals are also rejected by filters. In effect, the filters set the bandwidth of the amplifier and reject signals that are above or below the filter passband. For example, a 60 Hz sine-wave modulated by high-frequency noise can be "cleaned up" considerably by using a filter whose passband centers on 60 Hz. Conversely, to eliminate line-frequency hum, a filter that restricts the hum frequency should be used.

Several differential amplifiers, such as the Tektronix Type 2A61 Low-Level Differential Amplifier and Tektronix Type 1A7 High-Gain Differential Amplifier, have a series of internal filters that are adjusted by frequency-response controls on the instrument front panel. These controls allow the amplifier passband to be centered on the frequency of the desired signal. One note of caution—too severe restriction of the passband may cause distortion of non-sinusoidal signals.

Signal Source Impedance and Common-Mode Rejection

The common-mode rejection ratio specified for a differential amplifier is obtained by applying the same signal to both inputs. Since the signals are from the same generator, the source impedance of the signals is the same. (In the discussion that follows, the signals are 100 Hz sine waves.)

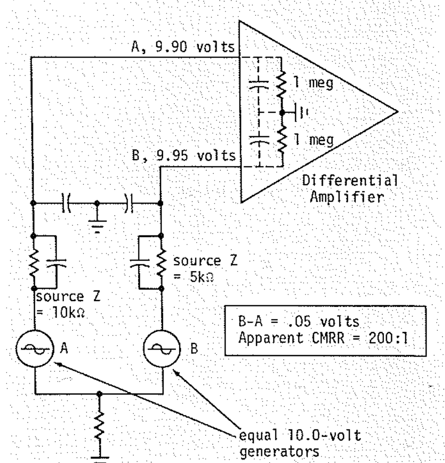


Figure 7. Schematic that shows the relationship of test-point source impedance to the amplifier-input impedance, and also shows the apparent CMRR caused by large value difference between test-point impedances.

If the two inputs to a differential amplifier are connected to circuits that do not have the same source impedances, the *apparent* CMRR will be lower than expected, even though the voltages from both sources are the same. (Note: This assumes a finite resistance such as 1 megohm from grid to ground at each input of the differential amplifier). The reason for this lower CMRR is: the source impedance of the circuit under test and the amplifier input impedance form a divider (both R and C) and the ratio between these two impedances determines the amount of signal presented to the grids.

For example, in Figure 7, the source impedance of generator A is 10 kilohms and the input impedance of input A is 1 megohm. The actual voltage present at the input A is 99.0% of the source or 9.90 volts.

Generator B has a source impedance of 5 kilohms which is in series with the 1 megohm input impedance of input B. This results in 99.5% or 9.95 volts applied to input B.

With 9.90 volts applied to input A and 9.95 volts applied to input B, the net difference between the two inputs is 0.05 volt. This difference voltage of 0.05 volt would be amplified and appear on the CRT screen. If one considered this voltage as the result of a common-mode 10.0-volt signal the ratio would be 200:1. However, as the illustration shows, the difference voltage of 0.05 volt was present at the input to the amplifier and because of this, cannot be considered as a common-mode voltage. In addition, the illustration shows that the difference voltage present at the amplifier input was a direct result of the difference in source impedance of the two signal sources.

One way to reduce inaccuracy due to different source impedance is to select test points with low source impedance. Figure 8 shows a difference voltage of .0005 volt applied to a differential amplifier when the source voltage is 10.0 volts and the source impedances are 50 Ω and 100 Ω respectively. In this case, the apparent CMRR is 20,000:1 (assumes infinite CMRR of the amplifier).

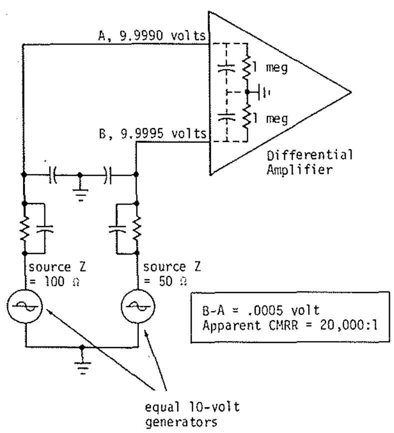


Figure 8. Schematic that shows the small affect on CMMR caused by low-impedance test points compared to that of Figure 7.

If a measurement must be made from two different high impedance points the source impedances can be calculated and allowance made for the difference voltage although this calculation can be quite difficult. A second way to handle this measurement is to use a differential amplifier with an infinite input resistance. The Tektronix Type W Plug-In Unit can be set by a front panel control to have 10,000 megohms input resistance. The remaining input capacitance of 20 pf will present approximately 80 megohms to the 100 Hz signal. When two dividers are calculated between 80 megohms and the 5-k and 10-k source impedances, the difference voltage from a 10-v signal is .0006 v.

As the frequency of signals increases, the error due to different source impedances also increases. There is really no solution to this problem other than to avoid the conditions that produce it. Thus, one should: (1) select low source impedance test points whenever possible, and (2) where high impedance test points must be used, try to use points of equal source impedance.

Ground Connections

Because differential amplifiers are capable of measuring difference signals at microvolt levels they are also sensitive to unwanted signals that may be present in the instrument environment. Proper grounding can often reduce these unwanted signals to a point where they do not interfere with a measurement. Figures 9a, b, and c illustrate the right and wrong way to connect a differential amplifier into a circuit.

Figure 9a is wrong because each probe shield acts much like an antenna in picking up stray signals from the environment. These signals will differ in both phase and amplitude between the two probe shields and will induce currents in the center conductors which result in small signal differences at the input to the amplifier. Figure 9b is wrong since a ground connection between the junction of the probe shields and the instrument under test would allow ground currents to flow through the shields. The presence of these ground currents increases the possibility of erroneous measurement due to resultant voltage differences applied to the inputs of the amplifier.

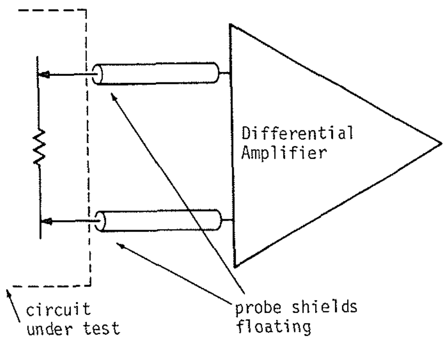


Fig. 9a. Wrong

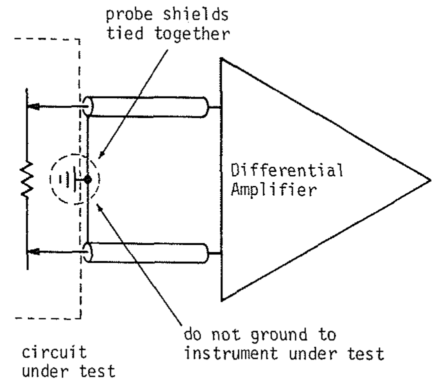


Fig. 9b. Wrong

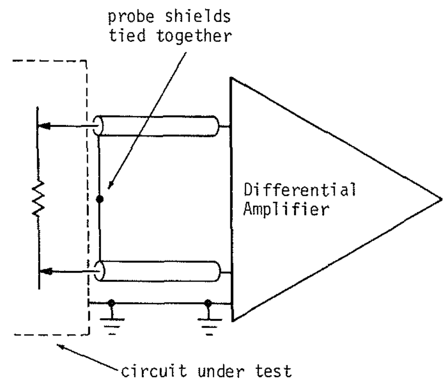
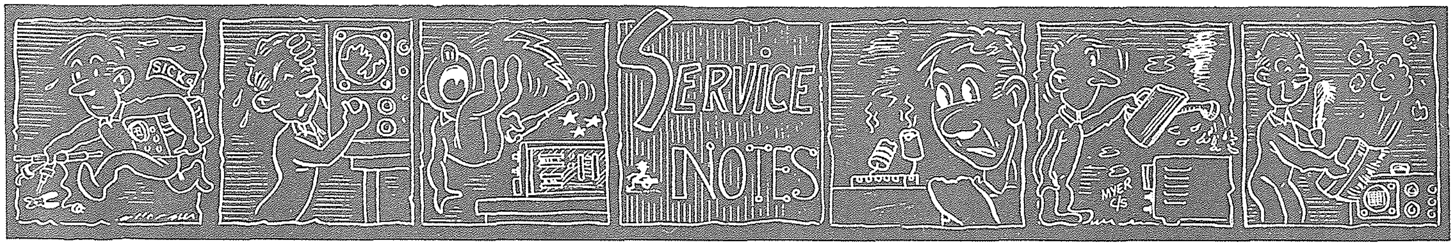


Fig. 9c. Right

Figure 9. The right and wrong way to connect a differential amplifier into a circuit. The ground shown in c is for safety purposes and not essential to the measurement.

Figure 9c shows that the correct way to connect the probes is to couple the shields together at the probe body (but not to instrument ground). This reduces interference by (1) reducing the impedance of the loop formed by the shield, and (2) equalizing the currents through the loop to allow the CMR of the amplifier to reject them. The chassis ground shown in Figure 9c is provided for safety between instruments; it is not essential to the measurement.

(Part 2, which concludes this article, will appear in the forthcoming October, 1965 issue of SERVICE SCOPE.)



TYPE 543B AND TYPE 545B OSCILLOSCOPES — IMPROVEMENT OF AUTOMATIC INTERNAL AND EXTERNAL TRIGGER

TRIGGER

	TRIGGER MODE	TRIGGER REQUIREMENTS
INTERNAL	AC	2-mm deflection from 150 cps to 10 Mc, increasing to 1 cm at 30 Mc. Will trigger below 150 cps with increased deflection.
	AC LF REJECT	2-mm deflection from 30 kc to 10 Mc, increasing to 1 cm to 30 Mc. Will trigger below 30 kc with increased deflection.
	DC	6-mm deflection to 10 Mc.
	AUTOMATIC	5-mm deflection at 150 cps. With increasing deflection, to 10 Mc. Will trigger to 50 cps with increased deflection.
EXTERNAL	AC	0.2 v from 150 cps to 10 Mc, increasing to 1 v at 30 Mc. Will trigger below 150 cps with increased signal.
	AC LF REJECT	0.2 v from 30 kc to 10 Mc, increasing to 1 v at 30 Mc. Will trigger below 30 kc with increased signal.
	DC	0.2 v to 10 Mc, increasing to 1 v at 30 Mc.
	AUTOMATIC	0.5 v at 150 cps. With increasing deflection, to 10 Mc. Will trigger to 50 cps with increased deflection.

Chart 1. Manual specifications of trigger requirements for Type 543B and Type 545B (Time Base A only) Oscilloscopes.

Some Type 543B and Type 545B Oscilloscopes, both conventional and RM models, offer a difficulty in meeting the 5 mm and 0.5 v Manual specifications, respectively on automatic internal and external trigger. (In the Type 545B Oscilloscope the difficulty is confined to the Time Base "A" trigger circuit). A nonsymmetrical trigger-output signal when the TRIGGER MODE control is in the AUTO position, will cause erratic auto triggering. Changing the resistor R38 from a value of 12 k to 18 k (1 w, 5%—Tektronix part number 303-0183-00) will improve the symmetry of the signal and allow stable triggering on the latest Manual specifications. See Chart 1.

After making the change, be sure to note the new value for R38 in the parts list and on the schematic in the Instruction Manual for the instrument.

This improvement is applicable to Type 545B Oscilloscopes, s/n 101 to 1235; Type RM545B Oscilloscopes, s/n 101 to 247; Type 543B Oscilloscopes, s/n 101 to 267; and Type RM543B Oscilloscopes, s/n 101 to 120.

TYPE G PLUG-IN UNIT — INTERMITTENT OSCILLATIONS IN TYPE 544, TYPE 546, AND TYPE 547 OSCILLOSCOPES

Some Type G Plug-In Units will, on occasion, exhibit intermittent oscillation when used in some Type 544, 546, and 547 Oscilloscopes.

A cure for this problem is the addition of two 0.01 μh ferrite cores (Tektronix part number 276-0528-00); one to the lead of L3977 (an 0.18 μh inductor) located between pin 1 of the Type G Unit's amphenol connector and ceramic strip #2, and the other to the lead of L4977 (an 0.18 μh inductor) located between pin 1 of the amphenol connector and ceramic strip #4. Install the ferrite cores on the leads that run between the ceramic strip and the inductors. Give the designation L3978 to the ferrite core added to the lead of L3977. Give the designation L4978 to the ferrite core added to the lead of L4977. Be sure to make the necessary corrections to the schematic and parts list in your Type G Unit's Instruction Manual.

TWO TYPE 3A1 PLUG-IN UNITS X-Y — POWER SUPPLY UNDERLOAD AT HIGH LINE

Type 3A1 Plug-In Units (s/n below 7930 only) will, under certain conditions shunt a little more current around the —100 v power-supply series regulator than the plug-in can actually use.

With two 3A1's installed, the —100 v in the Type 561, Type 561A or Type 564 Oscilloscopes (either conventional or rack mount versions) may fail to regulate when the power source (line voltage) exceeds 115 v. The Type 3A1/Type 3A1 is the only plug-in combination where the underload is significant.

Replacing the wire strap between pin 22 of the Type 3A1's amphenol connector and ground with a 1 k, 2 w, 10% resistor (Tektronix part number 306-0102-00) will reduce the power supply shunting to a level which will allow the use of Two Type 3A1's X-Y. Designate the new resistor R393 and make the necessary addition to the parts list and correct the schematic in your Type 3A1 Instruction Manual.

Generally speaking, two 3A1's is a rather unusual combination for dual-trace X-Y presentations. Type 3A1's have no facility for channel pairing,* phase characteristics do not match for the entire bandpass and the X-axis unit is limited to 8 cm scan (6 cm in units with serial number below 7930). However, in X-Y applications where these limitations are not serious, Type 3A1's below serial number 7930 will operate satisfactorily if modified as noted above. Type 3A1 Units with serial numbers 7930 and higher incorporate the modification.

*For single-trace X-Y presentations or for dual-trace X-Y presentations using a common signal applied to only one channel of one of the axis units, the lack of channel pairing does not present a problem.

INPUT TIME-CONSTANT STANDARDIZER — USE OF UHF-TO-BNC ADAPTERS NOT RECOMMENDED

Tektronix input Time-Constant Standardizers are available for standardizing the input time constant of plug-in having a nominal capacitance of 12 pf, 15 pf, 20 pf, 24 pf, and 47 pf. The individual standardizers for each time constant (except 15 pf X 1 meg) can be obtained with either

UHF or BNC connectors; the standardizer for 15 pf X 1 meg time constant is available with BNC connectors only.

The use of a UHF-to-BNC *adapter* with a Tektronix Time-Constant Standardizer equipped with UHF connectors will add one or two picofarads of capacitance to the plug-in input. This additional capacitance will have an effect on the accuracy of high frequency measurements. The higher the frequency of the applied signal the greater the effect of the additional capacitance.

Use a standardizer of the correct time constant equipped with connectors that match those of the plug-in whose input time constant you wish to standardize.

Listed below are the available Tektronix Time-Constant Standardizers:

	Tektronix Part #	
Input Cap.	UHF	BNC
12 pf X 1 meg	011-0051-00	011-0065-00
15 pf X 1 meg		011-0073-00
20 pf X 1 meg	011-0022-00	011-0066-00
24 pf X 1 meg	011-0029-00	011-0067-00
47 pf X 1 meg	011-0030-00	011-0068-00

TYPE 544, TYPE 546, TYPE 547 OSCILLOSCOPES — MODIFICATION FOR BETTER COMPATIBILITY WITH TYPE W HIGH-GAIN DIFFERENTIAL-COMPARATOR* AND TYPE Z DIFFERENTIAL COMPARATOR PLUG-IN UNITS

The Type W and Type Z Units are capable of more signal-output swing than other plug-in units used with these oscilloscopes.

Off screen signals saturate one or more of the two delay-line-driver transistors (Q1014 or Q1024). This raises the emitter voltage to an excessive level. When the signal waveform comes back on screen, a transient oscillation occurs in the lumped LC formed by L1018, C1035 and C1153. The oscillation-energy excursion diverts emitter current from the delay-line drivers and causes amplifier distortion as shown in Figure 1. The size of the aberration depends on the vertical position of the waveform.

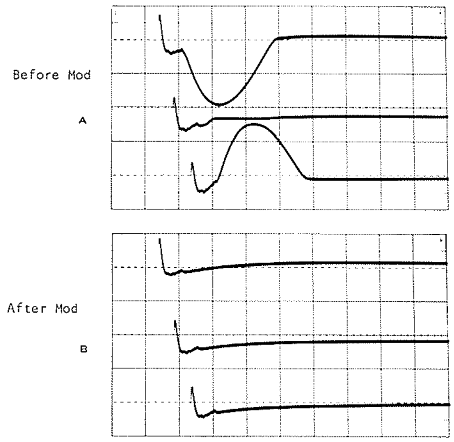


Figure 1. A—Waveform aberration before addition of R1020. B—After addition. Signal Source: 1 Volt Cal, Sweep Rate 1 μs/cm. Type W Unit Control Settings: V_c + 11, INPUT ATTEN 1, DISPLAY A-V_c, MILLIVOLTS/CM 5. (Triple exposure photos.)

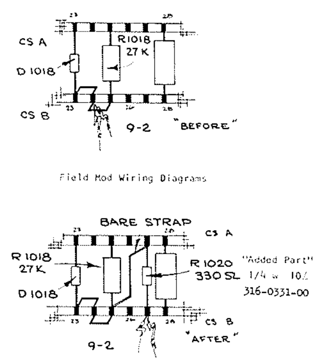


Figure 2. "Before" and "After" sketches showing how to install the 330 Ω resistor R1020.

A 330 Ω, ¼ w, 10% resistor (Tektronix part number 316-0331-00) connected effectively between the junction of the inductor, L1018, and the two capacitors, C1035 and C1153, will act as an oscillation damper and overcome this problem. The "Before" and "After" sketches in Figure 2 show how to install the 330 Ω resistor.

Designate this new resistor R1020 and make the necessary corrections to the parts list and on the schematic of your instrument's Instruction Manual.

This modification is applicable to the following instruments:

TYPE	SERIAL NUMBER
544	101-210
RM544	101-210
546	101-449
RM546	101-150
547	101-940
RM547	101-180

*In conjunction with this modification, Type W Units with serial numbers 101 through 169 will require the addition of an 0.1 μf discap (Tektronix part number 283-0057-00). Type W Units with serial numbers 170 and up have the additional capacitor installed at the factory.

The new capacitor is installed in parallel with R283, a 2-k, 5-w, wire-wound resistor.

To install the new capacitor, turn the Type W Unit upside down on the bench with the front panel facing you. R283 is located on the rear of the chassis to the left and just under the Amphenol connector. Solder one lead of the new 0.1 μf capacitor to the top lug of R283. Solder the other lead to the bottom lug of R283.

Designate the new capacitor C283 and add it to the parts list and schematic of the Type W Unit's Instruction Manual.

NEW FIELD MODIFICATION KITS

TYPE 310 OSCILLOSCOPES — SILICON RECTIFIERS

This modification replaces the selenium rectifiers SR601 or SR660 and SR630 with silicon rectifiers, offering more reliability and longer life.

The modification involves the removal of the old selenium rectifiers and the installation of a new silicon rectifier assembly. The new assembly includes three resistors (R601, R630, and R660), which compensates for a lower voltage drop across the twelve silicon diodes in the new assembly.

This modification is applicable to Type 310 Oscilloscopes, serial numbers 101-10000. Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0195-00.

TYPE 551 OSCILLOSCOPE—SILICON RECTIFIERS

This modification replaces the selenium rectifiers with silicon diodes which offer more reliability and longer life.

The modification involves the removal of selenium stacks SR690, SR660, SR640, SR700 and SR740 and the installation of a new silicon rectifier assembly. The new assembly includes resistors which compensate for a lower voltage drop across the 20 silicon diodes in the new assembly.

This modification is applicable to Type 551 Oscilloscopes, serial numbers 101-2357.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0206-00.

TYPE 551 OSCILLOSCOPES—MULTI-TRACE COMPATIBILITY

This modification assures compatibility between the Type 551 Oscilloscopes and Multi-Trace plug-ins (i.e., 53C, 53/54C, C, CA, M, 1A1, 1A2, etc).

The "Multi-Trace Units Sync Amplifier" V154 (a 6AU6 tube) is replaced with a 6DJ8 duo-triode which supplies Alternate Trace sync pulses to each plug-in.

The isolation of the two sync pulses prevents the differences in the plug-in Alternate-Trace switching circuitry and input impedances from locking up the switching circuitry in one or both of the plug-ins when they are in the Alternate Mode.

This modification is applicable to Type 551 Oscilloscopes, serial numbers 101-5953. A few instruments in the serial number range 5575-5950 were factory modified. Instruments within this range should be checked before the modification is ordered. If V154 is a 6DJ8, the instrument has been modified.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0398-00.

TYPE 524D TELEVISION OSCILLOSCOPES — HIGH-VOLTAGE POWER SUPPLY

This modification includes a new High-Voltage Power Supply which has been redesigned mechanically on a larger chassis.

With the new chassis, one can replace a defective part rather than replace the entire supply and the new layout provides greatly improved ventilation.

The modification is applicable to Type 524D instruments, serial numbers 101-1429.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0058-00.

TYPE 524AD OSCILLOSCOPES — PROBE POWER

This modification supplies the instructions and components for converting the Probe Power Supply in the Type 524AD from AC to DC filament voltage. The DC filament voltage reduces hum to a minimum when the instrument is used with a P500CF cathode-follower probe.

The modification is applicable to Type 524AD instruments, serial numbers 1843-6649.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0274-00.

TYPE 531 AND TYPE 535 OSCILLOSCOPES — B+ DELAY RELAY CONVERSION

This modification provides long-term reliability for K701, the B+ Delay Relay, by installing a more expensive relay designed around tighter specifications.

The modification is applicable to Type 531 Oscilloscopes, serial numbers 101-1280 and Type 535 Oscilloscopes, serial numbers 101-1703.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0085-00.

TYPE 540 SERIES AND TYPE 551 OSCILLOSCOPES — VERTICAL AMPLIFIER BIAS

This modification increases the bias on the 6DK6 tubes in the distributed amplifiers. This imparts a greater reliability to the tubes and a better stability to the Vertical Amplifier.

It is applicable to the following instruments:

Type	Serial Numbers
541	6475 - 7022
543	101 - 181
545	9292 - 11691
RM41	101 - 142
RM45	101 - 205
551*	101 - 291

*The Type 551 instrument has two identical main amplifiers. Order two modification kits for this instrument.

Order through your local Tektronix Field Office, Field Engineer, Representative, or Distributor. Specify Tektronix Part Number 040-0191-00.

TYPE RM567 OSCILLOSCOPES — IMPROVED FRAME PLATES

This modification supplies improved frame plates for the Type RM567 Oscilloscopes. The new left-hand frame plate contains a removable panel for ease of access to the Vertical plug-in unit during calibration. The new right-hand frame plate provides better access to the 6R1A Digital Unit's plug-in cards and their Bendix connectors.

Please note that, in order to accommodate the above improvements, the chassis tracks are relocated on both frame plates. The rack-mounted portion of the tracks must be relocated in the rack in order to maintain the same position of the instrument in the rack.

This modification is applicable to Type RM567 instruments with s/n's 101-2029.

Order through your local Tektronix Field Office, Field Engineer, Representative, or distributor. Specify Tektronix Part Number 040-0378-00.

TYPE 524D AND TYPE 524AD OSCILLOSCOPE — IRE RESPONSE NETWORK

In this modification a new IRE Response Network installed in the oscilloscope changes the roll-off characteristics to conform with the Revised Standard '58 IRE 23.1 as amended July 1, 1961.

This modification kit is applicable to Type 524D Oscilloscopes, s/n's 1400 - 1842 and Type 524AD Oscilloscopes, s/n's 1843 - 6835. It is also suitable for Type 524D's with s/n's below 1400 that have the four-position VERTICAL RESPONSE switch installed (Tektronix Field Mod Kit 040-057). It is *not* for use with instruments which have Tektronix Field Mod Kit 040-271 (Four - Position Vertical Selector Swtch) installed.

Order through your local Tektronix Field Office, Field Engineer, Representative, or Distributor. Specify Tektronix Part Number 040-0343-00.

Service Scope

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USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 34 PRINTED IN U.S.A OCTOBER, 1965

INTRODUCTION TO OSCILLOSCOPE DIFFERENTIAL AMPLIFIERS

by

Joseph E. Nelson

Tektronix Product Technical Information Group

This is the second and concluding half of an article describing oscilloscope differential amplifiers. The first half, which appeared in the August, 1965 issue of SERVICE SCOPE, discussed differential amplifier characteristics such as common mode rejection ratio, voltage range, frequency range, etc. The effect of probes and filters as well as the importance of source impedance was also discussed.

This second half of the article presents several applications that either require a differential amplifier or can more effectively be performed with a differential amplifier.

Part II
Applications

Differential Measurements

A differential input measurement is one in which the two inputs to a differential amplifier are connected to two points in a circuit under test and the amplifier displays the difference voltage between the points. In this type of measurement each input of the amplifier acts as a reference for the other and ground connections are only used for safety reasons. (Note: The term "differential input" is synonymous with "floating input".)

One application in which differential input was used to advantage concerned the power source of an electric railroad engine. This was a 3-phase transformer system with a solid-state controller that consisted of strings of silicon-controlled rectifiers. The measurement problem was to examine the individual rectifier switching characteristics and note risetime, ringing, and point of occurrence. The circuit (simplified) is shown in Figure 10.

The voltage across the silicon controlled rectifiers before switching was approximately 250 volts; however, the entire system was several kV off ground. Because of this latter voltage, two P6013 high-voltage X1000 probes connected to a differential amplifier were used. With this arrangement, the amplifier sensitivity was increased to a point where the switching transients could be seen and photographed.

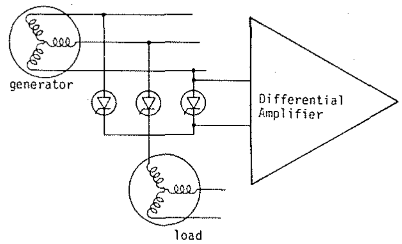


Figure 10. A differential amplifier connected for a differential input measurement in the power system of an electric train.

Slideback Technique

Slideback can be defined as the technique of applying a dc voltage to one input of a differential amplifier in order to change the vertical position on the crt screen of the signal applied to the other input. For example, if an oscilloscope differential amplifier is set for a vertical sensitivity of 0.01 V/cm (trace on-screen) and a +1 volt dc voltage is applied to input A, the trace will be deflected upward off screen. If a +1 volt dc voltage is now applied to input B, the trace will return on screen. One might say that the signal *slides back* on-screen as a result of the voltage (slide-back voltage) applied to input B. Also, and this is the principle of operation, the dc voltage applied to input B is common-mode with that of input A, and thus, both are rejected by the amplifier.

A measurement problem often encountered is the need to examine a pulse (say 0.01 volt height) that is superimposed on a dc level (say +1 volt), and make the measurement with the oscilloscope's amplifier dc-coupled.

If this composite signal is applied to input A of a differential amplifier and a +1 volt dc voltage (slideback voltage) is applied to input B, the two dc levels are common-mode and thus rejected, and only the pulse remains. In this situation, the vertical sensitivity could be increased to 5 mV/cm where the pulse would have a height of 2 centimeters.

Because the dc level of the composite signal in this example can be any voltage up to the maximum common-mode input voltage specified for the amplifier, the slideback voltage should be adjustable from zero volts up to this maximum common-mode input voltage level. With this source in a separate black box, an arrangement similar to that shown in Fig. 11 can be set up.

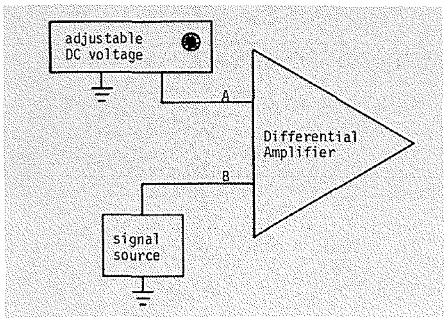


Figure 11. Circuit connections for the slide-back technique described in the text.

A second example of slideback technique concerns the detailed examination of small amounts (1 millivolt) of modulation superimposed on a pulse or square wave of +1.0 volt pulse height. If this pulse is applied to input A of a differential amplifier (at 0.2 V/cm) and the "black box" slideback voltage source applied to input B, the pulse displayed on the crt screen can be moved vertically by varying the slideback voltage. If the sensitivity is now increased to 1 mV/cm, the top of the pulse will go off-screen. It can be returned on-screen by adjusting the slideback voltage. Since the sensitivity remained at 1 mV/cm, the sought-for modulation on top of the pulse should occupy one vertical centimeter. (See over-scan limitations later in text).

This example introduces the concept of *effective* crt screen height. A 1 volt pulse was displayed on the crt screen at a sensitivity of 1 mV/cm. Through use of the slideback voltage any portion of the pulse could have been brought on-screen. Since the pulse height was 1 volt and the sensitivity 1 mV/cm, the effective screen height was 1000 cm. The formula for finding the effective screen height is:

$$\frac{\text{Slideback Voltage}}{\text{Vertical Sensitivity}} = \text{Effective screen height}$$

Applying this formula to the Tektronix Type W High-Gain Differential Comparator Plug-In Unit comes out as follows:

$$\frac{\pm 11.000\text{ V dc}}{.001\text{ V/cm}} = 11{,}000\text{ cm maximum}$$

Differential Comparator

Carrying the slideback technique one step further by making the slideback voltage a calibrated supply with a precision dial and building this into the amplifier makes the device a differential comparator. This instrument, sometimes called a slideback voltmeter, can make both ac and dc voltage measurements. The precision of these measurements in terms of a ± percent can be calculated from the differential comparator specifications (attenuator accuracy, comparison voltage accuracy, etc.; see example later in text).

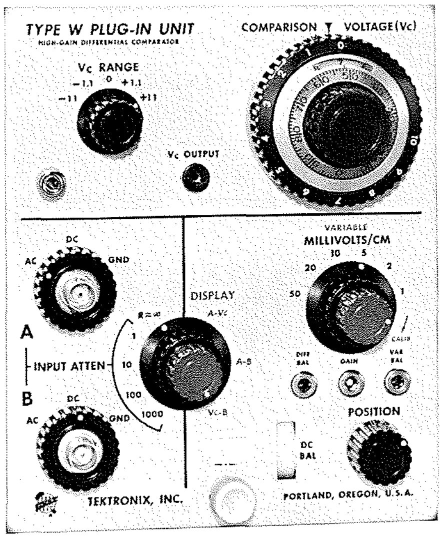


Figure 12. The Tektronix Type W High-Gain Differential Comparator Plug-In Unit.

Operation of the differential comparator as a precision voltmeter consists of applying the signal to be measured to input A with the front panel controls set for a comparison measurement. This internally connects the comparison (slideback) voltage (Vc) to input B. Figure 12 shows the front panel of the Type W High-Gain Differential Comparator Plug-In Unit. Note that the Vc range switch not only changes the range but also can change the polarity of the comparison voltage. This allows comparisons with both positive-going and negative-going signals.

In dc voltage measurements the signal-carrying cable is connected to the A input connector with the input attenuator at 1, but with the input coupling switch set to GND. The display switch is set to A-Vc which means a comparison between whatever signal is present at input A and the comparison voltage. The precision dial is set to zero and the position control used to move the trace (free-run) to the center vertical reference graticule line. This zero voltage line is the start and finish point of a measurement. All that remains is to turn the coupling switch of input A to dc, which allows the trace to disappear off-screen; then slide the trace back on-screen to the reference line with the precision dial. The value of the unknown voltage is the reading of the precision dial.

AC voltage measurements that use a-c input coupling have signals that pass through both polarity. To measure peak-to-peak, the comparison voltage dial is adjusted to bring one peak to a graticule reference line and the dial reading is noted. Then the Vc range switch is turned to the opposite polarity and again the precision dial is used to move the peak to the same graticule reference line. The dial reading is noted, and this reading, added to the first dial reading, equals the peak-to-peak voltage.

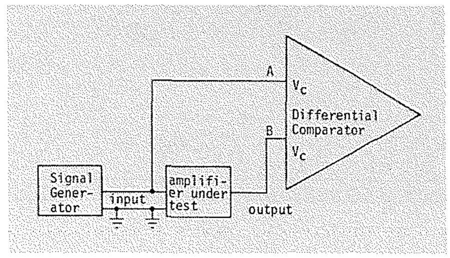


Figure 13. Test setup to measure amplifier gain.

An application in which the two inputs to a differential comparator are used to advantage is the gain setting of low-frequency amplifiers. Figure 13 shows a suggested arrangement in which input A of the comparator is used to measure the input signal (A-Vc Display) and then input B of the comparator is used to measure the output (B-Vc Display).

A second application is the measurement of transmitter carrier power. In the following description, correction must be made for carrier frequencies that are above the flat response portion of the amplifier passband. In addition, since this is a voltage measurement, the transmission line should be terminated so as to minimize standing waves. A "Tee" connector is inserted in the output transmission line and used to couple the *input of the differential comparator, through* attenuator probes, to the line center conductor. Figure 14 shows the connections.

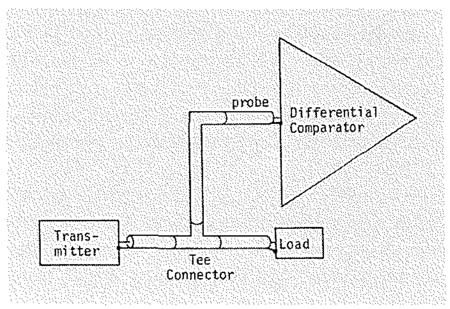


Figure 14. Test setup to measure transmitter power with a differential comparator.

The peak-to-peak sine wave carrier is measured with the differential comparator and the results used in the following formula:

$$\frac{\left[\frac{\text{P-P Voltage}}{2} \text{ X } 0.707\right]^2}{\text{Z of System}} = \text{Power}$$

For example, if 200 volts peak-to-peak carrier voltage is measured with a differential comparator and the transmission system is 50 Ω, the power is:

$$\frac{\left[\frac{200}{2} \text{ X } 0.707\right]^2}{50\,\Omega} = \frac{70.7^2}{50\,\Omega} = \frac{4998.5}{50\,\Omega} = 99.97\text{ W}$$

At low power, as in this example, the signal can be connected directly into the comparator, but at higher power levels attenuator probes must be used and the tolerance of these probes should be included in the power computation.

Limitations of Differential Comparators

Overscan Recovery is a characteristic of differential comparators that states the time required for the amplifier to recover to within some amount of voltage after a return to the screen. For example, in the discussion of effective screen height, the top of a pulse was brought on-screen by use of the slideback voltage. When the pulse falls and rises again, the rapid change causes peaking and ringing of the pulse leading edge. The overscan recovery specifications state that this ringing will reduce to within 10 millivolts after 300 nanoseconds (W unit). Because of this, measurements should not be made in the first 300 nanoseconds after the leading edge of the pulse reappears on the screen.

Rate of Rise is a specification of some differential amplifiers (Tektronix Type Z Differential Comparator Plug-In Unit) that is specified in volts per time. For instance, the maximum rate of rise of the Z unit is 1 volt in 7 nanoseconds. Signals that exceed this rate will cause grid current and subsequent waveform distortion. Similarly, rate of fall of the Z unit is 1 volt in 5 nanoseconds.

Recovery from the conditions caused by pulses that exceed these rates takes an amount of time that is proportional to the pulse amplitude. For example, a 10.0 volt pulse that exceeds the rate of rise specification (say 1.0 volt per 7 nanoseconds) would cause the first 70.0 nanoseconds, measured from the start of the rise, to be unusable.

Differential Comparator Measurement Accuracy

The accuracy of a differential comparator measurement depends on several characteristics of the amplifier. These are: comparison voltage (Vc) and linearity accuracy, CMRR, drift, and input attenuator accuracy. In addition to these characteristics which affect *all* measurements, certain other factors must be considered when measuring pulse amplitude. These include: errors due to amplifier recovery, shift in reference level, and input attenuator compensation.

Each of these characteristics, where applicable, can influence the overall accuracy of a measurement. By adding the tolerance figures of each characteristic, a "worst case" figure can be obtained for any particular comparator measurement. For example, the overall accuracy of a dc level measurement of approximately 25 volts (2.5 volts after X10 input attenuation) using a W unit would be:

Operator resolution (1 mm at 10 mV/cm)	0.04 %
Vc supply accuracy	0.15 %
Vc readout linearity (0.05% of 11.0 volt range)	0.22 %
CMRR (20,000:1)	0.005%
Reference drift (1 mV)	0.04 %
Input attenuator accuracy	0.05 %
Overall accuracy	0.505%

A pulse measurement in which the signal was approximately 25 volts (2.5 volts after X10 input attenuation) with a width of 0.75 microseconds would be:

Operator resolution (1 mm at 10 mV/cm)	0.04 %
Vc supply accuracy	0.15 %
Vc readout linearity (0.05% of 11.0 volt range)	0.22 %
CMRR (20,000:1)	0.005%
Reference drift (1 mV)	0.04 %
Input attenuator accuracy	0.05 %
Input attenuator compensation (1% with 20 microseconds time constant)	1.00 %
Recovery offset (10 mV)	0.40 %
Reference level shift (5 mV)	0.20 %
Overall accuracy	2.105%

The large influence of the input attenuator compensation (1%) in this example is due to the narrow width of the signal. When this width is increased to 100 microseconds, the overall accuracy figure is 0.958%.

The tolerance figures used to compute the overall figures can be obtained from the instrument instruction manual. The following formulas should be used to convert these figures to percentages where necessary.

$$\text{Vc readout linearity} = \frac{\text{Vc linearity (\%)} \times \text{range in volts}}{\text{Vc}}$$

CMRR error is the reciprocal of the CMRR expressed as a percentage

CMRR error (%) = 1/CMRR

$$\text{Reference drift} = \frac{\text{drift (volts)}}{\text{Vc}} \times 100\%$$

$$\text{Error due to amplifier recovery} = \frac{\text{offset (volts)}}{\text{Vc}} \times 100\%$$

In the above formula, offset refers to the voltage that remains due to overdrive recovery at the time a measurement is made.

$$\text{Error due to reference shift} = \frac{\text{shift (volts)}}{\text{Vc}} \times 100\%$$

Measuring Potentiometer Conformity

A differential amplifier combined with a storage oscilloscope and test jig can be used to measure linearity, tracking, and backlash of potentiometers. The test setup is similar for all three measurements and is shown in Figure 15.

Linearity (independent): This term is defined as the maximum deviation, expressed as a percent of the total applied voltage, of the actual function characteristic from a straight reference line with its slope and position chosen to minimize the maximum deviation over the actual electrical travel, or any specified portion thereof*.

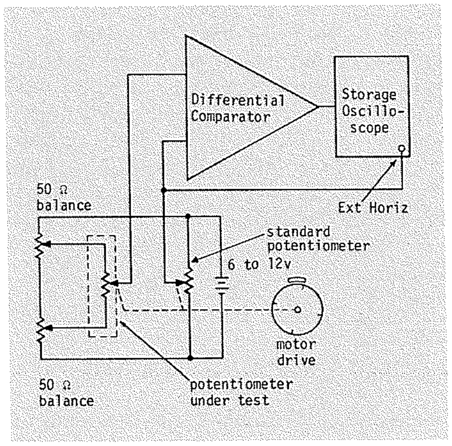


Figure 15. Test setup to check potentiometers for linearity, tracking, and backlash.

The test for linearity is a comparison between a standard and unknown. A standard potentiometer and the potentiometer to be tested are connected in the test circuit with their shafts mechanically coupled together. Both controls are set at the end of their shaft rotation (zero volts out) and the differential amplifier and the oscilloscope are adjusted to position the start of the trace at the vertical midline. Since the horizontal trace is driven by the voltage from the standard potentiometer, the horizontal amplifier should be adjusted to make the complete rotation of the potentiometers correspond to degrees, i.e., degrees per horizontal centimeter. Thus, deviations in linearity can be described in terms of voltage excess at specific points of shaft rotation. For example, a report on a test could read "20 mV beyond tolerance at 200° from ccw end."

With both potentiometers coupled together and connected to the amplifier, it only remains to determine the sensitivity setting of the amplifier before the actual test is run. This setting depends on the tolerance of the potentiometer under test. For example, ±0.1% linearity would mean that the difference voltage between standard and unknown should not exceed 0.1% of the total voltage applied across the controls. With 10.0 volts as a source voltage, the allowable deviation is ±0.010 volt. With the differential amplifier sensitivity set to 5 mV/cm, the tolerance is ±2 vertical centimeters from the midline.

The test is completed by turning the two controls throughout their range, either by hand or driven by a slow-speed motor. The interpretation of the trace is simply whether it is within the tolerance limits prescribed.

*From: *Wirewound Precision Potentiometers,* an Industry Standard published by the Precision Potentiometer Manufacturers Assn.

At this point the backlash** of the potentiometer can be checked by reversing the rotation of the control shafts and returning them to their starting point. If no backlash is present, the new trace will exactly superimpose over the first. But with backlash, the new trace will be shifted, and the amount of this shift is a measure of the backlash. This same check can be made after the tracking measurement described below:

Tracking: This term is defined as the difference at any shaft position between the output ratios of any two commonly actuated similar electrical elements expressed as a percentage of the single total voltage applied to them.

In tracking, the measurement is: how closely do two or more ganged potentiometers have the same output voltage as they are rotated throughout their range? The test setup is the same as that shown in Figure 15. The specification is usually given as: should track within some percentage such as 1.0%. With this specification and 10 volts applied across the potentiometers under test, the difference voltage should not exceed 1% of 10 volts or 0.1 volt. At these figures, the sensitivity of the differential amplifier should be set to 0.05 V/cm. This corresponds to ±2 vertical cm.

Backlash can also be checked as described above under linearity. However, in this case the results are total backlash for both controls.

**Backlash: Defined as the maximum difference in a shaft position that occurs when the shaft is moved to the same acutal output ratio point from opposite directions. This measurement excludes the effect of resolution and contact width.

About the Author

Joseph E. Nelson originally trained as a biochemist at Massachusetts Institute of Technology while a member of the U.S. Army. This was concurrent with 6 years as a clinical chemist in army laboratories during World War II.

At the conclusion of World War II, he entered electronics with stress on communications. During the fifties, while with Northrop Aircraft he became associated with standards and measurement techniques. He has published several articles on primary and secondary standards and their relationship to the calibration laboratory.

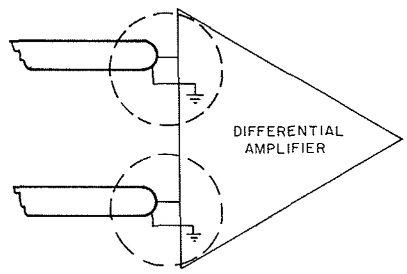
With Tektronix he has served as a technical writer of instruction manuals and currently as an engineering writer of technical application and instructional articles.

Drawing on his original training as a chemist, he is now active in seeking ways to apply electronic instruments such as differential amplifiers to the field of analytical chemistry.

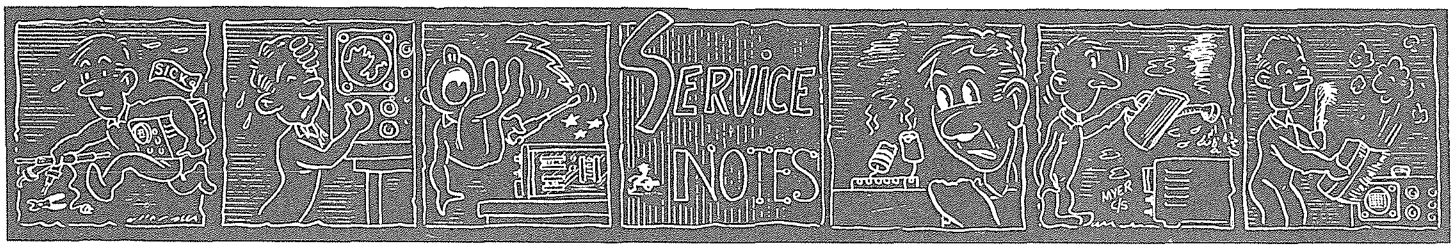
—The Editor

ERRATA

Figure 9 in Part I of Introduction to Oscilloscope Differential Amplifiers published in the August 1965 issue of Service Scope is incorrectly drawn. The probe shields, in all cases, should be shown grounded to the differential amplifier chassis as follows:



Also in the article, Introduction to Oscilloscope Differential Amplifiers under the heading Probes and Common-Mode Rejection, 2nd paragraph, page 3, the statement, "Tektronix Type 190B Sine-wave Generator at 1 kHz," should read, "General Radio Type 1210C Sine-Wave Generator set to 1 kHz."



IEEE STANDARD SYMBOLS FOR UNITS

In this issue of SERVICE SCOPE we initiate our use of the IEEE STANDARD SYMBOLS FOR UNITS. Future issues of SERVICE SCOPE will continue to use this standard.

The IEEE publication *IEEE Transactions on ENGINEERING WRITING AND SPEECH*, Volume EWS-8, No. 1, June 1965, presented the Symbols in an article entitled "IEEE Standard Symbols for Units". The Symbols first appeared in the publication "IEEE Standard Symbols for Units, No. 260 (Revision of Part of 51 IRE 21 S1), January 1965".* The Standard Symbols for Units was compiled by the Abbreviations Subcommittee of the IEEE Symbols Committee. It represents four years of careful consideration, thorough discussion and plain hard work by many people. It is consistent with the recommendations of the International Organization for Standardization (ISO) and with the current work of the International Electrotechnical Commission (IEC).

Tektronix, Inc. has decided to follow the lead of the IEEE and adopt the Symbols for Units as a standard for use in our texts, equations, in graphs and diagrams, on the panels and name plates. In so doing, we admit, along with the IEEE, that the Symbols for Units is not perfect. We do believe, however, that the potentialities it offers for better, unambiguous communication are great.

* Reprints are available ($1.00 for IEEE members; $3.00 for nonmembers) from IEEE headquarters, 345 East 47 Street, New York, N.Y. 10017.

TEKTRONIX PARTS REPLACEMENT KIT 050-0226-00 — ATTENTION U.S. AIR FORCE INSTRUMENT-CALIBRATION AND REPAIR PERSONNEL

The instruction sheet for parts replacement kit 050-0226-00 contains an error. This kit replaces the selenium rectifier stack SR741 or SR701 in the Type 180A Time-Mark Generator, or SR460 in the Type 315D Oscilloscope with a silicon rectifier bridge. The kit was produced as a special order for the U.S. Air Force.

The error in the instruction sheet is important only when the kit is used to replace SR701 in the +350-V supply of the Type 180A Time-Mark Generator.

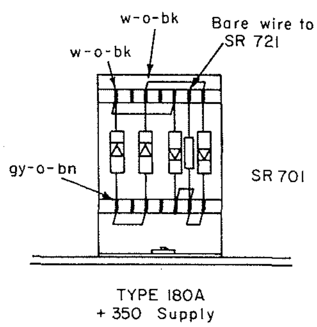


Figure 1 (a).

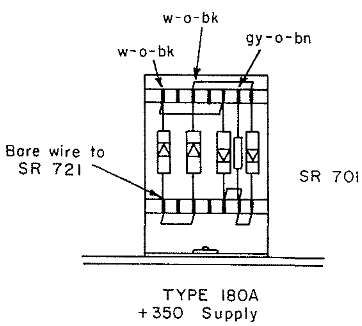


Figure 1 (b).

Figure 1 (a) is a reproduction of the SR701 rectifier diagram as it appears in the instruction sheet. Here the plus (gy-o-bn wire) and minus (bare wire strap) leads are called out incorrectly. With SR701 connected in this manner, the resistor R701 will smoke and burn. Figure 1 (b) shows SR701 connected properly. Notice that the plus and minus leads are connected the reverse of the way shown in Figure 1 (a).

Our thanks to Sgt. Haist of the Portland Air Force Base for calling this error to our attention.

TYPE 1A1 DUAL-TRACE UNIT—VAR. ATTEN. BAL. CONTROL REPLACEMENT

The following information applies to Type 1A1 Dual-Trace Units with serial numbers below 360.

R130 (Channel 1) and R230 (Channel 2) are the parts list and schematic designations for the potentiometers that serve as the VAR. ATTEN. BAL. controls for Channel 1 and Channel 2 in the Type 1A1 Unit.

Starting with serial number 360, these potentiometers were replaced with a more-serviceable potentiometer (Tektronix part number 311-0459-00). This is the potentiometer you should order when replacing R130 or R230 in units with serial numbers below 360. You should also order an adapter nut (Tektronix part number 220-0420-00) for each replacement potentiometer. The nut used to hold the original potentiometer will not fit the replacement.

TYPE 555 DUAL-BEAM OSCILLOSCOPE — FAILURE OF INTENSITY CONTROL TO TURN OFF BEAM

The Type 555 Oscilloscope has two INTENSITY controls—one for the Upper Beam and one for the Lower Beam. Inability of one of these controls to turn off its associated beam may be caused by failure of the type 5642 vacuum tube in the INTENSITY control's circuit. Schematic designation of this tube is V822 in the Upper Beam's INTENSITY control circuit or V922 in the Lower Beam's INTENSITY control circuit. Replacement of the defunct 5642 tube will generally clear up the problem.

TYPE M FOUR-TRACE PLUG-IN UNIT—CHANNELS A, B, C, AND D: CROSS-TALK REDUCED

The addition of four 0.01 μF capacitors (Tektronix part number 283-0050-00) will eliminate high-frequency cross-talk (approximately 0.5% at 20 MHz) in early Type M Four-Trace Units, serial numbers 101-3120.

To add the capacitors, install a #2 solder lug (Tektronix part number 210-0001-00) under the socket-mounting screw nearest pin 2 of each V5323 tube socket. V5323 is a type 7586 vacuum tube and there are four of them—one for each channel—in a Type M Unit. Solder an 0.01 μF capacitor between pin 2 of the tube socket and the newly installed solder lug of each V5323 tube.

Designate the capacitor C5323 and add it to the parts list and schematic of the Type M Unit's Instruction Manual.

Type M Units, serial numbers 3120 and up have this modification installed at the factory.

TYPE 3A3 DUAL-TRACE DIFFERENTIAL AMPLIFIER — UNSTABLE TRACE AND DC SHIFT

Some Type 3A3 Dual-Trace differential amplifier units within the serial number range 101-969, will sometimes exhibit an unstable trace and evidence of dc shift when the attenuator POSITION control is adjusted. This, when it occurs in Channel 1, is caused by oscillations in transistor Q143 and (or) Q243, and, when it occurs in Channel 2, by oscillations in transistors Q343 and (or) Q443.

The cure is the addition of 4 ferrite cores (Tektronix part number 267-0532-00). Install a ferrite core on the #22 wire strap that runs between the emitter pin and the ceramic strip of each of the four transistors, Q143, Q243, Q343, and Q443. Designate the cores L143, L243, L343, and L443 as shown in Figure 2. Add them to the parts list and to the Channel 1 Input Amplifier and the Channel 2 Input Amplifier schematics in your Type 3A3 Instruction Manual.

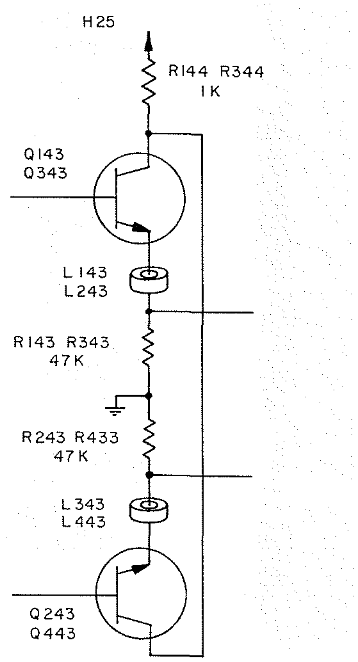


Figure 2. Partial schematic showing installation of ferrite cores to emittter leads of Q143, Q243, Q343, and Q443 in the Type 3A3 Unit.

TYPE 3A74 FOUR-TRACE PLUG-IN UNIT — PROTECTION AGAINST LARGE POSITIVE TRANSIENTS

The addition of a 1 k, ½ W, 10% resistor (Tektronix part number 302-0102-00) in early Type 3A74 Plug-In Units reduces the possibility of a failure of the Channel 1 trigger-amplifier transistor, Q503, caused by a large positive transient at the input connector. The new resistor replaces the wire strap between the collector and ground of the trigger-amplifier transistor Q503.

Designate this new resistor R501 and add it to the parts list and schematic in the Type 3A74 Instruction Manual.

This improvement is applicable to Type 3A74 Units, serial numbers 101-1309. In Units with serial numbers 1310 and up the protection is installed at the factory.

TYPE 2B67 TIME-BASE UNIT—PROTECTION FOR DIODE D126

A grid-to-plate short in V135 (a 6DJ8 vacuum tube) in the Type 2B67 Time-Base Unit, can cause damage to the diode D126, when the MODE switch is in the NORMAL position.

Changing R137, a 100 Ω ½ W, 10% resistor, to a 220 k, ½ W, 10% resistor (Tektronix part number 302-0224-00) and paralleling it with a 68 pF, 500 V speed-up capacitor (Tektronix part number 281-0549-00) will protect D126 against this damage. R137 is located between pins 1 and 7 of V135.

Designate the new capacitor C137 and add it to the parts list and schematic in your Type 2B67 Instruction Manual. Note also, in these sections of the Instruction Manual, the changed value for R137.

This information is applicable to Type 2B67 Units with serial numbers below 15380. Instruments with higher serial numbers have the new-value resistor and paralleling capacitor installed at the factory.

NEW FIELD MODIFICATION KITS

TYPE 544, TYPE 546, and TYPE 547 OSCILLOSCOPES — VERTICAL-OUTPUT AMPLIFIER PROTECTION

This modification protects the output transistors Q1114 and Q1134 in the Vertical Amplifiers of the above instruments (both conventional and rackmount versions) from excessive collector voltage. The excessive voltage is caused primarily by grid-to-cathode shorts in V707, a type 6080 series-regulator tube, in the +225 V supply.

The protective circuit consists of a new transistor, Q1109, in series with the collector supply of the output-amplifier transistors Q1114 and Q1134. The base of Q1109 is returned to +100 V through a new 105 V zener diode (D1109). Should the +225 V supply go out of regulation, the fixed base voltage of Q1109 limits the output transistors collector voltage to approximately 205 V.

The new transistors and associated circuitry are all mounted on a small sub-chassis. This sub-chassis mounts near the rear of the input Vertical-Amplifier chassis using an existing hole in this chassis.

This modification is applicable to the following instruments:

TYPE	SN's
544	101-374
RM544	100-119
546	100-449
RM546	100-149
547	100-2343
RM547	100-259

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0405-00.

ALTERNATE/CHOPPED COMPATIBILITY REWORK

This modification kit is applicable to Type 531, Type 535, Type 541 and Type 545 Oscilloscopes, sn's 101-20000, that have had Field Modification Kit 040-0403-00 (see SERVICE SCOPE, issue #5, December, 1960) installed; and, Type RM31, Type RM35, Type RM41 and Type RM45, sn's 101-1000, that have had Field Modification Kit 040-0198-00-01 (see SERVICE SCOPE, issue #5, December, 1960) installed.

Installation of the Alternate/Chopped Compatibilty Rework field modification kit gives to these instruments the ability to utilize the Alternate-Trace feature of the Type 1A1 and Type 1A2 Dual-Trace Plug-In Units.

These plug-in units require an alternate-trace sync pulse at pin 8 of the oscilloscope's plug-in interconnecting socket. This pulse is not available in the oscilloscopes listed above.

The Alternate-Trace/Chopped Compatibility Rework field modification kit corrects this situation by replacing the 6J6 tube in the V78 position with a 6DJ8 tube and changing the oscilloscope's Multi-Trace sync and Chopped-Blanking circuitry to conform to that in the Type 531A, Type 535A, Type 541A, Type 545A/B, Type 546, Type 547, etc., oscilloscopes.

To install the 6DJ8 tube it is necessary to enlarge the socket-mounting hole and replace the original socket for the V78 position with a 9-pin type.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0404-00.

12 KV HIGH VOLTAGE

This modification is applicable to the following oscilloscopes:

TYPE	SN's
541	101-20000
RM41	101-1000
541A	20000-up
RM41A	1001-up
543	101-3000
RM43	101-1000
543A	3001-up
RM43A	1001-up
545	101-20000
RM45	101-1000
545A	20000-up
RM45A	1001-up
581	101-3974
581A	3975-4999*
585	101-5968
585A	5969-8999*
RM85A	101-999*

The modification replaces the original 10-kV high-voltage transformer with a 12-kV transformer, thus increasing the crt accelerating potential to provide greater intensity at fast sweep speeds.

The vertical and horizontal deflection sensitivities of the crt are reduced approximately 15%; a special graticule (supplied with the kit) is used to compensate for this reduction. All front panel and manual references to "CM" should be interpreted as "DIV". For example, read "TIME/CM" as "TIME/DIV".

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0176-00.

*NOTE: This kit can be installed in instruments above these serial numbers provided they have external-graticule crt's. It can also be installed in those instruments above these serial numbers provided *the instrument is first converted to an external-graticule crt.*

The external-graticule crt must be ordered separately as follows:

Crt, external grat. P31 phosphor (T5810-31), Tektronix part number 154-0354-00.

Crt, external grat. P11 phosphor (T5810-11), Tektronix part number 154-0230-00.

Steps 17 through 22 on page 4 of the modification's instruction sheet tell how to remove the internal-graticule crt and install the external-graticule crt replacement.

TYPE 530 AND TYPE 540 SERIES OSCILLOSCOPES — DC FAN MOTOR

This modification supplies a dc fan motor to enable the following instruments to operate on 50-400 cycle power lines.

TYPE	SN's
531	5001-20000
RM31	101-1000
533	101-3000
RM33	101-1000
535	5001-20000
RM35	101-1000
541	5001-20000
RM41	101-1000
543	101-3000
RM43	101-1000
545	5001-20000
RM45	101-1000

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0255-00.

THE TEKTRONIX TYPE 453 DUAL-TRACE DC-TO-50 MHz PORTABLE OSCILLOSCOPE

Until rather recently, the need for a sophisticated oscilloscope offering DC to 50 MHz bandpass and versatile capabilities was, for the most part, confined to the laboratory. The need today however, for an instrument with these qualities, extends beyond the laboratory into many areas of servicing, research and development. Examples of these areas are: computer installations, radar and guidance systems, telemetry and microwave equipment, commercial aircraft, aerospace work, and defense systems.

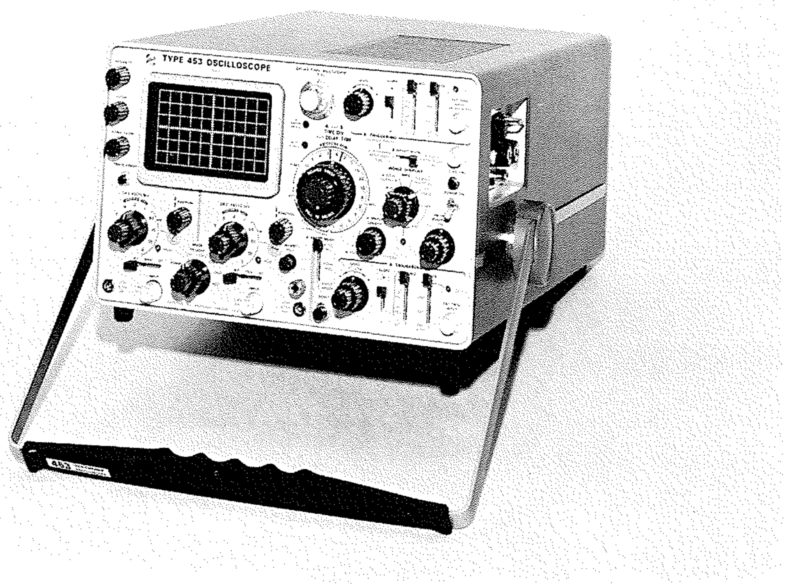
In addition to the capabilities stated above, an instrument designed for use outside the laboratory must be capable of withstanding a wide range of environmental conditions, be ruggedly constructed and compactly contained in a highly portable package. The Type 453 Dual-Trace, DC to 50 MHz Oscilloscope is just such an instrument in just such a package. It provides the highest performance compatible with cost and portability. It possesses rather extended environmental capabilities and delivers information with laboratory accuracy.

The vertical amplifier system of the Type 453 Oscilloscope combines in one oscilloscope many features normally available only in a plug-in type instrument using several different plug-in units. These features amongst others are: (a) high gain, low bandwidth; (b) medium gain, high bandwidth; (c) low gain, high bandwidth; (d) medium gain, medium bandwidth, dc coupled; (e) dual trace, low gain, high bandwidth; and, to a not inconsiderable degree, differential input capability.

Here, briefly, are some of this instrument's characteristics:

1). Dual-Trace Vert.
2). Signal Delay
3). 50 MHz basic Vert. bandwidth
4). 5 mV/div basic Vert. sensitivity
5). 1 mV/div maximum Vert. sensitivity at reduced bandwidth (One Channel only —Ch 1 and Ch 2 cascaded).
6). 5 sec/div minimum sweep rate
7). 10 nsec/div maximum sweep rate (with X10 magnifier).
8). Full bandwidth triggering
9). Normal sweep plus delayed sweep
10). 6 x 10 div* (4.8 x 8 cm) vert. and hor. crt display size
11). 10 kV crt accelerating voltage
12). Only 100 W power consumption
13). 31 lbs weight complete with accessories

The Type 453 maintains its full bandwidth of 50 MHz to a sensitivity of 20 mV/div, and drops to 45 MHz and 40 MHz at 10 mV/div and 5 mV/div respectively.



It presents the usual five vertical display modes of dual-trace instruments—CH 1, CH 2, ALT, CHOP, and ADDED. CH 2 has polarity selection to provide some differential amplifer performance in the ADD Mode. Sampling rate for the CHOP Mode is 0.5 MHz rather than 1 MHz—a relaxation that reduces the loss of brightness due to chopped transient blanking.

Internal triggering may be selected between either the displayed signal or that of a single channel. The latter selection enables stable triggering when observing time related events in either of the dual-trace modes.

The input impedance of 1 megohm paralleled by 20 picofarad is compatible to previous laboratory instruments.

All previous passive probes adjustable to this input capacitance are applicable to the Type 453 Oscilloscope. However, a new 10X probe, the P6010, was designed specifically to provide a smaller tip for use with the increasingly compact equipment that it is anticipated this oscilloscope will service. This new probe's tip is pencil size and free of adjustment.

Capacitance compensation is accomplished at the scope end of the probe. Two of these probes are shipped with each Type 453 Oscilloscope. Bandwidth figures quoted here include the effect of the P6010 probe.

The Type 453 utilizes a four-inch, rectangular-faced crt which features an internal graticule illuminated with edge lighting. The significantly improved display contrast of this crt provides enhanced viewing under high ambient light conditions. In addition, a fine mesh filter, placed in front of the crt, attenuates bothersome external reflections for easier viewing.

The Type 453 will operate on either 115 V or 230 V nominal power-line supplies; and, without the need to make internal wiring changes. Two power cords are shipped with the instrument, one for 115 V line supplies and one for 230 V line supplies. Selection of the correct power cords automatically adapts the instrument's power supply to the available line supply. The oscilloscope power supply automatically operates at either nominal voltage, when the appropriate power cord is inserted. A rear-panel switch permits operation on line voltage above or below nominal: high range—103 to 137 volts or 206 to 274 volts, low range—96 to 127 volts or 192 to 254 volts (when line contains less than 2% total harmonic distortion).

The Type 453 will accept the recently-announced Tektronix Type C30 Camera, thus assuring those whose applications require it the capability of trace photography.

Many will find that in the laboratory (where, incidently, it requires a minimum of bench space) the Type 453 delivers all the oscilloscope capability they require. In addition, it will provide them with an easily transported instrument—remember it weighs only 31 pounds—for servicing equipment or maintenance or research work in the field. This can be a mighty important consideration, particularly for those who must operate on limited budgets.

The Type 453 Dual-Trace DC to 50 MHz Portable Oscilloscope offers many other features not described here. Full appreciation of this advanced example of the state-of-the-art in portable oscilloscopes requires a demonstration of the instrument.

May we suggest you call your Tektronix Field representative or distributor to arrange one. He'll be pleased to accommodate you—no obligation on your part, of course.

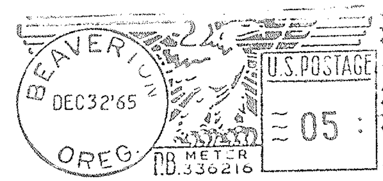
* 1 div = 0.8 cm

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon, U.S.A. 97005



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Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 35 PRINTED IN U.S.A DECEMBER 1965

THE FATAL CURRENT

Strange as it may seem, most fatal electric shocks happen to people who should know better. Here are some electro-medical facts that should make you think twice before taking that last chance.

It's The Current That Kills

Offhand it would seem that a shock of 10,000 volts would be more deadly than 100 volts. But this is not so! Individuals have been electrocuted by appliances using ordinary house currents of 110 volts and by electrical apparatus in industry using as little as 42 volts direct current. The real measure of shock's intensity lies in the amount of current (amperes) forced through the body, and not the voltage. Any electrical device used on a house wiring circuit can, under certain conditions, transmit a fatal current.

While any amount of current over 10 milliamps (0.01 amp) is capable of producing painful to severe shock, currents between 100 and 200 mA (0.1 to 0.2 amp) are lethal.

Currents above 200 milliamps (0.2 amp), while producing severe burns and unconsciousness, do not usually cause death if the victim is given immediate attention. Resuscitation, consisting of artificial respiration, will usually revive the victim.

From a practical viewpoint, after a person is knocked out by an electrical shock it is impossible to tell how much current passed through the vital organs of his body. Artificial respiration must be applied immediately if breathing has stopped.

The Physiological Effects of Electric Shock

Chart 1 shows the physiological effect of various current densities. Note that voltage is not a consideration. Although it takes a voltage to make the current flow, the amount of shock-current will vary, depending on the body resistance between the points of contact.

As shown in the chart, shock is relatively more severe as the current rises. At values as low as 20 milliamps, breathing becomes labored, finally ceasing completely even at values below 75 milliamps.

As the current approaches 100 milliamps, ventricular fibrillation of the heart occurs—an uncoordinated twitching of the walls of the heart's ventricles.

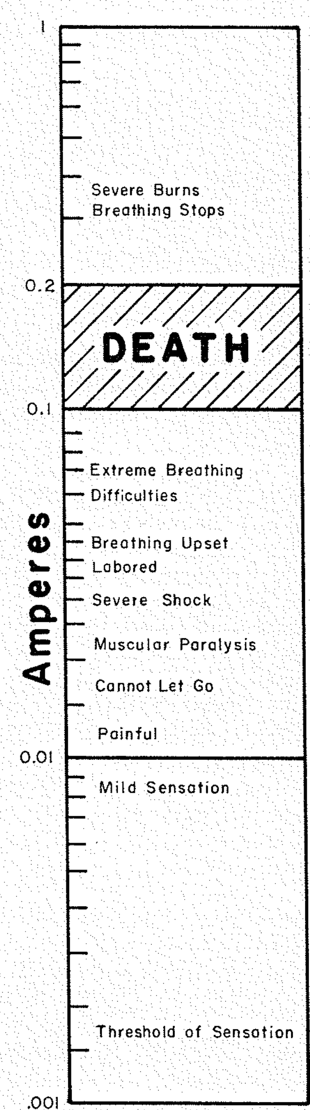
Above 200 milliamps, the muscular contractions are so severe that the heart is forcibly clamped during the shock. This clamping protects the heart from going into ventricular fibrillation, and the victim's chances for survival are good.

Danger — Low Voltage!

It is common knowledge that victims of high-voltage shock usually respond to artificial respiration more readily than the victims of low-voltage shock. The reason may be the merciful clamping of the heart, owing to the high current densities associated with high voltages. However, lest these details be misinterpreted, the only reasonable conclusion that can be drawn is that 75 volts are just as lethal as 750 volts.

The actual resistance of the body varies depending upon the points of contact and the skin condition (moist or dry). Between the ears, for example, the internal resistance (less than skin resistance) is only 100 ohms, while from hand to foot it is closer to 500 ohms. The skin resistance may vary from 1000 ohms for wet skin to over 500,000 ohms for dry skin.

When working around electrical equipment, move slowly. Make sure your feet are firmly placed for good balance. Don't



Physiological Effects of Electric Currents lunge after falling tools. Kill all power, and ground all high-voltage points before touching wiring. Make sure that power cannot be accidentally restored. Do not work on underground equipment.

Don't examine live equipment when mentally or physically fatigued. Keep one hand in pocket while investigating live electrical equipment.

Above all, do not touch electrical equipment while standing on metal floors, damp concrete or other well grounded surfaces. Do not handle electrical equipment while wearing damp clothing (particularly wet shoes) or while skin surfaces are damp.

Do not work alone! Remember the more you know about electrical equipment, the more heedless you're apt to become. Don't take unnecessary risks.

What To Do For Victims—

Cut voltage and/or remove victim from contact as quickly as possible—but without endangering your own safety. Use a length of dry wood, rope, blanket, etc., to pry or pull the victim loose. Don't waste valuable time looking for the power switch. The resistance of the victim's contact decreases with time. The fatal 100 to 200-milliampere level may be reached if action is delayed.

If the victim is unconscious and has stopped breathing, start artificial respiration at once. *Do not stop resuscitation until medical authority pronounces the victim beyond help.* It may take as long as eight hours to revive the patient. There may be no pulse and a condition similar to rigor mortis may be present; however these are the manifestations of shock and are not an indication the victim has succumbed.

—Printed through the courtesy of Fluid Controls Co. Inc., Cliffside, New Jersey, University of California Information Exchange Bulletin and Safer Oregon.

THE READERS' CORNER

Some readers have indicated an interest in articles written by Tektronix personnel. For these readers' information, we list here the title of the article, the author, the author's title, the publication in which the article appeared and the date of the issue. We include also, a thumb-nail sketch of the article's content.

Reprints of these articles are available through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor.

They are offered on a first-come, first-serve basis. When quantities are exhausted they will not be reordered. Another possible source for the articles is the back-issue file (in a public or company library) of the magazine in which the article originally appeared.

"Straight Scoop on Sampling Scopes", Cliff Moulton, Project Engineer (former employee). *MICROWAVES*, February, 1963. An early explanation of the sampling oscilloscope. What is is, how it works, how the various circuits differ from the conventional oscilloscope.

"Pulse Reflections Pin Down Discontinuities", Gordon Long, Design Engineer. *ELECTRONIC DESIGN,* May 10, 1963. Using a sampling oscilloscope to obtain high resolution measurements when using a pulse-reflection technique to test transmission lines.

"The Cathode Ray Oscilloscope", Will Marsh, Staff Engineer. *MACHINE DESIGN,* June 6, 1963. Using an oscilloscope to obtain precise (and sometimes otherwise unobtainable) information in the field of mechanical design.

"Storage to Picoseconds—a Survey of the Art", C. N. Winningstad, Manager, Display Devices Development. *ELECTRONIC INDUSTRIES,* June, 1963. A comparison of the sampling oscilloscope with the conventional oscilloscope in a series of topics including risetime, sensitivity, display modes, system interaction and interference, and continuing accent on tubes.

"Understanding Operational Amplifiers", Geoffery Gass, Staff Engineer. *ELECTRONIC INDUSTRIES*, February, 1964. An explanation of operational amplifiers and how they work.

"The Sophisticated Oscilloscope", John Kobbe, Manager, Advanced Circuitry Department. *INDUSTRIAL RESEARCH,* March, 1964. A discussion of present-day oscilloscopes and the techniques employed to record oscilloscope data.

"How To Get More Out of Your Spectrum Analyzer", A. Frisch and M. Engelson, Project Managers, *MICROWAVES,* May, 1963. Describes five useful microwave measurements that can be performed with a spectrum analyzer.

"Measuring the Cost of Programmed Instruction", Fred Davey and Jerry Foster, Programmed Instruction Group. *ADMINISTRATIVE MANAGEMENT,* September, 1964. Some guide lines for companies considering the feasibility of writing their own programs.

"How To Measure High-Current Recovery Times in Signal Diodes", C. C. Edgar, Design Engineer. *EEE* (Electrical Equipment Engineer), October, 1964. A technique for pulsing a diode on and off with current of 1 amp or higher and observing the current through the diode for the recovery time.

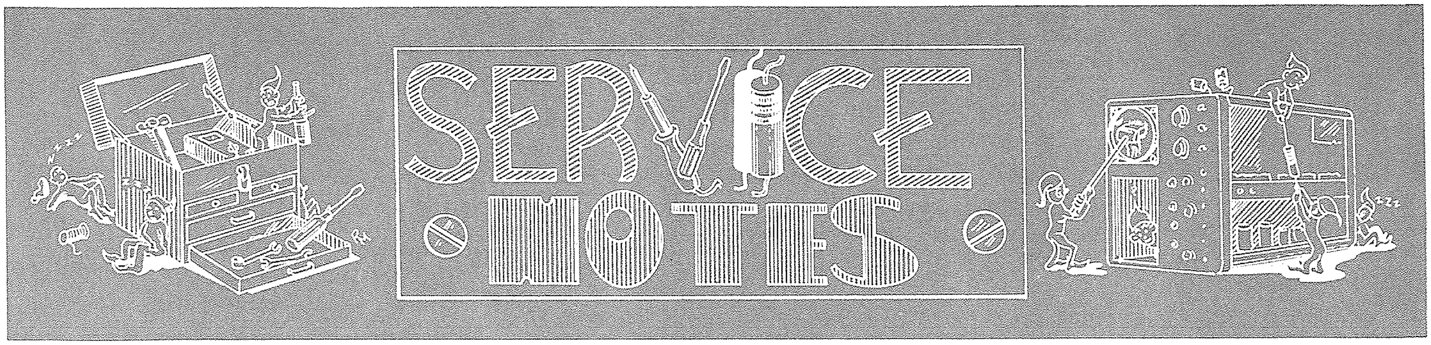
"Nanosecond Measurements with a Sampling Oscilloscope", H. Allen Zimmerman, Project Engineer. *ELECTRO-TECHNOLOGY,* January, 1965. A description of the sampling process and a discussion of the usefulness and versatility of a sampling oscilloscope.

"Oscilloscope Plug-In Spectrum Analyzers", Weis, Engelson, and Frisch, Project Engineers. *MICROWAVE JOURNAL,* March, 1965. Discusses the advantage of a plug-in spectrum analyzer as compared to a conventional spectrum analyzer.

"Design of Transistorized DC Amplifiers with Reduced Thermal Drift", Jerry Foster, Programmed Instruction Group. *ELECTRONICS AND COMMUNICATIONS* (Canada), March, 1965. A discussion of one of the prime considerations during the design stage of semiconductor/dc amplifier circuits — thermal compensation.

"Using a Transistor-Curve Tracer", Ralph Show, Instrument Engineering. *ELECTRONICS WORLD,* September, 1965. An explanation of the operation principles of the transistor-curve tracer. The method of interpreting curves to obtain parameters is also covered.

"The Sampling Oscilloscope", compiled from information supplied by Tektronix, Inc. *EDN* (Electrical Design News) Test Instrument Reference issue, 1965. How a sampling system works. How it buys sensitivity at the price of time. Some application techniques.



TYPE 1A1 WIDE-BAND DUAL-TRACE UNITS — OSCILLATIONS IN THE "ADD" MODE

Sometimes at turn on, an oscilloscope with a Type 1A1 Unit plugged into the vertical amplifier compartment will display a 10 MHz oscillation on the crt. See Figure 1.

This only occurs when the oscilloscope is turned on with the *MODE control in the ADD position.* The phenomena is normal and occurs because: with the MODE control in the ADD position, both halves of the channel-switching multivibrator (Q305 and Q315) are normally biased on. However, during the oscilloscope turn-on cycle, when the power relay (K601) pulls in, the resulting power-supply transients may turn off one side of the multivibrator and it will go into oscillation.

Switching the MODE switch out of ADD kills the oscillation and it will not come back unless you repeat the oscilloscope turn-on cycle with the Type 1A1 in the ADD mode.

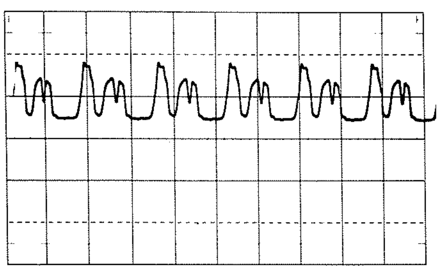


Figure 1. Typical oscillation waveform, caused by conditions described in text, displayed on a Type 547 Oscilloscope. Sweep rate 0.1 μs/cm. Waveform will be different on Type 545 (A), (B) Oscilloscopes but fundamental frequency will still be about 10 MHz.

TYPE RM529 WAVEFORM MONITOR —TERMINOLOGY

Early Type RM529 Waveform Monitors, sn's 101-399, use the terms ODD and EVEN to designate the two positions of the FIELD SHIFT switch. Subsequent to the introduction of the Type RM529, the Federal Communications Commission (FCC) chose to designate these fields as Field One and Field Two. This new system of designating the fields may be related to the ODD and EVEN terminology as follows: Field Two corresponds to the ODD position and Field One corresponds to the EVEN position of the FIELD SHIFT switch on the early Type RM529 instruments.

Beginning with serial number 400 in the Type RM529 we changed the front panel terminology. The designation for the FIELD SHIFT switch became FIELD and the two positions of this switch were relabeled to conform to the FCC's designation for fields of ONE and TWO.

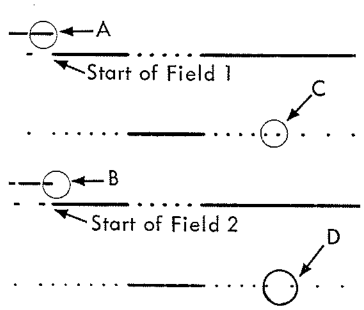


Figure 2. Waveform display showing that Field One is preceded by a full line of video (A) and Field Two by a ½ line of video (B). (C) and (D) indicate the equalizer pulses in the vertical blanking interval that determine correct instrument triggering.

Notice in the display shown in Figure 2, that Field One is preceded by a full line of video and Field Two by ½ line of video. (A and B in photo).

The Type RM529 actually uses the position of the first sync pulse after the last equalizer in the vertical blanking interval to determine correct instrument triggering. (See C and D in photo). The FIELD SHIFT (FIELD) switch selects and indicates the field which will initiate the sweep in all modes of operation. Hence, with the switch set to ONE, the vertical sync group seen at mid screen is the start of Field Two. Note the ½ line of video that precedes this group.

TYPE 544, TYPE 546 AND TYPE 547 OSCILLOSCOPES — USING THE AMPLITUDE CALIBRATOR WITH A TYPE 1S1 SAMPLING PLUG-IN UNIT

Amplitude Calibrator circuits in Tektronix instruments prior to the Type 544, Type 546 and Type 547 Oscilloscopes, were not intended to be loaded with anything less than 1 megohm. Consequently no effort was made to design the calibrator circuits to have a constant impedance. For the Type 544, Type 546 and Type 547 Oscilloscopes, however, we designed an Amplitude Calibrator circuit that, within the 0.2 millivolt to 0.2 volt range, delivers voltages having a constant 50 ohm source impedance. The development of the Type 1S1 Sampling Plug-In Unit which has a 50 ohm input impedance made such a calibrator desirable.

Here is a word of explanation for those using a Type 1S1 in a Type 544, Type 546 or Type 547 Oscilloscope and looking at the calibrator with the AMPLITUDE CALIBRATOR control set to one of the 0.2 millivolt to 0.2 volt (50 Ω constant source impedance) positions.

If you are checking the gain of the Type 1S1 (remember, it has a 50 Ω input impedance) you will find that the gain of the Type 1S1 appears to be 50% low. This is normal—the calibrator voltage indicated by the AMPLITUDE CALIBRATOR control will be twice the voltage available at the input of the Type 1S1. In other words, given a voltage with a 50 Ω source impedance and a 50 Ω load, the voltage across the load will be one-half the voltage of the generator.

One can look at it as shown in Figure 3, with the Amplitude Calibrator acting as

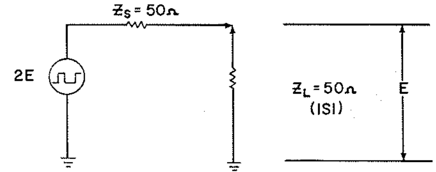


Figure 3. Simplified equivalent circuit representing the Amplitude Calibrator of a Type 544, Type 546, or Type 547 Oscilloscope and a Type 1S1 Sampling Unit.

the generator with a source impedance of 50 Ω and the Type 1S1 with an input impedance of 50 Ω acting as the load. If the Amplitude Calibrator open circuit voltage is 2E, then the voltage across the load will be E. So, if the Amplitude Calibrator is set for 0.2 volts one should read 100 millivolts on the Type 1S1.

We might mention here that when using the Amplitude Calibrator of a Type 544, Type 546 or Type 547 Oscilloscope in conjunction with a plug-in unit or other device having a high input impedance, the voltage delivered at the input of the plug-in or device will agree with the value indicated by the AMPLITUDE CALIBRATOR control setting.

TYPE 125 POWER SUPPLY—EXCESSIVE RIPPLE IN +135 V SUPPLY

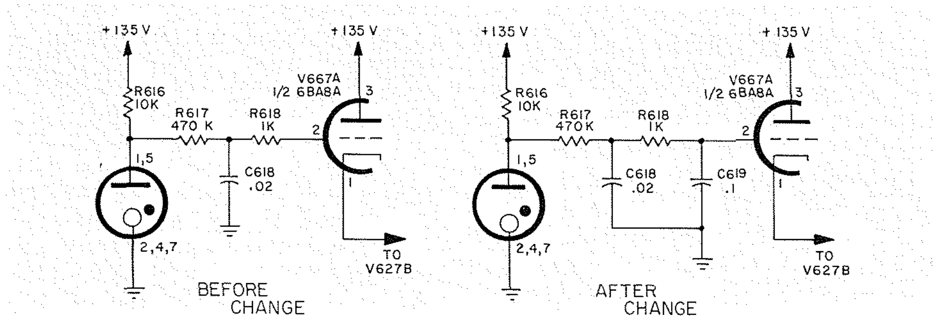


Figure 4. Before and After schematics showing installation of 0.1 discap in the +135 V supply of the Type 125.

In some Type 125 Power Supplies, ripple on the +135 V supply may exceed specifications (3 mV max). This is generally due to stray pick-up at the grid of V667A, one half of a Type 6BA8A tube that forms half a comparator circuit (V6278 and its circuitry form the other half). The solution to the problem is the addition of an 0.1 mFd, 200 V discap (Tektronix part number 283-0057-00) from the grid, pin 2, of V667A to the ground lug of the V667 tube socket. See Figure 4.

Designate the new capacitor C619 and add it to the parts list and schematic in your Type 125 Instruction Manual.

This modification is applicable to Type 125 Power Supplies, serial numbers 101-2169.

TYPE 1A2 DUAL-TRACE PLUG-IN UNIT—NEW SHAFT COUPLER IMPROVES VARIABLE VOLTS/CM POTENTIOMETER RELIABILITY

If you should have occasion to replace the Variable Volts/CM potentiometer in your Type 1A2 Dual-Trace Plug-In Unit, we suggest you also replace the control shaft and coupler. We now have a new style flexible shaft-coupler that secures with set screws and a new control rod to connect the potentiometer with the front panel control. Tektronix part numbers for the new parts are:

Coupler	376-0054-00
Control Rod	384-0276-00

The nylon pot-coupler formerly used requires a hard push to force the coupler sleeve onto the potentiometer shaft. The exercise of too much force here can cause damage to the potentiometer. The new type coupler and control shaft eliminate this hazard.

This information applies to Type 1A2 instruments with serial numbers below 1160.

TYPE 2B67 TIME-BASE UNIT — STABILITY ADJUSTMENT RANGE MADE LESS CRITICAL

In the early 2B67 Time-Base Units (below sn 10630), it was sometimes hard to find a compromise Stability Adjustment setting for both the NORMAL and SINGLE SWEEP operating modes. Changing resistor R126 from 220 k to a 680 k, ½ W, 10% resistor (Tektronix part number 302-0684-00) usually solves the problem. The original value of the resistor was chosen to compensate for the "spec" leakage in the transistor Q124, but few if any of the transistors ever develop this much leakage, resulting in overcompensation.

R126 is located in the front notches of the pair of ceramic strips that bracket the sweep-length potentiometer R176. After converting R126 to the new (680 k) value, be sure to note the new value in the schematic and parts list of your Type 2B67 Instruction Manual.

All Type 2B67 Time-Base Units, sn's 10630 and up have the modification installed at the factory.

TEST SET UP CHARTS

We would like to bring our readers up to date on the Test Set Up Charts now available.

As you may recall, the charts offer a ready means of recording instrument control settings for any given test or production set-up. For the laboratory this means that in so far as the oscilloscope is concerned, one need no longer rely on memory if the need to repeat the test should occur at a later date. Once the experiment or test has been performed, the oscilloscope control settings can be recorded on the test set up chart, a facsimile of the waveform resulting from the test drawn on the chart graticule (or a photograph of the waveform attached to the chart) and pertinent data recorded on the chart.

For production testing, an engineer generally devises the test procedure required to attain the desired result. He then designates the control settings on the chart and draws a picture of the display on the chart graticule, outlining the limits for acceptance or rejection. The production-test facility takes over at this point and performs the test with speed and accuracy. Often a non-technical person can handle this phase and release a highly trained person for more important work.

We know of several instances where girls from the production test line who had little or no experience with an oscilloscope, set up the oscilloscope and successfully performed the test required. These girls were able to do this using a previously prepared Test Set Up Chart and they required only a minimum of additional instruction.

Listed below are the oscilloscopes for which we now have Test Set Up Charts:

OSCILLOSCOPE	TEKTRONIX PART NUMBER
Type 262	070-0491-00
Type 422	070-0513-00
Type 453	070-0529-00
Type 502	070-0482-00
Type 502A	070-0488-00
Type 503	070-0483-00
Type 531	070-0492-00
Type 532	070-0493-00
Type 541	070-0494-00
Type 545A/CA	070-0481-00
Type 545A/R	070-0485-00
Type 545A/Z	070-0486-00
Type 547/1A1	070-0479-00
Type 561A/2A60/2B67	070-0540-00
Type 567	070-0487-00
Type 567/262	070-0490-00
Type 570	070-0484-00
Type 575	070-0480-00
Type 575 (MOD122C)	070-0489-00

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. The Test Set Up Charts come in pads of 100.

TYPE 545B AND TYPE RM545B OSCILLOSCOPES — TIMING ERROR AT SLOW SWEEP RATES

In some Type 545B and Type RM545B instruments, a timing error may occur in the Time Base B Generator. The error, when it occurs, affects only the slow sweep rates. It is caused by shield-to-cathode current leakage in V252, the dual-triode 12AL5 tube that serves as the disconnect diodes in the Time Base B Generator.

To cure the problem, disconnect, at ground, the #22 bare wire strap that runs from pin 6 of V252 to ground and reconnect it to pin 7 of V252.

This information applies to Type 545B instruments with serial numbers below 2021 and to Type RM545B instruments with serial numbers below 410.

TYPE 525 WAVEFORM MONITOR — PROTECTION FOR THE HIGH VOLTAGE TRANSFORMER

High line voltage or excessive line transients can cause failure of the High Voltage Transformer (T940) in the Type 525 Waveform Monitor. As protection against this hazard, we suggest the installation of a 390 Ω, 2 W, 10% resistor (Tektronix part number 306-0391-00). Install the resistor between the primary center tap of T940 and the +unregulated dc (360 V) supply.

This information applies to Type 525 instruments, all serial numbers.

TYPE RM561A OSCILLOSCOPE — HIGH VOLTAGE RIPPLE IN THE +125 V SUPPLY

Should you be troubled with high voltage ripple in the +125 V supply of a Type RM561A Oscilloscope, check C642 (A, B), a 160 μFd x 10 μFd, EMC capacitor in the power supply of the Type RM561A. Be sure that the twist tabs on this capacitor have a good low-resistance contact with the capacitor flange—*and that they are securely soldered to the flange.*

Failure of these twist tabs to make a good low-resistance contact with the flange may cause the Type RM561A to develop excessive high-frequency (HV oscillator) ripple in the +125 V supply. Amplitude of the ripple may measure up to 20 or 30 millivolts as against one or two millivolts normally. Actual ripple values and the effects on the display will vary considerably among instruments, with time and various plug-in type.

Because of a temporary change in assembly procedure, Type RM561A Oscilloscopes within the serial number range of 7800-8020 are more prone to the problem described here than other Type RM561A instruments.

TYPE 567 AND TYPE RM567 DIGITAL READOUT OSCILLOSCOPES—INSTALLATION OF IMPROVED CALIBRATOR MOD KIT

The calibration procedure for the Improved Calibrator Modification Kit (Tektronix part number 040-0380-00. See Service Scope #32, June, 1965) calls out a procedure to check the ground side of the square wave. This should be within 0.001 V of ground. Measuring this with a Fluke voltmeter you will find this tolerance cannot be met. The reading will typically be 50-100 mV or higher. The cause appears to be a pulse that is coupled through, even with Q925 removed, which affects the reading of the Fluke voltmeter.

Measuring the base line with a Type W High-Gain Differential Comparator Unit you will find the base line within 0.5 mV with a pulse riding on it of some 4.5 V amplitude and a microsecond or so wide at the 50% point. You will need to either make this measurement with the Type W Unit or to remove Q914 as well as Q925. This eliminates the pulse and allows the Fluke voltmeter to give an accurate reading.

NEW FIELD MODIFICATION KITS

TYPE 67, TYPE 2B67, TYPE 3B1, TYPE 3B3 AND TYPE 3B4 TIME BASE UNITS — SAWTOOTH DRIVE FOR TYPE 3L10 SPECTRUM ANALYZERS

This modification provides a sawtooth signal at pin 18 of the interconnecting plug of the above time-base units. This sawtooth signal is required by the Type 3L10 Spectrum Analyzer Plug-In Units to drive the analyzer's Swept Oscillator.

The sawtooth signal is a standardized *current* ramp of 66 μA/cm (nominal) fed from the sawtooth cathode follower of the time-base unit via a standardizing resistor to pin 18 of the time base interconnecting plug.

The current signal will drive a low-impedance circuit, such as the minus input of an operational amplifier or the emitter of a transistor, with a positive-going linear ramp of current. It will not drive two circuits (e.g. 3L10 and sawtooth out) at the same time, nor will it successfully serve as a "voltage" signal source—especially at faster sweep rates. The high source impedances of this signal prevent excessive cross-talk of the sweep signal into *vertical* plug-ins in which pin 18 of the interconnecting plug is open.

The sawtooth is provided by adding the standardizing resistor to the ceramic strips above the time base Sawtooth Cathode Follower. The standardizing resistor is connected between the cathode of the Sawtooth Cathode Follower and a length of coaxial cable. The other end of the coaxial cable is connected to pins 18 and 19 of the time-base interconnecting plug.

This modification is applicable to the following time base units:

Type	SN
67	101-5000
2B67	5001-15179
3B1	101-4039
3B3	100-4269
3B4	100-739

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix Part Number 040-0413-00.

CRADLE MOUNT — FOR LISTED OSCILLOSCOPES

This modification kit supplies a cradle-mount assembly that allows the instruments listed below to be rackmounted in a standard 19-inch relay rack. A vertical front panel space of 17½ inches is required.

The modification kit is applicable to the following Tektronix Oscilloscopes: Type 524AD, 531, 532, 535, 541, 545 and 570; serial numbers 5001 and up. Also, to Type 531A, 533, 533A, 535A, 536, 541A, 543, 543A, 543B, 544, 545A, 545B, 546, 547, 575, 581, 581A, 585, 585A and 661, all serial numbers.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix Part Number 040-0281-00.

TYPE 180 TIME-MARK GENERATOR SILICON RECTIFIER

This modification kit replaces the selenium rectifier SR401 in the Type 180 with a silicon rectifier. Silicon rectifiers offer more reliability and longer life.

The modification kit also adds a series resistor to compensate for the lower voltage loss through the new silicon rectifier.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix Part Number 040-0213-00.

DC FAN MOTOR — FOR LISTED OSCILLOSCOPES

This modification installs a DC fan motor assembly, a transformer and rectifier assembly, and a neon bulb assembly to allow the oscilloscope to operate on a 50-400 cycle power line supply. It is applicable to the following instruments:

TYPE	PART NUMBER
531A	22074-up
RM31A	1508-up
533A	3001-up
RM33A	1001-up
535A	24350-up
RM35A	1851-up
541A	21455-up
RM41A	1190-up
543A	3001-up
RM43A	1001-up
545A	27703-up
RM45A	1893-up

It is also applicable to instruments which have the DC Relay Field Modification Kit (Tektronix Part Number 040-258) installed.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix Part Number 040-0233-00.

TYPE 1A1 DUAL-TRACE PLUG-IN UNIT — ETCHED CIRCUIT CARDS IMPROVEMENT

This modification involves the Etched Circuit cards (Channel 1 Input Amplifier, Channel 2 Input Amplifier and the Output Amplifier) and the 14 wires that connect these boards with other parts of the Type 1A1.

Original equipment employed a jack-type connector on the etched circuit board and a pin-type connector on the associated interconnecting wire. This modification reverses the procedure. It installs interconnecting wires employing an improved jack-type connector on the etched-circuit-board end of the wire and installs pin-type connectors at the associated locations on the etched circuit board. Four of these locations use 45°-angle pin-type connectors. This is to prevent the bending or breaking of the connector in the event the etched circuit board is removed without disconnecting these connectors. The other ten locations use a straight pin-type connector.

The improved jack-type connectors reduce the failures caused by faulty contact in the old connectors. The new connectors also realize a reduction in noise caused by intermittent contact between pin and jack in the old connector.

This modification is applicable to Type 1A1 instruments with serial numbers 101 through 3179 that have the following etched circuit cards installed:

Channel 1 Input Amplifier — Models 1 & 2

Channel 2 Input Amplifier — Models 1 & 2

Output Amplifier — Models 1 through 7.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0402-00.

TYPE 531, TYPE 535, TYPE 541, TYPE 545 OSCILLOSCOPES — CHOPPING-TRANSIENT BLANKING

This modification provides a means of eliminating switching transients from the crt display by applying a blanking voltage to the crt cathode. Switching transients occur when a multiple-trace plug-in unit is operated in the chopped mode. The blanking voltage is applied by means of a crt CATHODE SELECTOR switch installed on the rear panel of the oscilloscope.

A 6DJ8 tube replaces the 6AU6 tube in the V78 position of the multi-trace unit's Sync-Amplifier circuit. One half of the new tube is used as the Sync Amplifier; the other half is used to generate the blanking pulse.

Installation of the modification involves replacing the old 7-pin socket for V78 with a 9-pin socket to accommodate the new 6DJ8 tube. Also, the addition of a crt CATHODE-SELECTOR switch to rear panel of the oscilloscope plus other minor circuit changes. The instructions divide the modification into several parts to facilitate the installation in the specific instrument at hand.

This modifiction is applicable to the Type 531, 535, 541 and 545 Oscilloscopes with serial numbers 101 through 19999 and Type RM31, RM35, RM41, and RM45 Oscilloscopes with serial numbers 101 through 999.

Order through your local Tektronix Field Office, Field Engineer, Representative or Distributor. Specify Tektronix Part Number 040-0403-00.

TYPE 180A TIME-MARK GENERATOR — SILICON RECTIFIERS

This modification kit replaces the selenium rectifiers in the Type 180A Time-mark generator with silicon rectifiers which offer more reliability and longer life. It is applicable to Type 180A instruments, sn's 5001-6385 with the exception of sn's 6380 and 6381. These two instruments were modified at the factory.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0214-00.

TYPE 531, TYPE 535, TYPE 541 AND TYPE 545 OSCILLOSCOPES—TRIGGER IMPROVEMENTS

This modification installs the PRESET STABILITY and fully automatic TRIGGER MODE capabilities in the following oscilloscopes:

Type	SN
531	608-6019
535	1075-6044
541	101-5414
545	101-5945

Setting the STABILITY control to the PRESET position establishes an optimum setting for correct triggering in most applications. Normally the control will require no further adjustment.

In the Improved AC AUTO Trigger Mode, the STABILITY and TRIGGERING LEVEL controls do not function and triggering becomes fully automatic.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix Part Number 040-0152-00.

TYPE 515, TYPE 515A, AND TYPE RM15 OSCILLOSCOPE — SILICON RECTIFIERS

This modification replaces the selenium rectifiers in the Type 515, Type 515A and Type RM15 Oscilloscopes with silicon rectifiers. The new rectifiers offer better reliability and longer life.

The installation consists of removing the original selenium rectifiers and installing a new silicon-rectifier bracket assembly and three additional resistors. The three resistors compensate for the lower voltage loss occasioned by the new rectifiers.

Order through your local Tektronix Field Office, Field Engineer, Representative, or Distributor. Specify for:

Type	Serial Number	Tektronix Part Number
RM15	101-1000	040-0205-00
515	1001-4029	040-0205-00
515A	101- 755	040-0208-00

TYPE 315D OSCILLOSCOPES — SILICON RECTIFIERS

This modification kit replaces the selenium rectifiers in the Type 315D Oscilloscope with silicon rectifiers which offer more reliability and longer life. It is applicable to Type 315D Oscilloscopes, all serial numbers.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0220-00.

Tektronix oscilloscopes are designed to accommodate line-voltage variations up to roughly ±10% from design center without loss of stability or accuracy; however, variation beyond these limits causes loss of accuracy and often, severe instability.

The problems reported seem to fall into three main catagories: (1) continuously high or low line voltage; (2) fluctuation between high and low line voltage; and, (3) serious waveform distortion, giving the effect of low line voltage. Here are some suggested solutions to these problems:

(1) Many Tektronix oscilloscopes are supplied with multi-tap transformers. These transformers allow selection of a tap with a voltage rating close to that of the available power line supply. Each selectable tap will operate at line voltages within ±10% of its design center.

Other Tektronix oscilloscopes have transformers with either 115 (117) volt or 230 (234) volt taps and no additional taps to allow selection. In either case, it may be necessary to provide some type of external step-down transformer to supply the necessary operating voltage to the oscilloscope.

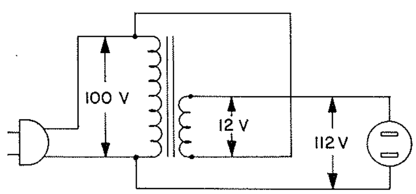


Fig. A. Low-cost line voltage boost or drop circuit, using a filament transformer. Connect as shown for 12 V boost; reverse secondary connections for 12 V drop. Filament winding must have a minimum rating sufficient to carry the oscilloscope load.

A variable autotransformer of the "Variac" or "Powerstat" type is particularly useful in accommodating a wide range of input voltages. An inexpensive filament transformer may also be used as an autotransformer in cases where the line voltage is consistently high or low. The filament transformer should be procured locally; they are not available from Tektronix. For an oscilloscope whose normal operating range is 105 to 125 volts, a 12-volt filament transformer will allow it to have an operating range of from 93 to 113 volts, thus making it compatible with 100 volt power line systems. Reconnected as shown in Figure A, the transformer's secondary voltage is added to or subtracted from the incoming line voltage to bring it within range. Be sure to check the oscilloscope specifications and then select a filament transformer with a current rating adequate to carry the oscilloscope load. For example: a Type 321 Oscilloscope, drawing 20 W will require a filament transformer rated to handle only ¼ amp, while a Type 517(A) Oscilloscope (drawing 1250 W) will require a filament transformer rated to handle 15 amps.

(2) The second problem is a little more difficult. Although slow periodic fluctuations in power-line voltage can be conveniently handled with a variable autotransformer, as above, there are many areas where wide line-voltage variations are so frequent that a constant-voltage-transformer type of regulator appears to be the only solution. However, for proper operation of the oscilloscope power supplies, it is extremely important that the regulator does not cause waveform distortion. The electronically-regulated power supplies in Tektronix oscilloscopes require not so much a certain rms voltage on which to operate, as a certain minimum pp (peak-to-peak) voltage. Many regulating transformers of the saturable-reactance type regulate primarily by limiting the peaks of the incoming sine waves. Either an rms or average-reading ac voltmeter (most voltmeters are of the latter type) may indicate the proper rms voltage for scope operation. However, the actual pp voltage supplied by most of the common "constant-voltage" transformers is insufficient for proper operation of the scope's power supplies. Under these circumstances excessive ripple, jitter, and instability will result. An increase of the pp voltage is not a solution in this case because this would increase the rms voltage also. While these regulated power supplies are dependent upon pp, the tube filaments are dependent upon rms. The power-line waveform must retain a sinusoidal form. Therefore, it is important to use only a low-distortion type of regulator—one having less than, say 5% distortion at the highest expected incoming line voltage under full oscilloscope load conditions. Regulators of this type are available through commercial channels, though at some increase in cost over the models without waveform correction.

The third major problem—serious waveform distortion—is the most difficult to overcome, since general-purpose correction systems are not always immediately available. To determine whether waveform distortion will seriously affect the performance of your instrument, an adapter such as that illustrated in Figure B can be used with a voltmeter to obtain pp measurement of the line waveform at moderate construction cost. An oscilloscope equipped for accurate differential voltage measurements in the 300-350 volt range can, through the use of a pair of P6023 probes, be used to make the pp voltage measurement directly from the power line. It is not recommended that a scope be used "single ended" to measure its own power line voltage because of possible measurement errors and serious shock and damage hazards. The oscilloscope power supplies should continue to regulate properly down to 295 volts pp. If the pp line voltage is less than 295 volts for an rms reading of 105 volts, but the scope power supplies do regulate correctly at 295 pp volts, then the trouble is mostly in the power-line waveform, and power-supply waveform; and, power-supply components are probably in good condition.

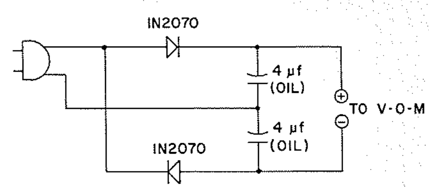


Figure B. Peak-to-peak reading adapter for 20,000 ohm/volt V-O-M. The use of silicon diodes and oil-filled (or Mylar, or paper) capacitors assures accurate voltage output.

RMS	Peak-to-Peak
105 V	297 V
117 V	331 V
125 V	354 V

If power-line waveform distortion exists on the power lines into your building, the easiest solution may be to have the local power company correct the waveform for you. However, if it's caused by in-plant equipment (any high-current, nonlinear load will cause some distortion), it may be necessary to apply your own waveform-correction, using a filter of appropriate design and a transformer (to compensate for filter losses) between the power line and the oscilloscope. In extreme cases where severe fluctuations and transients are also involved, it may be necessary to employ a motor-generator set to obtain a steady, sinusoidal waveform. As before, be sure that the current rating of the filter or motor-generator is adequate for oscilloscope operation.

Incidentally, it should be mentioned that a step-up transformer alone should not be used where waveform distortion is the primary cause of power-supply regulation problems. If the pp voltage of a seriously flattened power-line waveform is increased sufficiently to obtain good power-supply regulation, the unregulated filament lines in the oscilloscope will rise to excessive levels, causing premature tube failures from increased dissipation, gas, leakage, and filament burn-outs.

Service Scope

USEFUL INFORMATION FOR

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USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 36 PRINTED IN U.S.A FEBRUARY 1966

FIELD EFFECT TRANSISTORS

(Unipolar Transistors)

by Nelson Hibbs, Instructor

Tektronix Product Manufacturing Training Department

At last we have what amounts to a backward vacuum tube—a p-channel FET. In this device, electron current goes from drain (plate) to source (cathode).

The Field Effect Transistor (FET) is a comparatively new device whose operation differs radically from the more familiar n-p-n and p-n-p types of transistors. The FET is a single-junction *majority-carrier* device while the n-p-n and p-n-p transistors are double-junction *minority-carrier* devices.

FET manufacturers have settled on a new series of names for the three basic leads of this device; so, once again we encounter a change in terminology. Figure 1 compares an FET, a conventional transistor and the familiar vacuum-tube triode to show this change in basic-lead terminology.

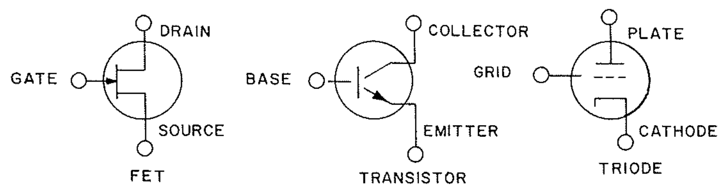


Figure 1. Comparison of basic lead terminology of FET's, transistors, and vacuum tubes.

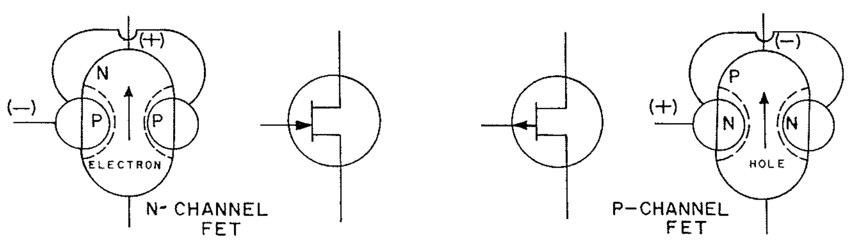


Figure 2. Comparison of an n-channel FET and a p-channel FET.

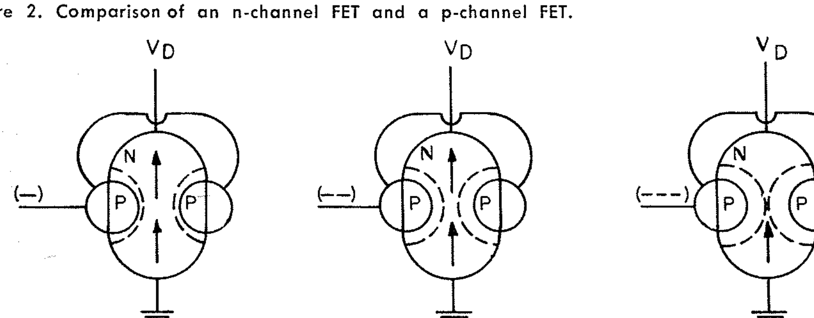


Figure 3. Illustration of how the voltage applied as back-bias can control the flow of current in an n-channel FET.

As with conventional transistors, which are represented by two types of devices (n-p-n and p-n-p), the FET is also represented by two types of devices. These are designated the n-channel and the p-channel types of devices (see Figure 2).

The electron in "n" material has a faster mobility than the hole in "p" material. Thus, the n-p-n transistor has a faster mobility than the p-n-p transistor and consequently a higher frequency response. A similar condition exists with the new FET's. The n-channel FET promises a greater frequency response than the p-channel device. This does not mean that the p-channel device is not being manufactured.

The FET is a single-junction device made up with the Source-to-Drain material (the majority-carrier path) doped in either the "n" or the "p" direction and with the Gate material doped in the opposite direction. By applying voltage so as to oppose the majority carriers in the channel (a negative voltage applied to the gate opposes electron flow in n-channel material—a positive voltage opposes hole flow in p-channel material) the device is back biased. Under these conditions, the n-channel or p-channel material becomes a constrictive layer of dielectric material past which majority carriers must flow and can thus be controlled. See Figure 3.

For a given voltage setting between the gate and the source (bias, if you will), the FET rapidly reaches a point of saturation in the source-to-drain majority-carrier path. This region of the curve gives the FET an effective R_p approaching infinity. This is where an increase in drain voltage (V_D) does not result in an increase in drain current (I_D). This area of the curve is spoken

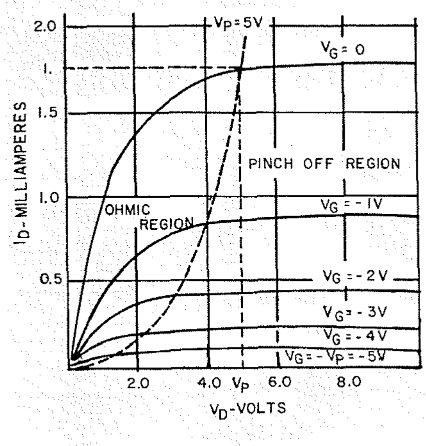


Figure 4. A chart of V_D vs I_D curves of an FET showing the pinch off region and Ohmic region at different values of bias voltage.

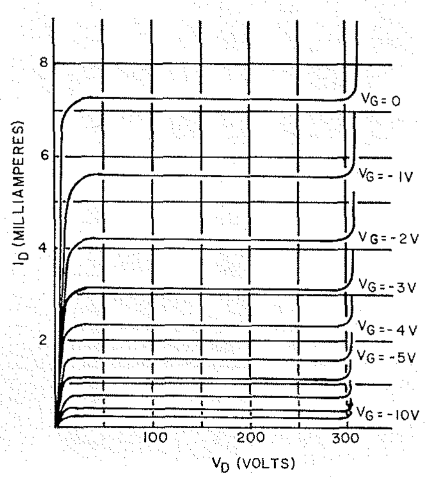


Figure 5. A chart of the V_D vs I_D curves of another FET showing Zener-knee breakdown of Gate-to-Drain back-biased diode. An extension of the curves shown in Figure 4 would reveal a similar tendency of this FET to avalanche at some certain V_D voltage.

of as the "Pinch-Off Region". See Figure 4. The area to the side of this (where an increase in V_D results in an increase in I_D—close to the graph axis) is termed the "Ohmic Region".

A study of the V_D vs I_D curves (see Figure 5) shows that with a given load line, the resultant transfer curve is nonlinear. This non-linearity is relative to the deviation in the resistance represented in the majority-carrier path as controlled by the biasing voltage. The best "g_m" occurs under zero bias conditions and the forward voltage at which saturation of this path occurs is called V_p (pinch-off voltage). V_p is counted as a characteristic of the individual device. Thus, in order to find the active g_m at a bias different than zero, we must multiply the zero-bias g_m by the factor one minus the ratio of gate voltage-to-pinch-off voltage raised to the two-thirds power.

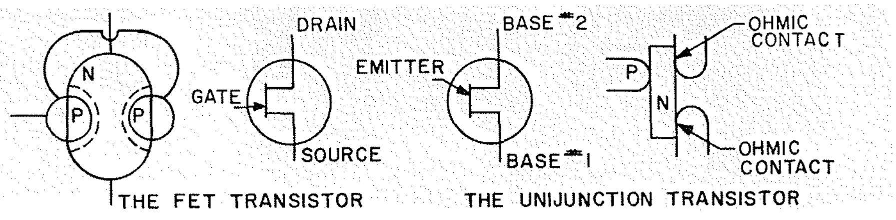


Figure 6. Comparison of an FET and a Unijunction transistor.

$$\text{Operational } g_m = g_m \text{ (at zero bias)} \left[1 - \left(\frac{V_G}{V_p}\right)^{2/3}\right]$$

Now, with a truly representative g_m available, one can closely predict the voltage gain of the device in a circuit by using the Pentode A_v formula:

$$A_v = \text{operational } g_m \times R_L.$$

Noting that the input to the device is a back-biased diode, one can see that it offers a high input impedance and that this back-biased junction will show a capacitative effect from gate-to-source and from source-to-drain. The latter also gives a miller effect. Note also, that the input-impedance will decrease with increasing frequencies at which the product $\frac{1}{2\pi f C_{GS}}$ becomes comparable to the input resistance. Also, the gain-bandwidth product will be approximately:

$$\text{Gain Bandwidth} = \frac{g_m}{2\pi\ (C_{in} + C_{out})}.$$

Again, similar to the vacuum tube pentode. This dictates the usual compromise between gain and bandwidth when using this device.

The FET should not be confused with the Unijunction Transistor. The theory of operation is totally different, although at first glance, the unijunction transistor looks almost like an n-channel FET. See Figure 6 for a comparison.

The unijunction transistor operates as a current-driven device with a *forward-biased* junction of p-to-n material injecting holes into the n material between the emitter and base #1 thus reducing the ohmic resistance of the contact. The FET operates with a voltage-driven gate and the resultant back-biased junction with the field restricting the majority-carrier flow through the body of the device. The FET, like a vacuum tube, is a normally "ON" device and must be turned "OFF". Conversely, the unijunction transistor is a normally "OFF" device (as a result of the ohmic contacts) and must be turned "ON" by the signal at the emitter—two totally different theories of operation.

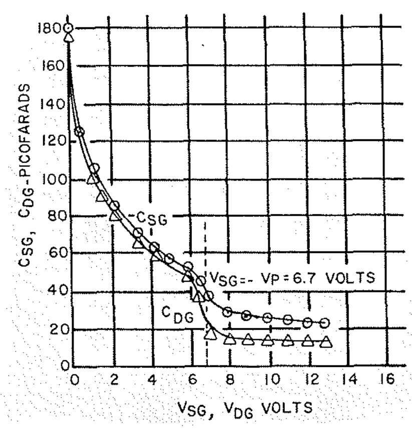


Figure 7. Variation of Source-to-Gate and Drain-to-Gate capacitance with voltage.

To summarize the properties and characteristics of the FET:

A. Input Impedance:

1. The FET is a high-input impedance device, the input terminal is essentially looking into a reverse-biased junction.
2. The FET has input capacitance that varies inversely with V_{SG} (bias). See Figure 7.

B. Mode of operation:

1. The FET is a voltage-controlled device just as a vacuum tube pentode.
2. The FET has a very, very high R_o (R_p) characteristic similar to a vacuum tube pentode.
3. The FET has a consistently nonlinear g_m characteristic.

C. Output Impedance:

1. The FET is a high-output impedance device (current source). However, different means of manufacturing

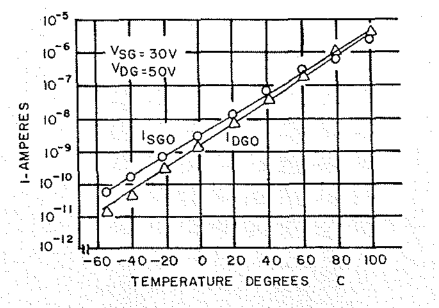
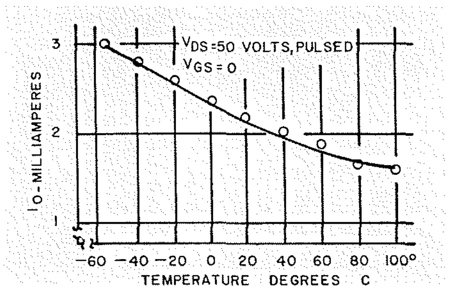


Figure 8. Plot showing leakage current from Source-to-Gate (I_{SGO}) and Drain-to-Gate (I_{DGO}) against temperature under zero bias conditions.

may result in relatively low ratings of this characteristic in comparison with the vacuum tube pentode.

Another noteworthy characteristic of FET's is their built-in protection against thermal run away. Because the input is a back-biased diode, the thermal-sensitive backward current (leakage current) flows from both the source-to-gate (I_{SGO}) and drain-to-gate (I_{DGO}). Plotting this linear current against temperature under zero bias conditions of the other element gives two straight line projections as shown in Figure 8.

This increase in leakage current in the gate junction has a resistive effect on the majority-carrier path resulting in a lower saturation current for a given bias voltage. For a graph of this action under zero bias conditions, and with the forward voltage from the drain to the source set at 50 volts, see Figure 9 (a). A cross graph of g_m and output resistance plotted against temperature is shown in Figure 9 (b). The combination of these two reactions to temperature is such that as temperature goes up, g_m goes down and R_o (counterpart of R_p in vacuum tubes) goes up. In other words, as the gate starts to lose control of the drain current, a greater portion of the actual drain current will be passed on to the load resistor thus tending to maintain the same change of voltage at the output. This is what we mean when we say that FET's have built-in protection against thermal run away. This statement is not wholly true in the case of MOS (Metal-Oxide-Insulated) FET's.



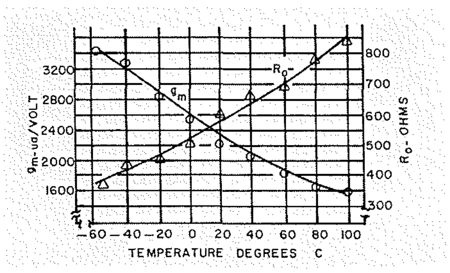


Figure 9. (a) Graph of saturation current under zero bias conditions and with the forward voltage from Drain-to-Source set at 50 volts. (b) Cross graph of g_m and output resistance plotted against temperature.

The MOS FET's separate the gate and channel with a layer of intrinsic material. As temperature increases on this device, the channel apparently increases also as it starts to include some of the insulating layer into the main channel. The MOS FET reacts more to changes in temperature than the regular FET's even though they do away with leakage currents in the gate circuit.

With standard FET's, leakage currents in the gate lead have been reduced to the neighborhood of 0.001 to 0.0001 mA and this can be tolerated where instability of I_D with temperature change cannot.

Characteristic curves of FET's can be displayed on a Type 575 Transistor-Curve Tracer. The EMITTER-GROUND (SOURCE-GROUND) mode is used with the POLARITY control of the Collector Sweep set to NPN (for n-channel FET's) or PNP (for p-channel FET's). The POLARITY control of the Base Step Generator should be set to MINUS for n-channel and PLUS for p-channel FET's.

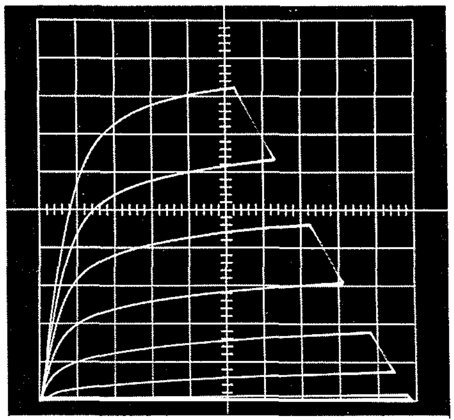


Figure 10. Drain characteristics. V_{DS} (horizontal) = 2 V/cm, I_D (vertical) = 1 mA/cm.

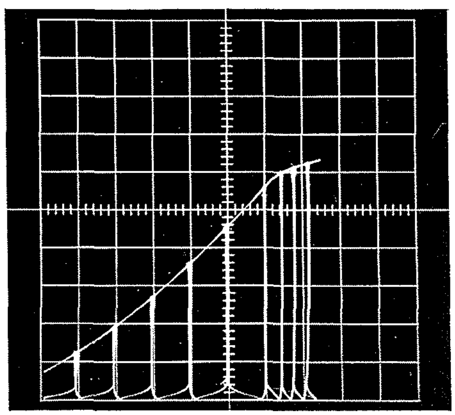


Figure 12. Transfer curve across zero bias. V_{GS} (horizontal) = 0.5 V/cm, I_{DSS} (vertical) = 2 mA/cm. ***Center vertical graticule line is zero bias.*** **Negative bias to left, positive bias to right of center line. Crowding of markers on right hand side is due to gate drawing current.**

FET's that require more than 2.4 volts to drive them to cut off—and the great majority are in this category—will require that a 1 kΩ, 1% resistor be connected between the BASE (GATE) and EMITTER (SOURCE) binding posts on the test panel of the Type 575. This, in order to convert the BASE current, as indicated by the STEP SELECTOR switch in MA, to Gate V_{GS} voltage in volts. Thus, 1 mA per step into 1 kΩ gives 1 volt/step and twelve steps at 1 mA per step can give up to 12 volts—ample in most instances to drive any FET to cut off.

The four waveforms represented in Figures 10, 11, 12, and 13 were obtained in this manner. The FET used in these tests was an Amelco U-1346 field effect transistor.

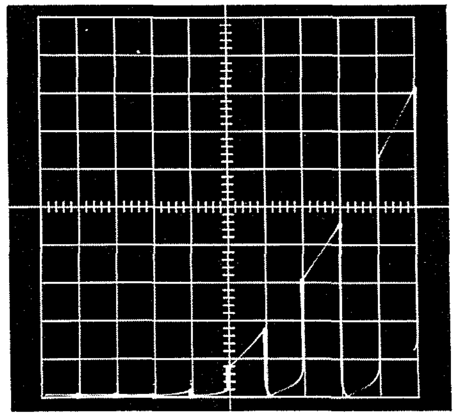


Figure 11. Drain current vs Gate Source Voltage (I_D vs V_{GS} with V_{DS} constant). V_{GS} (horizontal) = 0.5 V/cm, I_{DSS} (vertical) = 1 mA/cm.

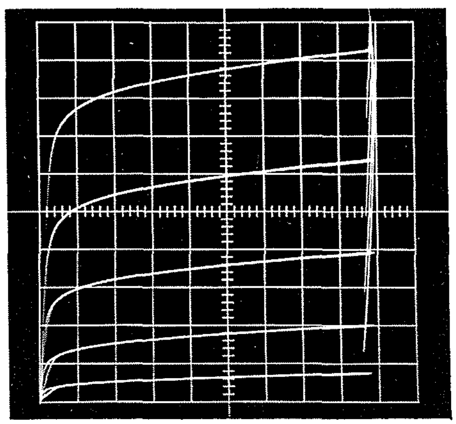


Figure 13. Drain curves showing avalanche (breakover at the Gate-to-Collector Zener Knee). V_{GS} (horizontal) = 5 V/cm, I_{DSS} (vertical) = 0.5 mA/cm.

TEKTRONIX-PRODUCED FILMS AVAILABLE

Ten films produced by Tektronix, Inc. have been certified as education films by the U.S. Information Service. These films are available on free loan as an aid to companies engaged in educational or training programs for their employees; or, if preferred, the films may be purchased.

Interested persons should contact their local Tektronix Field Office, Field Engineer, Field Representative or Distributor.

Listed below are the film titles, along with a brief review of the film:

"The Oscilloscope Draws a Graph" . . . A 20-minute color film in sound. The film explains that the oscilloscope display is usually in the form of a graph, and describes how to read or interpret the display.

"The Cathode-Ray Tube, Window to Electronics" . . . A 35-minute color film in sound with animated sequences. This film explains in simple terms how a cathode ray tube works. It depicts the heart of the oscilloscope, the cathode ray tube, as it is used in radar, sonar and many other electronic systems, including computers. The film also shows the step-by-step manufacturing process of cathode ray tubes at Tektronix, from the forming of metal "gun" parts to the final testing of completed tubes.

"The Square Wave" . . . A 25-minute black and white sound film. Discusses the theory of square waves, employed in computers and many other electronic devices; usually, in the form of coded information. Animated drawings show how sine waves contained in square waves are harmonically related. The film demonstrates the basic use of the square wave generator and oscilloscope and resulting information obtained from distortions. It discusses risetime and its importance in testing modern high speed electronic equipment. Suitable for audiences with at least a basic knowledge of electrical theory.

"Transmission Lines" . . . A 23-minute black and white sound film. Discusses the fundamentals of transmission lines. Animated drawings illustrate how electrical energy is transmitted along a line. An oscilloscope shows how reflections can occur in a line. Characteristic impedance, the importance of proper terminations, line losses, time delay, and velocity factor are also discussed.

"Time and Quantity" . . . A 27-minute black and white film in sound. Discusses the measurement of time and quantity from billions of years to billionths of a second. Shows the importance of the oscilloscope as the basic means of making accurate measurements of very small segments of time.

"The Oscilloscope, What It Is—What It Does" . . . A nine-minute color sound film. Presents a non-technical explanation of the oscilloscope and its uses. Stresses the importance of the instrument as a measuring tool in electronic and other fields. Oscilloscopes measure physical data in relation to small amounts of time. They are used in research, engineering, and education, and in production testing and maintenance of electronic computer and communication systems.

"Thevenin's Theorem" . . . A 12-minute black and white sound film. Presents a simplified approach to solving an electronic circuit which would otherwise involve complex mathematics.

"Solving the Unbalanced Bridge . . . A 17-minute black and white sound film. Normally a solution to an unbalanced bridge problem requires considerable mathematics involving three simultaneous equations. This lecture film shows and explains how simply this can be accomplished using Thevenin's Theory and Ohm's law.

"Triode Plate Characteristics . . . A 16-minute black and white sound film. Discusses plate characteristics of a typical triode (6DJ8) showing how the three basic tube characteristics, amplification factor, plate resistance, and transconductance, may be determined from a set of plate curves. It also plots a load line and shows how to determine the gain of a simple amplifier from these curves. In addition a continuous display of the curves of a tube under actual operating conditions is shown on the Type 570 Characteristic Curve Tracer, a special-purpose Tektronix oscilloscope.

"Ceramics and Electronics" . . . A 22-minute color film with sound. Shows the importance of ceramic elements in the electronic industries and stresses the application of ceramic insulating strips and other ceramic parts in oscilloscopes. It also shows the complete manufacturing process, including mixing of clays, firing, and glazing, at Tektronix.

* * * * * * * * * * *

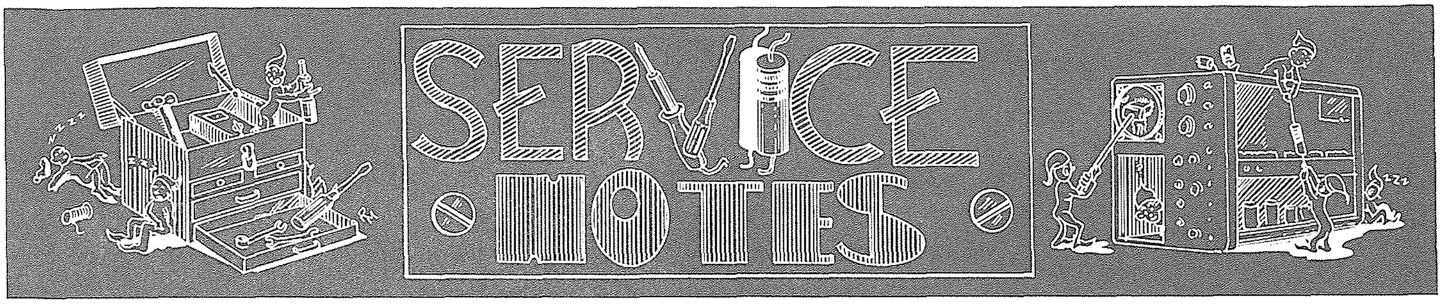
OOPS! WRONG PART NUMBER

In the October, 1965 issue of Service Scope two typographical errors involving part numbers, slipped by your editor. Both errors occurred in the article "Type M Four-Trace Plug-In Unit—Channels A, B, C, and D: Crosstalk". The part number listed as 283-0050-00 should have read 213-0005-00; and the part number listed as 210-0001-00 should have read 210-0201-00.

THE READER'S CORNER

"Current Measurements at Nanosecond Speeds" is the title of an article written by a Tektronix engineer and published in the October, 1965 issue of ELECTRONIC DESIGN NEWS. The article discusses the problems encountered when attempting to measure nanosecond and sub-nanosecond current pulses. It describes the use of a current transformer for accurate current measurements at nanosecond speeds.

Author of the article is Murlan R. Kaufman, Design Engineer with the Digital Instrument group at Tektronix, Inc. Reprints of the article are available. Contact your local Tektronix Field Office, Field Engineer, Field Representative or Distributor.



CRT MESH FILTER AND RFI SHIELD

Tektronix engineers have come up with a new CRT light filter and RFI shield that is unique. This new CRT Mesh Light Filter and RFI Shield is a metal screen of sub-visible mesh with the surface treated for extremely low reflectance. The screen is tautly mounted on a metal frame. This unique filter-shield is a direct replacement for the existing graticule cover on most Tektronix oscilloscopes. Two exceptions are the Type 422 and Type 453 Portable Oscilloscopes. The filter-shield for these instruments snaps into the CRT opening on the front panel.

The purpose of this new mesh filter-shield is to enhance visual CRT trace-to-background contrast and attenuate RFI radiated from the CRT faceplate. It accomplishes these purposes very well indeed. The curtailment of external ambient light reflections is highly efficient. Trace-to-background contrast is enhanced to a point where it provides an ability to view low-intensity traces in normal room light, or even in brighter-light environments. The metal mesh is grounded to the metal frame. Thus, when the filter-shield is in place on the oscilloscope, a ground path from mesh-to-frame-to-oscilloscope effectively carries a large part of the CRT-emitted RFI spectrum to chassis ground. Actual quantitative filtering depends upon the characteristics of the radiation and this varies between instrument types.

Following is a list of instrument types and the part number of the CRT Mesh Light Filter and RFI Shield they use:

TYPE	PART NUMBER
422	378-0571-00
453	378-0573-00
502, 502A, 503, 504, 515, 515A, 516, 517A, 524AD, 661; 530, 540, 550, and 580 Series	378-0572-00
506, 560 Series, 527, RM529, 647	378-0574-00

The CRT Mesh Light Filter and RFI Shields may be ordered through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor.

DUST COVERS FOR OSCILLOSCOPES

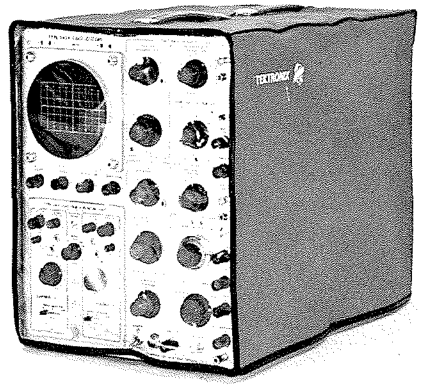


Figure 1. New dust cover for Tektronix oscilloscopes shown on a Type 545B Oscilloscope.

In response to numerous customer requests, we have designed and now have in stock dust covers for some Tektronix oscilloscopes. See Figure 1. The covers are made of blue vinyl material with a taffeta grained matte finish. There are black gimp seams around the bottom, front and back. A clear vinyl front allows easy identification of the oscilloscope and access holes in the top permit the oscilloscope to be moved with the cover in place. The Tektronix "bug" (trademark) and the word Tektronix are silk screened on the sides.

Covers are available for the following instruments:

TYPE	PART NUMBER
647 and 560 Series (except 565 and 567)	016-0067-00
500 Series	016-0068-00
565 and 567	016-0069-00
502 and 502A	016-0070-00
453	016-0074-00
422 (with AC/DC bat. pak.)	016-0075-00
422 (with AC pwr. sup. only)	016-0076-00

Covers may be ordered through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor.

TEST POINTS FOR B PLUS

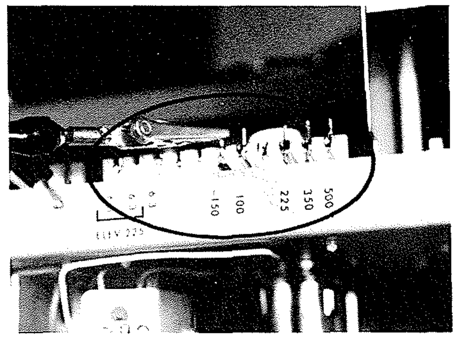


Figure 2. Short pieces of bare wire installed as B-plus test points in the ceramic strips of a Type 545B Oscilloscope.

L. E. Rishel, with the Otis Air Force Base in Massachusetts, has submitted to the Air Force and to Service Scope, a "do-it-yourself" modification that you may want to adopt.

The suggestion involves installing short pieces of bare wire in the ceramic-strip slots in Tektronix instruments at the B plus test points. These wires provide quick and easy attaching points for a voltage-measuring probe tip and are safe even when using the alligator clips often employed with a voltmeter.

We tried the modification on a Type 541A Oscilloscope (See Figure 2). Installation can be accomplished in a matter of minutes and offers no adverse effects on the scope's operation. The wire pieces need not extend more than ¼" above the ceramic strip. Installed thus, they provide an ample length for the voltage-probe tip to grasp, yet are not so long as to offer a hindrance in the normal maintenance and calibration of the oscilloscope.

With the emphasis toward ever more compact instruments, and the close spacing of components that results, we recognize the need for easily accessible test points. Some of our latest instruments have just such test points designed into them. We expect this trend to continue in future instruments.

TYPE 529 WAVEFORM MONITOR—HIGH FREQUENCY RESPONSE

Some Type 529 Waveform Monitors will show a HF (high frequency) response that differs when using the monitor push-pull, from that shown when using it single-ended. A capacitance unbalance between the "A" and "B" inputs most generally causes this unbalance. The unbalance results in a HF roll off of approximately 1.3 dB at 4 MHz. This effect becomes particularly noticeable when using the Type 529 in a balanced mode of operation, with the output terminated with a 110 or 120-ohm resistor—a practice employed by many telephone companies.

The following three-step procedure will correct the unbalance between input "A" and input "B" by balancing the emitter-to-ground capacitance of Q114 (input "A") and Q214 (input "B").

Step 1. From the underside of the Vertical Amplifier and DC Restorer chassis locate R119, a 100-ohm potentiometer that serves as the X5 Mag Gain adjustment. From R119 a bare strap runs to a 2.26 k, 1/8 W, 1% precision resistor in slot 11 of the adjacent ceramic strip. There is also a red and white wire running to another 2.26 k, 1/8 W, 1%, precision resistor in slot 9 of this same ceramic strip. Reverse these two leads at the ceramic strip. This should put the red and white wire at slot 11 and the bare strap at slot 9.

Step 2. Remove C133, a 2.8 pF, ceramic capacitor, located on the upper side of the RESPONSE switch. Re-install it on the VERTICAL MAG switch between the wiper on the last wafer of the switch and ground. Use the switch frame for ground.

Step 3. Adjust C133 for best common-mode rejection. You may need to readjust C269 for HF compensation.

EXTERNAL GRATICULES—RECOMMENDED CLEANING METHOD

We recommend the use of a mild soap, warm water (not hot) and gentle rubbing with a soft cloth for cleaning our external graticules.

We have employed several methods including silk screening, and (only quite recently) hot stamping, to imprint the reticules on external graticules. Accurately ruled reticules composed of sharply defined, consistently thin lines aid greatly in accurately interpreting or measuring the oscilloscope display. From this standpoint, there is little to choose between the silk screening and hot stamping methods. From the standpoint of visibility however, the hot stamped reticule offers a 10-to-1 advantage over reticules imprinted by other methods.

However, both the paint used in silk screening and the ink used in hot stamping the reticules are soluble in Anstac and other solvents. *Their use as a cleansing agent will remove the reticule from the graticule!* To be on the safe side, clean all graticules with a mild soap and warm water applied with a soft cloth and light rubbing action.

P6015 HIGH-VOLTAGE PROBE — REPLACEMENT OF DIELECTRIC

Only fluorocarbon 114 should be used when replacing the dielectric in a P6015 High-Voltage Probe. This gas is sold under several trade names all of which include the number 114. This number identifies the gas with the proper characteristics for use in the P6015 Probe. We supply a small can of fluorocarbon 114 with each P6015 Probe and stock additional cans for our customers' convenience. Tektronix Part Number is 252-0120-00.

The use of fluorocarbons other than 114 can involve a hazard. Some fluorocarbons are contained under a pressure much higher than that required by fluorocarbon 114. These higher-pressure fluorocarbons can be dangerous during the disassembly of a P6015 Probe. By escaping more violently than expected, they could damage personnel and equipment.

From the standpoint of toxicity, fluorocarbons offer no problem; they are not dangerously toxic.

NEW FIELD MODIFICATION KITS

TYPE 526 VECTORSCOPE — QUIET FAN MOTOR

This modification installs a lower rpm fan motor assembly for a reduction of the audible noise experienced from the original fan motor assembly. The new assembly is a direct replacement except for the addition of a motor capacitor which requires the drilling of two 5/32" holes in the rear panel of the Type 526. This modification is applicable to Type 526 Vectorscopes, sn's 101-909.

Order from your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix Part Number 040-0412-00.

TYPE RM16 OSCILLOSCOPE — SILICON RECTIFIERS

This modification replaces the selenium rectifiers with silicon rectifiers which offer greater reliability and longer life. It is applicable to Type RM16 Oscilloscopes, sn's 101-363. Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix Part Number 040-0216-00.

TYPE 262 PROGRAMMER — AUTOMATIC SEQUENCER

This modification supplies an Automatic Sequencer for the Type 262 that will scan up to eight programs. The Sequencer consists of two etched circuits (a synchronizer circuit and a counter circuit) each mounted in its own plug-in circuit card. Installation is simple because the Type 262 Programmer was designed with the automatic sequencer feature in mind and provisions made for its addition later. To install the modification, you need only to plug the circuit cards into their respective plug-in receptacles in the Type 262.

Front panel switches, in conjunction with the Automatic Sequencer, allow for interrupting the automatic sequence in accordance with pre-established upper and lower limits. Any combination of upper, middle or lower limits may be used.

The Automatic Sequencer can be synchronized with data recording devices such as printers or card punchers or with various test fixtures.

Both manual push button and external control are retained with the Automatic Sequencer installed.

A maximum of three Type 262 Programmers in series will handle a total of 24 different measurement programs. With an Automatic Sequencer Modification Kit installed in each programmer the entire 24 measurement programs can be automatically scanned. The measurement rate can be synchronized with auxiliary equipment or determined by the Type 567 and Type 262.

In the synchronized mode of operation, the sum of the Type 6R1 display time and the Type 262 display time determines the measurement rate—up to eight measurements per second can be made in this mode.

In the triggered mode of operation, upon completion of a measurement the display is held until an external completion pulse is received. Up to six measurements per second can be made in this mode.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix Part Number 040-0331-00.

TYPE 180 TIME MARK GENERATOR AND TYPE 536 OSCILLOSCOPE — SILICON RECTIFIERS

Two Field Modification Kits, one for each of the above instruments, replace silenium rectifiers with silicon rectifiers. The silicon rectifiers offer greater stability and longer life.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify, for:

TYPE	PART NUMBER
180A	040-0214-00
536	040-0215-00

TEKTRONIX TECHNICAL TERMINOLOGY

A handy guide to the electronic jargon used by Tektronix-oriented people.

Generally, in learning a foreign language, one is exposed primarily to the formal mode of that language. He will probably become quite adept at reading, speaking and writing the language in this form. However, when he encounters the language in its informal mode, the colloquialisms, slang expressions and trade jargon will almost surely puzzle and confuse him. Very probably, we in the United States are more prone to indulge in the vernacular than others.

Since Service Scope travels to our friends overseas, we do try to present its articles in the formal mode of our language. We do endeavor not to employ technical jargon and slang expressions. However, many of our overseas readers have expressed an amused (and perhaps confused) interest in these terms and expressions. For their benefit, we present here a few of these expressions and their interpretations.

AB, n. or a., Carbon composition resistor (from AB, trademark of Allen-Bradley Co.).

B.A., n. or a., Blanking Amplifier.

Bloom, v.i., To increase in size. The CRT display will bloom when high voltage supplies go out of regulation, reducing high voltage and increasing deflection sensitivity.

B.O., n. or a., Blocking Oscillator.

Bounce, n., Scattering of electrons that strike deflection structures in the CRT, producing **flare** (q.v.).

Blow-by, n., Capacitive coupling through an "off" diode gate.

Breathe, v.i., to vary slightly in level at a very slow rhythmic rate.

Bump, n., a short duration, small-amplitude aberration in transient response, somewhat wider (in time domain) than a wrinkle or glitch (q.v.).
Anticipation Bump, see preshoot.
Termination Bump, aberration due to a slight mismatch in a reverse- (source-) terminated delay line, appearing in time relatively long after the leading edge of a step function.

Cap, n. or a., Capacitor.

C.F., n. or a., Cathode-Follower.

Cathode Interface, n. a tube defect, specif., development of an insulating layer between the cathode sleeve metal and the emissive coating in a vacuum tube (incl CRT), resulting in an effective RC network in series with (part of) the cathode. Electrical effect is normal gain at very high frequencies, but lower gain at low frequencies. Time constants are in the ns-μs area, and are considerably affected by cathode temperature.

Cream, v.t., To ruin or destroy absolutely (by extension from pulverize).

Crunch, v.i., To saturate.
v.t., To drive into saturation, or to destroy.

D.A., n. or a., Distributed Amplifier.

Dag., n., Conductive coating, usually of carbon, applied to the inner walls of a CRT to maintain a large equipotential area; also used to form a helical resistor around the inner walls of a CRT to maintain a specific post-acceleration voltage gradient. From aquadag, a water suspension of carbon particles.

D.C. Shift, n., Shift of DC level following a step-function, over a few seconds or tenths. Similar to Dribble-up, but in a much longer time-domain.

Dogbone, n. or a., Ceramic tubular capacitor with radial leads.

Dot, n., A single sample presented on screen in pulse-sampling. **Dot Transient Response**, transient response independence from number of samples per display (sampling).

Dribble-up, n., Disproportionately long 50-100% or 90-100% response in relation to 10-50% or 10-90% risetime; usually with reference to the nanosecond time domain. Essentially similar to "DC Shift".

E.F., n. or a., Emitter-follower.

Eyeball, v.t., Originally, to avoid parallax error in oscilloscope measurements by lining up the reflection of the pupil of the eye with a graticule line and the trace. Now, to scrutinize in general.

Flare, n., Scattering of electrons in the CRT resulting in hazy light areas on the screen. Usually caused by bounce (q.v.) or secondary emission in the CRT. **Dag Flare**, Flare resulting from the beam striking the walls of the CRT. (See Dag).

Garbage, n. Large amplitude noise, commonly low-frequency noise, as contrasted with "Grass" (broadband noise).

Glitch, n., A waveform aberration consisting of a step or transient pulse in some portion of a CRT display which would be otherwise a smooth curve or straight line. A train of two or three small glitches might be referred to as a **wrinkle** (q.v.); a glitch of relatively long duration or smooth symmetry might be called a bump (q.v.). A glitch immediately (before or after) associated with the leading edge of a pulse usually carries its own terminology—e.g., pre-shoot, overshoot, hook, etc.

Grass, n., Baseline noise (broadband). CF "Garbage".

Gun, n., Electron gun. That portion of a CRT which generates and focuses the electron beam. The term does not usually include the deflection structure. **Gun voltage** refers, however, to the voltage from the CRT cathode to the average deflection-plate voltage.

Hook, n., A time constant (stray C or dielectric losses) in a compensated divider unrelated to the nominal component values. (From the effect on the display of a step function passed through such a divider.)

Hooky, a., Exhibiting or having a tendency to exhibit a hook (q.v.), especially of dielectric materials.

Interface, n., (1) The (electrical) boundary between two pieces of related or relate-able equipment. The conditions at the interface (typically an output-input relationship) determine electrical compatibility. The interface conditions between plug-in and main frame in an oscilloscope are usually standardized for interchangeability; i.e., voltage, current, and signal levels at this point are made to fall within specified limits. In computer usage, **interface equipment** is that which acts as a transducer between electronic and electromechanical, parallel and serial, or machine and human communications systems.
(2) Cathode Interface (q.v.).

Kluge, n., A lashup, a hastily or awkwardly constructed assembly.

Kluge, v.i., To collapse or fail utterly, usually violently.

Kluge, v.t., To shut down (permanently), smash or destroy.

Miller, n., A Miller integrator (sawtooth generator).

Mono., n., A monoaccelerator CRT.

Monoaccelerator, a. or n., (A CRT) having a single accelerating field, with no further acceleration of the electron beam between the deflection structure and the screen.

Multi, n., Multivibrator. Pronounced "Mul'-tee".

P.D.A., n. or a., Post-deflection accelerator (post deflection anode), or a CRT equipped with an accelerating field on the screen side of the deflection plates. Some manufacturers call this element the **"Ultor"**. **PDA ratio:** Ratio of the gun (cathode-to-deflection-plates) to post accelerator (deflection-plate-to-screen) voltages in a CRT.

Post, n., A post-deflection accelerator, or a tube equipped with such an accelerator. "10 kV on the post" means a 10 kV potential applied to this element. Distinguished from **mono-accelerator** CRT design.

Preshoot or Prepulse, n., A small negative excursion immediately preceding (the display of) a positive-going pulse, or vice versa.

Puff, n. or a., Picofarad (pF).

Puffer, n., A small capacitor, the value of which is indicated in picofarads. **One-puffer.**

Schmitt, n. or a., Schmitt (cathode-coupled) multivibrator ("Schmitt Trigger").

Slash, v.i., To produce a streak (usually vertical) instead of a dot (q.v.) on the CRT for each sample (sampling oscilloscopes).

Slash, n., A vertically elongated dot produced by spot motion during unblanking in pulse-sampling instruments.

Spudger, n., Fully insulated tool for dressing leads or components.

T.D., n. or a., Tunnel diode (Esaki diode).

Tweak, v.t., To adjust (an inductor, capacitor or internal calibration control) very slightly.

Tweaker, n., Tool for tweaking (usually one which fits only certain components).

Tweak up, v.t., To bring into proper adjustment by tweaking.

V.A., n. or a., Vertical Amplifier.

Wrinkle, n., A short-duration, small-amplitude aberration in transient response; usually a small echo in a delay line.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon, U.S.A. 97005

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Department of Transport
Telecommunications, Attn: CMO
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Ottawa, Ontario, Canada 9/65

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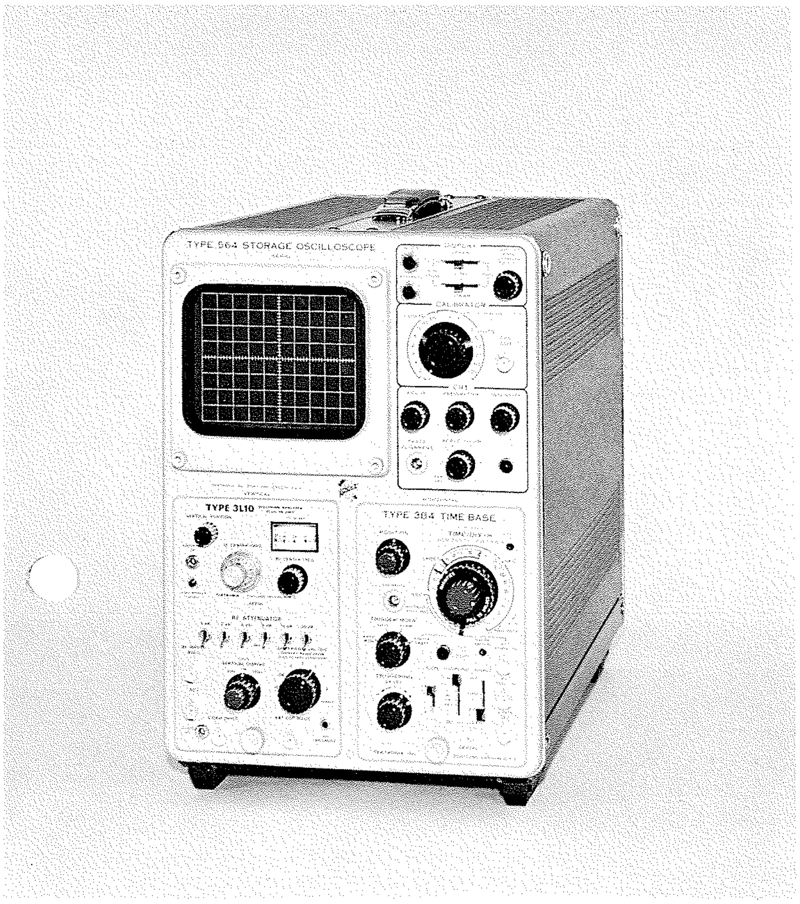
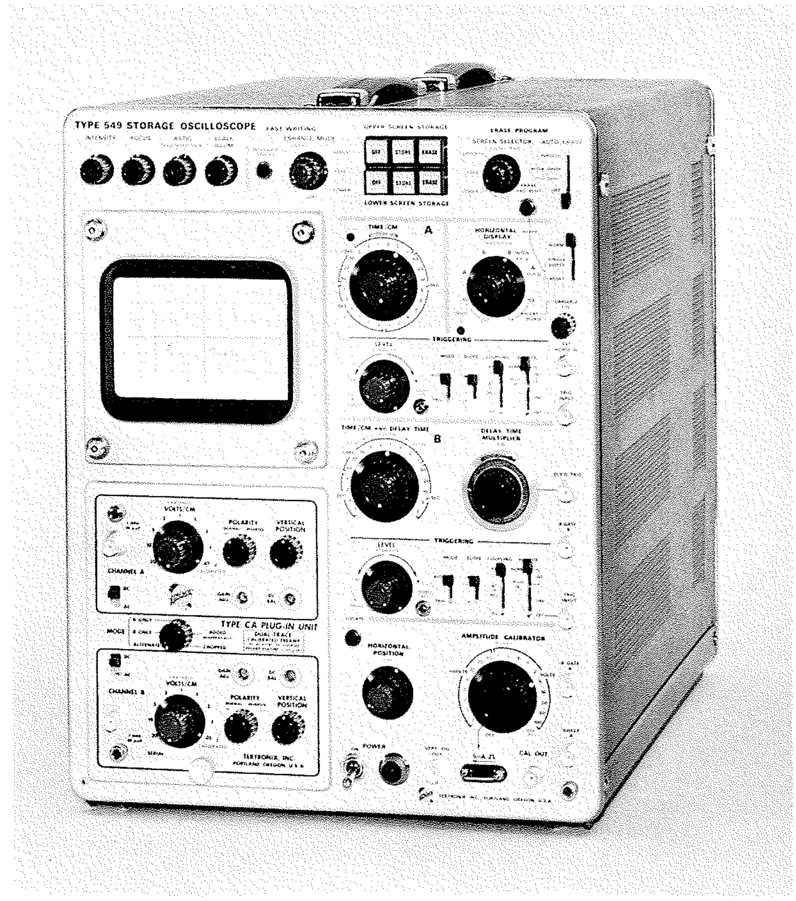
NUMBER 37 PRINTED IN U.S.A APRIL 1966





THE STORAGE OSCILLOSCOPE; WHY AND WHERE

by Geoffrey A. Gass

Tektronix, Inc.

A perhaps over simplified definition of a Storage Oscilloscope is: "A versatile instrument combining the advantages of a high speed storage system and a conventional laboratory oscilloscope."

Here are six specific applications in three general application areas where the storage oscilloscope out-performs the conventional oscilloscope.

One of the desirable and potentially more useful features of a general purpose conventional oscilloscope is its ability to display, however momentarily, erratic events. Unfortunately, the conventional oscilloscope cannot always present these events in a conveniently-observed manner. To conveniently display information for visual observation, measurement, and analysis, the conventional oscilloscope requires events that recur in identical form many times per second. Given these conditions, the display will be a bright and steady trace. Erratic events are not always so accommodating so as to repeat themselves indefinitely and allow the observer to revise or complete his estimates.

So in a conventional oscilloscope, the ability to display erratic events and the ability to present them in a conveniently observed manner are not always compatible.

A principal purpose for a high-speed storage system in a general-purpose oscilloscope, then, is to bring display convenience into greater agreement with display capabilities, preserving the unexpected waveform for as long as may be required to note down its significant characteristics and dimensions—or long enough to find a camera, requisition some film, and make a permanent photographic record.

For the most part, the purposes of a storage oscilloscope can be served by a conventional oscilloscope, a camera, and film—lots of film. The usefulness of a storage oscilloscope, then, is primarily one of degree rather than one of kind; one of convenience rather than one of unique capability. Even so, anyone who has attempted to photo-record carefully-prepared multiple-exposure of an elaborate series of waveforms, only to find that he'd already used the last exposure on his roll of film, needs no reminder that even a small improvement in the degree of assurance that critical data to be recorded *has* been recorded can be of considerable value.

In the notes below, we have outlined some of the ways in which the storage feature can be put to work in obtaining more useful and convenient oscilloscope displays for viewing or for simplified waveform photography.

GENERAL APPLICATION AREAS

The three primary uses for storage in a general-purpose oscilloscope are:

(1) To retain waveforms of single events which cannot be repeated—or which, if repeated, may change significantly with each repetition.

(2) To allow direct comparison by simultaneous display of events happening at different times, or of related repetitive events observed at various different points in a system or by means of different transducers.

(3) To retain information from very slow-moving traces—such as those from low repetition-rate sampling systems or high-resolution spectrum analyzers—until the entire display may be observed.

SPECIFIC APPLICATION AREAS

Nonrepetitive Events

Recording of random transients is the most familiar application in this area, since the storage oscilloscope may be left unattended for extended periods waiting to be triggered from an intermittent or random event. Within this category of applications are also destructive testing or testing to near yield-limits where repeated testing may change the characteristics of the device under test, and measurements of phenomena where a number of "mis-fires" may be expected before a satisfactory (e.g., worst-case) waveform may be obtained. Much testing in the mechanical and electromechanical fields falls into the non-repetitive area.

1. *Transistor Beta Characteristic Above Power Rating*

Using an operational amplifier to differentiate the collector output waveform of a grounded-emitter transistor driven by a linear ramp of current provides an output voltage proportional to the low-frequency AC beta of the transistor for a given collector load resistor. Plotting dV_c/dt against V_c gives a continuous plot of beta variation along the given load-line from cutoff to saturation if a sufficiently large base-current ramp is available[1]. Plotting dV_c/dt against I_b gives a direct indication of large-signal output linearity over the range encompassed by the current ramp.

Combining this measurement technique with the capability of completing and preserving a useful display in less than a millisecond on a storage oscilloscope permits convenient determination of characteristics at many times the nominal maximum steady-state collector-dissipation rating of the transistor, and without significant shifts in beta due to large changes in junction temperature.

A simple circuit configuration providing a linear base-current ramp of up to 5 mA peak for NPN transistors is shown in Fig. 1. For low-beta or high-power transistors, a power amplifier or external ramp source is required to obtain the necessary linearity; for PNP types, an inverting amplifier with output voltage swing capabilities V_{eb} must be used to provide the base-drive current ramp.

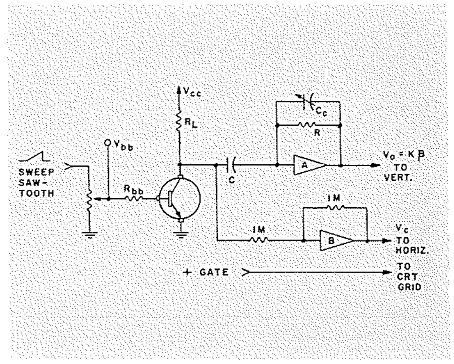


Fig. 1. Test circuit for plotting β vs I_c, V_c for NPN transistor. Differentiation V_c when I_b is a linear ramp produces a voltage proportional to β. Capacitor C_c (≈ 0.01 C) corrects for overshoot in differentiator.

Direct calibration of the oscilloscope vertical amplifier in terms of beta per centimeter is as follows:

$$\beta/\text{cm} = \frac{(\text{Volts/cm})\ (R_{bb})}{(R_L)\ (R_f C_i)\ (\text{Ramp } dV/dt)}$$

R_{bb} is the constant-current series resistor in the base drive circuit. Ramp dV/dt may be measured at the V_{bb} test point using the internal time-base display. R_L is the collector load resistance, and R_f and C_i are the differentiating components of the operational amplifier. A quick check of calibration may be obtained by removing the transistor and shorting together the base and collector terminals of the socket. A beta of −1 should be indicated in the display.

Figure 2 shows beta variation of a Type 2N1308 150 mW germanium transistor for a 50-Ω load line and a V_{cc} of 20 V. Peak dissipation is 2 W at I_c 200 mV, V_c 10 V.

Using this circuit, families of curves for a given transistor may be displayed on the storage oscilloscope for (a) various collector load values (changing V/cm or R_f with R_L to hold the β/cm value constant), (b) various V_{cc} values, or (c) various temperature values, using external heating and monitoring equipment and triggering a single display as the temperature passes through each desired point. This type of application properly belongs to the second category below, direct comparison of events happening at different times. A waveform photograph illustrating (b) is shown in application 4.

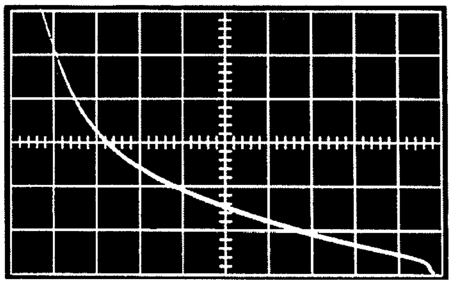


Fig. 2. Plot of β for 2N1308 transistor versus V_c, I_c for V_{cc} = 20 V, R_L = 50 Ω, V_{bb} 0 — 120 V, R_{bb} 24 k. Vertical calibration (β) 100/cm; horizontal, 2 V/cm, 40 mA/cm. Peak β of >600 is close to avalanche region for transistor. (Type 549 Oscilloscope, Type O Plug-In.)

2. *Transformer Inrush Current and Effects on Switches*

A major cause of AC power-switch failures in transformer-powered equipment is the so-called inrush current occurring during turn-on. A combination of four conditions establishes the magnitude of peak inrush current for a given turn-on: (a) the hysteresis of the transformer core material, (b) the phase angle of the AC power source at the instant of last turn-off, (c) the phase angle of the power source at the instant of turn-on and (d) the impedance of the input power loop, including the DC resistance of the transformer primary. In the worst case, inrush current amounts to essentially the peak power-line voltage divided by the DC resistance of the transformer primary circuit.

Where inrush currents alone are to be routinely measured, test-sets employing silicon controlled rectifiers and power diodes provide a means of providing a worst-case condition for each turn-on.

Where the frequency of usage does not justify specialized test equipment, or where the effects of inrush currents on the switch itself during the closure process are to be evaluated, the storage oscilloscope (with a suitable differential input amplifier and probe arrangement) permits observation of hundreds of turn-ons with minimum inconvenience or film waste, but with full assurance that permanent records may be kept of any turn-on waveform containing information of value.

Figures 3 and 4 show the test circuit for measurement of inrush current, and a typical waveform obtained by these means. A current transformer used instead of probes and a resistive shunt would allow use of a single-ended oscilloscope input. But the low-frequency response requirements to reproduce accurately the current waveforms of a transformer in a typical capacitor-input semiconductor power supply—for example—having a very small conducting angle and virtually no load for a large part of the cycle, are sometimes difficult to achieve and verify in a current transformer that will also give adequate indication of momentary peak currents in the 50 to 100 ampere region.

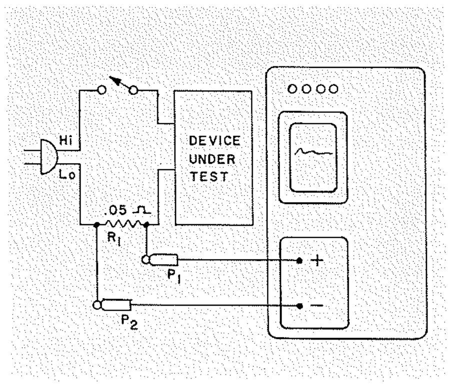


Fig. 3. Observation of inrush current using high-speed storage oscilloscope with differential input and differential probes. R_1, P_1, P_2 may be replaced with suitable wideband current transformer.

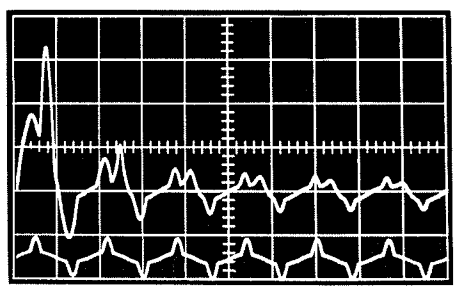


Fig. 4. Inrush current in nominal 120 V, 240 W system (upper trace) compared with current waveform after warmup. Vertical: 10 A/cm; Horizontal, 10 ms/cm. (Type 549 Oscilloscope, Type W Preamplifier.)

Figures 5 and 6 show the test circuit and typical results in measuring the potential drop across a switch in the process of closing a 60-Hz transformer primary circuit.

The display is obtained by triggering the oscilloscope from the inrush current signal. Good overload recovery characteristics in the input amplifier are essential for this measurement, as the full line voltage is impressed across the probes until the switch has closed.

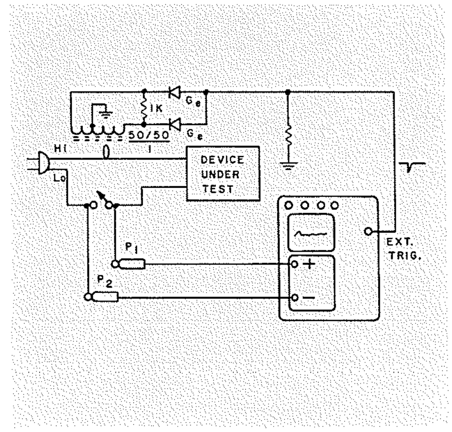


Fig. 5. Observation of switch closure characteristic during inrush. Current transformer 1:50:50 provides trigger for either polarity inrush. Switching "low" side of line makes amplifier requirements less critical.

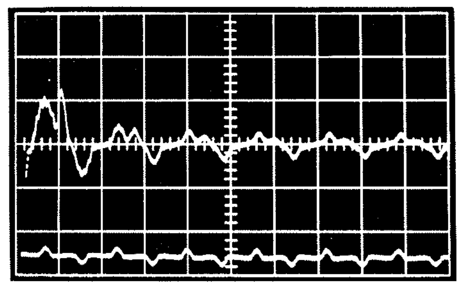


Fig. 6. Potential across switch contacts during inrush (upper trace) and after warmup. Vertical, 200 mV/cm; horizontal, 10 ms/cm. (Type 549 Oscilloscope, Type W Preamplifier.)

Direct Comparison of Events Happening at Different Times

Multiple-beam and multiple-trace oscilloscopes are designed to facilitate the direct comparison of events happening at the same, or very nearly the same time. The storage oscilloscope extends this capability to events happening at quite different times or at test points that are not conveniently close together.

3. *Speech Therapy for the Deaf*

A microphone, a storage oscilloscope, and suitable filters emphasizing the significant parts of word and syllable waveforms allow the student to practice vowels, syllables or words, with direct visual comparison of the subtle harmonic phase shifts which convey speech intelligence, against his instructor's standard waveform stored on the screen. The split storage target permits continuous trial-and-error operation on one half of the screen without losing the reference waveform on the other.

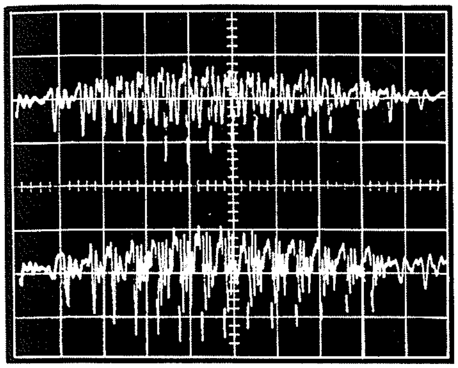


Fig. 7. Stored single-sweep waveforms of speech sounds aid in speech therapy. Upper trace: the word "reed". Lower trace: the word "red". Release of the "d" sound is offscreen to the right. Waveforms are somewhat distorted due to poor room acoustics. Sweep, 30 ms/cm. (Type 564 storage oscilloscope, Type 3A3 vertical amplifier set for 5 kHz bandwidth.)

In Figure 7, waveforms representing the pronunciation of the words "reed" and "red" are compared, using a 5-kHz bandpass filter. More elaborate normalizing systems may be employed in actual therapy work.

4. *Comparing the Effects of Circuit Adjustments*

A record of the effects of a series of adjustments or substitutions is often of value in circuit or component work. An illustration (Fig. 8) is the effect of changing collector supply voltage V_{cc} in application 1, showing the beta range for a given collector load resistance for four values of V_{cc}.

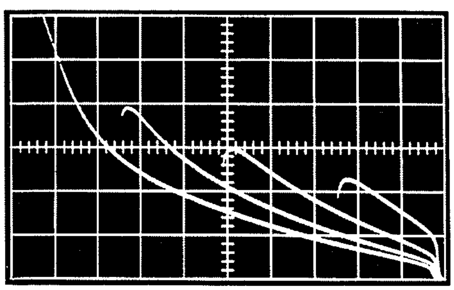


Fig. 8. Comparison of waveforms under variant operating conditions. Type 2N1308 transistor beta vs V_c, I_c as in Figs. 1 and 2, but V_{cc} of 20, 15, 10 and 5 V. Vertical calibration (β), 100/cm.

Preservation of Complete Slow Displays

The problem of retrieving data from oscilloscope displays of slow-rate information can result in loss of information either because the beginning of the slow trace is forgotten when the display is finished, or the display is deliberately completed at a faster than optimum rate, resulting in loss of information in the display itself.

5. *Sampling System at Low Signal Repetition Rates*

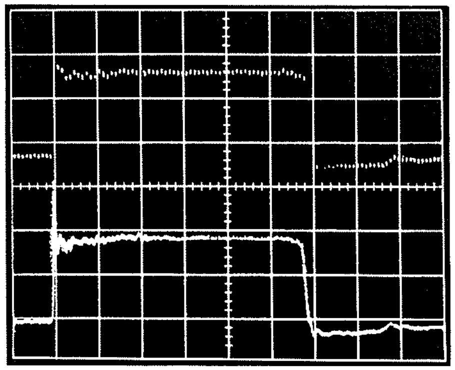


Fig. 9. Use of storage oscilloscope and manual scan feature of sampling system to obtain optimized dot density where needed. Upper trace, 10 dots/cm. Lower trace, manual scan. Fill-in required about 10 seconds with 100 Hz sampling rate, but provided same detail as $>$1000 dots/cm requiring $>$1.5 minute sweep. (Type 564 oscilloscope, Type 3T77 time base.)

The upper trace of Fig. 9 illustrates a case of possible information loss when a sampling oscilloscope dot density setting is insufficient to resolve all the significant data. In this particular case, the signal repetition rate was 100 Hz, completing the display shown (100 samples) in 1 second, but with a serious loss of information in the leading edge which occurred "between dots", so to speak. The alternative of increasing dot density to 1000 dots/cm to obtain the necessary resolution would have required over 1.5 minutes to complete the display.

The problem was solved in the lower trace by storing the low dot-density trace, and then using the manual scan of the sampling system to increase dot density only at the points where needed, completing the display in minimum time, and revealing the 70% overshoot which was hidden in the first trace. Whether with manual scan or internally-controlled high dot-density, the storage oscilloscope facilitates retrieval of high-resolution waveform information even from very slow-repetition-rate events from sampling systems.

6. *High Resolution Displays from Spectrum Analyzers*

The maximum sensitivity and resolution of a spectrum analyzer are achieved only when the dispersion (frequency sweep) df/dt is made to be very small. For normal viewing, in order to obtain a useful repetitive display, it's usually necessary either to confine the dispersion to a very narrow value, or keep the resolution low in order to maintain reasonable sensitivity and a usable display repetition rate.

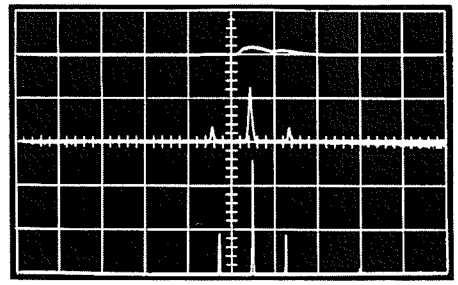


Fig. 10. Effects of df/dt on high-resolution spectrum analysis. Dispersion of 10 kHz, resolution 1 kHz. Sweep rates are: Upper trace, 20 ms/cm (50 kHz/s); middle trace, 200 ms/cm (5 kHz/s); lower trace, 2 s/cm (500 Hz/s). Signal is second harmonic of 5 MHz carrier modulated by 1 kHz squarewave (Type 549 Oscilloscope, Type L10A/1L10 Plug-In Spectrum Analyzer).

Figure 10 illustrates the effect of df/dt sweep rate on sensitivity and resolution in a representative spectrum analyzer application. Observing the second harmonic of a 5-MHz carrier modulated by a 1-kHz squarewave, a sweep of 10 kHz in 200 ms with a nominal 1-kHz resolution (top trace) produces only a hint of the signal and possible sidebands. Holding the same dispersion and resolution but reducing the sweep rate to 200 ms/cm (5 kHz/s) begins to reveal the true nature of the signal. In the bottom trace, reducing the sweep to 500 Hz/s provides sufficient resolution to identify the modulating signal as a squarewave. Time required to complete this 10 kHz sweep was 20 s. The advantage of the storage tube in preserving the entire display becomes evident.

SUMMARY

Applications making best use of the capabilities of a storage oscilloscope are those involving (a) non-recurrent waveforms, (b) comparison of waveforms of non-simultaneous events and (c) displays requiring several seconds for completion. Within the writing speed limitations of the instrument used, the storage feature may be used as a substitute for, or as an aid to, oscilloscope photography. Representative applications in these areas are: plotting transistor beta above nominal power rating; measurement of transformer inrush current and its effect on power switches; comparison of human speech waveforms; and improving resolution of sampling oscilloscope and spectrum analyzer displays.

Photographic Note: Waveform photographs reproduced here were taken with Polaroid® No. 47 film, using an exposure of 1/5 s at f/5.6, except Figs. 7 and 9, which were taken at 1/2 s, f/11.

[1]John V. McMillin, "Simple Curve-Tracer Displays Transistor Beta" *Electronics*, August 24, 1962.

TYPE 564 STORAGE OSCILLOSCOPES — REMOTE ERASE FEATURE

This modification provides an external Remote-Erase feature for the Type 564 Storage Oscilloscope.

It installs a circuit assembly which contains two monostable multivibrators—one for the Upper display area and one for the Lower display area. When activated from either the front panel Erase controls or the Remote-Source Erase controls these multis erase their respective display areas. The Remote-Source Erase control can be any switch contact that can short a wire from the Type 564 to ground or any equipment that can provide a negative-going 5-to-10 volt pulse for the multi of each display area.

The external connections are brought out to a four-contact connector on the rear of the Type 564 and a mating connector is included to permit attachment of the Remote-Erase control.

This modification applies to Type 564 Storage Oscilloscopes, all serial numbers. Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-0352-01.

P510 CATHODE-FOLLOWER PROBE —PROBE REPAIR KIT

This modification kit contains the parts necessary to repair several P510A Cathode-Follower Probes. The instructions are divided into sections, so that any individual portion of the probe can be repaired.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0287-01.

TYPE 531, TYPE 535, TYPE 541 AND TYPE 545 OSCILLOSCOPES—CHOPPING-TRANSIENT BLANKING

Installation of this modification supplies a means of applying a blanking voltage, to the cathode of the oscilloscope CRT, to eliminate switching transients from the display. These transients will occur when a multiple-trace plug-in unit—installed in the oscilloscope—is operated in its chopped mode. The blanking voltage is applied by activating a switch installed on the rear panel of the oscilloscope.

The modification involves the changing of V78 tube socket to a 9-pin type and adding a CRT CATHODE SELECTOR switch to the rear panel. Also, V78, a 6AU6 vacuum tube, operating as a Multi-Trace Unit's Sync Amplifier in the oscilloscope, is changed to a 6DJ8. One half of the 6DJ8 is used as the Sync Amplifier and the other half is used to generate the blanking voltage.

This information applies to Type 531, Type 535, Type 541, and Type 545 Oscilloscopes, serial numbers 101 to 20,000 and to all Rack Mount instruments in these types with serial numbers 101 to 1000.

Order from your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0403-00.

TYPE 532 AND TYPE RM32 OSCILLOSCOPES—SWEEP LOCKOUT

Your Type 532 or Type RM32 Oscilloscope can be modified for the study of one-shot phenomena by installation of this kit.

The Sweep Lockout feature permits you to "arm" the sweep to fire on the next trigger to arrive. After firing once the sweep is locked out and cannot fire again until rearmed by pressing the RESET button. All original features of the instrument are retained.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0147-00.

TYPE 453 OSCILLOSCOPE—PORTABLE-TO-RACKMOUNT CONVERSION

This modification supplies the necessary mechanical components and hardware to securely rackmount the Type 453 Portable Oscilloscope.

A special feature of this kit is the Rackmount Rear Support assembly. A Type 453 correctly installed as a rackmount and using the Rear Support assembly will successfully withstand an environmental shock of 30 G's or vibration of 4 G's. This can be an important consideration for Type 453's installed in mobile or shipboard units and in aircraft.

A frame, assembled from components and hardware in the modification kit, allows the oscilloscope to be mounted in a standard 19" open or closed relay rack, or slide out tracks.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0420-00.

TYPE 526 VECTORSCOPE — QUIET FAN MOTOR

This modification installs a lower r/min fan motor assembly to reduce the audio noise-level of the fan motor assembly. The new fan motor assembly is a direct replacement except for the addition of a motor capacitor, which requires the drilling of two 5/36 inch holes in the rear panel of the Type 526.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0412-00.

OSCILLOSCOPE CRADLE MOUNT

This modification enables the Tektronix Oscilloscopes listed below to be rack-mounted in a standard 19" relay rack. Required vertical front-panel space is 17½ inches.

The modification is applicable to the following oscilloscopes: Types 524AD, 531, 532, 541, 545, and 570, serial numbers 5001 and up; also, Types 531A, 533, 533A, 535A, 536, 541A, 543, 543A, 543B, 544, 545A, 545B, 546, 547, 575, 581, 581A, 585, 585A, and 661, all serial numbers.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0287-00.

DC FAN MOTOR FOR LISTED OSCILLOSCOPES

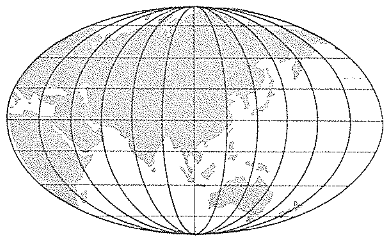
This modification enables the oscilloscopes listed below to operate on 50- to 400-cycle power lines. It installs a DC fan motor, a thermal time-delay relay, and a DC power supply relay.

The modification is applicable to the following instruments:

TYPE	SERIAL NUMBER
531A	20001-22073
535A	20001-24349
541A	20001-21454
545A	20001-27729
RM31A	1001-1579
RM35A	1001-1850
RM41A	1001-1189
RM45A	1001-1892

(Please note: If your instrument has the DC Relay Modification Kit 040-258 installed, use Field Modification Kit 040-0233-00.)

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0231-00.



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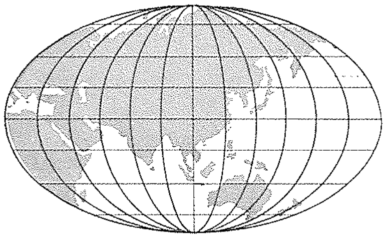

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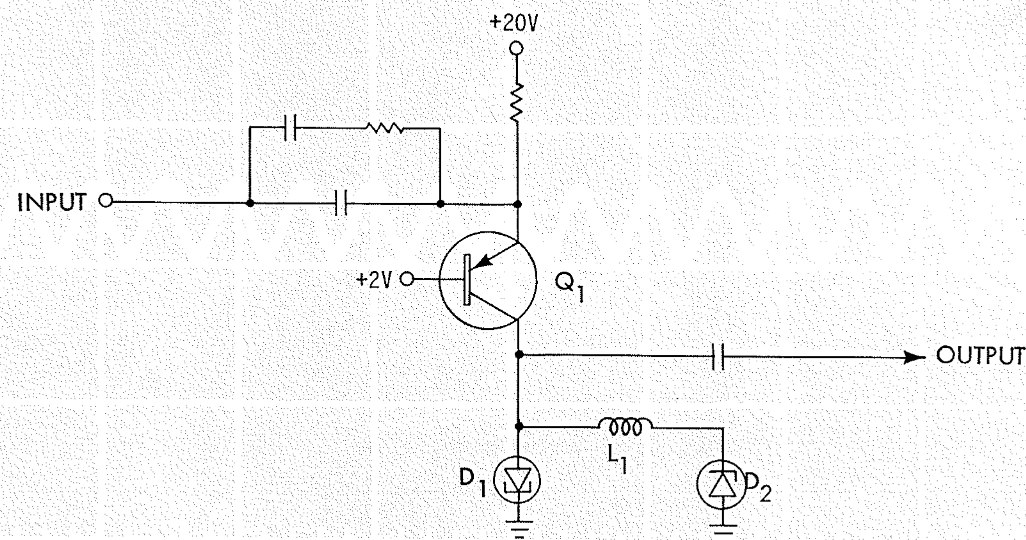


TUNNEL DIODE SWITCHING CIRCUITS AND THE BACK DIODE

By The Marketing Technical Training Department
Tektronix, Inc.

The concepts discussed in this article should lead to a better understanding of tunnel-diode switching circuits. It discusses in particular, the effect of a rather new component on tunnel-diode switching circuits—the back diode.

Several Tektronix sampling instruments incorporate the tunnel diode-back diode concept in their trigger recognition circuitry. Examples of these instruments are: the Type 3T4 Programmable Sampling Unit, Type 3T77 and Type 3T77A Sampling Time Base Plug-In Units, Type 1S1 Sampling Unit, Type 1S2 Reflectometer and Sampling Unit, and Type 5T1A and Type 5T3 Time Base Plug-In Units.

INTRODUCTION

Part I

Tunnel-diode switching circuits are widely used today in a variety of measuring and signal-generating equipment. For example: Tunnel-diode circuits are used for trigger recognition in sampling oscilloscopes, and wide-band conventional oscilloscopes, for gating sweep circuits and for generating fast-rise pulses. Some desirable features of tunnel-diode switching circuits are:

1. Fast switching speed.
2. Maximum obtainable pulse amplitude.
3. High sensitivity to triggering signals over a wide frequency range.
4. Low "idle" power dissipation.

Tunnel-diode circuit elements are combined to fulfill the above needs. One of these elements, the BACK DIODE, is responsible for improved performance in the areas of switching speed, sensitivity, and "idle" power dissipation.

This article is concerned with the theory, function and application of the back diode, in relation to tunnel-diode switching circuits. The first half of this article develops the need for such a device; the second half examines back-diode theory and discusses the function and applications of this unique diode to tunnel-diode switching circuits.

TYPICAL SAMPLING TRIGGER CIRCUIT

A basic sampling trigger circuit is shown in *Figure 1.* Q_1 is used to provide isolation between input and output. The back diode (D_2), tunnel diode (D_1), and inductance (L_1) form a one-shot multivibrator for trigger recognition. Synchronization on input signals is achieved by free-running this multivibrator.

The following discussion will develop this circuit and its related components. The emphasis will be on the function and operation of the back diode as a circuit element.

In order to understand the operation of the back diode, let us consider a few basic circuits. *Figure 2* shows a basic tunnel-diode (TD) switch.

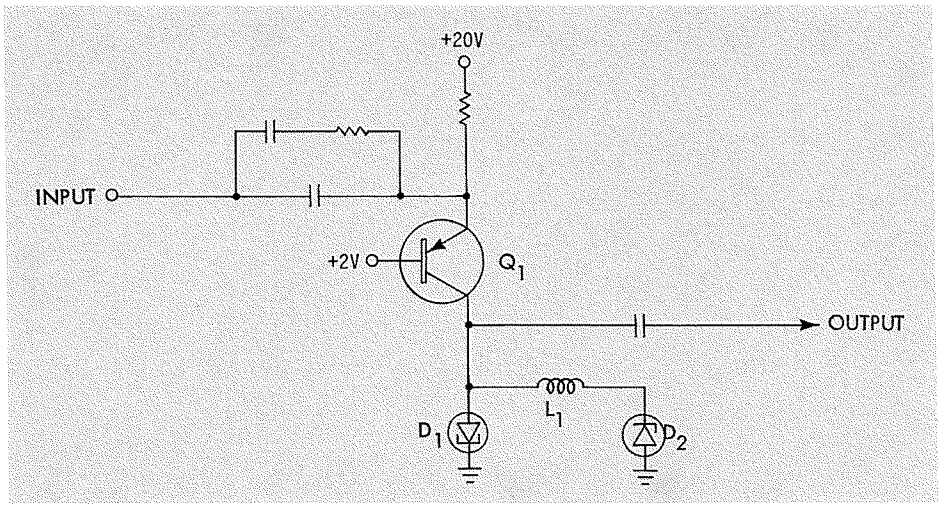


Figure 1 Typical Sampling Trigger Circuit.

BISTABLE OPERATION

A 20-V supply and a resistance, R_1, of 2.5 kΩ biases the TD at 8 mA. The DC load line is the solid line in Figure 2B. If the TD is in the low-voltage state, a 2-mA signal will cause the load line to move up toward the peak current point of the TD (dashed, or AC, load line in Figure 2B). The voltage across the TD increases along the slope of the TD curve at point "a". When the TD current reaches 10 mA (I_p), the voltage drop across the TD jumps almost instantly to the voltage at point "b". When the 2-mA signal is completed, the *load line* returns to its original mA position on the TD curve (point "c"). Notice that the *TD* does not return to the low-voltage state.

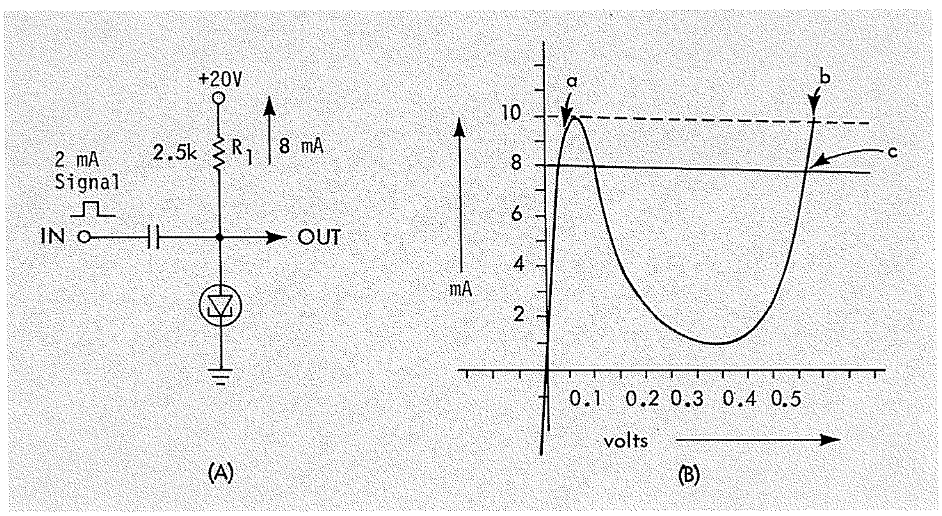


Figure 2 (A) Basic tunnel-diode switch circuit for bi-stable operation.
(B) AC and DC load lines superimposed on a 10-mA curve of the tunnel diode in Figure 2, (A).

MONOSTABLE OPERATION

The TD must return to the low-voltage state to respond to the next trigger signal. One way to insure that the TD always returns to the low-voltage state after a trigger occurs is to use a very small series R and a low voltage source. See *Figure 3.*

The 50-Ω series resistor will drop 0.4 volts at 8 mA. The TD will drop 0.03 volts at 8 mA, therefore the supply voltage will have to be 0.43 volts to put the quiescent point at "a" on the DC load line. The low impedance gives much more slope to the load line. When a 2-mA input signal arrives, the TD will switch to the high-voltage state. When the input signal ends, the load line drops below the switching point at "b" and TD reverts to the low-voltage state. The steep slope of the load line makes

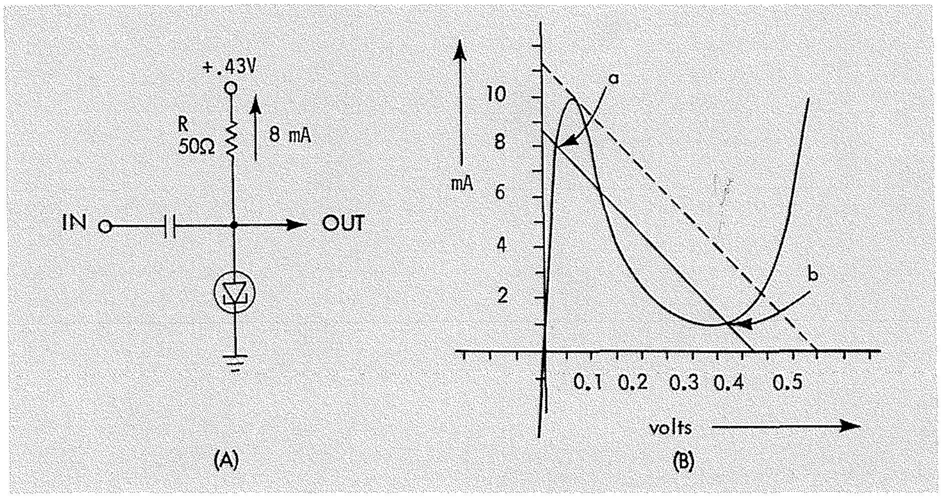


Figure 3 (A) Basic tunnel diode switch for monostable operation.
(B) AC and DC load lines superimposed on a 10-mA curve of the tunnel diode in Figure 3, (A).

the output voltage in Figure 3 less than the output voltage of the circuit in Figure 2. The duration of the output signal is the same as the input signal, resulting in monostable operation.

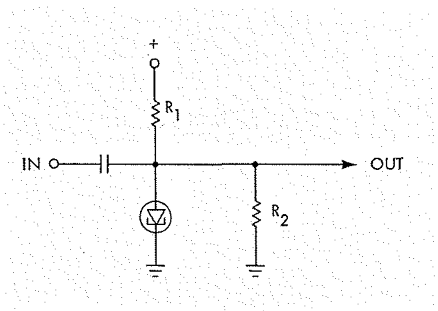


Figure 4

Figure 4 shows another method of obtaining the low impedance load described in the previous paragraph. This circuit has the same characteristics as the circuit in Figure 3 except:

1. A higher source voltage can be used.
2. Some additional current must be provided through R_1 to satisfy the needs of R_2.
3. Some additional signal current is needed to drive the shunt resistance of R_2.

A method of increasing the output voltage and switching speed is shown in *Figure 5A*. The coil provides a very flat load line during switching time (shown as dashed line in Figure 5B) because of the high impedance of the coil at the switching speed of the TD. Note the increase in the voltage excursion. Switching speed is increased because current which would have otherwise passed through R_2 is now available to charge the capacitance of the TD. This circuit is monostable if the load line is steep enough to cross only one positive slope of the TD curve. The slope of the load line depends primarily on the value of R_2. The width of the output pulse is controlled mainly by the L/R time of the circuit, where L is the inductance of L_1 and R is the resistance of R_2 in series with the impedance of the TD. The impedance of the TD in the high-voltage state is different from the impedance of the TD in the low-voltage state.

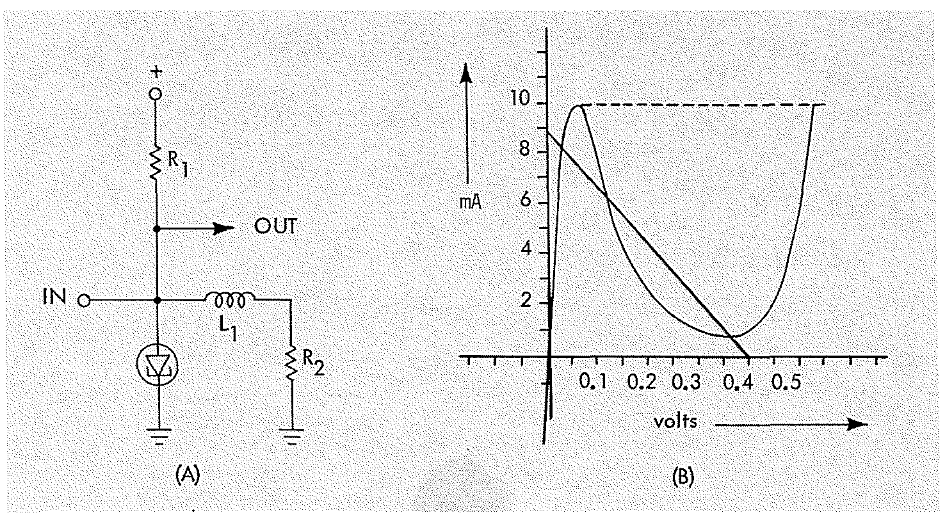


Figure 5 (A) Another version of a monostable tunnel-diode switching circuit. The coil, L_1, helps to increase the output voltage and switching speed.
(B) AC and DC load lines superimposed on a 10-mA curve of the tunnel diode in Figure 5, (A).

OSCILLATOR OPERATION

Circuit operation as an oscillator is also possible. *Figure 6* shows the addition of R_3, a bias control. Resistor values are chosen to place the TD near its current peak (low-voltage state) when R_3 is in the center of its range.

If the resistance of R_3 is reduced, more current flows from the —20-V supply and less current flows through the TD—the TD will now be biased at some point below peak current (as indicated by the dashed line paralleling the R_2 25-Ω line in Figure 6 (B). If the resistance of R_3 is increased (reducing the current through R_3), more current will flow through the TD—if this current exceeds 10 mA, the TD will switch to its high-voltage state, along the dashed load line to point "a". If the DC load line produced by R_2 intersects the lower negative resistance portion of the TD curve (point "b", Figure 6), the TD will automatically switch back to its low-voltage state. The effective load line will change from a high impedance (point "a") to a low impedance (point "b"). This change will take place at an L/R rate—when point "b" is reached, the TD will revert to a position on the DC load line, as determined by R_3. If this load line places the TD current above 10 mA, the circuit will oscillate.

CIRCUIT ANALYSIS

The tunnel diode and the resistor, R_2, in Figure 6A can be considered as parallel elements. Let us assume a value of 25 Ω for R_2. *Figure 7* shows a 25-Ω resistance plot superimposed on a 10-mA TD curve. The instantaneous current of each element can be found by drawing a perpendicular line at the voltage point of interest—for instance, at about 80 mV, the TD is close to its peak current state at 10 mA. The current through the resistor, R_2, with an 80-mV drop will be:

$$I = \frac{E}{R} = \frac{80 \times 10^{-3}}{25} = 3.2 \text{ mA}.$$

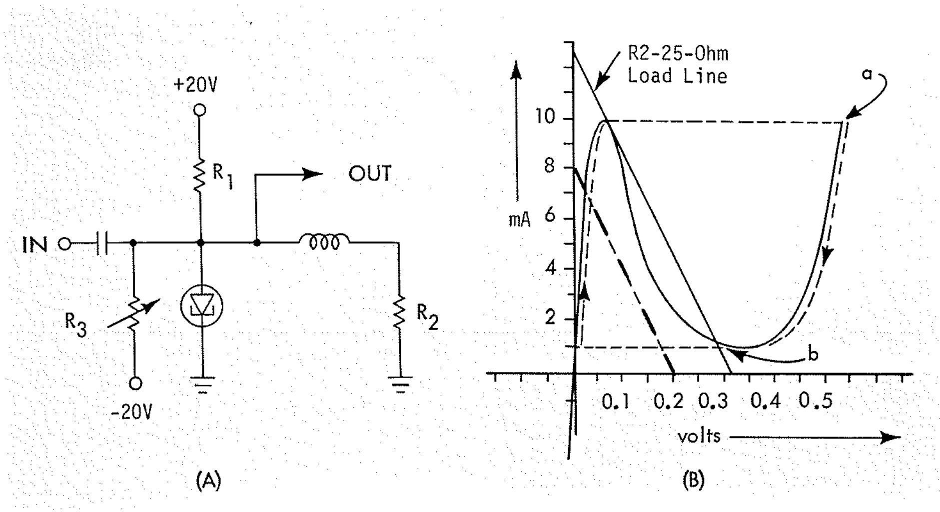


Figure 6 (A) The addition of a variable resistor, R_3, enables the circuit shown in Figure 5, (A), to operate as an oscillator.
(B) AC and DC load lines superimposed on a 10-mA curve of the diode shown in Figure 6, (A).

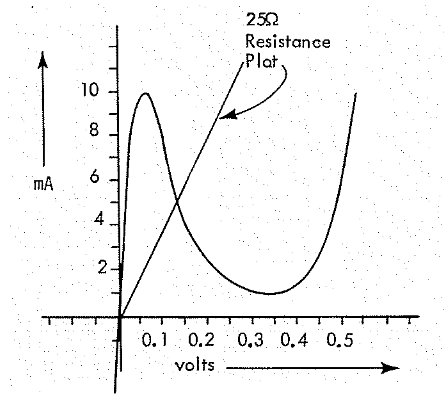


Figure 7 25-Ω resistance plot on a 10-mA tunnel-diode curve.

The +20-V supply must therefore furnish 13.2 mA to the TD-R_2 combination through R_1.

When a small positive-going signal is applied to the circuit in Figure 6, the TD switches to its high-voltage state. Because the coil provides a fairly flat load line (shown by the dashed line in Figure 6B), the output voltage will be a little greater than 0.5 volts. After the L/R time the DC load line will become effective and determine the current distribution through the TD-R_2 combination. The total current supplied to the circuit via the current control resistor, R_1, is about 13.2 mA. As the L/R time constant decays a greater voltage drop will appear across R_2. When this voltage drop reaches ≈300 mV, the current through the 25-Ω resistor will be about 12 mA—as the total current supplied to the circuit is 13.2 mA, only 1.2 mA will be available to the TD. At this current-voltage point the TD will switch back to its low-voltage state. When the circuit is at "idle"—near its current peak, the voltage across the TD-R_2 combination will be about 80 mV, and about 3.2 mA will be "lost" in the resistor, R_2.

The best component available to replace R_2 is a back diode. The back diode is simply a tunnel diode that is usually selected for its reverse conduction characteristics.

Editor's Note: This concludes the first half of this article. The theory, function and application of the back diode to tunnel-diode switching circuits will be taken up in the next (August) issue of SERVICE SCOPE.

MORE ON TEKTRONIX-PRODUCED FILMS

We have experienced a tremendous response to our announcement in the February, 1966, issue of SERVICE SCOPE on the availability of Tektronix-produced films. The requests by our readers for the use of these films have exceeded our wildest expectations and sorely taxed our ability to promptly supply the films.

We are filling all requests on a first-come, first-served basis and earnestly solicit your patience and understanding if we fail to supply the wanted film promptly. All requests from qualified sources will be honored; but, there may be a delay of several weeks in supplying some of the more popular films.

A new Tektronix-produced film is now available to schools or to companies engaged in educational or training programs for their employees. This film like the previously announced ones may be obtained on a free loan basis, or may be purchased. Title of the new film is 'Transresistance". It is a lecture-type film that offers an explanation of the transresistance method of analyzing transistorized circuitry. (An article in the December, 1964, issue of SERVICE SCOPE, "Simplifying Transistor Linear-Amplifier Analysis" discussed transresistance as an aid in troubleshooting or evaluating transistor circuits.) Audiences for this film should have a sound basic knowledge of transistor theory and terminology.

People interested in showing these films should contact their local Tektronix Field Office, Field Engineer, Field Representative, or Distributor.

THE READER'S CORNER

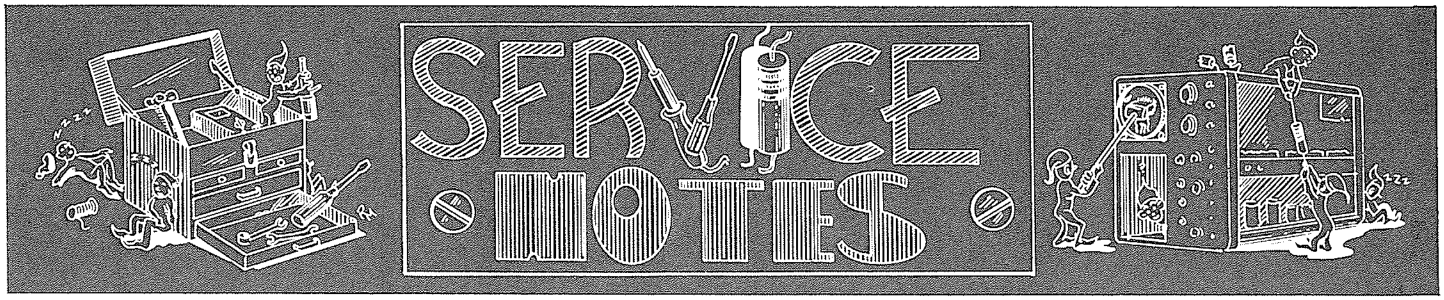
Here are some additional articles, authored by Tektronix personnel, that have appeared in recent issues of trade publications. Listed along with the author's name and the title of the article is the magazine and the month of issue in which the article appeared. Also included is a thumb-nail sketch of the article's content.

Local Tektronix Field Offices, or your Tektronix Field Engineer, Field Representative or Distributor can supply you with reprints of these articles.

"Differential Comparatör Extends Measurement Accuracy," by John J. Horn, Design Engineer. Electronic Design, October 25, 1965. A discussion of how a differential comparator can refine oscilloscope voltage-amplitude measurements for either DC or pulse signals.

"Advances in Storage Oscilloscopes," by Donald C. Calnon, Project Engineer. Electronic Industries February, 1966. Discusses state-of-the-art storage tubes and the more versatile oscilloscope they make possible. Some terminology is defined.

"The Sampling Oscilloscope: A Nanosecond Measurement Tool," from information supplied by Tektronix, Inc. The 1965 Test Instrument Reference Issue (A Cahners publication). Tells how the sampling oscilloscope displays high speed phenomena. Explains how it buys sensitivity at the expense of time.



AN INSULATED EXTENDER FOR A PROBE'S RETRACTABLE-HOOK TIP

Here is a "do-it-yourself" project you may want to try. This insulated extender for a probe's retractable-hook tip can be made from an ordinary paper clip and two pieces of insulation or "spaghetti". It makes a handy extension for reaching into those hard-to-get-at places when trouble shooting or checking circuits.

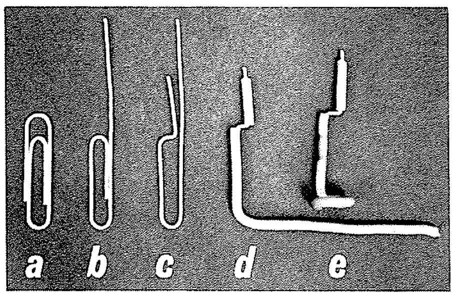


Figure 1. Progressive steps in forming the retractable-hook tip extender.

Figure 1 shows the steps in forming the extender. A. Start with an ordinary paper clip. B. Straighten the outside wire. C. Bend the inside wire to leave a crook. D. Bend the longer wire to form a right angle to the short wire and slip two pieces of insulation over the wire leaving the crook bare. E. With the retractable-hook tip, grip the partially formed extender at the crook and wrap the longer insulated portion around the shaft of the retractable-hook trip to form a one turn coil. *Figure 2* shows a probe with the retractable-hook tip gripping the completed extender.

The extender will offer no problems when used with oscilloscopes having bandpass capabilities of up to 50 MHz. We do not recommend the use of the extender with the Type 580 Series Oscilloscope and the P6008 combination. With this combination, when investigating high frequency signal, the probe ground strap must be kept as short as possible for best results. A probe ground strap in excess of three inches will cause objectionable ringing. An extender and hook tip combination on the probe requires that the probe ground strap be at least 5″ inches in length.

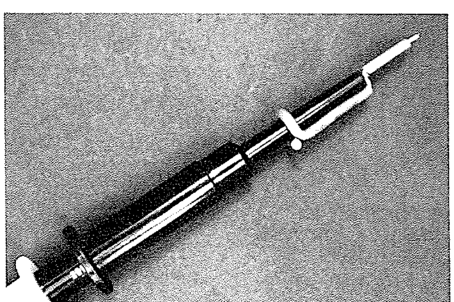


Figure 2. Completed insulated extender in position on a retractable-hook tip.

Our thanks for this idea go to a member of our Instruction Manuals Group, Keith Morrill, who developed the extender and brought it to our attention.

SOLDERING FLUX OR SOLDER RESIST ON ETCHED-CIRCUIT-CARD CONNECTOR TABS

Incompletely removed soldering flux or, more rarely solder resist, can cause poor contact between the connector tabs on etched circuit cards and the connector sockets into which the tabs fit. Soldering flux can be removed with Socal, Fotocal (denatured alcohol), Freon, or Chlorothene. Use a Q-tip to apply the cleaner.

Solder resist which is more tenacious may require a light abrasive, such as a lead pencil eraser, for complete removal. *Use the eraser very lightly.* The connector tabs and connector sockets for Tektronix etched-circuit cards are gold plated to assure a minimum of contact resistance. Care must be taken not to remove this plating.

CRT MESH LIGHT FILTER AND RFI SHIELD—PART NUMBER CORRECTION

In the February, 1966, issue of SERVICE SCOPE we announced a new CRT Mesh Light Filter and RFI Shield. We included a list of oscilloscopes plus the part numbers of the particular filter-shield the instrument would accept.

We have since discovered several errors in that list. Also, we now have a model to fit the Type 321A Oscilloscope.

Here is the corrected list:

TYPE	PART NUMBER
321A	378-0577-00
422	378-0571-00
453	378-0573-00
All Tektronix oscilloscopes with 5″ round CRT's	378-0572-00
506, 527, 529, and 561A	378-0575-00
647	378-0574-00

TRANSISTOR FAILURE IN HYBRID CIRCUITS

When an otherwise unexplainable transistor failure occurs in a hybrid circuit, it pays to consider, as a probable cause, an intermittent short in what appears to be a perfectly good vacuum tube. There have been instances where failure of a transistor located in the grid circuit of a vacuum has been traced to intermittent arc-over in the tube. Frame-grid tubes such as the 6DJ8 are particularly prone to this type of failure; but, they are by no means the only offenders. Normally a grid-wire breaking and shorting to the plate will wipe out the tube. There have been some, however, where the short has "healed" itself after passing enough current to destroy an associated transistor.

DUST REMOVAL AND TEKTRONIX INSTRUMENTS

In all Tektronix instruments using forced-air ventilation, the air entering the instrument is filtered. Nevertheless, some dust will eventually penetrate into the interior. This dust should be removed occasionally due to its conductivity under high humid conditions. The best way to clean the interior is to first carefully vacuum all accessible areas. Next blow away the remaining dust with *dry low-pressure* compressed air. Avoid the use of high-velocity air which might damage some of the components. Remove stubborn dirt with a small soft paint brush or a cloth dampened with a mild water-and-detergent solution.

Pay special attention to high-voltage circuits, including parts inside the high-voltage shield. Arcing in this area due to dust or other causes may produce false sweep triggering which in turn will cause an unstable CRT display.

Don't neglect those instruments that do not use forced-air ventilation. Dust will collect in these instruments too. Its presence will have the same effect on these instruments as in the case of forced-air ventilated equipment. The same removal procedure applies to both types of instruments.

Air Filter—The air filter (too often one of the most neglected parts of an instrument) should be visually checked every few weeks and cleaned if dirty. Obviously, more frequent inspection and cleaning will be required for those instruments located in areas with severe environmental conditions.

Older Tektronix instruments use a metal mesh filter. Later instruments use a more recently developed plastic-foam material as the filter element. The following information applies to both types of filter material. To clean the filter, wash it out as you would a plastic sponge (swish metal mesh filters up and down and around). Use a mild warm water-and-detergent solution. Rinse the filter thoroughly and let it dry. Coat the dry filter with fresh "Filter-Kote" or "Handi-Kote". (These products are available from your local Research Products Company, and from some air-conditioner suppliers.) Let the filter dry thoroughly before reinstalling.

The plastic-foam filter is quite a bit more efficient than the older metal-mesh filter. It can be used as a replacement on some of the Tektronix instruments that came equipped with metal-mesh filters. Here is a list of those instruments and the plastic-foam filter kit they will accept.

TYPE	REPLACEMENT KIT NO.
541, 541A, 543A, 545, 545A, 551*, 555*	050-0123-00
175	050-0087-00
1121, 123, 133	050-0148-00

*This replacement kit is for the indicator unit only. Order replacement kit 050-0253-00 for the power supply unit of these instruments.

NEW FIELD MODIFICATION KITS

In the April issue of Service Scope, in this column, we typographically elevated the P510A Probe to the status of a Cathode Follower Probe. A cathode follower it is not! The P510A is a ten times probe that presents an input impedance of 10 megohms paralleled by 14 pF. This probe has not been produced since 1959. It was, in its day, however, a very popular probe and many are still in use, performing very well with the instruments for which they were designed.

The Field Modification Kit 040-0287-01 which was reviewed in this column last issue contains the parts necessary to repair several P510A Probes.

OSCILLOSCOPE CRADLE MOUNT—INCORRECT PART NUMBER

The correct part number for the Oscilloscope Cradle Mount Modification Kit reviewed in this column last issue is 040-0281-00. This is the modification kit that alters the following instruments to fit into a standard 19" relay rack: Type 524AD, 531, 532, 535, 541, 545, and 570, serial numbers 5001 and up; Types 531A, 533, 533A, 535A, 536, 541A, 543, 543A 543B, 544, 545A, 545B, 546, 547, 575, 581, 581A, 585, 585A, and 661, all serial numbers.

TYPE 532 AND TYPE RM32 OSCILLOSCOPES—SILICON RECTIFIERS

This modification replaces the selenium rectifiers in a Type 532 or Type RM32 Oscilloscope with silicon rectifiers. Silicon rectifiers offer greater reliability and longer life. The modification is applicable to Type 532 Oscilloscopes serial numbers 101 through 6921 and Type RM32 Oscilloscopes, serial numbers 101 through 499.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0218-00.

MAXIMUM INTENSITY MODIFICATION KIT—FOR LISTED OSCILLOSCOPES

This modification replaces the one megohm INTENSITY potentiometer of the listed oscilloscopes with two two-megohm potentiometers in parallel. One potentiometer serves as the front-panel INTENSITY control. The other serves as the MAXIMUM INTENSITY control and is screw-driver adjusted. With this arrangement, when observing phenomena at slow sweep speeds the MAXIMUM INTENSITY control can be adjusted to provide the best phosphor protection and prevent the CRT phosphor from burn damage. Or, when observing phenomena at the fastest sweep speeds, the MAXIMUM INTENSITY control can be adjusted to provide the best writing rate.

The modification is applicable to the following instruments, all serial numbers:

Type 531	Type 535	Type 543
Type 531A	Type 535A	Type 543A
Type 532	Type 541	Type 545
Type 533	Type 541A	Type 545A
Type 533A		

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0159-00.

TYPE 551 OSCILLOSCOPE—12-kV HIGH-VOLTAGE TRANSFORMER

This modification replaces the 10-kV High-Voltage transformer with a 12-kV transformer in Type 551 Oscilloscopes, all serial numbers. The increased high voltage offers greater trace intensity at the fastest sweep speeds.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0238-00.

BLANK PLUG-IN UNITS

Two modification kits supply the necessary "skeleton" parts (with assembly instructions) to construct blank plug-in units. These units are intended to house circuitry of your own design to provide special-purpose plug-in units.

Modification-kit instruction sheets list pertinent electrical information so that the installed circuitry may be designed to be compatible to the oscilloscope for which the special-purpose plug-in unit is intended.

Special plug-in units may be made to operate in conjunction with a standard Tektronix plug-in unit or with a second special plug-in unit.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor.

For Tektronix Oscilloscopes using Letter Series or 1 Series Plug-In Unit, specify Tektronix part number 040-0065-00.

For Tektronix Type 560-Series Oscilloscopes, specify Tektronix part number 040-0245-00.

TEKTRONIX TYPE 1S2 MAKES REFLECTOMETERY EASY

As an analytical technique in the study of high-speed transmission systems and components, TDR (Time Domain Reflectometry) has won wide acceptance. This is particularly true since the advent of the sampling oscilloscope and its fractional nanosecond risetimes.

A new Tektronix oscilloscope plug-in unit, the Type 1S2 Sampling Unit, provides an unusual degree of user convenience for TDR measurements—and does so without sacrificing its sampling capability. The Type 1S2 is designed to operate in Tektronix Type 530, Type 540, Type 550, and Type 580 (with Type 81 Adapter) Series Oscilloscopes.

The essential parts of a TDR system include a fast-flat-top pulse source for launching an incident waveform into a test line. The Type 1S2 contains, within itself, two such pulse sources: (1) a tunnel diode supplying a quarter-volt pulse with a 50-picosecond risetime (giving a TDR system risetime of 140 picoseconds) for observing, with a high degree of resolution, small discontinuities in relatively short 50-ohm systems; and, (2) a one-volt pulse with 50-ohm source impedance and a 1-nanosecond risetime to maximize the signal-to-noise ratio when observing discontinuities in long 50-ohm transmission lines. Either pulse can be fed (via the signal channel containing the sampling-oscilloscope pickoff) into the line under test.

A TDR system discloses, basically, three types of information: (1) the *type* of discontinuity the incident edge encounters as it travels down the line under test, (i.e., whether it meets a new characteristic impedance, or whether it sees a lump of series inductance or shunt capacitance); (2) the *magnitude* of the discontinuity (such as the actual value of shunt capacitance or series inductance); (3) the *location* of a discontinuity with respect to the pulse source and the oscilloscope.

These three types of information can be obtained separately from the Type 1S2. The *type* of discontinuity and its *magnitude* are obtained from the vertical axis of the display. The Type 1S2 offers two sets of scale units on the vertical axis; one calibrated in reflection coefficient "ρ" (rho), and the other in volts per division. A switch provides for scale selection. With the switch in the ρ position, one can read the display of a reflection directly in terms of percent of the incident-pulse amplitude.

By means of an OFFSET control, one can position the display vertically. Also, since the offset voltage itself is available at a front panel jack, slide back measurements of reflection—either in terms of ρ or volts—can be made. The primary function of the OFFSET control, however, is to provide a variable voltage which is essentially added in series to the Type 1S2 input. With this arrangement, when an operator is confronted with a small reflection of interest sitting on a DC voltage, the DC voltage can be cancelled out using the OFFSET control. The signal of interest can thus be examined at a more revealing deflection factor.

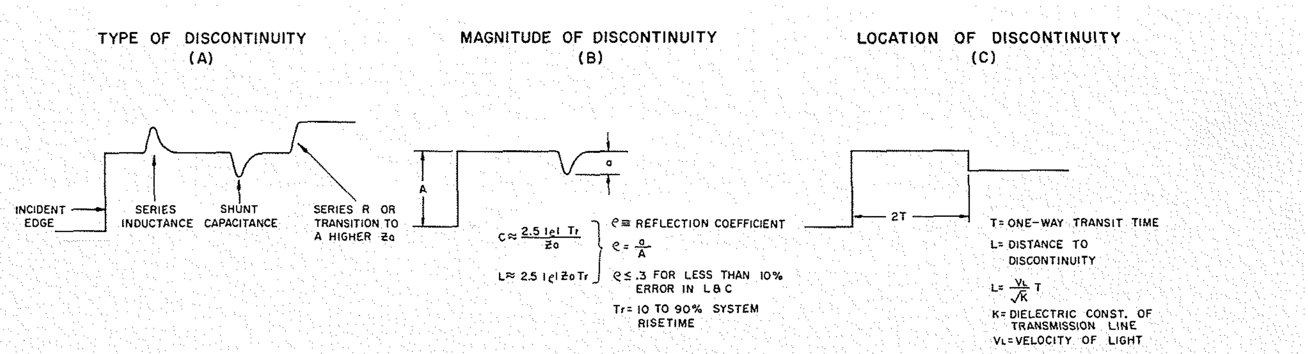
The third type of information, that of the location of a discontinuity is displayed on the horizontal axis of the Type 1S2. This axis also offers two sets of scale units; one calibrated in distance-units per division, the other, in time-units per division. The desired scale is selected via a HORIZONTAL UNITS/DIV front panel control. The actual horizontal units per division changes with the setting of three controls. Therefore a readout indicator is provided to automatically calculate and directly display the actual distance or time units per division.

Separating the processes of locating the discontinuity and analyzing the degree or size of the discontinuity is often desirable. This is very easy to do with a Type 1S2 Unit. When a position range has been selected and the POSITION control set to zero, the leading edge of the incident pulse will be positioned or referenced to the "1" vertical graticule line (graticule lines numbered 0 through 10—left to right), independent of the time-distance settings of the RANGE control. Turning the POSITION control will now cause the leading edge of the incident pulse to go off screen to the left and will bring the aberration, caused by a "down-the-line" discontinuity, to the reference line. With the aberration so positioned, the location of the discontinuity can be determined by multiplying the reading of the POSITION control by the selected range.

When a discontinuity has been thus located, advancing the MAGNIFIER control will expand the display horizontally about the reference line.

With the HORIZONTAL UNITS/DIV switch in the DISTANCE position and the DIELECTRIC control set to the dielectric of the line under test, the location of a discontinuity can be determined directly in meters. DIELECTRIC control positions for air, TFE, and polyethylene lines are provided. The PRESET position of this control provides a relative velocity of propagation from 0.6 to 1. This extends the instrument's distance calibration for use with foam transmission lines, many printed-circuit strip lines and lines with other unusual dielectrics. When a test line is composed of unknown or several different types of dielectrics, it may be more convenient to use the time-scale calibration. The POSITION control will then indicate the round-trip transit time of the incident edge down the test line and back to the oscilloscope.

As a sampling unit, the Type 1S2 offers a flexible high-speed trigger circuit that accepts pulse and sinewave triggering through 5 GHz. However, the low sampling density that occurs in the display at low trigger rates makes trigger rates above 1 kHz desirable. The through-signal channel is then available to provide 90-ps risetime along with vertical deflection factors from 5 mV/div to ½ V/div, and time units from 1 μs/div to 100 ps/div. In either mode of operation—TDR or Sampling—single sweeps are available for photography or storage convenience along with a manual or external scan of the display; most convenient when driving X-Y or Y-T recorders directly from outputs provided at the Type 1S2's front panel.



IDEALIZED WAVEFORMS SHOWING THREE KINDS OF INFORMATION FROM A TDR DISPLAY

Service Scope

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USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 39 PRINTED IN U.S.A AUGUST 1966

TUNNEL DIODE SWITCHING CIRCUITS AND THE BACK DIODE

By The Marketing Technical Training Department
Tektronix, Inc.

PART II

This is the concluding half of an article intended to give the reader a better understanding of tunnel-diode switching circuits. The first half of the article appeared in the June, 1966 Service Scope. It reviewed the several methods of tunnel-diode circuit operation and, in a circuit analysis, developed the need for a device, such as the back diode, in these circuits. This half of the article discusses the theory of the back diode and the application of this rather new device to tunnel-diode circuits.

BACK DIODE

In order to avoid the waste power in R_2, during "idle" time of the circuit, the ideal component to replace R_2 would be a 200-mV zener diode (see Figure 8). Normally when the TD is biased on the first positive slope, there would be essentially no current supplied to the zener. The steep slope of the zener that extends between the peak and valley current points of the TD would cause very positive switching back to the low-voltage state. Unfortunately, 200-mV zeners are not available.

A more practical solution is the use of a back diode[1].

The back diode is simply a tunnel diode that is usually chosen for its reverse conduction characteristics. If the peak current is small compared to the operating current, the peak current can be ignored. The BD-4 back diode has a peak current of from 50 μA to 100 μA (see Figure 9A). When a 200-mA peak to peak sinewave is applied to the BD-4, the E-I characteristics of the back diode are represented by the curve in Figure 9B. Notice that the negative resistance characteristic cannot be seen.

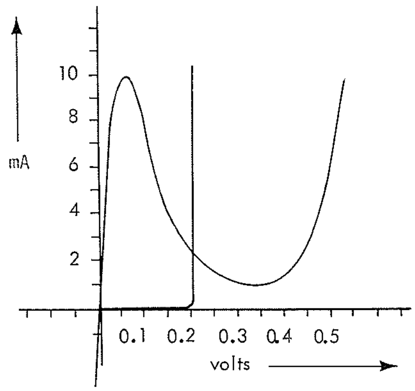
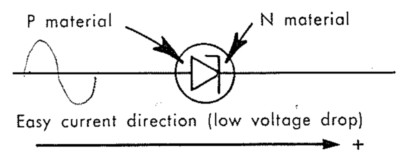


Figure 8 Curve of a hypothetical 200-mA zener diode superimposed on a 10-mA tunnel-diode curve.

[1]The back diode is a tunnel diode whose reverse characteristics are being used. Just as there are many symbols for tunnel diodes, many symbols have been used for back diodes. In order to avoid confusion, the symbol shown below has been chosen to represent a "backward" diode in this article.



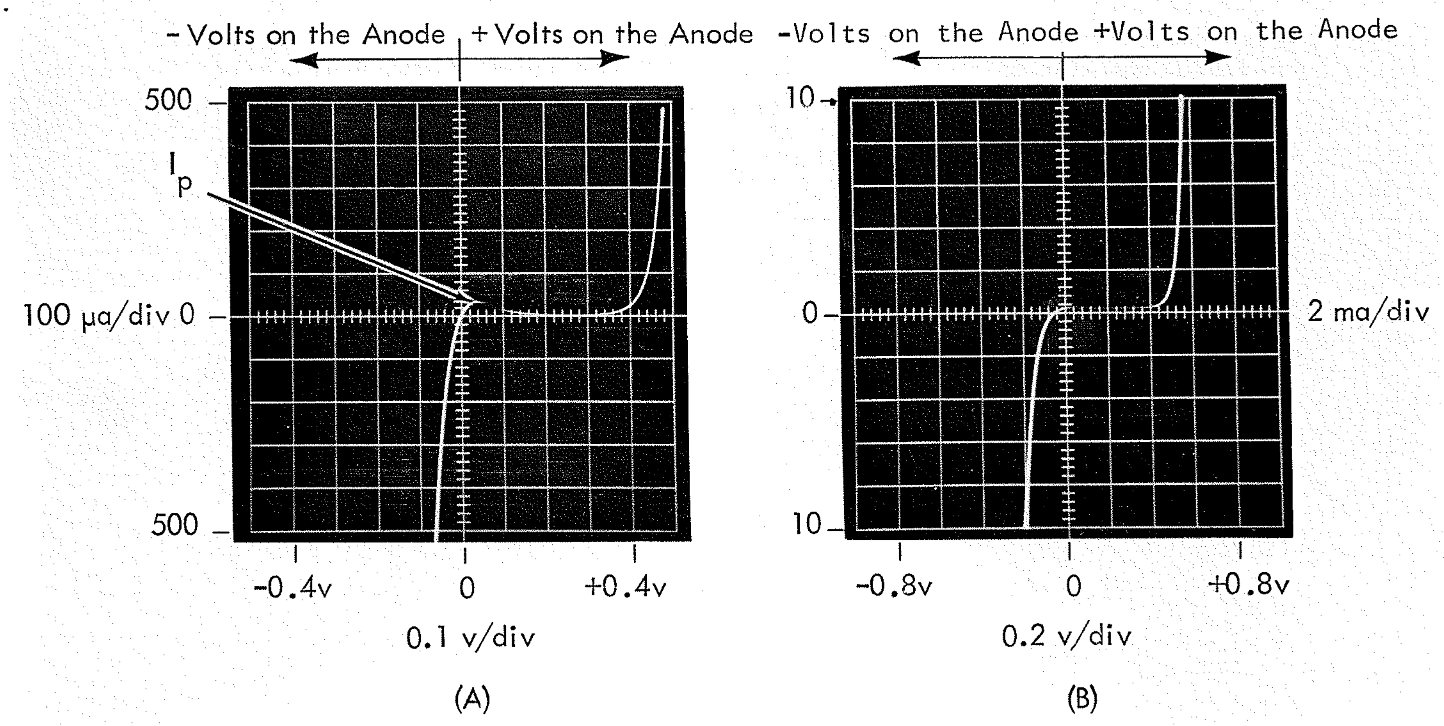


Figure 9 (A) Waveform photo showing peak current of a BD-4 back diode.
(B) Waveform of a BD-4 back diode with a 20-mA sinewave applied.

Since the back diode is operated in the reverse direction, the conduction curve in Figure 9B must also be reversed to give a proper picture of the conduction characteristics of the device. See Figure 10. Notice this appears like a regular diode with a low-voltage zener region and an extremely low forward voltage drop. Any TD can be used as a back diode, although the high forward-current tunnel diodes will have a less desirable "reverse" characteristic.

Figure 11A shows curves of a tunnel diode type TD253B and a back diode type BD-4 superimposed. These curves were taken on a Tektronix Type 575 Curve Tracer with the vertical deflection factor set to 1 mA/div and the horizontal set to 0.1 volts/div.

In Figure 11B, if the TD bias resistor, R_3, is adjusted so that the tunnel diode is biased at some current below I_p, the TD circuit is in a triggerable mode. The new DC load line, using the back diode as a load for the TD, is shown in Figure 12. The curve of the load line is the inverse of the impedance of the back diode. The AC load line is still the flat line (dashed) produced by the coil. At the time the peak current on the tunnel diode is reached, the current in the back diode is approximately 1 mA. This compares to 3.2 mA of "lost" current when using the 25-Ω resistor. As more current flows in the back diode, the non-linear impedance decreases substantially. The back diode must conduct about 10 mA when switching the TD to the low-voltage state. At this point (10 mA) the impedance of the BD-4 is about 2 Ω. This low impedance will cause a very positive "back to low-voltage state" switching of the tunnel diode. The non-linear impedance of the BD-4 offers the following advantages over a resistor:

1. The high impedance at low current insures that the triggering point of the TD does not depend on the rate of rise of the trigger signal because the L is essentially disconnected.
2. The very low impedance at high current will insure that the TD always returns to its low-voltage state after a trigger.

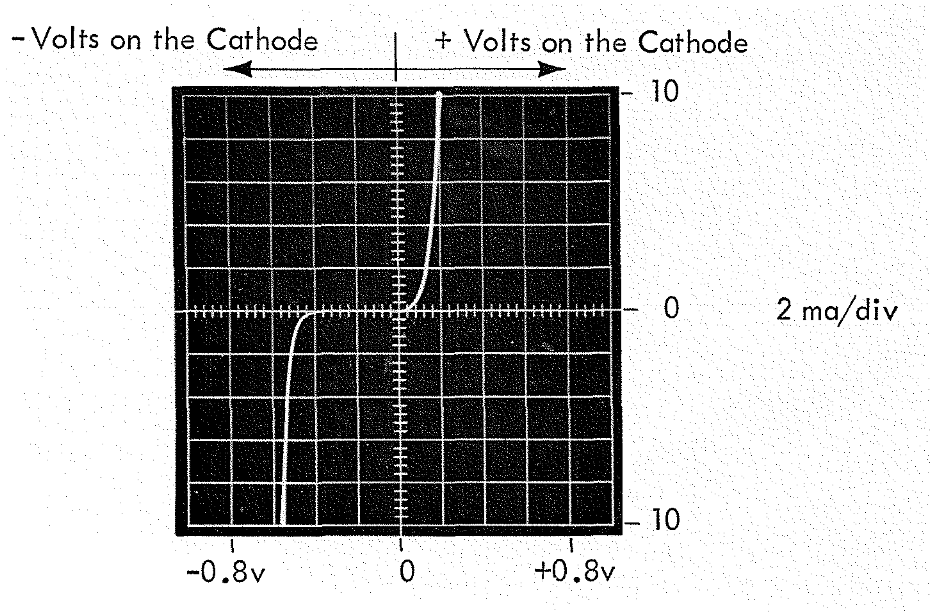


Figure 10 Conduction curve in Figure 9, (B) reversed to give a proper picture of conduction characteristics.

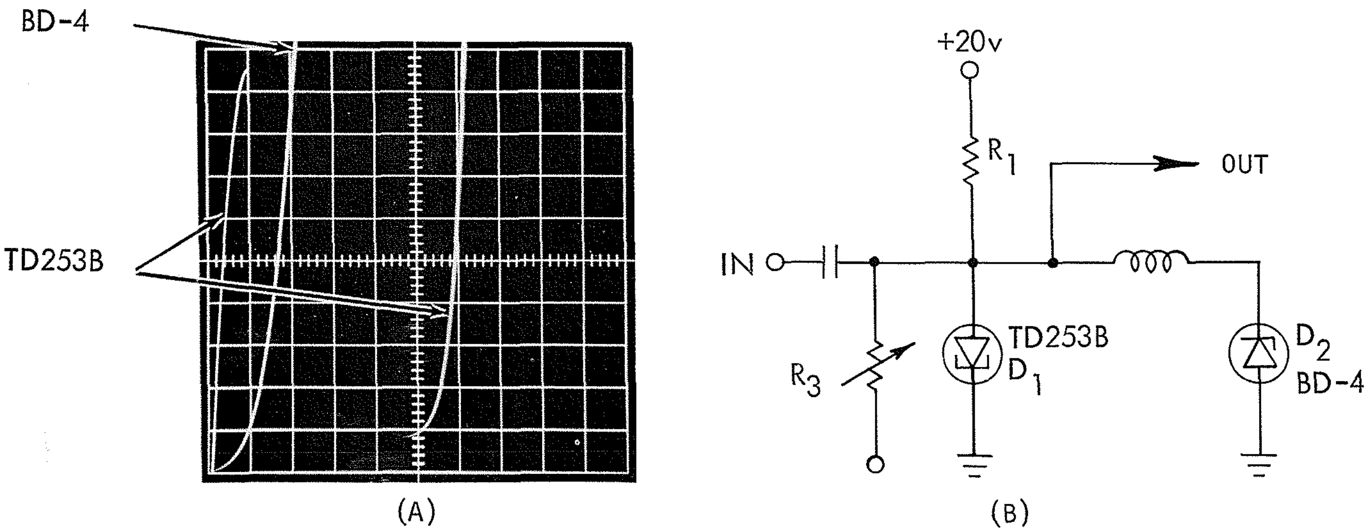


Figure 11 (A) Curves of a TD253B tunnel diode and a BD-4 back diode superimposed.
(B) Same circuit as in Figure 6, (A) except here a back diode, D_2, is the load for the tunnel diode.

3. The static power requirements are less.

The BD-4 also aids in operation of the circuit as a count-down unit. It has been noted that the circuit in Figure 11B will oscillate if the TD is biased above the peak current point. Current switching will take place between the TD and the back diode. The frequency can be influenced by changing bias on the TD. If the circuit has a free-running frequency of 49 MHz and a 200-MHz signal is applied, the TD multivibrator circuit will synchronize with some sub-multiple of 200 MHz—in this case 50 MHz. In any case, the output frequency will be some sub-multiple of the input frequency when the input frequency is significantly higher than the circuit free-running frequency.

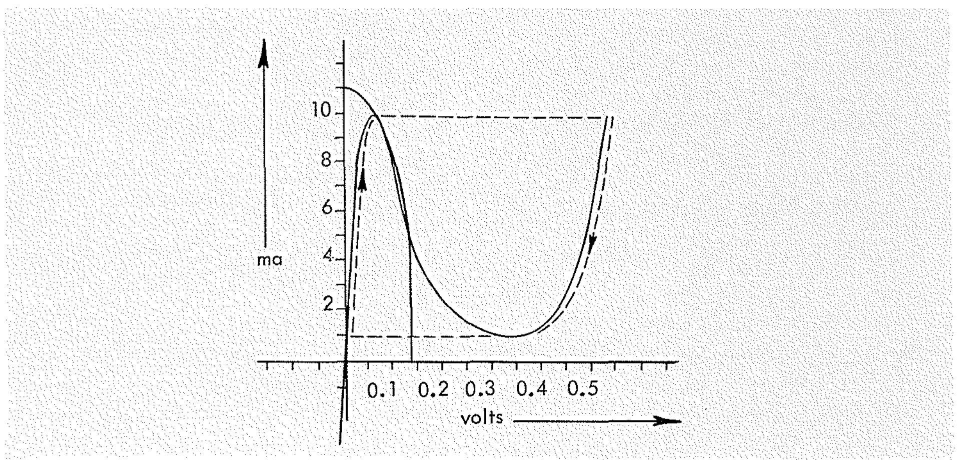


Figure 12 AC and DC load lines of tunnel diode in Figure 11 (B) superimposed on a 10-ma tunnel-diode curve.

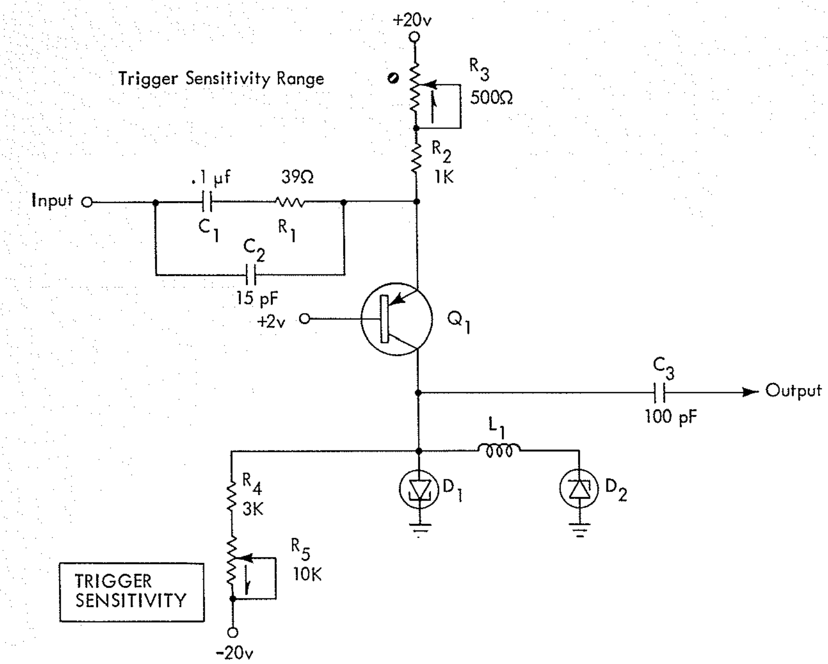


Figure 13 A few refinements to the circuit in Figure 11 (B) are included in the circuit shown here. See text for explanation.

A few refinements to the circuit in Figure 11B are included in the circuit in Figure 13. The transistor is a fast PNP device which isolates the voltage excursion of the TD circuit from the input signal. Static current in the transistor is adjusted by R_3 to compensate for circuit values and peak current differences of TD's. Normally, R_3 is adjusted for a free-running TD circuit when R_5 is at the center of its range. When R_5 is set in the center of its range, the circuit operating conditions are as follows:

1. Current from the —20 V supply to D_1 anode is $\frac{E}{R} = \frac{20\text{ V}}{8\text{ k}\Omega} = 2.5\text{ mA}$.
2. D_1 must be biased at peak current which is 10 mA.
3. D_2 will have a reverse current of $\approx$1 mA.
4. Current in Q_1 must equal R_4, R_5 current plus D_1 current plus D_2 current which total 13.5 mA.
5. Voltage drop across R_2, R_3 is +20 V minus emitter voltage of +2 V (base voltage) plus $\approx$0.6 V (base-emitter drop) which equals 20 — 2.6 or 17.4 volts.
6. Required total resistance of R_2, R_3 is $\frac{E}{I} = \frac{17.4\text{ V}}{13.5\text{ mA}} = 1.29\text{ k}\Omega$.
7. Current requirements are satisfied when R_3 is adjusted for 290 Ω.

The input signal is AC coupled by C_1 and C_2. If the input frequency is sufficiently high, the impedance of C_1 can be ignored and input impedance is R_1 in series with the transistor emitter resistance; 39 Ω + 11 Ω = 50 Ω. The small capacitor, C_2, provides additional high-frequency coupling of the input signal to compensate for the increase in emitter resistance at higher frequencies, thus the input impedance is held fairly constant throughout the circuit operating range. Since the input impedance is a predictable 50 Ω, the signal current can be found by $I = \frac{E\text{ signal}}{R\text{ input}}$. For a 10-mV signal, I becomes $\frac{10\text{ mV}}{50\ \Omega}$ or 0.2 mA. An increase in current is required to switch D_1 so the circuit responds to positive signals only.

When triggered operation is desired, R_5 is set ccw of center (less than 5 kΩ). More current is furnished to the transistor collector by R_4, R_5 — perhaps 2.7 mA. The additional 0.2 mA through R_4, R_5 subtracts from the current in the TD. The TD is biased at 0.2 mA below peak current or 9.8 mA. A positive 10 mV signal will cause an increase of current in Q_1 of 0.2 mA and the TD will switch. The TRIGGER SENSITIVITY control is usually adjusted so that the current requirements of D_1 are compatible with the input signal.

When synchronized operation is desired, D_1 is made to free-run by reducing the shunt current through R_4, R_5. (R_5 is adjusted for greater than 5 kΩ.) D_1 current increases to greater than peak current and D_1, D_2 and L_1 act as an oscillator. The oscillating frequency is influenced by the additional current through D_1, D_2 and L_1 when the resistance of R_5 is increased. As current increases, frequency decreases because even though the time constant remains the same, a longer time is required to switch the *additional* current from D_1 to D_2.

Let us assume the TD has just switched to the high state. Current through D_2 increases exponentially as fast as L_1 and the impedances of D_1 and D_2 will allow. As the current in D_2 increases, current in D_1 will decrease proportionally until D_1 switches to the low-voltage state. At this time, the current in D_1 will increase as current in D_2 decreases until D_1 peak current is reached and switching occurs again.

When a high-frequency signal is applied at the circuit input, each positive peak will cause a small increase of current in Q_1. If D_1 is almost ready to switch when a current increase occurs in Q_1, the switching of D_1 and the positive peak of the input signal occur coincidently. (The increase in Q_1 current will cause D_1 to switch.) When the free-running frequency of D_1 D_2, and L_1 is such that one of several input signals always causes D_1 to switch, the TD multivibrator circuit will be in synchronization with the input signal. Since the TRIGGER SENSITIVITY setting influences the free-running frequency of the circuit, it can be adjusted to achieve optimum synchronization.

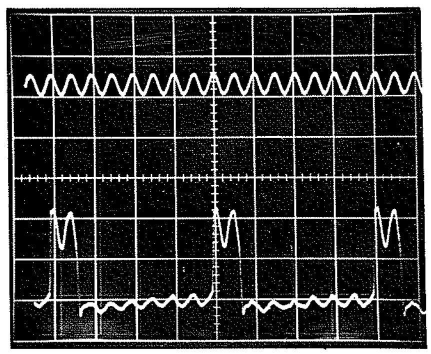


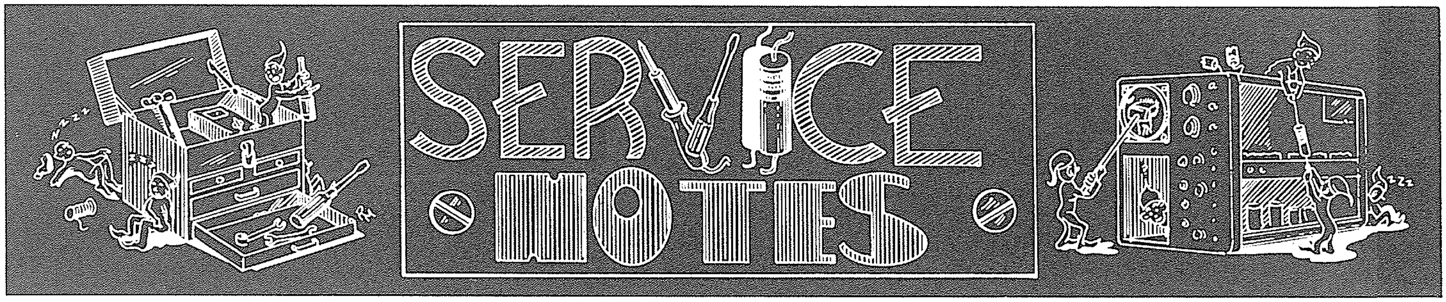
Figure 14 Waveform photo showing a 200-MHz input signal on the upper trace and the synchronized switching of the TD circuit on the lower trace.

The photo in Figure 14 shows the 200-MHz input signal on the upper trace and the synchronized switching of the TD circuit on the lower trace.

The obvious advantages of this type of trigger circuit are:

1. The circuit is *very* sensitive to small input signals.
2. The circuit can be made to oscillate and produce a trigger in the absence of an input signal.
3. In synchronous operation, high-frequency input signals can be converted to a more useable frequency.
4. The TD circuit operates at low power levels so radiation interference is correspondingly low.

In the interest of simplicity the influence of the usual hold-off circuitry has been deliberately ignored. By adjusting circuit values in Figure 13, current in Q_1 has been increased to include TD bias current normally supplied by the hold-off circuitry.



TYPE 580/580A SERIES OSCILLOSCOPES WITH TYPE 82 DUAL-TRACE PLUG-IN UNITS—A SYSTEMATIC STEP-BY-STEP PROCEDURE FOR MAKING GAIN ADJUSTMENTS

A Type 580/580A Series Oscilloscope in combination with a Type 82 Dual-Trace Plug-In Unit has eight gain adjustments which must be adjusted in the proper sequence to realize optimum vertical-amplifier performance. These eight gain adjustments —five potentiometers and three solder-in resistors—are necessary to compensate for the effects of parameter variations of transistors and tubes. Before we outline a systematic step-by-step procedure by which these adjustments are made, we should point out that the three solder-in resistors are selected during the initial factory calibration of the Type 82 and Type 580 Series Oscilloscope—*they will very seldom require changing.* However, to make a complete story, the selection procedure for each of the three solder-in resistors has been included in the adjustment procedure. The adjustment procedure was written with the Type 581A and Type 585A Oscilloscopes in mind. Certain notes have been added to make the procedure equally useful for the Type 581 and Type 585 Instruments.

The step-by-step gain adjustment procedure which follows is intended to delete one step in the Calibration section of the Instruction Manuals for the Type 580 Series Oscilloscopes and to replace one step. The steps deleted and replaced will depend upon whether the calibration procedure you are following is for a Type 581, Type 585, Type 581A, or Type 585A Oscilloscope. If your Instruction Manual is for a:

Type 581, delete step 15, page 6-8; replace step 16, page 6-9.

Type 585, delete step 15, page 6-9; replace step 16, page 6-10.

Type 581A, delete step 11, page 6-6; replace step 14, page 6-6.

Type 585A, delete step 11, page 6-6; replace step 14, page 6-7.

The Type 580 Series Indicator (Oscilloscope) deflection factor (Volts/cm) must first be verified before using the indicator for plug-in calibration.

Adjustment of the Type 580 Series Indicator Gain:

1. Install a Type 84† Plug-In Test Unit in the Type 580 Series Indicator.

   NOTE: If a Type 84 Plug-In Test Unit is not available, a Type 82 Dual-Trace Plug-In Unit can be used to provide the push-pull signal required—see Step 4-c. A second *calibrated* scope is the instrument you would choose to verify that the Type 82 Plug-In was delivering 100 millivolts peak-to-peak to the input of the indicator.

2. Set the Type 84 DISPLAY SELECTOR to CAL (2 cm), ALT. SYNC and free run the sweep.

3. Rotate the Type 580 Series Indicator Vert. Gain Adj. full clockwise (R1015).

4. Check the gain limits:
   a. If the deflection is less than 2.3 cm, the 6DJ8's on the upper vertical chassis and/or the 7788 CRT driver tubes may need replacements. (Type 581 & 585 used a single 7699 CRT driver tube.)

   NOTE: Typical voltage gains for each of the three sections of the vertical amplifier will be useful in determining if tubes should be replaced for insufficient gain. Typical gains are:

Delay Line Driver section (lower vertical chassis)	X3 gain
Vertical Output section (upper vertical chassis)	X5 gain
CRT driver chassis	X4 gain

   b. If the CRT deflection is greater than 2.5 cm, add a 2W 180-Ω resistor (R1016)* between the Vert. Gain Adj. pot (R1015) and the cathode bus wire. (R1016 replaces a wire strap.) Until Type 585A, sn 10870, R1016 was usually 0 Ω (wire strap) and not listed in the manual. If GE 6DJ8's are used in the vertical amplifier, gain may be excessive—requiring use and selection of R1016. R1016 can have any value between 0 Ω and 200 Ω.

   c. Vary the line voltage from 105—125 V AC. With marginal tubes, the CRT display will shift vertically about 1.8 mm and the peak-to-peak deflection will change about 2 mm (10%). With new tubes, line voltage variation will cause virtually no vertical shift or gain change. Return the line voltage to 117 V AC.

   NOTE: With a 2-cm display and change of line voltage from 105—125 V AC, vertical trace shift of 0.5 cm and a peak-to-peak deflection change of nearly 1.0 cm can be expected on a Type 585 which has not been modified by installation of kit 040-0303-00 (Vertical DC Filament Supply Modification Kit).

   Type 585A should not produce 1.0 cm of CRT deflection when 100 mV of peak-to-peak signal is *differentially* applied to the indicator between pins 9 and 11 of the Amphenol connector. A Type 82 or 86 Plug-In Unit develops a differential (push-pull) signal at these pins.

Adjustment of the Type 82 Gain:

Remove the Type 84 Plug-In Test Unit from the indicator and install the Type 82; allow 10 to 15 minutes warm-up time. Perform all manual checks and adjustments pertaining to gas, microphonics, position range, and grid current before starting the gain adjustments.

NOTE: Prior to sn 3000, the Gain Bal. Adj. pot was in Channel B instead of Channel A and designated R277. For these early Type 82's, Steps 1-5 should be performed in Channel B; Step 7 should be performed in Channel A.

1. Set Channel A and B VOLTS/CM to 0.1, VARIABLE VOLTS/CM clockwise and MODE switch to A only.

2. Apply 0.2 V from the Type 585A calibrator (±3%) to the A Channel input.

3. a. Vary the line voltage from 105—125 V AC. If the change in CRT deflection is 5—10% greater than the change noted in Step 4 c of the Type 585A adjustment section, replace the three output 6DJ8's in the Type 82. 6DJ8's with low transconductance will reduce the gain of the Type 82 output amplifier as much as 10%.

b. Mechanically center the front panel X1 GAIN ADJ. control. Rotate the Gain Bal. Adj. (R177), located on the circuit board assembly near Channel A Attenuator switch. If the range is not approximately ±3 mm (nominal 2-cm CRT deflection), select and install a new value of R550.* Typical range of R550 is 10 Ω to 68 Ω.

c. Change the 0.2-V calibrator signal to Channel B, MODE switch to B only (front panel X1 GAIN ADJ. is still mechanically centered), and select R262* for approximately 2-cm CRT deflection. Reducing the value of R262 will increase the CRT deflection; typical range of R262 is 390 Ω to 1.5 kΩ. (R262 is in parallel with R267 and, if present, is located on the circuit board assembly near B attenuator switch.)

4. a. Adjust the X1 GAIN ADJ. for exactly 2 cm of CRT deflection.

   b. Change the 0.2-V calibrator signal to Channel A, MODE switch to A only and adjust the Gain Bal. Adj. for exactly 2-cm CRT deflection.

5. With the calibrator signal still applied to Channel A, change the GAIN switch to X10 and the calibrator signal to 20 mV.

6. Adjust the X10 Gain Adj. (R356) for exactly 2-cm deflection.

7. Turn MODE switch to Channel B only, change the calibrator signal to Channel B and adjust the X10 Gain Adj. (R456) for exactly 2-cm deflection.

† The Type 84 designation for the Plug-In Test unit for the Type 580 Series Oscilloscopes has been changed to a Tektronix part number — 067-0523-00. This part number, rather than the Type 84 designation, should be used in ordering or referring to the Type 580 Series Oscilloscopes Plug-In Test Unit.

* The resistors identified by an asterisk are the three solder-in resistors that along with five potentiometers comprise the eight gain adjustments with which this procedure is concerned.

TRANSISTOR TESTING WITH THE TYPE 575 TRANSISTOR-CURVE TRACER AS AN AID TO TROUBLESHOOTING

Usually when a transistor fails one junction becomes shorted or open. Quick checks for opens or shorts can be made on suspect transistors by using a Type 575 Transistor-Curve Tracer to determine whether a typical family of curves can be produced. Nearly every transistor can stand a collector voltage of about 2 volts without danger of breakdown; and, base current drive of up to 100 microamperes will almost never exceed dissipation limits with only 2 volts on the collector. So, by limiting the collector voltage and the base drive on the Type 575, you can quickly and safely make nondestructive tests to determine if the transistor is functioning properly. To do this you need only to know whether the transistor is an NPN or PNP type, which leads go to the emitter, the base and the collector, and how to set up the Type 575. (Pages 2-5 and 2-6 in the Operating Instructions section of the Type 575's Instruction Manual contain information on how to set up the Type 575 to display a family of curves.)

The Beta of most transistors is usually between 10 and 200. Therefore, a vertical mA/division setting of about 20 times the amount of base current per step will usually produce a display of a typical-looking family of curves on the CRT of the Type 575. Putting it in terms of front-panel controls for the Type 575, the CURRENT OR VOLTAGE PER DIVISION switch (located in the Vertical block) should be set to a value on the COLLECTOR mA range, that is 20 times the value of the mA PER STEP setting of the STEP SELECTOR switch (located in the Base Step Generator block).

From an instrument troubleshooting standpoint, the Type 575 is a valuable tool. Transistor characteristics can be easily matched for use in push-pull solid state amplifiers. Verification of tunnel diode, zener diode, and signal diode characteristics is a relatively simple task. For maintenance activities, it proves to be quite a time saver.

NEW FIELD MODIFICATION KITS

TYPE 316 AND TYPE 317 OSCILLOSCOPES—DC FAN MODIFICATION

Installation of this modification enables the Type 316 and Type 317 Oscilloscopes to operate from a 50-to-400-cycle power source. The kit supplies a DC fan assembly and the necessary hardware and components along with step-by-step instructions for easy installation.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0228-00.

TYPE 316 AND TYPE 317 OSCILLOSCOPES—SILICON RECTIFIERS

This modification replaces the selenium rectifiers originally used in the power supplies of the Type 316 and Type 317 Oscilloscopes with silicon rectifiers. The new rectifiers offer more reliability and longer life than selenium rectifiers.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0212-00.

TYPE 422 OSCILLOSCOPE—PORTABLE-TO-RACKMOUNT CONVERSION

This modification is applicable to Type 422 Oscilloscopes, AC powered only. It is not applicable to Type 422 instruments with AC/DC Battery Power Supply.

The modification supplies an R422 Rackmount Assembly for rackmounting the Type 422 Oscilloscope. This assembly has two oscilloscope compartments. With this arrangement, two Type 422 Oscilloscopes can be mounted side-by-side in the same relay rack. Or, one Type 422 may be rackmounted in either the right or left compartment, leaving the remaining compartment to be used for storage of accessories or other equipment. A convenient pulldown door is provided for the storage compartment.

The kit also includes two Rackmount Rear Support brackets with instructions for their installation. These brackets are required when two Type 422's are rackmounted side-by-side. When properly installed the two Rackmount Rear Support brackets enable the Type 422's to withstand an environmental shock or vibration as described in the Characteristic section of the Type R422 Instruction Manual (page 1-3). If only one instrument is rackmounted, support to the storage compartment side of the assembly is not required.

The assembled R422 Rackmount Assembly may be installed in any standard 19-inch open or closed relay rack.

The slide-out tracks used on the Type 422 consist of two assemblies, one for the right side and one for the left side. Each assembly consists of three sections. The stationary section attaches to the rack, the chassis section attaches to the surrounding instrument frame, and the intermediate section fits between the other two sections. This allows the instrument to be pulled forward and extend out of the rack.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0419-00.

TEKTRONIX TECHNICAL PUBLICATIONS

A considerable number of varied forms of Technical Publications have been produced by Tektronix during the past few years. The main purpose of these publications is to educate the customer in techniques unique to Tektronix, and thus, enable him to apply our products more usefully. They also provide a fuller explanation of certain procedures and technical information mentioned all too briefly in some Instruction Manuals.

Much of the need for such a range of publications has been reduced because of the considerable improvements to, and expansion of material in many Tektronix Instruction Manuals.

PROGRAMMED INSTRUCTION

The use of Programmed Instruction is becoming quite widespread throughout the United States and many overseas countries. The Product Technical Information Department at Tektronix produces a range of such books. These are designed to be used as self-teaching devices to complete the training (of an individual who has some electronic background) in the theory of operation of Tektronix circuits.

At the present time eight programmed volumes are available and four more will be added to the range shortly. Two further volumes are available published in conventional text-book form.

Details are as follows:

Semiconductor Series	Order Part Number
Volume 1 Basic Theory	062-0053-00
Volume 2 Diode Devices	062-0112-00
Volume 3 Transistors	062-0067-00
Volume 4 Circuit Analysis 1	062-0216-00
Volume 5* Circuit Analysis 2	062-0217-00
Volume 6** Reference for Vol's 1 and 3	062-0422-00
Volume 7** Reference for Vol's 4 and 5	062-0432-00

Analysis of Passive Networks	Order Part Number
Volume 1 DC Equivalent Circuits	062-0605-00
Volume 2 AC Theory	062-0606-00
Volume 3 Integrators	062-0607-00
Volume 4 Differentiators	062-0608-00
Volume 5* Circuit Application	062-0609-00

Time Domain Reflectometry	Order Part Number
Volume 1*	062-0703-00
Volume 2*	062-0704-00

* Not presently available. To be added to the range in the near future.

** Available in conventional textbook form only.

The publication "Junction Functions" (061-0662-00) is no longer available. It has been superseded by Programmed Instruction.

In addition to these books several other specialized booklets are currently available. These are prepared in conventional text form and in the main cover specific applications or techniques:

Sampling Notes—First published in 1962. Describes basic repetitive sampling techniques (N, 3S76, 4S1, etc). 061-0557-00.

Storage to Picoseconds, a Survey of the Art—Reprint of magazine article, August, 1963. Comparison of sampling and conventional oscilloscope techniques. 061-0991-00.

Spectrum Analyzer Notes—A basic approach to the use of analyzers. 062-0433-00.

Strain Gage Measurement Concepts—A new booklet, published in 1966, describing basic techniques, circuits and applications to oscilloscope displays. 062-0710-00.

Some Transistor Measurements Using the Type 575—Describes exact use of instrument with varied types of semiconductors, 1959. 070-0192-00.

Typical Oscilloscope Circuitry—A 300 page book analyzing basic Tektronix circuits in use up to 1964. 070-0253-00.

Magnetic Ink Character Recognition—Published in 1962, this booklet describes the oscilloscope displays derived from Magnetic Ink readers. 070-0283-00.

Rackmounting Instructions—1964, information concerning the installation of the majority of Tektronix instruments in standard 19" (48.5 cm) racks. 070-0440-00.

Operational Amplifiers and Their Applications—1965, detailed techniques and uses. 070-0526-00.

Oscilloscopes at Work No. 1—Measurement of High Current Forward-Reverse Recovery Times in Signal Diodes—Technique utilizes Tektronix sampling system. A2271.

Oscilloscopes at Work No. 2—Measurement of Shock Imparted During Drop Test—Using a storage oscilloscope. A2270.

Oscilloscopes at Work No. 3—Monitor of Cortical Impedance During Periodically Increased Stimulation—Using 564/2A63/2B67 and 160 series generators. A2277.

Getting Acquainted with Spectrum Analyzers—A basic approach to analysis, reprinted from articles appearing in Service Scopes No.'s 31 and 32, April and June, 1965. A2273-1.

Fundamentals of Selecting and Using Oscilloscopes—A booklet designed to provide abridged details of the entire Tektronix product range and how to select an instrument for a particular application. X2146-7.

Some currently available booklets relate to Tektronix Instruments no longer in our product range. These will be of interest to customers who possess the instrument types concerned. Supplies of the booklets are rather limited.

Some Basic Circuits Used in Tektronix Instruments—Published in 1960, details of then current circuits—known as FIP-1. 061-0139-00.

Measuring the Angular Velocity and Acceleration Characteristics of Rotating Machines—1959, refers in the main to techniques involving the Rotan Angular Transducer—now discontinued. 061-0151-00.

567/3S76/3T77/6R1 Data Flow Diagram—1963, interconnections and signal paths diagram using the 6R1—not the 6R1A. 061-0938-00.

Using Your Oscilloscope Type 535/45—1958, not "A or B" series. FIP-1. 070-0185-00.

A Primer of Waveforms and Their Oscilloscope Displays—1960, basic waveform analysis, simple circuit discussion—FIP-7851. Refers to obsolete instruments and publications but still a good training guide. 070-0190-00.

Using Your Oscilloscope Type 535A/545A—1959. 070-0239-00.

Maintenance and Calibration of Type 545A Oscilloscope—070-0282-00.

For price and availability details concerning all the above described publications and any other Technical Publication originated by Tektronix, please contact the Tektronix Field Office, Distributor or Representative in your area or write to:

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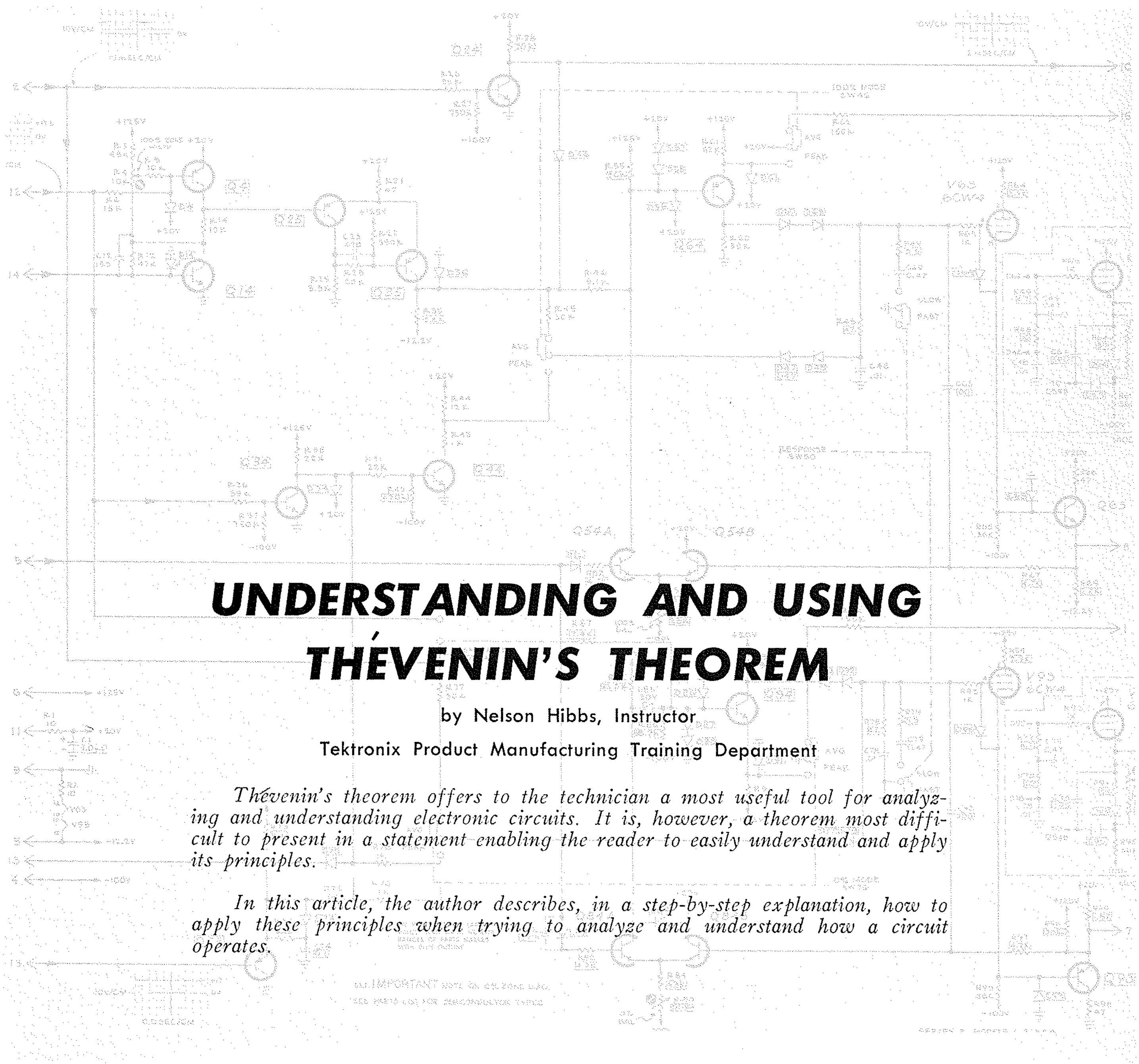

UNDERSTANDING AND USING THÉVENIN'S THEOREM

by Nelson Hibbs, Instructor

Tektronix Product Manufacturing Training Department

Thévenin's theorem offers to the technician a most useful tool for analyzing and understanding electronic circuits. It is, however, a theorem most difficult to present in a statement enabling the reader to easily understand and apply its principles.

In this article, the author describes, in a step-by-step explanation, how to apply these principles when trying to analyze and understand how a circuit operates.

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INTRODUCTION

Thévenin's theorem is one of the most useful extensions of Ohm's law ever devised. It is, however, a theorem most difficult to present in a statement that enables the reader to readily understand and easily apply its principles. For this reason perhaps, some college courses in electrical engineering do not delve into the theorem in any depth until in the senior year.

Once the electronics student or technician does understand Thévenin's theorem, he will find it a most useful tool for analyzing and understanding electronic circuits. The theorem is a general transformation which reduces any combination of active and passive circuit elements to a simple equivalent circuit consisting of a voltage source in series with an equivalent passive element. It is a general theorem applicable to all combinations of passive circuit elements.

With Thévenin's theorem, one can replace any portion of a circuit with a voltage source and an impedance in series, provided the portion replaced has only one pair of terminals. The voltage source in the Thévenin's equivalent circuit will have a value equal to the open circuit voltage appearing at the pair of terminals, and the series impedance will be the impedance that would be seen looking into the pair of terminals with all energy sources turned off and shorted.

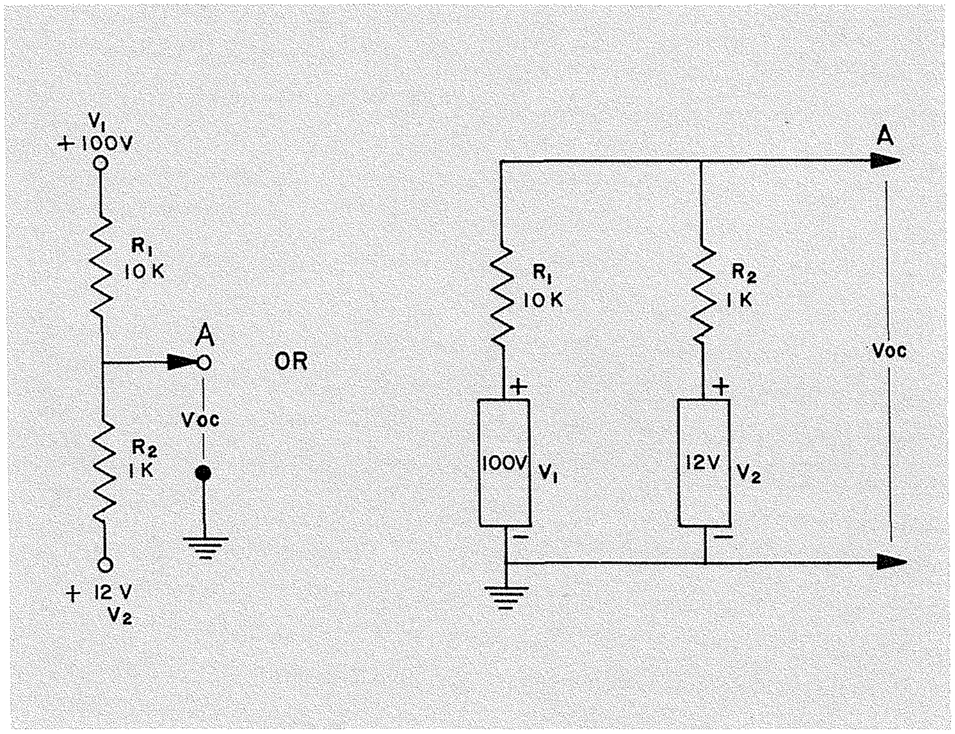


Figure 1. A simple circuit consisting of ideal voltage sources (no internal impedance) and resistors.

In this writer's opinion, one of the more understandable presentations of Thévenin's theorem is put forth by Phillip Cutler in his book "Electronic Circuit Analysis, Volume 1, Passive Networks".* On the bottom of page 18 Cutler writes, "1-5 Thévenin's Theorem. Thévenin's theorem states that any linear network of impedances and generators, if viewed from any two points in the network, can be replaced by an equivalent voltage source V_{oc} and by an equivalent impedance Z_{th} in series".

We will take a look at the mechanics by which this is achieved in a moment; but before we do, let us see what this presentation actually says.

*Copyright 1960 © McGraw-Hill Book Company, Inc., New York, Toronto, London

Apparently the first thing we need is a linear network of impedances and generators. To keep it simple, we will use resistors for the impedances and good solid voltage supplies for the generators. Our circuit might then look like the circuit in Figure 1.

Cutler's statement of Thévenin's theorem next says we must view this circuit from two points in the network; let us select for these two points, the ground and common lead at point A. Next it tells us that Thévenin pointed out we can make a substitution for the complex network made up of a single voltage source (which he called V_{oc}) and a single series resistance (which he called Z_{th}).

Let us define V_{oc} and Z_{th}. Since ground is one point of reference and the common lead the other, V_{oc} becomes the voltage difference between these two points. Thus in the circuit in Figure 1,

$$I = \frac{V_1 - V_2}{R_1 + R_2}$$

$$V_{oc} = V_2 + I\ (R_2)$$

$$= V_2 + \frac{(V_1 - V_2)\ R_2}{R_1 + R_2}$$

$$V_{oc} = 12\text{ V} + \frac{88 \times 1\text{ k}}{10\text{ k} + 1\text{ k}} \text{ or } 20\text{ V.}$$

If we assume we are using ideal batteries for our "good solid voltage supplies" we will, of course, have zero impedance within the voltage sources. Looking back then into the circuit from our selected reference points, through the resistors to the zero impedance point, we will see an impedance made up of the parallel resistance of the two divider resistors and this impedance becomes Z_{th}. Thus in the circuit in Figure 1,

$$Z_{th} = \frac{10\text{ k} \times 1\text{ k}}{10\text{ k} + 1\text{ k}} \text{ or .91 k ohms.}$$

According to Thévenin's theorem, these two units, V_{oc} and Z_{th}, will be seen in series when used as a substitute for our simple circuit, see Figure 2.

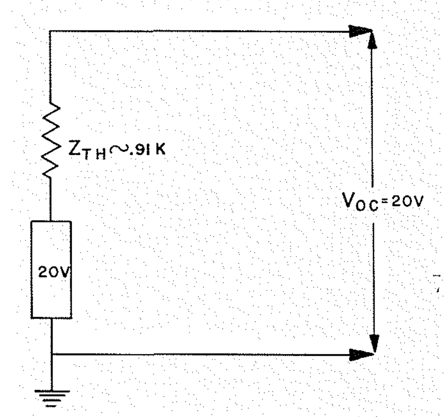


Figure 2. Thévenin's equivalent of the circuit in Figure 1.

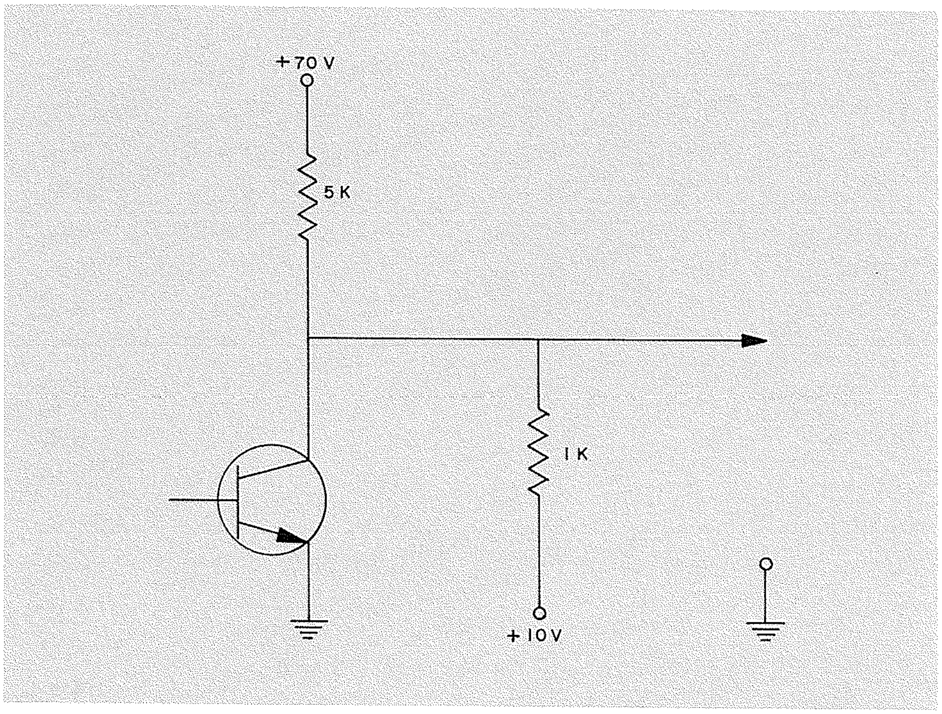


Figure 3. Transistor with a split collector load.

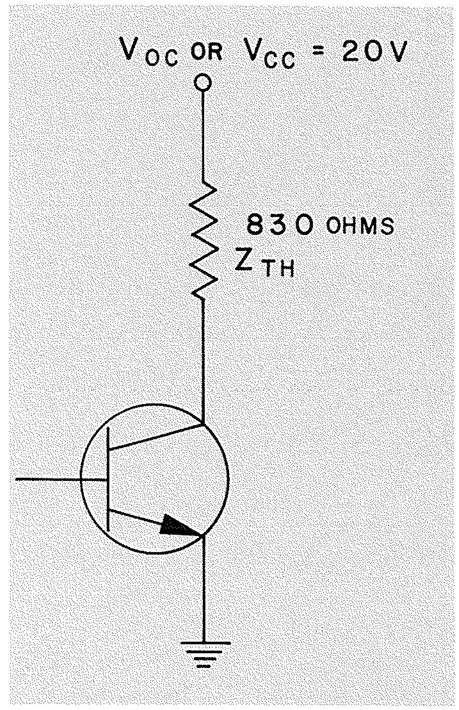


Figure 4. Thévenin's equivalent of the circuit in Figure 3.

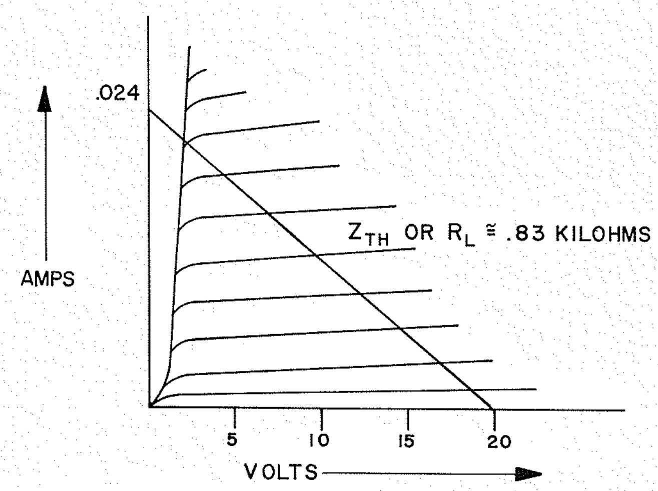


Figure 5. Load line drawn on the collector curves for the transistor in Figure 3 showing where the transistor is operating in that circuit.

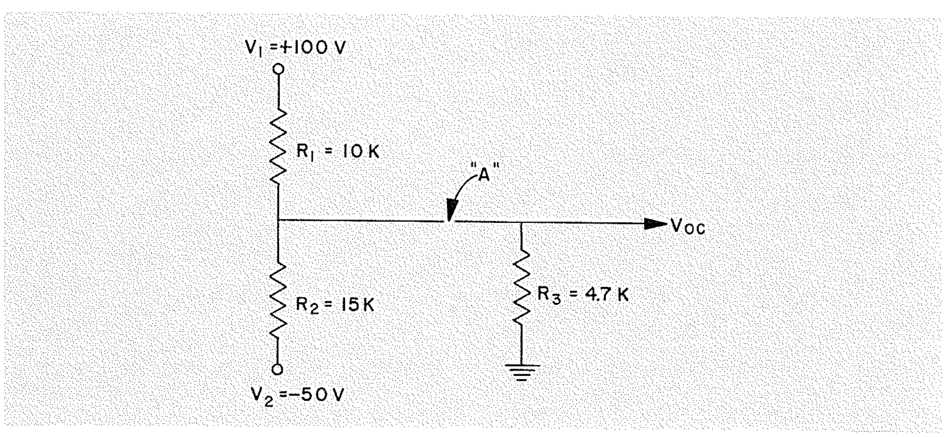


Figure 6. Illustration of a circuit a bit more complex than the one shown in Figure 1.

Now let us put this idea into the practical framework of a real circuit.

Figure 3 shows a transistor with a split collector load. Let us assume we have the collector curves for this transistor and we would like to draw in the load line to obtain an idea of where the transistor is operating and how we can expect it to perform in this circuit. We now need to know what the effective V_{cc} is and how much resistance is in the actual effective R_L. Applying Thévenin's theorem, V_{cc} turns out to be the V_{oc} and R_L becomes the Z_{th} of the theorem, thus the Thévenin substitute for the circuit in Figure 3 would be the circuit shown in Figure 4. We can now draw in the load line for the transistor as shown in Figure 5.

Naturally, the more complex linear networks will require a bit more figuring and will establish the reason for labeling Thévenin's voltage as V_{oc}, or open circuit voltage, rather than calling it the unloaded divider voltage or something else. However, as you have just seen, the figuring will involve only some very basic mathematics with which the electronic technician is (or should be) very familiar. There are other methods of analyzing complex linear circuits; but, they involve simultaneous equations which are time consuming; and, beyond the scope of this article.

As an example of a more complex circuit, let us consider the circuit in Figure 6. The procedure, when using Thévenin's theorem and analyzing a complex circuit, is to progressively apply the theorem to portions of the circuit until all elements of the

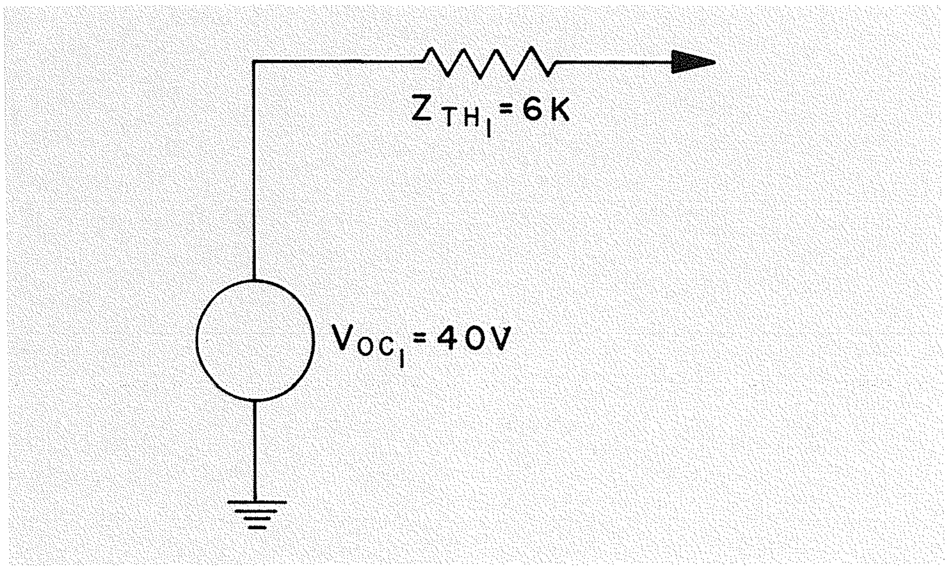


Figure 7. Thévenin's equivalent for that portion of the circuit in Figure 6 up to point "A".

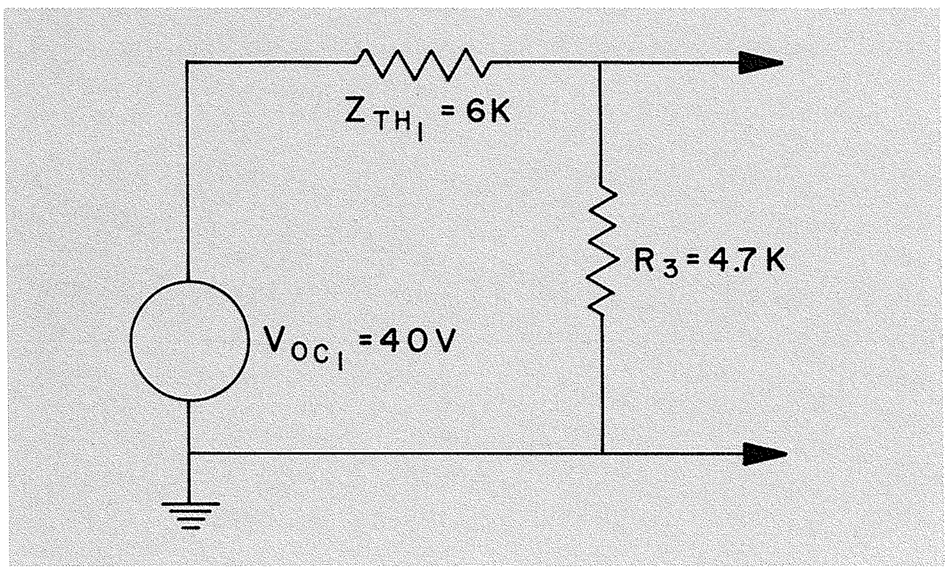


Figure 8. The circuit in Figure 6 redrawn with portion "A" replaced with the Thévenin equivalent.

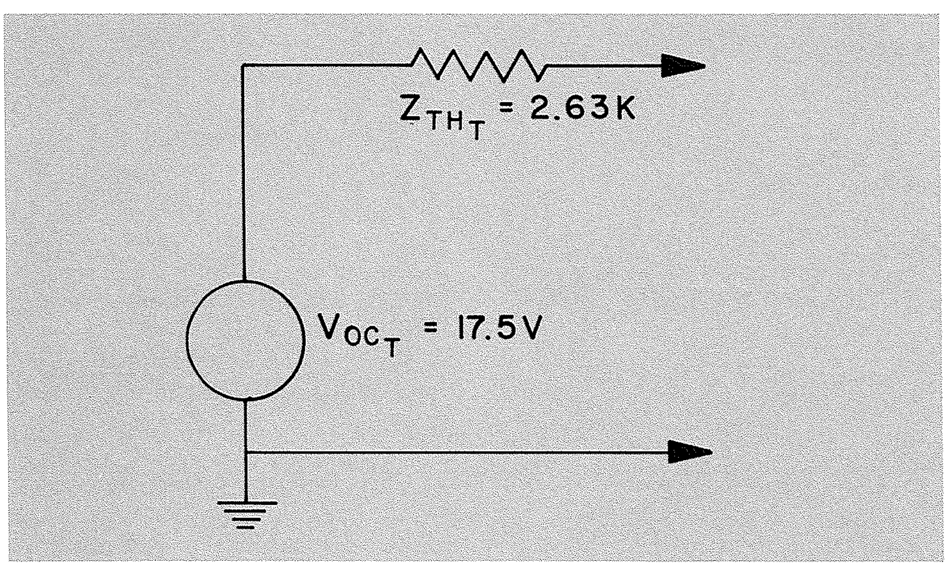


Figure 9. Thévenin's equivalent for the entire circuit in Figure 6.

circuit have been considered. If in Figure 6 then, we break the circuit at point "A", we can solve for V_{oc} and Z_{th} up to this point. In the interests of clarity, let us call the open-circuit voltage and impedance up to this point V_{oc_1} and Z_{th_1}, and the open circuit voltage and the impedance of the entire circuit V_{oc_t} and Z_{th_t}.

Thus:

$$V_{oc_1} = V_2 + \frac{(V_1 - V_2)\ R_2}{R_1 + R_2}$$

$$= -50\ V + \frac{[100\ V - (-50\ V)]\ 15\ k}{15\ k + 10\ k}$$

$$= -50\ V + \frac{150\ V \times 15\ k}{25\ k}$$

$$= -50 + 90\ V$$

$$= 40\ V$$

$$Z_{th_1} = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$= \frac{15\ k \times 10\ k}{15\ k + 10\ k}$$

$$= \frac{150\ k}{25\ k}$$

$$= 6\ k$$

The Thévenin equivalent then, for that portion of the circuit in Figure 6 up to point "A", is the one shown in Figure 7.

We can now redraw the circuit in Figure 6, replacing that portion of the circuit up to point "A" with its Thévenin equivalent. This gives us the circuit shown in Figure 8. We can now apply Thévenin's theorem to this circuit and obtain our original objective; ie, a complete analysis of the circuit in Figure 6.

Thus:

$$V_{oc_t} = \frac{V_{oc_1} \times \overset{4.7K}{\not{417}}\ k}{Z_{th_1} + 4.7\ k}$$

$$= \frac{40\ V \times 4.7\ k}{6\ k + 4.7\ k}$$

$$= 17.5\ V$$

$$Z_{th_t} = \frac{Z_{th_1} \times R_3}{Z_{th_1} + R_3}$$

$$= \frac{6\ k \times 4.7\ k}{6\ k + 4.7\ k}$$

$$= 2.63\ K$$

The open circuit voltage (V_{oc}) and the impedance (Z_{th}) then for the circuit in Figure 6 is 17.5 V and 2.6 k, respectively, and the Thévenin equivalent circuit is the one shown in Figure 9.

From the foregoing, it should be apparent that in analyzing complicated circuits we open the circuit so that we consider only two supplies and their resistances at a time. Look at the circuit in Figure 10. Here we would open the circuit at point "A", take V_1 and R_1 and V_2 and R_2 and simplify them into one voltage supply and its series resistance. To this we would add the next supply and its series resistance, apply the procedure of Thévenin and find this new equivalent, and so on, until we had simplified the entire circuit.

It is not difficult to use Thévenin's theorem once you understand it. We hope that in this article we have given you a better understanding of the theorem and a new tool for circuit analysis.

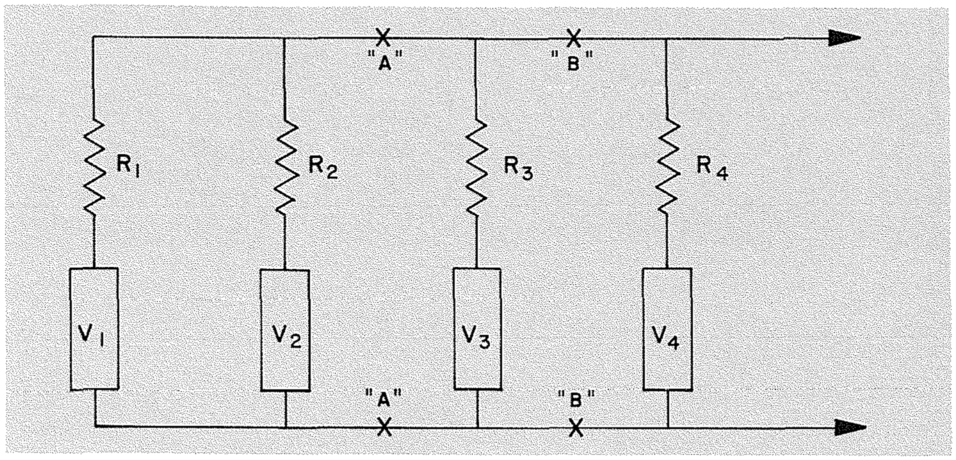
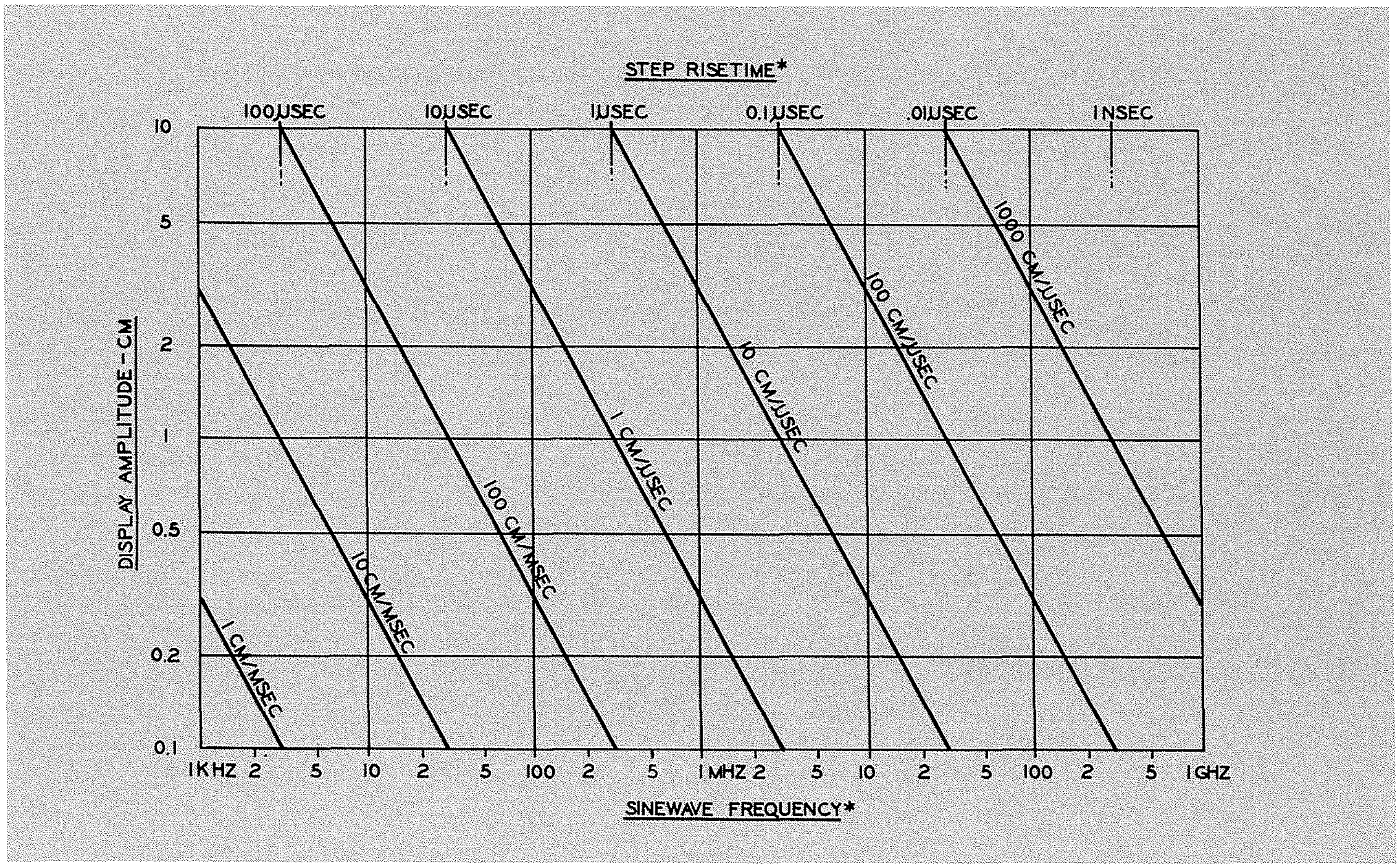


Figure 10. When using Thévenin's theorem to analyze a complicated circuit, open the circuit so that only two supplies and their associated resistors are considered at a time.

WRITING SPEED IN PRACTICAL TERMS



***If the principal spot velocity component is vertical. This chart was computed for 10-90% risetime displayed at about 55° angle from the horizontal and for sinewaves having a peak to peak amplitude about 3X the width of one cycle, to minimize the effect of the spot velocity vector introduced by the time-base.**

HOW TO USE THE CHART

Use any two factors to find the third.

Example 1: Determine what oscilloscope/camera system is required to photograph, on a single-shot basis, a display of 100 MHz sinewaves on 6 cm high.

Reading up from 100 MHz and across from 6 cm, we find the intersection to be somewhat beyond 1000 cm/μs diagonal. If the fastest recording system available has a single-shot writing speed of 300 cm/μs, it becomes evident from the chart that the maximum amplitude of 100 MHz sinewaves that can be fully recorded is about 1 cm. Larger amplitudes may record at the peaks, but not at the "zero" crossing.

Example 2: A storage oscilloscope having a single-shot writing speed of 1 cm/μs is to be used to display a single transient having a risetime of 200 ns. What is the maximum amplitude that will allow the entire leading edge to be stored?

Reading down from 0.2 μs (note that 0.2 μs would be to the *left* of 0.1 μs) to intersect with the 1 cm/s line, we find that about 2 mm is the maximum 100% amplitude that will assure storage of the 10-90% risetime with a single sweep. However, if gaps in the trace are allowable, a larger amplitude may be attempted.

SERVICE NOTES

TYPE W HIGH-GAIN DIFFERENTIAL COMPARATOR UNIT—CALIBRATION INFORMATION

Some confusion exists concerning Step 6 of the calibration procedure, Adjust DC Level R280, on page 5-3 in the Type W Unit's Instruction Manual. In step "a," you are instructed to connect a VOM between the emitter and connector leads of Q184. The problem is that the manual fails to point out that there is a test point installed in the ceramic strip nearest the amphenol connector in the Type W Unit and this test point is at the emitter lead of Q184. Some in attempting to perform this step are mistakenly connecting to the top of R281. Trying to adjust for 6 volts differential between this point and the collector of Q184 will lead to frustration. The reading will never be less than approximately 9 volts. The required reading must be made directly between the emitter and collector leads of Q184. Figure 1 shows a view through the rear panel of the Type W Unit. The points to which the VOM must be connected when adjusting the DC level of R280 are clearly identified.

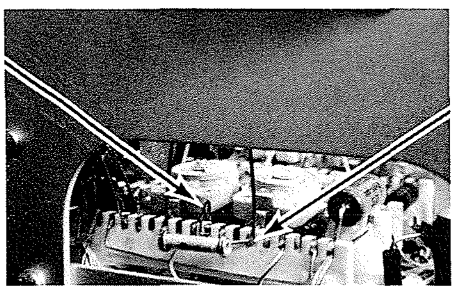


Figure 1. Arrows indicate the points to which the VOM must be connected when adjusting the DC level of R280.

We also call your attention to a correction to Step 22, Check Input A 1000X Attenuator, on page 5-8 of the calibration procedure of the Type W Unit. Change the information in your manual to agree with the following:

22. Check Input A 1000X Attenuator

a. Set the W Unit controls as follows:

COMPARISON VOLTAGE	0.011 v ~~(0-0-11)~~ (0-1-10)
INPUT ATTEN	1000

b. Check that the trace is centered.

c. Set the Vc RANGE switch to ~~+11~~ +1.1

d. Check that the trace ~~coincides with graticule center within a tolerance of ±0.2 cm.~~

e. Set the Vc RANGE switch to 0.

Doesn't move more than ±.2 cm when switching Vc range switch between the 0 position and the +1.1 position. J.A.M.

TYPE 422 OSCILLOSCOPE WITH BATTERY PACK — BATTERY PACK VOLTAGE CHECK

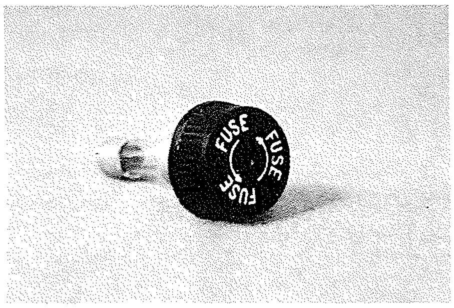


Figure 2. Type 422 Oscilloscope 3-ampere fuse holder with the thin-shell back pierced to allow insertion of a VTVM lead.

Here is a simple method for checking, under normal load conditions, the charge remaining in the battery pack of a Type 422 Oscilloscope.

First modify the 3-ampere fuse holder by piercing a hole thru the thin-shell back (see Figure 2). The thin-shell is composed of a plastic material and quite easily pierced with a metal scribe. To check the battery voltage, turn the POWER MODE switch to the INT BATT. position, turn the front panel POWER switch to ON, and insert one lead of a VTVM in the hole pierced in the 3-ampere fuse holder and connect the other lead to ground.

This method allows an accurate check of battery-pack voltage without removing the pack or power supply from the instrument.

TYPE 527 AND TYPE RM527 WAVEFORM MONITORS — USE WITH A GENERAL ELECTRIC TYPE TV83 DEMODULATOR

The following information concerns Type 527 and Type RM527 Television Waveform Monitors located in television transmitter installations, and then, only when they are used in conjunction with a General Electric Type TV83 Demodulator to monitor percent of modulation.

The flag pulse produced by the TV83 Demodulator will charge the coupling capacitor (C29) in the Type 527 and Type RM527 to a greater-than-normal value. This overcharge will exist for about 2 ms. While it exists, the over-charge will deactivate the Trigger and DC Restorer circuits in the Type 527 and Type RM527. During this period, the black level of the waveform under observation will be displaced about 30 IRE units above or below its normal level.

The solution to the problem is:

1. In the Sweep Trigger circuit of the Type 527 or Type RM527, remove the cathode lead of D32 (a 6061 diode) from ground.
2. Connect the cathode lead of a second 6061 diode (Tektronix part number 152-0061-00) to the cathode lead of D32.
3. Connect the cathode lead of the new diode to ground.
4. Install a 560 k ½ W, resistor (Tektronix part number 315-0564-00) between the junction of the two diodes and the —140 V supply.

(Figure 4 is a partial schematic showing the above four steps.)

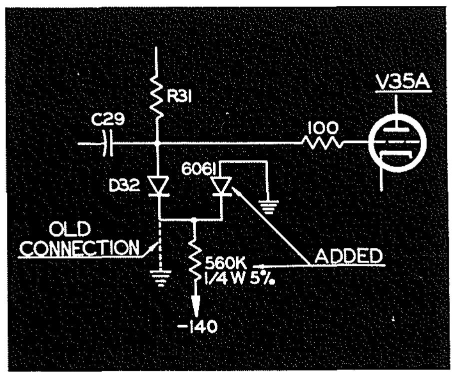


Figure 3.

5. In the DC Restorer portion of the Vertical Amplifier circuit, change the capacitor, C582, from a 100 pF to a 0.0033 μF capacitor (Tektronix part number 283-0051-00).

If the instrument you are concerned with is a Type 527 with a serial number below 745, or a Type RM527 with a serial number below 1190, we suggest you consult your Tektronix Field Engineer before attempting the above improvements.

BENT BNC CONNECTORS

Occasionally a female BNC connector will encounter an impact and become bent so it is no longer round. Often you can avoid the tedious and time-consuming job of replacing this damaged connector. If the connector is not too badly bent, the driver end of an Excellite #6, 3/16" nut driver makes an excellent tool for straightening it. The driver has just the right outside dimension to allow its insertion in the connector. After insertion, a little judicious wobbling will generally return the connector to a usable condition.

ADDITIONAL INFORMATION ON TEKTRONIX TECHNICAL PUBLICATIONS

Service Scope Number 39, August 1966 detailed some of the Tektronix Technical publications that are currently available. We are listing more of these items below and also some information regarding Technical Data which is obsolete and not now available.

TEST SET-UP CHARTS

These charts are reproductions of the front panels of Tektronix Oscilloscopes (combined with plug-in units where applicable). They enable an operator to set up the front panel controls for a particular display or series of displays. Charts are available in pads of 100 for the following instrument/plug-in arrangements.

INSTRUMENT	PART NUMBER
422	070-0513-00
453	070-0529-00
502	070-0482-00
502A	070-0488-00
503	070-0483-00
531	070-0492-00
532	070-0493-00
541	070-0494-00
545A/CA	070-0481-00
545A/R	070-0485-00
545A/Z	070-0486-00
547/1A1	070-0479-00
561A/2A60/2B67	070-0540-00
561A/3S76/3T77A	070-0548-00
567/3S76/3T77/6R1	070-0487-00
567/3S76/3T77A/6R1A	070-0547-00
567/3A2/3B2/6R1A	070-0541-00
570	070-0484-00
575	070-0480-00
575/MOD 122C	070-0489-00
262 Program Card	070-0490-00
262 Aux. Program Card	070-0491-00

TECHNICAL ARTICLE REPRINTS

Service Scope Number 35, December, 1965 carried a list of reprints that were available at that time. Stocks of the following are now exhausted:

Pulse Reflections Pin Down Discontinuities

How to Get More Out of Your Spectrum Analyzer

Measuring the Cost of Programmed Instruction

How to Measure High Current Recovery Lines in Signal Diodes

The following reprints are available in addition to those shown in Service Scope Number 35.

Current Measurements at Nanosecond Speeds by Murlan R. Kaufman. EDN (Electronic Design News). October 1965. Uses and applications of Tektronix High Frequency Probes and current transformers.

Advances in Storage Scopes by Donald C. Calnon. ELECTRONIC INDUSTRIES, February 1966. A description of recent advances in Tektronix Bistable storage CRT's and oscilloscopes.

Interpreting Spectrum Analyzer Displays by Morris Engelson, MICROWAVES, January 1966. A review of typical displays illustrating the versatility of Spectrum Analyzers in microwave measurement.

Monitoring of Vertical Interfield Test Signals by Charles Rhodes, JOURNAL OF THE S.M.P.T.E. (Society of Motion Picture and Television Engineers) February 1966. Methods of interpreting and displaying, with the aid of Tektronix TV Waveform Monitor, VIT signals which permit continuous quality control of TV signals.

Solid State Oscilloscope Circuitry by Tektronix Engineering Staff, ELECTRONIC PRODUCTS, February 1964 describes the development of the Type 647 oscilloscope circuitry.

Where to Use Storage Scopes by Geoffrey Gass, ELECTRONIC PRODUCTS, November 1965. Six applications for the storage scopes showing the display convenience available with storage facilities.

OBSOLETE PUBLICATIONS

The following is a list of current publications that should be ordered instead of the obsolete publications shown in the left-hand column. These obsolete publications may be available in limited quantities but, in most cases, have not been up-dated since 1960 or so. Those marked * are out of stock completely.

OBSOLETE PUBLICATION	REPLACED BY (Order Part No.)	CURRENT PUBLICATION
Fundamental Electronic Concepts for oscilloscope use and maintenance (1956)*	070-0190-00	A primer of Waveforms and their Oscilloscope Displays
'Junction Function' (1960)*		Programmed Instructions, Volumes 1-7. Basic Semi-conductors.
Calibrating the 181 Time-mark Generator (FIP-2) 1960	070-0292-00	Type 181 Instruction Manual
Adjusting the Delay Line and VA in the 541/545 (FIP 4) 1958	070-0203-00 070-0198-00	Type 541 Instruction Manual Type 545 Instruction Manual
310 Condensed Operating Information (FIP-6) or 310A Condensed Operating Information (FIP-6A) or 310A Recalibration and Trouble shooting (FIP-9)	070-0244-00	310/310A Instruction Manual
Calibrating the Type 105 square wave generator. (FIP-7) or Operating Information on the Type 105 (FIP 11581)	070-0371-00	Type 105 Instruction Manual
Type 517 re-calibration procedures (FIP-1282)	070-0229-00	517/517A Instruction Manual
Notes on the Practical Photography of Oscilloscope Displays (FIP-3)*	070-0383-01 070-0527-00	C12 and C27 Camera Manual and C30 Camera Manual
Interpreting Oscilloscope Displays of Magnetic Ink Testers* (FIP 10)	070-0283-00	Magnetic Ink Character Recognition
Frequency Comparisons using roulette patterns. (061-0147-00, A2024)	Service Scope No. 26 June 1964	(Up-dated in Service Scope article)

These reprints and publications are offered on a first come first served basis. When quantites are exhausted they will not be reordered.

For price and availability details concerning all the above described publications and any other Technical Publication originated by Tektronix please contact the Tektronix Field Office, Distributor or Representative in your area or write to

International Marketing
Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97005
U.S.A.

or

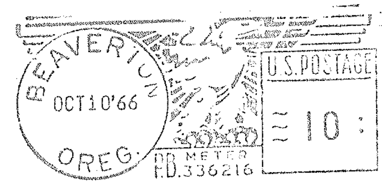
Tektronix Limited
P.O. Box 36
St. Peter Port
Guernsey, Channel Islands
British Isles

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon, U.S.A. 97005



4/66

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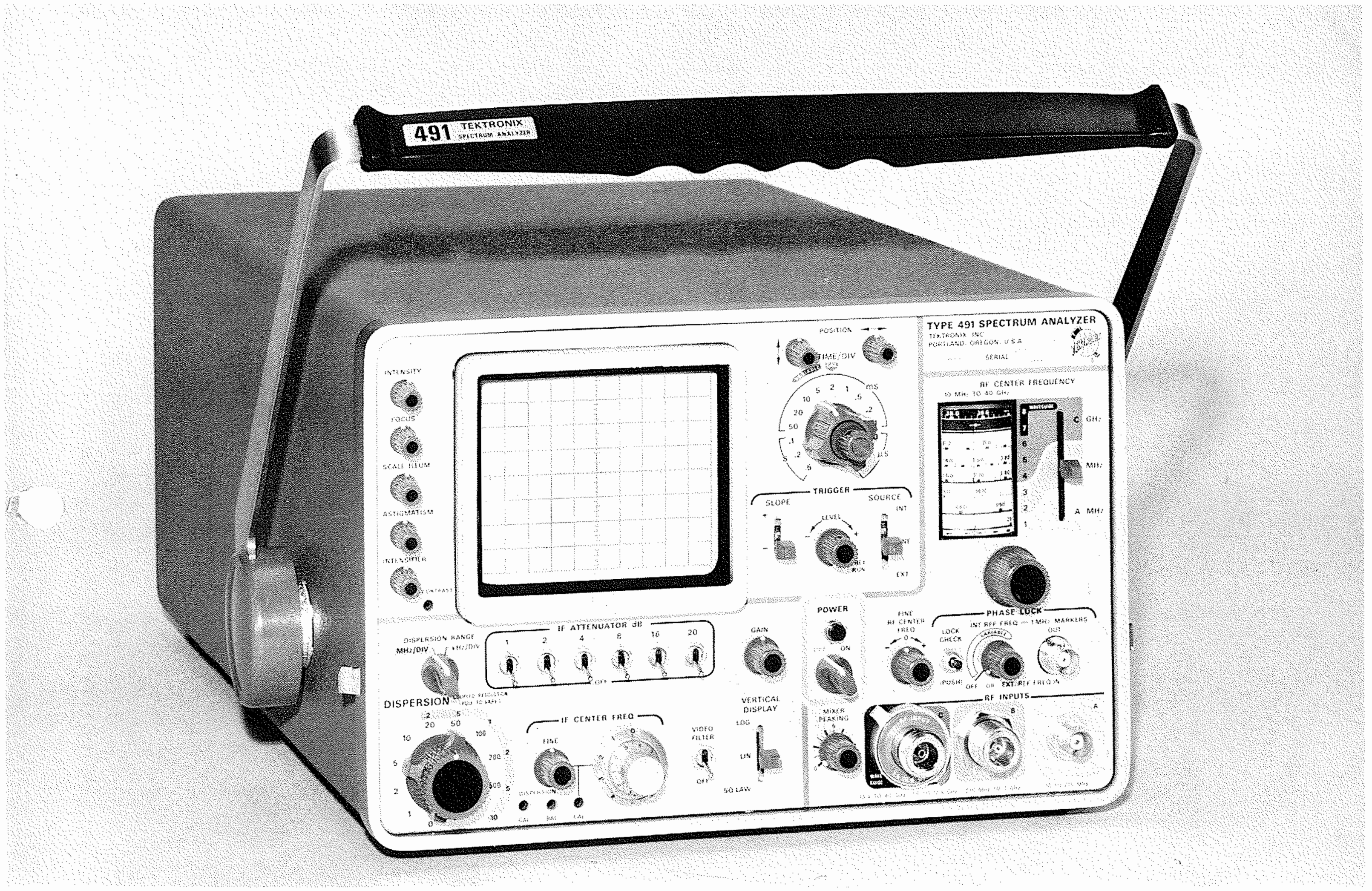
USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 41 PRINTED IN U.S.A DECEMBER 1966



INTERPRETING SPECTRUM ANALYZER DISPLAYS

by Morris Engelson
Project Engineer
Tektronix, Inc.
Beaverton, Oregon

Reprinted from Microwaves, January 1966 issue.

Here is a portfolio of typical displays illustrating the versatility of spectrum analyzers in microwave measurement. By their clarity, these photos also provide a standard for proper instrument and equipment settings.

INTRODUCTION

Spectrum Analyzer displays illustrated in this article include: frequency stability (long- and short-term), amplitude modulation, frequency modulation, pulse modulation, ECM measurements, time-domain measurements, balanced modulator adjustment, antenna pattern measurements, video pulse spectra, and wide-dispersion measurements.

It is assumed that the reader is reasonably familiar with the operating principles of the superheterodyne spectrum analyzer. Therefore, the accompanying discussion stresses the interpretation of the displays rather than the procedures to generate them. For background reading, however, the appended bibliography is suggested.

All displays are actual, unretouched photos. Figures 1 through 33 were taken by Russ Myer of Tektronix using the following Tektronix instruments: spectrum analyzer plug-ins—1L10, 1L20, 1L30, 3L10; oscilloscopes—547, 549, 555, 564; time domain plug-ins—1S1, 3B4; signal sources—114, 184, 190. Figures 34 and 35 were taken by George Thiess of Microwave Physics Corp.

In all photos each horizontal division is one cm.

FREQUENCY STABILITY

The spectrum analyzer can measure both long- and short-term frequency stability. But the measurement is limited by:

(1) Spectrum Analyzer Stability. Obviously oscillator stability cannot be measured if the unit under test is more stable than the oscillators used in the spectrum analyzer.

(2) Resolution Capability. The analyzer's ability to determine the type and/or source of the instability depends strongly on the instrument's resolution bandwidth. For example, we cannot determine whether an oscillator is FM'ing at a 60 or 120 hertz rate when spectrum analyzer resolution is 500 hertz.

Short-term stability. This measurement concerns fast frequency changes such as those caused by power-supply noise and ripple, vibration or other random factors.

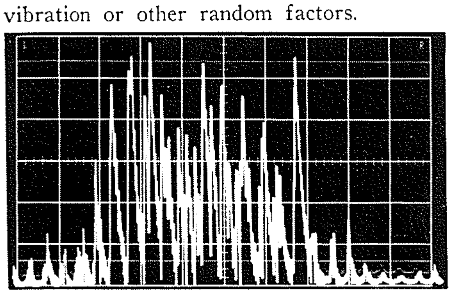


Figure 1.

Fig. 1 shows the random FM characteristic of a 3-GHz klystron. Spectrum analyzer dispersion is 2 kHz/cm and the resolution is 1 kHz. Oscillator FM is about 10 kHz —equivalent to 3 ppm.

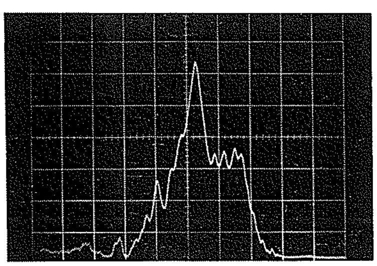


Figure 2.

A short-term stability measurement taken on a storage scope is shown in Fig. 2. A stored display is convenient here because of the extremely slow sweep speeds necessary to narrow-dispersion displays. Dispersion is 50 Hz/cm, resolution is 10 hertz and the input signal is 60 MHz. The test signal has a spectral width of about 150 hertz. This is equivalent to a stability of 2.5 ppm.

Long-term stability. Here we show the measurement of frequency drift as a function of time. The procedure depends on the characteristics of the spectrum analyzer used. One could photograph the screen at given intervals, and compare the position of the signal on the various photographs. If the spectrum analyzer has an auxiliary vertical output capable of driving a paper chart recorder, a permanent record can be obtained without photography.

The use of a storage oscilloscope is even more convenient with the scope set on a single sweep and triggered at appropriate intervals, thus storing a complete record of drift on the CRT.

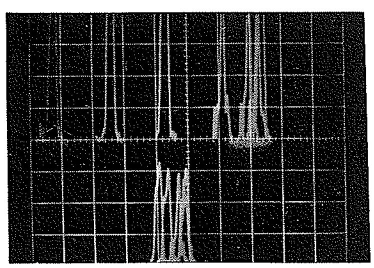


Figure 3.

For the storage-scope photo of Fig. 3, spectrum-analyzer dispersion is 1 kHz/cm, and the input frequency is 60 MHz. The upper half of the screen shows the drift of an unstabilized oscillator as it was heated. The oscilloscope was manually triggered at one-minute intervals. The drift was about 2 kHz per minute during the first three minutes, but diminished in rate thereafter, becoming nearly stable by the sixth minute. The total drift is on the order of 6.5 kHz or 108 ppm.

Temperature compensation can be computed easily since the amount and direction of drift is known. The lower half of the photo shows the drift after modifying the oscillator. Total drift is now about 1 kHz, an improvement of 6.5:1.

AMPLITUDE MODULATION

Modulation frequency and modulation percentage are the quantities usually desired in an AM measurement. Spectrum analysis is particularly useful in complex situations such as multi-tone modulation or overmodulation.

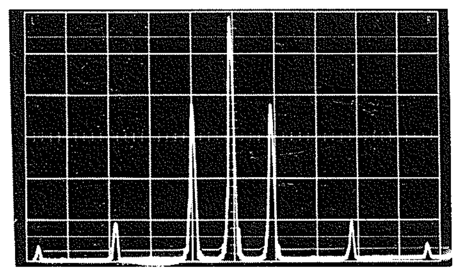


Figure 4.

Fig. 4 shows an overmodulated AM signal. Note the characteristic AM spectrum, consisting of a carrier and two sidebands, and the presence of additional, unwanted sidebands. Spurious sidebands, together with primary sidebands where amplitude is greater than one-half the carrier (100% modulation yields sidebands which are one-half the carrier amplitude) positively identify overmodulation.

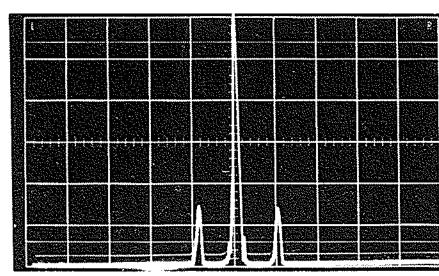


Figure 5.

Fig. 5 shows the same signal, but with the modulation reduced to 50%. The dispersion of the spectrum analyzer is 1 kHz/cm; the vertical display is linear. Thus, the modulating frequency is seen to be 1 kHz. Since the sideband amplitude is one-quarter that of the carrier, the modulation is 50%.

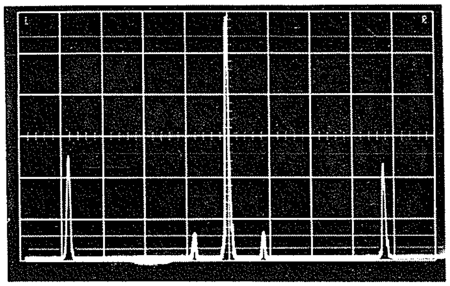


Figure 6.

Fig. 6 was photographed at a dispersion of 2 kHz/cm; vertical display is linear and center frequency is 60 MHz. Observe that the 60-MHz carrier is modulated at two frequencies; 1.6 and 7.5 kHz. Modulation is approximately 85% at 7.5 kHz and 20% at 1.6 kHz.

Overmodulation can be distinguished from two-tone modulation in two ways, evident by comparison of Figs. 4 and 6: (1) Spacing between overmodulated sidebands is equal while two-tone sidebands are arbitrarily spaced; (2) The amplitude of overmodulated sidebands decreases progressively from the carrier, but amplitude of two-tone sidebands is determined by the modulation percentage and can be arbitrary.

FREQUENCY MODULATION

FM measurements generally concern modulation frequency, spectral width, index of modulation and deviation. A typical FM

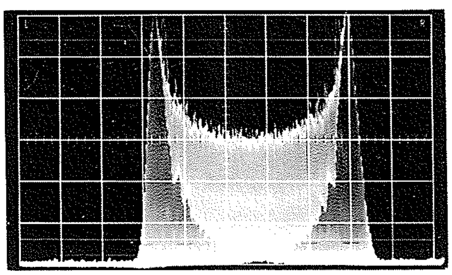


Figure 7.

spectrum is shown in Fig. 7. Dispersion is 200 kHz/cm and the spectral width is about 1 MHz. The exterior modulation envelope, typically resembling a $\cos^2$ curve, identifies the frequency modulation. The interior envelope appears on the screen because the FM rate is of the same order as the analyzer's resolution bandwidth. Consequently side bands are not resolved adequately and the trace cannot return to the base line at every pulse.

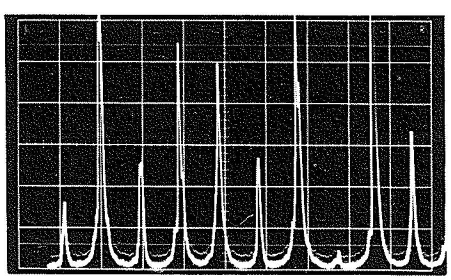


Figure 8.

The same FM signal appears in Fig. 8 but the dispersion has been reduced to 10 kHz/cm and the resolution is 1 kHz. The double-envelope display does not occur and the sidebands are clearly visible. Modulation frequency is 10 kHz.

FREQUENCY DEVIATION

There is no clear relationship between spectral width and deviation, since, in theory, the FM spectrum extends to infinity. But in practice, the spectral level falls quite rapidly as shown in Fig. 7. Experience indicates that the deviation is on the order of ½ the observed spectral width.

Very accurate deviation measurements can be obtained if the modulation frequency can be varied. It can be shown that for FM the carrier goes to zero at a modulation index (ratio of deviation to modulating frequency) of 2.4; other nulls occur at other modulation indices—e.g., the second null occurs at an index of 4.8.

This knowledge is the basis of a very powerful deviation measurement method known as the carrier null method. Figs. 9, 10 and 11 demonstrate this method. These figures were taken at a dispersion setting of 200 kHz/cm and a resolution of 100 kHz.

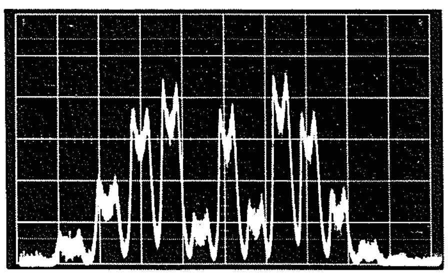


Figure 9.

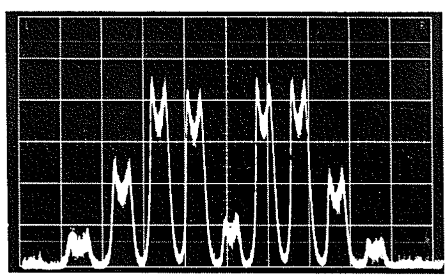


Figure 10.

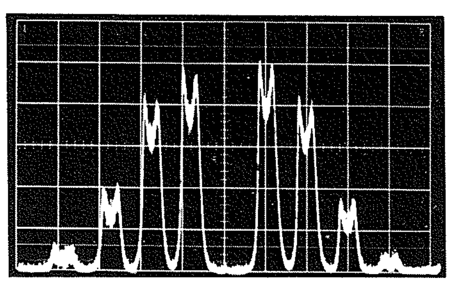


Figure 11.

Note that the spectral width is the same as in Fig. 7 but the modulating frequency has been increased so that individual sidebands can be resolved. In all three figures, the signal has been adjusted so that the carrier is at the center of the screen.

Fig. 9 shows a fairly large carrier. In Fig. 10, the modulation frequency is increased and the carrier level has decreased. In Fig. 11, the modulation frequency is increased further so that a null occurs at the position of the carrier. Since the observed modulating frequency is 200 kHz and since the observed index of modulation is 2.4, the deviation is 480 kHz.

PULSE MODULATION

Square pulses—A pulse-modulated signal generates a complex spectrum of the familiar sin x/x type. For example, a square pulse generates a spectrum described by $\sin \pi f t / \pi f t$, where t is pulse width and f is frequency deviation from the carrier. Fig. 12 shows the spectrum of a 1-GHz carrier modulated by a 0.67-μs square pulse. Observe that the spectrum is entirely above the baseline, whereas Fourier theory indicates that adjacent lobes should be out of phase by 180 deg. This phenomenon occurs because the spectrum analyzer is insensitive to phase. A second apparent inconsistency is that while the spectrum should be (in theory) solid, the display consists of vertical lines. This stems from the fact that the superheterodyne spectrum analyzer is not a real-time device. It takes many pulses to trace out the spectrum. Thus, each vertical line represents the sampling of one pulse.

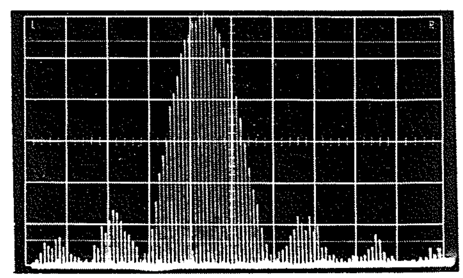


Figure 12.

Now we can manipulate the spectrum-analyzer controls to determine the characteristics of the signal. In Fig. 12 the spectrum-analyzer dispersion is 1 MHz/cm and the vertical display is linear. For a square pulse the theoretical pulse width $t = 1/f_o$, where f_o is the spectral sidelobe width. From Fig. 12, $f_o \simeq 1.5$ MHz. Therefore $t = 0.667\ \mu$s. Assuming that the vertical display is perfectly linear, we find that the ratio of main lobe to first sidelobe is 6:1.2. This is equivalent to 14 dB. More accurate measurement using the spectrum analyzer's calibrated attenuators gives a ratio of 13 dB. Theoretically, the main lobe is 13.2 dB greater than the first sidelobe.

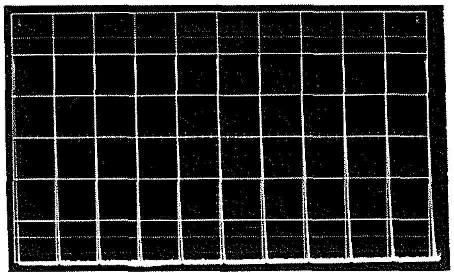


Figure 13.

Fig. 13 shows the same signal but with the dispersion set to zero. (This means that the sweep is only in time rather than in frequency; the analyzer is now a microwave receiver with a CRT readout). The display is merely a set of equally spaced lines. Since each line represents a pulse, the pulse rate can be easily measured. Here the scope is sweeping at a 1-ms/cm rate; one cycle of the modulating pulse requires 1 ms. The pulse rate is therefore 1 kHz.

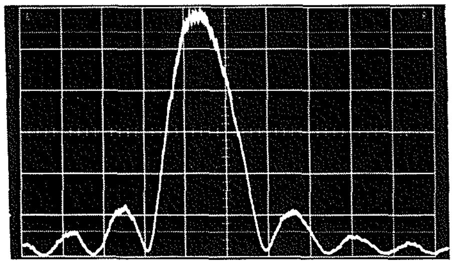


Figure 14.

As previously indicated, it is not the lines themselves, but only their envelope that is of interest. Sometimes it is advantageous to present an integrated display showing only the outline of the spectrum. Such a display, shown in Fig. 14, is obtained by using a postdetection (video) filter. This kind of display has several advantages: The baseline and its accompanying glare are eliminated and weak signals are more apparent. Noise is reduced automatically by integration and anomalies are removed. On the other hand, bandwidth and sensitivity are reduced (often by 1 to 5 dB). Sweep speed also decreases.

Sometimes it is desirable to limit the signal's spectral width by filtering, pulse shaping, etc. It then becomes important to identify low-level signals. This is accomplished by operating the analyzer in its logarithmic mode so that low level signals are enhanced relative to large signals.

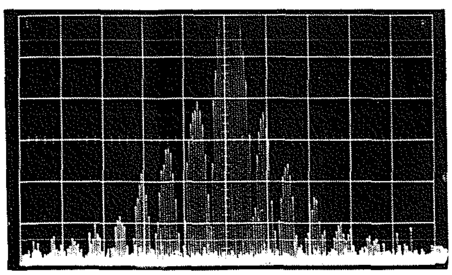


Figure 15.

In the logarithmic display of Fig. 15, the main lobe and the first eight side lobes are discernible.

PULSES IN THE PRESENCE OF FM

All signal sources, regardless of how carefully designed, have a certain amount of incidental FM. This limits the type of pulse modulation that can be used.

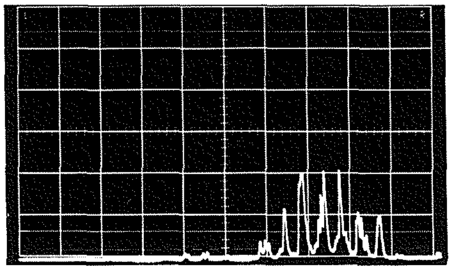


Figure 16.

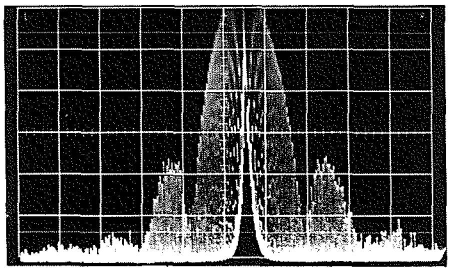


Figure 17.

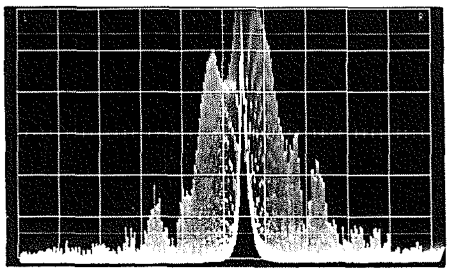


Figure 18.

Fig. 16 shows a carrier with incidental FM deliberately applied. Analyzer dispersion is 5 kHz/cm and FM spectral width is on the order of 12 kHz. Fig. 17 shows the carrier with the FM removed. (The large signal in the center of the main lobe is due to a poor on-off ratio in the modulator. This phenomenon is discussed in another section.) Fig. 18 shows the combination of FM and pulse modulations. Note that the signal is not symmetrical and that the sidelobes are uneven. An extensive discussion of pulsed RF in the presence of FM is found in Montgomery.[1]

EFFECTS OF PULSE SHAPING

Spectral width can be controlled by several means, including that of pulse shaping. The effect of pulse shape on spectral distribution s illustrated in the following spectrum analyzer displays. Fig. 19 shows the

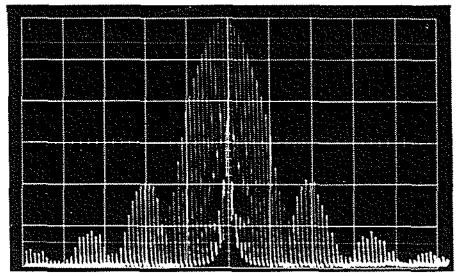


Figure 19.

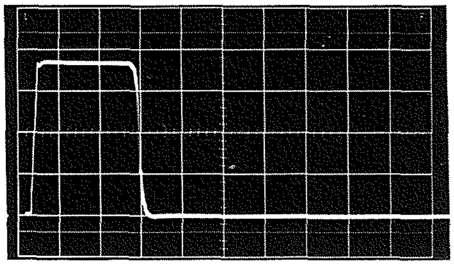


Figure 20.

conventional sin x/x spectrum of an RF signal modulated by the square pulse of Fig. 20.

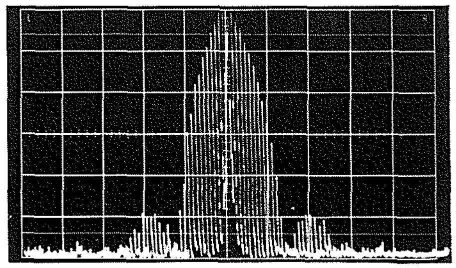


Figure 21.

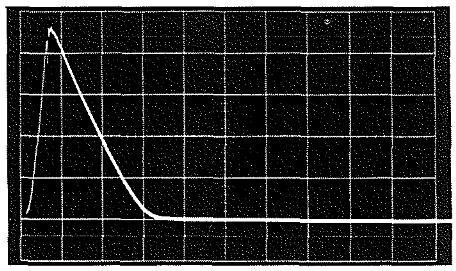


Figure 22.

Fig. 21 shows an RF signal modulated by the asymmetrical triangular pulse in Fig. 22. Note that the sidelobes in Fig. 21 are considerably lower than those in Fig. 19.

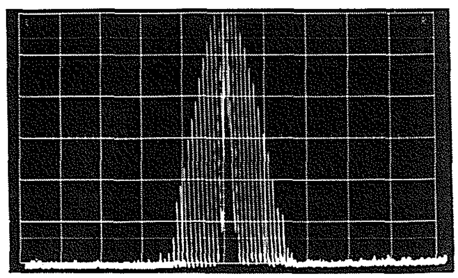


Figure 23.

Fig. 23 shows an RF signal modulated by the symmetrical triangular pulse shown

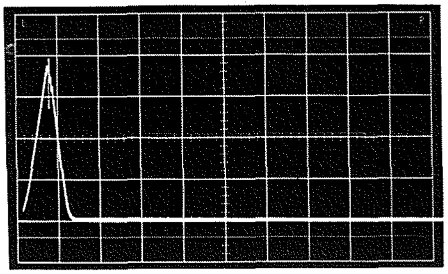


Figure 24.

in Fig. 24. Note that this spectrum is almost completely devoid of sidebands. As the effective pulse width changes, so does the width of the main lobe. The spectrum analyzer dispersion was adjusted between Figs. 19, 21 and 23, so that the main lobe would continue to occupy approximately the same number of divisions—this to better illustrate the disappearance of the sidelobes.

ECM MEASUREMENTS

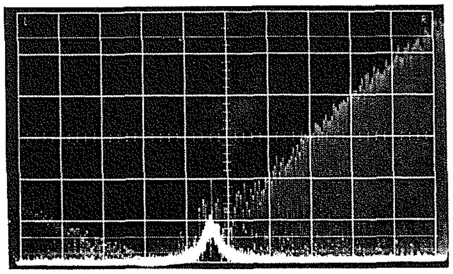


Figure 25.

In countermeasure work, intelligence is sometimes transmitted so as to be masked by another signal. An example is the transmission of information at the null point of a pulsed RF signal. Fig. 25 shows transmission of a 100-kHz-wide signal at the null point. The pulsed RF signal has been expanded using the scope horizontal magnifier control. The cw signal at the null point is clearly discernible on the analyzer but less so to a ferret receiver.

PULSE MODULATOR ON-OFF RATIO

Sometimes the carrier to be pulsed is not turned off completely during the pulse-off time. This results in a combination of cw and pulsed signals. Measurement of on-off ratio is complicated by the fact that the spectrum analyzer has higher sensitivity for cw signals than for pulsed signals. The ratio in sensitivity is $3/2\ t\beta$, where t

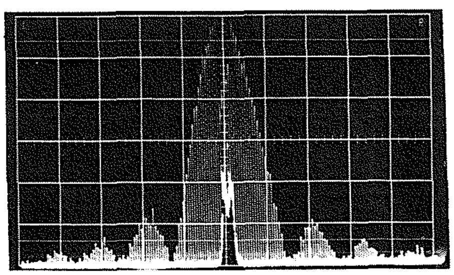


Figure 26.

is pulse width and β is spectrum analyzer's 3-dB bandwidth (resolution bandwidth).

Fig. 26 shows a typical pulsed RF signal generated by a modulator that has a poor on-off ratio as indicated by the large signal within the main lobe. Dispersion is 0.5 MHz/cm (pulse width 1.3 μs), resolution bandwidth is 100 Kc and the vertical display is linear. To find the on-off ratio we compute the loss in pulse sensitivity relative to cw:

$3/2\ (1.3)\ (10^{-6})\ (10^{5}) = 1.95 \times 10^{-1}$

. . . . . $20 \log_{10} 1/0.195 = 14.2$ dB

Next, from the vertical deflection in Fig. 26, the cw signal amplitude is 1/3 that of the pulsed signal. This is equivalent to a difference of $20 \log_{10} 3 = 9.5$ dB. The total on-off ratio is $9.5 + 14.2 = 23.7$ dB.

DUAL-BEAM SPECTRUM ANALYSIS

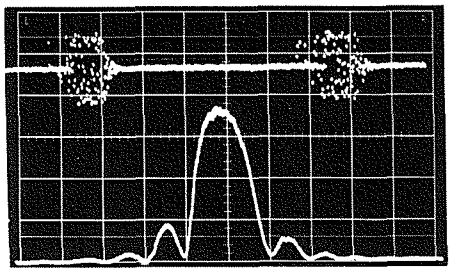


Figure 27.

It is sometimes useful to simultaneously observe both the RF spectrum and modulating waveform, as when shaping a pulse to generate a desired spectrum. With a dual-beam arrangement, we simultaneously observe changes in the modulating pulse and the resultant frequency spectrum. With microwave sampling scopes we can observe both the modulated carrier and the modulating pulse in time domain. Fig. 27 shows a dual-trace display of a 1-GHz carrier modulated by a 1-μs pulse. The upper trace is in time domain at 1 μs/cm. The lower trace is in frequency domain at 1 MHz/cm.

TIME-DOMAIN MEASUREMENTS

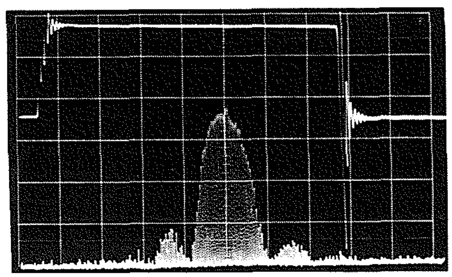


Figure 28.

Some spectrum analyzers can function both in time and frequency domains. Such instruments are not meant to replace oscilloscopes, as their sensitivity is rather poor (100 mV/cm) and their input impedance is low (50 Ω). In microwave systems, however, where detectors like to be terminated in 50 Ω, useful information can be obtained with such analyzers. Fig. 28 is a double-exposure photo showing the time domain characteristics of the modulating pulse as the upper trace and the output spectrum as the lower trace. The same display could have been obtained with a dual-beam oscilloscope.

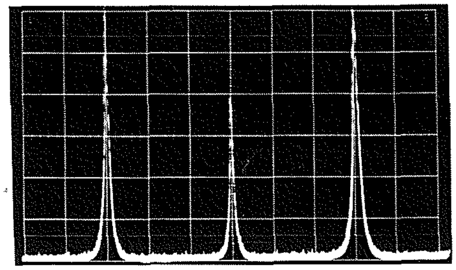


Figure 29.

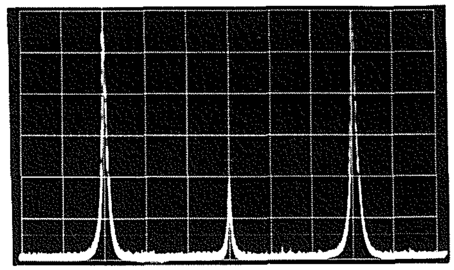


Figure 30.

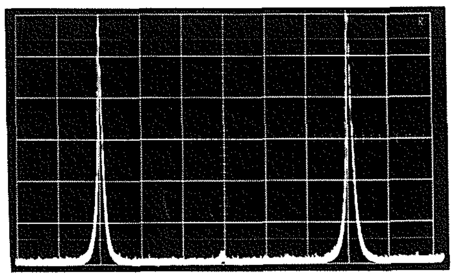


Figure 31.

BALANCED-MODULATOR ADJUSTMENT

Balanced modulators often are used to impose suppressed-carrier modulation. Figs. 29 to 31 illustrate how this application can be monitored by a spectrum analyzer. Fig. 29 shows a modulator that is not well balanced. The carrier is almost as large as the side bands. The balance controls are now adjusted to an intermediate stage of performance as shown in Fig. 30. The fully adjusted system, with the carrier almost entirely suppressed, yields the spectrum of Fig. 31.

ANTENNA-PATTERN MEASUREMENTS

The spectrum analyzer also can be used to provide antenna-pattern data. Assume that the transmitting antenna under test is stationary. A transmitted pulse is picked up by a receiving antenna and displayed on the analyzer as a typical sin x/x spectrum. If the analyzer's input frequency is centered on the main lobe and the dispersion reduced to zero we get a set of equal amplitude lines across the screen. Each line represents one transmitted pulse.

Assume now that the test antenna is rotating. A very strong signal is received when the pickup antenna is located in the main lobe of the transmitting-antenna pattern; signals are weaker in the sidelobes and minimal in the pattern nulls. If the spectrum analyzer is swept very slowly, so slowly in fact that one sweep corresponds to 360 deg. of antenna rotation, the CRT screen can be calibrated in degrees to display a complete antenna pattern.

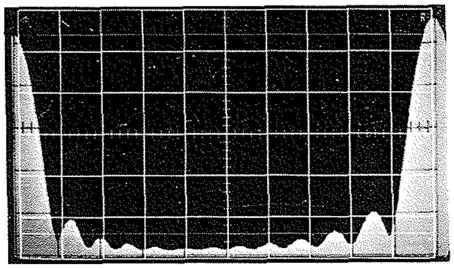


Figure 32.

Fig. 32 shows such a simulated antenna pattern. The ten horizontal screen divisions correspond to 360 deg. of antenna rotation, 36 deg. per division. Since the vertical display is linear with voltage we can compute amplitude differences directly. Thus, 3 dB is 0.707 of maximum deflection or 0.707 x 5.8 = 4.1 divisions.

The main lobe of the pattern is about one horizontal division wide at the 4.1 division height and the antenna therefore has a beam width of about 36 deg. The center of the screen corresponds to the 180-deg. position. The ratio of main lobe deflection (5.8 divisions) to that at 180-deg. rotation (0.2 divisions) is the antenna's front-to-back ratio, which for this antenna is 11.6, or 21.3 dB.

One precaution: the receiving antenna must have very low sidelobes and a narrow beam width in comparison to the transmitting antenna so as not to affect the recorded pattern. Keep in mind also that the analyzer must be swept quite slowly to record the pattern. A paper chart recorder or storage scope can therefore, be very helpful. Fig. 32 was displayed on a storage scope.

VIDEO PULSE SPECTRA

It is sometimes useful to examine the Fourier spectrum of a video-pulse train directly, without modulating a carrier. Whereas in a pulsed RF signal the spectrum is centered around the carrier frequency, the spectrum for a video pulse goes to zero frequency.

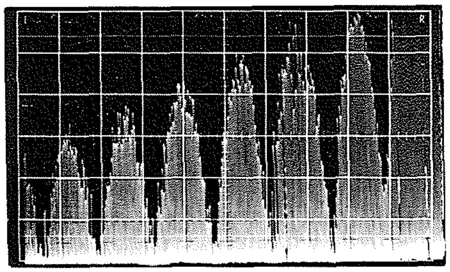


Figure 33.

Most spectrum analyzers having wide dispersions cannot display such low frequencies. However, some spectrum analyzers using balanced mixers for local oscillator suppression are suitable. Fig. 33 shows the spectrum of a 0.4-μs pulse. Analyzer dispersion is 2 MHz/cm.

WIDE DISPERSION MEASUREMENTS

A new class of spectrum analyzers having gigahertz dispersions recently has appeared on the market. The accompanying figures illustrate two applications of these new devices. Fig. 34 shows eleven signals spaced at 1-GHz intervals from 2 to 12 GHz. Analyzer dispersion is 10 GHz.

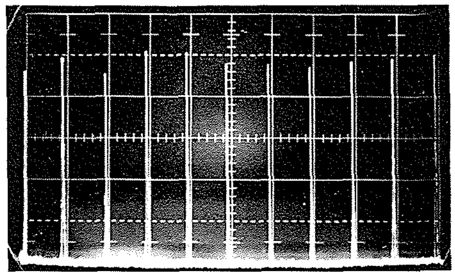


Figure 34.

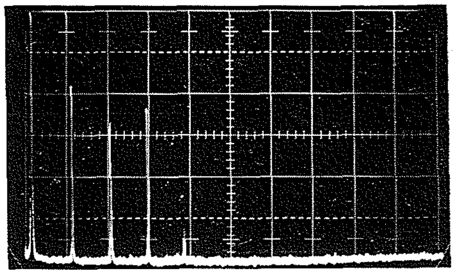


Figure 35.

Fig. 35 shows the harmonics of a 900-Mc MHz transistor oscillator. The spectrum analyzer is sweeping from 1.7 to 12.5 GHz. We observe that this oscillator has substantially no output beyond the 6th harmonic.

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REFERENCE

[1]Montgomery, Techniques of Microwave Measurements (New York: McGraw-Hill, 1945), RADLAB Series, Vol. XI.

SERVICE NOTES

TEKTRONIX PROBES — PROBE-IDENTIFICATION TAGS

While engaged in multi-probe applications, have you ever experienced frustration in quickly locating correlating probe ends or determining which probe cable led to which probe?

We have available, plastic probe-identification tags (see Figure 1) that help you locate correlating probe ends quickly and/or determine which probe cable leads to which probe.

These tags come in two versions, one version has a .125-inch center hole to fit around the smaller cable used on some of our probes, the other has a .178-inch — .185-inch center hole to fit around the larger cable used on other of our probes. The tags are packaged 20 tags of a center-hole size to a package — 2 tags each of ten colors.

For use on probes with the smaller cable order Tektronix part number 334-0789-00. For use on probes with the larger cables, order Tektronix part number 334-0789-01. Please order through your local Tektronix Field Engineer, Field Representative, or Distributor.

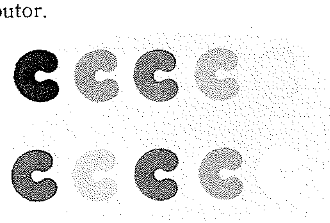

Figure 1. Probe Identification Tags

TYPE 310 AND TYPE 310A—CALIBRATION-PROCEDURE NOTES

In the Type 310 and Type 310A Instruction Manual, on page 5-12 of the Calibration Procedure section, paragraph "d" reads: "d. Connect the CAL OUT connector to the TRIG INPUT connector as well as to the INPUT connector." Change this to read: "d. Connect 0.2 V from the CAL OUT connector to the TRIG INPUT connector as well as to the vertical INPUT connector."

The specifications for the Type 310 and 310A call out 0.2 V as the trigger requirements for external trigger on these instruments. Failure to repeat the information in the calibration section of the instruction manual has caused confusion for some when calibrating these instruments. Our apologies to these people. We hope this information clears the confusion.

NEW FIELD MODIFICATION KITS

BLANK PLUG-IN

This field modification kit supplies the necessary hardware to construct a skeleton plug-in unit for use in a Tektronix Type 560 Series Oscilloscope. This kit is intended for those who wish to design their own special-purpose plug-in units.

From the information supplied in the kit, a skeleton plug-in unit can be constructed so as to be compatible with a specific Type 560 Series Oscilloscope or with several (or all) of these instruments.

The kit also supplies pertinent information so that the special plug-in may be designed to operate in conjunction with either a Tektronix-produced plug-in unit in a Type 560 Series Oscilloscope or with a second special plug-in unit.

This modification kit is applicable to the following Type 560 Series Oscilloscopes: 560, 561, RM561, 561A, RM561A (including MOD 210C), 564, RM564, 565, RM565, 567, and RM567.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0245-00.

TYPE 502 DUAL-BEAM OSCILLOSCOPE—VARIABLE TIME/CM

This modification adds a VARIABLE control to the TIME/CM switch on the Type 502 Oscilloscope. This provides a sweep rate continuously variable uncalibrated from 1 μsec/cm to over 12 s/cm.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0221-00.

TYPE 524K TELEVISION OSCILLOSCOPE — PROBE POWER

This modification installs a probe power socket on the front panel of the Type 524D Television Oscilloscope. This allows a P500CF cathode-follower probe to be used with the oscilloscope. DC filament voltage for the probe's vacuum tube reduces hum to a minimum.

The P500CF Probe presents a low input capacitance with minimum attenuation.

This modification kit replaces the Type 524D Probe Power Modification Kit (Tektronix part number 040-0059-00) which provided AC filament voltage for the probe's vacuum tube. It will also convert a Type 524D with the 040-0059-00 modification kit installed from AC to DC filament voltage for the probe's vacuum tube.

Order through your local Tektronix Field Office Field Engineer Field Representative or Distributor. Specify Tektronix part number 040-0273-00.

CORRECTION NOTE

In the October, 1966 issue of Service Scope there is a typographical error on page 4. The set of equations just opposite Figure 4, as printed reads:

$$V_{oc_t} = \frac{V_{oc_1} \times 417\,k}{Z_{th_1} + 4.7\,k}$$

It should read:

$$V_{oc_t} = \frac{V_{oc_1} \times 4.7\,k}{Z_{th_1} + 4.7\,k}$$

USED INSTRUMENTS FOR SALE

1—Type 511 Oscilloscope, sn 111. Price: $175. Contact: R. R. Chittenden, Electro Mechanical Company, P.O. Box 7886, Portland, Oregon. Phone: 289-8885.

1—Type 517 Oscilloscope, sn 781, with power supply and probe, good condition. Would like cash or a Type 541 Oscilloscope with a Type 53/54 C Dual-Trace Plug-In Unit. Contact: G. L. Boelke, 505 Main Street, West Seneca, New York 14224.

1—Type 515A Oscilloscope, sn 1687. Contact: Mr. George Dupont, New York Stock Exchange. Phone: 212-HA 2-4200 x 463.

1—Type Q Transducer and Strain Gage Plug-In Unit, sn 1742. About 2 years old, new condition. Price: $275.00, FOB West Palm Beach, Florida. Contact: Jerry Strasser, Solitron Devices, Inc., 1177 Blue Heron Blvd, Riviera Beach, Florida. Phone: 305-848-4311.

1—Type 585A Oscilloscope; 1—Type 82 Dual-Trace Plug-In Unit; 1—Type 202-2 Scope-mobile® Cart; and 1—C12R Oscilloscope Camera with projected graticule. Available for immediate delivery. Price: 10% off catalog list price. Contact: Mr. H. Brawley, 25 Hemlock Street, Norwood, Massachusetts. Phone: 617-769-3888.

1—Type 511 Oscilloscope, sn 438, P11A CRT. Price: $150.00. Contact: R. S. Komp, Box 372, Fairhaven, New York 13064. Phone: 315-947-1921.

1—Type 131 Amplifier. Approximate age 14 months. Contact: Tom Thompson, Bemis Bag Company, 325 - 27th Avenue, N.E., Minneapolis, Minnesota.

1—Type 105 Square Wave Generator. Price: $175. 1—Type 112 Preamplifier; 1—Type 121 Preamplifier. Price: $110 each. 1—Type 180S1 Time Marker. Price $290. We are interested in either purchasing or trading for used Type 321 Oscilloscope and Type 575 Curve Tracer. Contact: Denes Roveti, Technical Director, Roveti Instruments, 1643 Forest Drive, Annapolis, Md. 21403.

1—Type 561A Oscilloscope, sn 6000; 1—Type 3S76 Dual-Trace Sampling Plug-In Unit, sn 402; 1—Type 3T77 Sampling Sweep Plug-In Unit, sn 340. Contact: Allen Avionics, P. O. Box 350, Mineola, New York.

1—Type 512 Oscilloscope, sn 1997, includes most modifications. Was completely overhauled in 1961. Contact: Mr. J. R. Harkness, Briggs & Stratton Corp., P.O. Box 702, Milwaukee, Wis. 53201. Phone: 414-461-6600.

1—Type 551 Oscilloscope, sn 757; 1—Type 53/54 C Dual-Trace DC Plug-In Unit, sn 20847; 1—Type 53/54 H Wide-Band High-Gain DC Plug-In Unit, sn 591. Excellent condition, less than 200 hours total operation. Price: $1400 total, or will sell separately. Contact: Dr. B. J. Wilder, Neurology, J. Hillis Miller Health Center, University of Florida, Gainesville, Florida. Phone: 904-376-3211, Ext. 5418.

1—Type 544 Oscilloscope; 1—Type 1A2 Dual-Trace Plug-In Unit; 1—P6016 AC Current Probe; 1—Type P Fast-Rise Test Plug-In Unit, sn 2530. About 4 years old, new condition. Price: $50.00.

USED INSTRUMENTS WANTED

1—Type 531, 532 or 533 Oscilloscope less plug-in. Please state condition and price when answering. Contact: Mr. J. R. Harkness, Briggs & Stratton Corp., P.O. Box 702, Milwaukee, Wisconsin 53201. Phone: 414-461-6600.

1—Type 515 or Type 535 Oscilloscope. Contact: Fidelitone, Nick L. Miku, 6415 North Ravenswood Avenue, Chicago, Illinois 60626. Phone: 312-274-0075.

Wanted to buy used Type 516 Oscilloscope. Contact: Tim Denning, Tim's Electronic Service, Houghton, Iowa. Phone: 319-469-2364.

Used 500 Series Oscilloscope, at least 15 MHz band. Contact: Jim Worthington, 301 Longview Drive, Monroeville, Pennsylvania.

1—Type 310 or Type 310A Oscilloscope. Contact: Mr. R. L. Goodman, Clark Dunbar, 325 Jackson St., Alexandria, Louisiana. Phone: 318-443-7306.

1—used Type 515 Oscilloscope. Contact: Mr. John Bohinko, 117 Abbot Street, Plains, Pennsylvania.

1—Type 543B Oscilloscope; 1—Type 1A2 Dual-Trace Plug-In Unit; 1—Type 1A7 Differential Amplifier Unit. Contact: Brooks Delecktro, 41 East 42nd Street, New York, New York 10017. Attn: Miss Brooks. Phone: 212-687-4940.

Used Type 536 Oscilloscopes and Type T Time-Base Generator Plug-In Units. Contact: Mr. Julie, Julie Research Laboratories, 211 West 61st Street, New York, New York. Phone: 212-Circle 5-2727.

For complete information contact your Field Engineer, Field Representative, or Distributor.

MISSING INSTRUMENTS

Following are the instruments reported to us in the past 60 days as lost or presumed stolen. With each instrument (or group of instruments), we list their legal owner. Should you have any information on the present whereabouts of these instruments, or information that might lead to their eventual recovery, please contact the individual or firm listed here as the owner. If you prefer, you may relay your information to any local Tektronix Field Office, Field Engineer, or Field Representative.

1—Type 533A Oscilloscope, sn 3465; 1—Type CA Plug-In Unit, sn 19411; 1—Type D Plug-In Unit, sn 8630; 1—Type Z Plug-In Unit, sn 541, were removed from the premises of Electramatic, Inc., over Labor Day weekend. Anyone having information concerning these instruments, contact Mr. Arnold Gilbertson, 3324 Hiawatha Avenue, Minneapolis, Minnesota 55406. Phone: PA 1-5074.

Mr. Forrest Barker with the Los Angeles City College, has lost his four 502 Oscilloscopes. The serial numbers are 8506, 8854, 9280 and 9779. Mr. Barker would appreciate hearing from anyone with information on the whereabouts of his instruments. His phone number is 213-633-9141, ext. 259.

1—Type 310A Oscilloscope, sn 21352. This instrument disappeared, and is presumed stolen, from a car about two months ago. If you have information concerning this instrument, please contact Mr. Bill Wise, Mosler Safe Company, Pittsburgh, Pennsylvania.

1—Type 516 Oscilloscope, sn 1539, was reported missing last week of September, 1966. Contact: M. J. Coppler, Florida Telephone Corp., Leesburg, Florida. Phone: 904-787-4525.

1—Type 422 Oscilloscope, sn 1672 disappeared and is presumed stolen from Jean C. Bisset, "GEWSEN" Western GEEIA Region, McClellan AFB, California 95628.

1—Type 321 Oscilloscope, sn 000106 presumed stolen. Anyone having information concerning this instrument please contact: Mr. Vourganas, Baird Electronics, 630 Dundee Road, Northbrook, Illinois. Phone: 312-272-2300.

1—Type 321A Oscilloscope, sn 1366 disappeared on approximately May 13, 1966. Contact: Univac, Plant 3, St. Paul, Minnesota.

1—Type 321A Oscilloscope, sn 00194 reported missing on October 25, 1966. Contact: Univac Division (Sperry-Rand), 3645 Warrensville Center Road, Cleveland, Ohio 44122. Attn: W. Uminski. Call Collect, Phone: 216-752-7000, Ext. 36.

Service Scope

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DEPT. OF TRANSPORT
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USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 42 PRINTED IN U.S.A. FEBRUARY 1967

A PRACTICAL APPROACH TO TRANSISTOR AND VACUUM TUBE AMPLIFIERS

by F. J. BECKETT

Tektronix, Inc.

Electronic Instrumentation Group

Display Devices Development

Two articles published in past issues of Service Scope contained information that, in our experience, is of particular benefit in analyzing circuits. The first article was "Simplifying Transistor Linear-Amplifier Analysis" (issue #29, December, 1964). It describes a method for doing an adequate circuit analysis for trouble-shooting or evaluation purposes on transistor circuits. It employs the "Transresistance" concept rather than the complicated characteristic-family parameters. The second article was "Understanding and Using Thevenin's Theorem" (issue #40, October, 1966). It offers a step-by-step explanation on how to apply the principles of Thevenin's Theorem to analyze and understand how a circuit operates.

Now, in this issue of Service Scope, we present the first of three articles that will offer a practical approach to transistor and vacuum-tube amplifiers based on a simple DC analysis. These articles will, by virtue of additional information and the tying together of some loose ends, combine and bring into better focus the concepts of "transresistance" and the principles of Thevenin's Theorem. We suggest that a "refresher" reading of the two previous articles will enable our readers to more readily follow the information in this and the two following issues of Service Scope.

The Editor

Part I

THE TRANSISTOR AMPLIFIER

INTRODUCTION

Tubes and transistors are often used together to achieve a particular result. Vacuum tubes still serve an important role in electronics and will do so for many years to come despite a determined move towards solid state circuits.

Whether a circuit is designed around vacuum tubes or transistors or both, it is important to recognize the fact that the two are in many ways complementary. It is wrong to divorce vacuum tubes and transistors as separate identities each peculiar to their own mode of operation. Indeed, as this series of articles will show there is an analogy between the two. It is true of course, that the two are entirely different in concept; but, so often we come across a situation where one can be explained in terms of the other that it is very desirable to recognize this fact.

Transistor and vacuum tube data give us very little help in the practical sense. Parameter Curves and electrical data show the behavior of these devices under very defined conditions. In short, they are more useful to the designer than the technician. We are often reduced to explaining most circuits in terms of an ohms law approach; so, it seems pointless not to pursue this approach to its logical conclusion.

In this first article we will look at a transistor amplifier as a simple DC model; and then, in the second article, look at a vacuum-tube amplifier in a similar light. We will assume that both devices are operated as linear amplifiers and then use the results in a practical way.

One must bear in mind that this approach cannot be assumed in all cases. It is, as it is meant to be, a simple analysis but the results will prove to be a valuable tool in trouble-shooting and understanding circuits.

Let us consider the general equation for current through a P.N. diode junction.

$$I = I_o \left[\exp \frac{V}{\rho V_e} - 1\right] \qquad (1)$$

where V = applied volts

I_o = reverse bias current

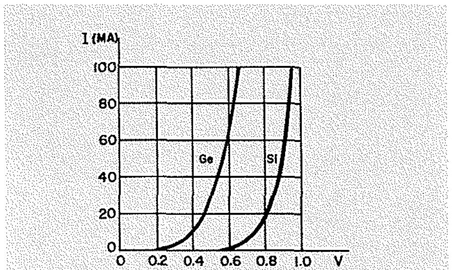
ρ = constant between 1 & 2

and $V_e = \frac{kT}{q}$ where k = Boltzmans Const., 1.38×10^{-23} Joule/°Kelvin

T = absolute temperature in degree Kelvin at room temperature, i.e., T = 300°K

q = electronic charge 1.602×10^{-19} Coulomb.

$$V_e = \frac{300}{11600} = 0.026 \text{ volts}$$



THE FORWARD VOLT-AMPERE CHARACTERISTICS OF A GERMANIUM AND SILICON DIODE

Figure 1.

Figure 1 shows a typical forward volt/amp characteristic for germanium and silicon diodes. Figure 2 is a plot of the collector current or the base current versus the base-to-emitter voltage of a transistor; point A on this curve is a typical operating point.

OBJECTIVE

The objective of this paper is to present a practical approach to Transistor and Vacuum-tube amplifiers based on a simple DC analysis.

The articles will be published in the following sequence.

1. The Transistor Amplifier.
2. The Vacuum-tube Amplifier.
3. An analysis of a typical Tektronix hybrid circuit (Type 545B vertical) based on conclusions reached in (1) and (2).

As a corollary they will bring forward some important relationships between vacuum tubes and transistors.

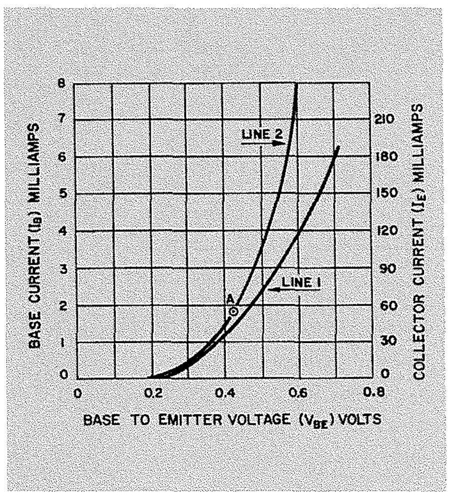


Figure 2. Line (1) is a plot of the base current versus the base-to-emitter voltage (V_{BE}). Line (2) is a plot of the collector current versus the base-to-emitter voltage (V_{BE}). Point "A" is a typical operating point.

One is quite justified in looking at a transistor in terms of the two-diode concept, refer to Figure 3. Therefore, assuming diode A to be forward biased and diode B to be reverse biased, as would be the case if we were to operate the transistor as a linear amplifier, the current through diode A will conform to equation (1). Let us take a closer look at Figure 2.

We define conductance in the general case as

$$g = \frac{I}{V}$$

and therefore at our operating point "A" the dynamic conductance

$$g' = \frac{\Delta I}{\Delta V} \qquad (2)$$

hence

$$g' = \frac{I_o \exp \frac{V}{\rho V_e}}{\rho V_e}$$

$$= \frac{I + I_o}{\rho V_e} \qquad (3)$$

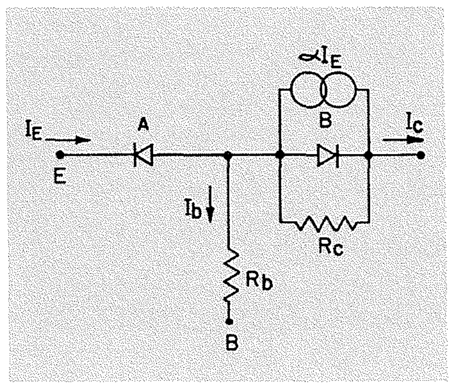


Figure 3. Illustration of the two-diode concept of a transistor.

but $I >> I_0$ then $g' = \frac{I}{\rho V_e}$

$$\text{or } g' = \frac{I}{0.026\rho} \text{ mhos} \qquad (4)$$

The term "ρ" takes into account the recombination of carriers in the junction region. It is approximately unity for germanium and approximately 2 for silicon. At a typical operating point this term can usually be neglected. Therefore, we may say that

$$g' = \frac{I}{26} \text{ if I is in milliamps.} \qquad (5)$$

Now resistance is the reciprocal of conductance and therefore the value of conductance at point "A" can be given in terms of resistance

$$r_e = \frac{26}{I} \ \Omega\text{'s} \qquad (6)$$

This resistance (r_e) is commonly known as the dynamic emitter resistance.

At this point we will depart from our simple model and look at the transistor in another form; but, bear in mind our first thoughts. Transistor parameters are derived from various equivalent circuits depending upon the configuration i.e., common emitter, common base, or common collector. We will not consider any detailed analysis in this approach; but, to understand the approach it is necessary to know how these parameters are derived. It will be simple enough to derive another set of parameters once we have our basic model constructed.

The simplest and easiest equivalent circuit of a transistor is the "Tee" equivalent. It is a very good approximation about the behavior of a transistor, especially at DC and low frequencies. We can also represent either the common emitter or the common base simply by interchanging R_b and R_e. Figure 4 is a "Tee" equivalent circuit of the common emitter and the common base configurations.

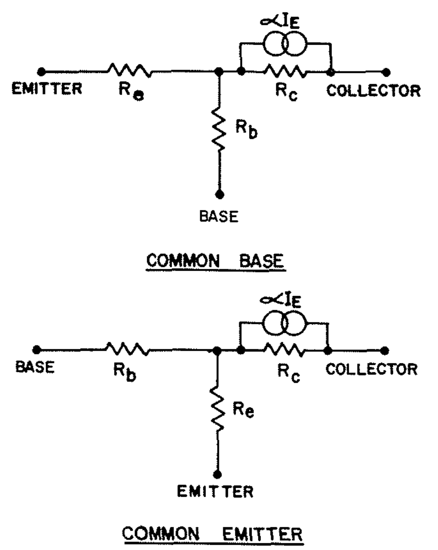


Figure 4. "Tee" equivalent circuits for the common-base and common-emitter configurations of transistors.

Firstly, let us define the term β (the small-signal current gain) as

$$\beta = \frac{\Delta I_c}{\Delta I_b} \qquad (7)$$

and since $I_E = I_c + I_b$

$$\text{then } I_E = I_c \left(1 + \frac{1}{\beta}\right) \qquad (8)$$

usually $\beta >> 1$ then $I_E \approx I_c$

Equation (8) shows us that only $\frac{1}{\beta}$ of the emitter current flows into the base. Hence, it is reasonable to suppose that any impedance in the emitter, when viewed from the base, will be β times as great; and, any impedance in the base, when viewed from the emitter, will be β times as small. That is to say, the dynamic resistance multiplied by β must equal R_e in our equivalent "Tee" circuit.

Hence $R_e = \beta re$

Our equivalent circuit shows a resistance R_b. This resistance is known as the base-spreading resistance. It is a physical quantity and can be expressed in terms of resistivity associated with the base-emitter junction. It can vary between a few ohms to hundreds of ohms, depending upon the type of transistor; and therefore, must be taken into consideration. Looking into the emitter we see it as an impedance whose value is divided by β and appears in series with the dynamic emitter resistance (r_e). Hence the emitter current encounters an impedance in the base/emitter junction which is equal to the sum of the dynamic resistance plus $\frac{R_b}{\beta}$, the latter term we will designate R_r and the sum of these two resistances we will designate R_t.

$$\text{Hence } R_t = r_e + R_r \qquad (9)$$

The value of R_r can vary anywhere between 2 Ω to 24 Ω depending on the value of R_b. R_b is difficult to measure and rarely given in electrical data on transistors. A figure of 250 Ω's is a typical value at low frequencies. Therefore, if β were 50 then R_r would be 5 Ω's.

Now if we look into the base in the common emitter or the common collector configuration it is reasonable to suppose we will see the resistance (R_t)—plus any other impedance which may be wired to the emitter terminal—multiplied by β, then

$$R_{in} = \beta(R_t + R_E) \qquad (10)$$

where R_E = the external emitter resistance.

If $R_E >> R_t$ then $R_{in} = \beta R_E$

So far we have had very little to say about R_e shunted by the current generator $\propto I_E$. If our equivalent "Tee" circuit consisted of resistances alone, it would be passive; i.e., it could supply no energy of its own. But a transistor can amplify energy to the signal. To represent this we have shown a current generator shunting R_e. The value of R_e will depend on the circuit configuration; i.e., tens of kilohms for a common emitter configuration, to many megohms for a common base configuration. In our approach it is not necessary to pursue this matter any further since we will not be considering a transistor in any extreme condition.

Now in a more practical sense, let us look at Figure 5, a typical common-emitter configuration.

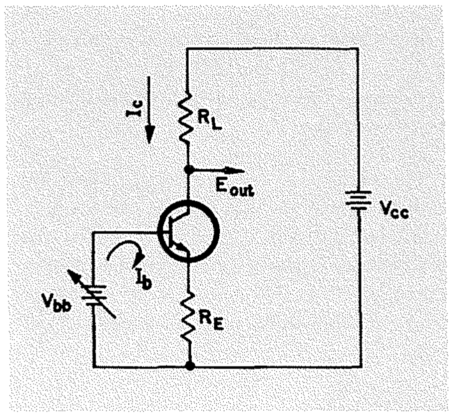


Figure 5. A typical common-emitter circuit.

Now we will assume $R_e >> R_L$.

Now by inspection

$$E_{out} = V_{cc} - \Delta I_c R_L \qquad (11)$$

$$\text{hence } \Delta E_{out} = -\Delta I_c R_L \qquad (12)$$

The input impedance we see looking into the base of a transistor in the common emitter configuration is

$$R_{in} = \beta(R_E + R_t) \qquad (10)$$

$$\text{also } \Delta I_b = \frac{\Delta V_{bb}}{R_{in}}$$

$$= \frac{\Delta V_{bb}}{\beta(R_E + R_t)} \qquad (13)$$

we also recall that

$$\beta = \frac{\Delta I_c}{\Delta I_b} \qquad (7)$$

$$\text{hence } \Delta I_c = \beta \Delta I_b \qquad (14)$$

Therefore substituting equation (13) in equation (14)

$$\Delta I_c = \beta \frac{\Delta V_{bb}}{\beta(R_E + R_t)} \qquad (15)$$

and from equation (15)

$$\Delta V_{bb} = \Delta I_c \ (R_E + R_t) \qquad (16)$$

we define the voltage gain as

$$A_{(v)} = \frac{\Delta E_{out}}{\Delta V_{bb}}$$

Then from equation (12) and equation (16)

$$A_{(v)} = -\frac{\Delta I_c\ R_L}{\Delta I_c\ (R_E + R_t)} \quad (17)$$

$$= -\frac{R_L}{R_E + R_t}$$

and if $R_E >> R_t$ then

$$A_{(v)} = -\frac{R_L}{R_E} \quad (18)$$

If we analyze the common-base configuration in a similar manner we arrive at the same result with the one exception that the sign is positive.

The conclusion we can draw from this analysis is that the gain of a transistor stage is set by external conditions provided that the emitter resistance is sufficiently great enough to "swamp" our internal resistance (R_t). In the absence of an emitter resistance

$$A_{(v)} = \frac{R_L}{R_t}$$

There is one very important fact we must remember about R_E. R_E will be that impedance in which the signal current will flow to the AC ground. We define an AC ground point as that point in a circuit at which the power level of the signal has been reduced to zero.

We normally encounter three types of an AC ground:

1. An Actual AC Ground.

This is the chassis point or the DC ground point. It is as well to remember the power supply can be placed in this category so far as the signal is concerned.

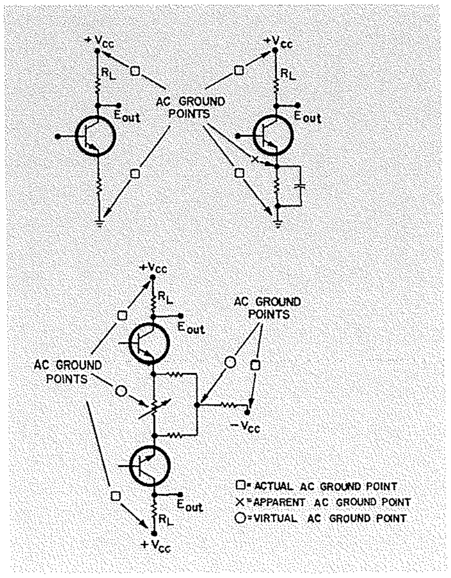


Figure 6. Illustrating the three types of AC ground normally encountered in electronic circuits.

2. An Apparent AC Ground.

The apparent AC ground may be represented by any point in a circuit which acts as to represent a low impedance between that point and the actual AC ground thereby bypassing the signal to an actual AC fround. A large value capacitor is a typical example should one side be returned to an actual AC ground.

3. The Virtual AC Ground.

The virtual A.C. ground point is perhaps the most difficult to recognize. It may best be explained as that point in a circuit where we have two signals of equal amplitude and frequency but exactly opposite in phase. Figure 6 will help clarify these points.

Figure 8 summarizes the results of our DC analysis of the common emitter, common base and common collector.

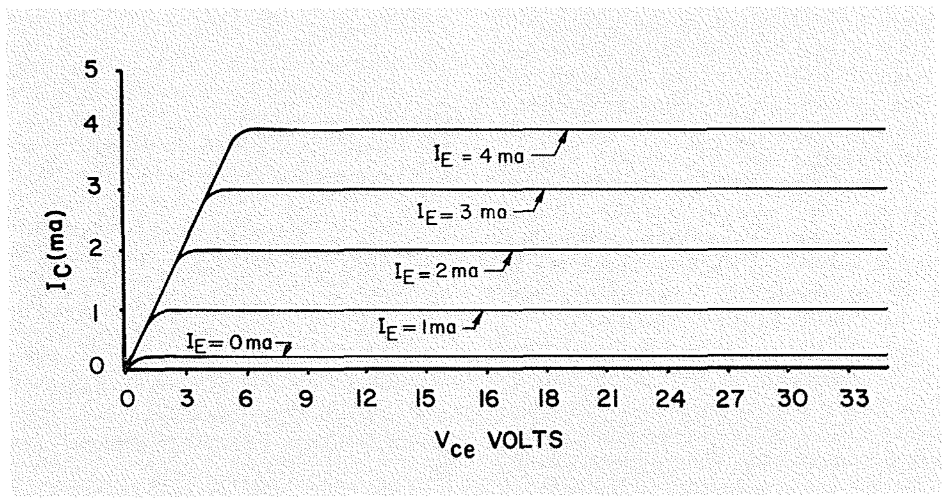


Figure 7. We define the parameter R_c in the common-base "Tee" configuration as;

$$R_c = \frac{\Delta V_{ce}}{\Delta I_c}\Bigg|_{I_E} \text{ ohms}$$

Where ΔV_{ce} is the change in the collector voltage because of the change in collector current ΔI_c, when we hold the emitter current I_E constant.

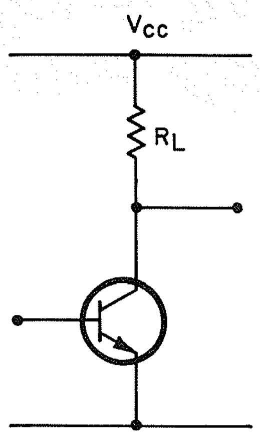
Once the collector becomes saturated, the change in I_c is very small for a large change in V_{ce}. Hence, R_c is a very large resistance and does not modify the DC equivalent circuit to any extent. For this reason it was omitted from Figure 7. Therefore; $R_{out} \cong R_L$ (Common Base).

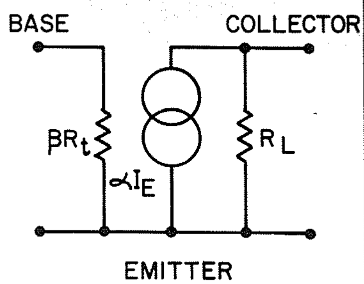
LIST OF SYMBOLS

$A_{(v)}$	Voltage gain defined as $\frac{\Delta E_{out}}{\Delta E_{in}}$
I_b	Base current
I_c	Collector current
I_E	Emitter current
R_c	Collector resistance (Tee Equivalent)
R_b	Base spreading resistance (Tee Equivalent)
R_e	Emitter resistance (Tee Equivalent)
R_E	External Emitter resistance (refer to text)
$R_{E(s)}$	The equivalent resistance between the signal source and the emitter terminal of the transistor in the common base configuration.
R_L	Load resistance
R_r	$\frac{R_s}{\beta}$
R_t	The "Transresistance" resistance ($re + R_r$)
re	dynamic emitter resistance
V_{bb}	Base voltage
V_{cc}	Supply voltage
V_{ce}	Collector to emitter voltage
Δ	(Delta) the change in the variable with which it is associated.

BASIC CIRCUIT	EQUIVALENT CIRCUIT	EQUATIONS	REMARKS

COMMON EMITTER





$\text{GAIN} = A(v) = -\frac{R_L}{R_t}$

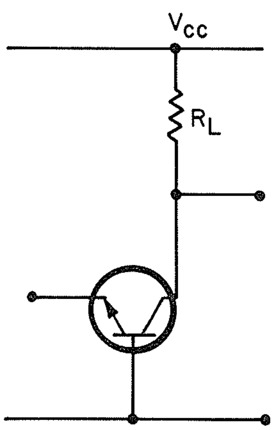
$R_{IN} = \beta R_t$

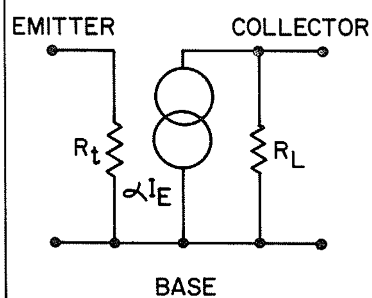
A resistance (R_E) between the emitter terminal of the transistor to the AC ground will modify the gain equation and the input impedance; then,

$A_{(v)} = -\frac{R_L}{R_t + R_E}$ and

$R_{in} = \beta\,(R_E + R_t)$.

COMMON BASE





$\text{GAIN} = A(v) = +\frac{R_L}{R_t}$

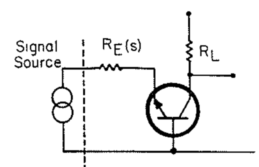
$R_{IN} = R_t$

$R_{OUT} = R_L$

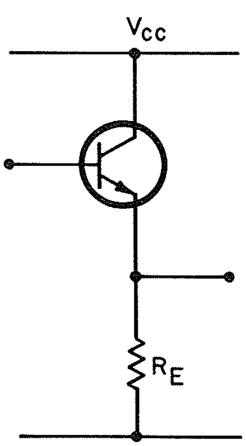
The equivalent resistance $R_{E(s)}$ between the input signal source and the emitter terminal of the transistor will modify the gain equation and the input impedance as seen from the signal source; then,

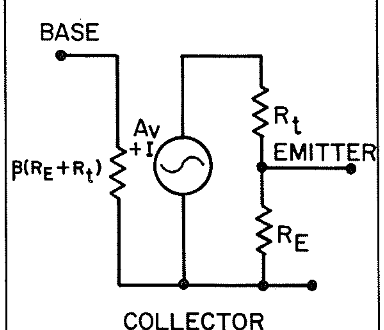
$A_{(v)} = +\frac{R_L}{R_t + R_{E(s)}}$ and

$R_{in} = R_t + R_{E(s)}$.



COMMON COLLECTOR





$\text{GAIN} = A(v) = \frac{R_E}{R_E + R_t}$

$R_{IN} = \beta\,(R_E + R_t)$

$R_{OUT} = (R_t + \frac{1}{\beta})$ in parallel with R_E

The actual value of R_{out} will depend on what resistance is connected to the base. Let us assume the base is directly coupled to the preceding stage. The equivalent output impedance of the preceding stage becomes the numerator over beta in the second term in the parenthesis and the output impedance of the stage under consideration R_{out} is modified accordingly; eg., if the output impedance of the previous stage is 100 Ω, then

$R_{out} = (R_t + \frac{100}{\beta})$ in parallel with R_E.

Figure 8.

SERVICE NOTES

SILVER-BEARING SOLDER AND SILVER SOLDER: TWO DIFFERENT THINGS

Many components in Tektronix instruments are mounted on ceramic strips. The notches in these strips are lined with a silver alloy and repeated use of ordinary tin-lead solder will breakdown the silver-to-ceramic bond. For this reason, we recommend the use of a silver-*bearing* solder containing 3% silver when performing service or maintenance work that requires soldering on these ceramic strips. This type of solder is used frequently in printed circuits and should be readily available from radio-supply houses.*

Silver-*bearing* solder should not be confused with silver solder. They are two different things!

The use of silver-*bearing* solder in the construction and maintenance and repair of electronic circuits is a safe and accepted practice. The silver-*bearing* solder used and recommended by Tektronix for ceramic strip soldering, melts at about 365 degrees Fahrenheit, and is applied with an ordinary soldering iron. It is composed of 60% tin, 37% lead, and 3% silver. It contains absolutely no cadmium! It produces no toxic or lethal fumes!

Silver solder, on the other hand, is a brazing alloy and is most commonly used by welders. It is composed essentially of silver, copper, zinc, and sometimes cadmium. When the alloy is composed of 45% silver, 30% copper and 25% zinc it requires approximately 1340 degrees Fahrenheit to melt it and it is usually applied with an acetylene torch. Should either the silver solder or the metals to which it is being applied contain cadmium, this high temperature will cause the cadmium to vaporize and release fumes. These fumes will be toxic and they can be lethal.

In summary, let us repeat; Silver-*bearing* solder and silver solder are two different things:

Silver-*bearing* solder is used primarily in the soldering of electronic circuits. Silver solder is an alloy used in the brazing and welding of metals.

Silver-*bearing* solder is applied with a soldering iron and requires only relatively low temperature to melt it. Silver solder is applied with an acetylene torch and requires a high temperature to melt it.

Silver-*bearing* solder absolutely does not produce toxic fumes. Silver solder, if it contains cadmium or is used on metal containing cadmium, does produce fumes that are toxic and can be lethal.

Positively no silver solder is used in any instrument produced by Tektronix, Inc.

*If you prefer you can order this solder directly through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Order Tektronix part number 251-0515-00.

OOPS! WRONG PART NUMBER

In the December 1966 issue of Service Scope, we transposed two figures in the Tektronix part numbers for the probe identification tags. The part number for the identification tags for use on the smaller (0.125" diameter) cables is 334-0798-00, and the number for the larger (0.178 to 0.185" diameter) cables is 334-0798-01.

COMPONENT LUBRICATION KIT FOR TEKTRONIX INSTRUMENTS

We have available a component lubrication kit for Tektronix instruments. The kit contains: a detent lubricant in a container-applicator; a switch-contact lubricant in a container-applicator; a pot lubricant in a container-applicator; 12 each detent-ball replacements (for lost or worn detent balls) in the following sizes—5/32", 3/16", and 7/32"; a #3 brush, and an instruction book.

The instruction book contains information on the cleaning and washing of Tektronix instruments and when an instrument needs lubrication. It also contains illustrations showing the different types of switches used in Tektronix instruments and tells how to lubricate them and replace worn or lost detent balls. The lubrication of potentiometers and fan motors and the care of air filters are also covered. Suggestions for the lubrication of rackmount tracks are given.

You may order the kit through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 003-0342-00.

TYPE 1L5, TYPE 1L10, TYPE 1L20, AND TYPE 1L30 PLUG-IN SPECTRUM ANALYZERS WITH A TYPE 132 POWER SUPPLY

These spectrum analyzers can be used in conjunction with a Type 132 Plug-In Unit Power Supply and the output displayed on any Tektronix oscilloscope that has a Sawtooth-Out sweep voltage available on the front panel.

Positive output-polarity voltage from the Type 132 can be applied to the DC-coupled input of the oscilloscope. Centering of the oscilloscope sweep is performed with the oscilloscope vertical-position control prior to RF signal application to the analyzer. The analyzer vertical-position control can then be used for trace positioning.

The Sawtooth-Out sweep voltage from the oscilloscope is applied to the Sweep-Input connector.

TYPE 1L10, TYPE 1L20, AND TYPE 1L30 PLUG-IN SPECTRUM ANALYZERS—VERTICAL TRACE SHIFT

If a vertical trace shift is encountered when a Type 1L10, Type 1L20, or Type 1L30 Plug-In Spectrum Analyzer is switched between linear and log mode, suspect a gassy input tube in the indicator (oscilloscope) vertical amplifier. The output impedance of the analyzer unit is much higher in the log mode than it is in the linear mode. If grid current is present in the input tube, this current will give a different voltage drop across the input resistance (analyzer output impedance); consequently, a DC shift of the trace will result.

simplify waveform measurements

Tektronix Type 502A

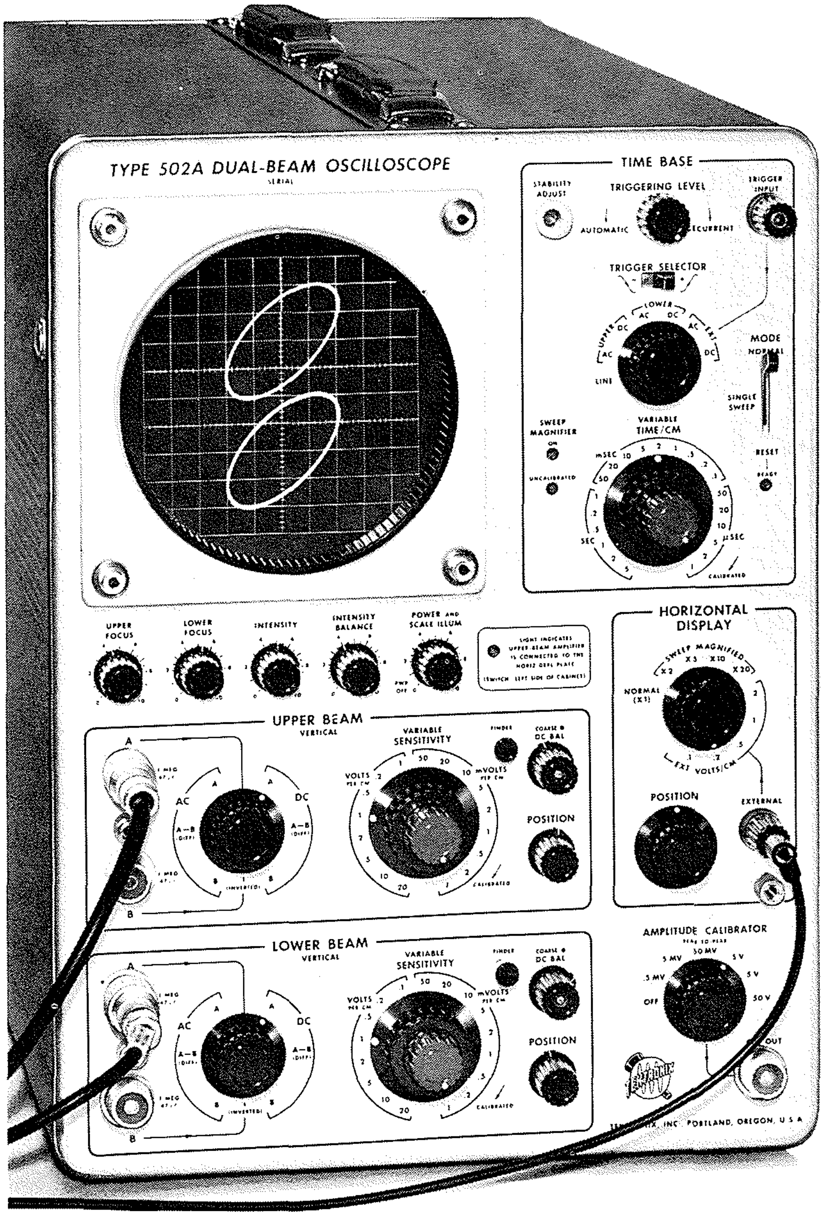
100 μV/cm dual-beam oscilloscope

☐ **Measure stimulus and reaction on the same time base.**

☐ **Measure transducer outputs, such as pressure vs. volume.**

☐ **Measure phase angles and frequency differences.**

☐ **Measure characteristics of low-level signals.**



The Type 502A combines the performance *capabilities unique to dual-beam oscilloscopes* with operational features designed to simplify and speed up your measurements.

You can examine two waveforms simultaneously by applying input signals to both of the identical vertical amplifiers. You can use each vertical amplifier in a differential display mode to examine the difference between two signals. You can also use the Type 502A as a single-beam X-Y oscilloscope or as a dual-beam X-Y oscilloscope with both traces plotted on the same X scale.

This performance is combined with operating conveniences which include pushbutton beam finders for quick location of off-screen signals, vertical signal outputs, intensity balance for identification of upper and lower beams, single-sweep operation, Z-axis input, variable control of vertical and horizontal deflection factors, electronically-regulated power supplies for stable operation, and other refinements.

performance characteristics include:

Bandwidth from DC to 100 kHz at 100 μV/cm, increasing to DC to 1 MHz from 5 mV/cm to 20 V/cm • Calibrated deflection factors from 100 μV/cm to 20 V/cm in 17 steps; continuously variable between steps, uncalibrated, and to 50 V/cm • Common-mode rejection of at least 50,000:1 from DC to 50 kHz ••Phase difference between amplifiers less than 1 degree from DC to 100 kHz • Calibrated sweep rates from 1 μs/cm to 5 s/cm in 21 steps • 2X, 5X, 10X, 20X sweep magnification • Flexible trigger facilities • Amplitude Calibrator • 10 cm by 10 cm display area.

Tektronix, Inc.

For complete information contact your Field Engineer, Field Representative, or Distributor.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon, U.S.A. 97005

FRANK GREENWOOD
DEPARTMENT OF TRANSPORT
T & E SYSTEMS LAB.
BOX 4028, STATION E
OTTAWA, ONTARIO, CANADA

1/67

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 43 PRINTED IN U.S.A. APRIL 1967

PRACTICAL APPROACH TO TRANSISTOR AND VACUUM TUBE AMPLIFIERS

BY F. J. BECKETT

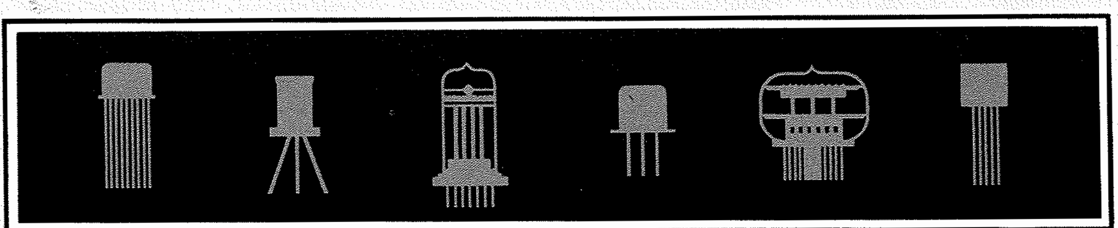
TEKTRONIX, INC.

ELECTRONIC INSTRUMENTATION GROUP

DISPLAY DEVICES DEVELOPMENT

PART 2

THE VACUUM TUBE AMPLIFIER



This is the second in a series of three articles offering a new approach to transistor and vacuum-tube amplifiers. This new approach is based on a simple DC analysis that incorporates the concepts of "transresistance" and the principles of Thévenin's Theorem.

Part 1, "The Transistor Amplifier", which appeared in the February, 1967 issue of SERVICE SCOPE considered the transistor amplifier as a simple DC model. This second article looks at the vacuum-tube amplifier in a similar light and sees some striking similarities in the two devices.

In the previous article (Part I, "The Transistor Amplifier) of this series, it was shown that the gain of a linear transistor amplifier is set by external conditions. The same reasoning can also be applied to vacuum tubes. The equivalent circuit of a vacuum-tube amplifier is shown in Figure 9. The current that is produced in the plate circuit by the signal (E_g) acting on the grid is taken into account by postulating that the plate circuit can be replaced by a generator, $-\mu E_g$ having an internal resistance (rp). We may also consider a vacuum-tube amplifier in terms of the constant-current form by replacing the voltage generator in the constant-voltage form with a current generator (gm E_g) shunting the internal resistance (rp).

These two approaches are valid in every respect but they do not convey much to us in the practical sense. Let us now consider a vacuum-tube amplifier from another approach.

In an amplifier which has its grid referenced to ground all plate-circuit impedances, R_L and rp, when viewed from the cathode are multiplied by the term $\frac{1}{\mu + 1}$. Also, by the same reasoning, the cathode impedances when viewed from the plate circuit are multiplied by the term $(\mu + 1)$. Therefore, the impedance we see looking into the cathode must be

$\frac{rp + R_L}{\mu + 1}$, where μ equals the amplification factor of the tube.

Hence it is reasonable to suppose that the voltage E_c, reference Figure 10, appears across this impedance we see looking into the cathode.

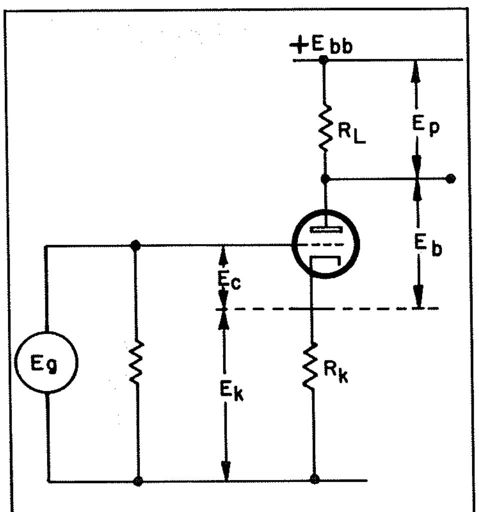


Figure 10. A vacuum tube amplifier in the grounded cathode configuration showing the various voltage measurements around the circuit.

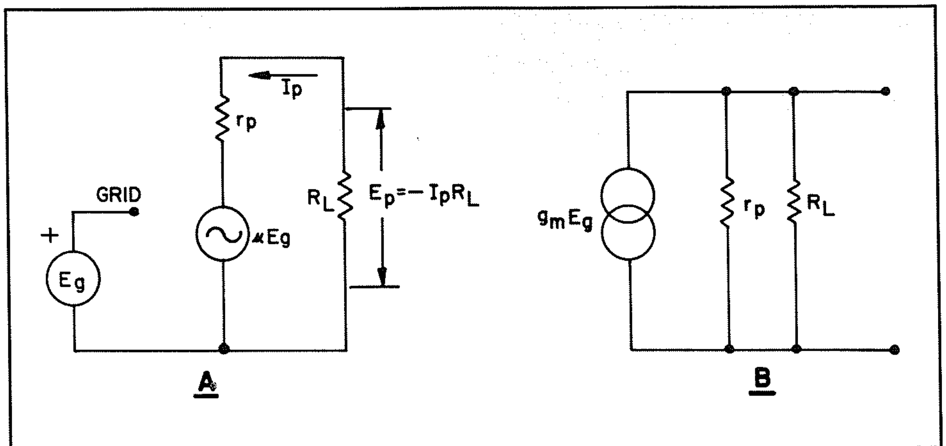


Figure 9. Illustrating the more familiar equivalent circuit of a vacuum tube amplifier.
(a) The constant voltage generator form or the Thévenin equivalent.
(b) The constant current generator form or the Norton equivalent.

The Triode Amplifier (Ground Cathode)

We will now look at a triode amplifier in terms related to our equivalent circuit. The common component is of course, the plate current. The change in this current due to the action of a control grid will determine the output voltage across the load impedance (R_L).

Now $E_g = E_c + E_k$ (19)

That is to say

$$E_g = I_p \left[\frac{rp + R_L}{\mu + 1}\right] + I_p R_k$$

$$\text{Or, } E_g = I_p \left[\left(\frac{rp + R_L}{\mu + 1}\right) + R_k\right] \qquad (20)$$

Also, $E_{bb} = E_b + E_p + E_k$ (21)

or $E_b = E_{bb} - E_p - E_k$ (22)

and $E_p = -I_p R_L$ (23)

We define the voltage gain $A_{(v)}$ as

$$A_{(v)} = \frac{E_p}{E_g} \qquad (24)$$

$$\text{Then } A_{(v)} = -\frac{I_p R_L}{I_p\left[\left(\frac{rp + R_L}{\mu + 1}\right) + R_k\right]}$$

$$= -\frac{R_L}{\left(\frac{rp + R_L}{\mu + 1}\right) + R_k} \qquad (25)$$

We now have arrived at an equation for gain which is a ratio of impedances. The same approach may be applied to the grounded-grid configuration and we arrive at a similar result, except the sign is positive.

The Pentode Amplifier

In the triode amplifier all the cathode current will flow through the output load impedance (R_L). However, in the case of the pentode and other multigrid tubes, some of this current is diverted into the screen. Equation (23) defines the output voltage in terms of the plate current. Therefore, to derive the actual gain figure we must determine the actual amount of cathode current which will finally reach the plate and become signal current. This figure can be arrived at from a graphical analysis of the mutual-conductance curves. In most cases, about 72% of the cathode current reaches the plate to become signal current. A typical example is a type 12BY7 pentode. However, this figure can be as high as 90% for some types—for example a 7788 pentode. The ratio of the plate current (I_p) to the cathode current (I_k) is the plate efficiency factor, i.e., $\eta = \frac{I_p}{I_k}$.

Now let is reexamine what effect this fact must have on the gain of a pentode amplifier as compared to a triode amplifier. The impedance we see looking into the cathode of a pentode is the same as for a triode.

That is $\frac{rp + R_L}{\mu + 1}$

however $rp >> R_L$ and therefore R_L can usually be neglected in this equation.

That is to say $\frac{rp}{\mu + 1} \approx \frac{1}{gm}$

and since conductance is the reciprocal of resistance we will call this impedance r_k.

$$\text{i.e. } r_k = \frac{1}{gm} \qquad (26)$$

We have seen that the gain equation of the triode amplifier is defined in terms of the parameters μ and rp. We should not lose sight of the fact that μ and rp are related to the plate current and therefore when these parameters are transferred to cathode dimensions these terms must be multiplied by the plate efficiency factor (η). That is to say the impedance we see looking into the cathode r_k must be multiplied by (η). With these facts in mind let us now derive the gain equation for a pentode amplifier.

We recall that:

$$E_b = E_{bb} - E_p - E_k \quad (22)$$

$$\text{and } E_p = -I_pR_L \quad (23)$$

$$\text{also } E_g = E_c + E_k \quad (19)$$

$$= \eta r_k I_k + I_k R_k \quad (27)$$

$$\text{but } I_k = \frac{I_p}{\eta} \quad (28)$$

Therefore substituting equation (28) in equation (27)

$$E_g = \frac{\eta r_k I_p}{\eta} + \frac{I_p R_k}{\eta}$$

$$= I_p\left(r_k + \frac{R_k}{\eta}\right) \quad (29)$$

and since the voltage gain

$$A_{(v)} = \frac{E_p}{E_g}$$

$$= -\frac{I_p R_L}{I_p\left(r_k + \frac{R_k}{\eta}\right)}$$

$$= -\frac{R_L}{r_k + \frac{R_k}{\eta}} \quad (30)$$

The same remarks we made about the external emitter resistor R_E (refer to Part No. 1, The Transistor Amplifier) apply equally as well to the cathode resistor, R_k; *namely, R_k will be that impedance in which the signal current will flow to the AC ground.*

In the case of the grounded plate (the cathode follower) we do not need to consider the plate efficiency factor if the amplifier is triode connected, therefore, the "gain" can be considered in terms of a simple divider network which can never be greater than unity.

$$A_{(v)} = \frac{R_k}{R_k + r_k} \quad (31)$$

The Push-Pull Amplifier

We can view a push-pull amplifier in a similar light by recognizing the existence of a virtual AC ground point between the cathodes of $V_{(1)}$ and $V_{(2)}$ as shown in Figure 11. Therefore, the gain of a push-pull triode amplifier will be:

$$A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{r_{k(1)} + r_{k(2)} + R_{k(1)} + R_{k(2)}} \quad (32)$$

where subscripts (1) and (2) are associated with $V_{(1)}$ and $V_{(2)}$.

And if:

$$R_{k(1)} = R_{k(2)}$$

$$\text{and } r_{k(1)} = r_{k(2)}$$

which is usually the case; then,

$$A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{2r_k + 2R_k} \quad (33)$$

$$\text{Where } r_k = \frac{r_p + R_L}{\mu + 1} \quad (\text{either } V_{(1)} \text{ or } V_{(2)})$$

$$\text{and } R_k = R_{k(1)} \text{ or } R_{k(2)}$$

With a push-pull pentode amplifier we must consider the plate-efficiency factor (η). Therefore,

$$A_{(v)}\ \text{pentode} = \frac{R_{L(1)} + R_{L(2)}}{2r_k + \frac{2R_k}{\eta}} \quad (34)$$

$$\text{where } r_k = \frac{1}{gm} \text{ either } V_{(1)} \text{ or } V_{(2)}$$

$$R_k = R_{k(1)} \text{ or } R_{k(2)}$$

η = plate-efficiency factor of either $V_{(1)}$ or $V_{(2)}$.

The Cascode Amplifier

The cascode amplifier fundamentally consists of two tubes connected in series, see Figure 12. Normally we usually fix the grid of $V_{(1)}$ at some positive voltage.

The key to understanding this type of circuit is to consider $V_{(2)}$ as a voltage-activated current generator. All the current delivered by $V_{(2)}$ passes through the output load impedance R_L. Any change in voltage appearing at the grid of $V_{(2)}$ appears as a change in current across R_L. We can derive the gain equation in the same way as we did for a pentode amplifier. There is no need to consider (η) if both tubes are triodes.

$$A_{(v)}\ (\text{stage}) = \frac{R_{L(1)}}{R_{k(2)} + r_{k(2)}} \quad (35)$$

$$\text{where } r_{k(2)} = \frac{r_{p(2)}}{\mu_{(2)} + 1}$$

$$= \frac{1}{gm_{(2)}}$$

where the subscripts (1) and (2) are associated with $V_{(1)}$ and $V_{(2)}$.

One of the advantages of this type of circuit is that the internal impedance which shunts R_L is extremely high.

In this respect the triode cascode amplifier closely approximates a pentode amplifier. If we compare the plate-current versus plate-voltage curves of both devices we see a close resemblance.

The Hybrid Cascode Amplifier

Figure 13 is a typical configuration consisting of a vacuum tube V_1 and a transistor, Q_1, connected in series. We can apply much the same approach as we did for the cascode vacuum-tube amplifier. Let us assume the base to emitter junction of Q_1 to be forward biased. The collector current of Q_1 becomes the plate current of V_1. Therefore, any change occurring at the base of Q_1 is reflected as a change in plate current in V_1.

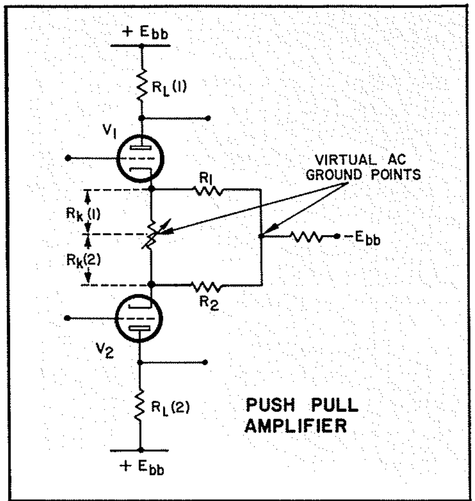


Figure 11. A typical push-pull triode amplifier. We normally encounter two virtual AC ground points between the cathodes V_1 and V_2. It may be necessary to consider the effect of the virtual AC ground point at the junction of R_1 and R_2. If R_1 or R_2 is large in value compared respectively to $R_{k(1)}$ or $R_{k(2)}$ then we can neglect this virtual AC ground and consider R_k in terms of $R_{k(1)}$ or $R_{k(2)}$. However, if this is not so, R_k will be the parallel combination of $R_{k(1)}$ and R_1 or $R_{k(2)}$ and R_2.

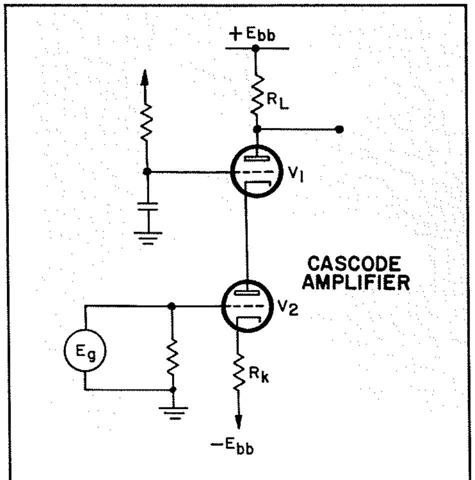


Figure 12. Illustrating a cascode amplifier using two triodes.

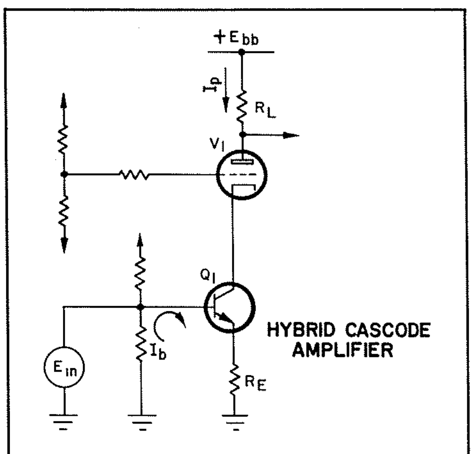
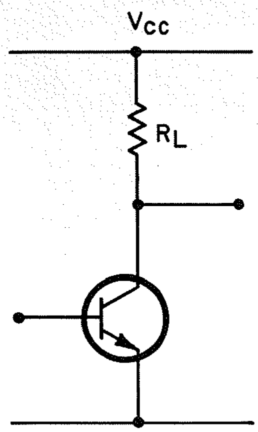
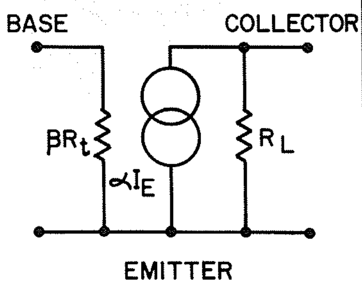
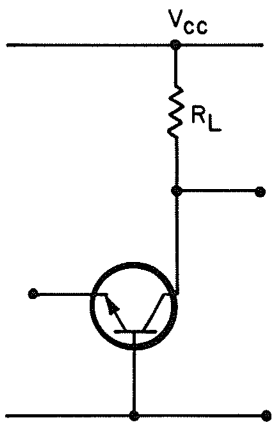
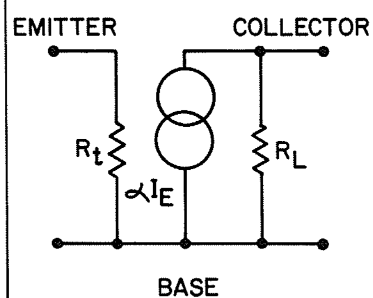
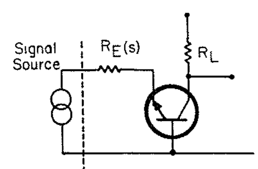


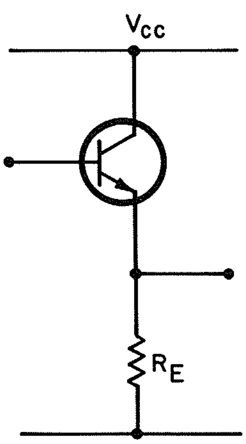
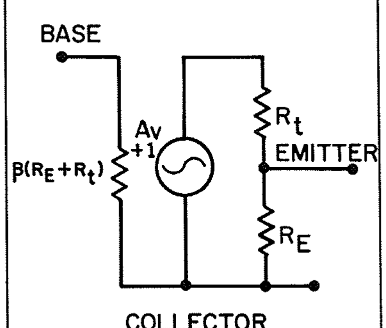
Figure 13. A typical hybrid cascode amplifier using a transistor and a vacuum tube.

BASIC CIRCUIT	EQUIVALENT CIRCUIT	EQUATIONS	REMARKS
		GAIN = $A(v) = -\frac{R_L}{R_t}$ RIN = βR_t	A resistance (R_E) between the emitter terminal of the transistor to the AC ground will modify the gain equation and the input impedance; then, $A(v) = -\frac{R_L}{R_t + R_E}$ and $R_{in} = \beta\ (R_E + R_t)$.

COMMON EMITTER

BASIC CIRCUIT	EQUIVALENT CIRCUIT	EQUATIONS	REMARKS
		GAIN = $A(v) = +\frac{R_L}{R_t}$ RIN = R_t ROUT = R_L	The equivalent resistance $R_{E(s)}$ between the input signal source and the emitter terminal of the transistor will modify the gain equation and the input impedance as seen from the signal source; then, $A(v) = +\frac{R_L}{R_t + R_{E(s)}}$ and $R_{in} = R_t + R_{E(s)}$. 

COMMON BASE

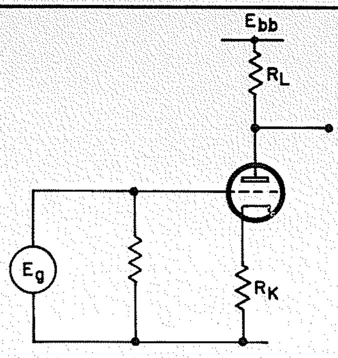
BASIC CIRCUIT	EQUIVALENT CIRCUIT	EQUATIONS	REMARKS
		GAIN = $A(v) = \frac{R_E}{R_E + R_t}$ RIN = $\beta\ (R_E + R_t)$ ROUT = $(R_t + \frac{1}{\beta})$ in parallel with R_E	The actual value of R_{out} will depend on what resistance is connected to the base. Let us assume the base is directly coupled to the preceding stage. The equivalent output impedance of the preceding stage becomes the numerator over beta in the second term in the parenthesis and the output impedance of the stage under consideration R_{out} is modified accordingly; eg., if the output impedance of the previous stage is 100 Ω, then $R_{out} = (R_t + \frac{100}{\beta})$ in parallel with R_E.

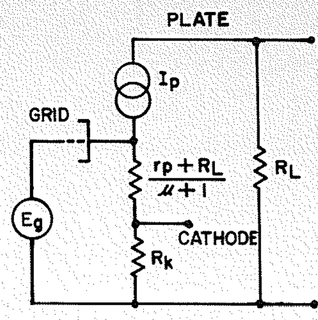
COMMON COLLECTOR

Figure 8.

BASIC CIRCUIT (TRIODE)	EQUIVALENT CIRCUIT	EQUATIONS

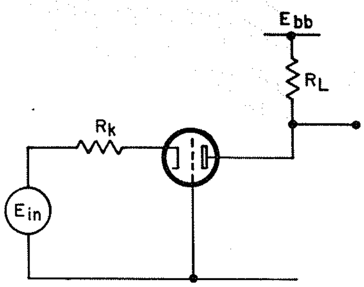
GROUNDED CATHODE

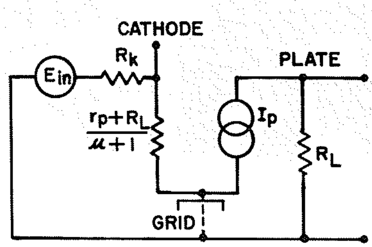




$$\text{GAIN} = A_{(v)} = -\frac{R_L}{\frac{r_p + R_L}{\mu+1} + R_k}$$

GROUNDED GRID

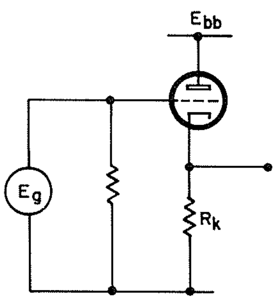


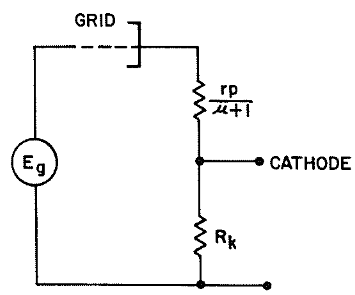


$$\text{GAIN} = A_{(v)} = +\frac{R_L}{\frac{r_p + R_L}{\mu+1} + R_k}$$

$$R_{IN} = R_k + \frac{r_p + R_L}{\mu+1}$$

GROUNDED PLATE





$$\text{GAIN} = A(v) = +\frac{R_k}{R_k + r_k}$$

$R_{OUT} = r_k$ in parallel with R_k

WHERE: $r_k = \frac{r_p}{\mu+1}$

PENTODE AMPLIFIER

$$\text{GAIN} = A(v) = \frac{R_L}{r_k + \frac{R_k}{\eta}}$$

WHERE:

R_L = LOAD RESISTANCE

$r_k = \frac{1}{gm}$

R_k = CATHODE RESISTOR (Refer Text)

η = PLATE EFFICIENCY FACTOR

PUSH PULL AMPLIFIER

TRIODE PAIR

$$\text{GAIN} = A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{2r_k + 2R_k}$$

WHERE:

$$r_k = \frac{r_p + R_L}{\mu+1}$$

PENTODE PAIR

$$\text{GAIN} = A(v) = \frac{R_{L(1)} + R_{L(2)}}{2r_k + \frac{2R_k}{\eta}}$$

WHERE: $r_k = \frac{1}{gm}$

SUBSCRIPTS (1) AND (2) ARE ASSOCIATED WITH V_1 AND V_2

CASCODE AMPLIFIER

$$\text{GAIN} = A_{(v)} = \frac{R_{L(1)}}{r_{k(2)} + R_{k(2)}}$$

WHERE:

$$r_k = \frac{1}{gm(2)}$$

HYBRID CASCODE AMPLIFIER

$$\text{GAIN} = A_{(v)} = \frac{R_L}{R_E + R_t}$$

WHERE:

R_L = LOAD RESISTANCE

* $R_t = r_e + R_r$

* R_E = EXTERNAL EMITTER RESISTANCE

* REFER PART I "THE TRANSISTOR AMPLIFIER"

Figure 16

We recall (Part 1, The Transistor Amplifier, Eq. 10) that the input impedance we see looking into the base of a transistor in the common-emitter configuration is:

$$R_{in} = \beta (R_E + R_t) \qquad (10)$$

Now $E_{in} = I_b R_{in}$

$$= I_b \, \beta (R_E + R_t) \qquad (36)$$

also $\beta = \dfrac{I_c}{I_b}$

or $I_c = \beta \, I_b \qquad (37)$

therefore substituting equation (37) in equation (36)

$$E_{in} = I_c (R_E + R_t) \qquad (38)$$

now the collector current Q_1 becomes the plate current of V_1. Then,

$$E_{in} = I_p (R_E + R_t) \text{ since } I_p = I_c \qquad (39)$$

also $E_p = -I_p R_L \qquad (23)$

and since

$$A_{(v)} \text{ (stage)} = \frac{E_p}{E_{in}}$$

then from equations (23) and (39)

$$A_{(v)} \text{ (stage)} = -\frac{I_p R_L}{I_p (R_E + R_t)}$$

$$= -\frac{R_L}{R_E + R_t} \qquad (40)$$

If the vacuum tube is not a triode but some other multigrid tube such as a pentode, the gain equation will have to be multiplied by the plate efficiency factor (η).

The same remarks concerning the output impedance of the vacuum-tube cascode amplifier can be applied to the hybrid counterpart.

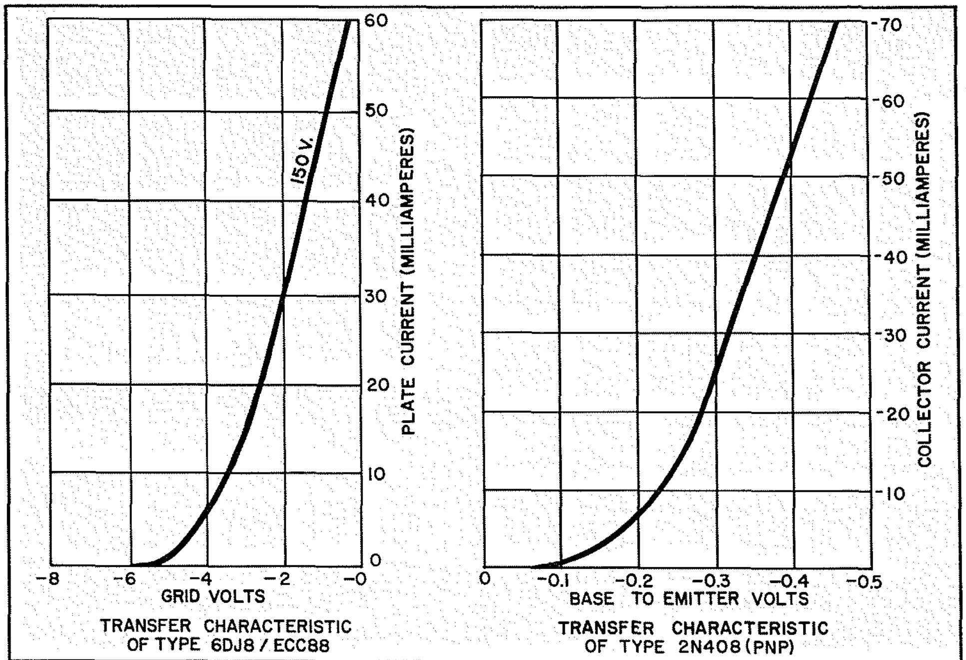


Figure 14. The transfer characteristic curves of a vacuum tube (6DJ8) and a PNP transistor (2N408), illustrating the basic similarity between vacuum tubes and transistors.

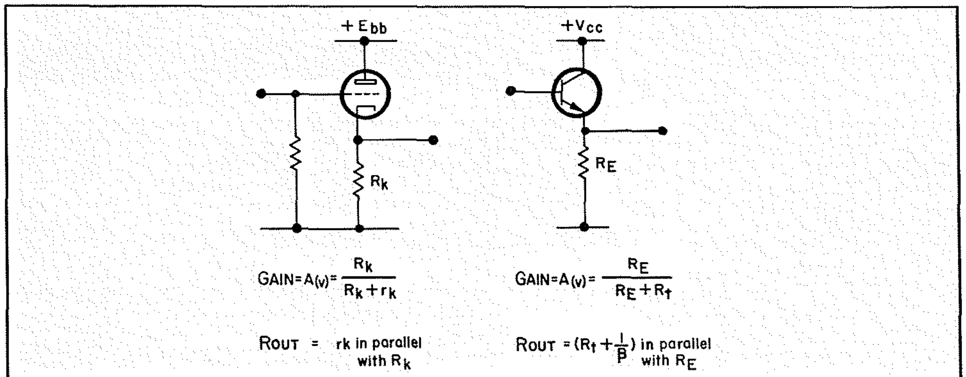


Figure 15. The analogy between the cathode follower (grounded plate) and the emitter follower (the common collector) in terms of "gain" and output impedances of both devices.

Summary

We have shown that the gain of a linear amplifier, transistor or vacuum tube, is a ratio of impedances. We can, of course, derive the gain equations for both devices in terms of mutual conductance. In fact, if we compare the transfer curves of both devices, Figure 14, we see a striking similarity. V_{BE} and E_g can be thought of in the same terms and in like manner I_p and I_c perform identical functions. Our analysis of both devices has shown that this fact is not coincidence.

It is not unreasonable to say that when we compare the cathode-follower (grounded-plate) against the common-collector configuration, Figure 15, we can think of both devices as being identical in operation—differing only in concept. The same argument can be put forward about the common-base amplifier and the grounded-grid amplifier. So too, the common-emitter amplifier and the grounded-cathode amplifier if we chose to ignore the input impedances of both devices.

Figure 16 (see page 5) summarizes the results of our analysis of the grounded cathode, grounded grid, and grounded plate amplifiers. Opposite this Figure we have reprinted Figure No. 8 from the previous article (Part I, The Transistor Amplifier) which summarized the results of the analysis on the three types of transistor amplifiers. These two charts will assist you to follow more closely our analysis of the 545B vertical amplifier (appearing in the next issue of SERVICE SCOPE) and to make a comparison between transistor and vacuum tube amplifiers.

It is not surprising we sometime find ourselves explaining one device in terms of another. Nature has a charming way of making most things interdependent upon one another. Recognize this fact and most tasks become a little easier.

The third and concluding article in this series will appear in the June, 1967 issue of SERVICE SCOPE. That article will present an analysis of a typical Tektronix hybrid circuit—a Type 545B Oscilloscope's vertical amplifier.

The analysis will be based on conclusions reached in Part 1 (February, 1967 issue) and Part 2 (this issue) of the series of articles.

ERRATA

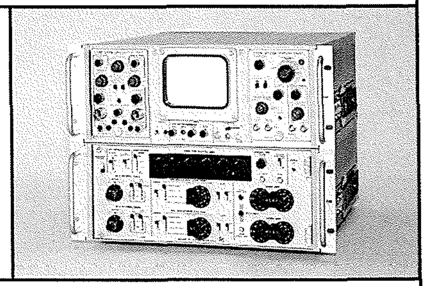
We call your attention to a typographical error in the caption under Figure 7 in the February issue of SERVICE SCOPE. The Figure referred to in the last line of this caption should be Figure 8—not Figure 7.

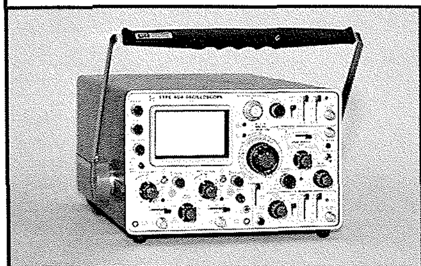
New From Tektronix, Inc. In 1967

For complete information, contact your Field Engineer, Field Representative, or Distributor.

DIGITAL READOUT OSCILLOSCOPE

The Type 568 Readout Oscilloscope accepts sampling and real-time amplifiers and time-base units. Used with the Type 230 Digital Unit, digital readout of measurements (in addition to the analog CRT display) is provided, allowing faster and more accurate answers than using the CRT alone. A wide variety of repetitive pulse measurements can be made digitally, without operator error: pulse voltage, risetime, delay time, storage time, and pulse width, among others. Measurement limits may be selected to provide Go/No-Go indicators.





DC-to-150 MHz PORTABLE OSCILLOSCOPE

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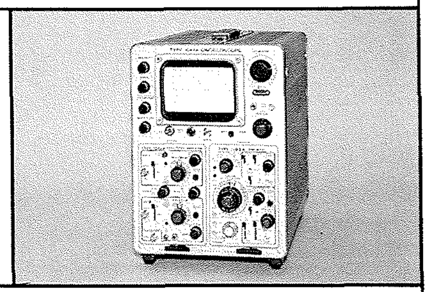
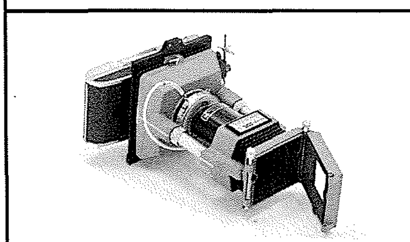




HIGH-SPEED CAMERA

The C-40 is a high-performance camera for Tektronix portable oscilloscopes. The f/1.3—1:0.5 lens and Polaroid* Roll-Film back for 10,000-speed film provide the writing speed necesary to record single-shot events on the Type 454 Oscilloscope.

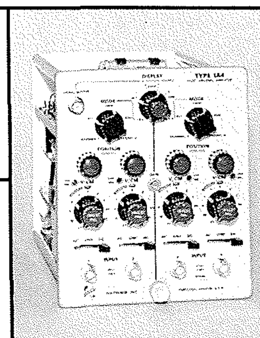
*Registered Trade-Mark Polaroid Corporation

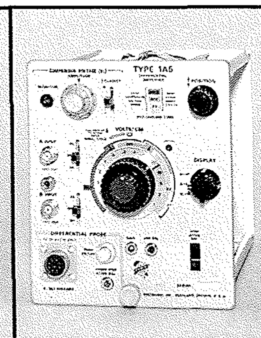
DC-to-50 MHz FOUR-TRACE AMPLIFIER

The Type 1A4 Plug-In Unit for Type 530, 540, 550, and (with adapter) 580-Series Oscilloscopes provides the equivalent of two wide-band, dual-trace units connected to a third wide-band, dual-trace unit. Unique display logic provides unprecedented display flexibility including four-channel adding (±1 ±2) + (±3 ±4). Deflection factor is 10 mV/cm to 20 V/cm.

DC-to-50 MHz DIFFERENTIAL AMPLIFIER

The Type 1A5 Plug-In Unit for Type 530, 540, 550, and (with adapter) 580-Series Oscilloscopes achieves a new high in common-mode rejection. Gain-bandwidth products exceed those previously available in a differential amplifier. Bandwidths from DC to 50 MHz can be achieved at 5 mV/cm, DC to 45 MHz at 2 mV/cm, and DC to 40 MHz at 1 mV/cm. A ±5-V comparison voltage is built in.



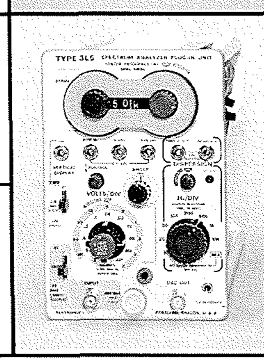


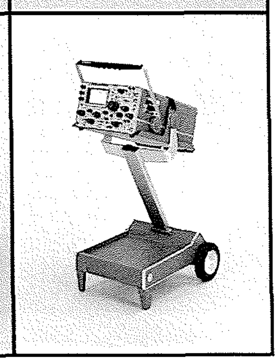
50 Hz-to-1 MHz SPECTRUM ANALYZER

The Type 3L5 Plug-In Unit for Type 561A and 564 Oscilloscopes operates over a center-frequency range of 50 Hz to 1 MHz, and provides accurate spectral and time-based displays from 10 Hz to 1 MHz. Deflection factors extend to 10 μV/div RMS for spectral displays, and to 1 mV/div P to P for time-base displays. Dispersion is calibrated from 10 Hz/div to 100 kHz/div. Resolution bandwidth is ≤10 Hz to ≥500 Hz.

SCOPE-MOBILE ® CARTS

Model 200-1 holds Type 454 or other portable instruments. Friction locks provide tilting from 0 to 60 degrees. Cart occupies less than 18 inches of aisle space, goes up and down stairs easily. Model 200-2 is similar, holds Type 422. Model 205-2 and 205-3 hold Type 568 or other instruments of similar size. Plug-in compartments are provided for three Letter Series or 1-Series plug-ins, or four 2- or 3-Series plug-ins.





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USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 44 PRINTED IN U.S.A. JUNE 1967

A PRACTICAL APPROACH TO TRANSISTOR AND VACUUM TUBE AMPLIFIERS

BY F. J. BECKETT

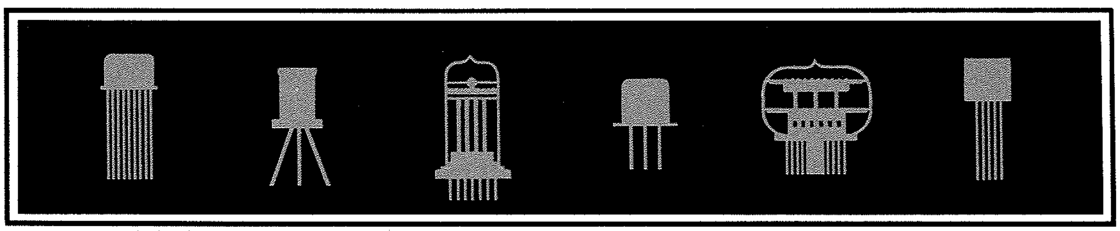
TEKTRONIX, INC.

ELECTRONIC INSTRUMENTATION GROUP

DISPLAY DEVICES DEVELOPMENT

PART 3

A DC ANALYSIS OF A TYPICAL TEKTRONIX HYBRID CIRCUIT



This is the third in a series of three articles offering a new approach to transistor and vacuum-tube amplifiers. This new approach is based on a simple DC analysis that incorporates the concepts of "trans-resistance" and the principles of Thévenin's Theorem.

In this article, conclusions reached in Part 1, "The Transistor Amplifier" (Service Scope #42, February 1967) and Part 2, "The Vacuum Tube Amplifier" (Service Scope #43, April 1967) form the basis for a DC analysis of a typical Tektronix, Inc. hybrid-amplifier circuit.

As a typical example of a Tektronix, Inc. hybrid circuit on which to demonstrate our DC analysis, we have chosen the vertical amplifier of a Type 545B Oscilloscope. This circuit is representative of the hybrid circuit one encounters so often in electronic instrumentation today.

The Type 545B vertical amplifier is a hybrid push-pull amplifier operating in a class A mode. It incorporates a few extra circuits such as trigger pick-off amplifiers necessary to accomplish its function, but, basically it is a hybrid push-pull amplifier.

To begin our analysis of the amplifier, the first thing we must do is select a portion of the amplifier circuit which will give us the information necessary for us to make our first calculation. We are going to analyze the whole circuit so we can choose our point of entry. The input circuit is as good a point as any. Bear in mind that, for our purpose, this is not the only point of entry. Any point on the circuit which will give us useful information would do.

A quiescent DC voltage of +67 volts is the nominal voltage at the output of the plug-in amplifiers used in the Type 545B oscilloscope. This voltage appears at terminals 1 and 3 of J11 in Figure 17, and thus, at the grids of V494A and V494B, a 6DJ8 dual triode. The input cathode follower (V494 A & B) has a bias of about 4 volts; therefore, both cathodes will be at +71 volts. The base voltage of Q514 and Q524 is then fixed at 71 volts. This sets the emitter voltages of Q514 and Q524 at one junction drop more negative (they are both NPN transistors) than the base. Therefore, the voltage at the emitter of Q514 and Q524 is 70.5 volts. T500 is a small toroidal transformer used for high-frequency common-mode rejection. The DC BALANCE Control, R495, sets the quiescent condition. We mean by this that the trace is centered.

We have made certain assumptions about the bias of a vacuum tube and the base-to-emitter voltage drop of a transistor. This is quite justifiable since we know what function the device performs. One helpful hint about transistors is that you can expect a base-to-emitter voltage drop of about 0.5 to 0.6 volts for a silicon transistor and about 0.2 volts for a germanium transistor.

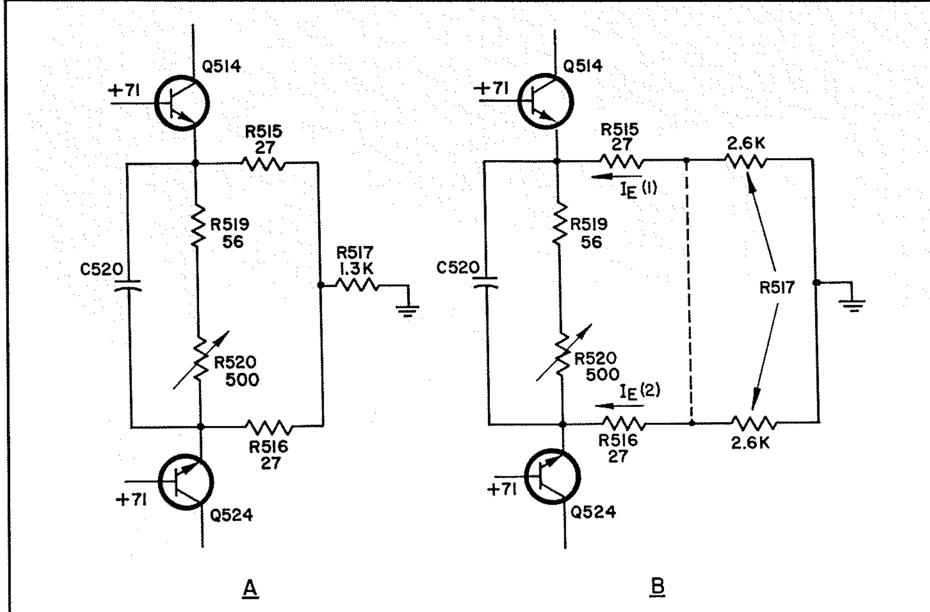


Figure 18. The circuit which will determine the DC emitter currents for either Q514 or Q524. (A)—The actual circuit as shown in Figure 17. (B)—The equivalent DC circuit considering R517 as two resistors through which the individual emitter currents will flow.

We are now able to calculate the emitter current of either Q514 or Q524. The DC-emitter current will flow through R515 or R516 and into R517 to ground. Since the emitter currents of Q514 and Q524 both pass through R517, we may think of R517 being made up of two resistors, each of 2.6 kΩ in value, in which the individual emitter currents will flow, refer to Figure 18: Therefore,

$$I_E \text{ (1) or (2)} = \frac{70.5 \times 10^3}{2.627 \times 10^3} \text{ mA}$$

$$= 27 \text{ mA}$$

We can now calculate the value of r_e, the dynamic-emitter resistance,

$$r_e = \frac{26}{I_E} = \frac{26}{27}$$

$$= 0.96\ \Omega$$

to this we can add our constant, R_r, of say, 4 Ω. We recall that:

$$R_t = r_e + R_r \qquad (9)$$

therefore:

$$R_t = 0.96 + 4 = 4.96\ \Omega$$

or approximately 5 Ω. We have now established the value of the emitter current and the value of R_t for Q514 and Q524.

Our next step is to find the value of R_E. We must know this value in order to calculate gain. You will recall that R_E will be that impedance through which the signal current will flow to the AC ground. Let us take another look at the resistive network between the emitters of Q514 and Q524. The signal currents flowing in this circuit will be equal and opposite at two points, refer to Figure 19. These points are virtual AC-ground points; therefore, the impedance seen by the signal current from the emitters of Q514 or Q524 will be the parallel combination of 153 Ω and 27 Ω or approximately 23 Ω to the AC ground points. Hence, R_E for Q514 or Q524 will be 23 Ω.

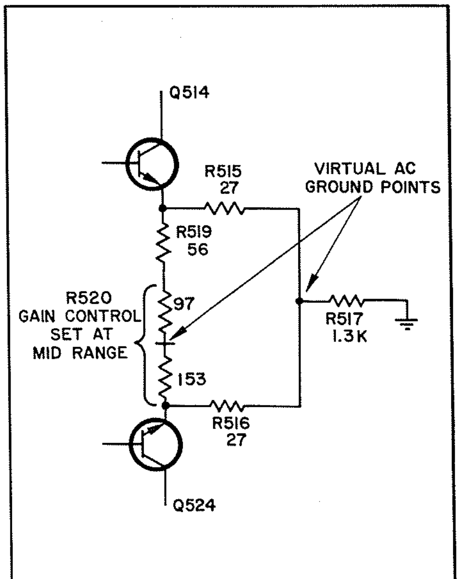


Figure 19. The location of the virtual AC ground points between the emitters of Q514 and Q524.

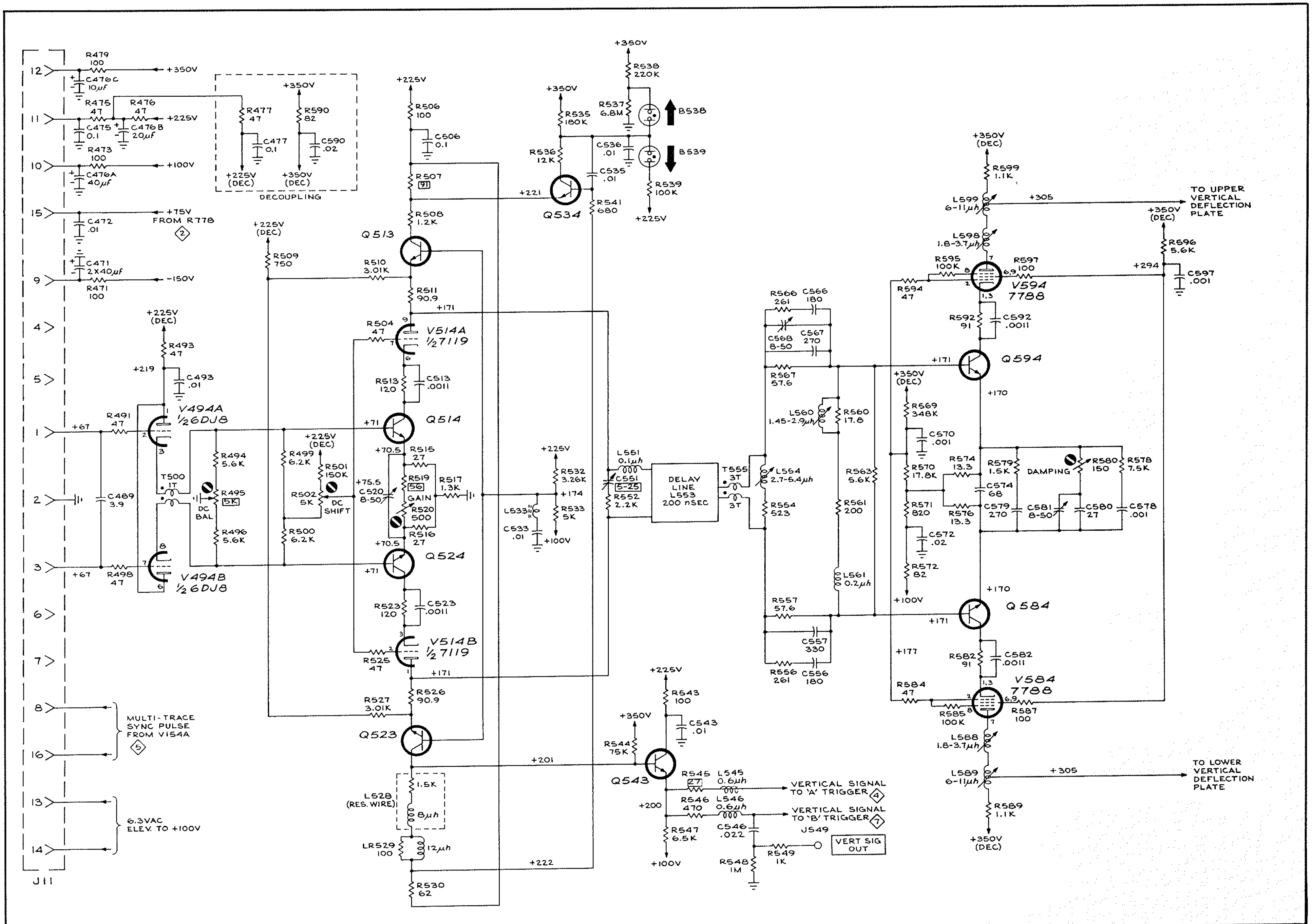


Figure 17.

TYPE 545B OSCILLOSCOPE

VERTICAL AMPLIFIER

We have now calculated from this part of the circuit all of the information we need to progress further into the circuit. Let us turn our attention to the circuit around Q513 and Q523. The first thing we notice is that the base of Q513 and Q523 are tied together at an AC-ground point. You will recall that the impedance we see looking into the emitter of the common-base configuration is R_t. In order to calculate R_t we must, of course, calculate r_e and add our constant for R_r of $4\,\Omega$; r_e will be a function of the actual value of current flowing into the emitter. 27 milliamps has been set in the emitter circuit of Q514 and Q524; but not all of this current will flow into the

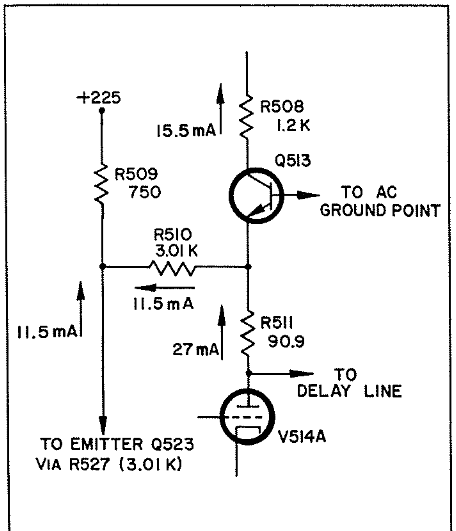


Figure 20. The DC current paths in the emitter circuit of Q513 or Q523.

emitter of Q513 and Q523. 11.5 milliamps will flow through R510 and R527, refer to Figure 20. The actual value of current into Q513 or Q523 will be 15.5 milliamps. Therefore, the impedance (R_t) we see looking into the emitter of Q513 and Q523 will be

$$R_t = r_e + R_r \qquad (9)$$

$$= \frac{26}{15.5} + 4\,\Omega$$

$$= 5.68\,\Omega$$

This impedance of $5.68\,\Omega$ plus R511 or R526 ($90.9\,\Omega$) constitutes part of the load impedance of the hybrid cascode amplifier Q514, V514A or Q524, V514B and the necessary matching impedance for the delay line.

There is one point we should make clear here. We have assumed a value of $4\,\Omega$ for R_r which you will recall is equal to $\frac{R_b}{\beta}$. R_r can vary from between $2\,\Omega$ to $24\,\Omega$ depending upon the type of transistor (refer to Part 1, "The Transistor Amplifier" SERVICE SCOPE #42, February 1967). This is one of those few times we should be really a bit more specific about assuming a value of R_r. The sum of the impedances $5.68\,\Omega$ and $90.9\,\Omega$ should be equal to $93\,\Omega$ since our delay line is a $186\,\Omega$ balanced line. Therefore, we have a difference of $3.58\,\Omega$ between the theoretical value and the calculated value, or an error of approximately 3.7%. This error has been due in part to our presupposed value of R_r to be $4\,\Omega$. Such an error could not be tolerated in design work but it is acceptable here for our purpose of DC analysis. Bear this limitation in mind when you apply this analysis.

There is another point we must clear up. What is the load impedance of the hybrid cascode amplifier Q514, V514A or Q524, V514B? Clearly it will be that impedance or impedances connected from the plate of V514A or V514B to the AC ground. We are using a balanced delay line of $186\,\Omega$, ($93\,\Omega$ to a side), referenced to the AC ground. Therefore, the delay line impedance ($93\,\Omega$) must shunt R511 in series with R_t (or R526 in series with R_t) making an effective load impedance of approximately $47\,\Omega$ in the plate circuit of V514A or V514B. We now have all the necessary information to calculate the gain to this point.

$$A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{R_{E(1)} + R_{E(2)} + R_{t(1)} + R_{t(2)}}$$

$$= \frac{47 + 47}{23 + 23 + 5 + 5}$$

$$= \frac{94}{56}$$

$$A_{(v)} = 1.68$$

Q523 is the trigger pick-off amplifier and Q543 is an emitter follower providing isolation between the vertical amplifier and the trigger circuits.

The trigger pick-off amplifier Q523 is one part of a transistor cascode amplifier. The input stage is Q514 and Q524. Normally, the gain of a transistor cascode amplifier is the ratio of R_L to $R_E + R_t$. The gain in this case must be multiplied by 0.5 for the following reason. The signal current is equally divided at the plate of V514B, half of the signal current will flow through the delay line impedance ($93\,\Omega$) and the other half through R526 and finally through the load impedance of Q523. The load impedance will be that impedance which is connected to the AC ground. The collector of Q523 is connected to the base of Q543. The impedance we see looking into the base of Q543 is

$$R_{in} = \beta\,(R_E + R_t) \qquad (10)$$

If we choose to neglect the input circuit of the trigger amplifier we see that R_E in this case is R547 $6.5\,k\Omega$. A beta of 50 is a close figure to use for Q543, and since $R_E >> R_t$ then,

$$R_{in} = \beta\,R_E$$

$$= 50 \times 6500\,\Omega$$

$$= 325\,k\Omega$$

This impedance shunts R544 ($75\,k\Omega$) and L528 a $1.5\,k\Omega$ wire-wound resistor. We may then, for all practical purposes, consider L528 the collector load resistance (R_L); therefore,

$$A_{(v)} = 0.5\left[\frac{R_L}{R_{E(1)} + R_{E(2)} + R_{t(1)} + R_{t(2)}}\right]$$

$$= 0.5\left[\frac{1500}{23 + 23 + 5 + 5}\right]$$

$$= 13.3$$

Q534 is the beam-indicator amplifier. Its function is to drive two neon lamps situated above the CRT on the front panel of the oscilloscope. These neons indicate the position of the trace in a vertical direction. In the quiescent condition the voltage at the junction of R535 and R536 is 287 volts. Both indicator neons, B538 and B539, have 62 volts across them, not enough voltage to strike either neon. (This type of neon has a striking voltage in excess of 68 volts.)

When we apply a negative signal to the vertical input of the oscilloscope, the base of Q524 is driven negative and the base of Q514 moves in a positive direction by a similar amount. Therefore, the current through R530 decreases and the current through R507 increases. The voltage at the emitter of Q534 increases and the voltage at the base of Q534 decreases. As a result, the base-to-emitter junction of Q534 becomes reverse biased and Q534 ceases to conduct. Therefore, the voltage at the junction of R535 and R536 rises towards 350 volts striking neon B539 which indicates trace has shifted down.

R513 and R523 and the DC SHIFT control R502 are thermal-compensation networks. The thermal time constants are long and the visible result appears on the CRT display as a DC shift in trace position after a step function. The DC SHIFT control is adjusted for the best dynamic thermal compensation, typically about 1% tilt.

We will now analyze the output circuits to the right of the delay line, refer to Figure 17. The first thing we must do is to calculate the voltage at the base of Q594 or Q584. The voltage at the junction of R532 and R533 (174 volts) will set the base voltage of Q513 and Q523. Assuming a junction drop of 0.5 volt the voltage at the emitter of Q513 and Q523 will be 173.5 volts. The current through R511 and R526 is 27 milliamps, hence the voltage drop across these resistors will be

$$\frac{90.9 \times 27}{1000}$$

$$\approx 2.5 \text{ volts}$$

therefore, the voltage at the plate of V514A and V514B is

$$173.5 - 2.5 = 171 \text{ volts.}$$

This 171 volts is directly coupled to the base of Q594 and Q584 via the delay line. The voltage at the emitter of both Q594 and Q584 is then 170.5 volts. We will now calculate the current flowing into the emitter of Q594 or Q584. Figure 21 shows a step-by-step approach in solving this problem. The simplest approach is to use Thévenin's Theorem to simplify the resistive network R569, R570, R571 and R572. The result is we have a V_{oc} of +100 volts and a Z_{th} of 900 Ω to the junction of R574 and R576. Therefore, looking from the emitter of either Q594 or Q584 we see an impedance of 13.3 Ω in series with 1800 Ω to +100 volts.

$$I_E = \frac{(170.5 - 100)\,10^3}{1.8 \times 10^3} \text{ mA}$$

$$= \frac{70.5}{1.8}$$

$$= 39 \text{ mA}$$

we now calculate r_e

$$r_e = \frac{26}{I_E} = \frac{26}{39}$$

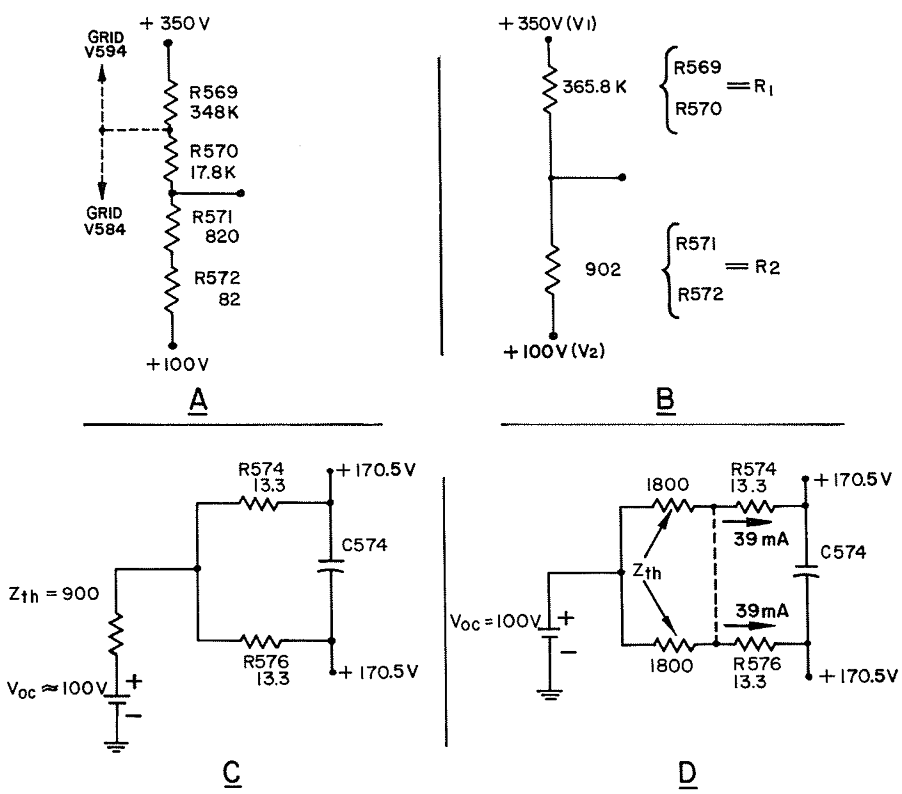
$$\approx 0.7\ \Omega$$

and to this we add our constant R_r of 4 Ω; therefore,

$$R_t = r_e + R_r \qquad (9)$$

$$= 0.7 + 4.0$$

$$= 4.7\ \Omega\text{'s}$$



$$Z_{th} = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{365.8 \times 10^3 \times 9.02 \times 10^2}{(365.8 \times 10^3) + (9.02 \times 10^2)}$$

$$Z_{th} = 900\,\Omega$$

$$V_{oc} = V_2 + \frac{(V_1 - V_2) R_2}{R_1 + R_2} = 100 + \frac{(350 - 100) \times 9.02 \times 10^2}{(365.8 \times 10^3) + (9.02 \times 10^2)}$$

$$V_{oc} \approx 100 \text{ VOLTS}$$

Figure 21. Illustrating the use of Thévenin's Theorem to simplify a network consisting of a voltage source and a resistive network. (A)—The network whose Thévenin equivalent is to be determined. (B)—Determining the equivalent source impedance (Z_{th}) and the equivalent voltage source (V_{oc}). (C)—The Thévenin equivalent network of (A) connected to the junction of R574 and R576. (D)—The equivalent circuit considering Z_{th} as two resistors through which the individual emitter currents will flow.

We have only one point in this circuit (a virtual AC ground point) at which the signal currents will be equal and opposite. That point is the junction of R574 and R576 (13.3 Ω resistors). This fact sets R_E at 13.3 Ω. The purpose of the RC network to the right of R574, R576 is to compensate the high frequencies.

The input impedance we see looking into the base of Q594 or Q584 is

$$R_{in} = \beta\ (R_E + R_t) \qquad (10)$$

A beta of 75 for this type of transistor is a close figure to use for practical purposes. Therefore,

$$R_{in} = 75\ (13.3 + 4.7)\ \Omega\text{'s}$$

$$= 1350\ \Omega$$

The value of R_{in} is part of a resistive network which will terminate the delay line in its correct impedance. Therefore, before we leave this section we must check to see if our value of R_{in} is within practical limits. Figure 22 shows a progressive breakdown of this network.

This network will induce a loss between the two stages. The signal is reduced in amplitude by a factor of 0.64 because of the voltage divider network consisting of 57.6 Ω and the parallel combination of 100 Ω, 2800 Ω, and the input impedance into Q594 or Q584.

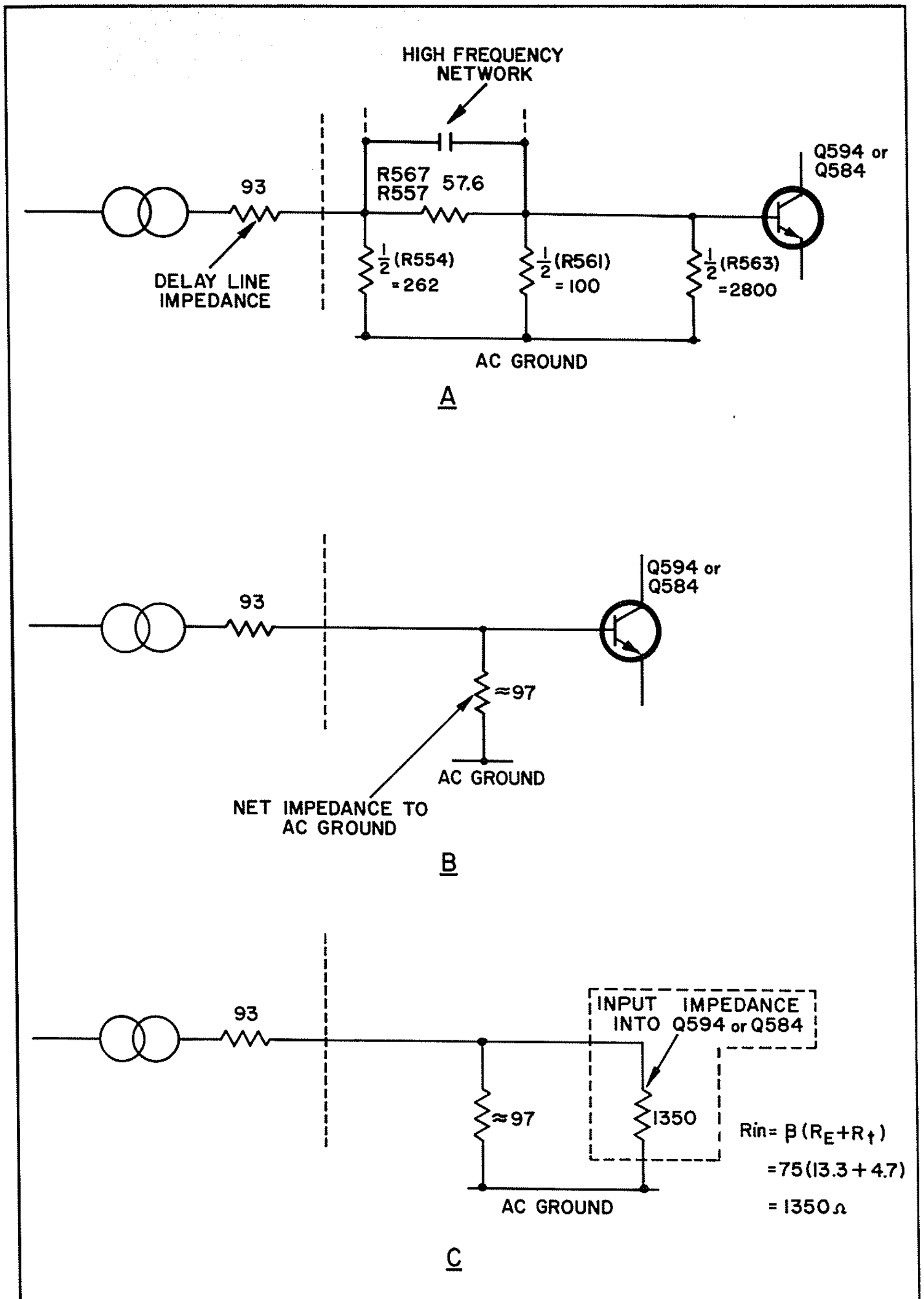


Figure 22. Illustrating a step-by-step approach for analyzing the circuit between the output of the delay line and the base of Q594 or Q584. (A)—The circuit between the output of the delay line and the base of Q594 or Q584. (B)—The net impedance of the circuit in (A) to the AC ground between the output of the delay line and the base of Q594 or Q584. (C)—The input impedance into Q594 or Q584 and the net impedance, as shown in (B), providing the terminating impedance for the delay line.

The gain of the output stage is

$$A_{(v)} = \left[\frac{R_{L(1)} + R_{L(2)}}{R_{E(1)} + R_{E(2)} + R_{t(1)} + R_{t(2)}}\right]\eta$$

$$= \left[\frac{1100 + 1100}{13.3 + 13.3 + 4.7 + 4.7}\right]\eta$$

$$= \left[\frac{2200}{36}\right]\eta$$

$$= 61\ \eta$$

You recall that the gain equation of a hydrid cascode amplifier (refer part 2, "The Vacuum Tube Amplifier," Service Scope #43, April 1967) must be multiplied by the plate efficiency factor (η) if the vacuum tube is not a triode. The plate efficiency factor (η) normally varies from between 0.7 to 0.9. In this case (η) is approximately 0.9 - 0.88 to be exact. So finally,

$$A_{(v)} = 61 \times \frac{9}{10}$$

$$= 54.9$$

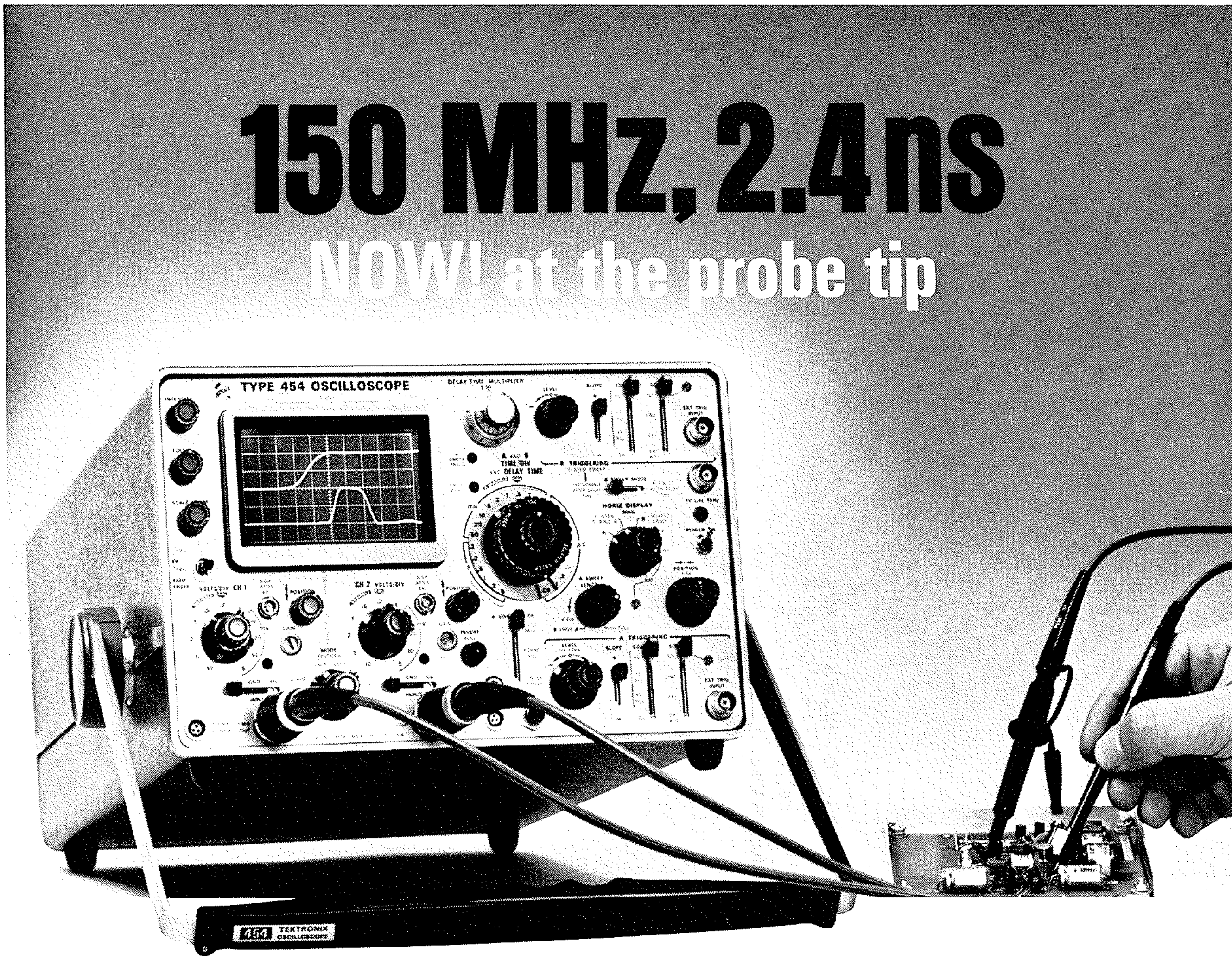
The gain of the complete Type 545B vertical amplifier is

$$A_{(v)}\ (\text{total}) = 54.9 \times 1.68 \times 0.64$$

$$= 59$$

Summary

This brings to a close this series of three articles dealing with a practical approach to transistor and vacuum-tube amplifiers. This approach has been offered as a direct method of trouble shooting and understanding circuits. There are limitations as to its application as we have seen. However, these limitations do not impair the practical approach we must apply to our everyday maintenance and trouble shooting problems.



The Tektronix Type 454 is an advanced new portable oscilloscope with DC-to-150 MHz bandwidth and 2.4-ns risetime performance where you use it—at the probe tip. It is designed to let you make convenient measurements of fast-rise pulses and high-frequency signals previously outside the range of conventional oscilloscopes.

The Type 454 is a complete instrument package with dual-trace vertical, high-performance triggering, 5-ns/div delayed sweep and solid-state design, all in a rugged 31-lb. instrument. You also can make 1 mV/div single-trace measurements and 5 mV/div X-Y measurements with the Type 454.

The 2.4-ns risetime and DC-to-150 MHz bandwidth are specified at the tip of the new miniature P6047 10X Attenuator Probe. The dual-trace amplifiers provide the following capabilities with or without probes:

*Deflection Factor**	*Risetime*	*Bandwidth*
20 mV to 10 V/div	2.4 ns	DC to 150 MHz
10 mV/div	3.5 ns	DC to 100 MHz
5 mV/div	5.9 ns	DC to 60 MHz

*Front panel reading. Deflection factor with P6047 is 10X panel reading.

The Type 454 features a new CRT with distributed vertical deflection plates and a 14-kV accelerating potential. It has a 6 by 10 div (0.8 cm/div) viewing area, a bright P-31 phosphor and an illuminated, no-parallax, internal graticule. The Type C-30 and the New Type C-40 (high writing speed) cameras mount directly on the oscilloscope.

The instrument can trigger to above 150 MHz internally, and provides 5-ns/div sweep speeds in either normal or delayed sweep operation. The calibrated sweep range is from 50 ns/div to 5 s/div, extending to 5 ns/div with the X10 magnifier. Calibrated delay range is from 1 μs to 50 seconds.

The Type 454 is designed to be carried and has the rugged environmental characteristics required of a portable instrument. A rackmount, the 7-inch-high Type R454 oscilloscope, is available with the same high performance features. Also available is the new Type 200-1 Scope-Mobile® Cart.

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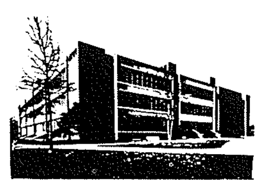

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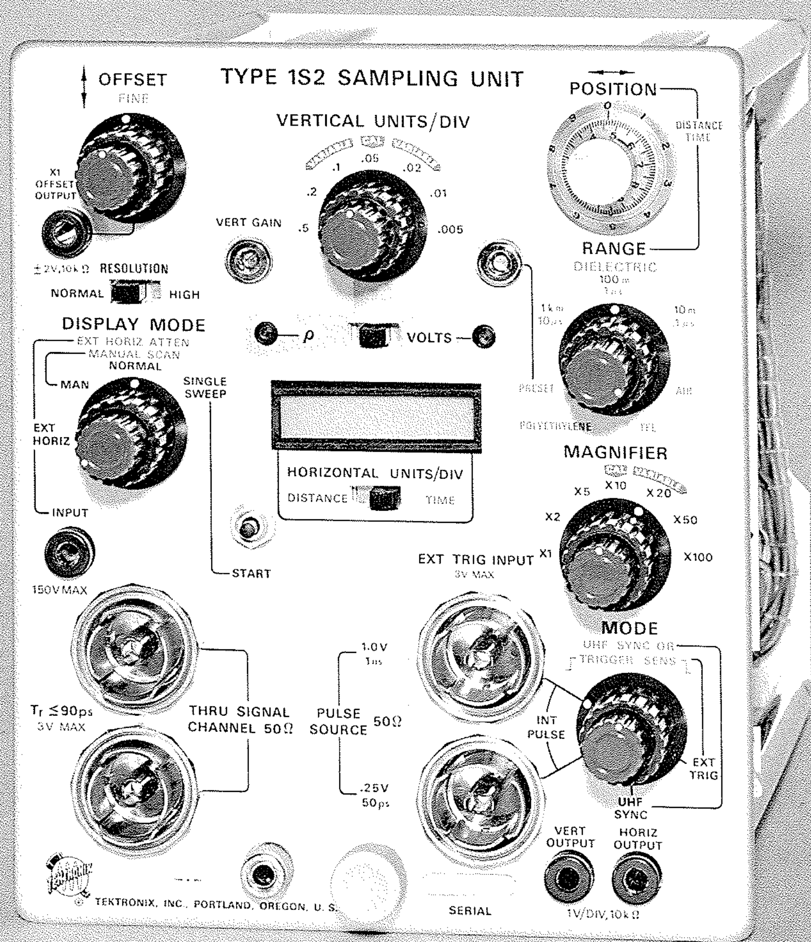


A Discussion of
Time Domain Reflectometry
Theory and Coaxial
Cable Testing.

TIME-DOMAIN REFLECTOMETRY THEORY AND THE TESTING OF COAXIAL TRANSMISSION LINES

INTRODUCTION:

Maintaining the fidelity of electronic signals that of necessity have to be transmitted from point to point is of primary concern to those that design, build and maintain electronic equipment. The simple, inexpensive coaxial transmission line is perhaps the most common method used to accomplish this task. The techniques for determining transmission line performance vary from simple visual inspection to elaborate instrumentation set-ups that require a great deal of skill and time. The availability of instruments such as the Tektronix Type 1S2 TDR Plug-In Unit have simplified the testing of transmission line performance.

This article begins with a comparison between two methods of testing transmission lines - Sinewave testing and Voltage step-function testing. The Sinewave testing method is known as Frequency-Domain Reflectometry (FDR) and the Voltage step-function method is known as Time-Domain Reflectometry (TDR). The FDR-TDR comparison is followed by a basic description of TDR testing principles; reflections from capacitors and inductors; reflections from resistive discontinuities; coaxial-cable response to a step signal; and finally, special applications.

The waveforms illustrated throughout this article were taken with a C-12 Camera using a Type 547 Oscilloscope and the Type 1S2 TDR Plug-In. The Type 1S2 Plug-In converts any Tektronix 530, 540, 550-Series Oscilloscope to a TDR measurement system.

FDR-TDR COMPARISON

Frequency domain reflectometers, the slotted line and bridges, drive and observe the input terminals of a transmission line as a function of frequency. They do not locate discontinuities on a distance basis. As a result, measurement techniques and the unique advantages of such devices differ from those of TDR.

A pure resistance measured by either time domain or frequency domain devices will appear as an infinitely long lossless transmission line. Thus, a perfectly terminated short length of lossless line will yield the same information to both kinds of testing, and neither test system can locate the termination. However, if the termination includes a small inductive or capacitive reactance, both systems will indicate its presence, but the TDR system will show where in the line the reactance is located.

The following comparisons of TDR and frequency domain (FDR) devices are supported by four specific examples and illustrations.

1. FDR measures Standing Wave Ratio (SWR) directly, but a TDR display can speed FDR testing by locating resonant frequencies of resonant networks prior to FDR testing.

2. TDR locates discrete discontinuities and permits analysis of their value. But FDR will indicate two different resonant discontinuities which may be located very close together when TDR may not.

3. FDR measures an antenna standing wave ratio directly while TDR will not. But TDR will locate faults more quickly and identify the type of fault more rapidly than will FDR, should a change in SWR indicate problems. The time domain display will validate a transmission line to an antenna, while frequency domain reflectometry cannot, unless the antenna is disconnected and the transmission line terminated.

4. TDR can locate small changes in transmission line surge impedance (such as a too-tight clamp holding a flexible line) while FDR will show whether or not the SWR is acceptable.

5. Both test systems will quantitatively evaluate single discrete reactances, with higher degree of accuracy possible with FD.

6. Both TDR and FDR have advantages, each being very valuable in its own way. Thus, the two systems complement each other and both aid where observations and measurements are required.

TDR vs FDR Measurements

A one pF discrete capacitor inserted in parallel with a transmission line will produce almost no TDR indication if the step pulse has a risetime of 1 nanosecond. The same capacitor will produce a significant reflection if the step pulse has a risetime of 150 picoseconds. A FDR test will produce a large SWR at the series resonant frequency determined by the capitance and its lead inductance. Such a discontinuity would require considerable time for proper FDR testing due to the numerous frequency test points, but with a fast rise TDR system the capacitance and resonant frequency can be quickly determined.

Fig 1 shows waveforms and SWR curves of first a single capacitor and then two capacitors inserted in parallel with a transmission line. Note that the FDR measurement on the right side of the figure plainly shows the two resonant circuits of the two closely spaced small capacitors, while the TDR display at the left shows two resonant frequencies, but not in a manner to permit separation of the two capacitors.

The single capacitor of this example was made of 1/4 inch wide strip copper, 5/8 inch long, with one end soldered to the side of a component insertion unit (Tektronix Part No. 017-0030-00) and the other end near the center conductor. The insertion unit was modified to have a continuous center conductor using three inner transition pieces (Tektronix Part No. 358-0175-00). One of the inner transition pieces was shortened to fit between the two mounted end pieces, and then soldered in place. The second capacitor (resonant at 2.1 GHz) was a 0.5 to 1.5 pF piston trimmer with a total lead length of about 5/16 inch, and it was adjusted to about 1.2 pF. The piston capacitor was soldered in place in parallel with the strip copper capacitor about 1/8 inch away. It is obvious from both testing methods that neither capacitor was critically damped by the characteristic impedance of the transmission line. The physical and equivalent circuit of the single shunt capacitor is shown in Fig 2. The single capacitor test was made with a shield in place completely covering both openings.

Fig 3 shows the ability of TDR to locate an off-impedance point in a transmission line, and quickly resolve its value. The same through-connected insertion unit used in example number 1 was tested without any component inserted in it. The shield was in place for both TDR and FDR testing.

The TDR display of Fig 3 shows the increased surge impedance due to the increased diameter of the outer conductor at the two cutout access slots. Such a TDR display will permit rather rapid correction to be made to the center conductor diameter if one desires to make a truly constant impedance through the length of the insertion unit.

The SWR curve shows some changes from a constant impedance transmission line, but does not help to locate an aberration if it is inside a continuous piece of cable. Either FDR or TDR would help one to make the unit have a constant impedance if such a unit were being designed.

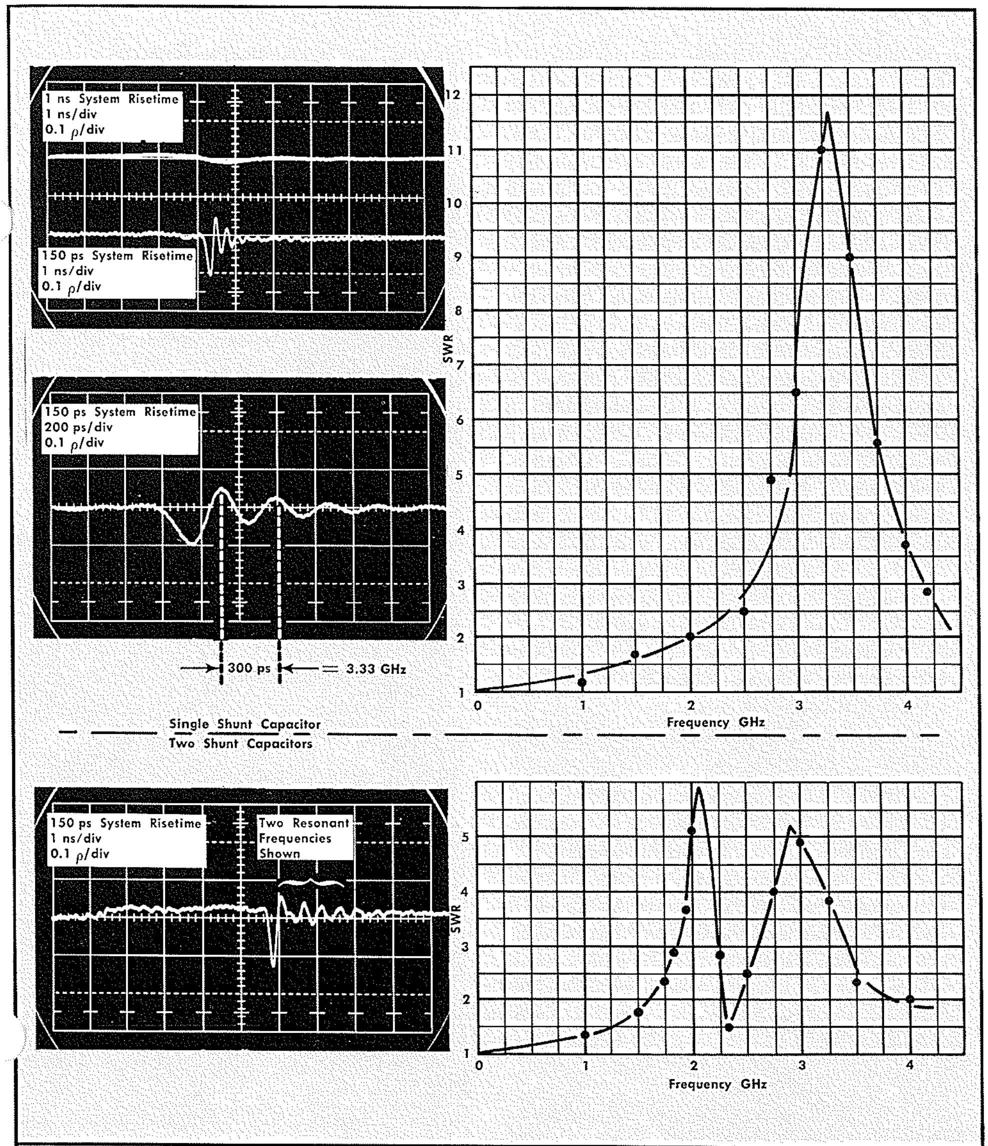


Fig 1. Two examples of discrete shunt capacitors.

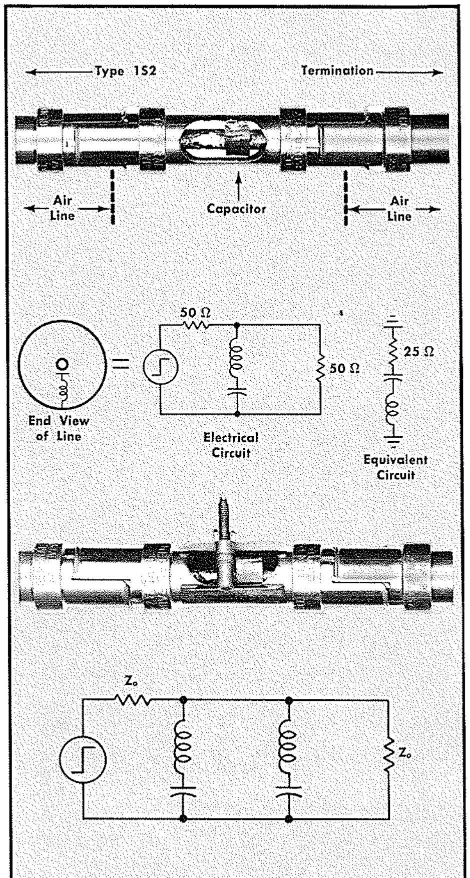


Fig 2. Capacitors measured in Fig 1.

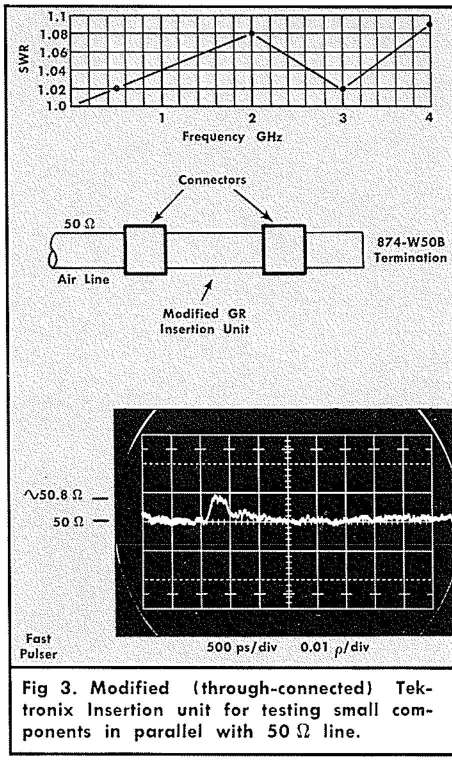


Fig 3. Modified (through-connected) Tektronix Insertion unit for testing small components in parallel with 50 Ω line.

Fig 4 shows two TDR and two SWR plots of a simple dipole antenna. The TDR waveforms at the left were photographed first, quickly locating the two radiating resonant frequencies and permitting a saving in time for the FDR testing. The SWR curves permit a direct evaluation of the antenna radiation resistance ($\frac{R_L}{Z_0} = \frac{V_{max}}{V_{min}}$ if R_L is purely resistive), while the TDR display tells only the transmission line quality and the radiating resonant frequencies of the non-shorting type antenna. An antenna design engineer could use the SWR data and FDR test equipment to test a compensating network to be located at the antenna to minimize standing waves in the transmission line. The TDR system cannot be used for such design assistance.

Fig 5 shows both TDR and FDR tests of a General Radio Type 874-K series blocking capacitor. The upper TDR display permits direct calculation of the series capacitance, in this case approximately 6.2 nanofarads ($0.0062\mu F$).

The SWR curve shows that the series capacitor does not upset the transmission line significantly except for low frequencies. The middle TDR waveform shows the change in surge impedance due to the physical shape of the series capacitor. Note that the disc capacitor reduces the transmission line surge impedance to approximately 49 ohms for only a very short period of time. The same display also permits the precise location of adjacent discontinuities that affect the high frequency performance. The combined TDR and FDR data tells more about the series capacitor unit than either testing method does alone.

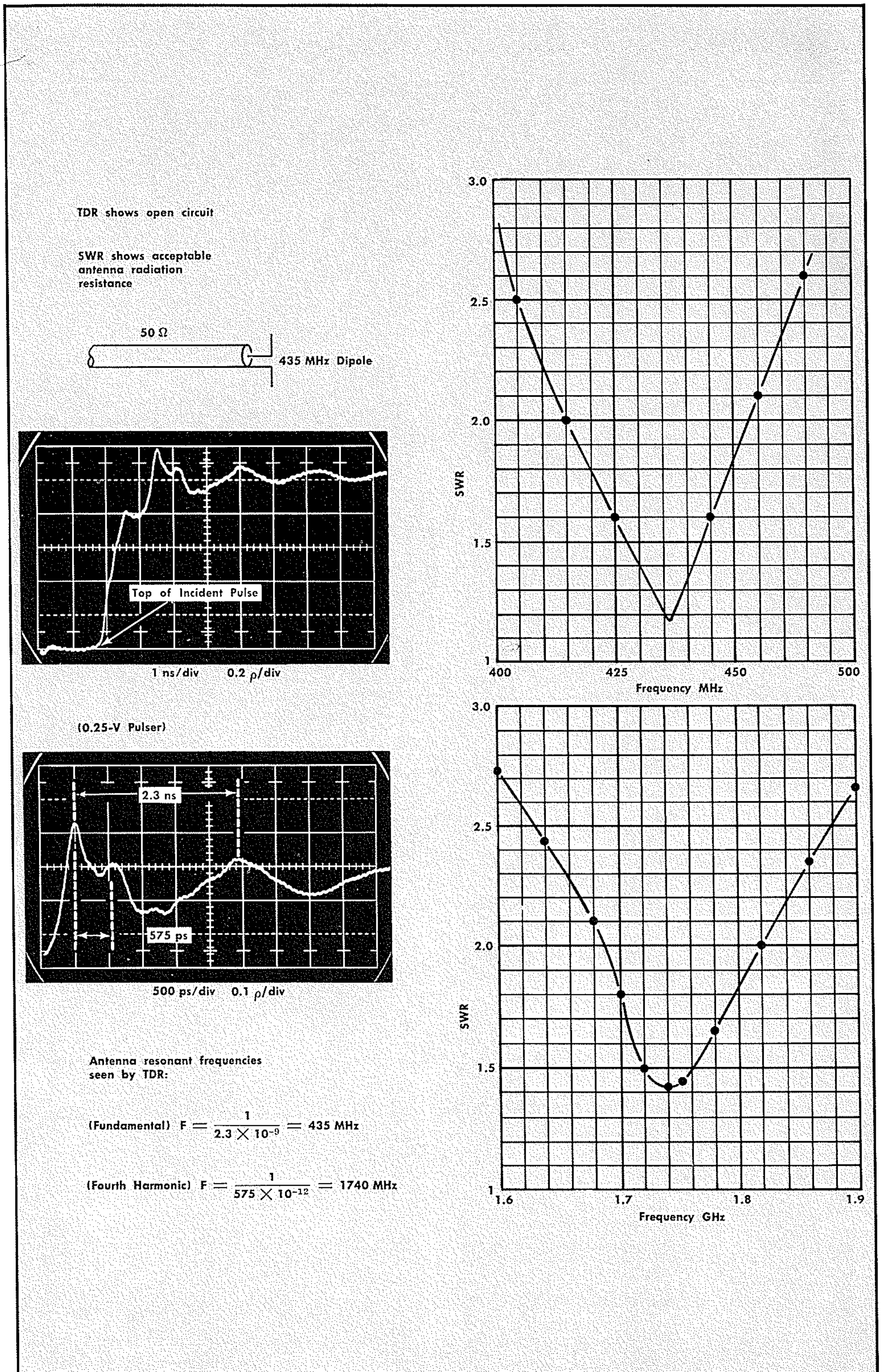


Fig 4. Two plots of 435 MHz dipole antenna.

BASIC APPROACH TO TDR

Time Domain Reflectiometry can be understood most easily if its operation is first compared with a DC circuit.

DC Analogy

Fig 6 shows three simple circuits that can be related to transmission lines and TDR. Fig 6A is the diagram of an ordinary resistance voltage divider, where the voltage across

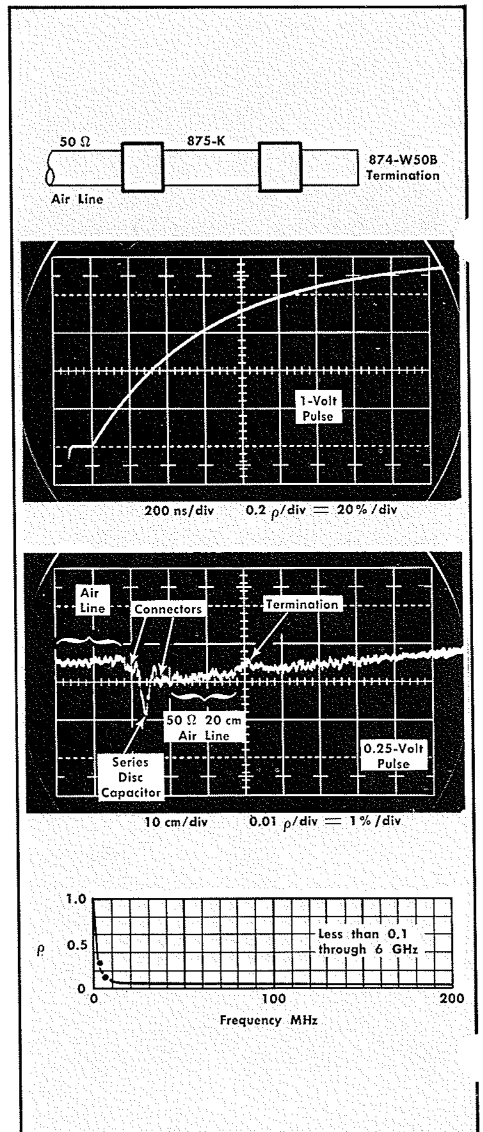


Fig 5. Series blocking capacitor: General Radio Type 874-K.

R_2 is $E_{R2} = \frac{R_2}{R_1 + R_2} \times E$ of the battery. (1)

Fig 6B substitutes R_{line} (or Z_o) for R_2, and substitutes R_g (generator resistance) for R_1. It is assumed the battery has zero internal resistance and that R_g is an inserted series generator resistance. If the battery is 1 volt and if $R_g = R_{line}$, then a voltmeter across R_{line} will indicate 0.5 volt when the switch is closed.

Fig 6C indicates a pair of zero resistance wires of same length physically connecting R_{line} to the battery and switch. A voltmeter across R_{line} will still indicate 0.5 volt when the switch is closed.

Adding the Time Dimension

Fig 7 substitutes a step generator for the battery and switch of Fig 6. The generator has zero source resistance so R_g is again added in series with the generator. The generator and R_g drive a finite length transmission line that has a characteristic impedance of Z_o. The transmission line has output terminals that permit connecting a load R_L. An oscilloscope voltmeter measures the voltage signal(s) at the input end of the transmission line.

Assume that no load resistance is connected to the transmission line output terminals ($R_L = \infty$) and that $R_g = Z_o$ (Z_o acts exactly as if it were the DC resistor R_{line} of Fig 6). As the zero impedance step generator applies its 1-volt step signal to R_g, the oscilloscope voltmeter indicates 0.5 volt. The oscilloscope voltmeter will continue to indicate a 0.5 volt signal until the wave has traveled down the line to the open end, doubled in amplitude due to no current into $R_L = \infty$, and reflected back to the generator end of the line. The oscilloscope finally indicates a signal of 1 volt after the measurable period of time required for the step signal to travel down and back the finite length of open ended transmission line.

Reflection Signal Amplitudes

Fig 8 shows TDR oscilloscope (voltmeter) displays related to the value of R_L vs the value of the transmission line Z_o. Apply resistance values of 50 Ω to R_g and Z_o, and 75 Ω to R_L of Fig 7. By formula (1), the oscilloscope display of the reflection amplitude will be 0.6 volt. The actual reflection, however, is only 0.1 volt added to the 0.5-volt incident step.

Reflection Coefficient

A somewhat more convenient method of handling signal reflections than has just been suggested, is to consider the reflection as having been added to or subtracted from the incident pulse. Thus the reflection amplitude is not measured from zero volts, but is referenced to the incident signal amplitude. This permits establishing a ratio between the incident and reflected signals which is called the reflection coefficient, rho (ρ). The value of ρ is simply the reflected pulse amplitude (the display total amplitude minus the incident pulse amplitude) divided by the incident pulse amplitude. Fig. 9 shows the two parts of the display appropriately labeled to identify the incident and reflected signals.

When $\rho = 0$, the transmission line is terminated in a resistance equal to its characteristic impedance Z_o. If the line is terminated in $R_L > Z_o$, then ρ is positive. If the line is terminated in $R_L < Z_o$, then ρ is negative. The dependence of ρ on the transmission line load is

$$\rho = \frac{R_L - Z_o}{R_L + Z_o} \qquad (2)$$

If ρ is known, R_L can be found by rearranging formula (2);

$$R_L = Z_o \left(\frac{1 - \rho}{1 + \rho}\right) \qquad (3)$$

Formula (3) applies to any display that results from a purely resistive load. The load shown in Fig 9 is assumed to be at the end of a lossless coaxial transmission line.

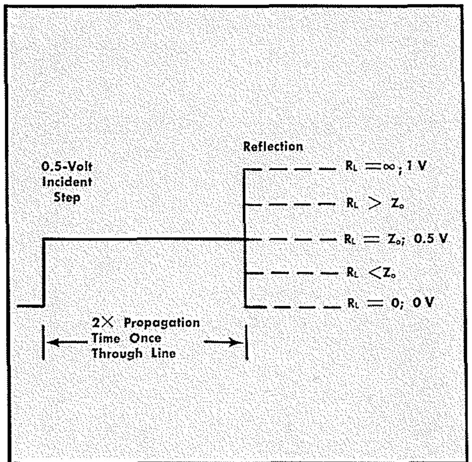


Fig 8. Oscilloscope voltmeter displays for circuit of Fig 7, dependent upon value of R_L vs. Z_o.

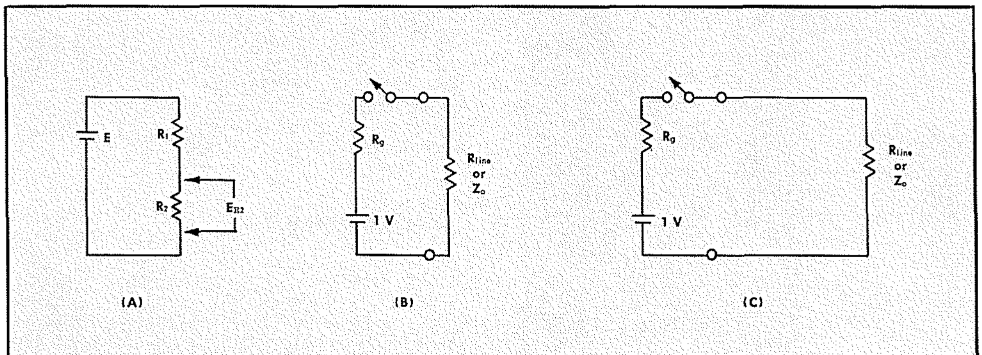


Fig. 6. Circuits showing DC analogy of TDR.

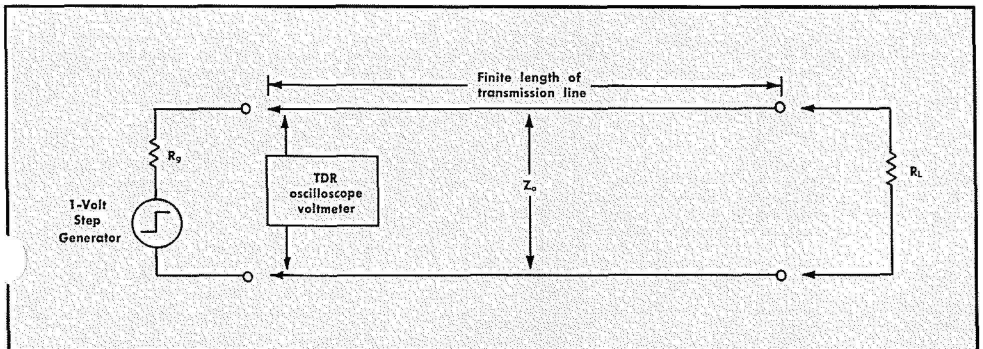


Fig 7. Adding the time dimension to the circuit of Fig 6.

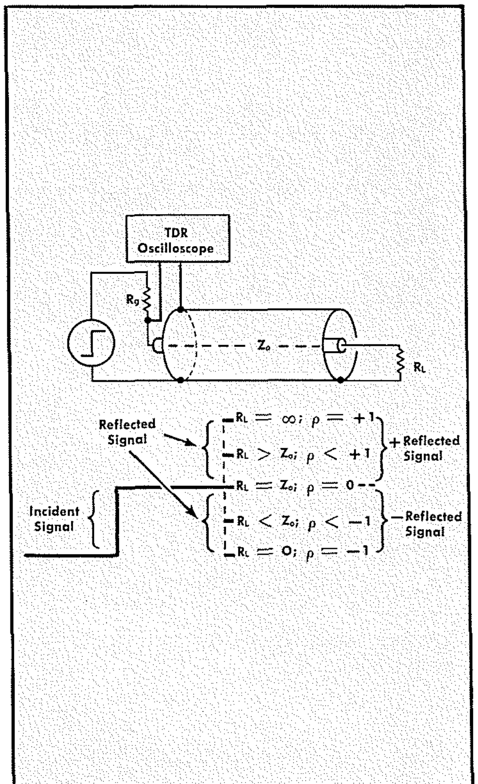


Fig 9. TDR oscilloscope displays for various values of R_L vs Z_o.

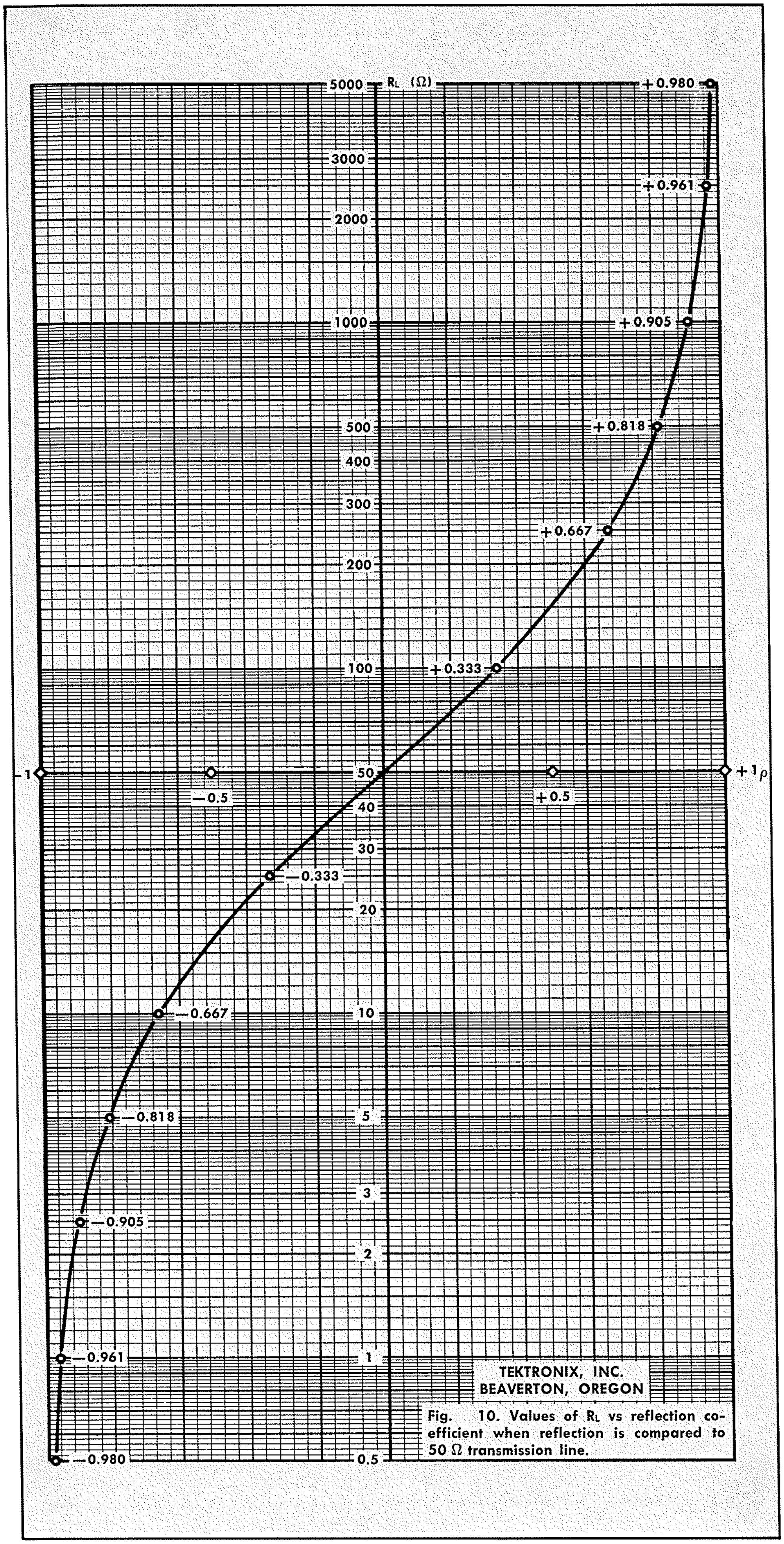


Fig. 10. Values of R_L vs reflection coefficient when reflection is compared to 50 Ω transmission line.

Substituting 50 Ω for Z_o in formula (3), calculations for small values of ρ show that each division of reflected signal is approximately equal to a certain number of ohms. Table 1 lists the ohms per division for vertical deflection factors of 0.005 ρ, 0.01 ρ and 0.02 ρ. Or, for R_L values near 50 Ω, you may use the approximation formula

$$R_L \approx 50 + 100\,\rho.$$

This approximation formula has an error of $\leq 2.2\%$ for absolute values of $\rho \leq 0.1$ and an error of $\leq 8\%$ for absolute values of $\rho \leq 0.2$.

R_L for reflections with ρ up to essentially +1 or —1 can be quickly determined using the graph of Fig 10. Fig 10 is based upon a transmission line surge impedance of 50 Ω just prior to the discontinuity that causes the reflection signal. The graph of Fig 10 may be photographically reproduced without special permission of Tektronix.

TABLE 1

R_L Approximations For Reflection Coefficients of 0.005, 0.01 and 0.02 Related to a 50 Ω Transmission Line

ρ/div	Ω/div	Error/div
0.005	½	~0.016 Ω
0.01	1	~0.066 Ω
0.02	2	~0.2 Ω

REFLECTIONS FROM CAPACITORS AND INDUCTORS

Contrary to frequency domain measurements, TDR response to a reactance is only momentary. Thus either an inductor or a capacitor located in a transmission line will give only a short duration response to the TDR incident pulse. Analysis of large reactances is relatively simple and makes use of time-constant information contained in the reflection display. Small reactances are not so simple to evaluate quantitatively, so will be treated separately.

Large Reactances

The difference between a "large" and a "small" reactance is not a fixed value of capacitance or inductance, but is instead related to the TDR display. If the displayed reflection includes a definite exponential curve that lasts long enough for one time constant to be determined, the reactance is considered "large".

Discrete (single) capacitors connected in series or parallel with a transmission line start to charge at the instant the incident pulse arrives. Inductors start to conduct current at the arrival of the incident pulse. Both forms of reactance cause an exponentially changing reflection to be sent back to the TDR unit. When a capacitor is fully charged, the TDR unit indicates an open circuit. When an inductor is fully "charged" (current through it has reached its stable state), the TDR unit indicates a short circuit. The TDR unit will indicate an inductor's series DC resistance if its value is significant in relation to Z_o. The general form of reflection and long term effect upon the TDR display by both inductors and capacitors is listed in Table 2 and Table 3.

Finding One Time Constant

In practice, TDR reactance displays usually contain aberrations of the desired pure exponential reflection. Such aberrations prevent finding the normal 63% one time-constant point of the curve accurately. (The aberrations are due to either the environment around the reactance, i.e. stray inductance in series with a capacitor, or stray capacitance in parallel with an inductor, or secondary system reflections.) However, accurate time-constant information can be obtained from less than a complete exponential curve. The principle used requires that a "clean" portion of the display must exist. The "clean" portion used must include the right-hand "end" of the displayed curve (a capacitor is then fully charged, or an inductor current has stopped changing). The "end" of the curve will appear on the display to be parallel to a horizontally scribed graticule line. Thus, aberrations that exist at the beginning of the curve can be ignored.

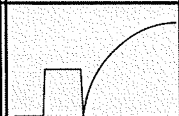
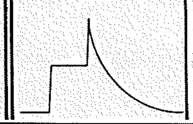
Fig 11 shows the first example of obtaining valid time-constant information from less than a full 100% exponential curve. The technique is to choose any "clean" portion of the display that includes the "end" of the exponential curve and find the half-amplitude point. The time duration from the beginning of any new 100% curve section to its 50% amplitude point is always equal to 69.3% of one time constant. Thus, the time duration for a 50% change divided by 0.693 is equal to one time constant.

Fig 11 shows the TDR displays of a capacitor placed in series with a transmission line center conductor (2 Z_o environment). This picture and the other waveform pictures shown in this article were taken with a Tektronix C-27 Camera mounted on a Tektronix Type 547 Oscilloscope with a Tektronix Type 1S2 Reflectometer and Wideband Sampling Plug-In Unit. Fig 11A waveforms comprise a double exposure with the left curve taken while the Type 1S2 RESOLUTION switch was at NORMAL and the right curve taken when the switch was at HIGH. Both curves give sufficient information to measure one time constant. Note that the top of the incident pulse is indefinite (in the displays) due to the sweep rate and short length of cable used between the Type 1S2 and the capacitor. Such a display does not have a definite beginning of the normal 100% exponential curve. This prevents 63% of the total curve from being read directly from the display. (It is also quite possible for lead inductance to cause a capacitor to ring. When a TDR display shows capacitor ringing, the ringing can sometimes be reduced by: 1. using the slower 1-Volt pulser, and/or 2. changing the transmission line environment to place a lower value Z_o in parallel with the capacitor.)

The double exposure of Fig 11B shows a full exponential curve beginning in the vicinity of 1 division from the graticule bottom. Then the same curve has been time-expanded for easier reading. The indefinite beginning of the 500 ns/DIV exponential curve prevents finding one time constant by measuring the time of 63% of the total curve amplitude. The new arbitrarily chosen 100% amplitude portion of the curve begins at the graticule center horizontal line and extends (off the right of the graticule) to the top graticule line. Three divisions were chosen for the new 100% exponential curve, with the 100% and 50% points marked. Then, dividing the time for the 50% amplitude change by 0.693 gives a total one time-constant time value of 650 ns. Since the equivalent circuit shows 2 Z_o in series with the capacitor, its value is found by formula (4) (Table 4) to be 6.5 nanofarads.

TABLE 3

Single Capacitor or Inductor TDR Displays when Connected Across End of Transmission Line

Reactance	Display	Line Impedance at Reactance
CAPACITOR		Z_o
INDUCTOR		Z_o

Large Capacitors

The difference between a "large" and a "small" capacitor is not a fixed value of capacitance, but is instead related to the TDR display. If the display includes a definite exponential curve that lasts long enough to permit one RC time constant to be determined, the capacitor value can be found by using a normal RC time-contsant formula). The actual formula varies according to the equivalent circuit in which the capacitor is located. Table 4 lists the possible configurations and their related formulae.

The first example of "large" capacitance measurement was given under the previous heading Finding One Time Constant. The large value of capacitor used is easy to measure and usually causes only one aberration to the exponential curve. That aberration is the indefinite curve beginning.

Moving A Reflection Aberration

When testing small capacitors that still produce a usable exponential curve, it may be difficult to get accurate time-constant data when there are reflections within the system.

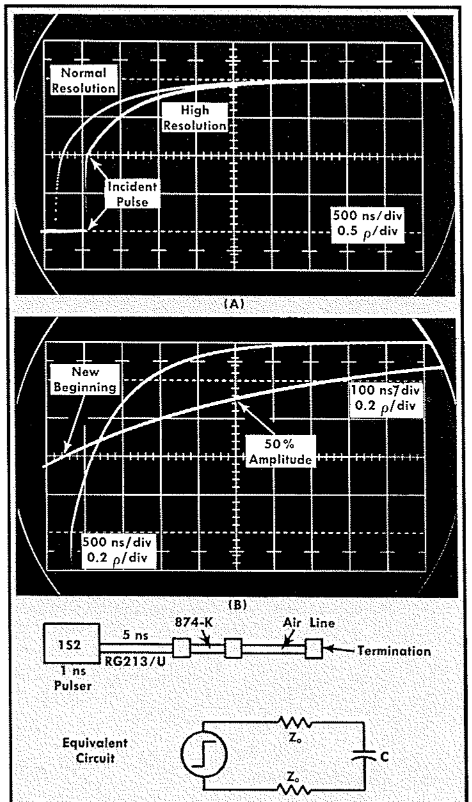


Fig 11. Exponential curves and circuit of 6.5 nF capacitor in series with terminated transmission line.

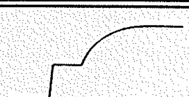
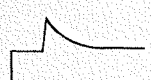
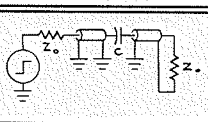
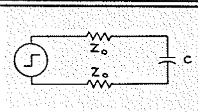
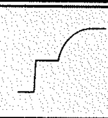
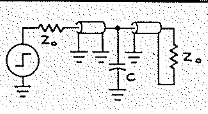
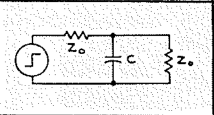
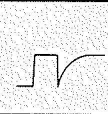
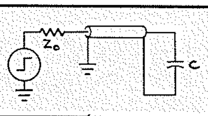
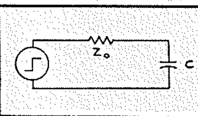
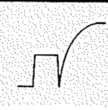
Reactance	In Series with Line	In Parallel with Line	Line Impedance at Reactance
CAPACITOR			SERIES: 2 Z_o PARALLEL: $\frac{Z_o}{2}$
INDUCTOR			SERIES: 2 Z_o PARALLEL: $\frac{Z_o}{2}$

TABLE 2 Single Capacitor or Inductor TDR Displays Related to Terminated Transmission Lines.

Circuit		Equivalent Circuit	Formula	Display
Series with terminated line			$C = \frac{1}{2}\frac{TC}{Z_o}$ (4)	
Parallel with terminated line			$C = \frac{1\ TC}{Z_o/2}$ (5)	
Across line end			$C = \frac{1\ TC}{Z_o}$ (6)	

Where C = Farads; TC = Time Constant; Z_o = Line Surge Impedance.

TABLE 4 "Large" Capacitor Circuits and Formulae.

For example, a 100 pF discap was soldered into a General Ratio Radiating Line section (Fig 12). The 1-Volt pulser was used; re-reflections from the pulser distort the exponential curve at the arrow of Fig 12A. The re-reflection is moved to the right just outside the time window by placing a 20 nsec signal delay RG213/U cable between the pulser and the sampler. The acceptable waveform is shown in Fig 12B. Fig. 12C is a double exposure that shows first how the "end" of the exponential curve is set to a graticule line. Then the display is time expanded to 500 ps/DIV (leaving the vertical position as adjusted) and the new arbitrary 100% exponential curve is chosen and marked. The capacitor's value taken from the time expanded curve of Fig 12C and using formula (5) is 104 pF ($1.8 \times 10^{-9}/0.693 \div 25 = 1.04 \times 10^{-10} = 104$ pF). Note that the vertical ρ factor was changed for Fig 12C in order to make the time constant measurement from a clean section of the curve near its end.

Large Inductors

The difference between "large" and "small" inductors follows the same general display limits as large or small capacitors. A "small" inductor in series with a transmission line center conductor will give a display that does not permit normal time-constant analysis. The same inductor in parallel with a terminated transmission line may give a display that does allow normal time-constant analysis.

Ringing in the exponential TDR display is often observed when measuring inductors. It is usually caused by distributed capacitance across the coil that has not been adequately damped by transmission line surge impedance. Since an inductor with stray capacitance will ring unless adequately damped, an inductor in parallel with a transmission line ($Z_o/2$ environment) will be less likely to ring than the same inductor in series with a line ($2\ Z_o$ environment).

Fig 13 shows waveforms taken of the reflections from a seven turn ⅜ inch diameter coil. The coil was connected across the end of a 50 Ω transmission line (Z_o environment). Fig 13A was made using the Type 1S2 0.25-Volt fast pulser at High Resolution. The ringing makes it impossible to obtain an accurate time constant measurement from the display. Fig 13B was made using the Type 1S2 1-Volt pulser at Normal Resolution. Here the slower risetime incident pulse does not excite the ringing, and in addition the time averaging of fast changes by Normal-Resolution operation permits a time constant to be measured. Ringing could also have been reduced by a $Z_o/2$ environment by placing a termination across the inductor, or placing the inductor at a convenient mid point of a long line.

The triple exposure of Fig 13B includes three curves: #1, the total reflected signal at 10ns/div and 0.5 ρ/div; #2, increased vertical deflection and the exponential-curve end positioned to be one division below the graticule center horizontal line; and #3, the #2 curve time expanded to 1 ns/div for measurement of the L/R time constant. The new 100% to 50% amplitude time duration of curve #3 is shown as 3¾ ns. $3.75/0.693 = 5.41$ns for 1 time constant. Since the coil is at the end of a 50 Ω transmission line, the inductance is calculated by formula (9) of Table 5 to be 270.5 nH ($L = 50 \times (5.41 \times 10^{-9}) = 2.705 \times 10^{-7} = 270.5$ nH).

Small Reactances

"Small" reactances are here defined as series-connected inductors and shunt-connected capacitors that cause TDR reflections without apparent time-constant reaction to the incident pulse. Some small reactances are capable of being "charged" (capacitor voltage is stable; inductor current is stable) at a rate faster than the 0.25-Volt pulser incident pulse rate of rise. If the TDR display has no exponential section, normal RC and L/R calculations cannot be made. All small reactances generate TDR reflections with less than $+1\ \rho$ or $-1\ \rho$.

Small discrete capacitors with leads always include stray series inductance of a significant amount. Fig. 1 and associated discussion is an example of such a capacitor with inductive leads. Small shunt capacitors without leads may be produced by either an increase in a coaxial cable center conductor diameter or a reduction of its outer conductor diameter. Leadless capacitors are sometimes treated as a small reduction in Z_o rather than as a capacitor. Usually, such small capacitors are considered capacitance when the section of reduced Z_o line is so short physically that no level portion can be seen in the TDR display.

Small series inductors rarely have sufficient parallel (stray) capacitance to be significant in the TDR display. However, the coaxial environment around such a small inductor does affect the TDR display. Small series inductors without capacitive strays are sometimes caused by changes in diameter of a coaxial cable: decreased center conductor diameter, or increased outer conductor diameter. This form of inductor is usually treated as a small increase in Z_o rather than as an inductor. Usually, such inductors are considered to be inductance when the section of increased Z_o line is so short physically that no level portion can be seen in the TDR display.

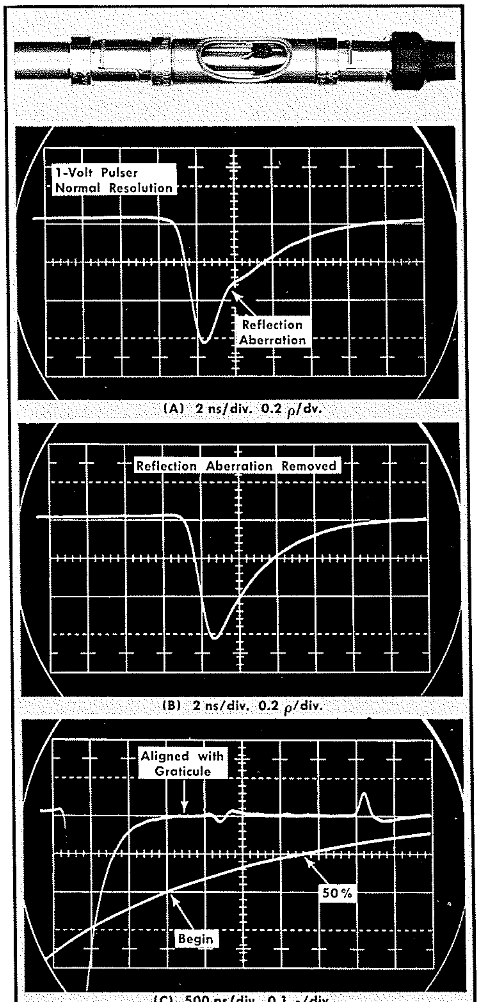


Fig 12. Example of moving display reflection aberrations to obtain a "clean" exponential curve.

Assumptions that Permit Analysis of Small Reactances

The usual TDR system does not have the required characteristics for accurately measuring small reactances. Yet small reactances can be measured provided the following assumptions are made regarding the TDR system.

1. That the actual TDR system may be adequately described by a model having a simple ramp as the pulse source and a lossless transmission line with an ideal sampler;

2. That the rounded "corners" of the actual pulse source may be ignored;

3. That the transmission line high frequency losses classed as "skin effect" or "dribble up" are not significant. ("Dribble up" is explained under Measuring Technique in connection with Fig 17).

4. That the sampler is non-loading, non-distorting and of infinitesimal risetime;

5. That parasitic (stray) reactances are insignificant.

The formula for small series inductance and small shunt capacitance in a tranmission line contain factors for (1) the system risetime at the spatial location of the reactance, (2) the observed reflection coefficient, and (3) the transmission line surge impedance.

The system risetime may be measured from the display by placing either an open circuit or a short circuit at the spatial location of the reactance.

The value for a small series inductor can be calculated using the formula

$$L = 2.5\,\alpha\, Z_o\, t_r \tag{10}$$

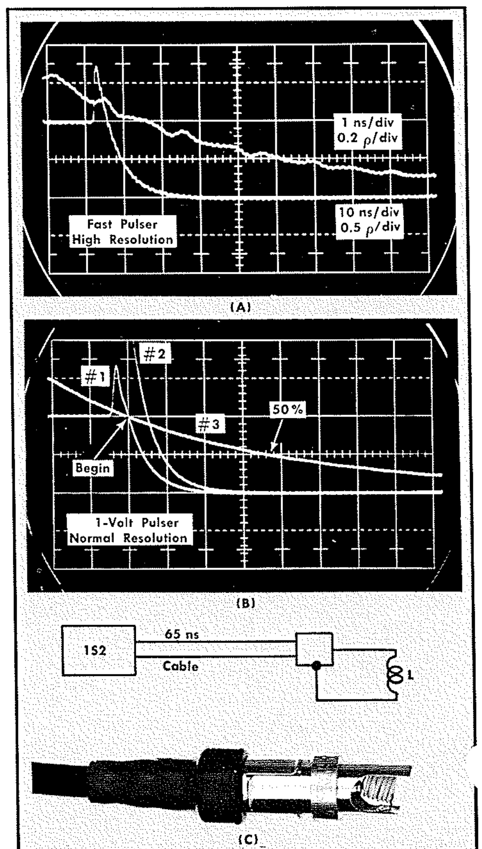


Fig 13. Seven turn coil across end of 50 Ω line.

where L is in henries, Z_o is in ohms, t_r is the system 10% to 90% risetime in seconds, and α is a dimensionless coefficient related to the observed reflection coefficient ρ by either the graph or Fig 14, or formula (11).

$$|\rho| = \alpha \left(1 - \varepsilon^{\frac{-1}{\alpha}}\right) \qquad (11)$$

A small shunt capacitor's value can be calculated using the formula

$$C = \frac{2.5\ \alpha\ t_r}{Z_o} \qquad (12)$$

where C is in farads, and the other units are as in formula (10).

Circuit	Equivalent Circuit	Formula	Display
Series with terminated line		(7) $L = 2\ Z_o \times 1\ TC$	
Parallel with terminated line		(8) $L = \frac{Z_o}{2} \times 1\ TC$	
Across line end		(9) $L = Z_o \times 1\ TC$	

TABLE 5 "Large" Inductor Circuits and Formulae

Small Series Inductor

Fig 15 is an example of TDR displays from a small inductor (1¾ turn) placed in parallel with a 50 Ω line at (A), and in series with the 50 Ω line at (B). Calculations were made on Fig 15A first because the display is a clean exponential that permits L/R time constant analysis. Waveforms #1 and #2 of Fig 15A show first the full exponential decay through five CRT divisions, then at #2 the waveform was positioned vertically so the exponential end is at —1 division. Waveform #3 used the same vertical calibration, but was time expanded to obtain the new 100% to 50% time duration.

The time duration of the 50% amplitude change section of the exponential curve is 450 ps. This time divided by 0.693 produces a one time-constant time duration of 650 × 10^{-12} seconds. Then from formula (8), the value of the inductor is 16.22 nH (1.622 × 10^{-8} H).

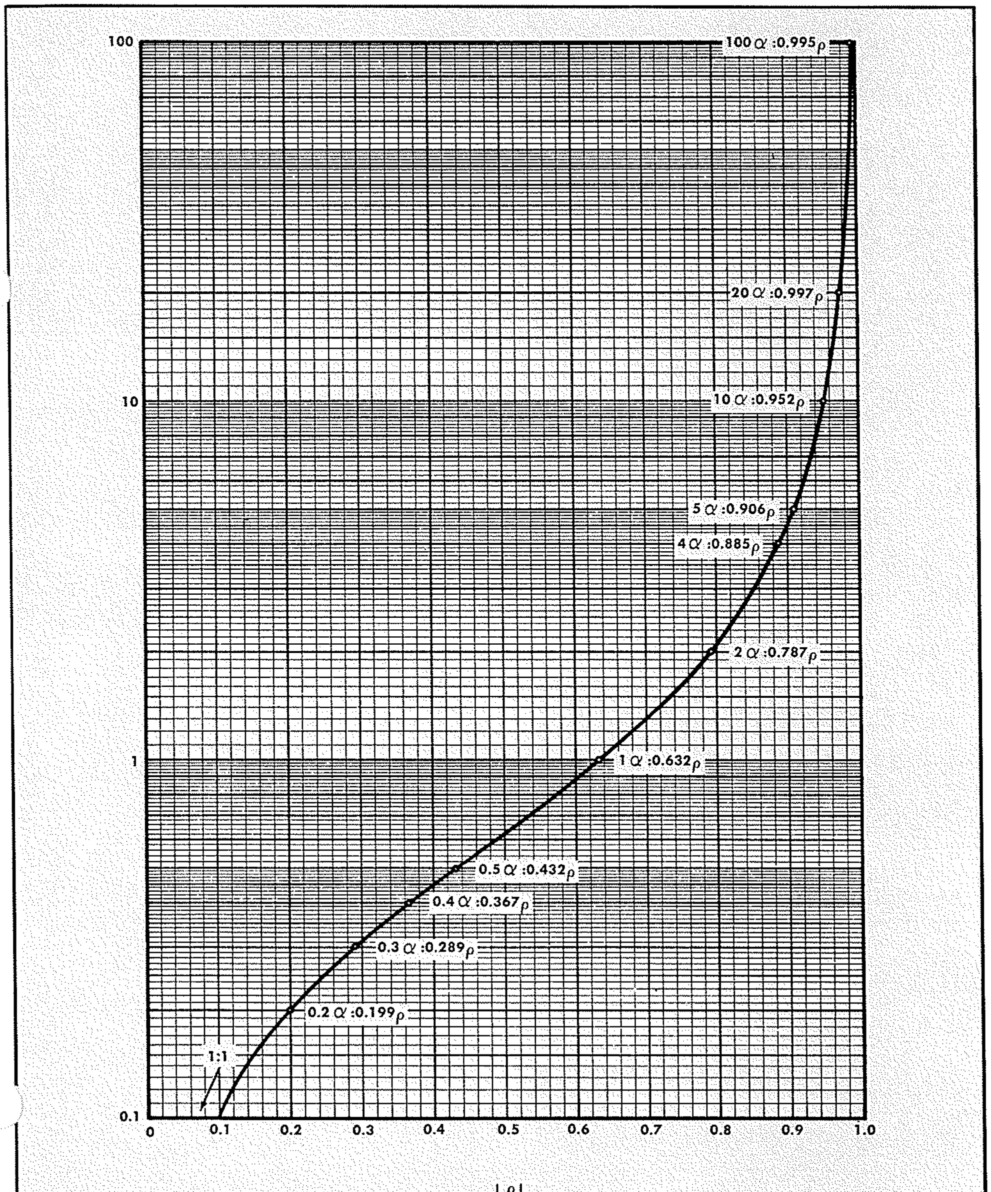


Fig 14. Graph for conversion of small reactance observed ρ to α for use in formulae (10) and (12).

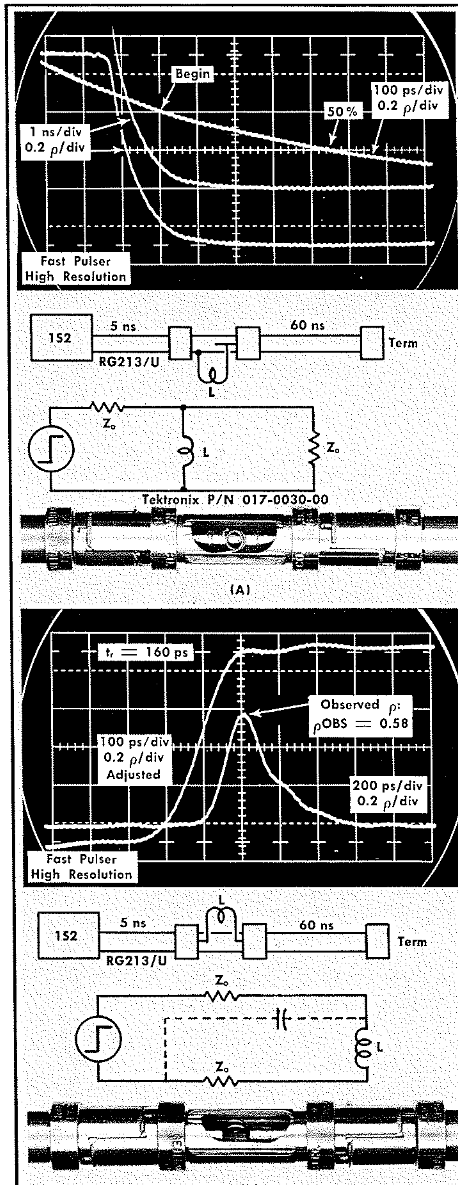


Fig 15. (A) 1¾ turn coil in parallel, (B) same coil in series, with 50 Ω coaxial line.

The waveform of Fig 15B has an observed deflection coefficient of +0.58. From the graph of Fig 14, 0.58 ρ is equal to 0.82 α. The risetime of the system was found to be 160 ps by disconnecting the insertion unit in which the inductor was located and measuring the reflection signal risetime. These figures placed into formula (11) give a value for the series inductor of 16.4 nH (1.64×10^{-8} H). This correlates very well with the previous parallel measurement.

Small Shunt Capacitor

Fig 16 is an example of a small shunt capacitor placed across a 50 Ω coaxial cable by compressing the cable outer diameter. Since the cable (RG8A/U) has normal impedance variations along its length, the peak reflection from the capacitor can only be approximated. Assuming a ρ of —1 division in Fig 16, then by formula (12), the capacitance is approximately 0.085 picofarads.

The Type 1S2 is useful for observing similar small discontinuities along transmission lines. In particular, high quality cable connectors can be evaluated for their ability to maintain a constant impedance where two cables are mated. Or, the quality of production installation of high quality connectors to flexible cable can be easily evaluated.

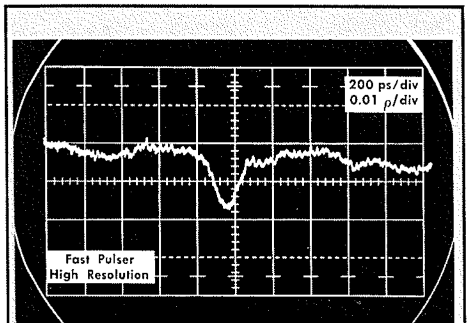


Fig 16. Shunt capacitor, ≈0.085 pF, caused by compressing RG8A/U coaxial cable with pliers.

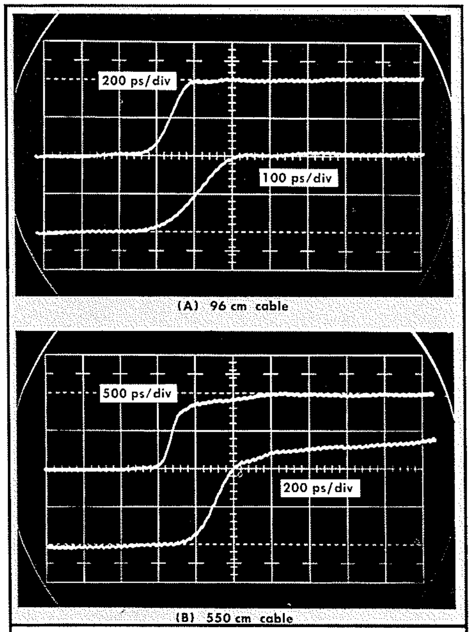


Fig 17. "Dribble up" characteristics of two lengths of RG8A/U.

Measuring Technique

The measurement of the small series inductor of Fig 15B is explained here to point out necessary techniques for measuring small reactances.

In evaluating small reactances with the TDR system, we have assumed the driving pulse to be a linear ramp; therefore, the ramp risetime must be determined for each change in the test system. The words "dribble up" refer to the characteristic of a coaxial cable to transport a step signal with distortion. The time required for the cable output signal to reach 100% of the step signal input amplitude is many times longer than the interval needed for the output signal to change from 0% to 50%. If we consider that the small reactance receives a pure ramp signal, then the rounded corners of the output pulse must be ignored.

Fig 17 shows the degradation of the Type 1S2 incident signal pulse by two different lengths of RG8A/U coaxial cable. Fig 17A is the reflection from an open cable 96 cm long, (192 cm signal path) and Fig 17B is the reflection from an open cable 550 cm long (1100 cm signal path). The upper waveform in each case was made with the Type 1S2 VERTICAL UNITS/DIV control set to 0.5 ρ/DIV, calibrated. The lower waveform in each case was made with the Type 1S2 vertical VARIABLE control advanced slightly clockwise to approximate a deflection factor of 0.5 ρ/DIV for just the ramp portion of the waveform. In each case the signal continues to rise after the inital step, but Fig 17B shows the "dribble up" characteristic very plainly. The lower waveform of Fig 17A and B does not permit an accurate measurement of the system risetime because the waveforms as shown are not large enough. However, the upper waveforms of Fig 18A and B are large enough to permit a reasonable measurement of the 10% to 90% risetime of the ramp that drives the small inductor. It is also obvious from Fig 18A and B that the series inductor peak reflection is truly caused by just the ramp portion of the driving signal and not by the "dribble up" portion.

Calculations made from Fig. 18A and B using formula (11) and the curve of Fig 14, indicate the series coil has an inductance of 16.40 nH at Fig 18A and inductance of 16.51 nH at Fig 18B. (Fig 18A: $L = (2.5)\ (0.82)\ (50)\ (1.60 \times 10^{-8}) = 1.64 \times 10^{-8}$ H.) (Fig 18B: $L = (2.5)\ (0.66)\ (50)\ (2.0 \times 10^{-8}) = 1.651 \times 10^{-8}$ H.) This indicates that an inductor in series with a coaxial transmission line can be accurately measured so long as the risetime of the ramp portion of the incident signal can be measured. Fig 18B indicates that a cable of RG8A/U a bit longer than 550 cm might make it difficult to measure the ramp risetime from the display. If a cable has sufficient length to prevent a reasonable display to measure the ramp 10% to 90% risetime, the small series inductor cannot be measured.

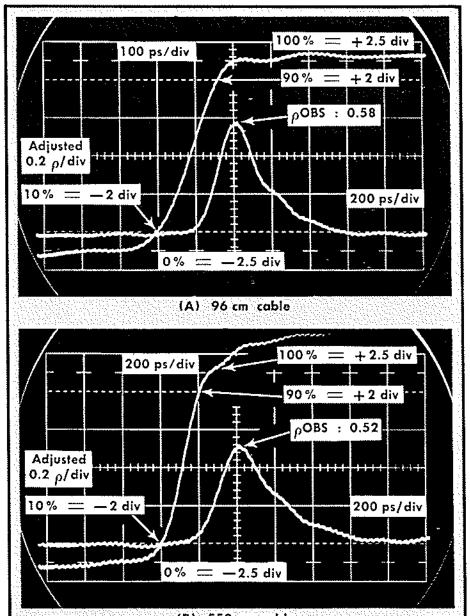


Fig 18. Small series inductor measured 96 cm and 550 cm away from Type 1S2 in RG8A/U coaxial cable.

Calculations of cable risetime will not permit small inductor measurements because the Type 1S2 vertical ρ/DIV calibration must be adjusted in each case. Once the vertical gain has been increased to measure the ramp risetime, the same new adjusted vertical ρ/DIV setting is used for measuring the observed ρ from the series inductor. If the cable is long enough to make it impossible to "see" the top of the ramp, the inductor cannot be measured. The same limitations apply when measuring small shunt capacitors.

Locating Small Reactances

The discussion of small reactances has thus far assumed that the TDR operator has access to all the cable between the TDR unit and the reactance being measured. This is, of course, not always the case. When a long length of cable indicates a fault, the reflected signal has not only been reduced in amplitude, it has also been smeared in time. The discontinuity is then located in time, closely related to the approximate 10% amplitude point or the beginning edge of the display rather than, as might be expected, at the peak of the reflection.

REFLECTIONS FROM RESISTIVE DISCONTINUITIES

Two types of reflections occur from two types or resistive discontinuity. They are a

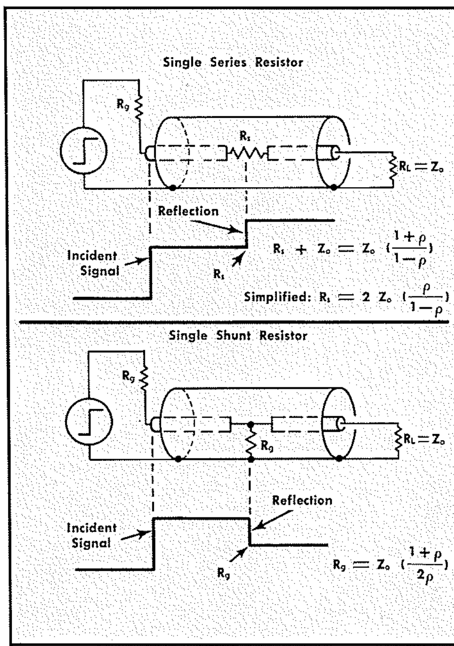


Fig 19. Single resistor discontinuities.

step reflection, or a continuously changing reflection. A resistance in series with a transmission line causes a positive reflection. A resistance in parallel with a transmission line causes a negative reflection. Discrete single resistors cause a step reflection, while distributed resistance causes a continuously changing reflection. The discrete resistor reflections are shown in ideal form in Fig 19, and the distributed resistance reflections are shown in ideal form in Fig 20.

Fig 20 has been exaggerated by showing the distributed resistance beginning at a particular point in the line. Normally, such series or shunt distributed resistance will be found in the total length of line tested by TDR.

All four forms of resistance are an indication of signal losses between the input and output ends of the transmission line. The single resistor discontinuities can occur due to discrete components or may indicate a loose connector with added series resistance. Such discontinuities can be physically located by special use of the POSITION RANGE control of the Type 1S2. Distributed losses are usually part of the particular line being tested and the TDR display can be of value for quantitative analysis of resistance per unit of line length.

No reflection should occur from a properly fabricated matched attenuator. Therefore, a TDR unit will not indicate losses when matched attenuators are used.

Distributed Resistance Examples

The examples of distributed resistance reflections that follow deal with the normal characteristics of transmission lines. Both small diameter lossy cables and moderate diameter quality cables are discussed.

Small, Lossy Cables

A small diameter 50 Ω transmission line (such as ⅛ inch diameter cable) will have sufficient DC resistance to mask "skin effect" losses. The DC resistance in its center conductor will cause a nearly exponential changing reflection. See Fig 21A. As the incident signal propagates down the line away from the TDR unit, the small series resistance causes small reflections to return to the TDR unit. If you mentally integrate the line into small sections of series resistance, you can then understand the continuous return of energy to the input end of the line. Each reflected energy "bit" is additionally attenuated on its way back to the TDR unit. This return attenuation is the factor that prevents the display from being a linear ramp, converting it into a nearly exponetial reflection. (Note the curve of the reflection between the incident signal plus step and the termination of Fig 21A.

Another way of expressing the effect of the nearly expoential reflection is to say that the transmission line input surge impedance changes with time. Fig. 21A shows the line surge impedance to be essentially 50 Ω at the beginning of the exponential reflection and to be approximately 64 Ω after 130ns ($+0.12\,\rho = 64\,\Omega$).

The long nearly exponential decay after the termination of Fig 21A is related to high frequency losses and the previously described "dribble up". The negative reflection occurs at the termination because the 50 Ω termination was driven by approximately 64 Ω. If the long exponential decay after the termination were expanded vertically, it would follow the rules for distortion to pulses by coaxial cables described with Fig 25.

If the small diameter cable is shorted at its end instead of terminated, the TDR display will appear similar to Fig 21B. A lossless line would have a full $-1\,\rho$ after the short, but the small lossy cable not only has attenuation of the signal to the short, but attenuation of the reflected signal back to the TDR unit. Again, the long nearly exponential curve after the short is caused by the cable distorting the reflected step signal.

Fig 21B also allows measuring the total cable DC resistance between the TDR unit and the short circuit of Fig 21B. The vertical distance between the incident pulse peak level and the right end flat portion of the reflected signal is due strictly to the cable DC resistance. In this case, —3.8 divisions = -0.76ρ which is equal to 6.5 Ω (from curve of Fig 10). (A bench multimeter type ohmmeter indicated 6.8 ohms for the same cable.)

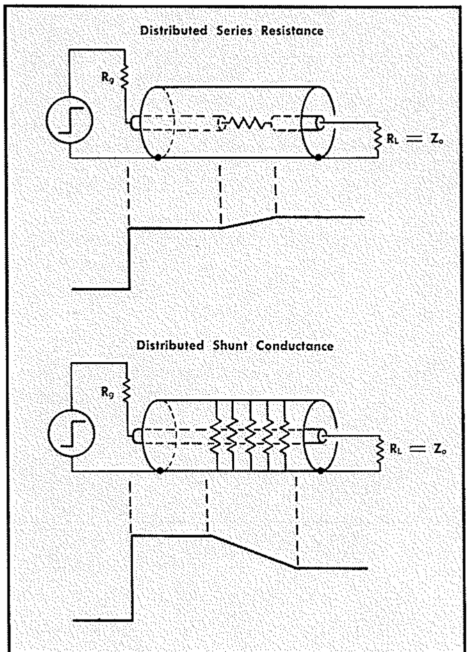


Fig 20. Distributed resistance reflections.

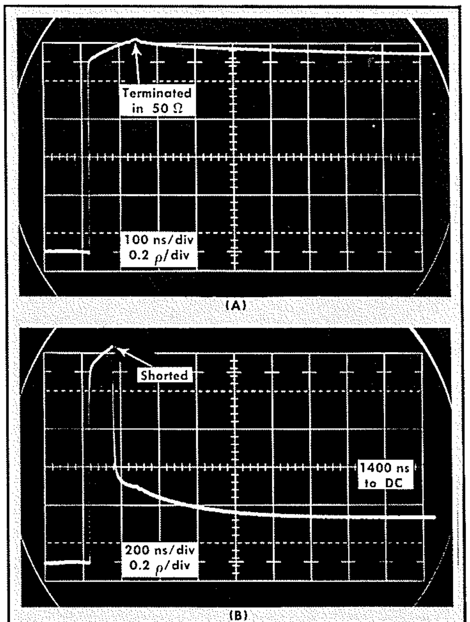


Fig 21. Waveforms of ⅛ inch diameter lossy 50 Ω cable.

Quality Cables

A quality cable, such as RG8A/U (52 Ω), RG213/U (50 Ω) or RG11/U (75 Ω) will exhibit similar characteristics to the small lossy cable just described, but the cable must be much longer to obtain a similar display of series resistance. Fig 22A and B show the same rising type of waveform caused by center conductor series resistance in RG213/U. Fig 22C shows the residual DC resistance of the line when shorted. Fig 22D is a time and voltage expansion of the (A) and (B) waveforms to show a possible use for the Type 1S2 in troubleshooting cable fabricating equipment.

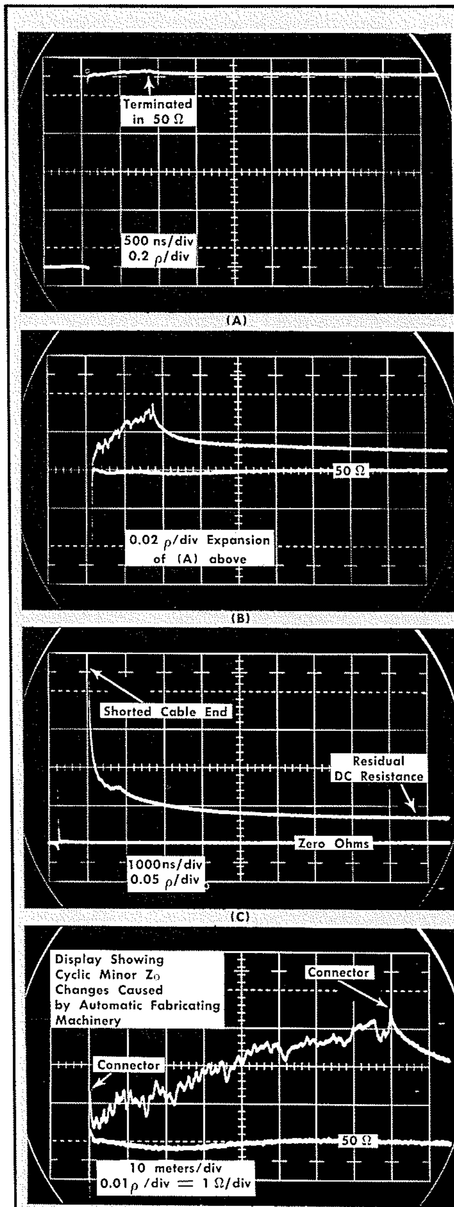


Fig 22. Quality RG213/U cable resistance and ΔZ_o characteristics. (Cable tested 260 feet long).

Fig 23 shows the same series resistance characteristics for RG11/U cable. However, instead of terminating the cable end, the series resistance was measured first with the end open, and then with the end shorted. Note the difference in slope of the waveform (apparent change in resistance) after the signal has traveled to the indicated line end. The change in slope is due to distortion of the originally flat incident pulse by traveling through the cable once. As the non-flat signal reaches the cable end, its reflection back through the cable is altered a second time. The net result is an obvious distortion to the true resistive slope of the reflected "bits" of the distributed series resistance during the 2nd half of the reflection. This example is given to show the desirability of properly terminating any line section in which you wish to measure its total distributed series resistance. (Conditions leading to this changing slope phenomenon are described by H. H. Skilling on page 397 of his text "Electronic Transmission Lines", McGraw-Hill, 1951.) Each of the three waveform pictures of Fig 23 is a double exposure with the lower waveform showing the normal Type 1S2 response to a termination resistance at (A) and (B) and a short circuit at (C).

COAXIAL CABLE RESPONSE TO A STEP SIGNAL

Coaxial cable have a step-function response that distorts the original signal. The distortion is caused by cable losses of several types which are frequency dependent. The longer the cable length, the greater the distortion. Response to a step signal can be evaluated by placing the cable in a TDR system, or by placing it between a fast rise pulser and a fast risetime sampler. (When a cable is tested by a TDR device, the signal traverses the line twice; when a cable is placed between a pulser and a sampler, the signal traverses the line once.)

Studies in the past that considered skin effect losses only[1] have indicated that some types of coaxial cables have a step-function response with decibel attenuation that varies as the square root of the frequency. Based upon this assumption (of skin effect losses only), the step response time from 0% to 50% will increase by a factor of 4 through a cable whose length is twice that of a previous test. Such is not the case in practice as seen by use of the Type 1S2. Other forms of losses due to the dielectric material between inner and outer conductors, radiation from lines whose outer conductor is braided, and reflection losses from surface variations of the conductors, are discussed in detail in an article by N. S. Nahman[2]. Nahman considers several techniques which are useful in analyzing the transient behavior of coaxial cables that have these forms of high frequency losses.

Long Cables

Distortion to pulse signals in coaxial cables is most easily evaluated (visually displayed on a CRT) when the cable is long. A long cable is here defined as one that exhibits significant losses in the system in which it is used. The tests shown in Fig 24 were made on a 100 foot section of RG11/U and a 260 foot section of RG213/U. In each case the signal traversed the line twice in a normal TDR manner. The cable far end was left an open circuit so that a return signal of $+1\rho$ could be observed. This gives the same effect as having sent the Type 1S2 signal through a line twice as long.

The term T_o, shown in Fig 24, is the length of time between the 0% amplitude and 50% amplitude points along the step rise of the cable output signal. 0% to 50% is chosen because it contains the fastest part of the transition and because it is easy to read. The usual practice of measuring risetime from 10% to 90% is perfectly valid if the display has an adequate rate of rise at the 90% point. The cables tested for Fig 24 have a 10% to 90% risetime that lasts about 18 times longer than T_o. Fig 24 shows plainly that the step response of a coaxial cable does not have the familiar Gaussian shape. For this reason the risetime of systems containing long coaxial cables cannot be calculated using the square root of the sum of the squares of the individual unit risetimes.

The length of time required for the output signal to rise to 100% of the input signal is many times longer than T_o. This distortion is called "dribble up" as first discussed earlier under Measuring Technique when measuring a small series inductor in a transmission line. Fig 25A is a double exposure using the 260 foot length of RG213/U connected between the Type 1S2 1-Volt pulser and the terminated Thru Signal Sampler. Both traces were made at 100 ns/div. The upper trace at 0.2 ρ/DIV and the lower trace at 0.05 ρ/DIV. The lower trace leads us to believe that the output pulse reaches 100% amplitude sometime between 4000 and 5000 ns after the initial step rise. More exact measurements can be made by comparing the cable output with the Type 1S2 no-cable response as shown in Fig 25B. Here both traces were made at 1000 ns/DIV and 0.02 ρ/DIV with an intentional small vertical repositioning. When the two traces become a constant distance apart, you can be relatively certain the cable output signal has reached 100% amplitude. Fig 25B indicates a possibility that the output signal had not completely reached 100% amplitude even after 8000 ns (8 μs).

Short Cables

Even though information just given on Long Cables is true for any length cable, a physically short cable can be treated as if it

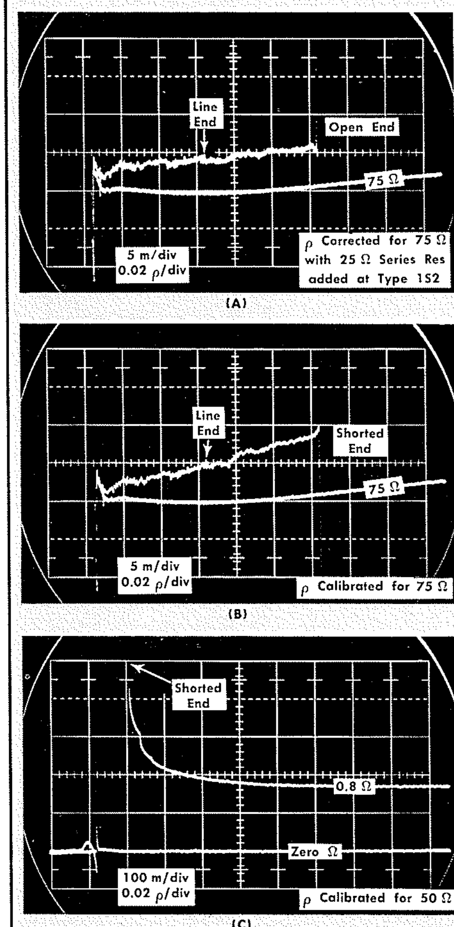


Fig 23. Quality RG11/U cable resistance and ΔZ_o characteristics. (Cable tested was 100 feet long).

[1]R. L. Wigington and N. S. Nahman, "Transient analysis of coaxial cables considering skin effect," Proc. IRE, vol. 45, pp. 166-174; February 1957. Q. Kerns, F. Kirsten and C. Winningstad, "Pulse Response of Coaxial Cables," Counting Notes, File No. CC2-1, Rad. Lab., University of California, Berkely, Calif.; March, 1956. Revised by F. Kirsten; Jan. 15, 1959.

[2]N. S. Nahman, "A Discussion on the Transient Analysis of Coaxial Cables Considering High-Frequency Losses," IRE Transactions On Circuit Theory, vol. CT-9, No. 2, pp. 144-152; June, 1962.

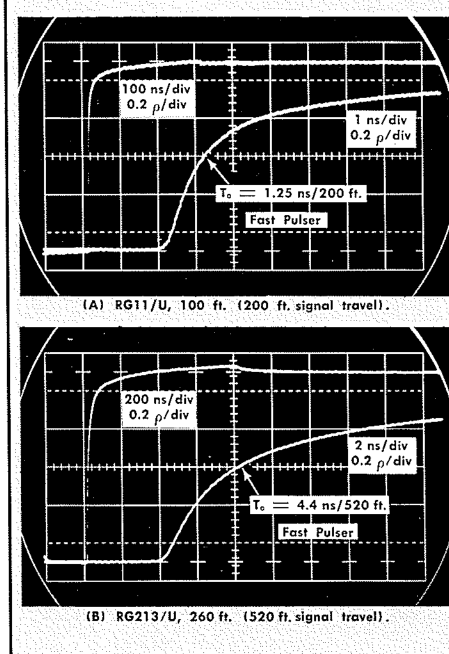


Fig 24. RG11/U and RG213/U distortion to a step signal. Waveforms are reflections from cable open end.

were Gaussian. A short cable will have a T_o sufficiently faster than the Type 1S2 fast pulser 10% to 90% risetime, that the long slow rise ("dribble up") of Fig 25 will not be evident. Under these short cable conditions, it is reasonable to assume the bandpass upper limit of a cable and its system can be approximated from the 10% to 90% risetime display. A display of 10% to 90% risetime in 100 picoseconds then approximates a sine wave upper frequency 70% amplitude of: $0.35/(1 \times 10^{-10}) = 3500$ MHz.

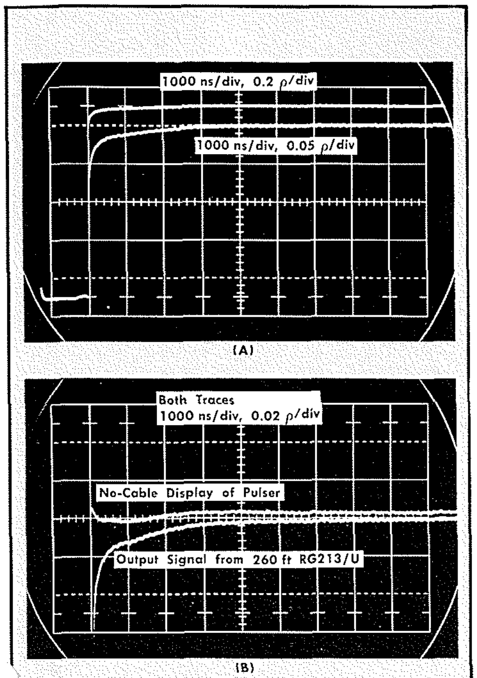


Fig 25. "Dribble up" output signals from 260 ft. RG213/U.

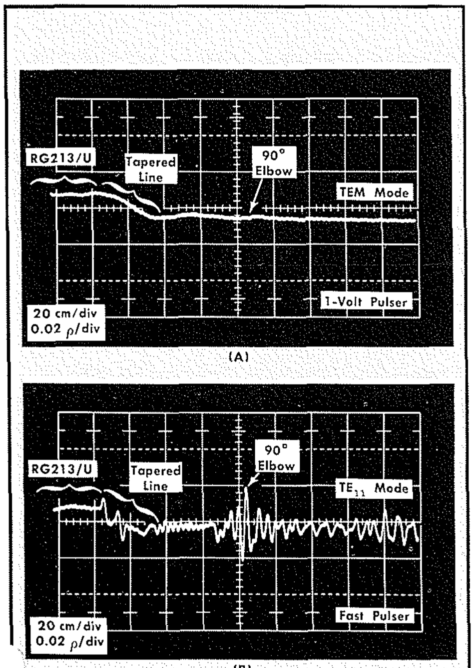


Fig 26. Propagation mode change in large diameter transmission line when driven by the Type 1S2 fast pulser.

Large Diameter Transmission Lines

Use of the Type 1S2 0.25-Volt fast-risetime pulser should be limited to use on lines whose outer conductor inner diameter is less than about one-quarter wavelength at 3500 MHz. Normal signal propagation mode in transmission lines is TEM, but will change to a waveguide mode, TE_{11}, if too high a frequency is used. Fig 26 shows both modes of propagation in a transmission line 3⅛ inch in diameter. Fig 26A picture was taken using the Type 1S2 1-Volt pulser. Fig 26B picture was taken using the Type 1S2 0.25-Volt fast pulser. The line elements were the same in each case; 1) a short section of RG213/U cable between the Type 1S2 and a tapered line section; 2) the tapered line section; and 3) a section of 3⅛ inch diameter rigid air line with a 90° elbow in the display time window. The numerous aberrations of Fig 26B are due to a change in propagation mode when the signal arrived at the 90° elbow. The resulting multiple reflections are of no value to the operator testing the line.

SPECIAL APPLICATIONS
General

Much of the previous portion of this article deals with using the Type 1S2 as a Time Domain Reflectometer. Many more uses can be made of the unit in a TDR mode, limited only by the measurement needs of the user. Listed below are suggestions of other TDR applications not yet described.

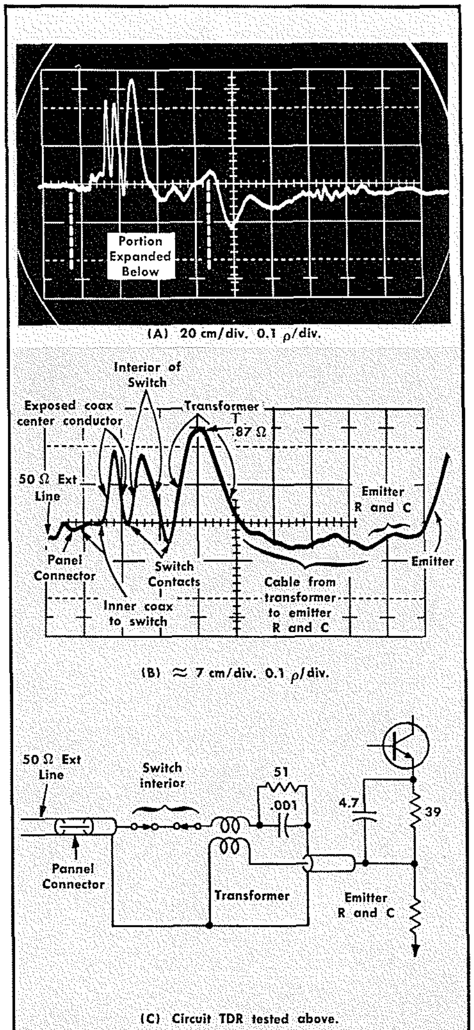


Fig 27. TDR view of broadband amplifier input circuit.

Signal Generator Output Impedance

The Type 1S2 can be connected to the output terminal of a signal generator to measure its output impedance. If the generator output signal can be turned off while keeping the output circuit active, a clean TDR can be obtained.

Broadband Amplifier Input Impedance

Fig 27 shows two pictures of a broadband amplifier input circuit. Fig 27A includes the active emitter circuit of the input common-base transistor amplifier. Fig 27B includes the parts between the input connector and the transistor emitter. The power was off when Fig 27B photo was taken to show the transistor emitter spatial location accurately.

Circuit Board Lead Impedance

Fig 28A shows changes in surge impedance of leads along an etched circuit board. (The board reverse side was fully plated.) The major dip is due to a right angle corner while the minor dip is due to a rounded corner.

Changes in surge impedance due to a change in lead width is also plainly seen by TDR. Fig. 28B shows an inductive section of line when the physical width of the line was reduced one half for a length of about 1.25 inches.

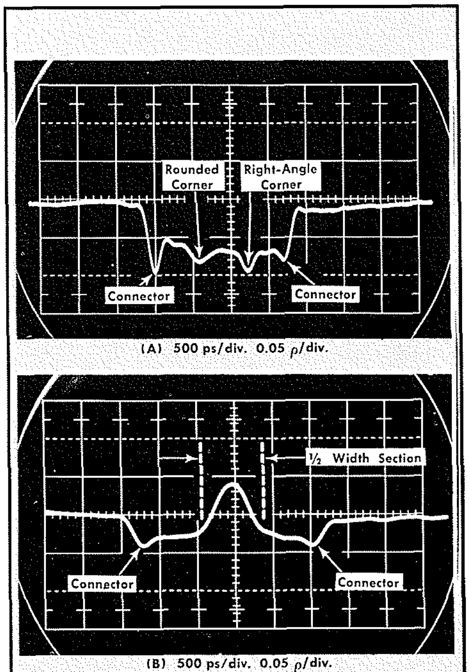


Fig 28. Etched circuit board Z_o checked by TDR.

Frequency Compensation of Lossy Cables

A lossy coaxial cable connected between one of the Type 1S2 pulsers and the sampler (terminated) permits a view of the cable output signal. Fig 29 shows the same lossy cable described earlier with Fig 21. A double exposure shows at the top how the cable distorts the 1-Volt pulser while the lower waveform is flatter due to a simple RC compensation network placed between the pulser and the cable. The TDR unit will permit testing such compensation networks.

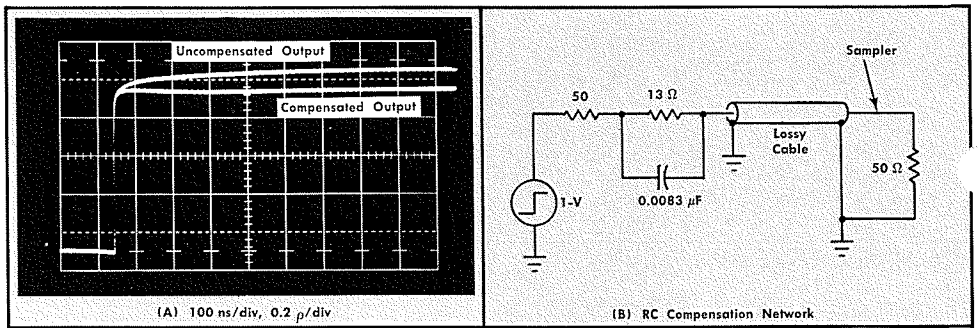


Fig 29. Simple frequency compensation for lossy coaxial cable.

Evaluation of Ferrite Beads and Cores

Ferrite beads and cores can be evaluated using the Type 1S2. Simple inductors wound on toroid ferrite cores are represented by an equivalent circuit which is essentially an inductance in parallel with a resistance. The resistance results from core losses and may be typically as low as 10 to 30 ohms/$(turn)^2$. Both the resistance and inductance characteristics of ferrites can be seen in a TDR display.

Fig 30 shows two displays and the special adapter jig used to test a ferrite bead. The adapter jig is made from one half of a Tektronix Insertion Unit (Part No. 358-0175-00). The end of the center piece was flattened and a formed piece of #10 copper wire soldered in place with a ferrite bead included. Thus, there is only a small diameter change of the 50 center conductor (pip in both displays) and one turn through the ferrite center. (Use smaller wire for smaller beads.)

Fig. 30A shows the basic display. L/R time-constant analysis is similar to that of Fig. 15 and formula (8) of Table 5, except the core R is in parallel with the driving line Z_o.

Fig 30B shows the ferrite bead resistance as $-0.16\ \rho$, or 36 Ω. (The 36 Ω is read directly from the curve of Fig 10.) The resistance value of a core is read by finding the curve knee (as marked in Fig 30B) where the inductance affect becomes obvious. The positive pip is ignored.

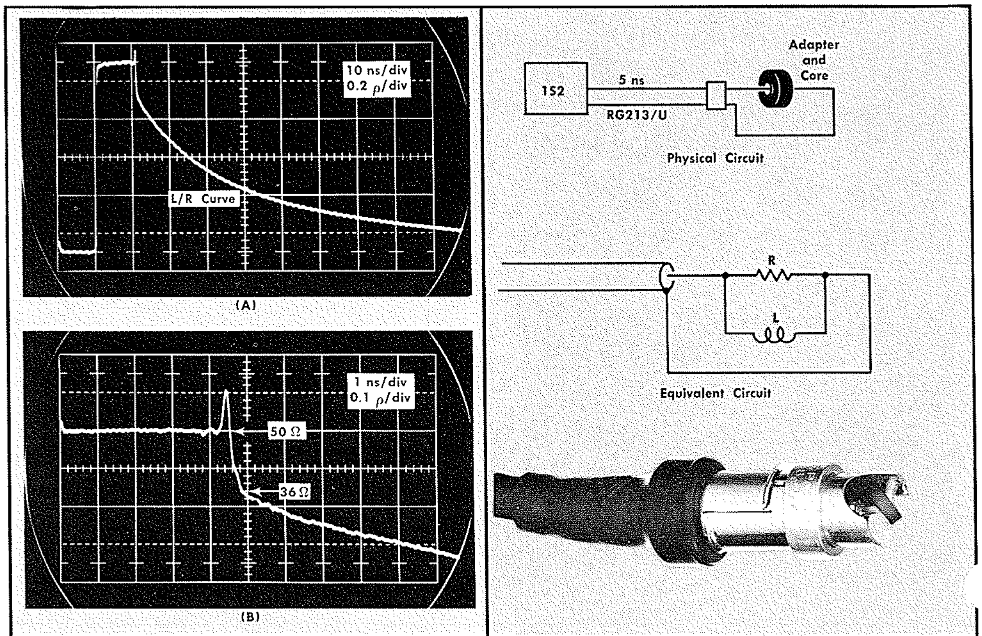
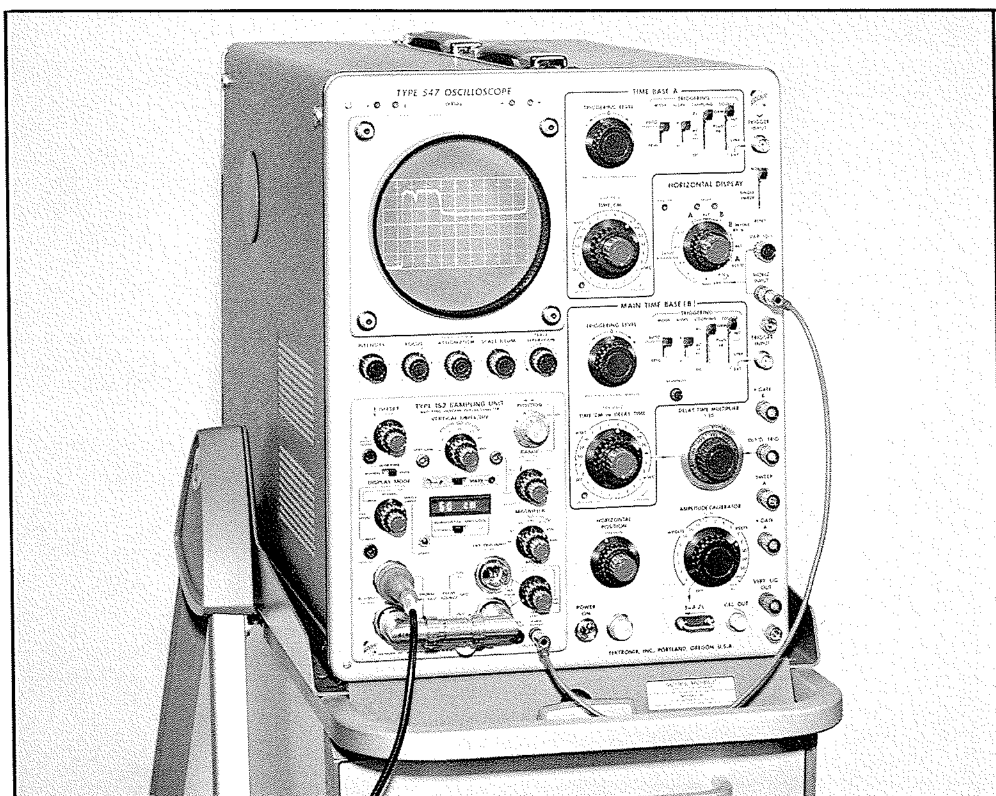


Fig 30. Evalution of a ferrite core.



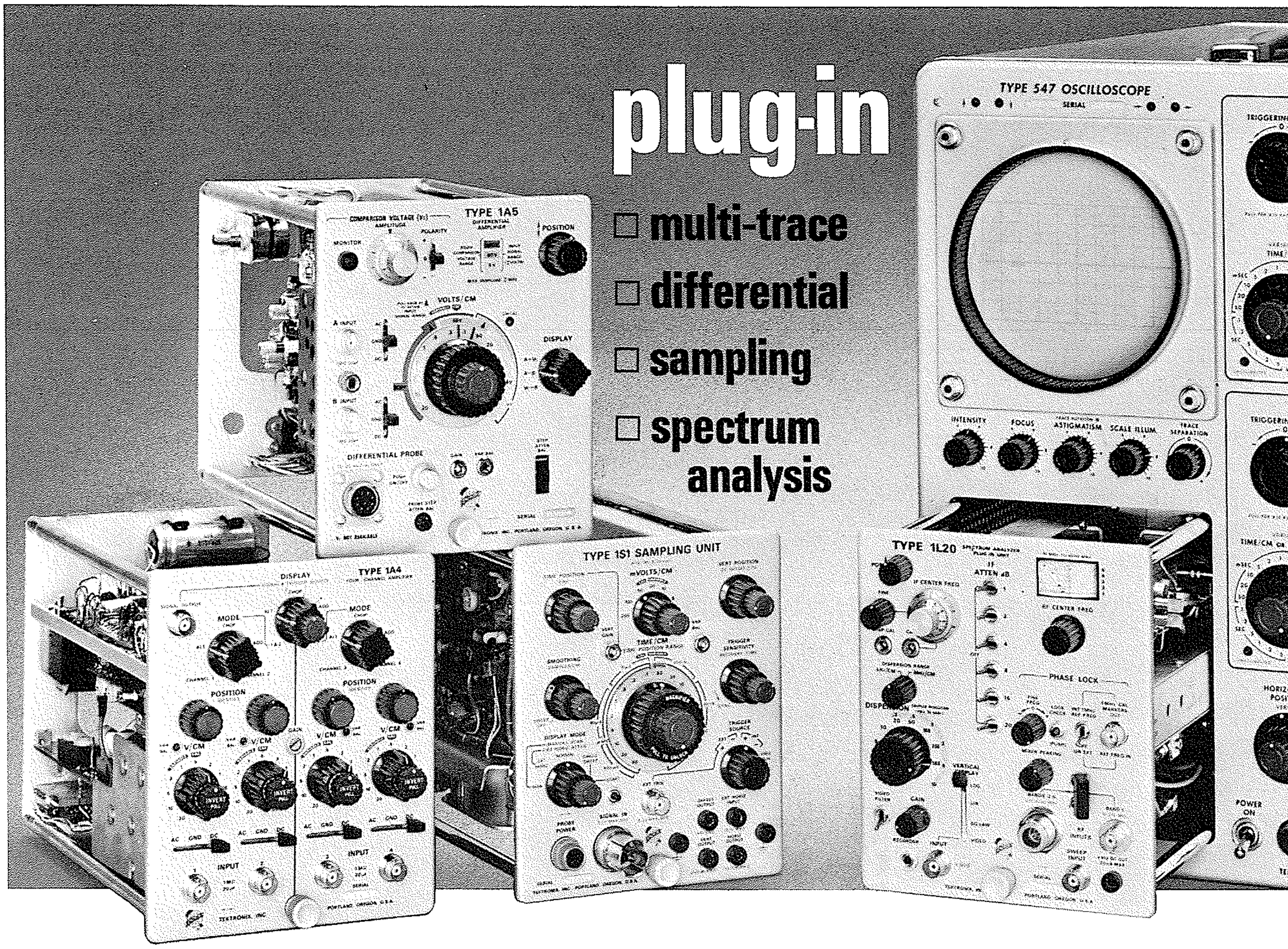
Tektronix Type 547 Oscilloscope with a Type 1S2 Sampling Plug-In Unit.

The measurements described in this article can be easily made with the Type 1S2 Plug-In Unit.

The Type 1S2 Sampling Plug-In converts any Tektronix 530, 540, 550-series oscilloscope to a time-domain reflectometry measurement system. It also has the ability to make many general sampling measurements.

As a TDR, the Type 1S2 has a system risetime of 140 ps and is calibrated in ρ (rho) from 0.005 ρ/div to 0.5 ρ/div. The horizontal is calibrated from 1 cm/div to 100 m/div for dielectrics of air, TFE and polyethylene. A 10-turn dial reads directly the one-way distance to the test-line discontinuity. Two pulse outputs provide either 50 ps T_r at 250 mV into 50 Ω or 1 ns T_r at 1 V into 50 Ω.

The 90-ps risetime, 5 mV/div deflection factor, 100ps/div sweep and built-in triggering capability make the Type 1S2 useful in many other sampling measurements.



Tektronix 530, 540 and 550-series plug-in oscilloscopes offer a wide range of performance, designed to meet your changing measurement needs. Select the performance and measurement functions you need from multi-trace, differential, sampling and spectrum analyzer plug-ins.

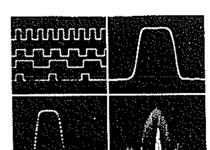
For multi-trace applications, the new Type 1A4 Four-Channel amplifier offers constant DC-to-50 MHz bandwidth and 7-ns risetime capabilities over its 10 mV/cm to 20 V/cm deflection factor range. Operating modes include alternate or chopped four channel, dual channel differential, and 2, 3, or 4 channels added or subtracted. Two dual-trace plug-ins are also available, the Type 1A1 with 28 MHz at 5 mV/cm (50 MHz at 50 mV/cm) and the Type 1A2 with 50 MHz at 50 mV/cm.

For differential applications, the new Type 1A5 Differential amplifier features 1 mV/cm deflection factor, 1,000:1 common-mode rejection ratio at 10 MHz, ± 5 V comparison voltage and 50 MHz bandwidth with 7-ns risetime at 5 mV/cm. The low-cost Type 1A6 Differential plug-in with 1 mV/cm deflection factor, 10,000:1 CMRR and 2-MHz bandwidth and the high-gain Type 1A7 Differential plug-in with 10 μV/cm deflection factor, 50,000:1 CMRR and 500 kHz bandwidth are also available.

For sampling applications, choose from two high performance plug-ins, the Type 1S1 general purpose sampling plug-in and the Type 1S2 TDR sampling plug-in. The Type 1S1 features internal triggering, 0.35-ns risetime, DC-to-1 GHz bandwidth and calibrated sweep speeds from 100 ps/cm to 50 μs/cm. The Type 1S2 is a time-domain reflectometer with a system risetime of 140 ps, 0.005 *ρ*/div deflection factor and sweep rates from 100 ps/div to 1 μs/div. With its 90-ps risetime, 5 mV/div deflection factor and built-in triggering, the Type 1S2 can be used in many other sampling applications.

Four spectrum analyzer plug-ins covering the spectrum from 50 Hz to 10.5 GHz convert your oscilloscope to a high-performance spectrum analyzer. The plug-ins cover the following frequency bands: Type 1L5 from 50 Hz to 1 MHz with 10 μV/cm deflection factor; Type 1L10 from 1 MHz to 36 MHz with —110 dBm sensitivity; Type 1L20 from 10MHz to 4.2 GHz with—110 to—90 dBm sensitivity; and Type 1L30 from 925 MHz to 10.5 GHz with —105 to —75 dBm sensitivity.

Multi-trace *differential*



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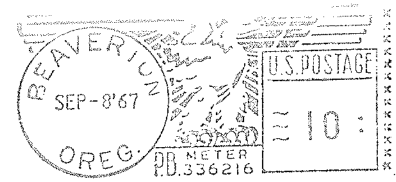

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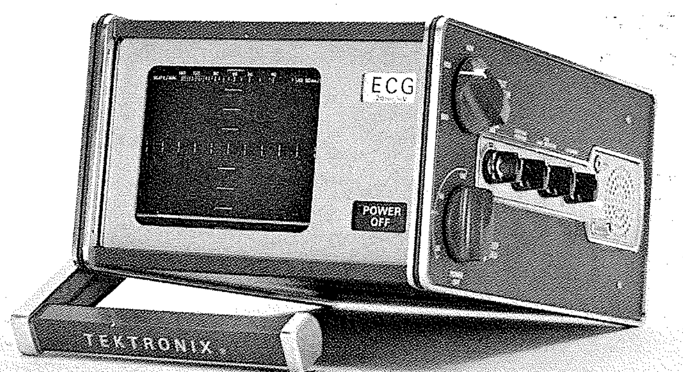
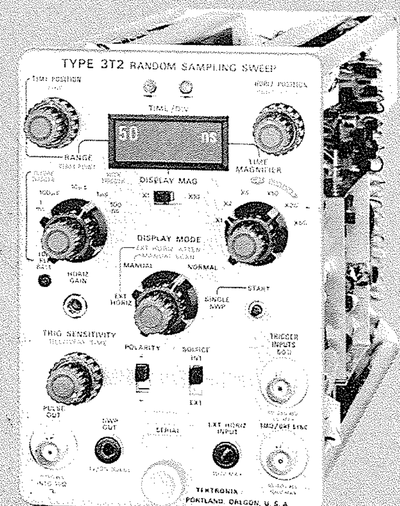


A NEW
PHYSIOLOGICAL
MONITOR

Page 2



A NEW
MEASUREMENT CONCEPT—
RANDOM SAMPLING

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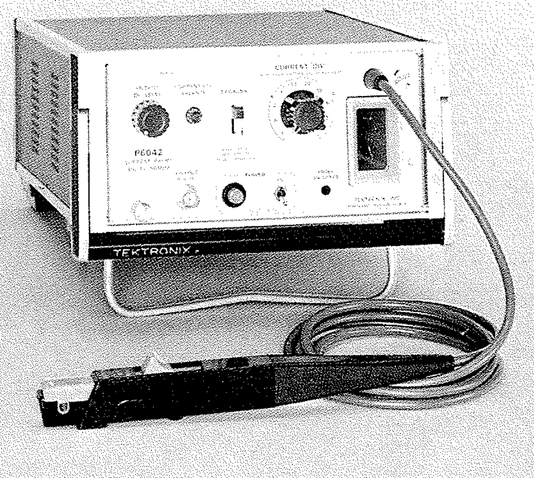

A NEW
DC-TO-50 MHz
CURRENT PROBE

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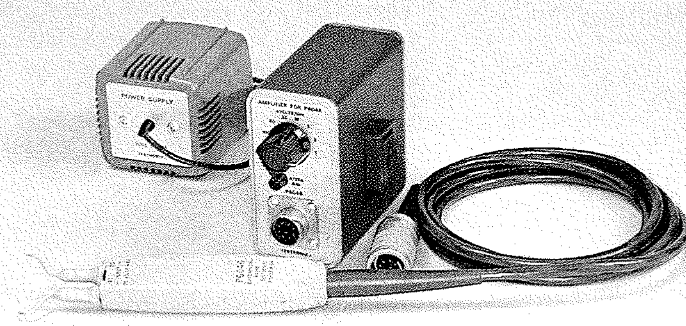

A NEW
DC-TO-100 MHz
DIFFERENTIAL PROBE
AND AMPLIFIER

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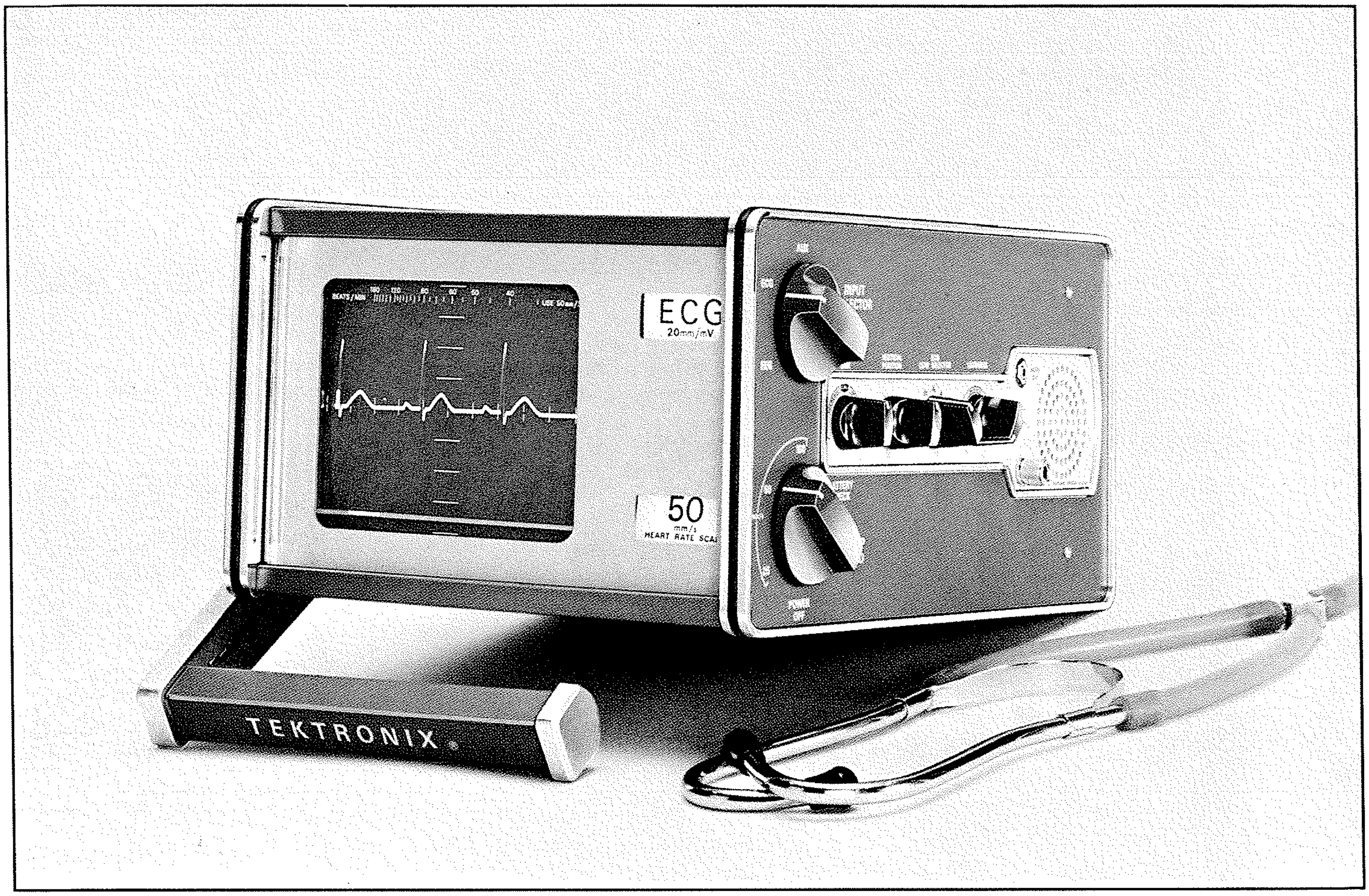
A SIMPLIFIED OSCILLOSCOPE FOR THE OPERATING ROOM

by Don L. Clark



INTRODUCTION

Tektronix recently introduced the Type 410 Physiological Monitor, a special purpose oscilloscope for use in clinical medicine. The instrument is *small* and powered by a rechargeable battery pack. Despite its compactness, it features a large 8 x 10 centimeter display area made possible by a wide-angle, magnetically-deflected cathode-ray tube (CRT). More importantly, the monitor is tailored to the unique requirements of the medical clinician.

For example, the controls are greatly simplified from those found on many oscilloscopes and are labeled in terms meaningful to medical personnel (Fig 1). The size and optional mounting fixtures permit the instrument to be used in the crowded perimeter of the surgical operating table.

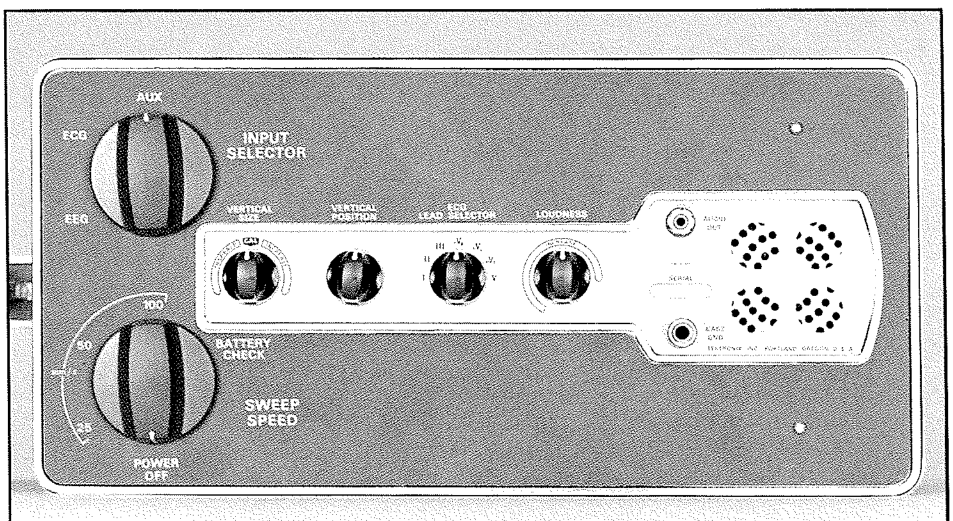


Fig 1. Type 410 Operating Controls

You can monitor any of three important physiological signals with the Type 410:

ECG—(or EKG, the Electrocardiogram) An electrical signal produced by the heart which can be detected on the surface of the body.

Pulse—Pulsations of blood sensed in the finger or elsewhere with the appropriate transducer.

EEG—(Electroencephalogram) An electrical signal produced by the brain.

The 410 was designed to be used wherever surveillance of patient condition is vital. In the operating room, a physiological monitor provides information regarding reactions to anesthesia and surgical procedures. In the recovery room and the intensive care unit, which by their very existence indicate the importance of constant surveillance, the physiological monitor provides a continuous display of valuable data.

SIGNALS FROM THE HUMAN BODY

The human body provides many indexes of relative well-being. Excessive body temperature has long been known to accompany ailments ranging from the minor to the serious. In a similar sense, and with varying degrees of reliability, eye dilation, pulse rate, respiration rate and others provide worthwhile information regarding the viability of the human body. When considered in the time domain, certain of these physiological indicators become more critically important and can yield substantially more information than others.

For example, one or two degrees of excessive body temperature persisting for several days would be of comparatively less cause for alarm than a heart stoppage for ten seconds. Moreover, the thermal mass of the body is such that hourly sampling might provide all the information required. But the nature of the heart is such that significant information may be observed from events lasting only a few hundredths of a second.

Thus, the physiological signals can be classified according to (1) the magnitude of deviation from the norm, (2) the relative importance to the human body, (3) the rapidity with which the change can occur, and (4) the time duration of the shortest significant event within the data. Signals involving comparatively short duration cyclical events and potentially rapid change can yield considerable information when displayed in graphical form on a monitor such as the Type 410.

THE ELECTROCARDIOGRAM (ECG)

Among the key physiological indicators is the ECG; a graphical recording of the heart electrical activity. This signal is associated with the muscular contraction which produces the pumping action. Effective pumping requires coordination of the individual heart muscles, with related cyclical patterns in the electrical signal.

While the electrical signal occurs within the heart muscle tissue, it can be detected on the surface of the body. The sensing electrodes can be placed at many different sites and each pair or combination of electrodes provides a different perspective of the complex three-dimensional signal generator, the heart.

Figure 2 shows an idealized waveform representing the electrocardiogram from one of the more popular monitoring configurations which consist of a differential measurement between electrodes on the right arm and left leg with a third electrode on the right leg serving as a common-mode reference to the monitoring system.

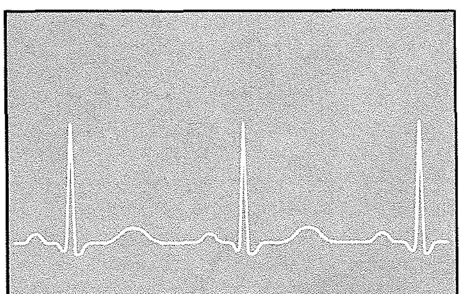


Fig 2. ECG Waveform

The information obtainable from the ECG is far too broad and technically complex to detail here, but several general uses can be mentioned: (1) Heart rate can readily be determined as can improper rhythm. (2) Heart attacks may involve dead tissue and coagulated blood in portions of the heart which can produce an abnormal ECG. (3) During certain stages of pregnancy, the fetal ECG can be detected. The presence of more than one fetus has sometimes been determined by this method. Orientation of the fetus in the womb may be determined by noting the fetal ECG polarity. (4) Victims of electrical shock may die due to heart fibrillation, a condition in which little or no blood is pumped by the heart. Fibrillation is a total loss of coordination between the various heart muscles which causes the heart to quiver rapidly rather than rhythmically contracting and expanding. Defibrillation can often be accomplished by applying a powerful electrical shock (up to 400 watt seconds in a ten-millisecond pulse) which temporarily locks the heart muscles. Within a few seconds after the intentional shock, the heart will often restart with the proper coordination. The electrical activity of the heart before and after defibrillation is readily monitored with the Type 410. Input circuitry of the instrument is protected against destruction by the defibrillator pulse so that there is no need to disconnect the monitoring electrodes during defibrillation.

THE PULSE

A normal ECG is no proof that blood is properly circulating throughout the body. Monitoring of the pulse by touch on the wrist, neck or elsewhere can show that blood is circulating, at least in that portion of the body and, in some cases, the judgement can be made that the pulse is "weak" or "strong".

The Pulse Sensor can more than replace the conventional touch method. The sensor is easily attached to the patient and will provide continuous, hands-off monitoring.

As the blood pressure rises and falls with each heart beat, the amount of blood present in any particular portion of the flesh varies slightly with the expansion and contraction of the blood vessels. This slight change can be detected from the correspondingly slight change in the translucency of the flesh. A small, low-power incandescent lamp directs light into the flesh and an adjacent photoresistor senses the light variation.

The finger tip, toe, and forehead are particularly good locations for the sensor. Contact pressure between the sensor and flesh is an important factor; excessive pressure will block blood flow and too little pressure will result in an excessive sensitivity to movement, thereby introducing interference. The Pulse Sensor is shown in Figure 3 with a removable finger adapter.

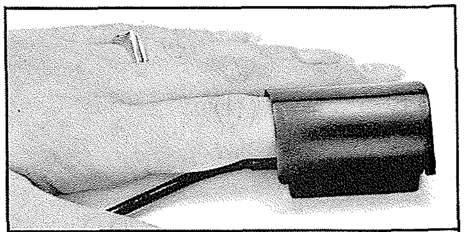


Fig 3. Pulse Sensor

This spring-loaded adapter not only holds the sensor against the finger with the proper pressure, but also excludes potentially interfering modulated light from fluorescent lamps or other sources. The adapter can be quickly attached and is self-holding on the finger.

For quick determination of heart rate, a direct reading Heart Rate Scale is provided across the top of the Type 410 graticule as shown in Figure 4. This scale is possible through the use of automatically triggered sweeps for both ECG and pulse displays,

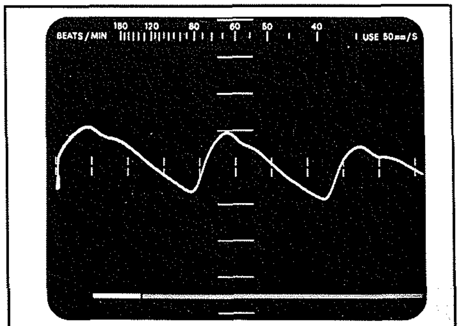


Fig 4. Pulse Sensor Waveform

and by the accurate sweep speeds of the Type 410. Three sweep speeds are provided: 25, 50, and 100 millimeters per second. The Heart Rate Scale is calibrated for use with the 50 mm/s speed.

The portion of the signal which has the greatest amplitude triggers the sweep and therefore appears at the lefthand edge of the graticule as shown in Figure 4. The corresponding portion of the next cycle appears to the right of the first at a distance determined by the time interval between the events and the horizontal sweep speed of the Type 410. From the known sweep speed and the measured distance, a simple calculation gives the pulse rate. The Heart Rate Scale is derived from this calculation and can be used with either a pulse or ECG display. (Display shows 75 beats/min.)

While the event which produces sweep triggering remains stationary at the lefthand edge of the graticule with successive sweeps, the second event changes position with any variation in heart rate. If the heart rate is uniform, the display need be watched for only two or three seconds to obtain an accurate rate indication. The scale can also be used with slightly less accuracy with the other two sweep speeds; dividing by two on 25 mm/s and multiplying by two on 100 mm/s.

THE ELECTROENCEPHALOGRAM (EEG)

In some surgical procedures, the heart is intentionally stopped and blood circulation is maintained by an external mechanical pump making it more difficult to determine the relative well being of the patient. In such cases the Type 410 can be used to monitor the EEG, the electrical activity of the brain. This complex signal, seemingly random to the layman (Figure 5), can yield valuable information through analysis of amplitude and frequency content.

The EEG is detected upon the surface of the head with electrodes similar to those used for ECG.

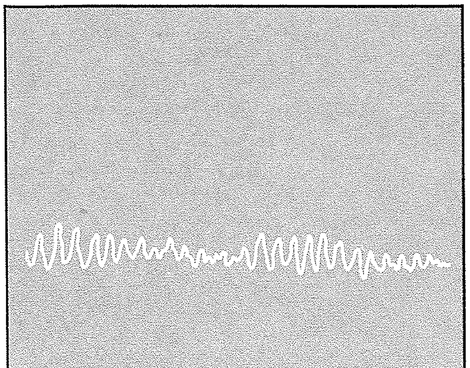


Fig 5. EEG Waveform

MONITORING CONVENIENCE

Note that all three types of signals previously discussed as applicable to the Type 410 are not only among the *most* important indicators of patient well being, but that all are available at the surface of the body.

For maximum monitoring capability and cross correlation between signals, seven electrodes and the pulse sensor may be connected to the patient as shown in Figure 6. Using only the INPUT SELECTOR switch, the user can select the EEG, ECG, or pulse waveform. With a second switch, the ECG LEAD SELECTOR, any of seven standard combinations of ECG electrodes may be chosen.

THE CLINICIAN AND HIS ENVIRONMENT

The Type 410 is of particular value to the anesthesiologist, a medical doctor specializing in anesthesiology. His activities in the operating room go far beyond the administration of anesthetics; he is responsible for monitoring patient well-being, assists the patient's breathing, monitors blood loss and replacement, monitors blood pressure, administers drugs, and in general watches for any unfavorable reaction due to the anesthetic or the surgical procedure.

Instrumentation which can provide some of the needed data can be of considerable value. To provide the anesthesiologist with continuous information, the Type 410 produces an audible "beep" coincident with the most significant event in each cycle of the ECG or pulse waveform. Most doctors and nurses, through experience, will be able to estimate heart rate quite accurately by listening to the "beep" and will most certainly be able to detect poor rhythm. Should a more qualitative determination of heart rate be desired, a quick look at the Heart Rate Scale will suffice. With the LOUDNESS control, the sound can be made audible to the entire surgical team or only to the anesthesiologist.

Several features of the Type 410 combine to insure that a display is available under nearly all circumstances. These features include the elimination of input coupling capacitors so as not to retard recovery from overdrive by high amplitude defibrillator pulses or electrocautery arcs. AC coupling for drift elimination is provided between amplifier stages and includes an overdrive scan limiter for quick recovery.

Automatic sweep triggering circuits, which require no operator controls, seek out the event of dominant amplitude in the ECG or pulse signal, regardless of polarity. If the amplitude of the dominant event should suddenly decrease, the sweep and audio "beep" temporarily stop while the trigger circuits search for lower amplitudes. However useful information continues to be available. The CRT spot will appear at the lefthand edge of the graticule and any available heart signal will cause the spot to bounce vertically. If, within two to four seconds, the triggering circuits have not found a lower amplitude signal, the audio "beep" restarts, sounding at a rapid rate to serve as an alarm.

The operating room presents several unique restrictions to the use of instrumentation. The area immediately surrounding the operating table is often crowded with people and equipment. Certain of these people must move around during the operation and their pathway must not be obstructed by equipment, patient monitoring cables or power cords. *Battery operation* of the Type 410 avoids power cords across the floor.

A suitable location for the Type 410 is available on the anesthesiologist's gas machine. This machine is usually located near the patient's head and is a wheeled cart containing gas cylinders, distribution manifolds, valves, flow gauges, etc. There is often a set of drawers in a cabinet which provides a small table top. Hoses from the gas machine connect to the face mask through which the patient breathes. By mounting the Type 410 on this machine, the patient cable parallels the hoses to the patient and therefore is not an added obstruction to traffic. The instrument is then at a convenient viewing distance for the anesthesiologist and the controls are within easy reach.

An optional mounting fixture is available for mounting the Type 410 to the side of the gas machine so that the much-needed table space is not occupied. The mount can be attached to a flat surface on the side of the drawer cabinet or to one of the vertical pipes used as structural support in some machines. The Type 410 is supported five feet above the floor by the mounting fixture in order to comply with safety regulations, and is a convenient level which permits most members of the surgical team to see the display when desired.

When a surgical operation is completed, the patient must often remain under close observation for several hours. The first stage of observation usually takes place in the recovery room adjacent to the operating room. It is sometimes undesirable to interrupt the electronic monitoring of the patient while moving from surgery to recovery room. The battery-operated Type 410 simply lifts off the mounting fixture and is easily carried along with the patient for continuous monitoring.

MEASUREMENT BARRIERS

The real test of any physiological monitor is the fidelity with which it displays the bioelectric signal. The human body is considerably less than an ideal signal source. The signals of interest are small, about one millivolt. Unless the body is grounded, it usually bears an interfering 60-Hertz signal of several volts which is electrostatically induced by power line sources such as nearby lighting fixtures and appliances. This signal will

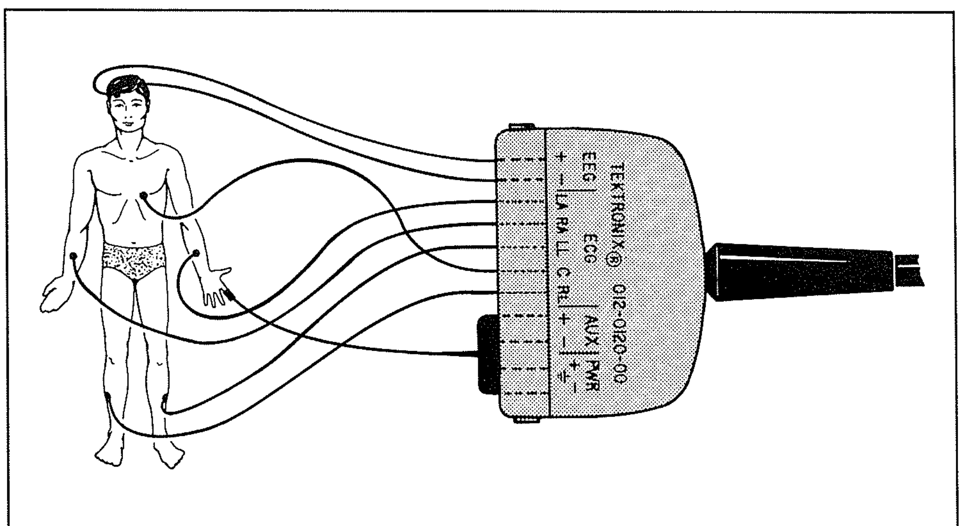


Fig 6. Electrode and Sensor Connections for Cross Correlation of Signals

be common to all active signal leads to the monitoring device and is termed common-mode signal.

The outer layer of skin is of comparatively high resistance and is therefore an undesirable element in the signal path. Moreover, when a metallic electrode is placed upon the body, the body fluids constitute an electrolyte and one-half of a battery is formed. Dissimilarities among the several electrodes on the body can cause a DC voltage to exist between them. But since they form a poor battery, the terminal voltage can vary with patient movement, perspiration, etc. This voltage variation cannot be separated from the desired bio-electric signal and therefore must be eliminated at its source.

Certain desirable characteristics of a physiological monitor can now be described. High skin resistance must be reduced and any voltage difference between electrodes must be small and stable. The monitor should be unaffected by the common-mode interference signal.

The ability of a monitoring system to reject a common-mode signal is often limited by an inability to transport the common-mode signal to the monitor by the two different paths without having the signal arrive at the monitor in dissimilar forms. If this happens, at least part of the signal is no longer in common mode, but has become a differential signal which cannot be rejected by the monitor. This problem can occur due to the skin resistance at each electrode forming an attenuator with the shunt input impedance to circuit ground within the monitor.

It is common practice to use a saline paste under each electrode to impregnate the skin, thus reducing the resistance between the highly conductive body fluids and the electrode. This can reduce skin resistance from a high of perhaps one megohm to as little as a few hundred ohms with careful preparation. However, a more practical degree of skin preparation will result in resistances ranging from one to five kilohms. Since it is highly unlikely that the resistances at the various electrode sites will match, it is probable that dissimilar attenuators will be formed with the monitor input circuitry. A few simple calculations will show that shunt impedances to circuit ground within the monitor of several hundred megohms are required to reduce this effect to an acceptable level.

The Type 410 provides excellent common-mode interference rejection capabilities by actively driving the shunt impedances in the input circuitry. This technique is called "guarding" and effectively multiplies the input impedances to several thousand times their actual values. The common-mode signal therefore arrives at the monitor in a form which permits virtually complete rejection.

The silver/silver-chloride electrodes supplied with the Type 410 eliminate virtually all of the electrochemical problems associated with ordinary electrodes. These small electrodes can be comfortably worn by the patient for many hours at a time. Electrode adapter cables are also provided with the

Type 410 which permit the use of many other standard electrode types.

POWER REQUIREMENTS

The Type 410 obtains power from a removable battery pack in the rear of the instrument. The pack contains ten rechargeable size "C" Nickel-Cadmium cells and a complete line-operated charger. Recharging is started by simply inserting the power cord into the rear of the battery pack. The battery provides eight to twelve hours of instrument operation for each recharge.

When the Type 410 is used in an Intensive Care Unit, continuous operation for days or weeks may be required. This presents no problem. With the power cord attached, the instrument can operate indefinitely because the charging current slightly exceeds the current required by the monitor.

PACKAGING CONCEPTS

The top, bottom, and sides of the Type 410 are rugged aluminum-alloy castings which provide an easily cleaned, dust-tight cabinet. The monitor weight is only 12½ pounds including the battery pack. Eighteen handle positions are provided for carrying or for tilting the instrument to the best viewing angle. The handle hub is specially shaped to fit into a cup-shaped bracket on the mounting fixture (Fig. 7).

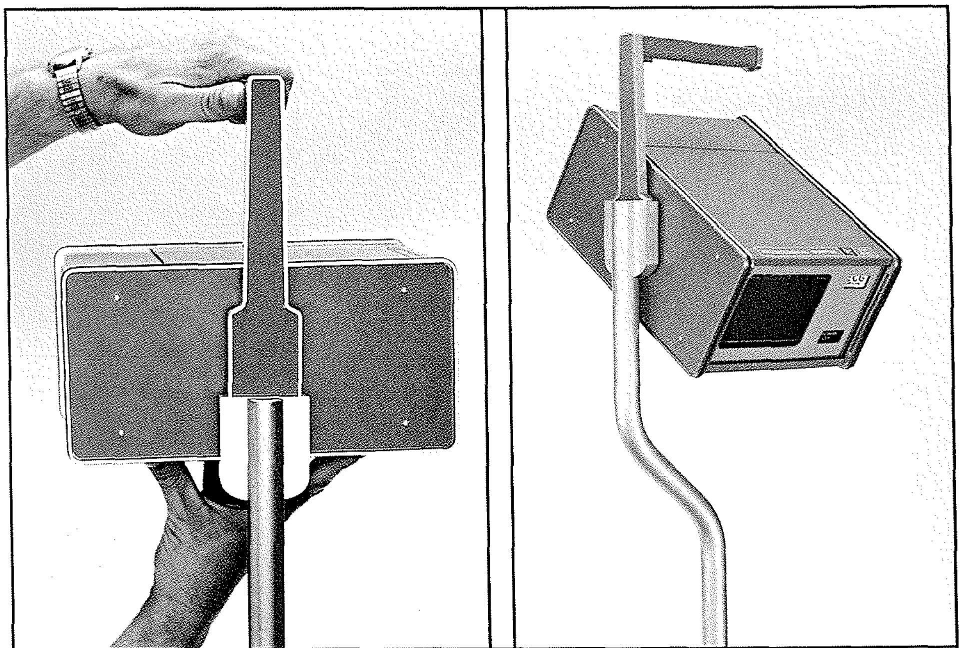


Fig 7. Attaching the Type 410 to the Mounting Stand

SUMMARY

The Type 410 Physiological Monitor was designed for patient surveillance. Only a few of the many necessary considerations have been discussed here; the physiological signals, the intended user, the environment, the fidelity of signal display, etc. The area of possible application is broad.

Output signals available from the rear of the monitor can drive a recorder to provide a permanent record as is usually required in diagnostic applications. This portable, simple-to-operate instrument will also find application in medical research with both people and animals, as well as in Veterinary Medicine.

TYPE 410 PHYSIOLOGICAL MONITOR CHARACTERISTIC SUMMARY

VERTICAL

Bandwidth

ECG and AUX	≤0.1 Hz to 250 Hz ±15%
EEG	≤0.1 Hz to 100 Hz ±15%

Calibrated Deflection Sensitivity

Display mode	Deflection Sensitivity	Accuracy ≤20 mV DC offset	Accuracy At 100 mV DC offset
EEG	10 mm/50 μV	±5%	0 to −10%
ECG	20 mm/mV	±5%	0 to −10%
AUX	2 mm/mV	±5%	0 to −10%

Vertical Size Range ≤ X1/3 to ≥ X3

Differential Input Resistance

EEG and ECG	2 MΩ ± 15%
AUX	20 MΩ ± 15%

Differential Dynamic Range

At least 100 mV of either polarity

Common Mode Rejection Ratio

With ≤5-kΩ Source Impedance unbalance (at 60 Hz) and using properly applied electrodes.

EEG	≥ 150,000:1
ECG	≥ 150,000:1
AUX	≥ 150,000:1

Common-Mode Dynamic Range

+3 V to −3 V

Drift

≤0.5 cm/h (after 10 s warm-up)

Nondestructive Input Voltage Limits

Instrument need not be disconnected from patient during DC defibrillation or cautery

Differential Overload Recovery Time

≤4 seconds (all cases)

TRIGGER

Trigger Requirements

0.5 cm ECG display (≥ 40 beats/min)
0.5 cm blood pulse display (≥40 pulsations/minute)

Delay Before Sweep Free-runs

2 to 4 s after last trigger

HORIZONTAL & AUDIO

Sweep Speed

25, 50, 100 mm/s ±5%

Battery Check Scale

Green—Normal Operation
Yellow—Recharge needed
Operation not harmful to instrument
Red—Do not operate

Heart Rate Scale Accuracy

±5% of reading (50 mm/s range, 35 to 110 beats/min)

Audio

Audio "Beep" at heart rate with alarm activated upon loss of signal

POWER SOURCE

Line Voltage

90 V to 136 VAC
180 V to 272 VAC

Line Frequency

48 Hz to 440 Hz

Battery Operating Range

11.9 V to 15.0 V

AC Input Power

≤7 W at 115 V, 60 Hz

Battery Pack

Ten Size "C" NiCd cells; 1.8 Ah

Charging Time

14 to 16 hours

Discharge Time

8 to 12 hours operation with maximum accessory load at +20° to +25° C

OTHER

Turn-on time

≤4 sec

Warm-up time

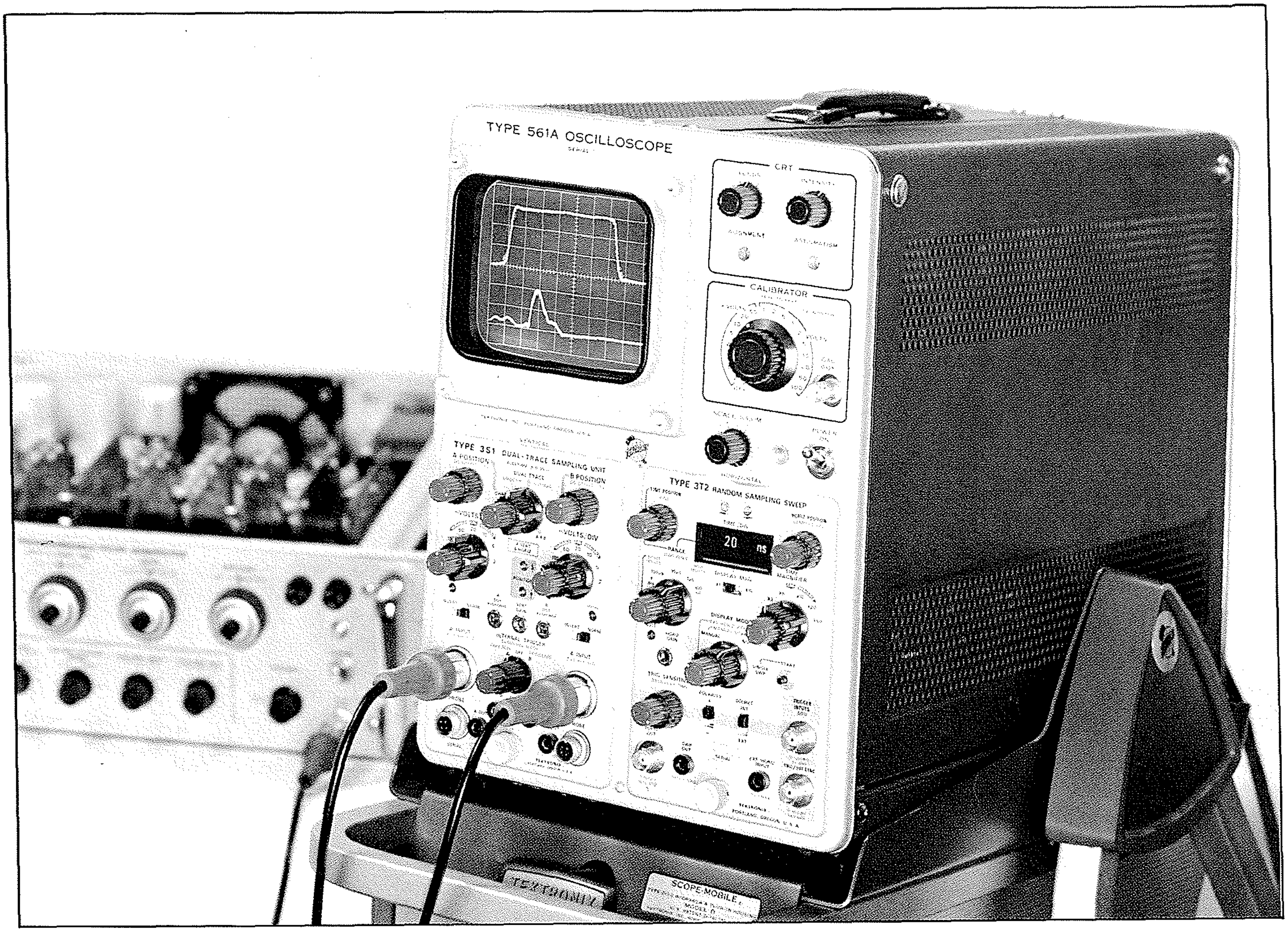
≤10 sec

CRT

5" with P-7 phosphor

RANDOM SAMPLING—
A NEW WAY OF FAST PULSE DISPLAY

by Al Zimmerman



INTRODUCTION

The Type 3T2 Random Sampling Sweep Unit provides a unique state of the art advancement in measurement capability. It permits observation of the leading edge or other portions of the signal even when used with vertical units that have *no delay lines and without a pretrigger.*

The advantages of eliminating delay line or pretrigger application are evident:

1. The inherent distortions and risetime limitations of signal delay lines are eliminated.

2. It is no longer necessary to work into the 50-Ω characteristic impedance of a delay line, so that direct sampling probes may be used for convenient high-impedance in-circuit signal pickup.

3. Trigger may occur prior to, coincident with, or after the displayed signal without sacrificing lead time in the display.

4. Signals with no convenient source of a stable pretrigger can be observed without display jitter.

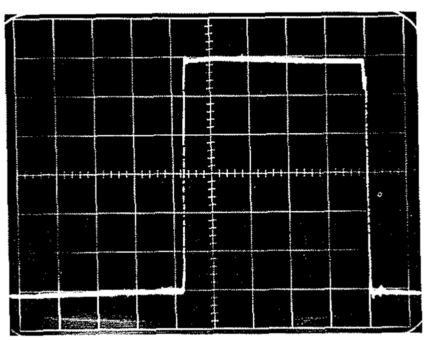


Fig 1A. 3T2 Unit in "BEFORE TRIGGER" mode: the leading edge can be observed.

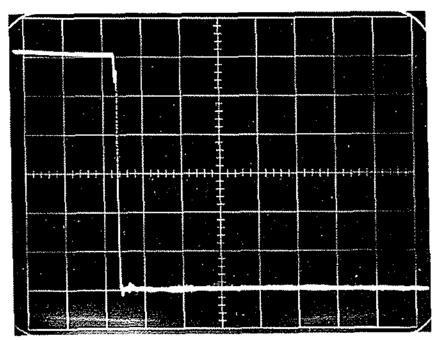


Fig 1B. 3T2 Unit in "WITH TRIGGER" mode (conventional sampling): the leading edge cannot be observed without a delay line or pretrigger.

HOW RANDOM SAMPLING WORKS

In the following explanation of the principles of the Random Sampling process, (how it is used in Tektronix Type 3T2 Plug-in Unit) an understanding of conventional sampling is advantageous.

The Random Sampling process is composed of two basic operations:

1. Originating the sample pulses randomly distributed in a time window around the part of the signal to be displayed.

2. Constructing a pulse display by deriving two analog signals, representing X and Y coordinates, from a series of those samples.

ORIGINATING THE SAMPLE PULSES

To find the right time for originating the samples a "Trigger Rate Meter" is used, which measures the trigger repetition rate. This rate meter gets its input from the trigger recognizer and holdoff circuit. On the basis of several sequential trigger rate measurements, the rate meter starts a negative going signal (slewing ramp) which generates samples within the time window. The start time of this slewing ramp is *before* the next trigger signal (ΔT) and is a forecast resulting from the previous trigger-rate measurements. So it can be seen that the start time of the slewing ramp is not in a fixed time relation to the next trigger signal, but more the "best guess" of the rate meter.

The display thus becomes a random sampling display because of the inability of the rate meter to make a perfect "guess" of when to take a sample.

The rate meter provides maximum display dot density by gathering the samples around just that section of the waveform that is used for the CRT display (see Fig. 2). This time window can be a very small portion of the total signal period. The samples which fall outside the time window do not have any contribution to the display construction and are kept as few as possible.

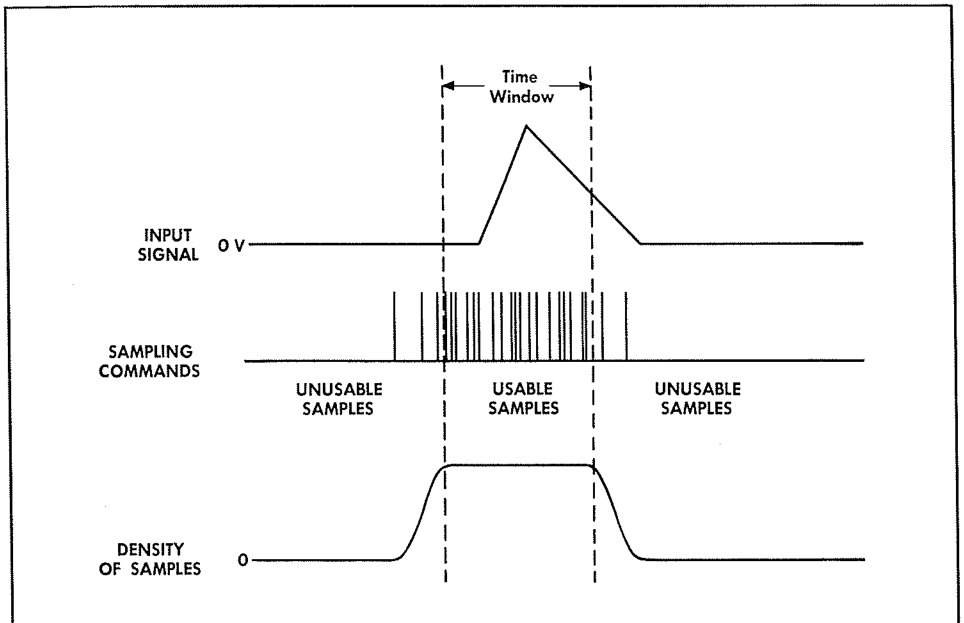


Fig 2. Distribution of samples over a time window, which covers the section of the signal to be displayed.

Error Correction

If too many samples fall outside the time window, on either one side or the other, a correction of the rate meter "guess" has to be made. The principle of that correction is based on a comparison (dot position comparator) of the horizontal signal with the staircase signal. An error signal is generated when the horizontal signal does not track along with the staircase on a basis of an average of many samples. The error signal adjusts the rate meter to make a better "guess" or forecast for the next start of the slewing ramp. Fig 3 shows the correction loop.

CONSTRUCTING A PULSE DISPLAY

In order to be displayed, a sample must have a particular time relationship to the sampled pulse. The rate meter has tried to place each sample within the time window. If a sample does occur in this time window, a dot is displayed on the CRT.

The "Y" or vertical coordinate of a sample is obtained by the same sample-and-hold process used in a conventional sampling oscilloscope. The "X", or horizontal, coordinate of the sample is obtained differently, however, and this process is illustrated in Figure 4.

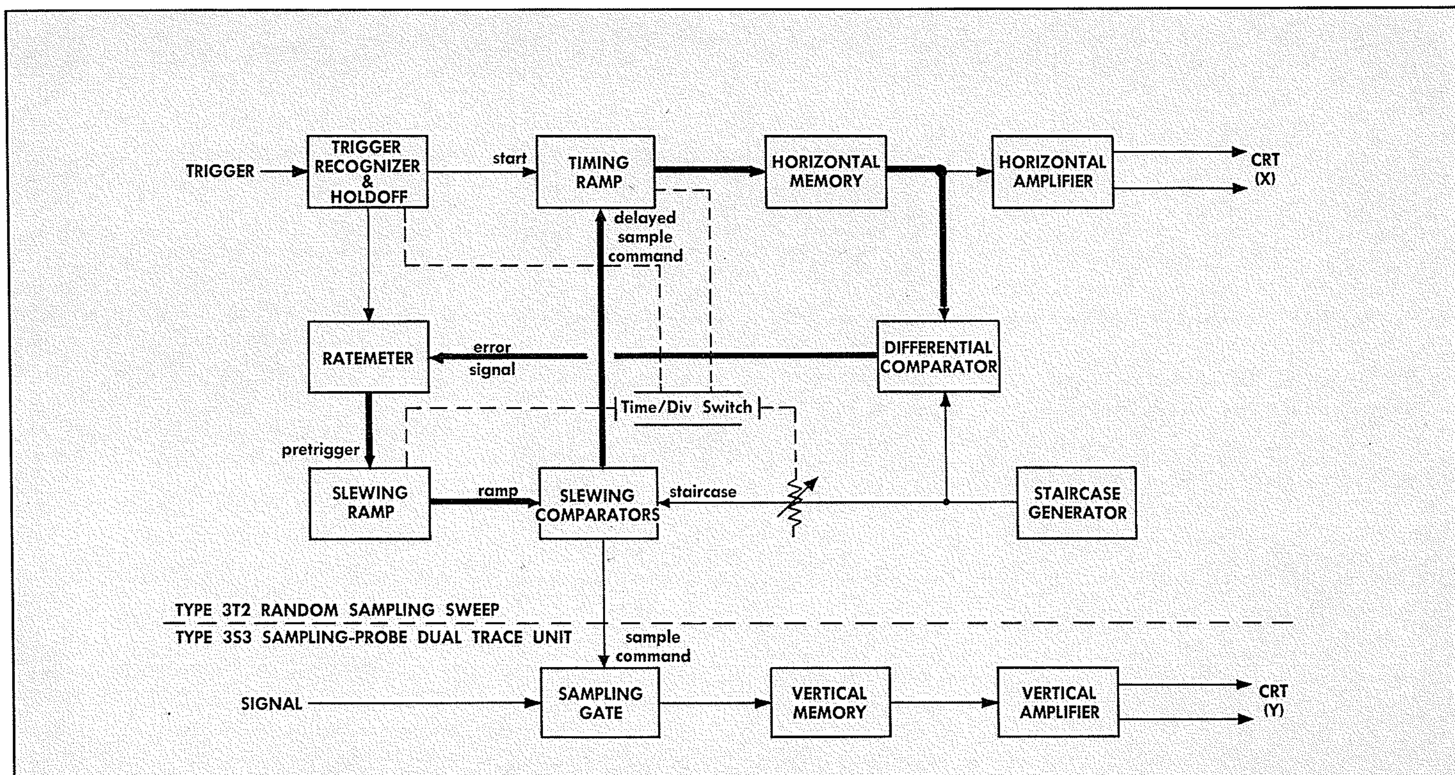


Fig 3. Block diagram of the Random Sampling process used in Tektronix Type 3T2. The dark line shows the correction process for the slewing ramp start.

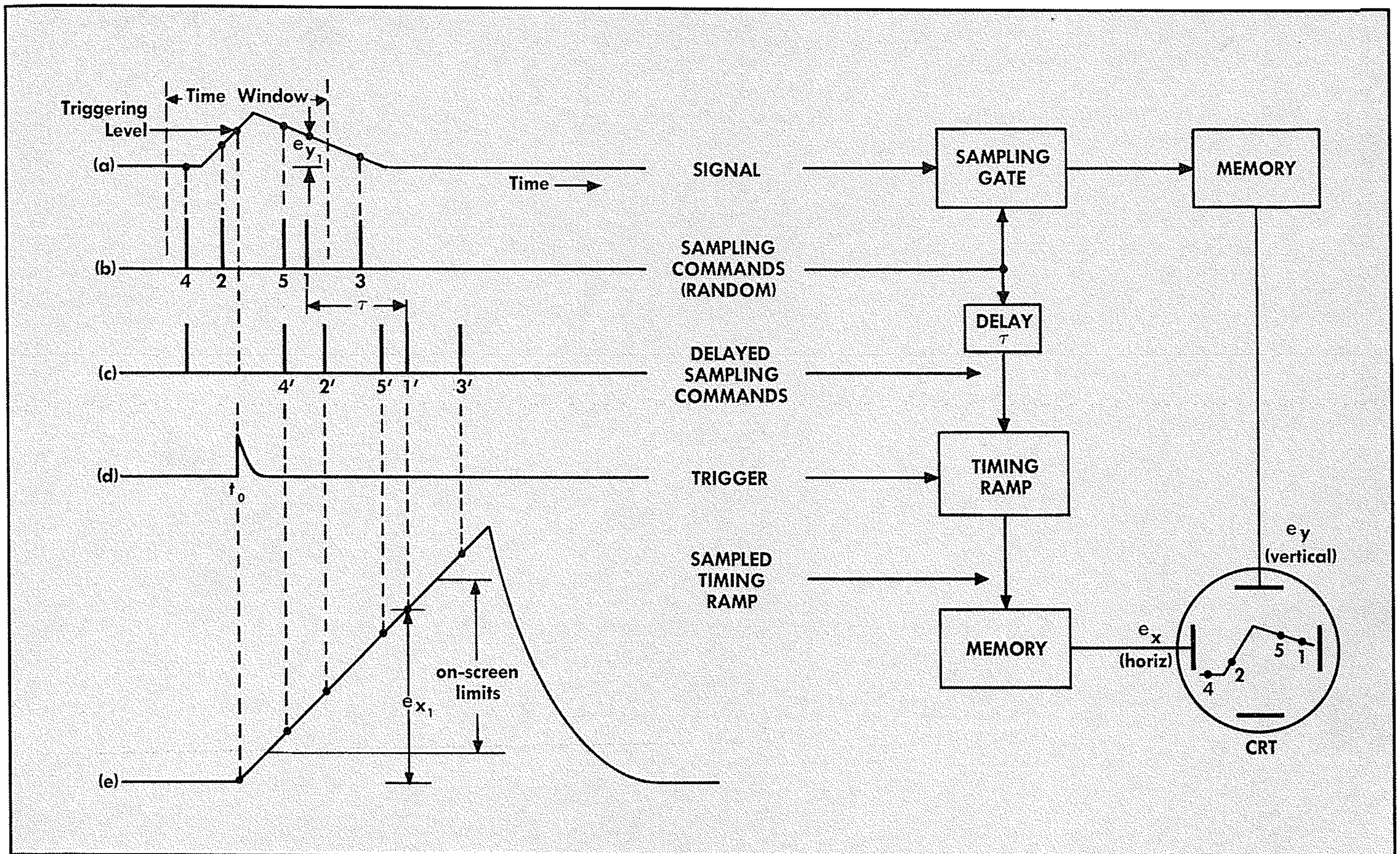


Fig 4. Derivation of "x" and "y" deflection signals.

As shown, five randomly placed samples are taken of the signal. It must be kept in mind that these five samples are taken on SUCCESSIVE repetitions of the signal. They are random samples in the "best guess" time window.

The y-component, e_y, of the first sample is held and subsequently used to position the CRT spot vertically. The sampling command which took the first sample is then delayed by a *fixed interval* τ, as indicated in Figure 4c. This delayed sampling command 1′ is used to sample a timing ramp which was started by trigger recognition along the input signal at t_0. The resulting sample e_x is held and subsequently used to position the CRT spot horizontally.

By this same process subsequent samples supply both vertical and horizontal information to deflect the CRT beam from dot to dot thus constructing a display of the signal from those samples which fall within the time window.

Some reflection will show that as the fixed interval τ is increased, more lead time will appear in the display. It should be clear that such an increase in τ for more lead time will also require a time shift of the sampling distribution to the left in Figure 4b (i.e. earlier in time) in order that the required information be collected for the display.

Figure 3 shows a complete operational block diagram of the random sampling oscilloscope including those portions which control the distribution of samples across the time window.

CHARACTERISTICS

SWEEP TIME/DIV

100 μs/div to 200 ps/div, 1-2-5 sequence, extending to 20 ps/div with X10 DISPLAY MAGNIFIER. Basic accuracy without X10 magnifier, ±3%; with magnifier, ±5%. TIME/DIV is a resultant of the combined settings of TIME POSITION RANGE, TIME MAGNIFIER, and DISPLAY MAG. The sweep rate is displayed (digitally) in the TIME/DIV "window" for all combinations of these controls.

TIME POSITION RANGE

100 ns, 1 μs, 10 μs, 100 μs, and 1 ms. TIME POSITION and FINE variable controls position start of the display through a time scale equal to TIME POSITION RANGE setting.

SAMPLES/DIV

Continuously variable adjustment of samples displayed per horizontal division from approx 5 samples/div to an immeasurable number of samples/div.
An internal switch, CALIBRATED SAMPLES/DIV, disables the front-panel SAMPLES/DIV control and converts to 100 samples/div, calibrated, for use in Digital Oscilloscopes.

START POINT

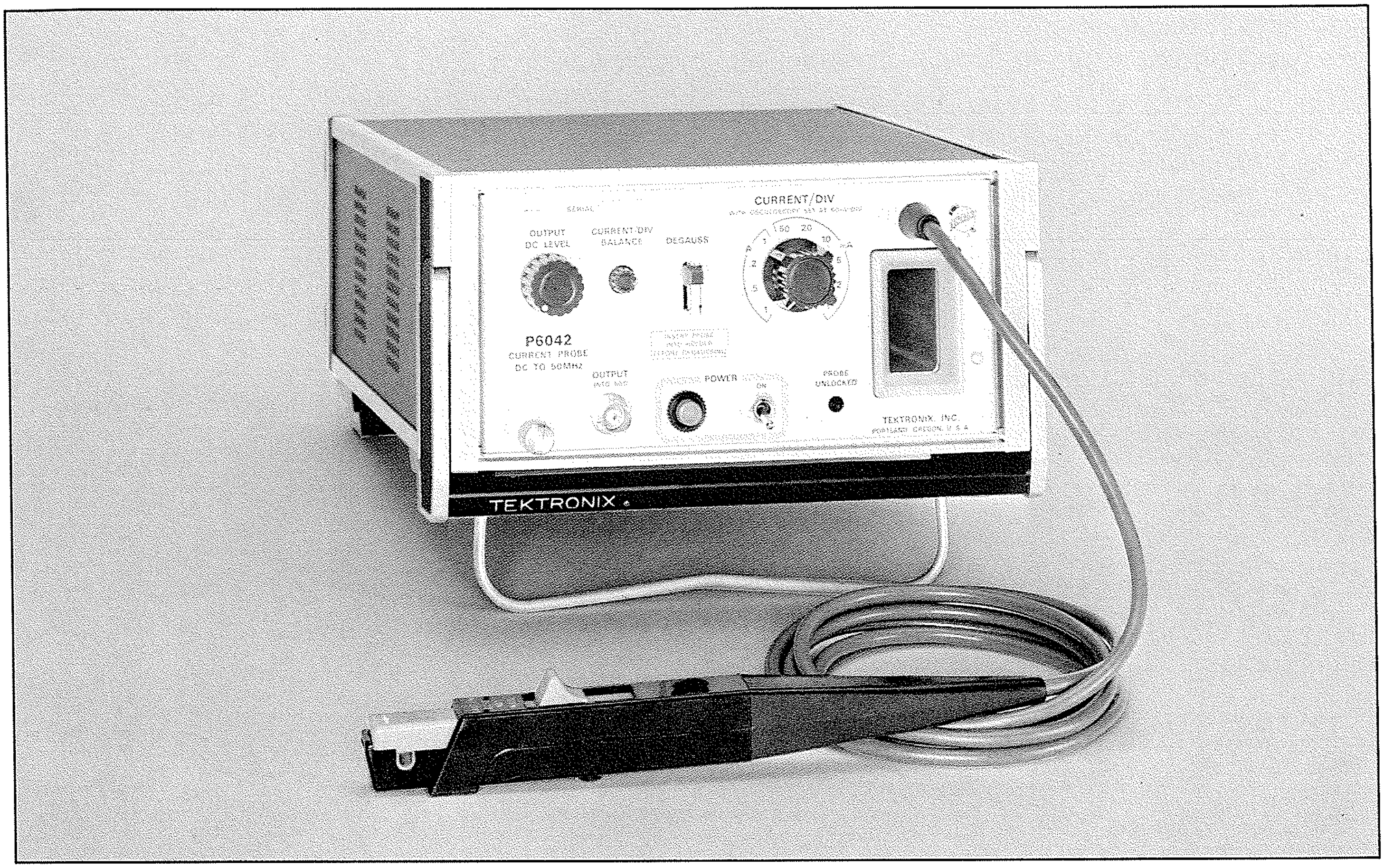
Two-position switch (concentric with TIME POSITION RANGE switch) selects either random sampling (BEFORE TRIGGER) or conventional, sequentially-stepped sampling (WITH TRIGGER).
In BEFORE TRIGGER mode, the displayed "time window" may be positioned in time up to one-half times the TIME POSITION RANGE setting ahead of the trigger. This provides a base line up to 5 divisions long before the leading edge of the pulse to be viewed.

TRIGGER JITTER

Depends on signal shape, repetition rate, triggering mode. May be as low as 30 ps under optimum conditions.

P6042 DC-to-50 MHz CURRENT PROBE

by Cal Hongel



INTRODUCTION

Current probes have become increasingly useful and popular with the expanding use of semiconductor devices which are current sensing devices (current amplifiers). A new current probe has just been developed at Tektronix that provides unique measurement capabilities.

Utilizing the Hall-effect plus AC current probe technology (P6019/P6020), the P6042 DC-to-50 MHz current probe can be used simultaneously for both high-frequency and direct-current measurements. AC signals with DC components can be displayed on an oscilloscope with true waveform presentation. The probe is particularly useful for evaluating the performance of semi-conductor circuits where a wide range of parameters exist. Fast switching transients, low-frequency response, and DC level can all be displayed simultaneously (Figure 1). The P6042 can also be used to measure the sums or differences of currents in separate wires. When the probe is clipped around two wires carrying current in the same direction, the sum is displayed; around two wires carrying current in the opposite direction, the difference is displayed. For increased sensitivity the wire can be looped through the probe several times increasing the sensitivity by the number of loops.

The probe is easy to use. The conductor is simply placed into the slot of the probe and the spring loaded slide closed . . . no need to break the circuit under test. Measurements can be made only when the probe is in the locked position (push slide forward to lock). A warning light on the front panel indicates when the slide is in the unlocked position. A compartment is provided in the front panel for convenient storage of the probe when the system is not in use and an inter-lock is provided in this compartment for degaussing the probe. The probe can be degaussed only when in the compartment to prevent possible damage to the circuit under test.

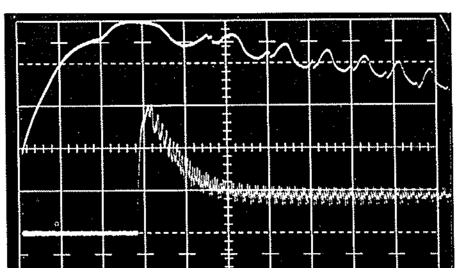


Fig 1. Double exposure photograph using the P6042 and a Type 547/1A5 Oscilloscope to display the current characteristics of a small DC motor. Lower display shows the zero current level, starting current, and running current. Current/div setting is 0.2 A/div with a sweep rate of 50 ms/cm. In the upper display, the sweep rate is increased to 5 ms/cm to show the current change as the commutator bars pass the brushes.

DESIGN CONCEPTS

The P6042 Current Probe includes a sliding-core type probe and associated amplifier as shown in Figure 2. The probe contains a stationary core around which is wound a 50-turn secondary, a moveable core which slides over the end of the stationary core and the current-carrying conductor, and a Hall voltage device. The amplifier houses the power supplies, low-frequency amplifiers, attenuators and the output amplifier.

High Frequency

High-frequency measurements are made in the same manner as in an AC current probe. The AC current probe is basically a transformer. The current-carrying conductor forms a one-turn primary winding for the transformer; the windings in the probe around the core form the 50-turn secondary winding. The relationship between the current, voltage and turns is shown below:

$$N_p I_p = N_s I_s$$

For a one-turn primary,

$$I_p = N_s I_s$$

Then for a 50-turn secondary,

$$I_s = \frac{I_p}{50}$$

The secondary voltage is

$$E_s = I_s\, R_s$$

R_s is 50 Ω, so $E_s = \frac{I_p}{50}\ (50\,\Omega)$

or $\qquad E_s = I_p\ (\Omega)$

For AC signals the voltage output of the current probe into the secondary load (R_s) is 1 mV per mA of input current.

DC and Low Frequency

The heart of the DC measurement capability is a highly-sensitive Hall device developed by the Tektronix Integrated Circuit Department. The Hall device is located in a cross section of the ferrite core contained in the probe head. At the point where the AC response of the core becomes ineffective due to the low-frequency L/R time constant of the core, the back EMF of the secondary no longer cancels the flux generated in the core by the primary current. The flux remaining in the core (primarily flux due to DC and low-frequency current) passes through the Hall device generating a small voltage directly related to the applied field. Figure 3 shows the current, voltage, and flux relationship of a Hall device.

The Hall device voltage (about 50 μV per mA of applied current) is amplified by the operational amplifier (A-1) and applied to the 50-turn secondary, to cancel the remaining flux in the core. Most of the flux in the core is cancelled either by the back EMF of the secondary or by feedback from the operational amplifier. As a result, the non-linearity of the core does not affect accuracy, nor does it directly limit maximum current handling ability. At DC and low frequencies, the operational amplifier supplies an output across the secondary load (R_s) of 1 mV per mA of primary current.

The maximum input current is related to the current handling ability of the operational amplifier. To handle ± 10 A in the primary, the amplifier (A-1) must supply $10\text{ A} \times \frac{1}{50}$ to the 50-turn secondary to cancel the flux at DC and to supply ± 200 mA across R_s.

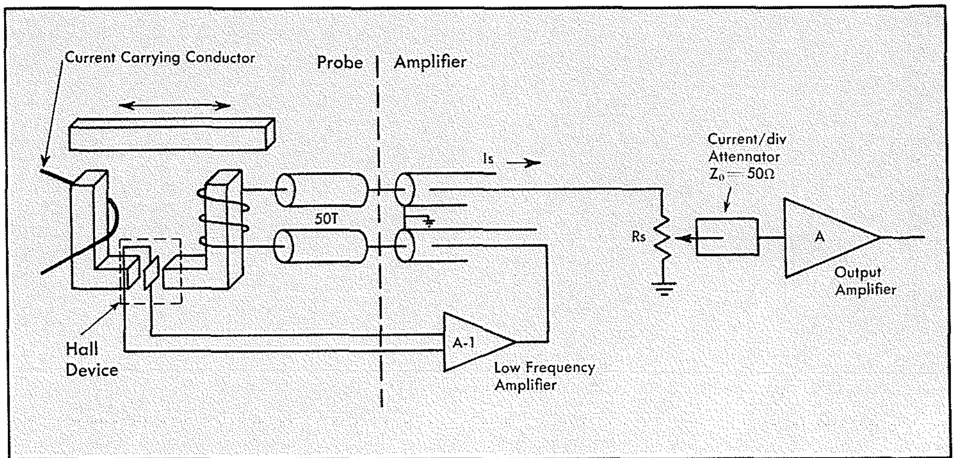


Fig 2. Block Diagram of P6042 Probe.

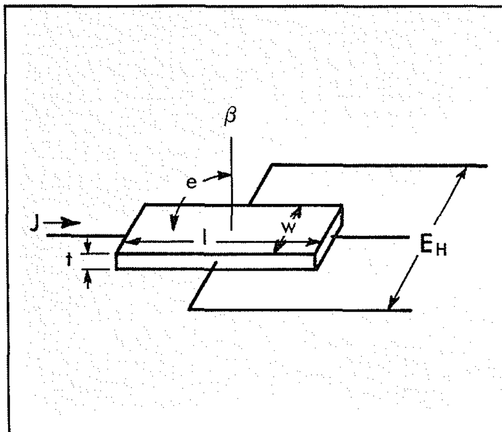


Fig 3. Hall device.

The Hall device is a thin rectangular sheet of semiconductor material sandwiched in the stationary portion of the transformer core. The Hall effect is a voltage generated across opposite edges of a current carrying conductor placed in the magnetic field.

The basis for the effect is the Lorentz force which is the deflection of charged particles moving in a magnetic field. The force is both perpendicular to the direction of the particle (current) flow and the direction of the magnetic field.

Equation follows:

$E_{Hall} = wR_H\ J\ \beta\ \sin\ \phi$

E_{Hall} = voltage from Hall device

w = width of Hall element

R_H = Hall coefficient

J = current density

β = field strength

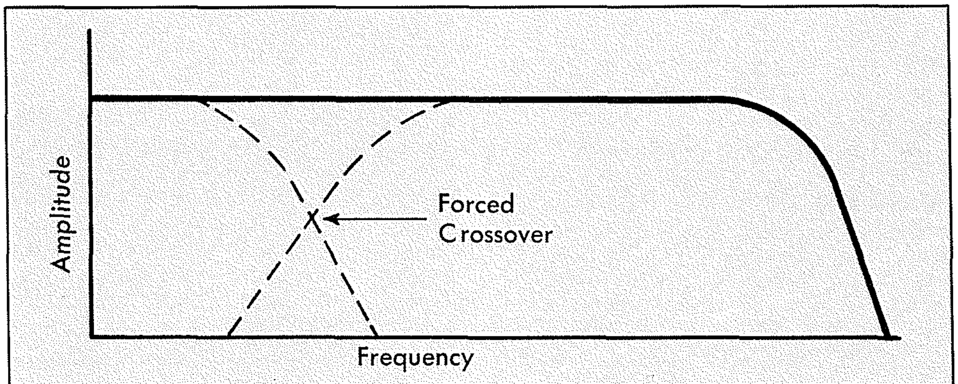


Fig 4. Forced crossover.

Attenuator and Output Amplifier

The current induced in the secondary by the primary (at high frequency) and the current applied to the secondary at low frequency by amplifier (A-1), produces a voltage across the secondary load that is directly related to the input current. The adding of the low-frequency signal to the high-frequency signal is done in such a way as to force one to take over where the other leaves off (see Figure 4). This is commonly known as a forced complement system.

The sensitivity at this point is 1 mV output for a 1 mA of primary current (input current). The 50-Ω secondary load is in the form of a 50-Ω attenuator that provides attenuation of up to 1000X (1 A/div) in 10 steps with a 1-2-5 sequence. The signal from the 50-Ω attenuator is applied to a 50X DC-to-50 MHz output amplifier. The output amplifier supplies an output of 50 mV per mA of primary current or 1 mA/div with the oscilloscope deflection set at 50 mV/div.

The P6042 output amplifier has an output impedance of 50 Ω. A 50-Ω termination is supplied with the P6042 probe for use with oscilloscopes having 1-MΩ inputs.

CIRCUIT LOADING

All probes load the circuit under test in one form or another. Voltage probes have input capacitance and DC resistance. Current probes load in a different manner. They have an insertion impedance due to the secondary load being reflected into the primary and very low-capacitive loading.

Reflected Load

The secondary inductance and load resistance is reflected through the turns ratio squared and appears as a series load in the primary (current-carrying conductor). Calculations of the typical reflected loading of P6042 current probe is shown below:

$$R_p = \frac{R_s}{T^2} = \frac{50\,\Omega}{(50)^2} = 0.02\,\Omega$$

$$L_p = \frac{L_s}{T^2} = \frac{0.5\text{ mH}}{(50)^2} = 0.2\,\mu\text{H}$$

Shield Inductance

Another factor affecting circuit loading is the reflection of the current probe shield into the current carrying conductor. The shield appears as a shorted turn around the conductor. Leakage inductance also appears in series with the primary.

Stray Capacitance

The only other factor involved with circuit loading is the stray capacitance between the probe and the conductor. This capacitance depends on the size of the current carrying conductor and its position in the hole. It is typically 1 pF and can be measured using a Type 130 LC Meter. As with voltage probes, stray capacitance can limit the risetime of the measurement ($T_{rise} = 2.2\ R_{source}\ C_{strays}$). By inserting the current probe on the ground or B+ side of the load resistor the stray capacitance loading can be reduced.

The total insertion impedance can best be represented by the graph in figure 5.

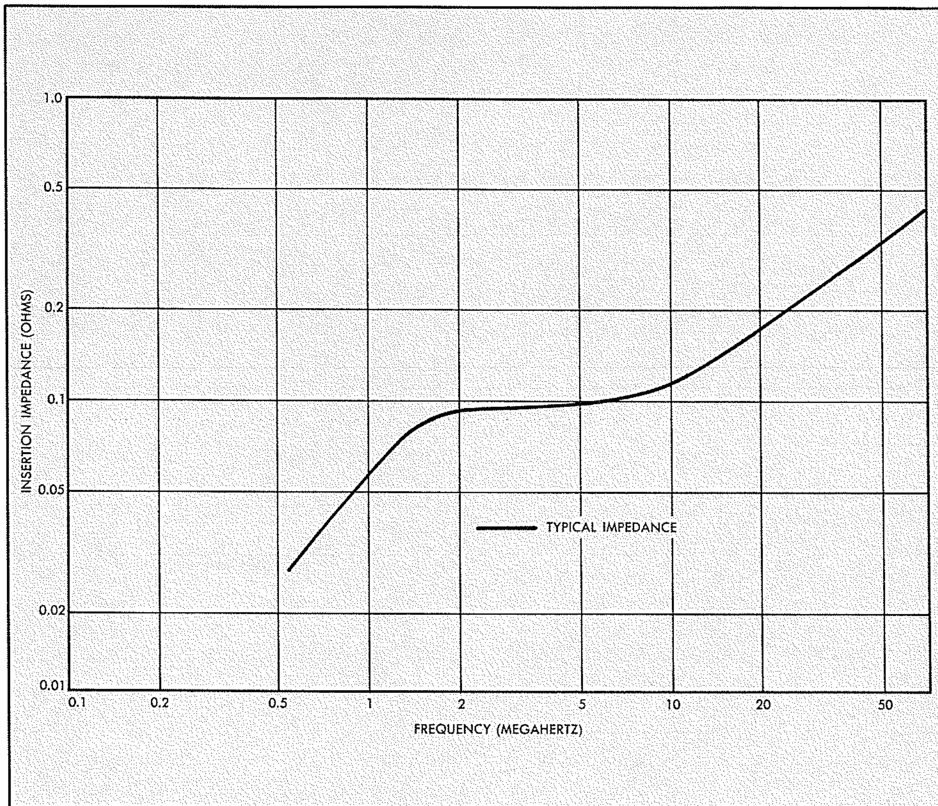


Fig 5. Insertion impedance.

PROBE DEGAUSSING

Whenever a magnetic field is applied to the transformer core in the probe with the system turned off, or if a current beyond the maximum specified level is applied, the core may become magnetized. A portion of this magnetic flux is likely to remain in the current probe core causing measurement errors. To remove this flux the probe is placed in the storage compartment and the degaussing switch is depressed. The degaussing switch connects the 50-turn secondary winding to an oscillator as shown in Figure 6. The oscillator produces a 10-kHz exponentially decreasing sinewave which initially saturates the core. The decaying current eliminates stored flux due to core hysteresis.

An interlock switch for the degaussing oscillator is provided in the probe storage compartment. The switch eliminates any possibility of introducing transformed current from the oscillator into the test circuit. The compartment, accessible from the front panel, provides convenient storage for the probe when not in use.

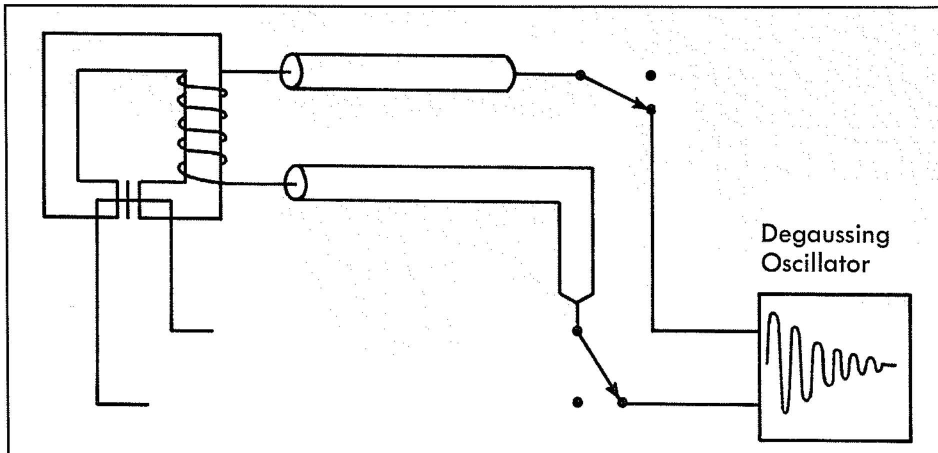


Fig 6. Probe degaussing.

CHARACTERISTICS

Probe and Amplifier

SENSITIVITY is 1 mA/div to 1 A/div in 10 calibrated steps, 1-2-5 sequence, accurate within 3% (with an oscilloscope deflection factor of 50 mV/div).

BANDWIDTH is DC to 50 MHz at 3-dB down.

RISETIME is 7 ns or less.

DYNAMIC RANGE is + and − 10 divisions of display.

NOISE (periodic and random deviation) is 0.5 mA or less plus 0.2 or less major divisions of display. Random trace shift is 1.5 mA or less.

THERMAL DRIFT is 2 mA/°C or less, plus 0.2 or less major division of display per °C.

MAXIMUM INPUT CURRENT is 10 A (DC plus Peak AC).*

*Peak-to-peak current derating is necessary for CW frequencies higher than 2 MHz. At 50 MHz, the maximum allowable current is 2 A.

MAXIMUM INPUT VOLTAGE is 600 V (DC plus Peak AC).

OUTPUT IMPEDANCE is 50 Ω through a BNC-type connector. A 50-Ω termination is supplied with the probe for use with 1-megohm systems.

AMPLIFIER POWER REQUIREMENT is approximately 10 W, 50 Hz to 400 Hz. Quick-change line-voltage selector permits operation from 90 V to 136 V or 180 V to 272 V.

DIMENSIONS AND WEIGHT of the amplifier are 4½ in. (11.4 cm) high by 7½ in. (19.2 cm) wide by 9¾ in. (24.8 cm) deep; 6½ lbs. (3.1 kg).

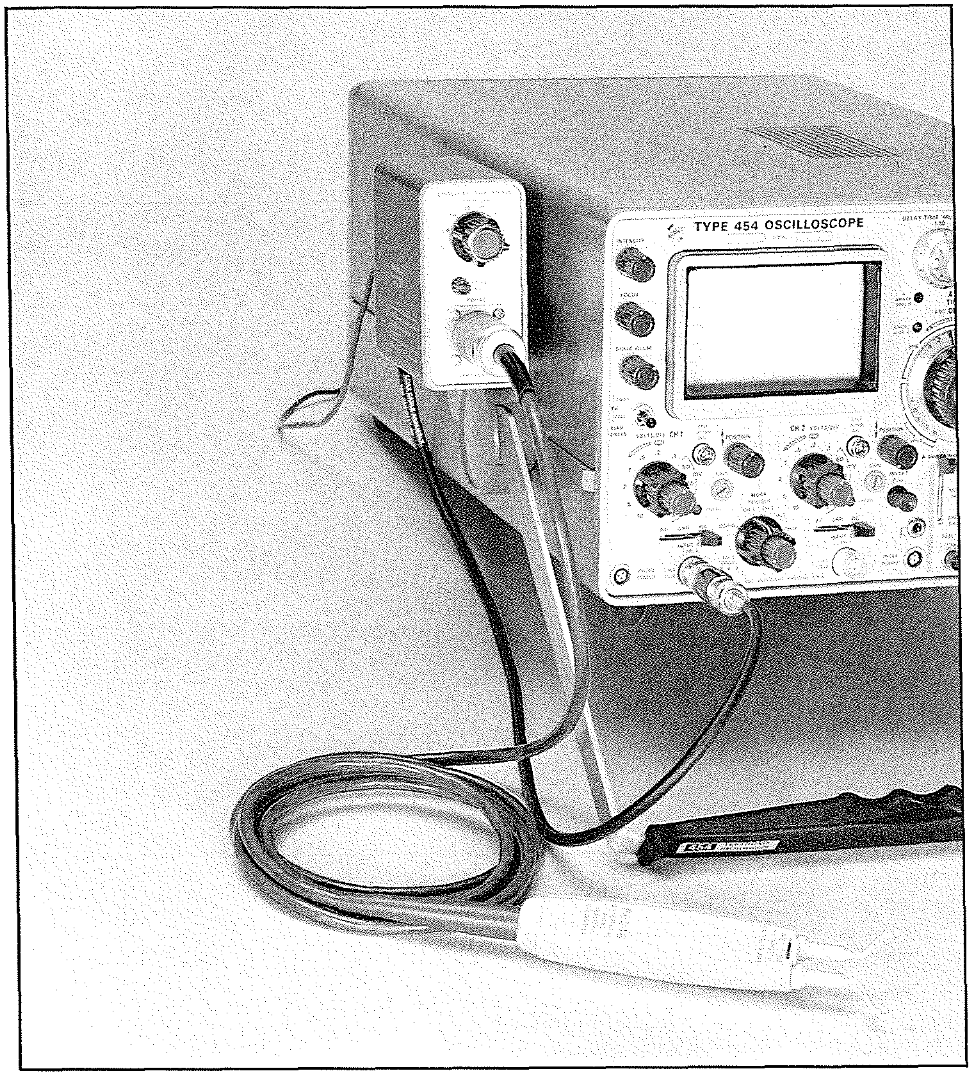
PROBE CABLE is 6 feet long, permanently connected between the probe head and amplifier.

P6042 DC CURRENT PROBE PACKAGE (010-0207-00)

Includes: 50-Ω BNC cable (012-0057-01); 50-Ω BNC termination (011-0049-00); 3-inch ground lead (175-0263-00); 5-inch ground lead (175-0124-00); two alligator clips (344-0046-00); 3-wire to 2-wire adapter (103-0013-00); instruction manual (070-0629-00).

P6046 DC-to-100 MHz DIFFERENTIAL PROBE AND AMPLIFIER

by Glenn Bateman



INTRODUCTION

The P6046 Differential Probe and P6046 Amplifier Unit provides new measurement capabilities when used with all Tektronix oscilloscopes. With this new probe system, the differential-signal processing takes place in the probe itself, resulting in high common-mode signal rejection at higher frequencies. Differential probe-tip signal processing minimizes the measurement errors caused by differences in probes, cable lengths, and input attenuators. In addition, the wide-band capability of the P6046 Probe and Amplifier provides DC-to-100 MHz single-ended measurement performance.

The P6046 probe circuitry utilizes 13 semiconductors including dual FET's for the balanced input. A switch on the probe selects AC or DC input coupling. Accessories include a plug-on 10X attenuator for increasing the differential input voltage range, and a ground tip for applications requiring single-ended input. Unique swivel tips provide variable spacing to accommodate the varying distance between test points.

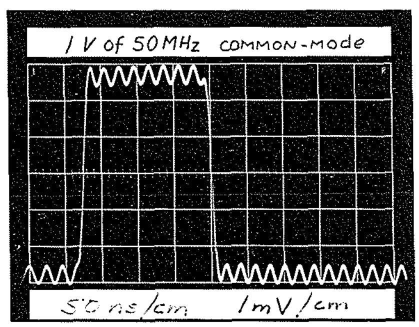


Fig 1. High-frequency differential measurement.

The P6046 Amplifier mounts conveniently on the side of the oscilloscope and features a calibrated 1 mV/div to 200 mV/div (2 V/div with 10X attenuator) deflection factor (oscilloscope deflection factor set at 10 mV/div). Output impedance of the amplifier is 50 Ω. A 50-Ω cable and termination is supplied with the amplifier for use with 1-MΩ systems.

DIFFERENTIAL AMPLIFIERS

The primary use of differential amplifiers is to measure the signal difference between two points that need not be referenced to ground.

An oscilloscope differential amplifier is a device that amplifies and displays the voltage difference that exists at every instant between signals applied to its two inputs. For example, two pulses that differ in both amplitude and coincidence that are applied to a differential amplifier will cause the oscilloscope display to be a complex waveform that represents the instantaneous difference between the two pulses. On the other hand, two signals that are identical in every respect will cause no output on the CRT screen (limitations to this statement will be described under Common-Mode Rejection).

The amount of difference signal due to common-mode signal that one can expect from a particular differential amplifier is specified by the common-mode rejection ratio (CMRR). This ratio and associated terms are defined as follows:

Common-Mode Signal—The instantaneous algebraic average of two signals applied to a balanced circuit, all signals referred to a common reference.

Common-Mode Rejection—The ability of a differential amplifier to reject common-mode signals.

Common-Mode Rejection Ratio (CMRR)—The ratio of the deflection factor for a common-mode signal to the deflection factor for a differential signal.

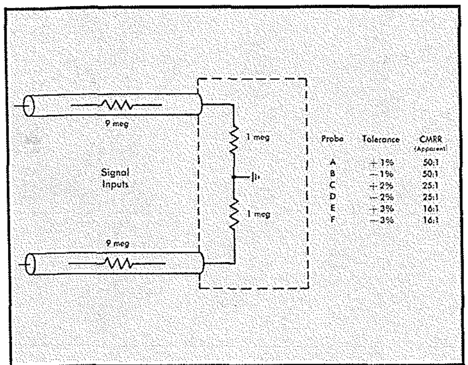
Differential Signal—The instantaneous, algebraic difference between two signals.

Measurements made with a differential amplifier should contain an allowance for the output voltage that is due to a common-mode signal. For example, if an amplifier with a CMRR of 1,000:1 is used to measure the difference between two similar five-volt signals, the output seen on the oscilloscope screen is the result of two voltages: (1) the actual difference between the input signals, and (2) the difference voltage that results from the common-mode signal. Because of this combination, the actual difference voltage cannot be exactly measured. Therefore, the voltage measured on the CRT screen should include a tolerance that is equal to the computed, or measured output voltage due to the common-mode signal.

In the above example, CMRR of 1,000:1 with a common-mode signal of 5 V, if a difference signal of 0.015 V is measured on the CRT, it should be recorded as 0.015 V ±0.005 V.

MEASUREMENT PROBLEMS

The major difficulty in making differential measurements is in connecting the signal source to the measuring device. Measurement errors can be caused by differences in probes, cable lengths, and input attenuators.



Probe	Tolerance	CMRR (Apparent)
A	+1%	50:1
B	−1%	50:1
C	+2%	25:1
D	−2%	25:1
E	+3%	16:1
F	−3%	16:1

Fig 2. Simplified input circuit and table that shows the change in CMRR (apparent) due to X10 probes that have a 1, 2, and 3% difference in their attenuation value.

Probes

Attenuator probes extend the usable voltage range of a differential amplifier by reducing the input signals to a level that is below the maximum common-mode linear dynamic range. In doing this, however, the probes may cause a reduction in the apparent CMRR due to component value differences within the probes. For example, Figure 2 illustrates the change in CMRR (apparent) due to X10 probes that have a 1, 2, and 3% difference in their attenuation value. Bear in mind that the reduction in apparent CMRR can also be caused by different values of the signal source resistance.

Cable Length

Probes and cables of different lengths may introduce enough signal delay between them to cause a difference voltage at the input to the amplifier. At 50 MHz, an 0.1-inch difference in cable length will reduce the CMRR from 1,000:1 to 250:1. Also an inductance difference due to a ⅛-inch difference of lead length at 50 MHz can reduce the CMRR from 1,000:1 to 400:1. Processing the differential signal in the probe reduces these problems.

Input Attenuators

To minimize measurement errors due to input attenuators, the P6046 Probe and Amplifier provides attenuation by reducing the differential gain and common-mode gain within the amplifier. High-frequency common-mode rejection is difficult to obtain when using input attenuators. This is due to the stray capacitance that is distributed along the resistor length resulting in an infinite number of RC time constants that cannot be compensated for over a wide frequency range.

The dual 10X attenuator head included with the P6046 is calibrated with the P6046 to provide maximum CMRR. The attenuator head is keyed with the probe so that the + and − inputs are always matched. The attenuator head should be used only when necessary as it will reduce the CMRR at 50 MHz from 1,000:1 to ≈50:1.

Source Impedance

As the signal source impedance increases, the common-mode measurement problems increase. If the source impedance of the two signals to be measured is different, the CMRR will change due to the different ratios between the source impedance and the input impedance. At high frequencies an increase of source impedance will magnify the problems of CMRR measurements due to a mismatch of stray capacity.

DESIGN CONCEPT

The design objective was to develop a system that would overcome most of the differential measurement problems of high frequency differential amplifiers. The solution was to process the differential signal at the signal source, thereby eliminating most of the problems caused by probes, cable length and input attenuators. It was also necessary to obtain good common-mode rejection for high-frequencies of reasonable voltage levels. These capabilities had to be built into a reasonably small and convenient-to-use probe.

P6046 Probe

In order to obtain high common-mode rejection ratios at higher frequency, the design is a departure from conventional input systems using emitter followers, bootstrapped for all frequencies into the differential comparator. This approach is limited at high frequencies by the bootstrap system.

The input comparator of the P6046 rejects the common-mode signals directly without using an emitter-follower input stage. The thermal time constants of the dual FET's limits the low-frequency CMRR. To eliminate these problems, the input comparator is bootstrapped only for low frequencies (DC-to-100 kHz).

The input-comparator FET's operate with a gain of 0.4. This low gain permits a larger differential dynamic range and a wider bandwidth. An amplifier in the probe restores the probe gain to unity. The probe has one differential attenuator circuit that is controlled from the amplifier and reduces the differential gain and common-mode gain to 1/10.

P6046 Amplifier

Gain changing and converting from a differential-signal to single-ended operation is accomplished in the P6046 Amplifier. Gain changing in the P6046 Amplifier eliminates the differential measurement problems associated with input attenuators.

The P6046 Amplifier has a gain of 10 and features a calibrated 1 mV/div to 200 mV/div deflection factor (with oscilloscope deflection factor set at 10 mV/div).

The output impedance of the amplifier is 50 Ω. A 50-Ω termination is supplied with the P6046 Amplifier for use with oscilloscopes having 1-MΩ input impedances.

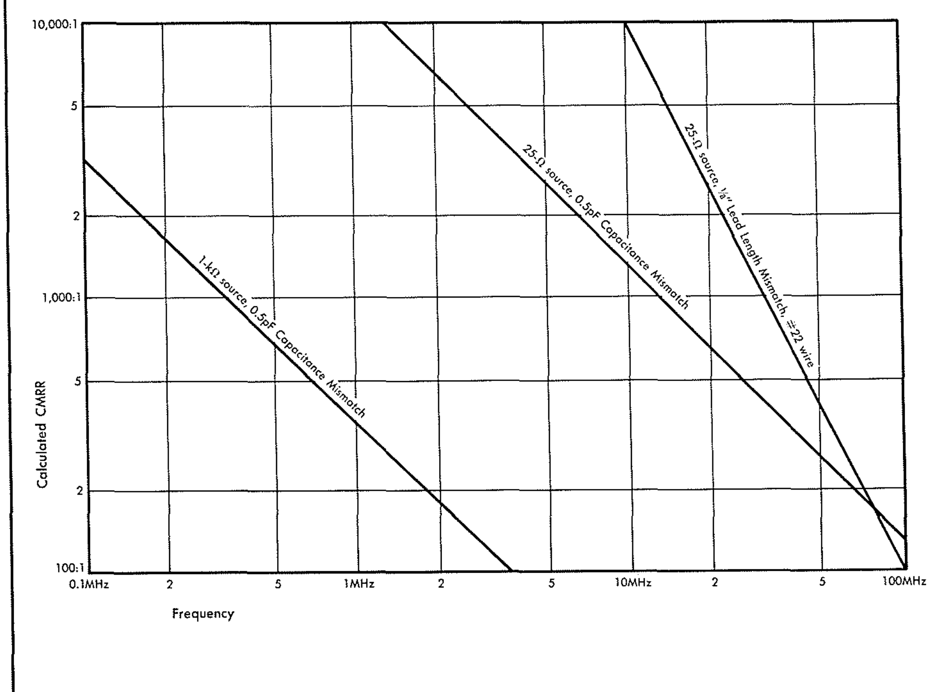


Fig 3. CMRR vs frequency with capacitance mismatch and different source impedances.

MECHANICAL DESIGN

Mechanically, the P6046 probe is made as rugged as possible without sacrificing performance or usability. Thirteen semiconductors, including dual FET's for the balanced input, are housed in the P6046 probe.

The body of the probe is made of high-impact plastic, plating grade. The inside of the body is plated with a low-resistance material that provides an excellent ground plane and electrostatic shield from outside radiation.

Several probe tips have been designed for the P6046 probe. The probe-tip input connectors are mounted on ½-inch centers and are designed to mate with coaxial connectors permanently mounted on circuit boards. The permanent connectors provide excellent ground and signal connection and should be used whenever possible.

When it is not convenient to use the permanent coaxial connectors, a number of special tips are included. For making measurements from test points that are not spaced ½-inch apart, swivel tips are included that provide variable spacing from 3/16 inch to 1½ inches. See Figure 4.

Also included is a ground tip that shorts one of the input tips to the coaxial ground for single-ended measurements, hooked tips for hanging the probe into circuits, and sleeve-type adapters for insulating the tip's coaxial ground. The dual 10X attenuator head included with the P6046 probe has the same tip configuration as the probe.

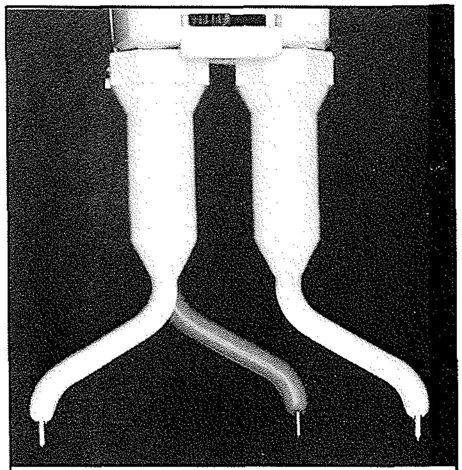


Fig. 4. P6046 Swivel tips.

CHARACTERISTICS

Probe and Amplifier

DEFLECTION FACTOR is 1 mV/div to 200 mV/div in 8 calibrated steps, 1-2-5 sequence, accurate within 3% (with an oscilloscope deflection factor of 10 mV/div).

BANDWIDTH is DC-to-100 MHz at 3-dB down.

RISETIME is 3.5 ns or less.

COMMON-MODE REJECTION RATIOS with deflection factors of 1 mV/div to 20 mV/div are 10,000:1 at DC, 1,000:1 at 50 MHz, and typically 100:1 at 100 MHz.

COMMON-MODE LINEAR DYNAMIC RANGE is ±5 V (DC + peak AC), ± 50 V with 10X attenuator.

INPUT RC is 1 MΩ paralleled by approximately 10 pF.

INPUT COUPLING is AC or DC, selected by a switch on the probe. Low-frequency response AC-coupled is 3-dB down at 20 Hz, at 2 Hz with 10X attenuator.

NOISE (periodic and random deviation) referred to the input is 280 μV or less.

MAXIMUM INPUT VOLTAGE is ±25 V (DC + peak AC), ±250 V with 10X attenuator.

OUTPUT IMPEDANCE is 50 Ω through a BNC-type connector. A 50-Ω termination is supplied with the probe for use with 1-megohm systems.

LINEAR OUTPUT is ± 10 div with the oscilloscope set at 10 mV/div.

PROBE CABLE is 6-feet long, terminated with a special nine-pin connector.

P6046 DIFFERENTIAL PROBE AND AMPLIFIER (010-0106-00)
Includes P6046 Probe (010-0214-00); Amplifier for P6046; 50-Ω BNC cable (012-0076-01); 50-Ω BNC termination (011-0049-00); dual 10X attenuator head (010-0361-00); four swivel-tip assemblies (010-0362-00); special ground tips (010-0363-00); 5-inch ground lead (175-0124-00); 12-inch ground lead (175-0125-00); two alligator clips (344-0046-00); two hook tips (206-0114-00); two test jacks (131-0258-00); two insulating tubes (166-0404-00); two ground clips (214-0283-00); carrying case (016-0111-00); two instruction manuals (070-0756-00).

THE TYPE 1A5 DIFFERENTIAL PLUG-IN with the Type 530, 540, 550, 580-Series Oscilloscopes can use the P6046 Differential Probe without the P6046 Amplifier. The P6046 probe extends the Type 1A5 differential measurement capabilities to 50 MHz, CMRR is 1,000:1 at 50 MHz.

P6046 PROBE PACKAGE (010-0213-00)

TEKTRONIX

SERVICE SCOPE

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

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P.O. Box 500
Beaverton, Oregon, U.S.A. 97005

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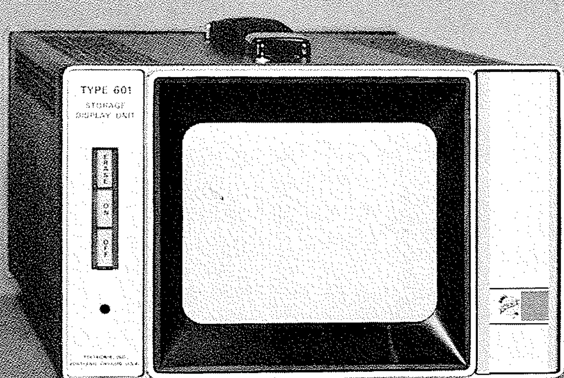
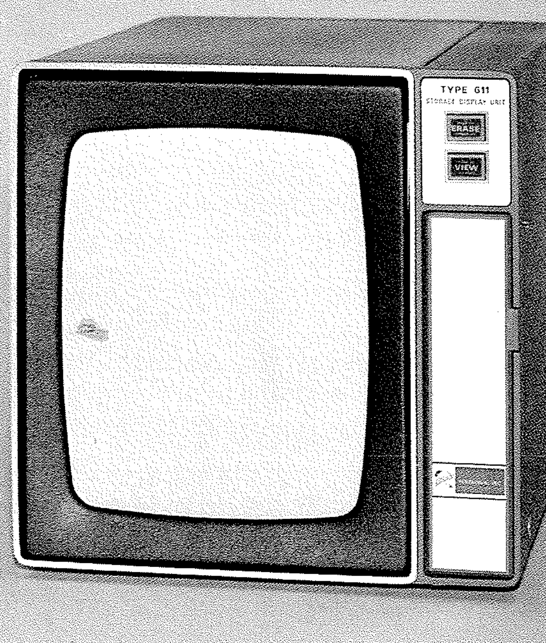
SERVICE SCOPE

NUMBER 47 DECEMBER 1967

A NEW VECTORSCOPE, Page 2





STORAGE DISPLAY INSTRUMENTS, Page 6

A NEW VECTORSCOPE

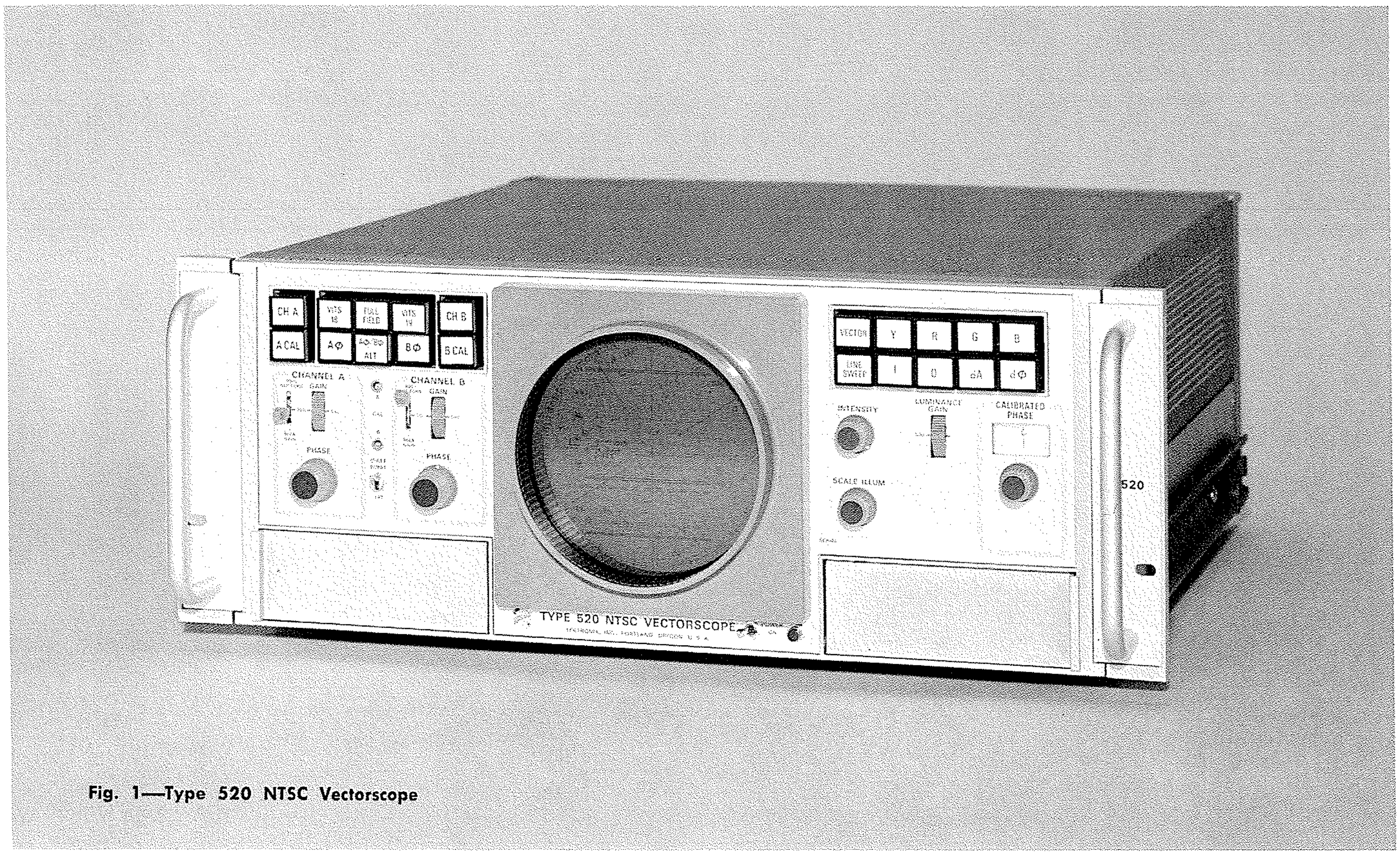


Fig. 1—Type 520 NTSC Vectorscope

INTRODUCTION

Color TV has caused Television Broadcast facilities to expand at a rapid rate. The resulting increase in the quantity and complexity of studio equipment has created a need for more versatile, easier to use, measuring equipment. Oscilloscopes are extensively used in the TV Broadcast industry as program monitors to measure picture levels, as troubleshooting devices to isolate equipment malfunctions, and as a measurement tool to determine waveform compliance with FCC Standards.

The studio operator now routinely verifies or adjusts a variety of parameters that were not required with black and white equipment; burst phase, I, Q, burst level, color bar phase, luminance to chrominance level and others.

In addition to the variety of color system setup requirements, greater emphasis is being placed on in-service monitoring of picture quality. Signal distortion limits which define acceptable picture quality are well established. Suitable test signals have been developed to check distortion; i.e. NTSC Color Bar Test Signal, Linearity stair-step, etc. Using these standard test signals as reference values, quantitative measurements of picture quality are readily made. However, certain signal distortions—particularly differential phase may be difficult to identify or diagnose.

NEW VECTORSCOPE

A new Vectorscope was developed, to assist the Broadcast Engineer and Technician in making these color measurements. The new Tektronix 520 NTSC Vectorscope (Fig 1) was designed with emphasis as an "operating" instrument rather than a special test oscilloscope used only to identify or solve special video problems.

The new oscilloscope is designated as a "vectorscope", however, the addition of a luminance channel has extended the measurement versatility to include most of the routine checks required in a color camera chain.

While measurement versatility is important when considering the purchase of any piece of equipment, ease of operation and long term reliability are equally important. Through special design efforts the Type 520 Vectorscope provides the user with stable drift-free displays at the touch of a button, without sacrificing measurement resolution or accuracy.

PUSH-BUTTON OPERATING CONVENIENCE

The push-button operating controls are arranged into two groups—one for signal selection and one for measurement display mode. All controls unnecessary for specific measurement are automatically disconnected from use to eliminate front-panel confusion. Controls such as the CRT display focus and positioning controls which require only periodic adjustment are located behind front-panel doors.

Fig 2 shows the typical vector display of a 75% saturated color bar test signal. Note the sharply defined spots which permit increased phase-angle resolution, particularly useful for detecting phase jitter or very small phase errors.

Fig 3 illustrates the comparison of two signals on a time-shared basis. Channel A is displayed for two scanning lines and channel B displayed on the next successive two scanning lines. The time-shared signals appear as if they were being displayed on a dual-beam oscilloscope. The time difference between the two input signals normally causes a phase-angle displacement between the two displays (Note Fig 3). This condition is normal and is due to subcarrier reference in the instrument being locked to only one of the signals. By adding a second phase-control knob to the front panel and time sharing its operation with the first phase control, the burst of each input signal can be independently rotated to the X axis permitting an overlay of the vectors for direct comparison. For example, Fig 4 illustrates the input and output waveforms of a distribution amplifier, with intentional distortion, applied to Channel A and Channel B inputs respectively. Differential phase and differential gain can easily be seen to exist on the yellow, cyan and to a lesser extent, the green, red and magenta vectors. Only slight differential phase is evidenced by the blue vector. While this illustration is somewhat severe, note that the differential gain is more severe than the differential phase—a valuable clue when determining the cause of the distortion, such as clamping failure in an amplifier.

DIFFERENTIAL GAIN AND DIFFERENTIAL PHASE

One of the more familiar applications of the vectorscope is the measurement of differential phase and differential gain. The Type 520 Vectorscope provides these measurement capabilities quickly and accurately at the touch of a button. Fig 5 illustrates the Differential Gain operating mode using a modulated stairstep waveform. A different graticule is used to measure differential gain than was used to make the measurement in Fig 4. The IRE Graticule and the parallax-free vector graticule are in place but each graticule is selectively illuminated when the button for the desired measurement is depressed. The one percent error on the tenth step (counting from left to right) is easily observed.

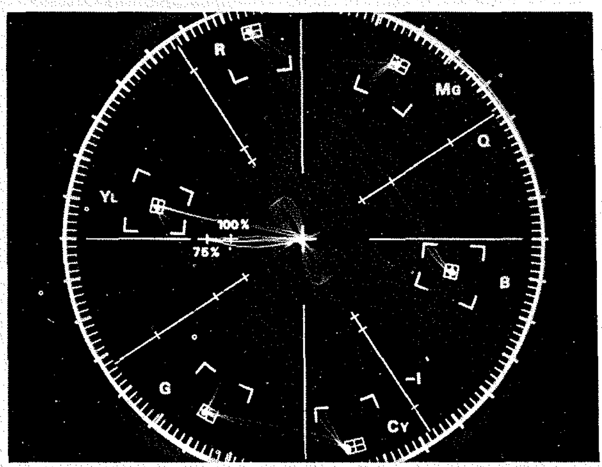


Fig 2—Vector display of 75% saturated color bar test signal

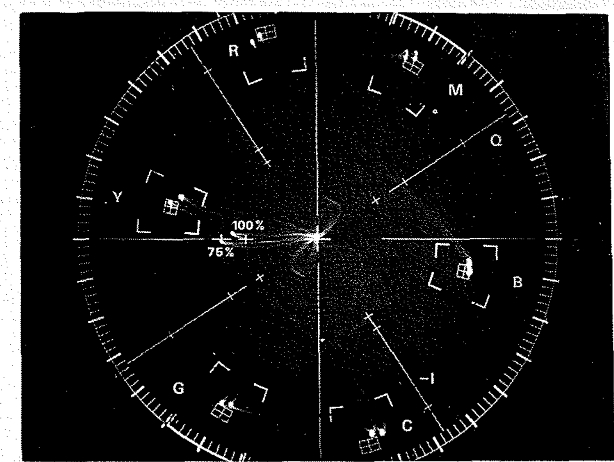


Fig 3—Vector display with channel A and B time-shared

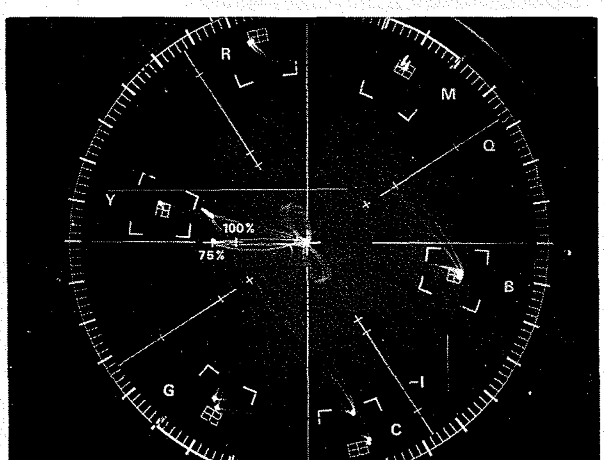


Fig 4—Vector display of input and output waveforms from a distribution amplifier

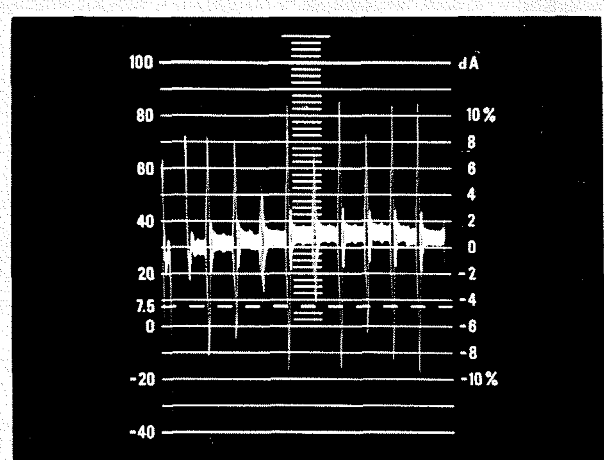


Fig 5—Differential Gain display using a modulated stairstep waveform

When the d ϕ (differential phase) button is depressed, the display is automatically repositioned to the center of the CRT and the graticule illumination removed. The measurment is then taken from the calibrated phase shift dial and the CRT display now serves only as a null indicator. Since considerable amplifier gain is required to resolve phase differences of 0.2 degree or less, small amounts of noise existing on either the applied signal or in the vectorscope will make display interpretation difficult. Display interpretation is simplified by alternately inverting the display to produce the mirror image observed in Fig 6. Any noise on the display (as evidence by a wide trace) can then be averaged out by simply adjusting the overlayed traces for minimum trace width. In Fig 6 each step has a phase transient in the middle amounting to about 0.09°.

NEW MEASUREMENT CAPABILITY

The Type 520 Vectorscope utilizes the luminance portion of the composite color signal to permit measurement of the transformed red, green and blue picture values which normally appear at the picture tube of a color monitor. The Y (or M) luminance signal and the chrominance signal are transformed at the receiver into red, green and blue picture components. Currently, the only means by which the transformation can be verified is by observing the display from the color picture tube itself. Subjective evaluations of picture quality made from color bars viewed directly on a color monitor are influenced by several variables:

1) Phosphor light output efficiency is reduced with age or usage.
2) Color response of the human eye varies from viewer to viewer making consistent readings difficult.
3) Picture monitor characteristcis may vary.
4) Small error differences between the luminance and chrominance waveform amplitudes are almost impossible to detect without using picture comparison techniques.

MEASURING Y, R, G, and B

Measurement of the transformed signal is made by selecting one of four buttons labeled Y, R, G, B. These buttons correspond to luminance, red, green and blue video displays.

When saturated colors (75% or 100%) are displayed on a picture monitor, the monitor electron guns are either on or

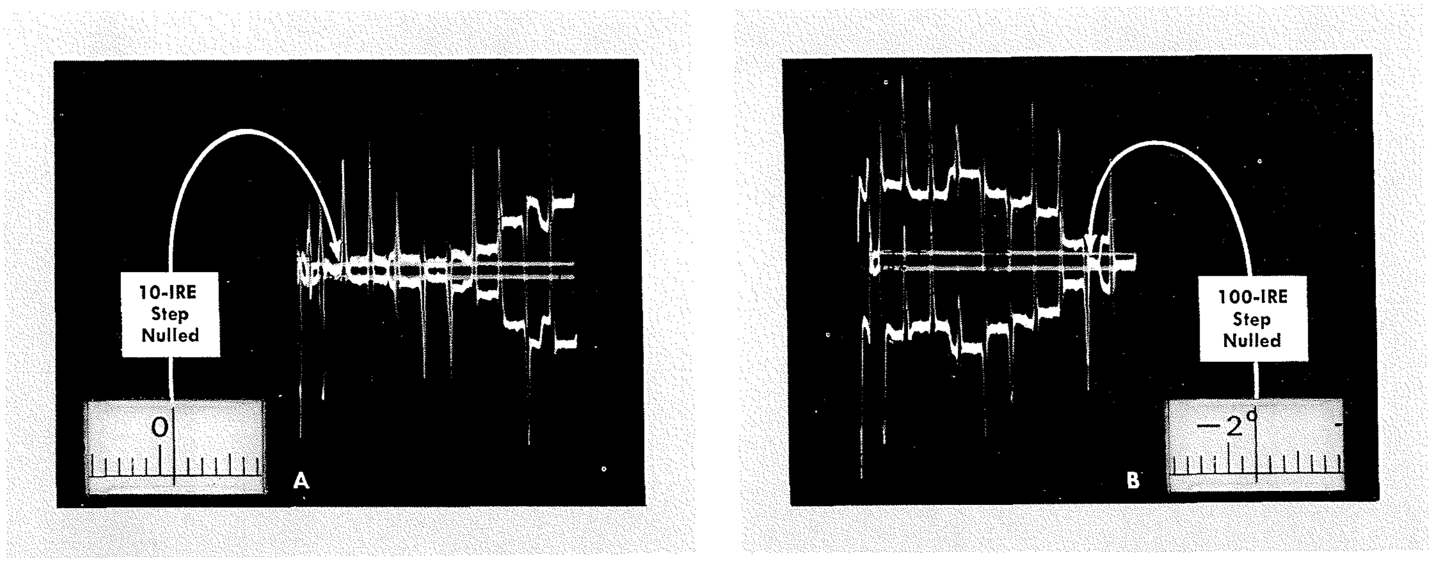


Fig 6. Differential Phase measurement using a modulated stair-step signal. Dial reading A to dial reading B indicates 2.1° differential phase.

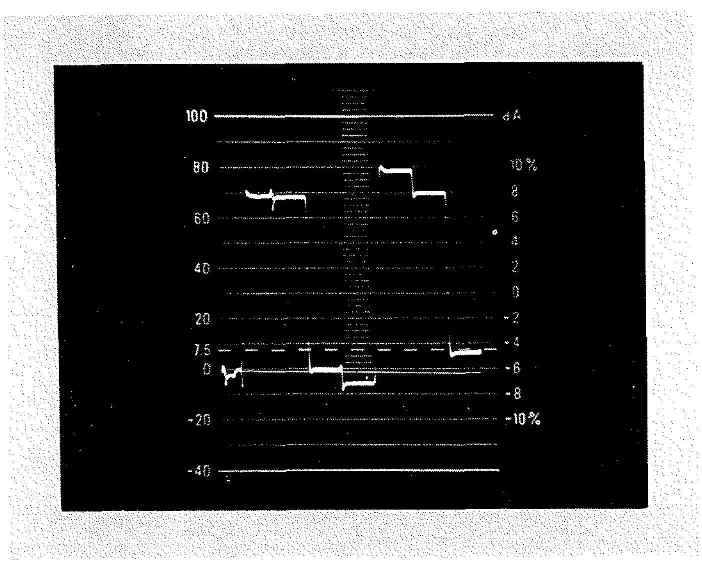


Fig 7—Red values of NTSC Color Bar Test Signal with magenta and red bars oversaturated

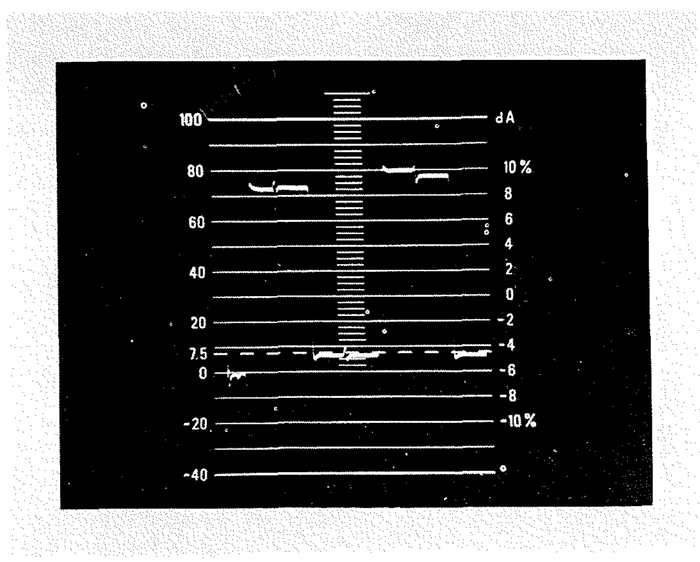


Fig 8—Red values of the NTSC Color Bar Test Signal with luminance amplifier nonlinearity in the white region

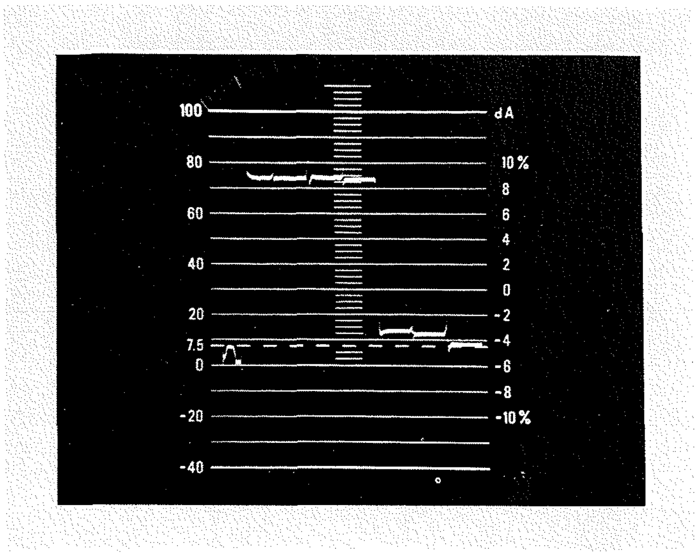


Fig 9—Green values of NTSC Color Bar Test Signal

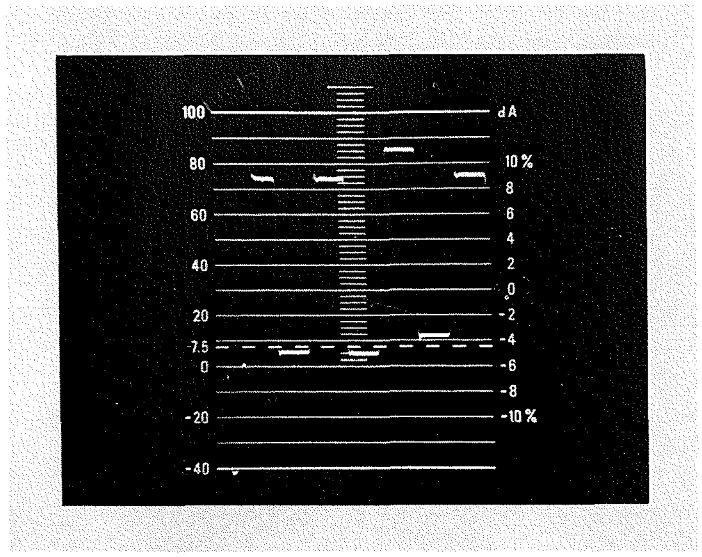


Fig 10—Blue values of NTSC Color Bar Test Signal

off as primary and complementary colors are reproduced. During the primary color "Red", for instance, the red gun is on and green and blue guns are off. The complementary color of "Red" is "Cyan", which is reproduced by the green and blue guns with the red gun held off.

In Fig 7 the red (R) "image" is displayed on the vectorscope using the "standard" decoded color bar signal. The colors are arranged from the left of the display to the right in order of descending luminance—grey, yellow, cyan, green, magenta, red, and blue. Note that the magenta and red bars are over-saturated, however, the error is not easily detected by the eye on the picture monitor because the error is not too large. Observing the vector display of the same signal in Fig 2 indicates that the chrominance portions of the encoded color bars are correct. Therefore the luminance levels for magenta and red must be incorrect —too high in this case. In this illustration, since only two color bars are affected, the error is not due to non-linear luminance gain but simply because the luminance pedestal levels of the color bar generator are incorrectly adjusted.

Fig 8 shows the same display except that the luminance amplifier is non linear in the white region. The *effect* however, is not apparent on the grey and yellow bars but on the magenta, red and blue bars and is due to the luminance amplifier gain having been adjusted with a white pedestal.

Fig 9 illustrates the green (G) display of the same waveform. Note the luminance distortion previously observed affects the green more seriously. Green should be off during the last three bars. While the slight presence of green during the red bar will cause the displayed red to appear orange to the eye (because red is a primary color) the magenta error would be more difficult to detect in the reproduced picture.

Fig 10 shows the blue picture display which is not as seriously affected by luminance errors.

SUMMARY OF 520 NTSC VECTORSCOPE CHARACTERISTICS

Push-button controls provide new operating convenience and permit rapid selection of displays for quick analysis of television color signal characteristics. Amplitude calibrated displays of chroma and luminance are assured with internal calibration test signals to verify amplifier accuracy. The luminance component of the composite color signal is derived for displaying separately or in combination with the red (R), green (G), or blue (B) components.

Two 0° to 360° phase-shifters provide independent phase control of channel A and B. Phase differences caused by unequal signal paths are easily cancelled. A precision calibrated phase shifter with a range of 30°, spread over 30 inches of dial length provides excellent resolution for making small phase angle measurements. Video cable lengths can be accurately matched for time delay at the color subcarrier frequency to less than 0.5° phase difference. Differential gain and differential phase measurement capabilities are provided with accuracies within 1% for gain and 0.2° for phase.

A digital line selector permits the display of a single line Vertical Interval Test Signal from a selected line of either field 1 or field 2.

A parallax-free vector graticule, or IRE graticule, is automatically selected and edge-lighted concurrent with operating mode selection. All silicon solid-state design provides long-term reliability and cool, quiet operation.

The Type 520 NTSC Vectorscope is available in electrically identical cabinet or rackmount models.

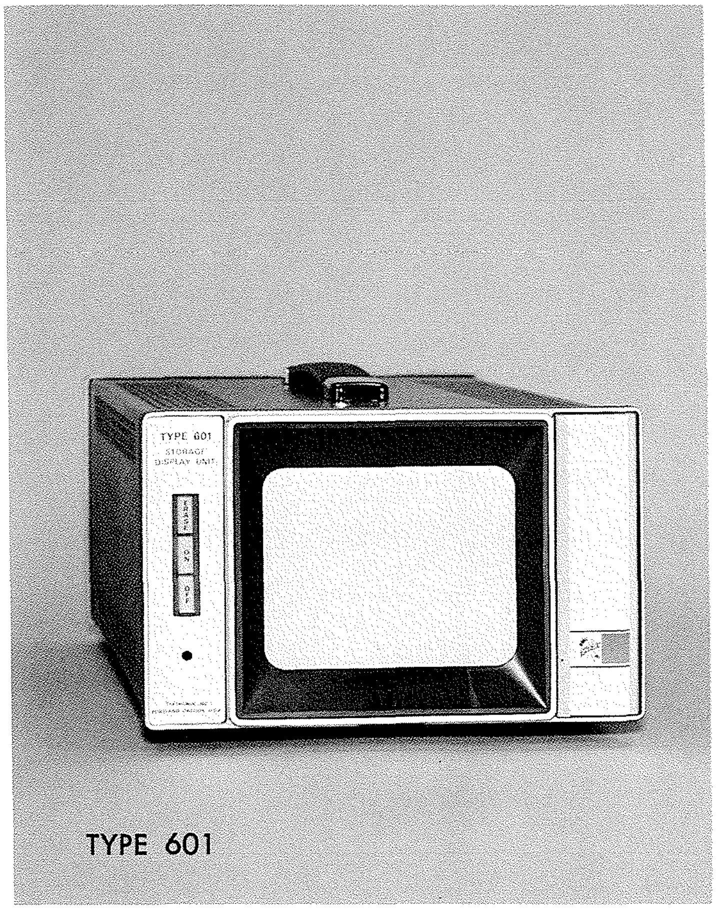
A more complete description of this instrument is found in the Tektronix New Products Catalog Supplement recently distributed.

TYPE 520 NTSC VECTORSCOPE $1850

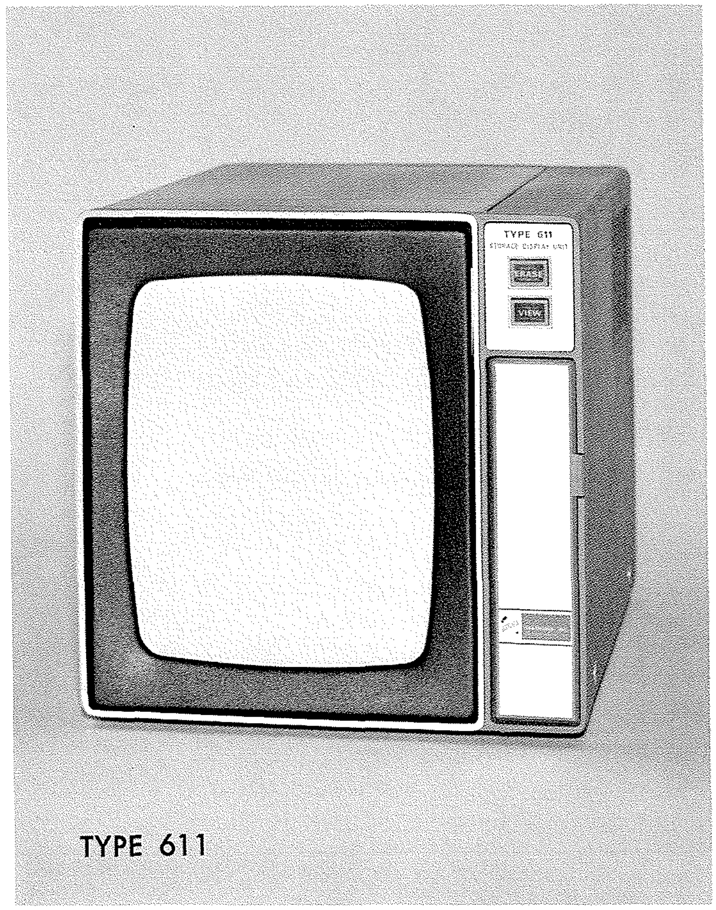
TYPE R520 RACKMOUNT $1850

U.S. Sales Price FOB Beaverton, Oregon

STORAGE DISPLAY INSTRUMENTS



TYPE 601



TYPE 611

INTRODUCTION

The Type 564 Storage Oscilloscope, a measuring instrument, served as an excellent exploratory tool to determine the advantages of bistable-storage cathode-ray tubes as computer readout devices. Several groups experimented with the bistable storage tube in this application and the results show that a bistable storage tube when used with the appropriate periphal equipment provides high-resolution, non-refreshed, alpha-numeric and graphics displays without flicker or fade.

A sequence of events occurred as the computer market developed that contributed toward the development of the bistable storage tube as a computer display device.

(1) Computer usage was being discouraged by man-to-machine interface problems, that is, a problem is submitted through a programmer, a misunderstanding is found after a period of time, the problem is resubmitted, etc.

(2) Larger and faster computers were developed to help offset computation costs.

(3) Techniques to improve computer time utilization were developed.

(4) Computer time-sharing appeared to be a solution to efficient use of computer time but because of input-output limitations, many parallel or time-shared users are required in order to keep the computer busy.

(5) Time-sharing a central computer requires remote terminals convenient to the users.

(6) The cost per remote terminal for time-sharing application must be sensibly low.

(7) A major economic consideration of remote terminals is local memory cost, especially if arbitrary format alpha-numeric and graphic capabilities are required. It is not economically wise to provide display refreshing from the computer memory, and even with a buffer memory the communication link bandwidth may be too narrow to allow refreshing a display at above flicker rates.

(8) For applications where flexible format is required and large amounts of data are to be presented, the Tektronix simplified direct-view bistable-storage CRT provides an economic solution to the memory/display problem.

A NEED FOR NEW INSTRUMENTS

The interested groups who experimented with the Type 564 Storage Oscilloscope as a computer remote-terminal readout device were encouraged by the results obtained and indicated the need for an instrument optimized for computer display rather than measuring applications. Producing an instrument specifically for computer readout purposes required different design objectives than those for measuring devices.

(1) Writing-speed parameters could be traded off for more uniform and smaller spot size.

(2) Plug-ins replaced with built-in amplifiers resulting in a more compact unit.

(3) The Z axis modified for "on-off" operation.

(4) The CRT target modified for improved isolated stroke or dot appearance (a key contribution).

NEW DISPLAY DEVICES

The recently announced Types 601 and 611 Storage Display Units were designed to be used as integral parts of computer remote terminals. When driven by the appropriate periphal equipment these units will present non-refreshed displays of alpha-numerics and graphics without flicker or fade.

The Type 601 and 611 are intended for *individual* use, *not* group viewing. The high resolution of the 601 and 611, require the viewer to sit fairly close to the instruments in order to resolve the displayed information.

5-INCH STORAGE DISPLAY UNIT

The Type 601 Storage Display Unit features a new, Tektronix developed, 5-inch bistable-storage display tube, providing clear, non-fading presentations. Resolution in an 8-cm x 10-cm display area is 100 stored line pairs in the vertical axis and 125 stored line pairs in the horizontal axis providing an information capacity of about 400 alphanumerics. The information storage rate is 100-thousand dots per second and time required to erase the stored information is 200 ms. All solid-state modular circuit design insures long-term stable performance.

The operating functions are remotely programmable by simply grounding program lines at a rear-panel connector. Access to X, Y and Z inputs is through rear-panel BNC connectors or a remote program connector.

11-INCH STORAGE DISPLAY UNIT

The Type 611 Storage Display Unit features an 11-inch magnetically deflected, bistable-storage display tube developed by Tektronix. This new storage tube offers high information density and excellent resolution on a 21-cm x 16.3-cm display screen. The information capacity of the Type 611 is about 4000 alpha-numerics. Dot settling time is 3.5 μs/cm plus 5 μs and dot writing time is 20 μs. The time required to erase and return to ready-to-write status is 0.5 seconds.

The operating functions are remotely programmable through a rear-panel connector with access to X, Y and Z inputs through rear BNC connectors or the remote program connector. A "Write-Through Cursor" feature permits positioning the writing beam to any point on the display area without storing the cursor or destroying previously stored information. Write through for alpha-numerics and graphics can be done by shortening the unblank pulse duration from the normal value of 9 μs (Type 601) or 20 μs (Type 611). This mode of operation is useful for manual graphics, with the aid of equipment like the Rand Tablet or with an SRI Mouse. An internal test signal provides a quick check of focus, storage and general performance status of the instrument.

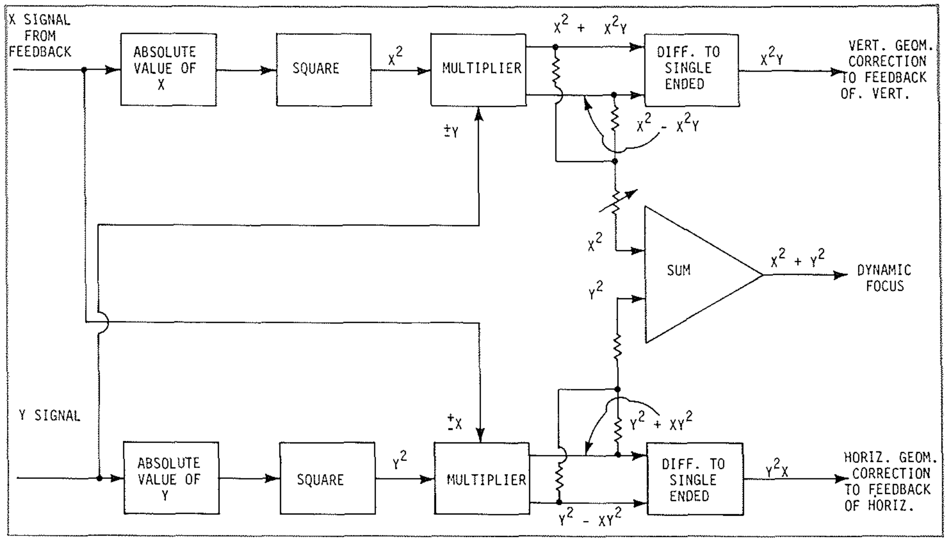


Fig 1—Block diagram of Type 611 pincushion and dynamic focus correction.

SOME DESIGN CONSIDERATIONS

Compatibility between the Types 601 and 611 is maintained with regard to the input connectors and selection of common functions, such as erase. However there are differences which should be kept in mind. The Type 601 has ± 6 cm continuously variable position controls for X & Y, while the Type 611 has three position switches that permit the operator to select one of nine beam resting positions. Variable controls provide a ±10% range for small adjustments of each position. The limited variable range was chosen because of the more stringent drift requirements of the Type 611. Both units have internal gain calibration adjustments to set the full screen deflection voltage within 2% of 1 volt. Both units have provision for other less-sensitive deflection factors.

Trace alignment of the two instruments is different. The Type 611, using an electromagnetrically-deflected tube, has an external deflection yoke which may be rotated to align the traces; orthogonality is a function of how well the yoke was manufactured. The larger screen requirement of the Type 611 requires magnetic deflection through an angle of 70°, in order to keep the length of the instrument reasonable (the Type 611 is about 20% longer than the Type 601). The wide magnetic deflection angle of the Type 611 CRT, together with the flat faceplate, requires correction to the deflection geometry, linearity and focus. Without going into the mathematical details, it can be said that both pincushion and dynamic focus require squared deflection terms. Figure 1 shows the block diagram. The squaring circuit is a single FET. The multiplier is a differential pair driven from a current source. Thus with comparatively simple circuitry, the circuit generates the required X^2Y and Y^2X for pincushion correction, and $X^2 + Y^2$ for focus correction. The dynamic focus summing circuit gets its input from the multipliers, rather than the squaring circuits directly, because of the signal levels involved; that is, the output of the multiplier is at a more convenient level than the squaring circuit. This combination of corrections appears to be new, and unexpectedly simple.

The Type 601 with an electrostatically deflected tube has a *unique* method of correction; instead of the usual rotation coil, signals are independently mixed from the X and/or Y amplifiers into the Y and/or X amplifier, thus introducing tilt and/or slant as necessary to correct trace alignment and/or orthogonality. Because of this cross-mixing, the use of the Type 601 as a waveform monitor should be restricted to applications involving bandwidths below 100 kHz. The smaller deflection angle and lower resolution requirement of the Type 601 make dynamic scan or focus corrections unnecessary.

SUMMARY

The first instrument to use the Tektronix developed bistable storage tube was the Type 564 Storage Oscilloscope, introduced in the spring of 1962. Since that time, the Type 564 has found extensive use in a multiplicity of applications including information display. Early experiments with the Type 564 as an information display device proved the validity of the concept and helped define new storage tube requirements; the Type 601 and 611 Storge Display Units are the first display instruments to employ these new storage tubes.

A more complete description of these new instruments is found in the Tektronix New Products Catalog Supplement recently distributed.

Type 601 Storage Display Unit .. $1050

Type 611 Storage Display Unit .. $2500

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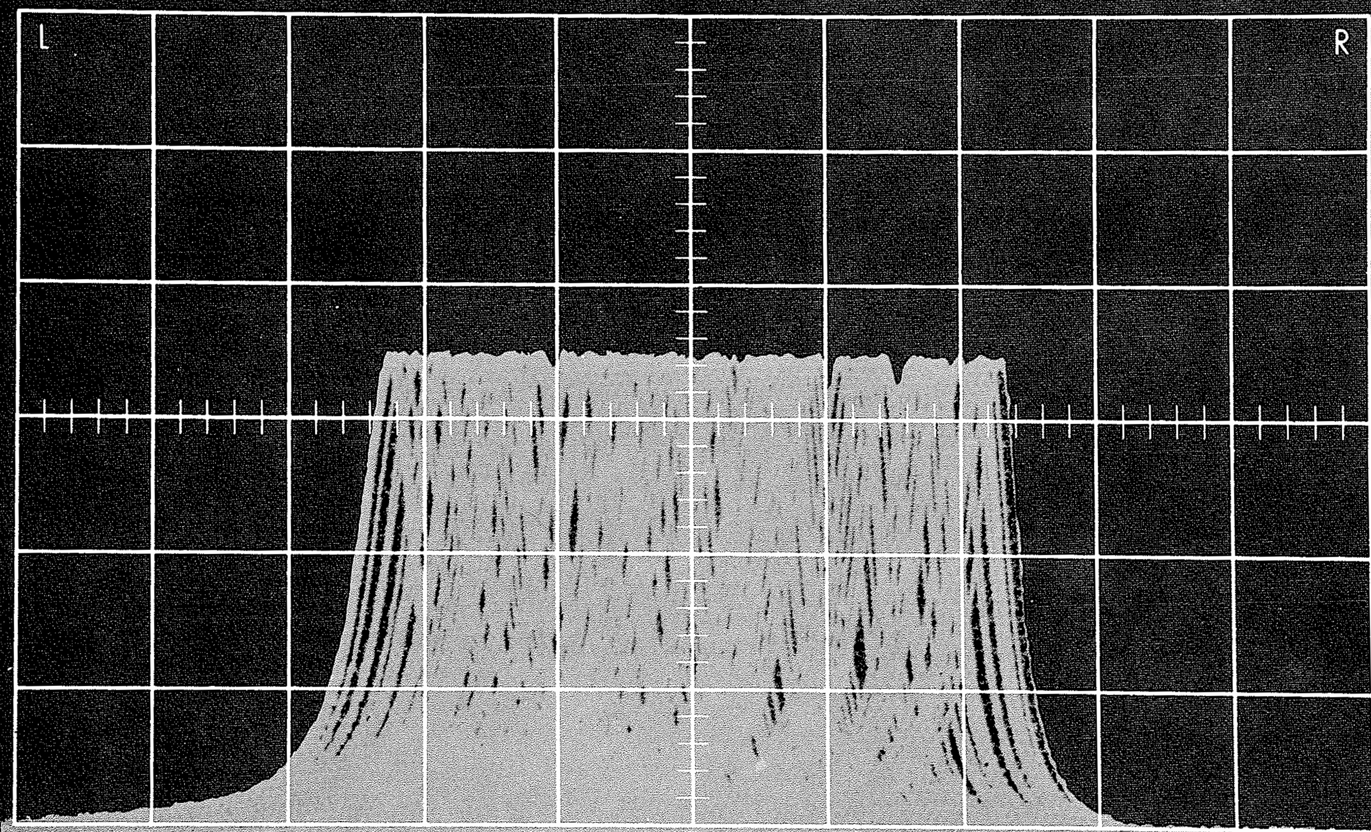
Frequency Domain Stability Measurements....



..... Using Spectrum Analyzers

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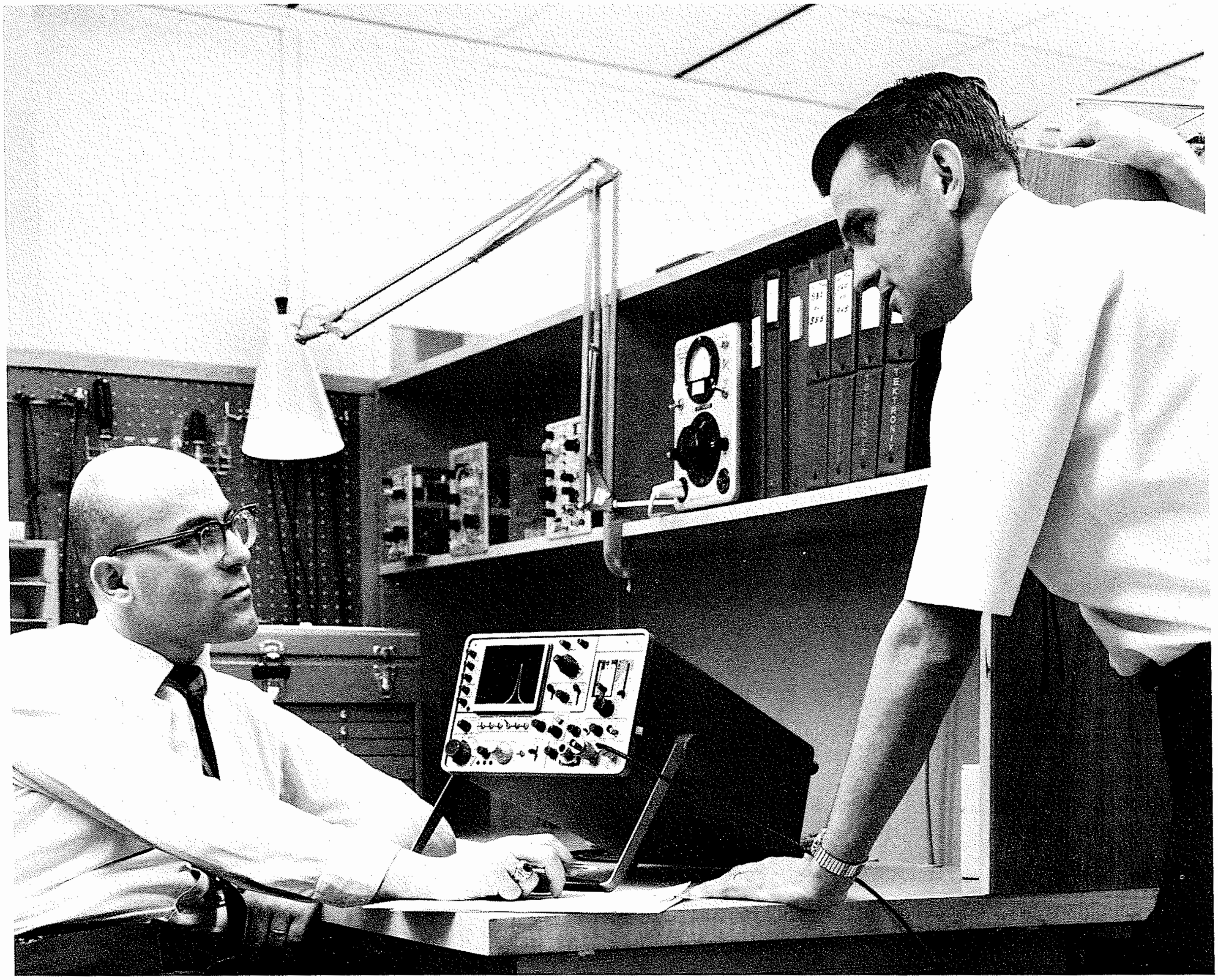

Frequency Domain Stability Measurements

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Spectrum Analyzer Techniques for Frequency Stability Measurements

The objectives of this paper are: to examine the presently available techniques of frequency stability measurement in the frequency domain, i.e., by the use of spectrum analyzers; to examine some of the advantages and limitations of spectrum analyzers for this application and to present examples of typical measurements.

INTRODUCTION

Designers of microwave instruments are interested in measuring and specifying the frequency stability associated with their equipment. Stabilities on the order of 0.1 to 10 P/M are usually sufficient for the majority of commercial instruments, such

Morris Engleson and Gene Kaufman, Tektronix Project Engineers confer over a Type 491 Spectrum Analyzer.

as signal generators and receivers. We shall, therefore, concentrate on this small range of measurements.

The questions we shall examine are:

1. How does one differentiate between long-term and short-term stability? This question can be considered from several viewpoints. a) Does a specific change have to occur in seconds, in milliseconds or in microseconds to be considered short-term? b) How short does the measurement time have to be (again, in seconds, in milliseconds, or in microseconds) in order for the phenomenon to be measured to be considered short term?

2. How does one measure frequency stability? This question too has several facets. a) What instrumentation should one use; counters, frequency deviation meters, spectrum analyzers, etc? b) Should the measurement be made in time domain (i.e., P/M or frequency domain (i.e., spectrum width)?

Frequency stability measurement techniques in time domain by means of a frequency counter are well known in the industry. This technique has the advantage of simplicity, ease of operation, and the capability of making measurements on highly stable oscillators (i.e., better than one part in 10^7). Frequency stability measurement techniques in frequency domain by means of spectrum analyzers, on the other hand, are not too well known. This technique permits many measurements (such as that of signal purity; i.e., noncoherent sidebands or AM as opposed to FM) which cannot be performed with a counter. We shall concentrate on these measurements and show in which respects the spectrum analyzer is superior to the counter. This is not to imply that the counter does not have its place or that the counter is not superior to the spectrum analyzers in many areas of frequency measurement.

DEFINITIONS

There are at least two acceptable ways of specifying oscillator stability. One describes the phenomena in time domain, the other in frequency domain. The question of how to characterize (time or frequency domain) any particular signal is almost impossible to answer. However, one can arrive at a reasonable compromise by converging on the subject from both ends, i.e., starting with signals that are definitely in one or the other category.

It is quite obvious that two or more CW signals coexisting simultaneously side by side can be characterized most meaningfully in the frequency domain. By the same token, to characterize the drift of an extremely stable CW signal, such as a frequency standard, in terms of spectral distribution is inconvenient. Other signals are more difficult to characterize. Thus, an FM signal can certainly be legitimately described by a carrier and sidebands. Yet, as the FM rate gets smaller, the FM signal approaches slowly drifting CW; under such circumstances it should logically be described in time domain.

As another example, consider a pulsed RF signal, such as encountered in radar or a squegging oscillator. Radar pulses are nearly always described by a spectral distribution in the frequency domain. Yet, surely as the pulse width gets wider and the pulse repetition rate lower, a point is reached where a description in frequency domain is not generally useful. Therefore, it appears that arbitrary standards without regard to the measurement technique or application are not helpful.

It seems the best description, whether frequency or time domain, should be dependent on the characteristics of the measurement device or application. Experimental experience indicates that as long as the frequency changes in the device under discussion occur in a time interval one-fifth to one-tenth of the basic time constant of the associated equipment, one cannot differentiate between simultaneously coexisting signals and a single signal whose frequency is changing with time. On the other hand, when the instabilities in the device under test occur in a time interval of the same order of magnitude as the time constant of the associated equipment it becomes quite obvious that things are happening as a function of time. Thus, a good demarcation line for the two methods of describing frequency stability might be:

1. Frequency domain for phenomena that occur faster than one-fifth of the basic time constant of the end use contemplated.

2. Time domain for phenomena that occur at a slower rate than one-fifth of the basic time constants of the associated equipment.

Similarly, to our way of thinking, the required measurement time and/or the time for a particular frequency change to occur in an oscillator must be individually redefined for each application. We know of no satisfactory practical definition without recourse to an application or measurement technique. Thus, those phenomena which occur faster than some basic time interval (e.g., detector time constant in a receiver) of the measurement instrument, or instrument in which the oscillator is to be used, can be considered as short term.

Phenomena which take a longer time interval to occur than the basic instrument interval can be considered as long term. Let us apply these definitions, as a case in point, to the swept frequency spectrum analyzer. The oscillator can be considered as either an integral part of the spectrum analyzer or an independent entity being checked for stability with a spectrum analyzer. It can be shown[1] that a basic time interval for a spectrum analyzer is

$T = \frac{D}{\sqrt{5.13\,(B^2)}}$ where D is total dispersion (i.e., dispersion in Hz/div times the number of horizontal divisions for full screen) and B is the final amplifier 3 dB bandwidth. On the surface, it appears that the boundaries were picked artificially. In practice there is a definite noticeable difference in the spectrum analyzer display depending on the analyzer settings and the type of instabilities present.

The following photographs will illustrate these points. Fig 1 is a spectrum analyzer display of a frequency modulated carrier. The FM rate is 10 Hz or 0.1 s for a complete frequency excursion. It will be noted that the display exhibits a definite spectral width, namely 4 cm. The spectrum analyzer was sweeping at a rate of 0.2 s/div, or a total of 0.8 s for 4 div.

In this case, the phenomenon under measurement is occurring at a rate eight times faster than the measurement time. Fig 2 shows the same signal displayed with the same spectrum analyzer with all controls set identically to those for fig 1 except for sweep time. Here the sweep time has been set for 20 ms/div or 80 ms for 4 div. Observe that the characteristic FM spectrum has disappeared. As far as the spectrum analyzer is concerned it might as well be responding to a CW signal.

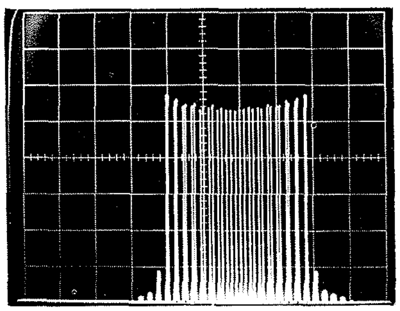


fig 1 Frequency modulation-slow analyzer scanning rate.

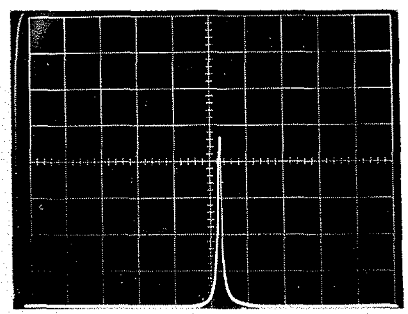


fig 2 Frequency modulation-fast analyzer scanning rate (single sweep).

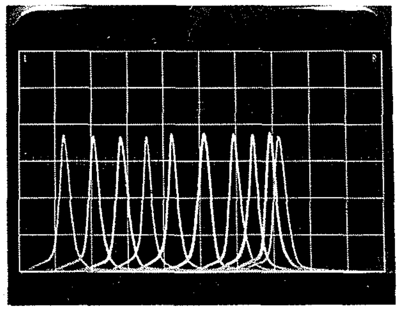


fig 3 Long term drift measurement.

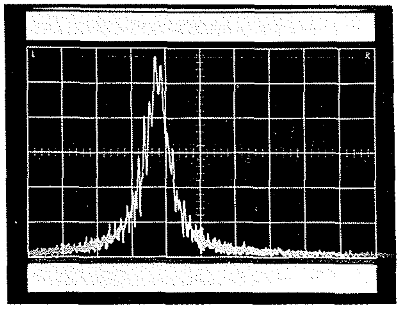


fig 4 Short term FM measurement.

Fig 3 shows the long term drift of an oscillator obtained by triggering the spectrum analyzer sweep in 1 minute intervals. It will be noted that each of the several sweeps has generated a clean display tracing out the shape of the resolution bandwidth.

We can now calculate total drift, drift in P/M or drift/min from a knowledge of the spectrum analyzer control settings. The numbers thus obtained represent a long term stability specification for the oscillator. We can say very little about the short term characteristics as the analyzer controls were not set for a high resolution analysis. Fig 4, on the other hand, shows the short term characteristics of an oscillator without telling us anything about long term performance. Here the dispersion was set for 500 Hz/cm at a resolution of 100 Hz and a sweep time of 0.2 s for full screen. It will be noted that a definite frequency change has occurred during the time interval of the single sweep. The trace is spread out over approximately 1.5 cm for a total of 750 Hz.

Were this oscillator to be used as a component of the measuring analyzer, it would have a definite effect on the short term stability of the analyzer. This could be surmised by observing that a definite frequency change occurs in a time interval less than T =

$$\frac{D}{\sqrt{5.13(B^2)}} = \frac{5000}{\sqrt{5.13(100^2)}} \approx 0.22 \text{ s}$$

MEASUREMENT TECHNIQUES

The following experiments indicate the versatility of the spectrum analyzer and present comparison data between spectrum analyzer and counter for frequency stability and signal purity measurements.

Long Term Drift

Both the counter and spectrum analyzer are well suited to long term drift measurements. Fig 3 was obtained by triggering a spectrum analyzer to sweep once every minute. Analyzer settings were center frequency 400 MHz and dispersion 50 kHz/cm. Readings were simultaneously taken in one minute intervals on a counter and the data in Table I was obtained.

Table I

Long Term Drift

Interval Number	1	2	3	4	5
Frequency MHz	400 .55	400 .51	400 .47	400 .43	400 .39
Interval Number	6	7	8	9	10
Frequency MHz	400 .35	400 .31	400 .28	400 .26	400 .25

From the spectrum analyzer data we observe that oscillator drift during the ten minutes of observation was 6.1 cm and at 50 kHz/cm this is equivalent to 305 kHz. The counter data indicates that total drift was 300 kHz. Similarly, drift during the first minute, drift during the tenth minute, average frequency change per unit, time, etc., can be calculated from both counter and spectrum analyzer data. Clearly the counter is superior in accuracy to the spectrum analyzer which had an error, in this case, of 5 kHz out of 300 kHz or 1.7 per cent compared to the counter.

Incidental Frequency Modulation

Incidental frequency modulation is usually of a random nature so that given a short enough averaging interval and a sufficiently long observation time one can get an excellent idea of the peak to peak frequency deviation by the use of a counter.

Spectrum Analyzer General Information

SENSITIVITY—SIGNAL TO NOISE

Sensitivity of a Spectrum Analyzer is specified as the signal power input required to produce a 2 to 1 ratio of signal + noise power to noise power at the output. Noise power is a function of amplifier bandwidth and gain. Therefore, signal power is noise limited or noise dependent.

Noise power vs signal power may be stated at 100 kHz bandwidth (Resolution control) to be —85 dBm. At 1 kHz bandwidth (minimum bandwidth), the sensitivity may be stated as —105 dBm. This indicates a 20 dB greater sensitivity at 1 kHz bandwidth than at 100 kHz bandwidth. This is confirmed by a 100 to 1 (bandwidth reduction) ratio being equal to 20 dB (a dimensionless number, but an expression of power ratios).

A sensitivity of —105 dBm says that a signal with a power level of 105 dB below a reference of 1 mW, plus the noise power, will be 2 times (3 dB) greater than the noise power alone; or, signal plus noise equals 2X noise; noise being a function of bandwidth and gain.

Knowing the amplifier bandwidth, sensitivity may be measured at any bandwidth. In the interest of time and ease of measurement, the sensitivity figure, measured at 100 kHz bandwidth, plus 20 dB (100 to 1 ratio) is correct for a bandwidth of 1 kHz, as is specified in the catalog. The actual measurement at 1 kHz bandwidth is tedious to make, requiring minimum dispersion and a very slow sweep.

491/1L20/1L30 DIAL ACCURACY

The RF Center Frequency dial accuracy of ±(2 MHz + 1% of dial reading) may at first appear as an unusually large frequency tolerance to be ascribed to a 10 MHz RF signal. It could just as well have been described as ±1% of local oscillator fundamental or harmonic frequency. However, the latter explanation would not allow calculation of the dial accuracy limits from the dial reading.

When the dial reads 10 MHz the local oscillator is tuned 200 MHz higher in frequency to 210 MHz. One percent of 210 MHz is equal to 2.1 MHz. On the other hand ±(2 MHz +1% of 10 MHz) is also equal to 2.1 MHz. Generally it is much easier to derive the frequency accuracy limits from the dial reading than having to determine the fundamental or specific harmonic frequency of the local oscillator for a particular dial reading.

REFERENCE CHART

CHARACTERISTICS	TYPE 1L5 PLUG-IN	TYPE 3L5 PLUG-IN	TYPE 1L10 PLUG-IN	TYPE 3L10 PLUG-IN	TYPE 1L20 PLUG-IN	TYPE 1L30 PLUG-IN	TYPE 491 PORTABLE	TYPE R491 RACK MODEL
CENTER FREQUENCY	50 Hz to 1 MHz		1 MHz to 36 MHz		10 MHz to 4.2 GHz	925 MHz to 10.5 GHz	10 MHz to 40 GHz	
SENSITIVITY	10 μV/div RMS for spectral displays. 1 mV/div P to P for time-based displays.		—100 dBm		—110 dBm to —90 dBm	—105 dBm to —75 dBm	—110 dBm to —70 dBm	
CALIBRATED DISPERSION	10 Hz/div to 100 kHz/div 100 Hz to 1 MHz full scale		10 Hz/div to 2 kHz/div 100 Hz to 20 kHz full scale		1 kHz/div to 10 MHz/div 10 kHz to 100 MHz full scale			
COUPLED RESOLUTION	≤10 Hz to ≥500 Hz		10 Hz to 1 kHz		1 kHz to 100 kHz			
	coupled with calibrated dispersion positions and separately switchable							
INCIDENTAL FM	≤3 Hz from 50 to 9900 Hz ≤10 Hz from 9.9 to 990 kHz		IF—5 Hz LO—26 Hz to 61 Hz		<300 Hz at fundamental, with Phase Lock			
VERTICAL DISPLAY	log, linear, video		log, linear, linear X10 (1L10 only), video		log, linear, square law, video		log, linear, square law	
OSCILLOSCOPES USED WITH	530, 540, 550, and (with adapter) 580 Series	Type 561A and 564	530, 540, 550, and (with adapter) 580 Series	Type 561A and 564	530, 540, 550, and (with adapter) 580 Series		self contained	
PRICE	$1000	$1100	$1150	$1260	$1925	$1925	$4400	$4500

Table II

Peak to Peak Frequency Deviation of Incidental Frequency Modulation

Int. No.		1	2	3	4	5	6	7	8	9	10	11	12	13
Freq. MHz*		78	72	67	65	70	71	73	68	70	73	74	75	62
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
71	74	76	75	66	70	65	69	63	63	56	62	66	58	63
29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
69	71	65	65	76	79	80	81	80	85	90	87	90	91	96
44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
94	91	94	91	94	89	81	81	81	76	66	66	59	62	65
59	60	61	62	63	64	65	66	67	68	69	70	71	72	73
53	63	68	65	67	62	61	64	72	74	75	74	77	76	72
74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
78	72	77	86	77	68	75	75	76	77	72	71	70	68	72
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
67	70	71	63	56	64	59	64	61	59	52	60	62	52	55
104	105	106	107											
62	65	70	61											

* *Frequency 392.4578, for convenience only last two digits are listed.*

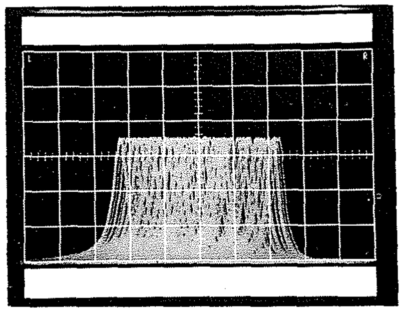


fig 5 Incidental FM measurement; center frequency: 392 MHz; dispersion: 1 kHz/cm.

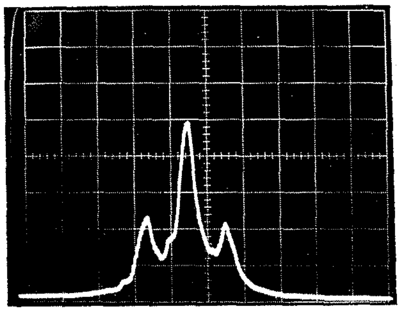


fig 6 Amplitude modulation measurement; center frequency: 400 MHz; dispersion: 1 kHz/cm.

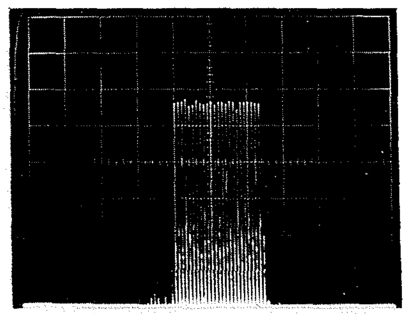


fig 7 Symmetrical FM measurement; center frequency: 405 MHz; dispersion: 1 MHz/cm.

By analogy, given a sufficiently fast sweep and sufficiently long observation time, a spectrum analyzer will indicate the peak to peak deviation. Fig 5 and the data presented in Table II were obtained by sweeping the spectrum analyzer and reading the counter in two-second intervals for a total observation time of about four minutes.

From fig 5 the peak to peak incidental frequency modulation is about 4.7 kHz. From this and the center frequency we can calculate a frequency stability of about 12 P/M.

The counter indicates a maximum deviation of 4.4 kHz or 11.2 P/M. The 300 Hz difference is probably the error introduced by the spectrum analyzer, which is specified to be less than 400 Hz under the above conditions. The counter is, of course, the more accurate instrument. However, the spectrum analyzer has the advantage in that the signal level required is on the order of microvolts, whereas the counter requires many millivolts.

Amplitude Modulation

Some oscillator specifications require not only low incidental FM, but a high degree of spectral purity as well. Spectral purity cannot be conveniently measured with a counter but is very easy to determine with a spectrum analyzer. A case in point is undesired amplitude modulation. Fig 6 clearly shows the 1 kHz amplitude modulation. A counter would not indicate this.

Symmetrical FM

When an oscillator is swept symmetrically (plus and minus) with respect to a center frequency a long-term time average will not show any frequency change. Thus, unless the sweep interval is substantially greater than the counting interval, a frequency counter will show a stable signal which, in fact, may be frequency modulating. The following illustrates this.

An oscillator sweeping at a 60 Hz rate was checked with a counter and spectrum analyzer. The results are recorded in Table III and in fig 7.

Table III

Frequency Change as Indicated by Counter

Int.*			1	2	3	4	5	6	7	8	9	10	11	12
Freq. MHz**			274	293	272	331	275	343	288	350	295	312	304	293
13	14	15	16	17	18	19	20							
339	304	357	313	378	328	374	335							

* *Count interval 1 s spaced 3 s apart.*

***MHz 408.274, used only last three digits for convenience.*

The spectrum analyzer shows a peak to peak frequency excursion in excess of 2 MHz, whereas the counter shows a maximum frequency change of only 102 kHz.

Fine Grain Analysis by Checking the Reference Signal

Many stable microwave signals are derived from lower frequency sources by frequency multiplication, phase locking or other means. Fine grain analysis of the reference signal will very often yield valuable information concerning the microwave output without the necessity of utilizing costly or complicated microwave test equipment.

Fig 8 shows the results of such an analysis. The signal is the 1 MHz reference source used for phase locking the local oscillator of a microwave spectrum analyzer. It is observed that the reference signal has good spectral purity (no observable extraneous outputs in the vicinity of the carrier) hence the reference oscillator could be eliminated as a cause should there be difficulty in phase locking.

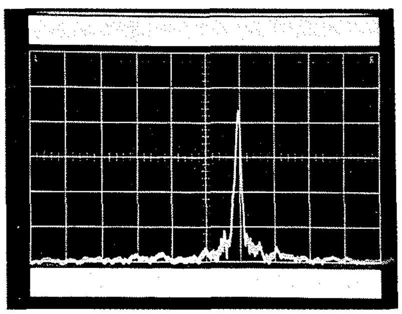


fig 8 Fine grain analysis of reference signal; dispersion: 50 Hz/cm; resolution: 10 Hz.

Fine Grain Analysis by Down Conversion

Sometimes it is not possible to check the stability of a signal's reference source, or such a measurement does not yield sufficient information, or the signal is not derived from a lower frequency source. Under these conditions it is still possible to use a low frequency spectrum analyzer for fine grain analysis by down converting the unknown signal. This can be accomplished by heterodyning the signal to be measured with a second, known to be stable signal, or a second source having the same general characteristics as the signal to be measured.

Fig 4 is the result of such a measurement. Here two phase-locked 2 GHz oscillators whose frequencies differ by 0.5 MHz were heterodyned in a mixer and the result displayed on a spectrum analyzer tuned to 0.5 MHz. Spectrum analyzer dispersion is 500 Hz/cm. It will be observed that the combined incidental FM of both 2 GHz oscillators is on the order of several hundred Hz. Since the incidental FM characteristics of the two oscillators are random and not coherent, several photographs would have to be taken to be assured that the maximum deviation is observed. In addition, slower sweep time measurements would have to be performed in order to make certain that the display broadening is, in fact, due to FM and not something else.

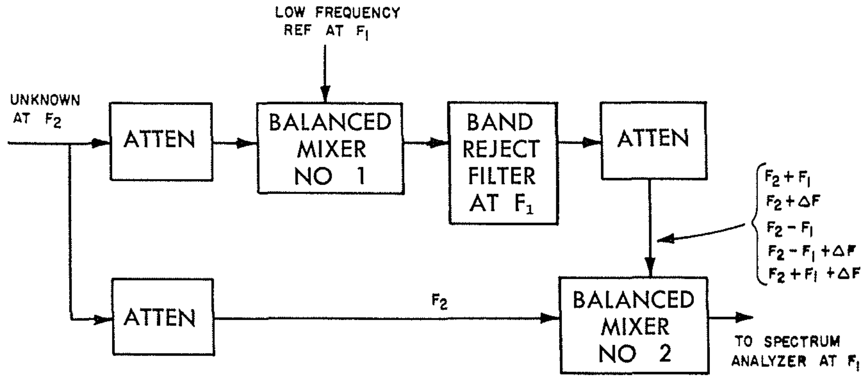


fig 9 Block diagram of spectral purity measurement.

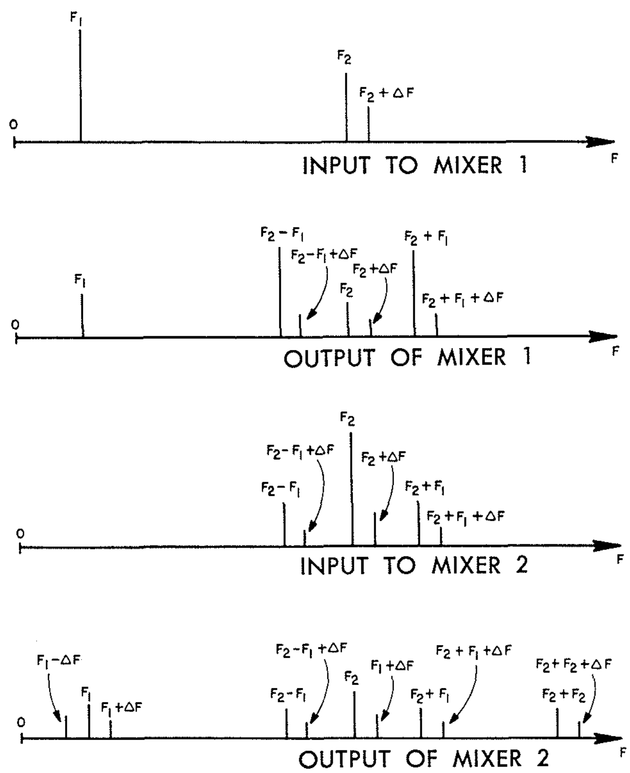


fig 10 Frequency relationships for the system of fig 9.

Spectrum Purity Measurements in Presence of FM

Sometimes it is desirable to observe multiple outputs or amplitude modulation in the presence of FM. This can be accomplished by utilizing the system shown in the block diagram of fig 9. This system is best understood with reference to the frequency diagram of fig 10.

In order to illustrate this technique we have assumed that the signal to be analyzed has a small spurious sideband at a frequency Δf above the main signal at f2. This signal is heterodyned with a stable (e.g., crystal oscillator) low frequency signal at a frequency f1. Neglecting harmonic conversions, the output of the mixer consists of signals at the sum and difference frequencies of the two inputs and the two inputs themselves reduced by mixer loss and the degree of mixer balance. The mixer output at f1 is now eliminated by means of a band reject filter (a high-pass filter rejecting f1 can also be used). This signal, reduced in amplitude by an attenuator, is now applied to a second mixer where it is heterodyned against the original signal at f2. Here again, the output signal consists of the sum and difference of the input frequencies and reduced versions of the two inputs. The output of the second mixer, among other things, contains a component at the frequency f1, having two sidebands at a frequency separation of Δf.

One important assumption in this analysis is that when the unknown signal is used as the local oscillator (larger of the two signals) for mixer 2, the sideband at $f2 + \Delta f$ does not enter into the mixing action. This assumption presupposes that the sideband at $f2 + \Delta f$ is at least 20 dB below the carrier at f2. Thus, the sideband power level is insufficient to act as an efficient local oscillator and all conversions with $f2 + \Delta f$ will be negligibly small. In order not to violate this assumption, the input levels to mixer 2 should be kept as low as possible.

One point that was neglected is incidental modulation of f2. With reference to fig 9, it is obvious that the output of mixer 2 at frequency f1 is a function of the instantaneous frequency difference of the two inputs. Assuming negligible time delay in the first mixer, the filter, and the attenuator, frequency modulating of f2 will have no effect on the final output.

It will be noted that we have translated the signal to be measured from f2 to a lower frequency f1. It should also be observed that in the process the signal has acquired a second sideband. A similar analysis for a double sideband signal will show that no additional sidebands are created, but the sideband level is increased by a factor of two relative to the carrier.

Thus, the technique will indicate the presence of sidebands, their spacing with respect to the carrier, and the maximum level of the sidebands relative to the carrier. This technique cannot be used to determine whether a single or double sideband signal is involved or to determine the true level of the sidebands relative to the carrier. Utilization of a more complex system using imageless mixers would eliminate these restrictions. Fig 11, 12 and 13 illustrate this technique.

Fig 11 was obtained with f1 = 1 MHz, f2 = 400 MHz and the spectrum analyzer set for a center frequency of 1 MHz, a dispersion of 50 Hz/cm and a resolution of 10 Hz. The 60 Hz amplitude modulation of the signal is clearly observed.

Fig 12 shows the spectrum of a 2 GHz signal. The spectrum analyzer is set for a dispersion of 500 kHz/cm. It is observed that the spectral width of the signal is close to 2 MHz. We are unable to determine if any AM is involved.

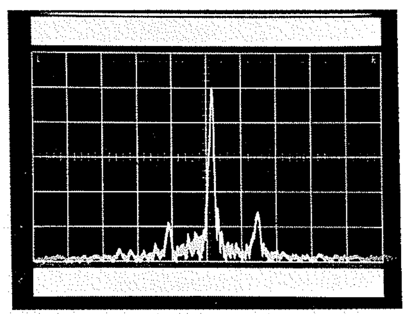


fig 11 Fine grain analysis of microwave signal.

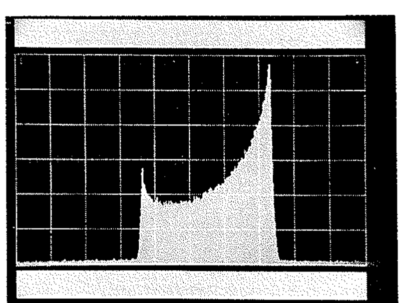


fig 12 AM in the presence of FM.

The photos for this article were taken with the following Tektronix equipment types: 1L5 and 1L20 Spectrum Analyzer Plug-ins in a 549 Storage Oscilloscope and a C-12 Camera with projected graticule; 491 Spectrum Analyzer with C-30 Camera.

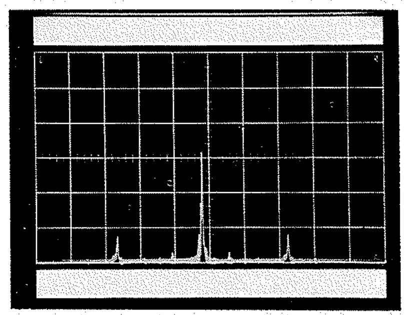


fig 13 AM in the presence of FM with the FM cancelled out.

Fig 13 shows the AM characteristics of this 2 GHz signal obtained by using the setup shown in fig 9, with f1 set at 1 MHz. This dispersion is 500 Hz/cm, indicating the presence of amplitude modulation at 1300 Hz.

CONCLUSION

As these experiments indicate, there is a considerable overlap in measurement capabilities between the basic "time domain" versus "frequency domain" methods.

The ultimate decision as to which instrument to use in a specific measurement application must be made with respect to such things as; required accuracy, required form of data (i.e., quantitative or qualitative), convenience and availability of equipment.

Quite often, however, trade-offs might be made; e.g., if a counter were not available, a measurement to a very high degree of accuracy or stability might be made with a spectrum analyzer at the expense of convenience, the data being limited only by the accuracy or stability of the reference frequency and the ingenuity of the user.

REFERENCE

1. Long, G. and M. Engelson, "Optimizing Spectrum Analyzer Resolution," Microwaves, December 1965.

Interpreting Markings on Semiconductor Components

The following information will be of use when trying to identify a semiconductor supplied by Tektronix with, or for, a Tektronix instrument.

Color codes should be read starting with the dot or band nearest one terminal or lead. By strong convention, that terminal or lead goes to the "N" material (cathode) if the component is a diode. Any single dot, band, or unique symbol that appears on a diode is supposed to be adjacent to the "N" material terminal. If the device is a transistor, any one special mark is supposed to be adjacent to the collector.

EIA STANDARD COLOR CODE

Black	— 0
Brown	— 1
Red	— 2
Orange	— 3
Yellow	— 4
Green	— 5
Blue	— 6
Violet	— 7
Grey	— 8
White	— 9

1. 1Nxxxx or 2Nxxxx printed on the component indicates the JEDEC-registered type number.

2. Nine-digit numbers starting with 151, 152, or 153 are the Tektronix part numbers. Tektronix components whose nine digit part number begin with 151 are transistors. Components whose part number begin with 152 are diodes. Tektronix part numbers beginning with 153 are selected components and will consist of both diodes and transistors.

3. Seven-digit numbers starting with 151, 152, or 153 will be a number code for a Tektronix part number. The digits will stand for the first seven digits in the part number with the last two digits in the part number understood to be zeros.

4. Six-digit numbers starting with 151, 152, or 153 will be a number code for a Tektronix part number. The last three digits in the number code will correspond to the fifth, sixth, and seventh digits of the Tektronix part number. The fourth, eighth, and ninth digits in the part number will be zeros.

5. Four-digit numbers will probably be a number code for a Tektronix part number. The four digits in a four-digit number code correspond to the fourth, fifth, sixth, and seventh digits in the Tektronix part number, with the last two digits in the part number both zeros. The first three digits will be 152 if a diode, and 151 (or possibly 153) if it has more than two connections.

6. Three-digit numbers that are alone will usually be a number code for a Tektronix part number. If not alone they will be a date code, or the manufacturer's type number. The three digits in our three-digit number code correspond to the fifth, sixth, and seventh digits in the Tektronix part number, with the fourth and last two digits in the part number understood to be zeros. The first three digits will be 152 if a diode, and 151 (or possibly 153) if the component has more than two terminals. The three digits in a date code stand for the year and the week when manufactured. The number 752 would stand for the 52nd week of 1967.

7. Four-band color codes will stand for a Tektronix part number, or a JEDEC-registered type number. If the first of four bands is pink or blue, the code is for a Tektronix part number; if not pink or blue, the code is for a JEDEC-registered type number. At some time in the future JEDEC numbers will reach 6000, and at that time the first of four color bands will be blue. At that time, Tektronix will be using a pink band exclusively on new components to indicate that the code is for a Tektronix part number.

8. Three-band color codes will stand for a JEDEC-registered type number or the manufacturer's type number. If the bands start with pink, blue, or black, it will not be a JEDEC type number. Some small three-band color codes may look like four-band color codes if you don't use a magnifying glass, because a trademark or initial may also be printed in color on the component, and appear to be a band. For instance, Transitron T12G diodes are presently coded black, brown, red, and have a yellow T next to the red band that sometimes appears to be a yellow band.

9. Dot color codes consisting of one, two, or three dots are manufacturer's type number codes, and normally cannot be interpreted without knowing who the manufacturer is. Tektronix-made diodes are also dot coded. Color dots on extremely small semiconductors may appear on a terminal or lead as well as the body.

10. Trademarks, initials, or the manufacturer's name sometimes appear on a semiconductor.

MANUFACTURER CODE

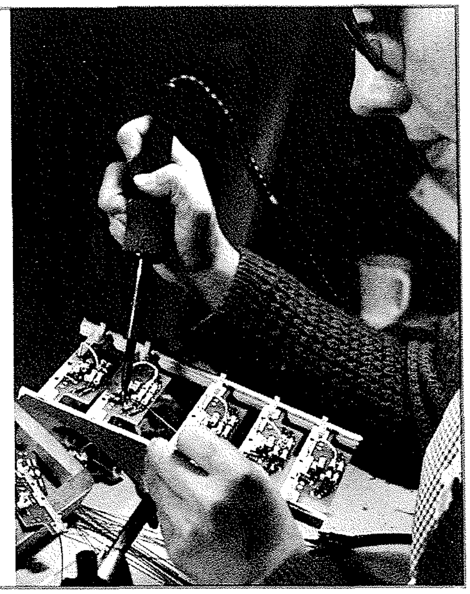
AMP	— Amperex	PHI	— Philco
CDV	— Continental Devices	PSI	— Pacific Semiconductor
ELM	— Elmar Electronics	RAY	— Raytheon
ERI	— Electron Research, Inc.	RCA	— Radio Corp. of America
FS	— Fairchild Semiconductor	SEM	— Semcor
GE	— General Electric	SPR	— Sprague
GI	— General Instrument	SYL	— Sylvania
HOF	— Hoffman	TEK	— Tektronix
HUG	— Hughes Semiconductor	TI	— Texas Instrument
IDC	— International Diode Corp.	TRA	— Transitron
IRC	— International Rectifier	TRW	— Thompson Ramo Woolridge
ITT	— International Telephone and Telegraph	TUN	— Tung-Sol
MIC	— Microwave Associates	UTR	— Unitrode
MOT	— Motorola	VAR	— Varo
OHM	— Ohmite	WES	— Westinghouse

Soldering Techniques

Soldering Tektronix Circuit Boards

Stan Chojecki
Vern McAdams Component Evaluation Engineers

Soldering Leadless Capacitors



INTRODUCTION

Soldering is an alloying process between two metals. In its molten state, solder dissolves some of the metal with which it comes in contact. The metals to be soldered are, more often than not, covered with a thin film of oxide that the solder cannot dissolve. A flux must be used to remove this oxide film from the area to be soldered. The solder used in most electronic work contains this flux as a center core which has a lower melting point than solder itself. When the molten flux cleans the metal it accomplishes two things:

1. It allows the solder to wet the metal.
2. It holds the oxides suspended in the solution.

The molten solder can then make contact with the cleaned metal and the solvent action of solder on metal can take place.

The soldering process then is the following:

1. The cored flux melts first and removes the oxide film on the metal to be soldered.
2. The solder melts, floating the lighter flux and the impurities suspended in it to the surface.
3. The solder partially dissolves some of the metal in the connection.
4. The solder cools and fuses with the metal.

METAL PREPARATION

To do a proper soldering job the following must be done:

1. The connection itself must become hot enough for the rosin to melt and clean the metal. The cored solder must be applied directly to the heated connection so that the flux, which melts at a lower temperature than the solder, will melt first and clean the connection by the time the solder has melted. (If the solder is applied to the soldering-iron tip, the flux, being lighter, will float on top of the solder. It will be unable to reach the connection and clean it.)
2. A good easy flow of heat from the soldering-iron tip to the connection must be obtained by a clean, well-tinned soldering-iron tip. A thin film of molten solder will transfer heat rapidly.

In soldering techniques for circuit boards, the basic principles for soldering prevail. We are now interested in the difference in the soldering of circuit boards and normal soldering.

CIRCUIT BOARD CONSIDERATIONS

The first consideration of soldering to circuit boards is the temperature limitation of the substrate. The Tektronix circuit boards have a substrate of fiber-glass epoxy, which has a temperature limitation of 530° F for not more than 5 minutes. Hotter temperatures reduce the time in inverse relationship; the hotter the temperature, the less time the boards will stand it before damage.

A second consideration is the soldering-iron-tip temperature, which is determined by the type of soldering iron and soldering-iron tip used. The wattage of the soldering iron and the configuration of the soldering-iron tip combined with the speed of soldering will determine the ultimate tip temperature as well as the working-tip temperature. Since we are here primarily concerned with the working-tip temperature, the soldering iron and tip should be chosen so that the working-tip temperature will at no time exceed the limitations of heat set forth above.

A third consideration in soldering of circuit boards is the type of solder used. The best type for use on the Tektronix circuit boards is a "eutectic"-type cored-wire solder of size #20 AWG, composed of 63% tin and 37% lead (as designated Fed Spec QQ-571c as Sn63) with a central core of activated rosin flux (Divco X-25 or equivalent).

A fourth consideration is the technique of repair—repair in this case consisting of replacement of components. The correct sequence in the replacement of a component is as follows:

1. Clip the leads of the soldered component.
2. Remove the component from the circuit board.
3. Remove the clipped leads individually from the circuit board.

Θ_{CS} = **THERMAL RESISTANCE OF MOUNTING.**

Can be reduced by employing various techniques such as:

(1) Honing to improve metal interface contact;

(2) Silicone grease or similar compound with high heat conductivity to fill in surface irregularities and improve surface contact between transistor and mounting surface.

Θ_{SA} = **THERMAL RESISTANCE OF "HEAT SINK" OR MOUNTING BASE.**

Value is determined by factors like surface area, color, volume of air passing over it, etc. Usually this factor is designed-in after the other elements have been optimized.

P_D = **POWER DISSIPATION**

Limited by ambient and maximum allowable junction temperature.

Silicone Grease for Tektronix Instruments

Of the many readily available silicone dielectric compounds, we suggest Dow Corning Type 4 or Type 5 Silicone Compound of heat sink use in current Tektronix instruments.

Some other types of silicone greases may be used that contain metallic oxides which increase the thermal conductivity. These are more expensive than ordinary silicone greases like Type 4 and Type 5, which we know will meet the thermal conductivity and temperature range requirements for our instruments.

A practical general rule for maintenance operations is to use silicone grease whenever replacing any heat-sink-mounted transistor.

When replacing such transistors, apply a thin film of silicone grease between the transistor case and the heat sink.

If a mica or other type electrically-insulating washer is used between the transistor and the heat sink, apply a thin film of grease to both sides of the insulating washer as well.

In some cases (such as the 547 VA output transistors), the transistor is electrically insulated from the chassis by a white beryllium oxide disk. If, for any reason, you remove the heat sink disk, you should also apply silicone grease where the disk contacts the chassis.

Try to avoid getting silicone grease on leads that have to be soldered. Soiled leads wiped clean with a cloth should respond well to standard soldering techniques.

Dow Corning Type 4 Silicone Compound is available in 2 oz and 8 oz tubes through electrical and electronic supply houses.

JUNCTION POWER DISSIPATION = CURRENT

OPPOSITION TO HEAT TRANSFER = RESISTANCE

AMBIENT TEMPERATURE = VOLTAGE

JUNCTION TEMPERATURE = VOLTAGE

Insulating Washer	Typical Thermal Resistance in °C/W (Θ_{CS})	
	Dry	W/Silicon Lubricant
None	0.2	0.1
Teflon	1.45	0.8
Mica	0.8	0.4
Anodized Aluminum	0.4	0.35

Service Notes

REED SWITCH INSTALLATION

The following considerations will be of interest to those who are concerned with the soldering of reed switches.

1. Stress: The less stress applied to the glass-to-metal seal, the more chance the reed has of performing its function. Bending a lead without supporting the lead inside the bend with a rigid support will cause changes in its operating parameters. The reed should be supported by the coil and never by its leads. The ideal situation is one where the coil supports and retains the reed, and nickel ribbon is soldered on the leads for circuit connections.
2. Contact Gap: Gap placement is not always in the center of the glass envelope. It is, therefore, important when installing a reed in its coil to be sure the contact gap is centered in its coil, regardless of where inside its glass envelope it may be.
3. Lead Length: Length is important in that a reed is purchased to a given ampere-turn pull-in rating which is checked with full-length leads. Cutting these leads short will increase the ampere-turn pull-in requirements for the reed. Leads cut to ¼-inch from the glass seal increase the ampere-turn requirements by 20%. Under normal conditions no lead should ever be shorter than ¼-inch.
4. Cutting: Cutting of leads will also, under some conditions, cause operating changes, due to the shock being transmitted up the lead. All cutting of leads should be done with good support of the lead inside the point of cutting. Good support will help keep the stress to a minimum and absorb the shock of cutting action.

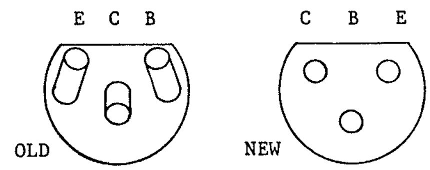
Poor installation practice will not always show up in calibration but is certain to cause problems eventually.

TOUCH-UP PAINT CANS CLOG

You can probably prevent pressurized cans of touch-up paint (252-0092-00) from clogging by observing a simple practice: As soon as a paint job is done, turn the can completely upside down, and spray into a rag for a few seconds to clear the nozzle and take-up tube.

PLASTIC TRANSISTOR LEADS CHANGE

Plastic transistors made by Texas Instruments are now being supplied with the leads emerging at the points of a triangle instead of in a straight line. That means the flat side of the new ones will face a different direction from before, so the flat side should not be used alone as a guide for how a replacement transistor should be oriented.



USED INSTRUMENTS FOR SALE

1—Type 545A; 1—Type 535A; 2—Type 502; 2—Type 560/60/67. Contact: Henry Posner, Pacific Combustion Engineering Co., 5272 East Valley Boulevard, Los Angeles, California 90032. Telephone: 225-6191.

1—Type B, SN 17266; 1—Type D, SN 15737. Possibly interested in a trade for a used CA, 1A2 or 1A6. Contact: Ashton Brown, 246 Cambridge, Kensington, California 94708. Telephone: (415) 524-3005.

3—Type D High-Gain DC Differential Units, SN 017118, 017120 and 017121. All instruments are in like-new condition. $115 each. Contact: Electronicraft, P. O. Box 13, Binghamton, New York 13902. Telephone: (607) 724-8785.

1—RM647/10A2/11B2—10 months old. Price $2100. Contact: John Robb, Lightning & Transient Research, 2531 West Summer Avenue, St. Paul, Minnesota 55113. Telephone: (612) 631-1221.

1—515A, SN 3899. Price $350. Contact: Mr. Sieger, General Resistance Company, 430 Southern Boulevard, Bronx, New York 14055. Telephone: (212) 292-1500.

1—Type 524D, SN 1328. Price $500. Good operating condition. Contact: Enrique Valdes Pages, WKAQ-TV, P. O. Box 5096, San Juan, Puerto Rico 00905.

1—Type RM504, SN 1589, like new. Price $400. Contact: Walker Medical Electronics, 8621 East 55th Street, Kansas City, Missouri 64127. Telephone: (816) 353-2038.

1—Type 547, SN 1342; 1—Type 1A1 dual-trace plug-in, SN 2043. Electrical and physical condition excellent. Contact: H. R. Greenlee, 430 Island Beach Boulevard, Merritt Island, Florida 32952. Telephone: (305) 853-9542 (during working hours).

1—Type 512, SN 2113, in excellent condition with Tektronix modifications. X10 probe and manual included. Price $180 FOB. Scope cart included with pick-up purchase. Contact: Robert A. Dessert, 6703 Greendale Road, Alexandria, Virginia 22310. Telephone: (703) 971-2941.

USED INSTRUMENTS WANTED

1—of the following type scopes: 533A, 535A, 524D or 531A. 1—Type CA plug-in; 1—Type H, L or B plug-in. Contact: H. R. Greenlee, 430 Island Beach Boulevard, Merritt Island, Florida 32952. Telephone: (305) 853-9542 (during working hours).

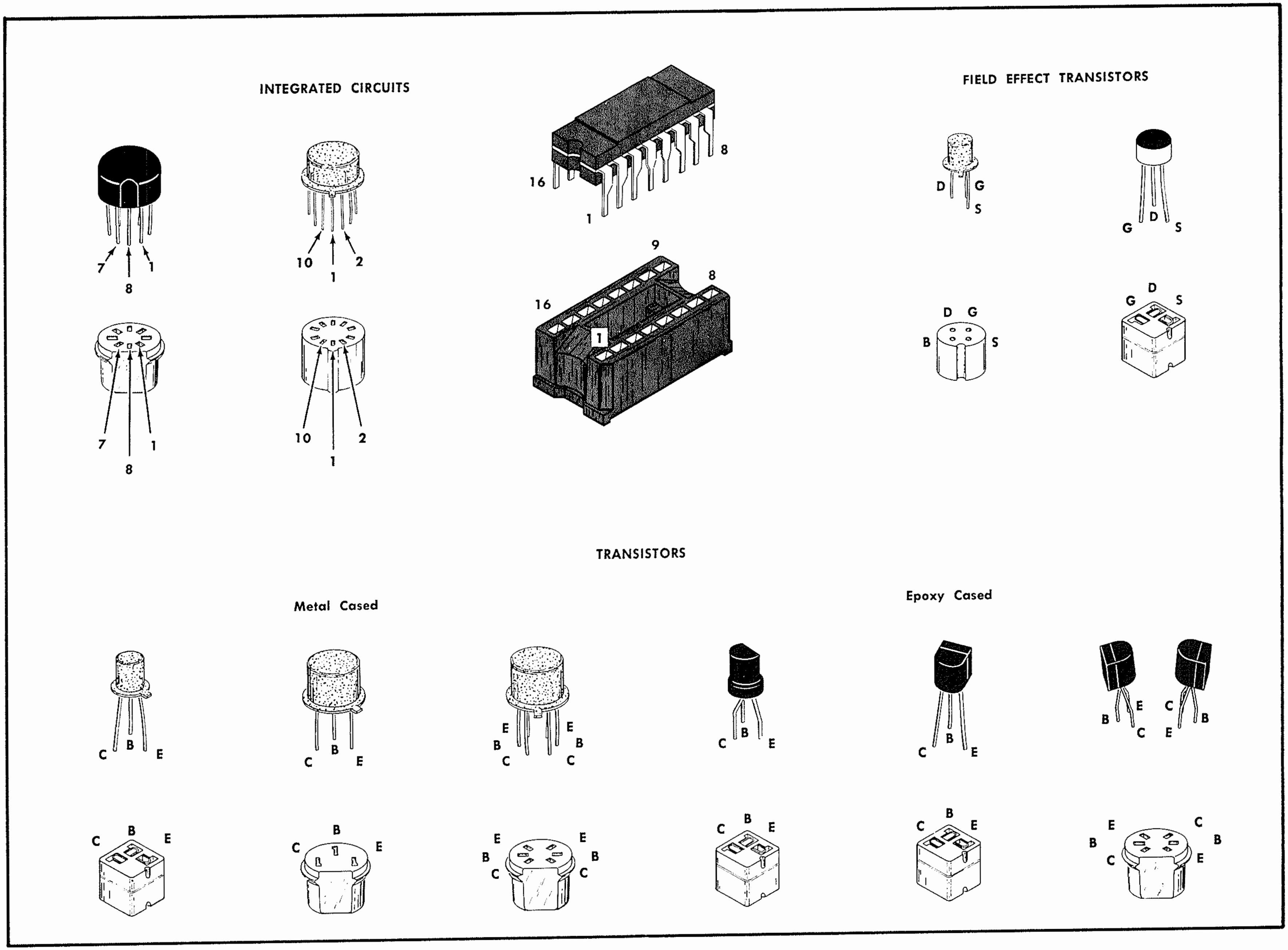
1—Type 503. Contact: Mr. B. Smalley, Intercontinental Dynamics Corporation, 8940 South Bell, Chicago, Illinois 60620. Telephone: (312) 238-8577.

1—Type 422. Consultant wants for personal use. Contact: Ross Hupp, 4961 La Gama Way, Santa Barbara, California 93105. Telephone: (805) 967-9331.

REFERENCE CHART

The reference chart shown on page 15 is useful for identifying the pin numbers of socket-mounted transistor and integrated circuits. By cutting along the dotted lines, the chart can be detached for use on your bench.

To remove, cut along dotted line.



Electrode configuration for socket-mounted transistors and Integrated Circuits, top view.

SERVICE SCOPE

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon, U.S.A. 97005

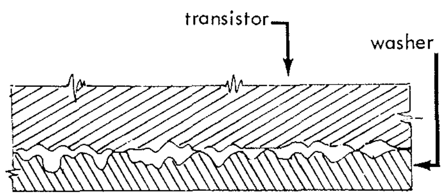
..., SR. ELECT. TECH. 9/67
...PORT
... LAB.
..., STATION E
OTTAWA, ONTARIO, CANADA

Silicone Grease for Transistor Heat-Sink Use

Some confusion apparently exists over the need for silicone grease in mounting heat-sinked transistors and if so, where do you put it.

The maximum power which may be dissipated in a transistor is limited by its junction temperature, T_J. An important factor in determining junction temperature is the ability to conduct heat away from it. There are several "thermal resistances" to be considered in series with heat transfer from junction to ambient air. An electrical analogy of these separate "resistances" is shown in fig 1. One of these, Θ_{CS}, is the thermal resistance from case to heat sink and is influenced by the method of mounting. If a mica insulating washer is used dry, the junction temperature rise per watt of power dissipated is about 1.0°C due to Θ_{CS} alone. This is mainly due to irregularities in the surfaces resulting in dead air spaces which do not readily transfer heat. See fig 2.

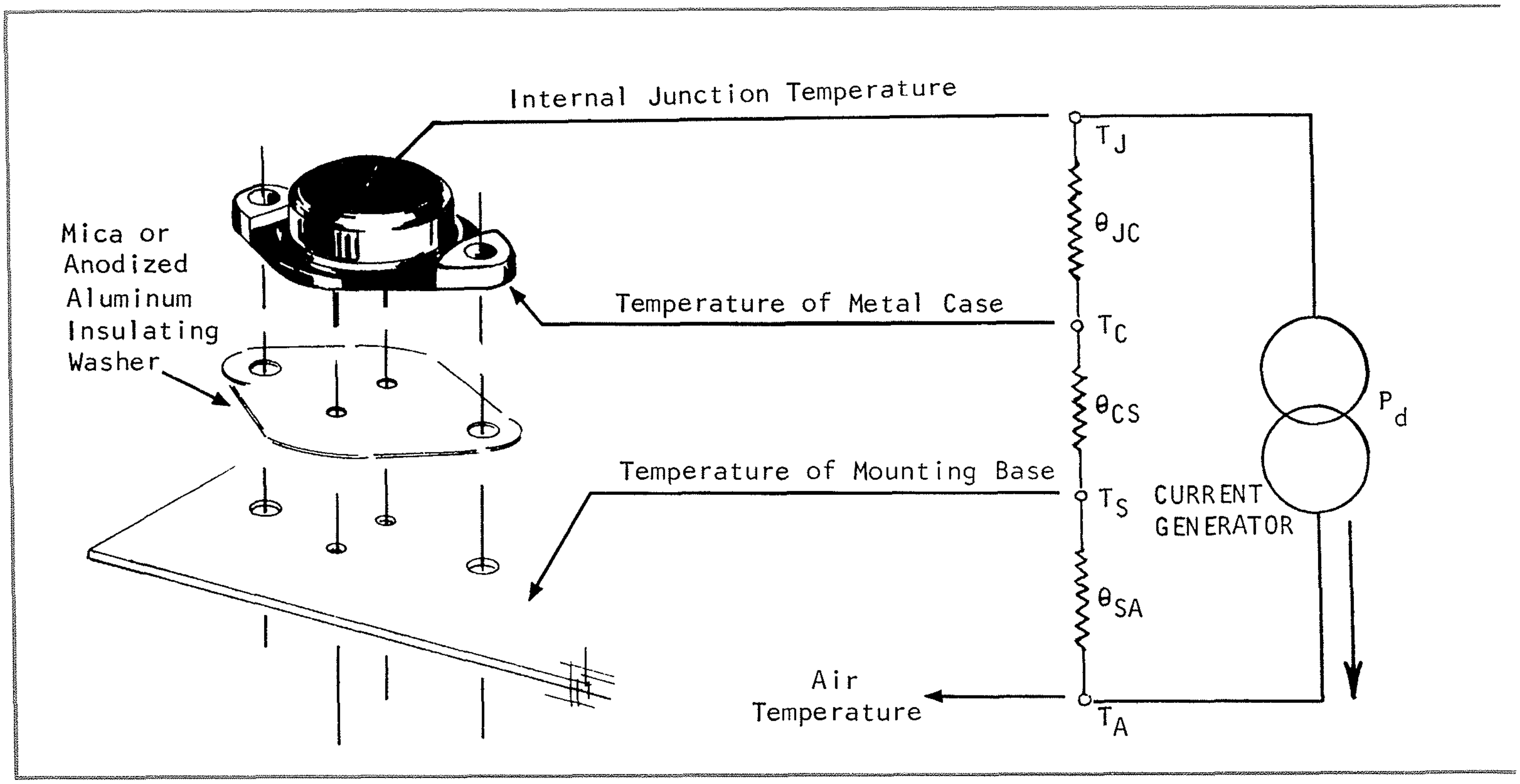
Polishing the surfaces to reduce the amount of dead air space would help, but is expensive. A more economical method is to fill the spaces with a substance superior to air in thermal conductivity. Nearly anything is better than dead air, but silicone grease has the advantage of being a good electrical insulator while readily conducting heat. The use of ordinary silicone grease can reduce the above mentioned 1.0°C rise per watt of power to about half, and some of the new types of greases bearing metallic oxides claim reductions to the area of 0.1°C/W. As an example, this would mean a difference of 22.5°C in the junction temperature of a power transistor dissipating 25 watts.



How A Magnified Cross-Section View Of The Surfaces Might Look

Θ_{JC} = **THERMAL RESISTANCE OF JUNCTION TO CASE BOND.**

Controlled by manufacturing process only.



Carelessness in reheating the solder connections for the removal and replacement of components is the only difficulty to be guarded against here. Caution must be taken not to overheat the substrate and this can best be accomplished with deft hands and by small applications of heat. If the removal or replacement is not accomplished in the first few seconds of heat application, avoid transferring too much heat to the substrate by **going to another connection or waiting a few minutes before reheating the connection.** Giving the connection these few minutes to cool will allow the heat to dissipate and help to avoid overheating the substrate. Heat dissipates quite slowly from some of the smaller connections and too long an application of the soldering iron will result in the overheating of the substrate.

TIP CONSIDERATIONS

Some things to be considered in order to obtain a low working-tip temperature are:

1. At slow soldering speeds, a 25-watt iron and a 1/8 inch tip.
2. At medium soldering speeds, a 40-watt iron and a 3/16 inch tip.
3. At fast soldering speeds, a 50- or 60-watt iron and a 1/4 inch tip.

A recommendation for soldering tips is that they be made of copper and have a chisel or bevel shape.

There are two areas on a circuit board which might require different soldering techniques. One is the large copper area used as a common connection in contrast to the smaller spot connections. The larger areas will absorb heat much more rapidly than the smaller spot connection. This may necessitate a hotter iron and a larger tip for these areas than the smaller spot connections.

With these cautions and recommendations in mind you should encounter no trouble when soldering Tektronix circuit boards.

Soldering Leadless Capacitors

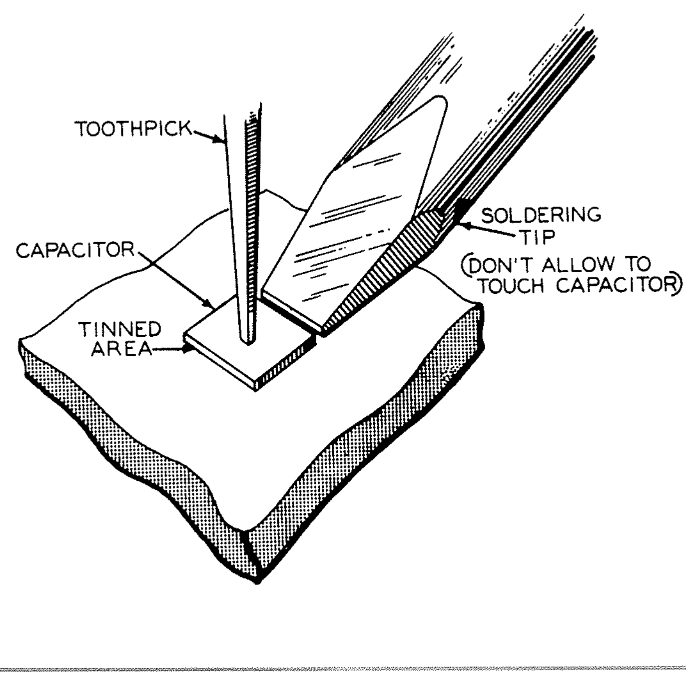
Special techniques are required to succesfully solder leadless capacitors to circuit boards. The following steps will minimize the problems that may be encountered when soldering leadless capacitors to circuit boards.

1. Tin the capacitor if it is not already tinned. This can best be accomplished by using a small soldering iron with low heat, and holding the capacitor down by weighting the edge of it with a silver coin.
2. Tin the area of the circuit board where the capacitor is to be attached. This is usually a relatively large ground-plane area.
3. Place the capacitor on the board in the desired location.
4. Apply heat to the board adjacent to, but not touching, the capacitor. This will require more heat than the tinning operation above. Do not attempt to effect a bond by applying heat on top of the capacitor as this will permanently damage the device.
5. Press down lightly on the top of the capacitor using a toothpick, or other small wooden stick, until it settles down onto the board—indicating that the solder has melted underneath. Remove the heat and allow to cool.

When soldering leads to the tops of leadless capacitors:

1. Solder the capacitor to the circuit board using the method above.
2. Bend wires or component leads over the top of the capacitor (within approximately one lead diameter) after the other end of the component has been secured in place.
3. Using a small iron, heat the component lead and apply solder until the solder wicks down onto the top of the cap.
4. Remove the soldering iron, and allow the lead to seek its own equilibrium. This will minimize the external stresses on the capacitor.

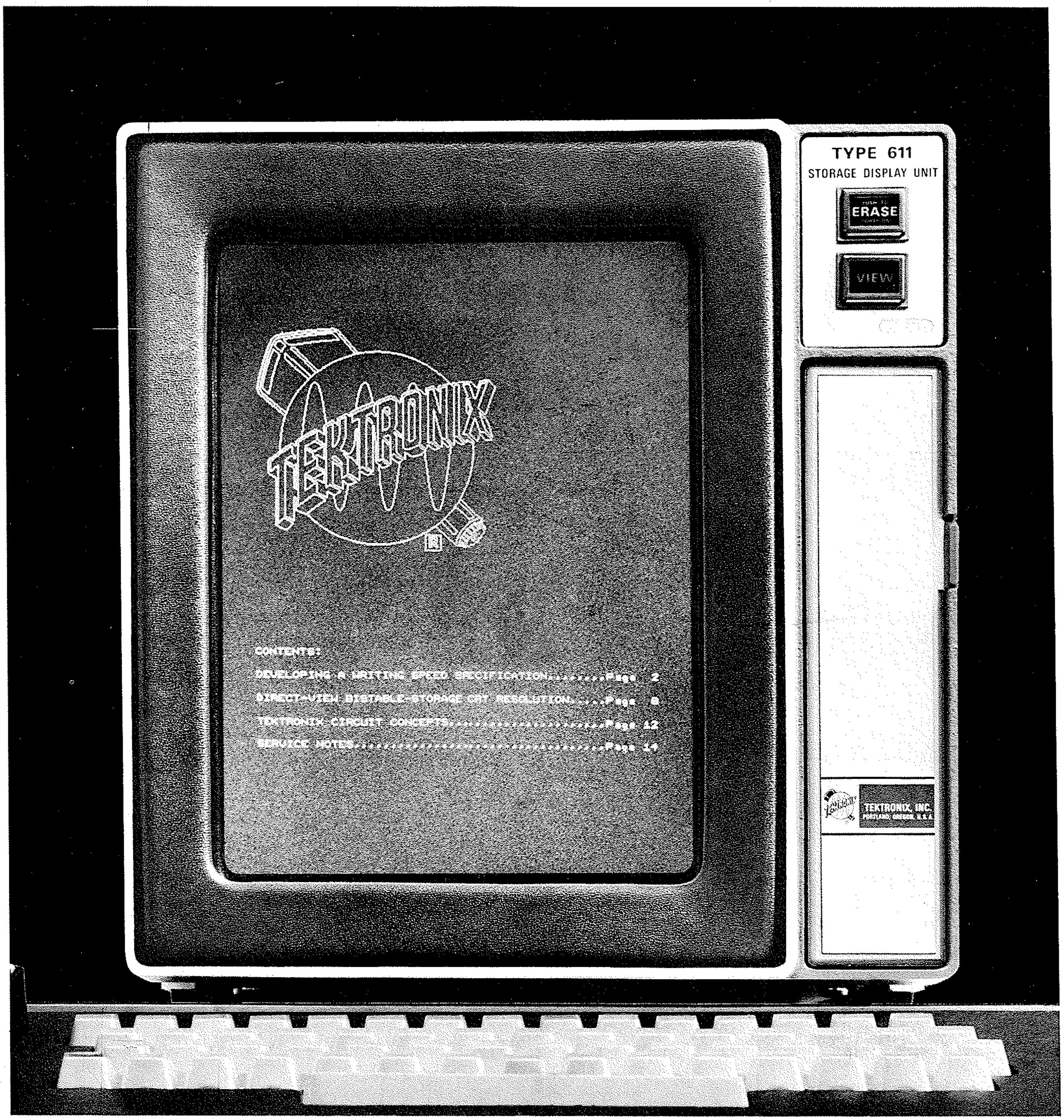
Remember, practice makes perfect!



TEKTRONIX®

SERVICE SCOPE

NUMBER 49 APRIL 1968



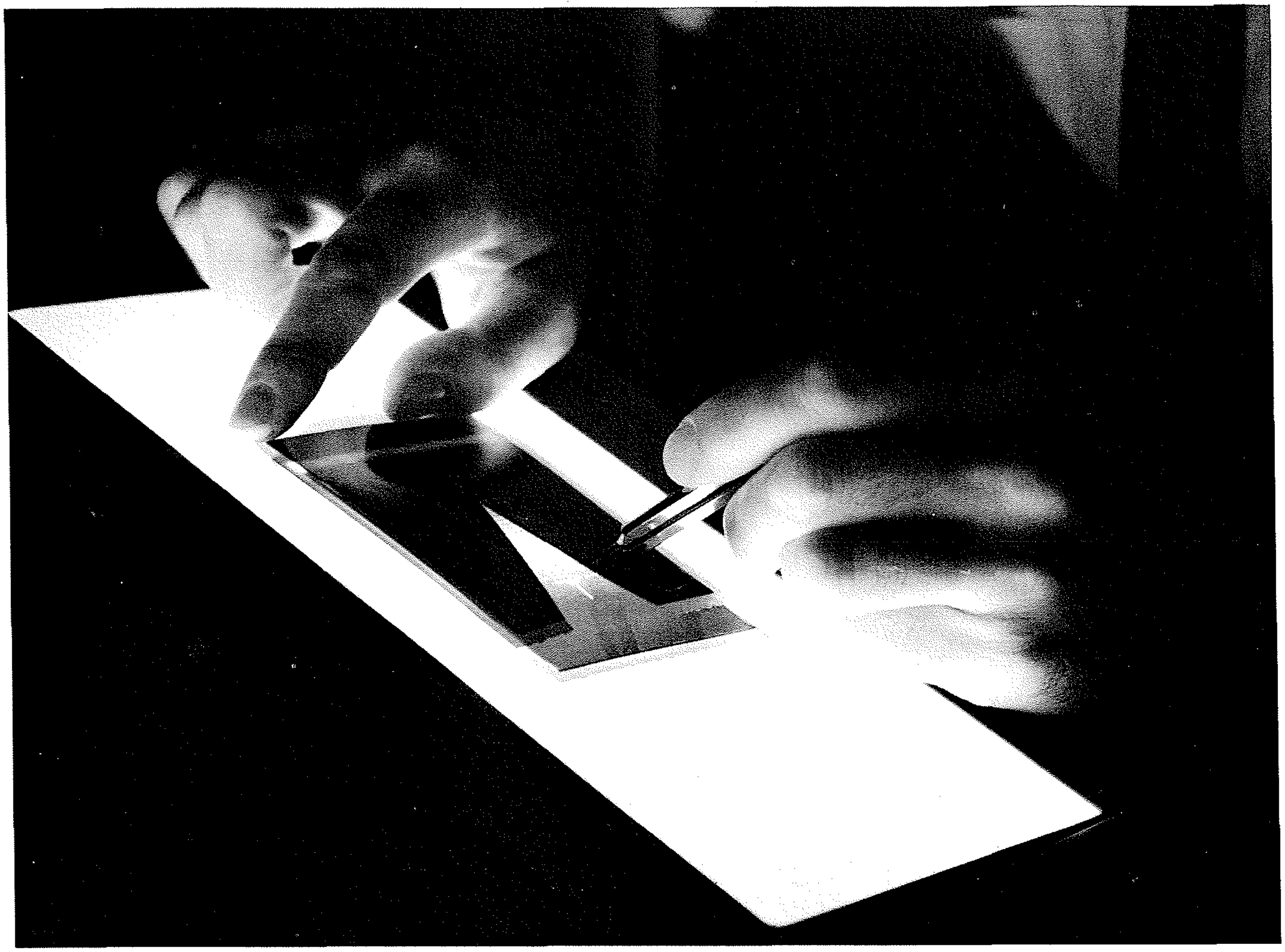


Fig 1 Determining writing speed from a backlighted photograph. Note the use of a mask to cover the peaks of the waveshape.

Developing a Writing Speed Specification

(2.5 cm/nanosecond)

COVER

The Type 611 Storage Display Unit is featured on this issue of SERVICE SCOPE. The familiar Tektronix trademark display was programmed from a disk memory unit and the table of contents entered from the accompanying keyboard. The Type 611's unique storage CRT eliminates the need for display-refreshing memories and provides excellent display resolution without flicker. For information on resolution of Tektronix Direct-View Bistable-Storage CRT's, see the story on page 8.

For some years now various groups at Tektronix have been striving to specify writing speed for new Tektronix instruments. The problem is difficult because of the number of variables entering into it. Table 1 illustrates the factors that can enter into specifying writing speed. If such a parameter is specified, then each factor must be carefully examined to determine its contribution. The subjective nature of some of these factors, plus the lack of control over others, (for example film history), all contribute to the problem.

Various approaches were taken in an attempt to control this parameter more completely and consistently. Photomultiplier and microdensitometer techniques, while appropriate for lab correlation, were not considered appropriate for customer use. An important consideration was that the customer be able to duplicate the test conditions at a reasonable cost. Without this requirement, much of the value of specifying writing speed would be lost, for many customers could not measure it.

The effort was then directed toward refining the techniques and controlling the factors that enter into the conventional determination of writing speed. To reduce the effect of variations in film sensitivity from roll to roll and frame to frame, five Polaroid* backs were used. Each contained Polaroid Type 410 film, and one exposure was made using each back. The results of the five pictures were then averaged and this value recorded.

The photographs are viewed while backlighted and masked as shown in fig 1. The use of backlighting (transillumination) tends to standardize the reading of recorded wave shapes. When determining writing speed, it is important that the photograph be well illuminated as the contrast sensitivity of the eye is a function of brightness. Backlighting is the preferred method of obtaining adequate illumination (approximately 1 foot-lambert) without the harsh glare that may accompany reflected light. This technique does not apply to Polaroid pack films as the plastic base is too opaque. Although the surface is glossy and harsh to the eye, adequate reflected light will achieve the same results as backlighting.

Using a mask to cover the peaks of the damped sine wave is important when making the measurement. The vertical velocity of a sine wave is zero at the peaks and maximum at the midpoint, so there is a considerable range of brightness on the photo. Without a mask there will be the illusion of seeing the complete trace, as the viewer will tend to connect the area between the bright peaks. Because of this he will tend to read a writing speed that is higher than the correct one. A line chosen as discernible without a mask may very well not be discernible when the peaks are covered with a mask.

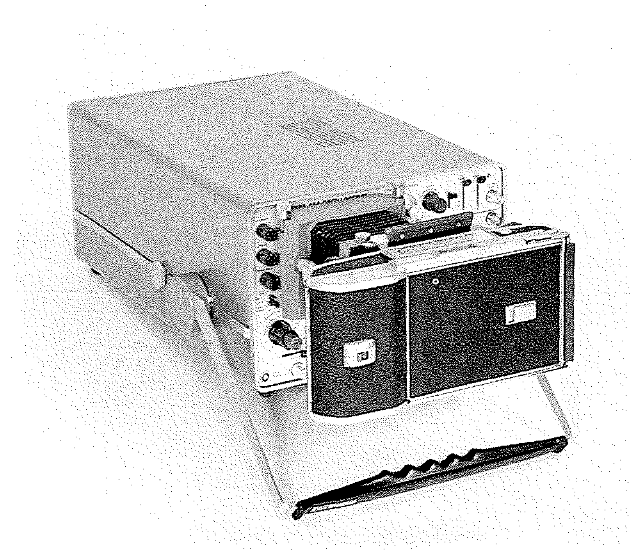


Fig 2 Shown above is the Tektronix Type 454 150-MHz Oscilloscope with the Type C-31 high writing speed camera system. The combination has a specified writing speed of 3200 div/μs with P11 phosphor.

To acquire enough information from which to compile a specification, a group of 74 instruments (Tek-

*Registered Trade-Mark, Polaroid Corporation

FACTORS INFLUENCING WRITING SPEED

Oscilloscope Controls and Circuitry	CRT Screen	Film
Focus misadjustment	Phosphor efficiency	Sensitivity (including change with age and environment)
Astigmatism misadjustment	Uniformity of phosphor efficiency across the screen	Spectral response
Intensity setting	Spectral distribution	Processing
Unblanking pulse height and shape	Persistence	Uniformity
Heater regulation	Phosphor graininess	Reciprocity
Calibration	"Sticking" of phosphor	
Accelerating potential		
CRT Gun	**Camera and Lens**	**Interpretation of Photographs**
Mutual conductance (Beam current vs. Grid drive)	Graticule transmission	Film fog level
Spot size	Dichroic mirror transmission	Trace contrast
Edge defocus	Effective aperture	Trace width
Plate intercept	Lens transmission (spectral response, and transmission efficiency)	Viewing conditions
	Lens shading (vignetting)	Human judgment
	Magnification (object-image ratio)	

Table 1 Major factors that affect writing speed.

tronix Type 454, 150-MHz Oscilloscopes) were used as a sample. The instruments were composed of 6 different groups taken over a 6 month period, and selected from manufacturing on a random basis.

The 74 instruments were read by the various readers subject to the following controls:

1. Intensity—adjusted to point of visual extinction with the oscilloscope in the single sweep mode.
2. Focus and Astigmatism—adjusted to produce a sharp trace on both horizontal and vertical axes during low repetition rate displays of a damped sine wave.
3. Phosphor dormant—5 minutes allowed between each exposure to allow decay to a consistent low level.
4. Camera System—Tektronix Type C-40 (f/1.3 lens with 1:0.5 object to image).
5. Exposure—5 seconds.
6. Film Type—Polaroid Type 410 (ASA 10,000).
7. Film Development—10 seconds.
8. Repeat Steps 3, 4 and 5 with 5 different rolls of film.
9. Mask photographs and view backlighted.
10. Record first central segment that is just discernible on each photo.
11. Calculate writing speed from formula— ws = 3.14 fA.
12. Average results and record.

Two readers were initially used: Reader 1 with no previous experience in determining writing speed; Reader 2 with considerable experience. The chart below shows the data taken by Reader 1. Note the mean of 1671 div/μs. Reader 2 consistently read higher and the mean value of readings was 1875 div/μs. Photos were then sampled from each of the 6 groups and given to 3 additional readers with no previous experience. This data when correlated with the other, resulted in a group average of 1656 div/μs. This then gave assurance that a specification based on Reader 1's data would be meaningful and repeatable. Note that only one of the 74 instruments fell below the specification of 1250.

In addition, studies were made with P11 phosphors. These studies confirmed that the Tektronix P11 phosphor had 100% more photographic writing speed than the Tektronix P31 Phosphor.

In a discussion of writing speed it is important to discuss briefly ASA exposure ratings as they are the accepted method of specifying negative speed in this country. ASA exposure ratings are measured at 1/50-second exposure to light of normal daylight spectral characteristics. Oscilloscope exposures are different in 2 very important aspects. First, most oscilloscope recordings are a very short exposure and so the normal relationship of exposure and density is subject to failure (reciprocity law failure). In addition, the spectral

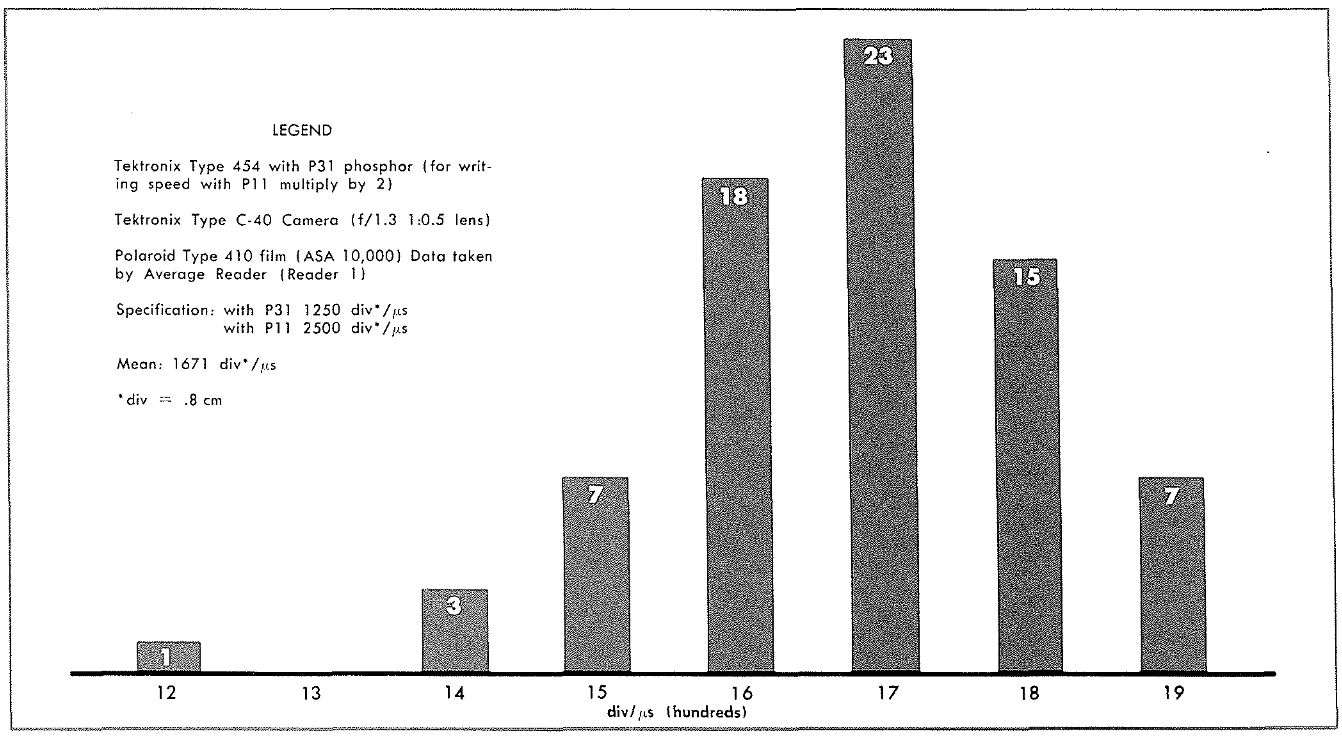
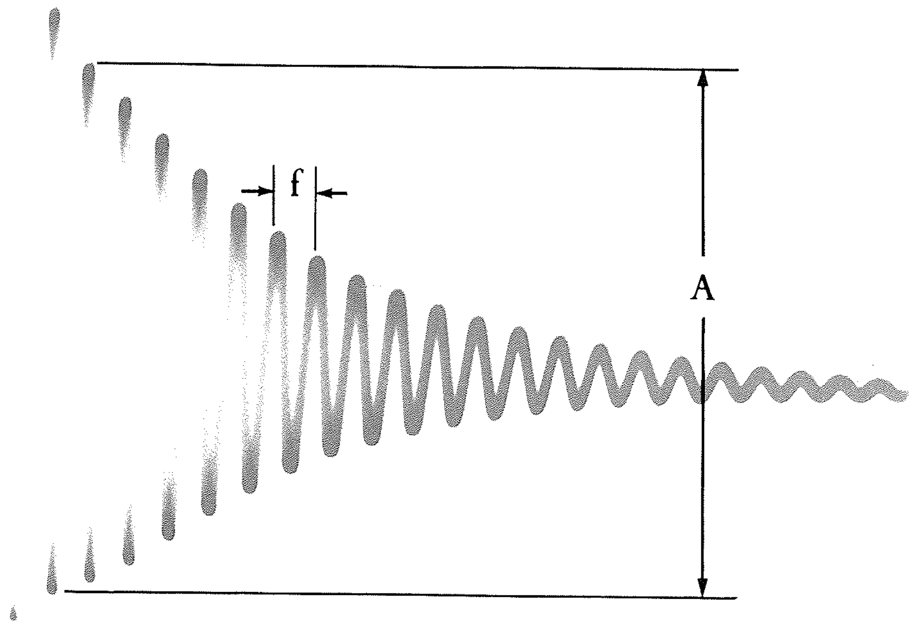


Fig 3 Writing speed distribution of Tektronix Type 454/C-40 (74 instruments).

Photographic Writing Speed



Photographic writing speed is a figure of merit which describes the ability of a particular camera, film, oscilloscope, and phosphor to record a fast moving trace. This figure expresses the maximum single-event spot velocity (usually in centimeters per microsecond) which may be recorded on film as a trace just discernible to the eye.

The results achieved are a function of the combined system performance of the oscilloscope, camera, film, recording technique, and the ability of the film reader to make a consistent interpretation of the results. Prefogging and postfogging of the recording film improve the apparent photographic writing speed of a particular system but the results are unpredictable and difficult to repeat. Because of this fact, Tektronix specifications are made without using fogging techniques. Should the user employ fogging, then the writing speed will be increased according to his skill. Writing speed figures 50-100% higher are possible with controlled techniques on Polaroid Type 47 and Type 410 film.

The illustration above shows the way in which writing speed is measured. Display a single trace of a damped sine wave whose frequency and amplitude is such that the rapidly rising and falling portions of the first cycle or two fail to record. The peak-to-peak amplitude of the sine wave should be three to four times as great as the horizontal distance occupied by one cycle. This is necessary to insure that the horizontal velocity component is small compared to the vertical velocity component.

The writing speed capability of the oscilloscope is determined as follows: mask out the sine-wave peaks on the photograph leaving the central one-third visible. View the photograph while backlighted. Starting from the left, find the first rapidly rising or falling portion of the damped sine wave which is discernible. Let A represent the vertical distance in centimeters between the peaks which are connected by this portion and let f be the frequency of the damped sine wave in megahertz. Since the maximum vertical velocity of a spot moving in simple harmonic motion is equal to fA, the writing speed in centimeters per microsecond may be calculated by: *photographic writing speed* $= 3.14\, fA$

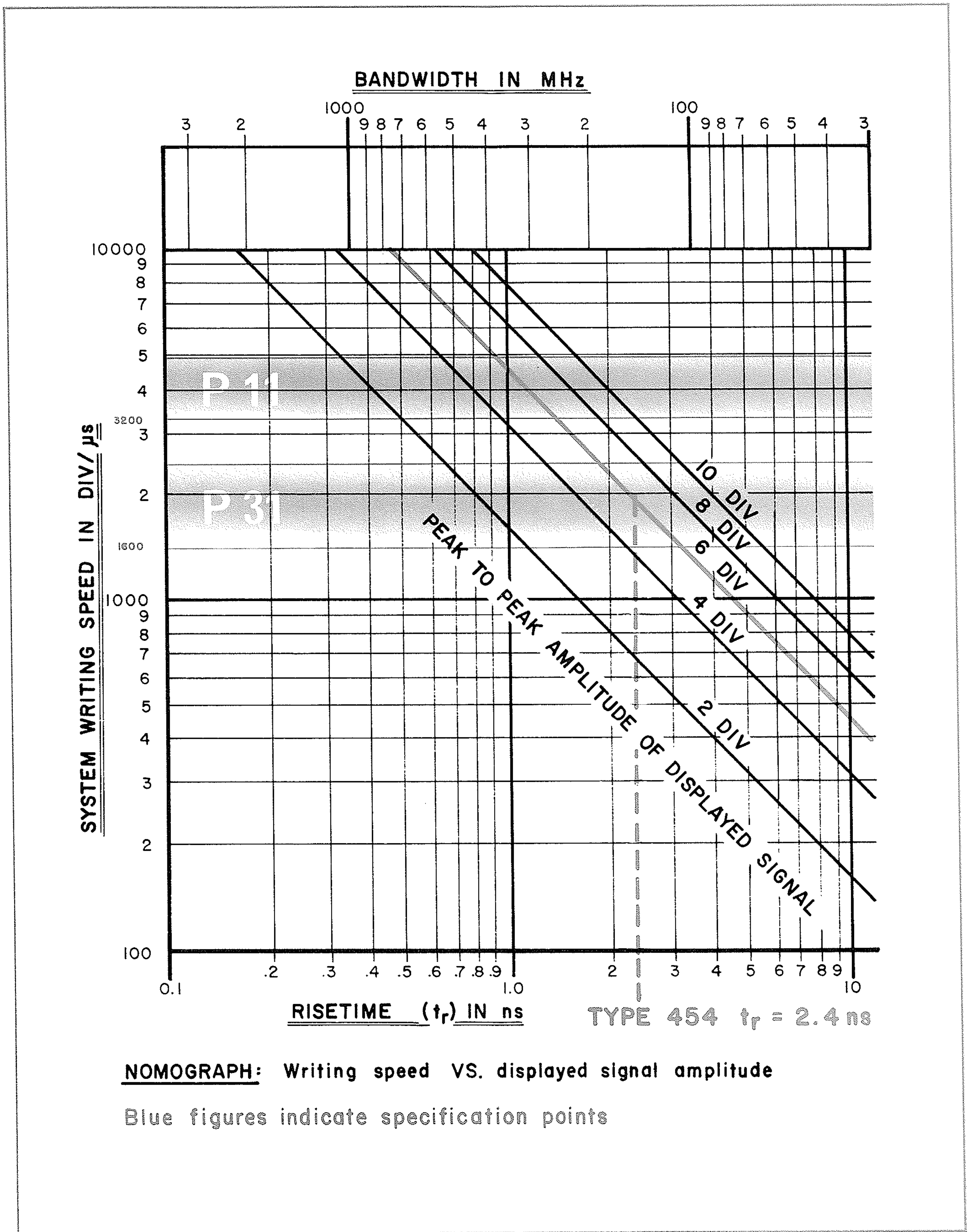


Fig 4 Type 454/C-31 Nomograph

distributions of the different phosphors used are all different from that of normal daylight. As a result the ASA ratings of film do not apply accurately to oscilloscope photography. There is usually some relationship between ASA rating and maximum writing speed, however. Thus, it would be safe to assume that a film with a very high ASA speed rating would probably have a higher maximum writing speed than a film with a lower ASA speed rating. For example, ASA 10,000 has approximately 2—2.5 the writing speed of ASA 3000.

What does the specification of writing speed mean to the oscilloscope user? First, the user may now determine whether an oscilloscope will meet his needs in single-shot applications. An oscilloscope with a stated risetime is one thing. To know that an oscilloscope is adequate to photographically record a single event is another thing entirely. The chart in fig 4 illustrates this. With P11, the Type 454 is capable of presenting 10 divisions of data with a pulse of 2.4-nanoseconds risetime being applied. Since the instrument has 6 divisions of vertical scan, the Type 454 has a comfortable margin of performance.

The other area where writing speed is of major concern is in marginal viewing applications of repetitive events. Oftentimes, a user will want to observe a specific pulse of a pulse train and examine it in detail. If the pulse of interest is, for example, the 30th one, then the effective repetition rate has been decreased by 30, since that time has been used to delay the sweep. Therefore, viewing may be quite difficult. In addition, ambient light may contribute to a marginal viewing condition. If marginal viewing is a continuing problem then an instrument with additional writing speed should be considered and evaluated.

Since the eye is more responsive to the yellow-green than to the blue-violet region*, visual writing speed and photographic writing speed have definite characteristics of their own. Most photographic film used in oscilloscope recording is more responsive to blue light, and a phosphor such as P11 peaked in this region will give excellent results. The eye will respond best to a phosphor such as P31 because its spectral characteristics are peaked in the green area. To concern ourselves with the two most commonly used phosphors, P11 has twice the photographic writing speed of P31, while P31 has nearly 7 times the luminance (spectral response corrected to that of the average eye) of P11.

The nomograph shows the relationship between writing speed, frequency, risetime and display size. In addition colored bands have been used to illustrate the writing speed distribution of the 74 sample instruments. These bands take into consideration the recently introduced Tektronix Type C-31 Camera. This camera has

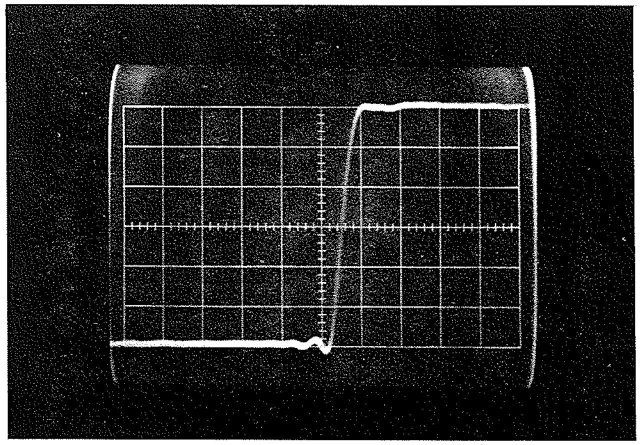


Fig 5 The Type 454/C-31 displays a single-event pulse with 2.4-ns risetime.

an f1.2 lens, a 1:0.5 object-to-image ratio and improves writing speed nearly 30% over its predecessor the Type C-40. The Type 454/C-31 with P11 phosphor has a writing speed of 3200 div/μs (2560 cm/μs). The P31 distribution is the one used in the control group. The P11 band is applicable because the photographic writing speed of P11 is twice that of P31. To use the chart, find the risetime or bandwidth of interest and follow the line until the display size desired is intersected. At this point read on the left axis the writing speed required to adequately record this information on a single event basis.

A significant step has been taken by incorporating writing speed into the Tektronix Type 454 Oscilloscope catalog specification. In addition, a considerable safety margin has been provided the oscilloscope user because of the following:

1.) No film fogging is relied upon. Skillful fogging techniques may allow up to 100% additional writing speed.

2.) Writing speed specification is based upon minimal performance not average.

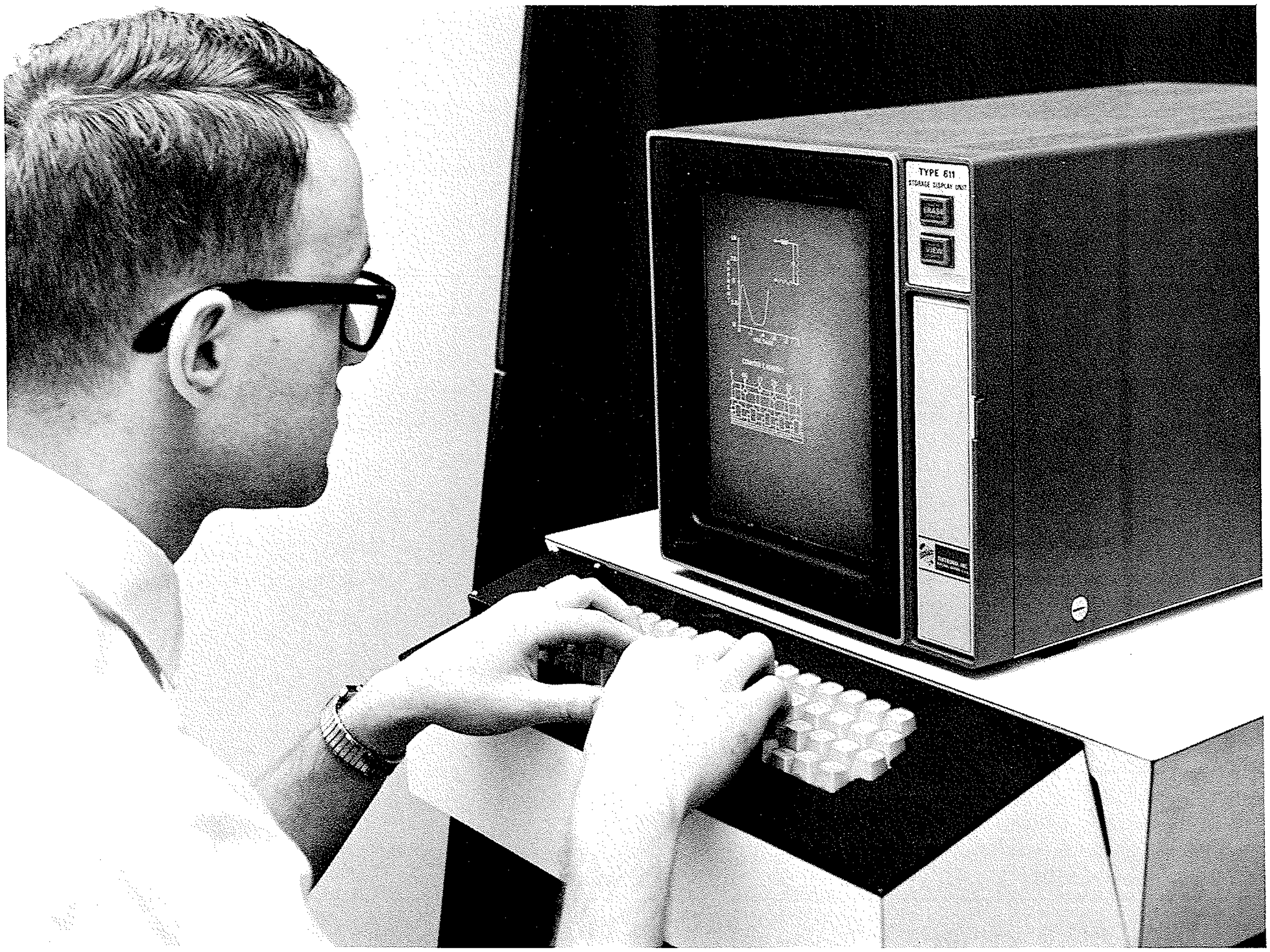
3.) There is sufficient writing speed to write 10 divisions vertically (CRT is 6 divisions vertically).

4.) Data is based on average of several inexperienced readers. Studies indicate that as readers become more experienced they are able to attain higher readings.

The oscilloscope user can now select his instrument, *knowing in advance,* the minimum writing speed he may expect. He is assured of having sufficient writing speed to record a single event at the risetime (or bandwidth) of the system.

For further information on the Type 454 Oscilloscope and Type C-31 Camera contact your local Field Engineer. Complete Type 454 specifications are given on pages 43-47 of Tektronix Catalog 27 (1968).

*See Human Eye Response, P13



Ray Goolsbey, Tektronix Digital Instruments Engineer, checks out his programs on the Type 611 Storage Display Unit. *See photo on page 9.*

Direct-View Bistable-Storage CRT Resolution

A Definition and Explanation of Resolution for Information Display Instruments

Introduction

In the case of nonstorage measuring oscilloscopes, resolution is usually given in terms of the width of the oscilloscope trace. The conditions under which the trace width was measured must be known before a value can be placed on the results.

(1) Was the width measured at normal or full writing speed?

(2) Was the measurement made photographically or with a shrinking raster?

(3) What percent is edge defocus?

In the case of the direct-view bistable-storage tube (DVBST), measuring trace width is not as difficult as in nonstorage CRT's. The transition from a nonwritten part of the CRT screen to a written portion is fairly abrupt. The gray-scale distance is insignificant and the trace remains stationary while you measure it. The Tektronix Type 601 and 611 Storage Display Units employ the DVBST as a display device and are intended for display of alphanumerics and graphics from computers. In this application the resolution of DVBST's becomes an important parameter. Their resolution is defined in terms considered most useful in the fields which require such displays.

The design objective for the Type 611 required enough resolution to make a set of 4000 alphanumerics unambiguously legible (well-spaced for clarity), based upon a 7 x 9 dot matrix of nominal 10-mil dots. For the Type 601, the resolution objective was to get as much resolution as practical using a conventional electrostatic deflection system in an 8 x 10 cm field. The electrostatic deflection requirement resulted in a spot size approximately twice as large as that of the Type 611, making it capable of displaying about 1250 characters (based upon a well-spaced 7 x 9 dot matrix of nominal 20-mil dots).

Center Resolution

For conventional tubes, the shrinking raster* test is handy for testing center resolution and about 20% correlation can be obtained between skilled operators. Photographic measurement is slow, tedious, and quite repeatable with skilled operators, with results usually more conservative than the shrinking raster method. This resolution test is usually expressed as either a trace width, or as lines per unit distance. One caution here—perform the test in both directions to be sure the CRT spot is round. Do not reset the astigmatism, focus, or intensity settings between tests. The lines per unit distance may be defined as **specific** resolution. The number of lines obtained by multiplying the specific resolution by the length of the display is then **total** resolution, if the display is uniform.

*See Trace Width, P12

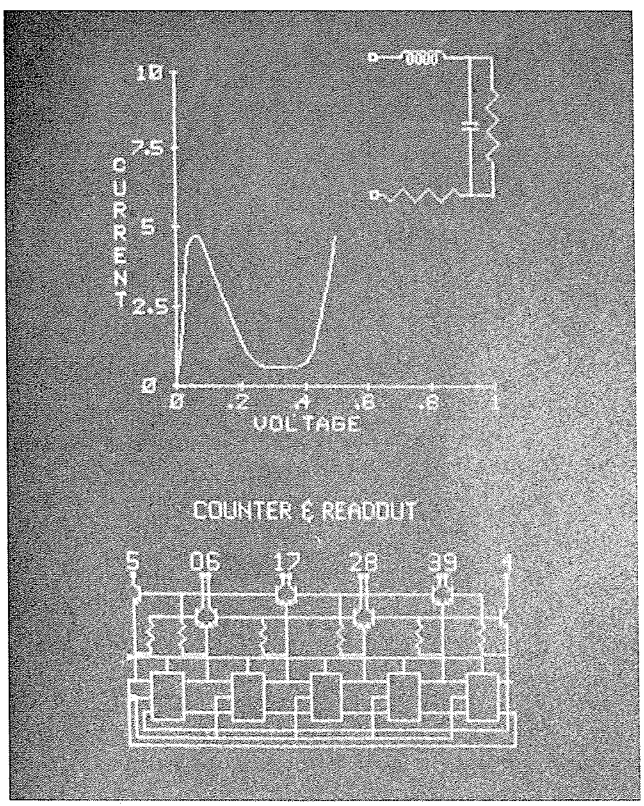


Fig 1 The curve and equivalent circuit of a 4.7 mA tunnel diode are shown on the upper display. The lower display shows the logic diagram of a Tektronix Decimal Counter with 10-line readout.

Effective Resolution

A **total resolution** of 525 lines (as used above) is more total resolution than 525 lines of **TV resolution**. In the case of television, approximately 40 of the 525 total lines are lost due to retrace blanking. As a result, only 485 lines are available for viewing. Even further, TV has less **effective resolution**, because its horizontal format may not be in registration. If a scene is composed of 243 horizontal white lines and 242 black spaces, the TV raster may not line up with a scene (it is understood that the 485 available TV lines are nominally just in contact so there is no space between TV lines). If the TV camera is aimed just right, where the lines of the raster scan just superimpose the scene, the scene will then reproduce correctly. However, if the camera target is moved ½-line width, all the lines reproduce gray, since the scanning line will be split horizontally—half white, half black—the camera will respond gray. To be certain of avoiding this problem (100% resolution or 0%, depending on how the scene is arranged), the system could be designed with twice the number of lines. Ordinarily this would be wasteful, since such severe scenes are not usually encountered.

In TV work, this problem is referred to as the Kell effect, and is accounted for by stating that the effective resolution of a non-registered raster is about 70% of the line count. A 525 TV line system then is actually about a 340 effective line system (vertical resolution), or about ⅔ of what it sounds like.

This is not true along a horizontal line; that is, there is no Kell effect along a line, because the video signal can appear anywhere along a horizontal line. For example, a properly gated 4-MHz sine-wave train could produce alternate black-to-white bars vertically along the screen. With about 54 μs visible along each horizontal line, there would appear to be 432 total alternate black and white bars across the screen. The bars can be moved to any desired position by simply shifting the starting phase of the gated 4-MHz signal. In other words, if a scene consisted of 216 white vertical stripes alternating with 216 black stripes, the camera would reproduce the stripes, even when the scene moves slightly, because there is no restriction on video time position **along** a line—only in registration of the lines themselves.

Computer Driven Displays

In most computer-generated displays, there is no Kell effect either, because the computer usually generates a registered format. For example, the computer might have 512 possible vertical addresses for the spot. It will never have to worry about something being in the 468½ memory! In figure 2a, the letter "A" is shown with each spot written at a specific address as determined from a grid which is basically 9 x 7 dots in size. If the dots are at the resolution limit of the CRT, it is tempting to measure the spot size, measure the screen, and predict the number of addressable points on the display. But note that if the CRT screen is substantially grainless (spot size bigger than the phosphor agglomerates), an improved "A" may be written by addressing the beam in half spot steps, as per figure

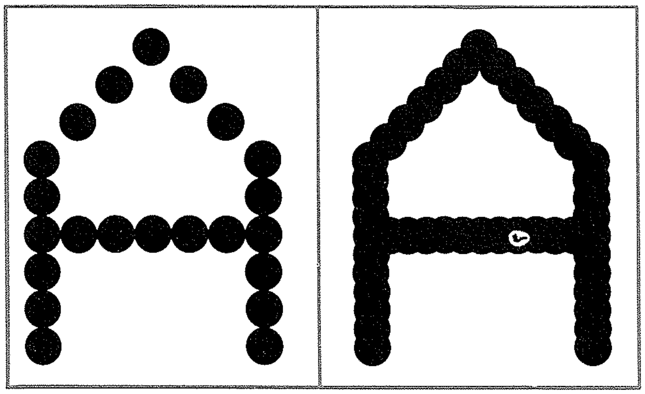


Fig 2a Letter A—9 x 7 matrix Fig 2b Letter A—½ spot width steps

2b. Thus, the number of addressable points is a property of the system, not the display device (an exception is when the display device is quantized, such as an array of gas-discharge cells, which can light up only at discrete positions). Thus a computer system of 1024 x 1024 addresses has about 10^6 addressable points, but if the display device has a 512 line x 512 line total resolution, then there are less than 3 x 10^4 **simultaneously** resolvable points for the system. In 4-MHz, 525-line TV (forgetting Kell effect for the moment) there are approximately 485 x 432 simultaneously resolvable points. However, there are an infinite number of addressable points—485 fixed vertical addresses with an infinite number of horizontal addresses! For a computer driven display, the addressable number of points are approximately equal to, or to some sensible low multiple of the number of simultaneously resolvable points.

Dot Resolution

Simultaneously resolvable points could be determined by building a generator which would fill the screen with dots based upon some coarse grid, see figure 3a. Turning up a control knob, to increase the number of dots would produce figure 3b. The problem is to know when enough dots are present. Because the dots are not uniform, some dots will touch before others. A realistic specification will take this into consideration.

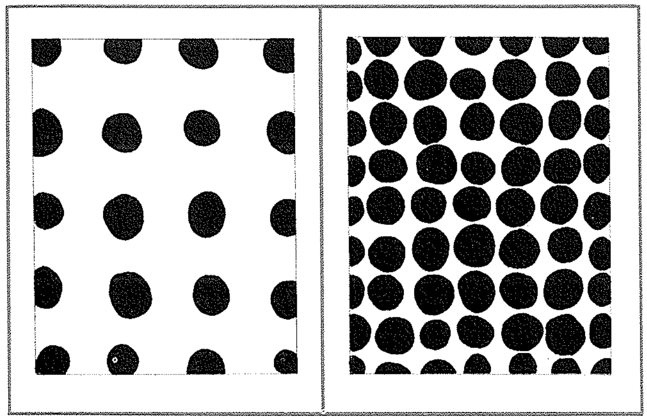


Fig 3a Coarse grid—few dots Fig 3b Fine grid—many dots

This non-uniformity of the written dots is the major reason for most of the problems in measuring resolution. There will inevitably be "noise" on a dot's dimension at the resolution limit. Thus for a quality display, the size of a "period" must be greater than the minimum dot size that can be written. Figure 4 illustrates a group of five dots written at the nominal spot size for spacing. Note that the effect of noise on the dimension of the written period has been substantially reduced. This means at normal viewing distances all the 5-spot periods look substantially uniform although the individual spots do not.

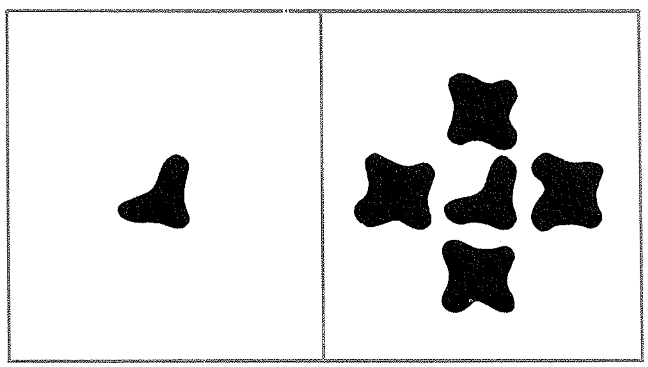


Fig 4a Single dot Fig 4b "Period" composed of 5 dots

Dotted Line Resolution

By writing the Type 611 screen with a 300 x 400 dot matrix the problem is simplified. Under ideal conditions there would be uniform round dots spaced one diameter apart. Actually, at the center of the CRT, the dot is generally smaller than nominal and not uniformly round with more than a diameter's spacing between dot edges. In the corners, the dots are generally elliptical and have less than nominal spacing. If the written dots in the center are not too small (for example, not less than half nominal size) and the dots in the corners do not touch (for example, less than 70% over size), then a written message should be clearly legible. The uniform nominal distance separating the dot centers is easy to set up and is consistent with computer grid usage. In addition, by looking for the areas

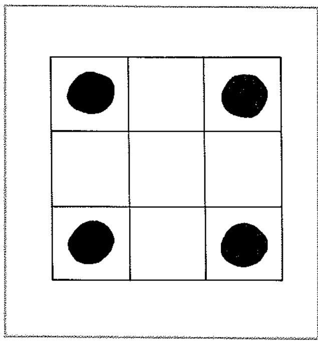


Fig 5a Center dots

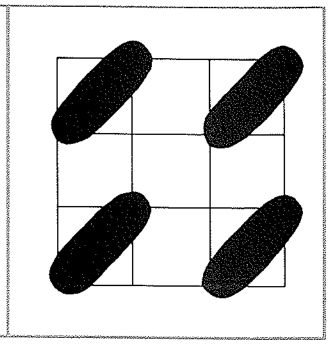


Fig 5b Corner dots

that appear brightest and dimmest, the places where measuring is worthwhile are easily seen. A quality criterion which might be applied in "in any group of 10 x 10 dots no more than 10 shall be missing, and no more than 10 pairs of bridging shall occur." The "missing" specification accounts for too small a dot and the "bridging" specification takes care of too large a dot. A further advantage is that with the dotted line method, the screen is approximately 25% written. This is closer to the percent of the screen which is written in an ordinary alphanumeric message. Using line pairs the screen is nominally 50% written.

Interpreting Resolution

There are many methods of ascertaining resolution, but the following factors should be kept in mind:

(1) A **total resolution** may be derived from the center specific resolution multiplied by the length of the display. This is usually an optimistic value, because the resolution is usually poorer off-center.

(2) Sometimes **total resolution** is derived from the integral of the various specific resolutions across the tube, multiplied by their respective distances over which they apply (sum of the actual maximum number of lines of varying width that can be fitted across the tube). This is hard to do, since the lines must be generated one at a time, and tried for "fit", to observe if the defocused width put it at the correct spacing from the preceding line, etc. This method, because of averaging, is close to a realistic number.

(3) **Total resolution** is derived from the worst case specific resolution multiplied by the length of the display. In a computer driven display this usually results in an overly conservative value.

Noise

When discussing noise consideration, let us note a general principle. A single written spot is not considered appropriate for an "unambiguously written" message. More than one dot is needed to have an economically sensible signal-to-noise ratio. For example, 15 to 25 dots are required to make up well-formed alphanumeric characters. A "dash" on a graph would seldom be shorter than 5 dots in a row.

In any system the effects of noise should be considered. If noise is defined as "anything which is not the message", then there are four outstanding noise sources to consider. These are discussed as they relate to direct-view bistable-storage tubes:

(1) Random noise on a recorded trace width due to the phosphor agglomerate variations.

(2) Spots on the CRT which remain written even after erasure. Since most messages use less than 10% of the CRT area, the probability is high a permanently written spot won't coincide with a desired written spot.

(3) Spots on the CRT which remain unwritten after the spot was excited properly with the writing gun (drop-out).

(4) Spots which appear after the message has been written for a period of time (fade-up).

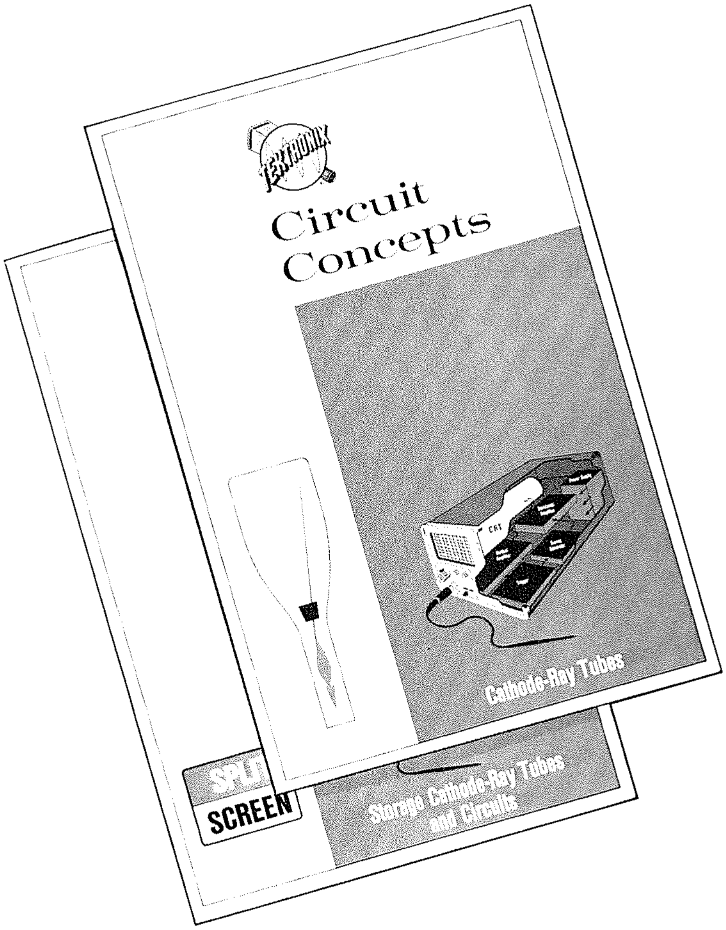
The "bridging" specification and specifying the acceptable size and number of spots which may appear bright takes care of the first two considerations. Drop-out is covered by specifying the number of dots that may be missing. Specifying contrast ratio after 15 minutes takes care of the last consideration.

Summary

Defining resolution in terms of line pairs has some advantages. Because the term has a history from the field of optics, it is less ambiguous than lines, which then raises the questions: TV lines? Kell effect corrected? etc. Line pairs implies that there are written and non-written lines laid down on a uniform grid where the center-to-center spacing of the written lines is uniform, and the space between written lines (unwritten lines) is equal to the nominal written line width. The actual width of the line and the line space sections vary somewhat but the line pair width is constant. Because of flood-gun collimation considerations, Tektronix tests with dotted lines rather than continuous line pairs. This results in a nominally 25% written field and allows testing under conditions similar to those encountered in information display usage.

The Tektronix Type 601 and 611 Storage Display Units employ new direct-view bistable-storage tubes. These instruments are designed specifically for information display and resolution is specified in terms of the number of line pairs resolvable in the X and Y axis. Defining resolution by this method appears to provide the most meaningful information to those concerned with this application.

For further information on Tektronix Display Units refer to pages 231-236 of Catalog 27 (1968) and consult your Field Engineer.



Circuit Concepts from Tektronix

The Circuit Concepts Program at Tektronix was initially established to fulfill an internal training need. A body of literature was needed to assist in the training of Field Engineer Trainees. As the program evolved, the material developed appeared excellent for customer use. As a result, a series of Tektronix Circuit Concept books are being created which will be helpful to many customers.

The intent was to develop a format that would be a reference book for various categories of information. The book is a convenient size (6 x 9) and is indexed for quick reference. Should you wish further information on Tektronix Circuit Concepts, contact your local Field Engineer.

The material on pages 13 and 14 is taken from "Cathode-Ray Tubes" and is indicative of the content. The other title currently available is "Storage Cathode-Ray Tubes and Circuits".

TRACE WIDTH

The term "trace width" has been used in a general sense without definition. A line or spot on a CRT is not uniform in brightness but is brightest in the center and decreases in brightness toward the edges. The distribution of the electrons in the beam causing the trace or spot are concentrated in the center and the density decreases toward the edges. This variation in brightness presents a problem in answering the question, "How wide is the trace?"

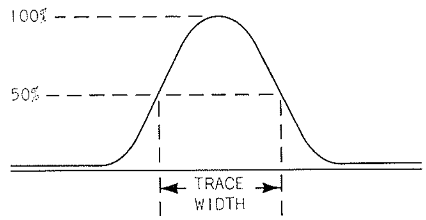


Fig 8-4. Gaussian distribution of trace width.

A solution (though not the only one) is to assume the distribution is Gaussian (fig 8-4) and use a shrinking raster method of making the measurement. This method requires a raster (our example uses 11 lines—fig 8-5). The measurement is made by shrinking the raster down until the 50% points of brightness on two adjacent lines merge. This 50% point is achieved when the dark line between the traces first disappears. The width of the raster is measured and the resultant trace width is 1/11 of the width. This yields a trace width measured between the 50% brightness points (fig 8-6). All CRT data is taken by this method.

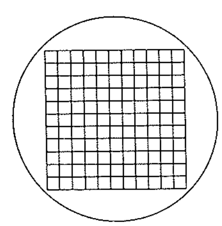


Fig 8-5. Raster to measure trace width.

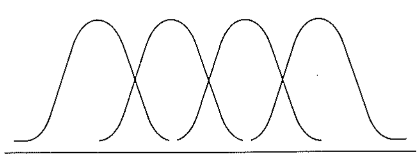


Fig 8-6. Trace width measurement using 50% brightness points.

HUMAN EYE RESPONSE

An important factor in selecting a phosphor is the color or radiant energy distribution of the light output. The human eye responds in varying degrees to light wave length from about 400 to 650 nanometers or from deep red (650 nanometers) to violet (400 nanometers). The human eye is peaked in its response in the yellow-green region at about 555 nanometers and falls off on either side in the orange-yellow area to the right and the blue-violet region to the left (fig 10-1). The eye is not very receptive to deep blue or red.

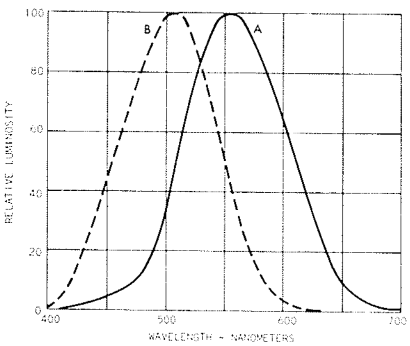


Fig 10-1. Standard luminosity curve.

If the quantity of light falling on the eye is doubled, the brightness "seen" by the eye does **not** double. The brightness of a color tone as seen is approximately proportional to the log of energy of the stimulus.

The response of the eye to various colors is believed to be due to the construction of the eye. One theory is that the cones of the retina respond to color stimuli and that each cone consists of three receptors. Each receptor is believed to respond to a different wave length of visible light; a yellow-blue, a red-green and a black-white receptor. An average can be taken of the color response of many people and a "standard" response curve for an average person, as shown in fig 10-1, can be compiled.

The term **luminance** is the photometric equivalent of brightness and is based upon measurements made with a sensor having a spectral sensitivity curve corrected to that of the average human eye. The unit commonly used for luminance measurements is the foot lambert. The term **luminance** implies that data has been measured in a manner, or has been so corrected, to incorporate the CIE standard eye response curve for the human eye. CIE is an abbreviation for "Commission Internationale de l'Eclairage" (International Commission on Illumination). The luminance graphs and tables are therefore useful **only** when the phosphor is being **viewed visually.**

PHOSPHOR BURNING

When a phosphor is excited by an electron beam having an excessively high current density, a permanent loss of phosphor efficiency may occur. The light output of the damaged phosphor will be reduced and in extreme cases complete destruction of the phosphor may result. Darkening or burning occurs when the heat developed by electron bombardment cannot be dissipated rapidly enough by the phosphor.

The two most important and controllable factors affecting the occurrence of burning are **beam-current density** (controllable with the Intensity, Focus and Astigmatism controls) and the length of **time** the beam excites a given section of the phosphor (controllable with the Time/Div control). Under normal conditions in CRT's with grid unblanking, the ambient voltage on the control grid will hold the tube in cutoff and no spot will be present on the screen.

When the sweep is triggered, the unblanking pulse turns on the gun and if everything else is working properly the beam can be seen as it moves across the screen. But what if the horizontal amplifier is inoperative? The horizontal plates will not receive a signal under that condition and the beam will not be deflected but it will be turned on by the unblanking pulse. Result?—possibly a burn mark on the screen!

The Intensity control can be adjusted to override the normal cutoff condition of the gun in the absence of an unblanking pulse in a CRT using grid unblanking. If this is done, a spot of reasonable intensity will be seen on the face of the CRT. If the sweep is now triggered, an unreasonably bright spot will occur. Result?—you guessed it—a burn mark.

Remember, burning is a function of intensity and time. Keeping intensity down or the time short will save the screen.

Any phosphor can be burned but some more easily than others. Phosphors may be divided into three groups when considering their burn resistance:

Group 1 phosphors are easily burned and should be used with care. Group 2 phosphors are about 10-100 times more difficult to burn than those in Group 1, so normal care should be exercised. Group 3 phosphors are about 100-1000 times more difficult to burn than those in Group 1. A P31 phosphor is quite difficult to burn. In fact, you really have to want to damage the phosphor even with a 10 kV tube.

The typical phosphor is about 10% efficient. This means that of the total energy from the beam, 90% is converted to heat and 10% to light. A phosphor must radiate the light and dissipate the heat; or as any other substance, it will burn.

Burn Resistance of Common Phosphors

Group 1	Low (easily burned)	P12, P19, P26, P33
Group 2	Medium (moderate)	P2, P4, P1, P7, P11
Group 3	High (hard to burn)	P31, P15

Service Notes

Tony Bryan of our Long Island Field Office offers this suggestion.

QUICK CHECK FOR TUNNEL DIODES

A method of tunnel diode evaluation using your Tektronix Type 454 Oscilloscope without special attachments is offered by the following setup.

Many times, in troubleshooting, substitution of components is recommended as a quick analysis of the circuit malfunction. Many times expensive tunnel diodes are not at hand to make a substitution.

A quick evaluation of the tunnel diodes' ability to switch and at what current level it does switch often helps in the troubleshooting process.

Using a Type 454, the TD may be evaluated using the sawtooth out as a current source for the TD. A 670-ohm resistor from the sawtooth out connector in series with the TD to ground will give a calibrated current/div horizontally of 1 mA/div. The sawtooth voltage goes from 0 volts to 10 volts. Therefore the horizontal display becomes current/div. Looking at the voltage drop across the diode will give a vertical display of the low voltage/high voltage states of the diode.

The display does not give an indication of switching time but confirms that the device has the ability to switch at the correct current level and will probably perform normally in its intended circuit.

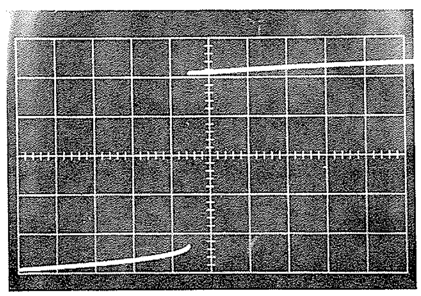


Fig 1 TD3A (4.7 mA)
horiz 1 mA/div: Vert .1 V/div

Figure 1 (photo) shows a TD measured on the Type 454 using the 10-V A SWEEP output voltage, through 670 Ω (plus 330 Ω source) to calibrate 1 mA/div horizontally.

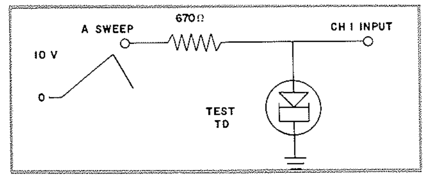


Fig 2 454 measuring circuit

DECORATIVE INSERT REPAIR

Decorative inserts or strips are used to cover certain screw and bolt heads on the outside of many of our instruments. The strips are installed with 3M EC 847, a rubber contact cement. An equivalent adhesive, such as rubber cement, will do the job when replacement is nescessary.

USED INSTRUMENTS FOR SALE

1—Type 517, SN 268; 1—Type 517, SN 483. Both in fair condition. Price: $200 each. Contact: Richard J. Pasco, Litton Industries, 1035 Westminster Drive, Williamsport, Pennsylvania 17704. Telephone: (717) 326-3561.

1—Type 561/63/67. Contact: Harold Rapp, Dialight Corporation, 60 Stewart Avenue, Brooklyn, New York 11237. Telephone: (212) 497-7600.

1—Type 531A, SN 026463; 1—Type H, SN 015488; 1—Type D, SN 025-698. Contact: G. W. Bandy Company, 3086 N. Avon, Burbank, California. Telephone: (213) 846-9020, 849-2962 or 767-6066.

1 — Type 564/3S76/3T77; 1 — Type 109; 1—Type 201-1. Been used only 4 hours. Two years old. Total package: $2700. Contact: Dr. Frank Avignone, Physics Department, University of South Carolina, Columbia, South Carolina 29208. Telephone: (803) 765-4121.

1—Type 526. Excellent condition. Price: $1325. Contact: KVOS, attn. John Price, Bellingham, Washington. Telephone: (206) 734-4101.

1—Type 531A; 1—Type B Plug-in; 1—Type D Plug-in. Excellent condition. Contact: Ash Brown, 246 Cambridge, Kensington, California 94707. Telephone: (415) 524-3005.

1—Type 107, SN 002436; 1—Type TU2, SN 001765; 1—Type P, SN 002-517. Contact: Jack Kane, Jr., Electro Optical Systems, 300 N. Halstead Ave., Pasadena, California 91107.

1—Type 317, SN 211. Contact: Mike Croslin, International Applied Science Labs., 510 South Franklin Street, Hempstead, New York 11550. Telephone: (516) 483-5494.

USED INSTRUMENTS WANTED

1—Type 531 or 1—Type 515 or A series oscilloscope and 1—Type B Plug-in Unit. Contact party at (714) 526-5281, Fullerton, California.

1—Type 104 or 1—Type 105. Contact: Roy Lang, Jr., 1003 Reseda Drive, Houston, Texas 77058. Telephone: (713) 483-2093.

1—Type 535A, 1—Type 545, 1—Type 547 or 1 Type 647 Oscilloscope with dual-trace plug-in: Contact: Vern Baker, TAME Company, Inc., 813 S. 4th Street, La Porte, Texas. Telephone: (713) 471-3069.

REFERENCE TABLE

Reference information for Tektronix Attenuators, Terminators and Adapters has been condensed for your convenience. By cutting along the dotted lines, the table on page 15 can be detached for use on your bench.

BASIC FUNCTIONS OF ATTENUATORS, TERMINATIONS, AND ADAPTERS

PERFORMANCE CHARACTERISTICS

ACCURACY OF INDICATED ATTENUATION RATIO:

TYPE	
UHF	±2% at DC; ±3% at 100 megahertz
GR	±2% at DC; ±3% at 1 gigahertz
TEKTRONIX 125-Ω	±2% at DC; ±3% at 1 gigahertz
BNC	±2% at DC; ±3% at 100 megahertz

VOLTAGE STANDING WAVE RATIO:

TYPE	
UHF	less than 1.2 up to 100 megahertz
GR	less than 1.1 up to 1 gigahertz
TEKTRONIX 125-Ω	less than 1.1 up to 1 gigahertz
BNC	less than 1.1 up to 100 megahertz

POWER RATING:

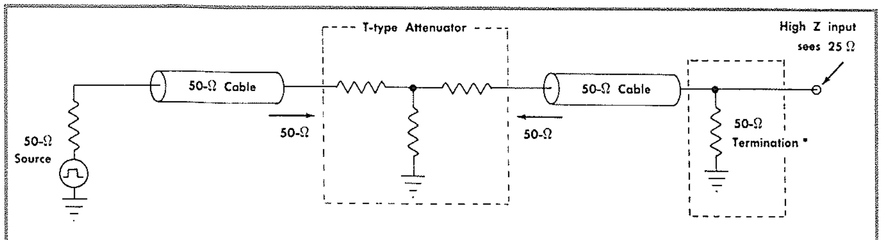
TYPE	
UHF	1.5 watts.
GR	1 watt.
TEKTRONIX 125-Ω	1 watt.
BNC	0.5 watt.

OUTPUT TO INPUT VOLTAGE RATIOS FOR MINIMUM-LOSS ATTENUATORS:

When properly terminated the E_{out}/E_{in} ratios for the various minimum-loss attenuators are as follows:

Connection	E_{out}/E_{in}
50 Ω → 75 Ω	0.63
75 Ω → 50 Ω	0.42
50 Ω → 93 Ω	0.59
93 Ω → 50 Ω	0.32
50 Ω → 125 Ω	0.56
125 Ω → 50 Ω	0.23
50 Ω → 170 Ω	0.54
170 Ω → 50 Ω	0.16

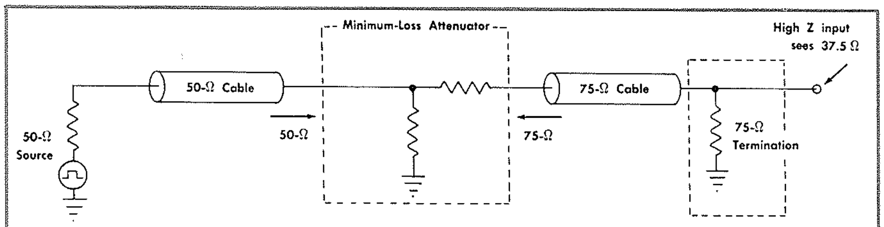
All attenuators, with the exception of minimum-loss types, are T-type attenuators.



Typical Use of a T-type Attenuator, and a Termination.

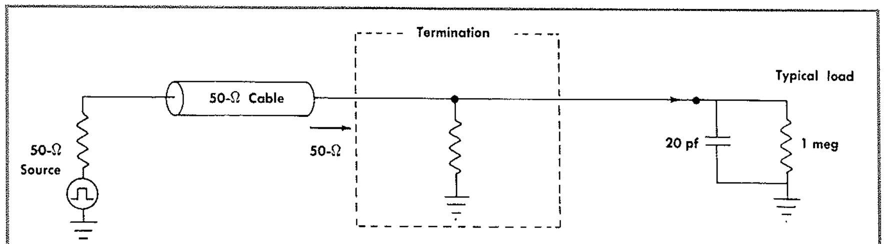
ATTENUATORS—*Two types are included under this designation, the T type and the minimum-loss type.*

T-TYPE—*Maintain the proper impedance match between the signal source and the input to an instrument while attenuating the signal by an indicated ratio. T-type attenuators must have a load of the correct impedance to give the indicated attenuation ratio.*



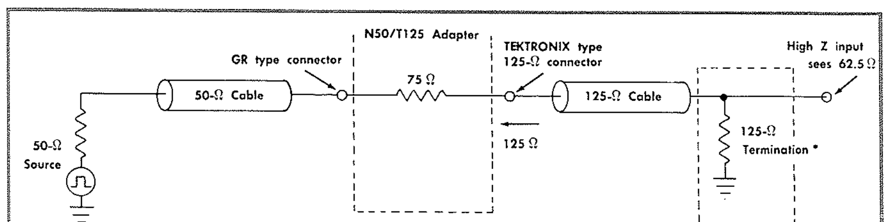
Typical Use of a Minimum-Loss Attenuator and a Termination

MINIMUM-LOSS TYPE—*Provide a convenient means of matching a source or load with cables of different characteristic impedances. Tektronix minimum-loss attenuators assure proper matching, with a minimum loss of signal strength.*



Typical Use of a 50-Ω Termination

TERMINATIONS—*Terminate a cable in its characteristic impedance. Improper termination, or no termination, can cause ringing, reflections, and other adverse effects. Tektronix 50-Ω and 125-Ω instruments have built-in terminations.*



Typical Use of a N50/T125 Adapter and a Termination

* Not necessary when instruments have built-in terminations.

ADAPTERS—*Connect cables of different characteristic impedances and different connectors. They are used only where impedance matching is not important. Tektronix adapters use the letter N to designate a non-terminated end and the letter T to designate a terminated end.*

SERVICE SCOPE

USEFUL INFORMATION FOR
USERS OF TEKTRONIX INSTRUMENTS

committed to progress in waveform measurement

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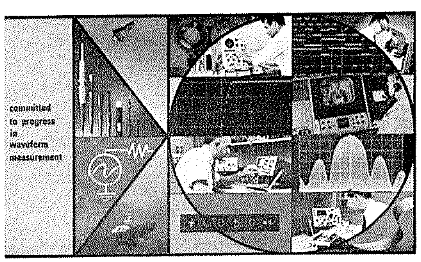
TEKTRONIX
OSCILLOSCOPES & ASSOCIATED INSTRUMENTS



CATALOG 27 (1968)

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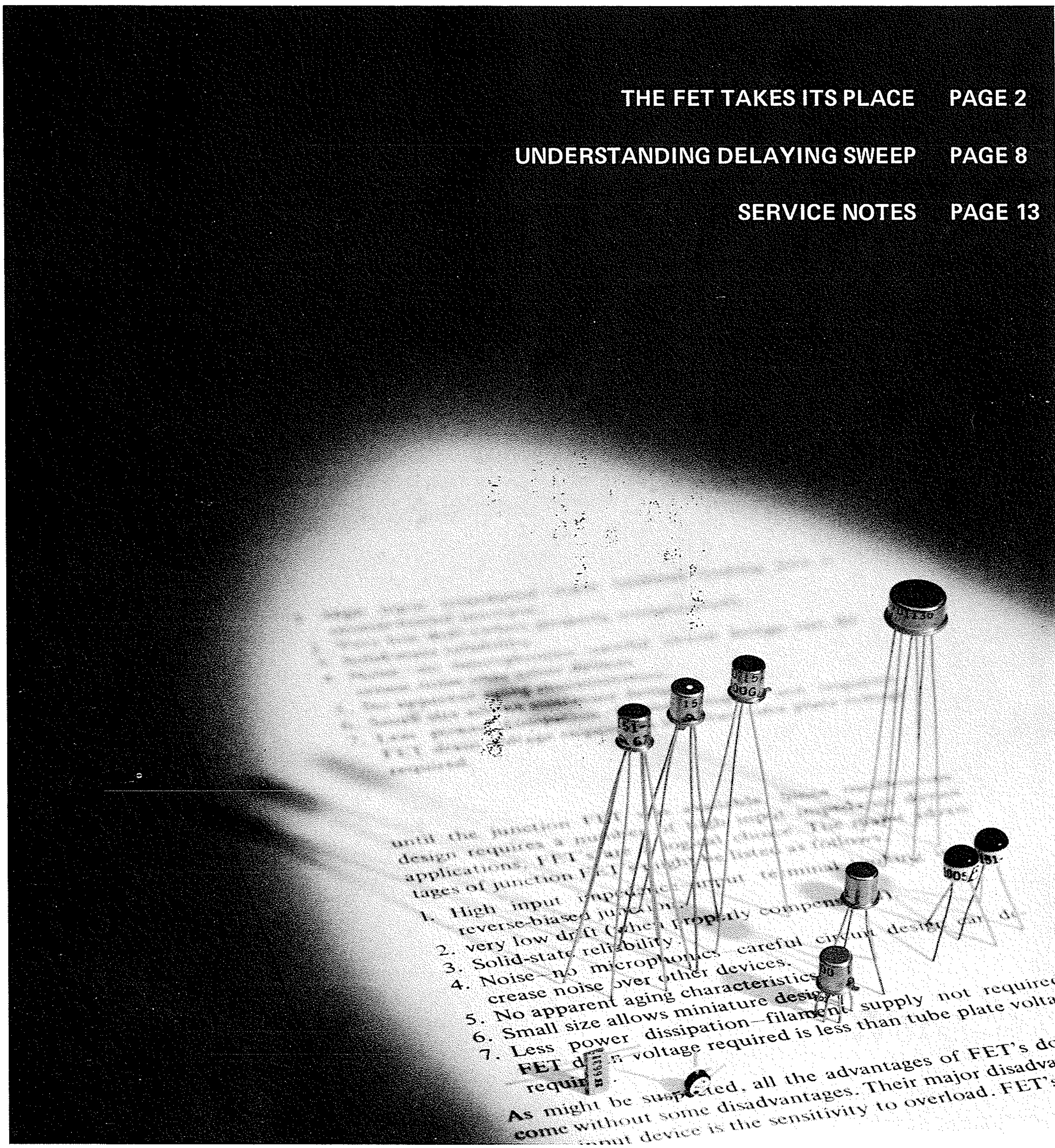
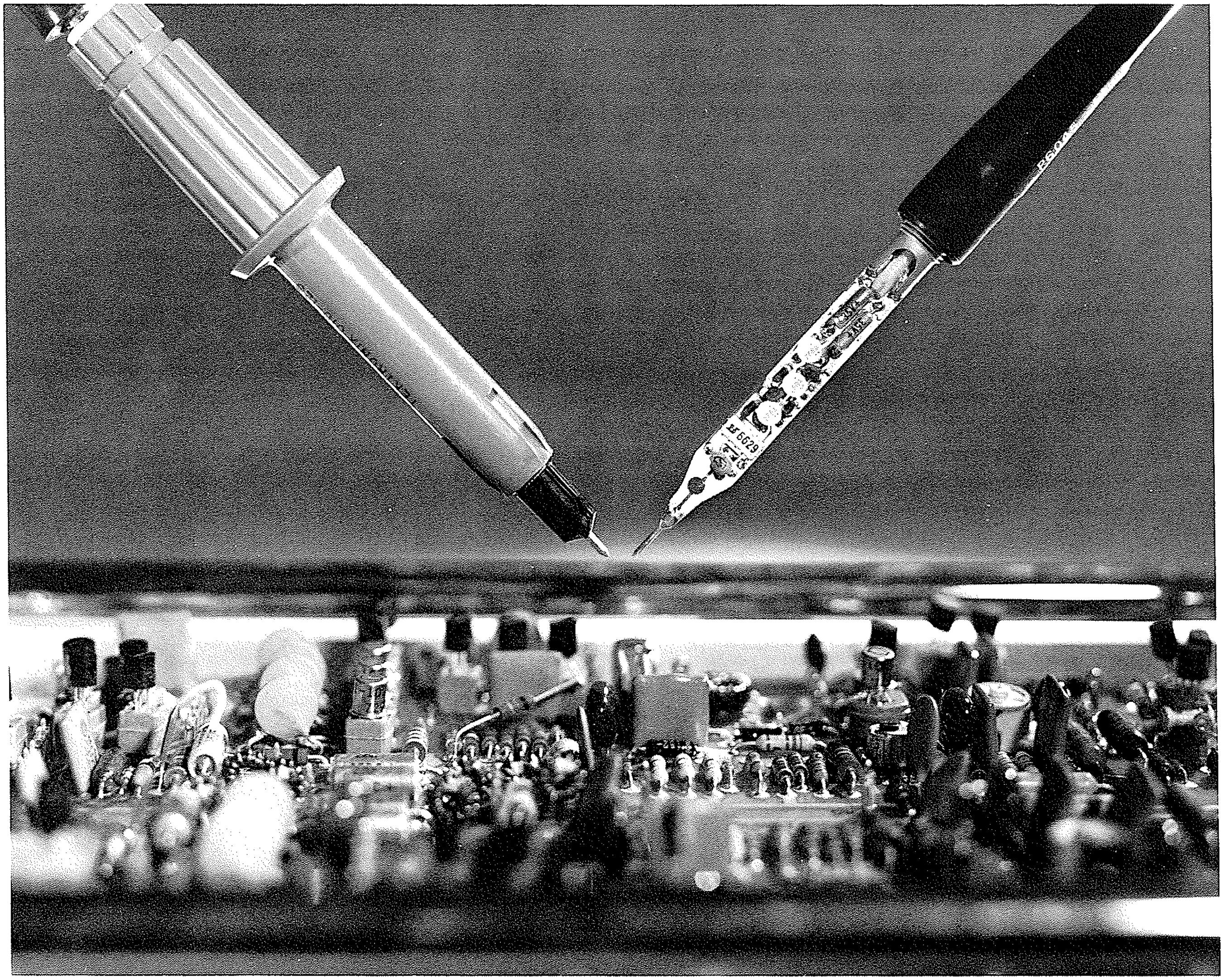


The FET takes its place



The P6045 X1 FET Probe is shown here with the P6006 X10 Probe. Note that the 1.5 ns P6045 with its active components and protective circuitry is smaller than the conventional passive probe.

The field-effect transistor is appearing in Tektronix instrument input stages with increasing frequency. Its high input impedance combined with the solid-state characteristics provide superior performance that has not previously been available. This article discusses some of the reasons for the widespread use of FET's in current Tektronix instruments.

COVER
Tektronix photographer Larry Jackson spotlights some of the FET's used in current Tektronix instruments.

Two years ago Tektronix introduced its first product using Field-Effect Transistors (FET's). Although Tektronix engineers had been evaluating and testing FET's since 1962, this was the first design that had proven completely feasible. The protective circuits required for an input design had been developed and refined in addition to the normal FET circuit operating considerations. The product was the Type 282 Probe Adapter which was designed to allow the use of conventional probes with Tektronix 50-Ω Sampling Instruments. A junction field-effect transistor was the logical choice for this useage since high input impedance was required and the probe power available at the sampling unit was limited. In addition, size was important as the 282 was designed to mount on the input connector.

Since that time, FET's have appeared in 26 other products at Tektronix. Many of these were designed with FET's initially; others that were designed before FET's were feasible have been converted to FET design.

What characteristics does the FET possess that cause it to be popular in instrument design at Tektronix? Its major use is as a solid-state high input impedance device. Tektronix circuitry has been predominantly solid state for some time now, but there has not been a suitable solid-state input device until the junction FET was available. Since oscilloscope design requires a number of high input impedance device applications, FET's are a logical choice. The major advantages of junction FET's might be listed as follows:

1. High input impedance—input terminal looking into a reverse-biased junction.
2. Very low drift (when properly compensated).
3. Solid-state reliability.
4. Noise—no microphonics—careful circuit design can decrease noise over other devices.
5. No apparent aging characteristics.
6. Small size allows miniature design.
7. Less power dissipation—filament supply not required. FET drain voltage required is less than tube plate voltage required.

As might be suspected, all the advantages of FET's do not come without some disadvantages. Their major disadvantage as an input device is the sensitivity to overload. FET's typically cannot withstand the abuse that vacuum tubes can handle. Because the FET has temperature-sensitive parameters, matching is used in critical applications. Tightly matched dual-FET's are now available from manufacturers to help solve this problem.

Once the design problems are solved (temperature compensation, bias tracking and protective circuitry to mention a few), performance may be obtained that is not available with any other device. FET's are especially useful in high-gain low-noise DC-coupled amplifiers with high common-mode considerations. The chart below compares some of the relative characteristics of tubes, junction FET's and insulated-gate FET's.

(continued on page 6)

Characteristics	Tube	Junction FET	Insulated Gate FET
Input Impedance	High	High	Very High
Noise	Low	Low	Unpredictable
Warm-up Time	Long	Short	Short
Size	Large	Small	Small
Power Consumption	Large	Small	Small
Aging	Noticeable	Not Noticeable	Noticeable
Bias Voltage Temp Coefficient	Low, Not Predictable	Low, Predictable	High, Not Predictable
Typical Gate/Grid Current	≈1 nA	≈.1 nA	≈10 pA
Gate/Grid Current Change With Temp	High, Unpredictable	Medium, Predictable	Low, Unpredictable
Reliability	Low	High	High
Sensitivity to Overload	Very Good	Good	Poor

FET Review

The FET may be referred to as a unipolar device compared to the "common" bipolar transistor. FET's use only one carrier type, majority carriers, while bipolar transistor operation requires both minority and majority carriers.

Fig 1 shows the basic lead configuration of the junction FET and illustrates the basic polarities for an n-channel device. The arrow points in the direction of conventional current flow across the p-n junction and normal voltage bias for the junction is always a reverse bias. Fig 2 compares the similar elements of vacuum tubes, transistors and FET's.

The field-effect transistor is a single junction device made-up with a source-to-drain material (the majority-carrier path) doped in either the "n" or the opposite direction. By applying voltage so as to oppose the majority carriers in the channel, the device is back biased. A negative voltage applied to the gate opposes electron flow in n-channel material and a positive voltage opposes hole flow in p-channel material. Under these conditions, the n-channel or p-channel material becomes a constrictive layer of dielectric material past which majority carriers must flow and can thus be controlled. Fig 3 indicates the polarities required for normal operation of both n-channel and p-channel FET's.

The junction FET is a "depletion" type device. Drain-to-source conduction is controlled by "depleting" the channel with reverse junction bias. Forward gate bias results in p-n junction forward current, and is not the desired mode of operation for the device. Fig 4 illustrates the effect on drain-to-source conduction as back bias is varied.

If the gate remains reverse biased, very little gate current flows so the control power is very small. The drain-source path may conduct current heavily however. The result is a basic device which is capable of very large current gain, substantial voltage gain, and thus a very large power gain.

Fig 5 illustrates the drain characteristics of a typical n-channel FET. To obtain these, the grounded emitter (source) mode of a Type 575 is used with NPN polarity. The base step generator is used in —POLARITY and a 1 kΩ, 1% resistor is connected between the base-and-emitter connections in order to convert base current in mA to gate voltage in volts. (See page 14)

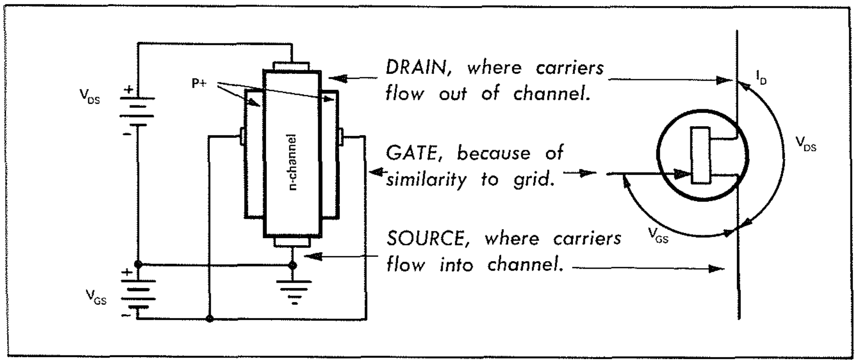


Fig 1 N-channel device and definitions.

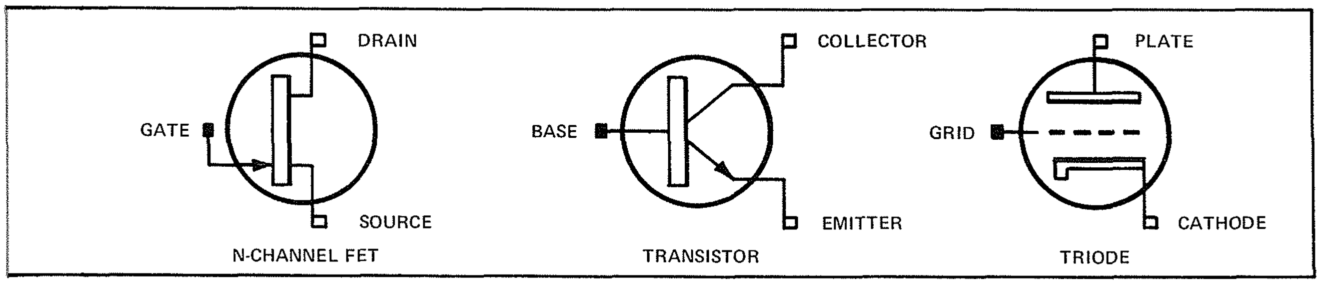


Fig 2 Comparison of basic lead terminology of FET's, transistors, and vacuum tubes.

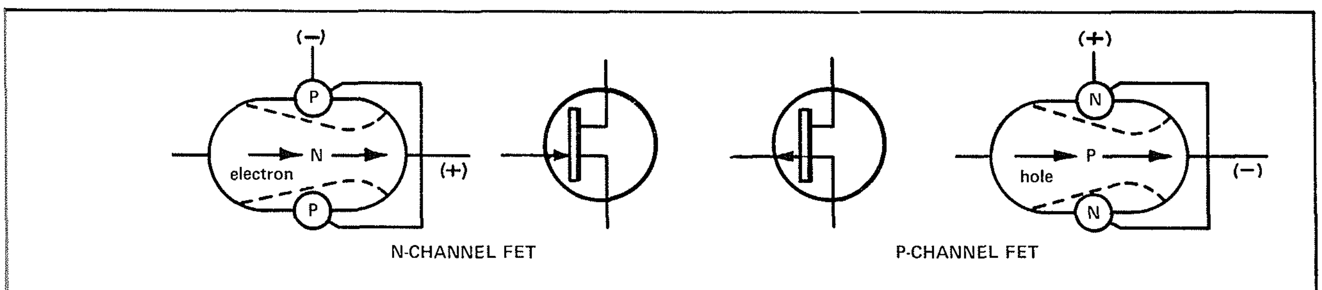


Fig 3 Comparison of an n-channel FET and a p-channel FET.

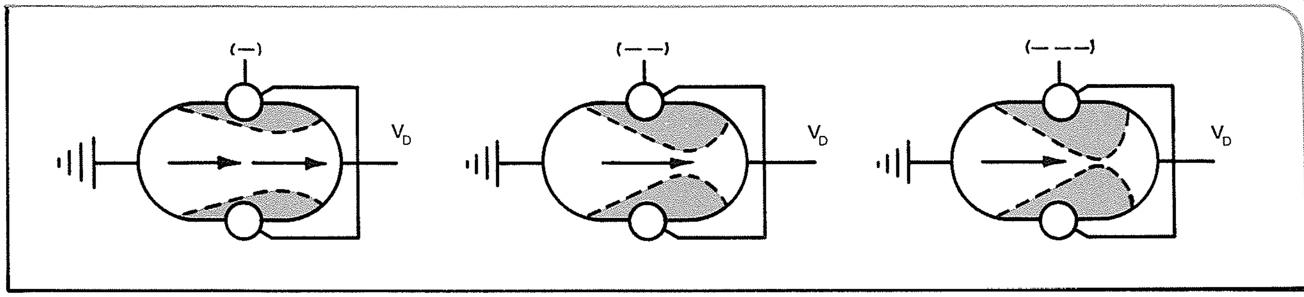


Fig 4 Back bias controlling current flow in an n-channel FET.

The result is a plot of drain current vs drain-to-source voltage for various gate voltages.

Note that the zero-biased curve is the highest current and succeeding curves result in turning the device off. The zero-biased characteristic in the A to B region can be understood by considering the conduction channel as the drain voltage is increased (see fig 5). For point A, where there is no bias on the device, there are only narrow depletion regions caused by the "contact" or "barrier" potential of the p-n junction.

The slope of the I vs V curve at point A is simply the conductance of the bulk n channel. As the drain-voltage increases, the gate-to-channel junction becomes increasingly reverse-biased at the drain end of the channel and the depletion region extends into the channel at this end. The depletion region is void of free carriers and is a space-charge region consisting of positive, immobile, impurity ions. Because the conduction channel becomes narrower as drain voltage is increased, the incremental conductance decreases until at point B the depletion regions nearly meet. At this point the gate-drain channel is said to be "pinched off" and further increase of drain voltage results in little additional drain current.

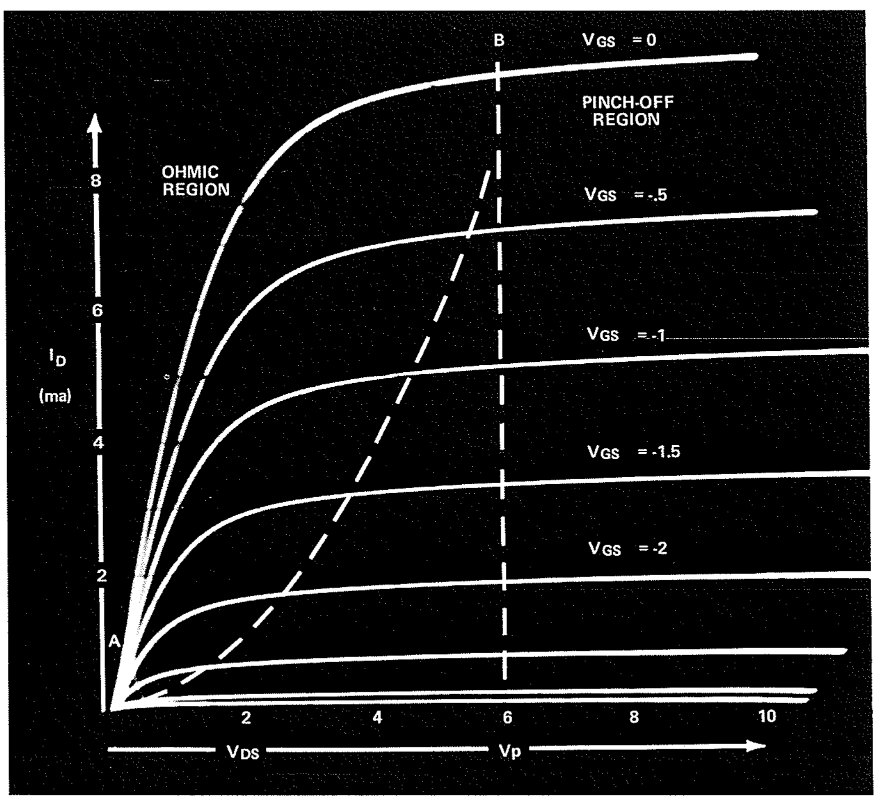


Fig 5 Drain characteristics of FET.

FET's are usually used in the regions to the right of B (fig 1) in the "drain pinch off" or "drain current saturation" region. Here the output resistance is very high since the current remains almost constant for large changes in V_{DS}. Note that in this region of its characteristic curve, the FET has an effective Rp approaching infinity.

The area to the left (where an increase in V results in an increase in I—close to the graph axis) is termed the "ohmic region." In this region the output resistance is relatively low but is controlled by the gate voltage.

The IGFET's (insulated-gate), sometimes called MOSFET's (metal-oxide-insulated), separate the gate and channel with a layer of intrinsic material. As temperature increases on this device, the channel apparently increases also as it starts to include some of the insulating layer into the main channel. The IGFET reacts more to changes in temperature than the regular FET's even though they do away with leakage currents in the gate circuit. Fig 6 indicates the symbol used by Tektronix for an n-channel device.

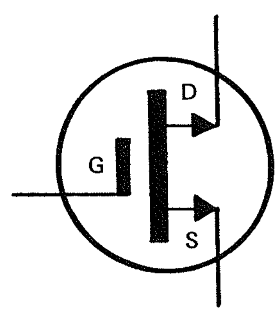


Fig 6 Tektronix symbol for n-channel IGFET.

In the case of the P6045 FET Probe which was introduced at WESCON '66, the FET was a necessity. The field-effect transistor, along with its protection circuitry, was designed into a package that was compatible with Tektronix miniature probes. This miniature probe, shown on the inside of the front cover, had size, power and input Z requirements that only a FET could meet.

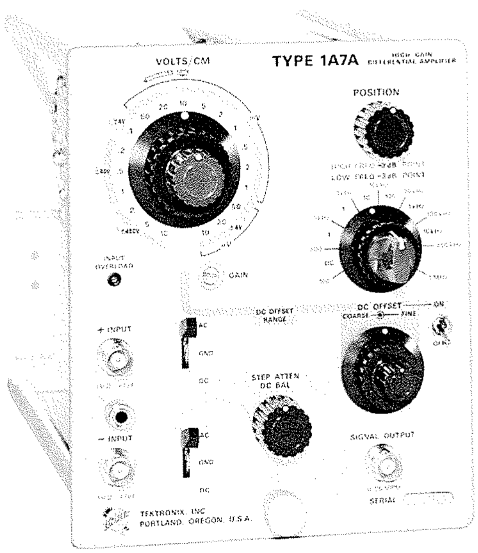
Tektronix sampling and digital circuitry makes extensive use of field-effect transistors. Memory slash (memory vertical drift when sampling gate is closed) used to be a limitation with low repetition rate signals. Because of the low leakage characteristics of FET's this is no longer a problem. The use of FET's in sampling preamplifier circuits provides better noise performance. Since FET's have become practical, the sampling preamplifier is no longer a significant source of noise.

In the case of the Type 611 Storage Display Unit, the FET was used for yet another reason. The Type 611 uses the FET as a square-law device. The dynamic correction circuitry necessary for the high resolution this instrument provides, requires an I^2 output from an E input. The FET is a square-law device that provides this characteristic in a single stage. The alternative was two transistor stages with the additional circuit complexity and cost.

FET's are used in the Type 410 Physiological Monitor for a number of reasons. One design consideration of the Type 410 concerned its rechargeable power pack. Field-effect transistors allowed the input circuit to operate effectively at 17 volts (10 standard 1.7-volt rechargeable cells). A vacuum-tube input in this circuit would have required a minimum of 25 volts, thus increasing the expense and weight of the power supply. At the same time the FET's contributed to a better common-mode design and assisted in a unique patient protection circuit.

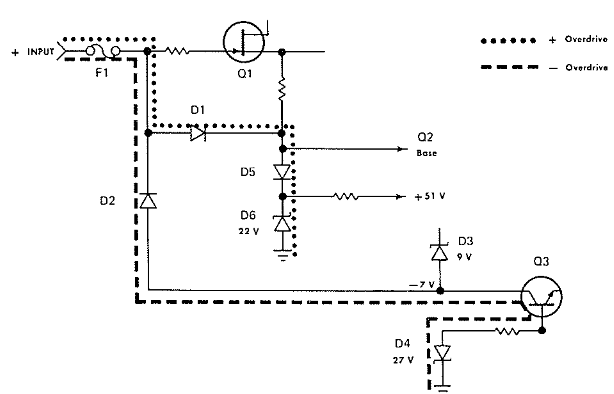
In the case of the Type 453, FET's improved overall circuit operation. Vertical drift was much reduced, reliability increased (elimination of microphonics, aging and shock), and the power requirement reduced by removing the vacuum-tube front end. Since the Type 453 is widely used in field service the reduced warm-up time is also desirable.

The use of FET's in plug-in vertical preamplifiers can increase overall performance and reliability. Performance of the Type 1A7A shown below represents a significant improvement from previous high-gain differential DC-coupled amplifiers. Maximum short-term drift is specified at 5 μV/minute and tangential noise is 15 μV at 10 μV/cm sensitivity and 1-MHz bandpass. FET design also allowed the elimination of a highly regulated 6.3-V filament supply that further simplified design and increased reliability. The input circuit of the 1A7A is fused against accidental severe overload as the simplified diagram below shows.



Above
Type 1A7A High-Gain Differential Unit

Right
Simplified Protection circuit for Type 1A7A.



Assume a steadily increasing positive voltage at the input. The floating power supply voltages continue to rise with the input. When the gate voltage of Q1 approaches approximately 23V, D1 turns on and clamps the gate, drawing current through F1. When the current through F1 exceeds 1/16A the fuse opens, removing the overdrive from the circuit.

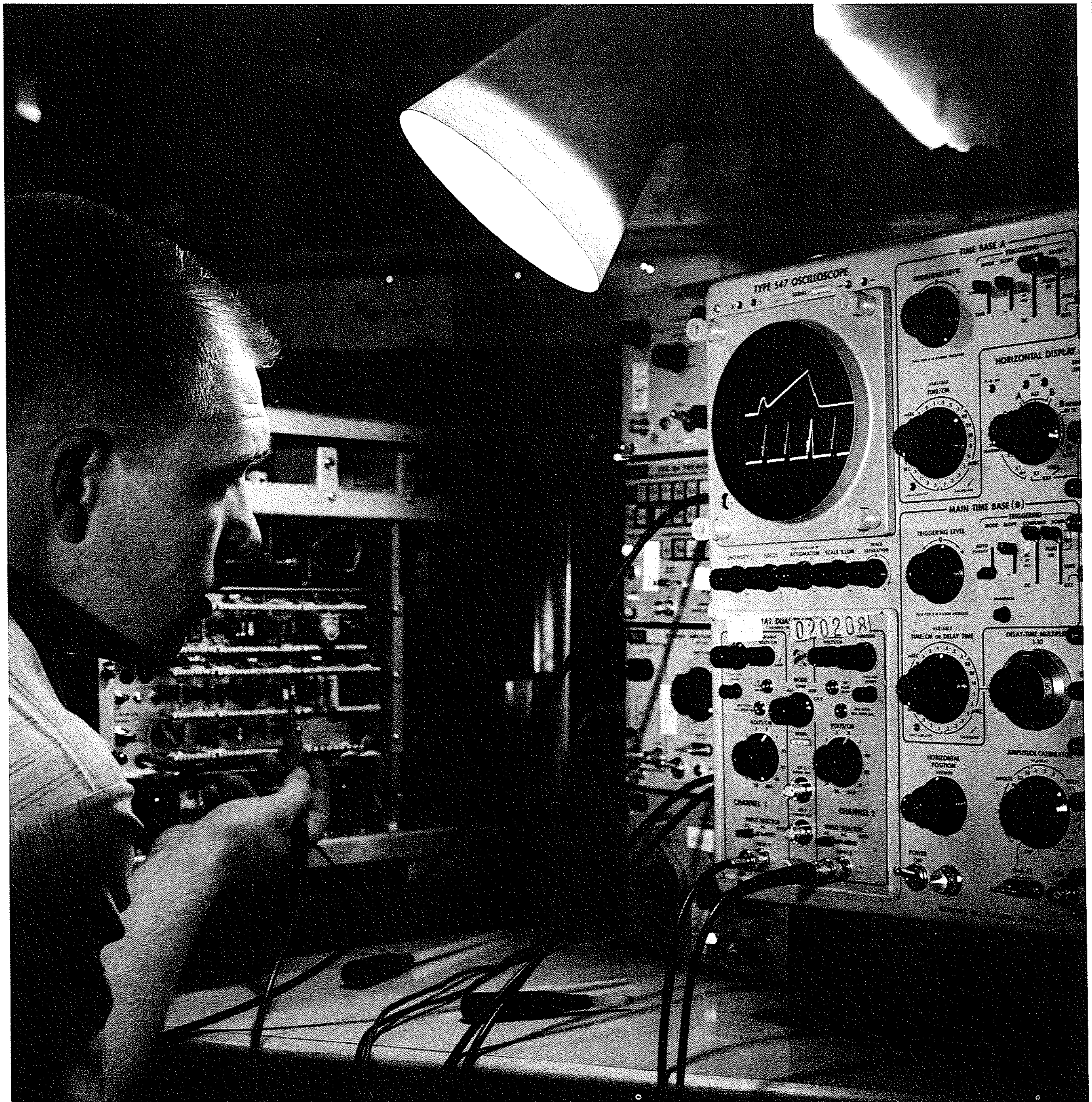
With a negative voltage whose magnitude is steadily increasing at the input, D2 turns on when the signal approaches approximately −7.6V and draws current through the −7V supply. The −7V supply becomes more negative (follows the input), causing the remaining supply voltages to go in the negative direction and Q2 cuts off. When the overdrive voltage becomes approximately −27V, the collector to base junction of Q3 becomes forward biased and conducts the overdrive current through D3. F1 opens when the current exceeds 1/16A.

GROUP	TYPE	CHARACTERISTICS	High Z In	Low Power Consumption	Small Size	Low Drift	Noise Characteristics	Short Warm-Up Time	Solid-State Reliability
			MAJOR FET CONTRIBUTION						
PROBES	282	50 Ω to 1 MΩ PROBE ADAPTER	✓	✓	✓	✓			✓
	P6045	DC-230 MHz FET PROBE	✓	✓	✓	✓			✓
	P6046	DC-100 MHz FET DIFFERENTIAL PROBE	✓	✓	✓	✓			✓
GENERAL PURPOSE PLUG-IN UNITS	1A1	DC-50 MHz DUAL TRACE	✓			✓			✓
	1A4	DC-50 MHz FOUR TRACE	✓			✓			✓
	1A5	DC-50 MHz DIFFERENTIAL COMPARATOR	✓			✓			✓
	1A7A	10 μV/cm DIFFERENTIAL	✓			✓			✓
	3A3	100 μV/div DUAL DIFFERENTIAL	✓			✓			✓
	81A	PLUG-IN ADAPTER	✓						✓
SPECTRUM ANALYZER PLUG-IN UNITS	1L5	50 Hz-1 MHz SPECTRUM ANALYZER	✓				✓		✓
	3L5	50 Hz-1 MHz SPECTRUM ANALYZER	✓				✓		✓
SAMPLING AND DIGITAL READOUT INSTRUMENTS	1S2	90-ps TDR	✓		✓	✓	✓		✓
	3S1	DUAL-TRACE SAMPLING	✓		✓	✓	✓		✓
	3S2	DUAL-TRACE SAMPLING	✓		✓	✓	✓		✓
	S1	350-ps SAMPLING HEAD	✓		✓		✓		✓
	S2	50-ps SAMPLING HEAD	✓		✓		✓		✓
	3S3	DUAL-TRACE SAMPLING PROBE	✓		✓	✓	✓		✓
	3T2	RANDOM SAMPLING SWEEP	✓		✓	✓	✓		✓
	230	DIGITAL READOUT	✓						✓
	568	READOUT OSCILLOSCOPE	✓						✓
PORTABLE INSTRUMENTS	323	DC-4 MHz	✓	✓	✓	✓		✓	✓
	453	DUAL-TRACE 50 MHz-SWEEP DELAY	✓	✓	✓	✓		✓	✓
MONITORS	410	PHYSIOLOGICAL MONITOR	✓	✓	✓			✓	✓
TV INSTRUMENTS	520	VECTORSCOPE	✓		✓	✓			✓
DISPLAY UNITS	601	STORAGE DISPLAY UNIT	✓						✓
	602	DISPLAY UNIT	✓						✓
	611	STORAGE DISPLAY UNIT	✓						✓

All of the preceeding designs discussed in this article have used junction FET's. Although the junction FET is the device best-suited for most oscilloscope designs, Insulated-Gate Field-Effect Transistors (IGFET's) are used in one Tektronix instrument.

The memory performance of Tektronix digital readout instruments has been improved with the use of an insulated-gate FET in the memory circuits. The extremely low leakage of these devices has contributed substantially to the improved performance and more accurate readout of the Type 230. The chart above shows those Tektronix instruments that incorporate FET's.

The Field-Effect Transistor is a welcome addition for the design engineer. Its high input impedance characteristic in addition to its solid-state properties of low power dissipation, small size, reliability, noise characteristics, etc. allow performance improvements in many circuits. The FET is replacing input vacuum tubes in much the same manner that bipolar transistors replaced vacuum tubes. Further evolution of the FET will surely result in even more FET circuits in oscilloscope applications.



UNDERSTANDING DELAYING SWEEP

The accuracy of time measurements taken from an oscilloscope is primarily limited to the accuracy of the oscilloscope time base. Although measurements may be made directly from the graticule of the CRT more accuracy is possible using delaying sweep. This article discusses time interval measurements using the precision delayed sweep.

Roger Loop, Tektronix technician, monitors a delaying-sweep display on a Type 547.

Introduction

Delaying-sweep measurements are based on the use of 2 linear calibrated sweeps. The first sweep, commonly called the delaying sweep, allows the operator to select a specific delay time. When this time is reached, the delayed sweep starts. The delayed sweep typically is a decade or two faster than the delaying sweep and offers additional resolution. The combinations of these two sweeps offers extra resolution and increases accuracy of time-interval measurement.

To understand delaying sweep operation, it is necessary to understand the time relationship between the delaying sweep and the delayed sweep. To illustrate, an event occurs that starts the delaying sweep at t_0. The delaying-sweep voltage ramp is applied to a voltage comparator that produces a trigger pulse at a later point in time, t_1. This trigger pulse occurring at t_1 starts the delayed sweep. Delay time, then, may be defined as the difference in time between the start of the delaying sweep and the start of the delayed sweep and can be expressed as $t_1 - t_0$.

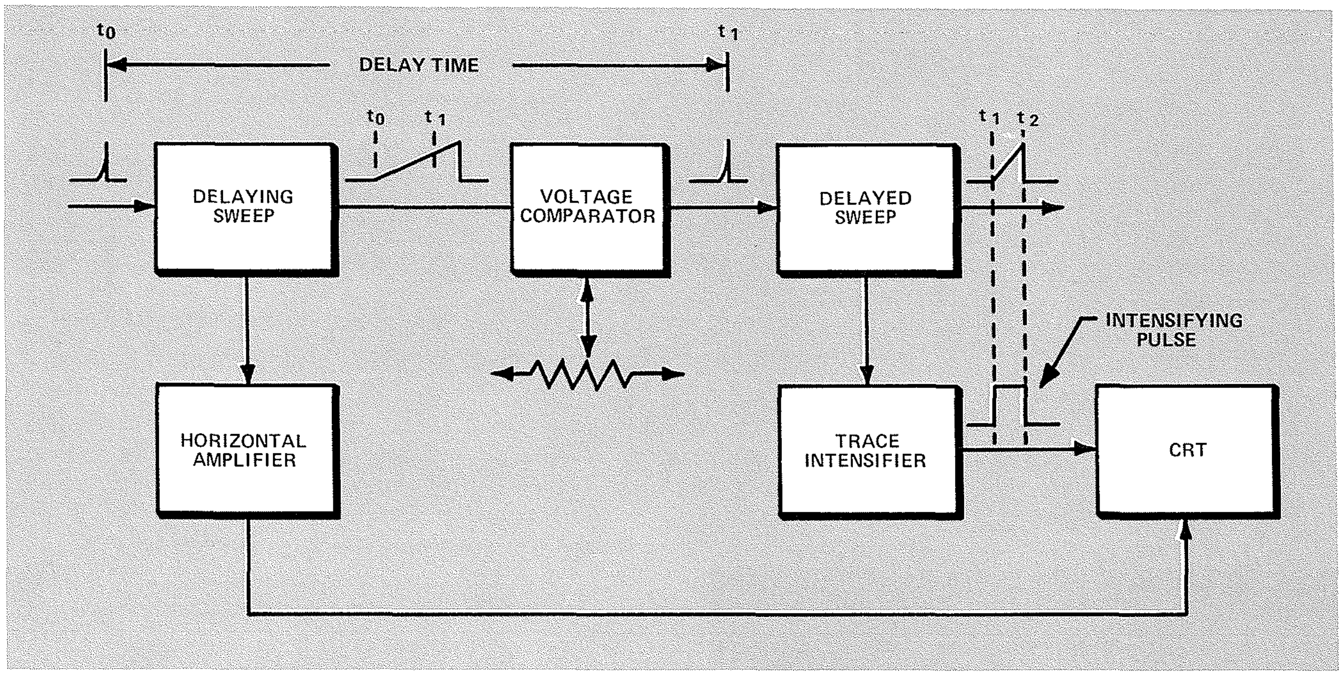


Fig 1 Block diagram of delaying sweep oscilloscope.

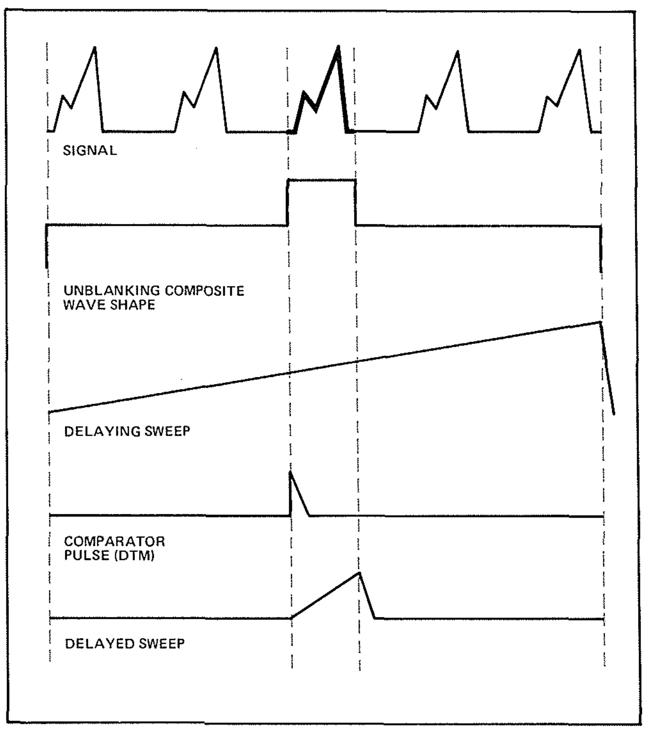


Fig 2 Delaying sweep oscilloscope circuit relationships.

The accuracy of delay time is basically determined by the delaying sweep and the potentiometer which sets the threshold level of the comparator. The horizontal amplifier and CRT **do not** affect the accuracy of delay time. An intensifying pulse indicates where the delayed sweep starts with respect to the delaying sweep, and so delay time can be determined independently of horizontal amplifier and CRT considerations. The portion of the delaying sweep that is intensified is a direct function of the duration of the delayed sweep as shown in fig 2.

Oscilloscope time-interval measurements usually involve finding the period of time between two events. By adjusting the delay-time multiplier (DTM), which controls a potentiometer in the comparator circuitry, the delay time from the start of the delaying sweep to both events is determined. The time between these events is the difference between their corresponding delay times.

The resolution of these delay times can be improved, thus improving the time-interval measurement accuracy, by driving the horizontal amplifier with the delayed sweep. The

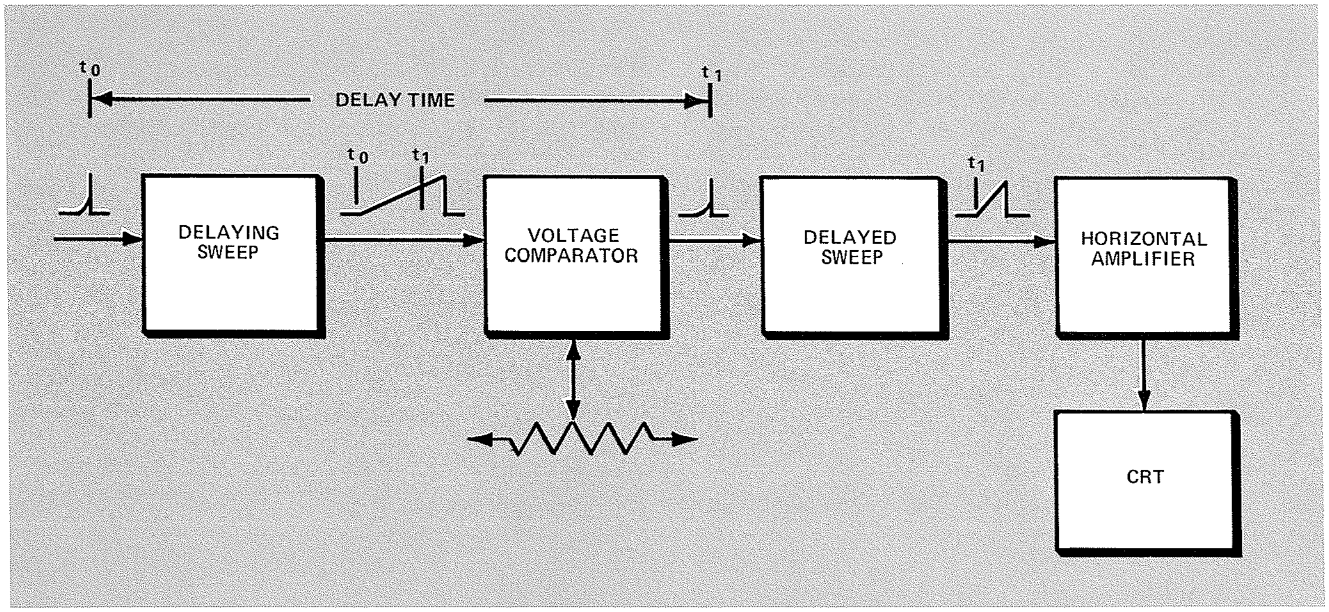


Fig 3 Delayed sweep mode.

intensified portion of the delaying-sweep presentation is now displayed over the full CRT display. In the case of fig 2, this appears as a 10X magnified display since 1/10 of the original waveshape time is now displayed over the same graticule area. A delaying-sweep oscilloscope, then, acts as a magnifier whose magnification power is the ratio of the delaying-sweep rate to the delayed-sweep rate.

$$\text{Magnification} = \frac{\text{delaying sweep rate}}{\text{delayed sweep rate}} = \frac{1 \text{ ms/cm}}{1\ \mu\text{s/cm}} = \frac{10^{-3}}{10^{-6}} = 1000{:}1$$

Fig 4 illustrates the use of delaying sweep to magnify a signal 1000X to allow closer examination of leading edge detail. Oscilloscopes such as the Tektronix Type 547 can provide a dual display of these two sweep rates. This is accomplished by using an internal multivibrator to switch between sweep rates and is referred to as automatic display switching.

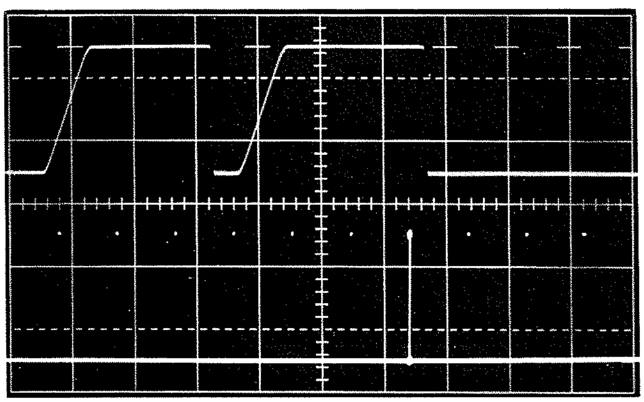


Fig 4 Display magnified 1000X resolves two pulses from apparent single pulse.

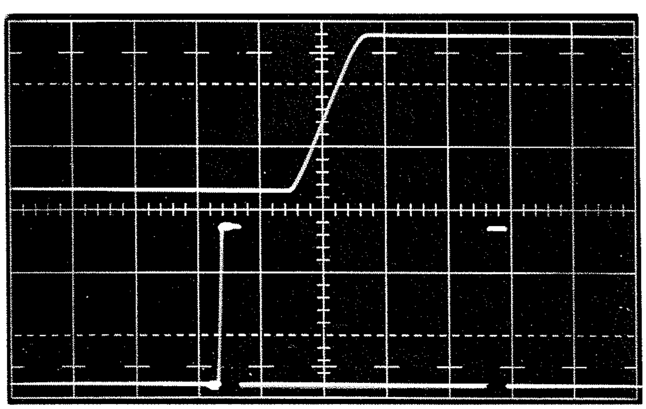


Fig 5 Determining delay time—pulse 1.

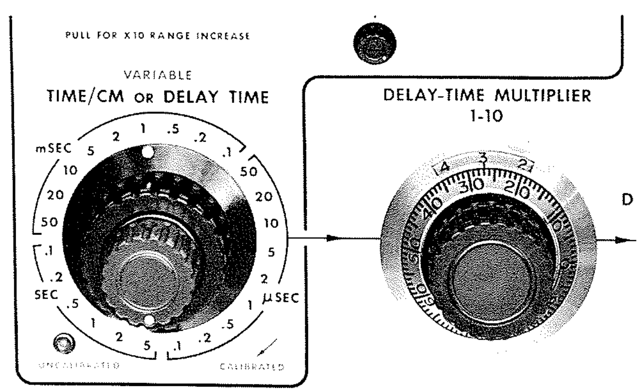


Fig 6 Delay time reading. 1 ms x 3.27 = 3.27 ms.

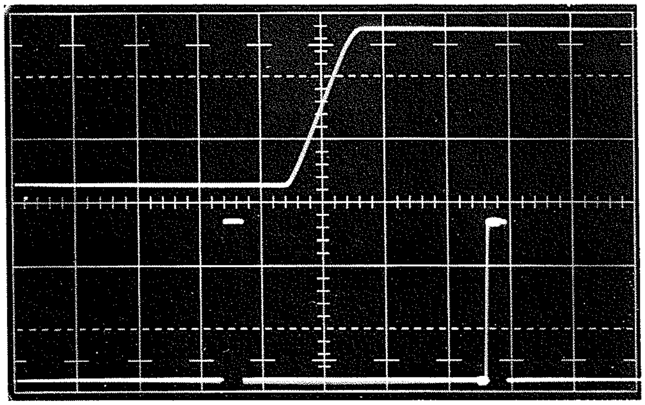


Fig 7 Determining delay time—pulse 2.

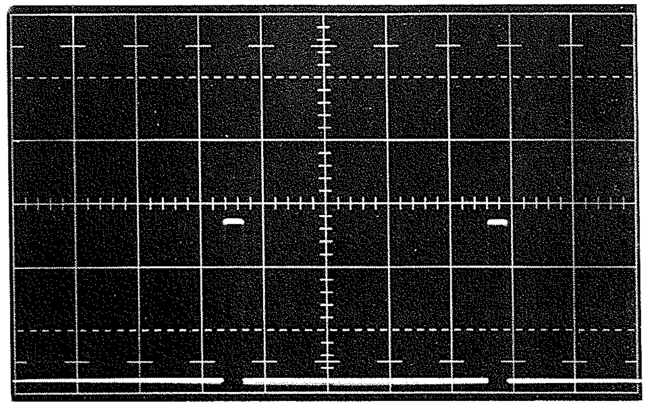


Fig 8 Determining time between events by graticule measurement.

Time-Interval Measurements

The example in fig 5 illustrates a typical time-interval measurement. Note the intensified portion of the lower waveform which is displayed in magnified form above it. The delay time associated with this event is determined by multiplying the delay time of 1 ms by the DTM reading of 3.27, as shown in fig 6. By turning the DTM until the next event is intensified and the upper waveform is in the same relative graticule position as before, a display like fig 7 is seen. If the delay time of this event is 7.47 ms, then the time interval may be computed.

It is not necessary to determine the actual delay time of the start of the event as indicated by the start of the intensified portion of the lower waveform. However, in both cases the DTM is adjusted until the magnified portion of both events is in the same relative graticule position. In the examples shown, the center (or 5-cm point) of the graticule is used. Any point on the graticule may be used as long as it is the same point for both events.

The difference between these two delay times is 4.20 ms and corresponds to the period of time between the two intensified events. Each minor division on the DTM represents 0.01 ms, which also represents the resolution of the delay time. Measuring with the graticule, the resolution is approximately 0.1 ms or reduced by a factor of ten. Fig 8 shows the same two events with a sweep rate of 1 ms/cm.

In fig 8, each minor horizontal graticule division corresponds to 0.2 ms. The time between the two events as read from the graticule is 4.2 ms. Making a graticule measurement, only one number past the decimal is significant because of the limitations in resolution due to trace width and display size. Thus the delaying-sweep method offers the additional resolution of an extra significant number.

Percentage of Error

In addition to improving resolution, the delaying-sweep method reduces percentage of error. The graticule method depends upon the oscilloscope's ability to line-up precision

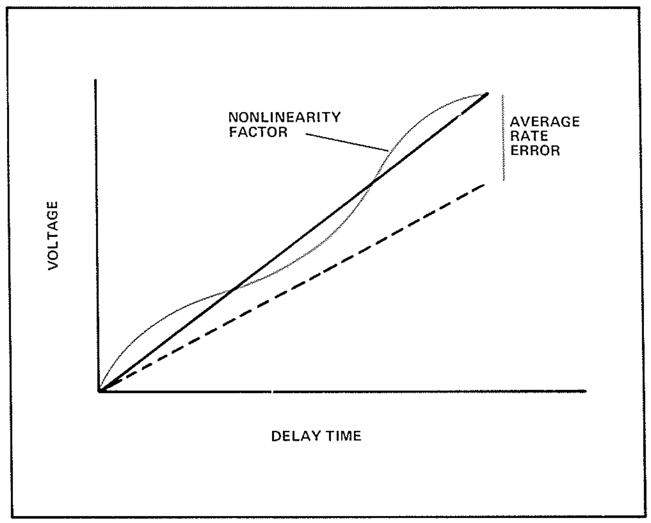


Fig 9 Basic error sources.

time-markers with major graticule divisions, and is subject to errors contributed by nonlinearity in the horizontal amplifier and CRT. The delaying-sweep method uses the CRT as a nulling device that does not affect the measurement accuracy.

The accuracy of the graticule method is determined by the accuracy of the sweep as observed on the graticule. With an accuracy of $\pm 3\%$, the 4.2 ms in the previous example has a maximum possible error of ± 0.126 ms. This type of error is easy to calculate because the $\pm 3\%$ specification normally includes both a timing or rate error and a nonlinearity factor. The delaying-sweep method also has these same basic factors which contribute to possible errors, although they are more complex in nature. Since the voltage ramp of the delaying sweep is the basic time base used in the delaying-sweep method, the basic sources of error in time-interval measurements can be illustrated as shown in fig 9.

The dotted line represents a no-error condition, while the linear solid line represents the average rate error due to differences of the timing networks in the delaying sweep.

The nonlinearity factor varies about the solid line and represents the actual delay time read on the DTM. This nonlinearity factor is a combination of both sweep and potentiometer nonlinearity, and is usually expressed in terms of dial divisions on the DTM. Delaying-sweep percentage error is then calculated by using this figure and the percentage figure for rate error.

Percentages of rate error are typically expressed in terms of actual delay time and are usually better than the sweep-rate accuracy as read on the CRT, because they do not depend on the horizontal amplifier and CRT. Delay-time accuracy is typically within ±1%. Also, because the average rate error lies totally on one side or the other of the no-error dotted line, the difference between any two delay times is accurate within ±1%, plus or minus the nonlinearity factor in dial divisions.

Another factor normally of lesser importance in making time-interval measurements is that of fixed delay. Fixed delay is a result of inherent circuit delays because the comparator requires time to generate a trigger pulse, and the delayed sweep and trace intensifier require time to generate an intensifying pulse. At faster sweep rates, this fixed delay is an appreciable percentage of the delay time. At these faster sweep rates, the delay time can be expressed as accurate within ±1% plus some fixed delay such as 100 ns. Because the fixed delay is included in both delay times it does not affect the accuracy of a time-interval measurement. Fig 10 represents fixed delay as a displacement of the error curve.

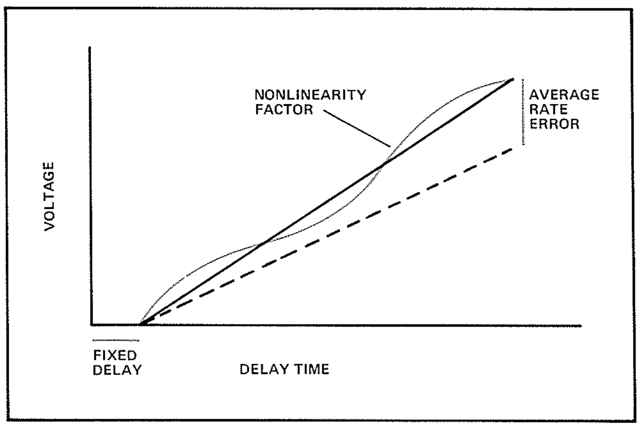


Fig 10 Basic error sources—fixed delay.

To calculate the error on the previous delaying-sweep method of time-interval measurement, a nonlinearity factor of ±2 dial divisions is assumed. Because the delaying-sweep rate is 1 ms/cm, the 100 minor dial divisions on the delay-time multiplier dial corresponds to 1 ms of time. Therefore, ±2 minor dial divisions is equal to ±0.02 ms.

If the delaying sweep rate is not changed, this nonlinearity factor remains ±0.02 ms regardless of the time increment measured. The total percentage of error is now ±1% of 4.20 ms ±0.02 ms or ±0.062 ms. Note that this error is about half as large as that using the graticule method (0.1 ms).

When using the delaying-sweep method, it is best to use the delaying sweep at the fastest possible sweep rate. The above ±2 dial divisions of nonlinearity factor then represents the smallest possible error. If the delaying sweep rate is 0.5 ms/cm, then ±2 minor dial division is equal to ±0.01 ms. This nonlinearity factor is only half as large as the previous one of ±0.02 ms.

When measuring short time intervals, it is not always possible to use the delaying sweep at a fast enough rate and still maintain a proper delaying sweep to delayed sweep ratio for the desired magnification. When this occurs, the graticule method may prove more accurate. For this reason, after using the delaying-sweep method, simply multiply the measured time interval by the delaying-sweep rate accuracy (as in the graticule method) and use the most accurate figure. In most cases, the delaying-sweep method will be the more accurate way of making time-interval measurements.

Improving Accuracy

Accuracy can be further improved by using a time-mark generator such as the Tektronix Type 184 to calibrate the DTM. By selecting time-marks so that accurate time-marks can be intensified and magnified for each ten major dial divisions, a calibration chart can be constructed for any delaying sweep rate that is needed. A calibration chart for a sweep rate of 1 ms/cm might look as follows:

TIME MARKS	DTM READING	ERROR
1.0 ms	1.000	.000
1.1 ms	1.100	.000
1.2 ms	1.200	.000
.	.	.
.	.	.
3.2 ms	3.205	+.005
3.3 ms	3.305	
.	.	.
.	.	.
7.4 ms	7.395	—.005
7.5 ms	7.495	
.	.	.
.	.	.
8.8 ms	8.800	.000
8.9 ms	8.900	.000
9.0 ms	9.000	.000

Fig 11 Calibration chart for optimizing accuracy.

Since 0.1 ms represents only 1/100 of the total sweep, the actual error of the delay-time multiplier dial reading of 3.27 ms can be considered +½ dial division high or +0.005

ms because both 3.20 ms and 3.30 ms contain this same error. For the same reason, the 7.47 ms reading can be considered low by the same amount or -0.005 ms. Therefore, a more accurate interval of time elapsed between the two previous events is time $= (7.47 \text{ ms} + 0.005 \text{ ms}) - (3.27 \text{ ms} - 0.005 \text{ ms}) = 7.475 \text{ ms} - 3.265 \text{ ms} = 4.210$ ms.

The accuracy of this final time interval is limited only by the accuracy of the time-markers and the nonlinearity that occurred in 10 dial divisions of the delay-time multiplier dial. This accuracy can be held to $\pm 0.1\%$ quite easily.

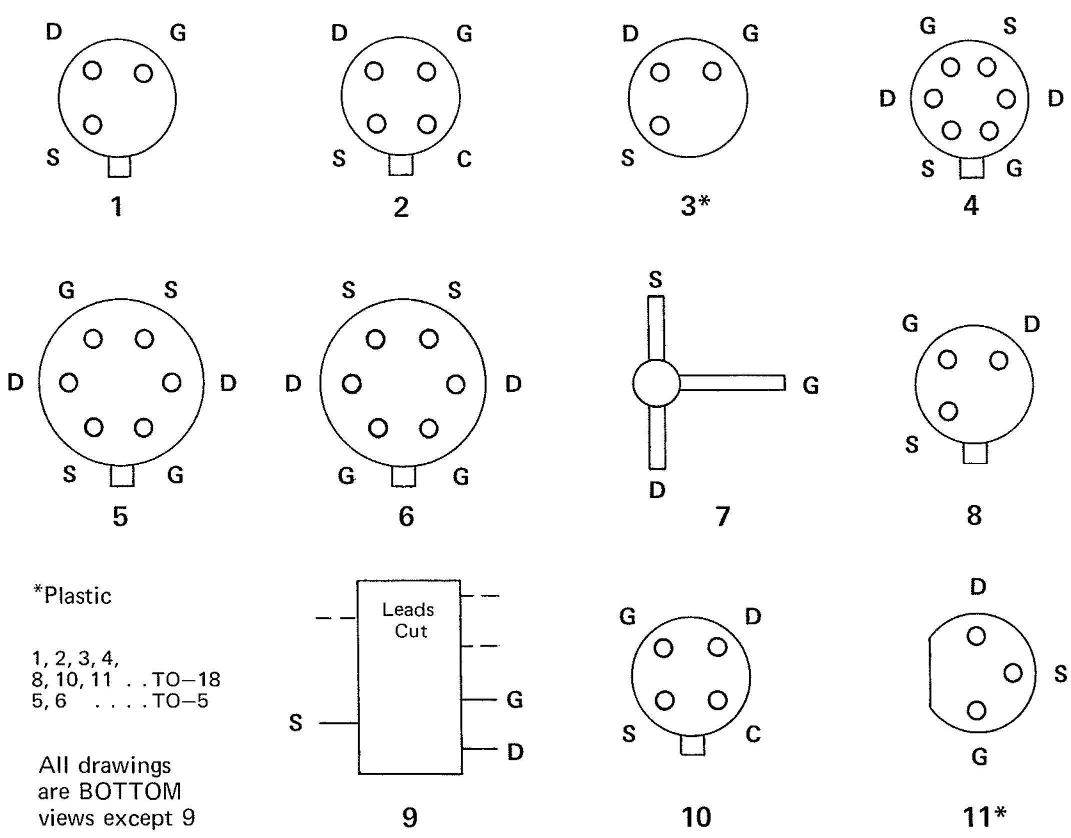
Summary

The delaying-sweep method of time-interval measurements offer additional resolution and accuracy for most measurements. Understanding the limitations of delaying sweep, as well as the advantages, allows the user to determine if this capability is required.

Service Notes

FET BASING DIAGRAM

Some confusion exists as to the different FET basing arrangements. The information below shows the basing for all of the FET's currently being used in Tektronix instruments.



*Plastic

1, 2, 3, 4,
8, 10, 11 . . TO–18
5, 6 . . . . TO–5

All drawings are BOTTOM views except 9

Tektronix PN	Basing No	Tektronix PN	Basing No	Tektronix PN	Basing No	Tektronix PN	Basing No
151-1001-00	9	151-1007-00	4	151-1013-00	4	151-1022-00	1
151-1002-00	8	151-1008-00	6	151-1015-00	2	151-1024-00	10
151-1003-00	4	151-1009-00	4	151-1017-00	7	151-1025-00	11
151-1004-00	3	151-1010-00	4	151-1018-00	10	151-1026-00	3
151-1005-00	3	151-1011-00	4	151-1019-00	4		
151-1006-00	3	151-1012-00	2	151-1020-00	4		

Measuring FET's with a Type 575

FET's are becoming common in current Tektronix instruments and the need arises for a method of checking them. The following method will quickly determine whether a suspected FET is faulty.

The Type 575 can easily be used to show the typical operating curves of field-effect transistors FET's by connecting a 1 kΩ, 1 W, 1% resistor from the base to the emitter binding post on the Type 575. This converts the mA/step of the base step generator to V/step, providing the voltage swing required for the gate. The 575's constant current source is now a constant voltage source which is developed across the 1 kΩ resistor. See fig 1.

When testing an FET, the drain lead goes to the collector connection; the gate lead to the base connection; and the source lead to the emitter connection.

For testing n-channel FET's set the controls as shown:

Collector Sweep

POLARITY	+(NPN)
PEAK VOLTS RANGE	200
PEAK VOLTS	0 (to start)
DISSIPATION LIMITING RESISTOR	1-2 kΩ (to start)

Base Step

STEPS/FAMILY	12
POLARITY	−(PNP)
mA/STEP	.2 (+.2 V/step)

Display Calibration

VERTICAL	.5 mA/div
HORIZONTAL	2 V/div

CAUTION: Adjust the STEP 0 carefully before testing the FET. N-channel field-effect transistors may be destroyed by application of over ½ volt of positive bias. A set of FET curves, resembling those of a pentode, will appear as the collector voltage approaches the FET ratings. If there is any doubt concerning the FET, compare it with a known good device or consult a specification sheet. Note that the zero bias curve is the top curve in fig 2.

If you wish to look at the breakdown characteristics, it is only necessary to change the horizontal calibration and increase PEAK VOLTS until breakdown occurs. See fig 3.

For testing p-channel FET's, set the collector sweep POLARITY to −(PNP)and the base step POLARITY to plus. An easy method of remembering this testing procedure is to correlate an n-channel FET with a PNP transistor test, as far as the collector to emitter and drain to source voltage polarity are concerned. However, when testing field-effect transistors, the base step polarity must always be opposite the collector polarity.

A drain current vs gate source voltage curve may be easily obtained by changing the horizontal display to .5 base volts and repositioning the display. See fig 4.

The Type 575 base step amplifier has the ability to supply gate voltage to 12 volts maximum. This is sufficient to observe the majority of FET's as used in Tektronix instruments. A complete redesign of the base step amplifier and power supply is required to accommodate a greater voltage swing.

If the positive gate bias characteristics are desired, this can be done to a limited extent if adequate protection is employed to assure that the gate drain and source currents do not exceed the maximum rating of the device under test.

CAUTION: Gate input voltages in excess of +.6 V typically run the FET beyond its current rating.

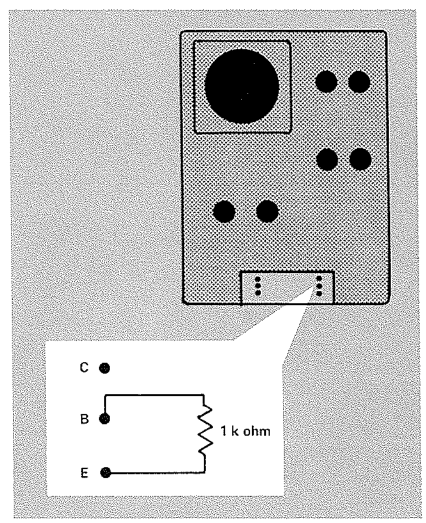


Fig 1 Type 575 modified for FET testing.

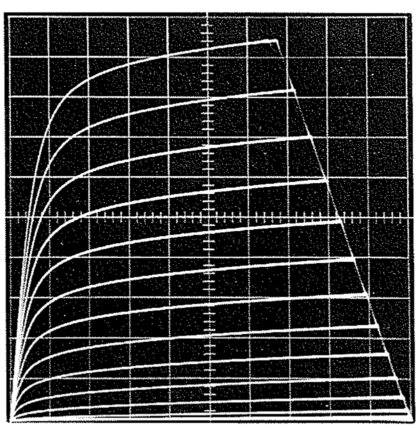


Fig 2 Drain family of characteristics V_{DS} vs I_D.

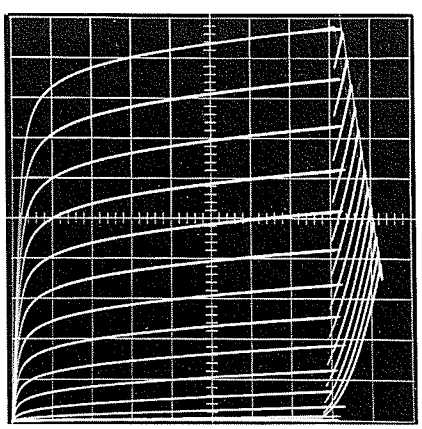


Fig 3 Drain family of characteristics showing avalanche V_{DS} = 10 V/div: I_D = .5 mA/div.

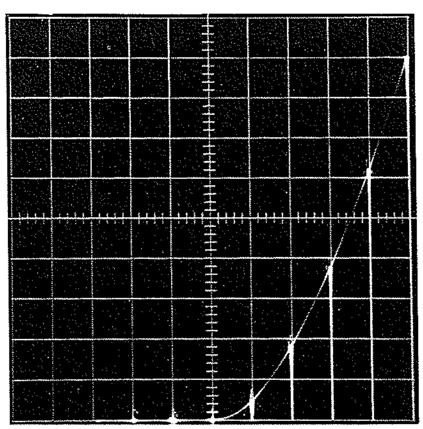


Fig 4 Drain current vs gate source voltage V_{GS} = .5 V/div: I_D = .5 mA/div.

USED INSTRUMENTS FOR SALE

1—Type 564 Storage Oscilloscope, SN 4897; 1—Type 201-1 Scope-Mobile® Cart; 1—Type 2A60 Single Trace 1-MHz Plug-In; 1—Type 2A61 Low Level Differential Plug-In; 1—Type 2B67 Time Base. Condition like new. Used very little. Price: $1,495.00. Contact: J. M. Edelman, M.D., 4550 North Boulevard, Baton Rouge, Louisiana 70806. Telephone: (504) 924-6266.

2—Type 3A72, SN 3116 and 2791. Contact: Dr. Zia Penefsky, New York Medical College, Fifth Avenue at 106th Street, New York, New York 10029. Telephone: (212) 876-5500 Ext. 539.

1—Type 511AD-121 Amp—Scopecart. Total price $225.00. Contact: Fred Chambers, 11 Locuswood Blvd., Elmont, New York. Telephone: (212) 775-6938.

1—Type 661 Sampling Oscilloscope with Type 5T3 Sampling Timing Unit and Type 4S2 Dual-Trace Sampling Unit. Price: $2,500.00. Contact: Grant Wales, G. T. Schjeldahl Company, Northfield, Minnesota. Telephone: (507) 645-5633.

1—Type 526, SN 1860. Used only 6 months. Contact: N. Friedman, Professional Closed Circuit TV, 342 Madison Avenue, New York 17, New York. Telephone: (212) 687-4422.

1—Type 517A. Excellent condition. Contact: Ed Knight, Industrial Communications, 8300 Fenkell, Detroit, Michigan 48238.

1—Type N Sampling Plug-In Unit. Like new. Price: $325. Contact: Dick Landis, Landis Associates, 5222 Venice Boulevard, Los Angeles, California. Telephone: (213) 933-8187.

1—Type 567, SN 2821; 1—Type 6R1A, SN 2191; 1—Type 3S76, SN 3961; 1—Type 3T77A, SN 4771; 2—Type P6032. Used only 4 hours. Price: $4900. Contact: Bill Burns, Digital Equipment Corporation, 146 Main Street, Maynard, Massachusetts 01754. Telephone: (617) 897-8821 Ext. 613.

1—Type 547/1A1/202-2. Contact: Meyer Bar, 5523 EauClaire Drive, Palos Verdes Peninsula, California. Telephone: 377-2121 (home); 772-8111 Ext. 6437 (office).

1—Type 517A, SN 1377. Sell or trade and cash for Type 535 or Type 545 and CA Plug-In. Contact: Duane Beyer, 1756 Elmhurst Lane, Concord, California. Telephone: (415) 682-6161, Ext. 372 (days); (415) 682-5273 (evenings).

1—Type 1A1 Dual-Trace Unit, SN 7420. Price: $425. Contact: L. Springer, Creative Electric, 18 Hulbert St., Auburn, New York 13021. Telephone: (315) 253-9759.

1—Type RM504, SN 001315. Less than 300 total hours on instrument. Price: $395 FOB Houston, Texas. Contact: D. D. Fitzgerald, Southwest Instrument Co., 7722 Westview Drive, Houston, Texas 77055. Telephone: (713) 682-7801.

1—Type 531, SN 493; Type 53A; Scope-Mobile. Price: $400. 1—Type 535, SN 692; Type 53/54C; Scope-Mobile Cart. Price: $550. Contact: Milt Groban, 9656 South Merrion, Chicago, Illinois 60617. Telephone: (312) 721-3442.

1—Type 535, SN 9913; 1—Type CA Plug-In, SN 19828; 1—Type 500/53A Scope-Mobile Cart. Price: $600. 1—Type 585A, SN 6687; 1—Type 82 Dual-Trace Plug-In, SN 1824; 1—Type 202-1 Scope-Mobile Cart. Price: $1,500. Contact: O. H. Fernald, Advance Research, Inc., 44 Hundreds Circle, Wellesley Hills, Massachusetts 02181. Telephone: (617) 237-1920.

1—Type 517 high speed with power supply. Condition of both good. Contact: D. Schendel, Electro Optical Industries, Inc., 92 Aero Camino, Goleta, California 93017. Telephone: (805) 968-2591.

1—Type 4S2, SN 000523. Price: $965. 1—Type 113, SN 001226. Price: $165. Contact: Robert Williams, University of Virginia, Physics Department, Charlottesville, Virginia. Telephone: (703) 295-2166 Ext 3345.

1—Type 503, SN 7345. Price: $500. Contact: Chuck Fredricks, Nortec, Richland, Washington 99352. Telephone: (509) 943-9141.

1—Type 4S2A; 1—Type 5T3 Plug-In Unit; 1—Type 661. Contact: Jerry Borchert, 3300 Hillview Avenue, Palo Alto, California. Telephone: (415) 326-9500.

1—Type 511A, SN 4235. Price: $100. 1—Type 543 and CA Plug-In, SN 353 and 5032 respectively. Price: $1170. 1—500 Scope-Mobile Cart. Price: $79. 1—Type 180A Time Mark Generator, SN 5908. Price: $468. Contact: Stabro Laboratories, Inc., 25 Kensington Avenue, Salt Lake City, Utah 84115. Telephone: 467-8011.

USED INSTRUMENTS WANTED

1—Type 564 Storage Oscilloscope, 3A75/2B67 Plug-In Units. Contact: Charles Stuart, 1 Finch Place, Huntington, New York 11743.

Type 575 Transistor Curve Tracers. Contact: Mr. Schaeffer, Dage Corporation, 757 Main Street, Stamford, Connecticut. Telephone: (203) 324-3123.

1—Type 511; 1—Type 512; 1—Type 513; 1—Type 514. Maximum—$200. Contact: R. Stayton, 4403 Vangold, Lakewood, California 90712. Telephone: 429-9429.

1—Type 502; 1—Type 502A. Contact: Don Modlin, Reflectone Division, Otis Elevator Company, 2051 West Main Street, Stamford, Connecticut 06902. Telephone: (203) 325-2251.

Will trade 1—Type 541, SN 6092 for 1—Type 531A, no plug-ins. Contact: John Bowen, Pressure Products Industries, Inc., 412 South Warminster Road, Hatboro, Pennsylvania 19040. Telephone: (215) 659-3300.

1—Type 515 or comparable scope. Will consider more sophisticated type with 10-MHz bandwidth. Contact: Tom Annes, P.O. Box 2232, Denver, Colorado 80201.

1—Type 515A, 541 or 545. Please state condition and price. For personal use. Contact: E. D. Haley, Jr., 909 Monticello Avenue, Charlottesville, Virginia 22901. Telephone: (703) 296-2037.

1—Type 575 Curve Tracer. Contact: Robert J. McNaul, Spar Electronics, 7969 Engineer Road, San Diego, California 92111. Telephone: 279-1641.

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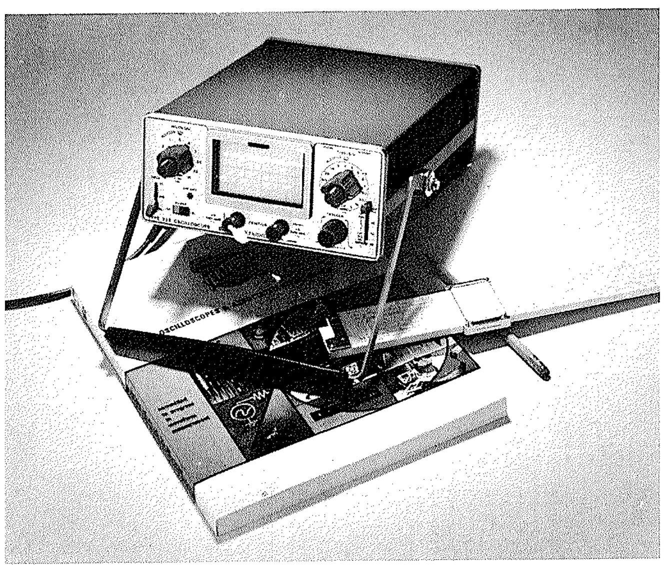

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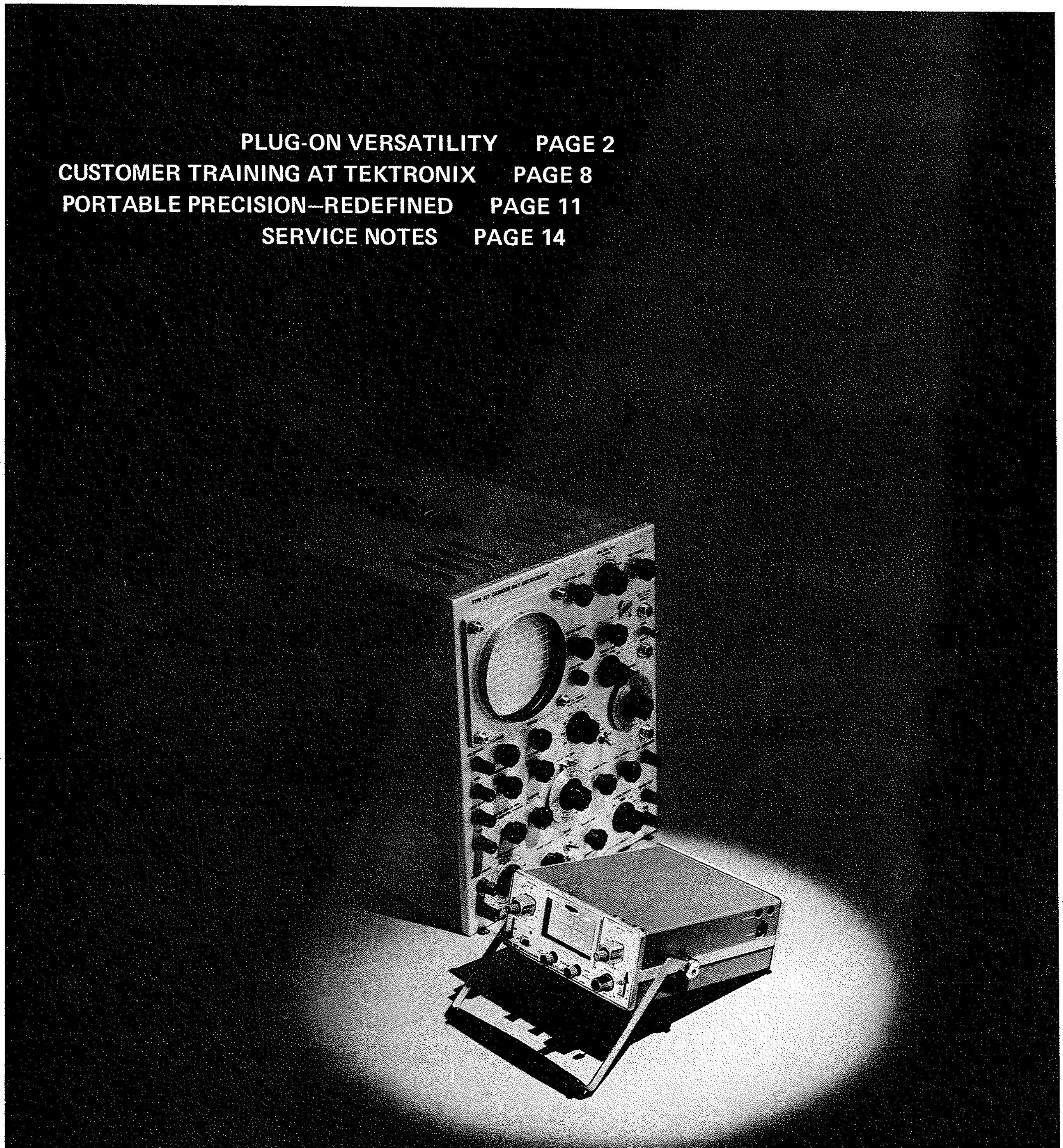
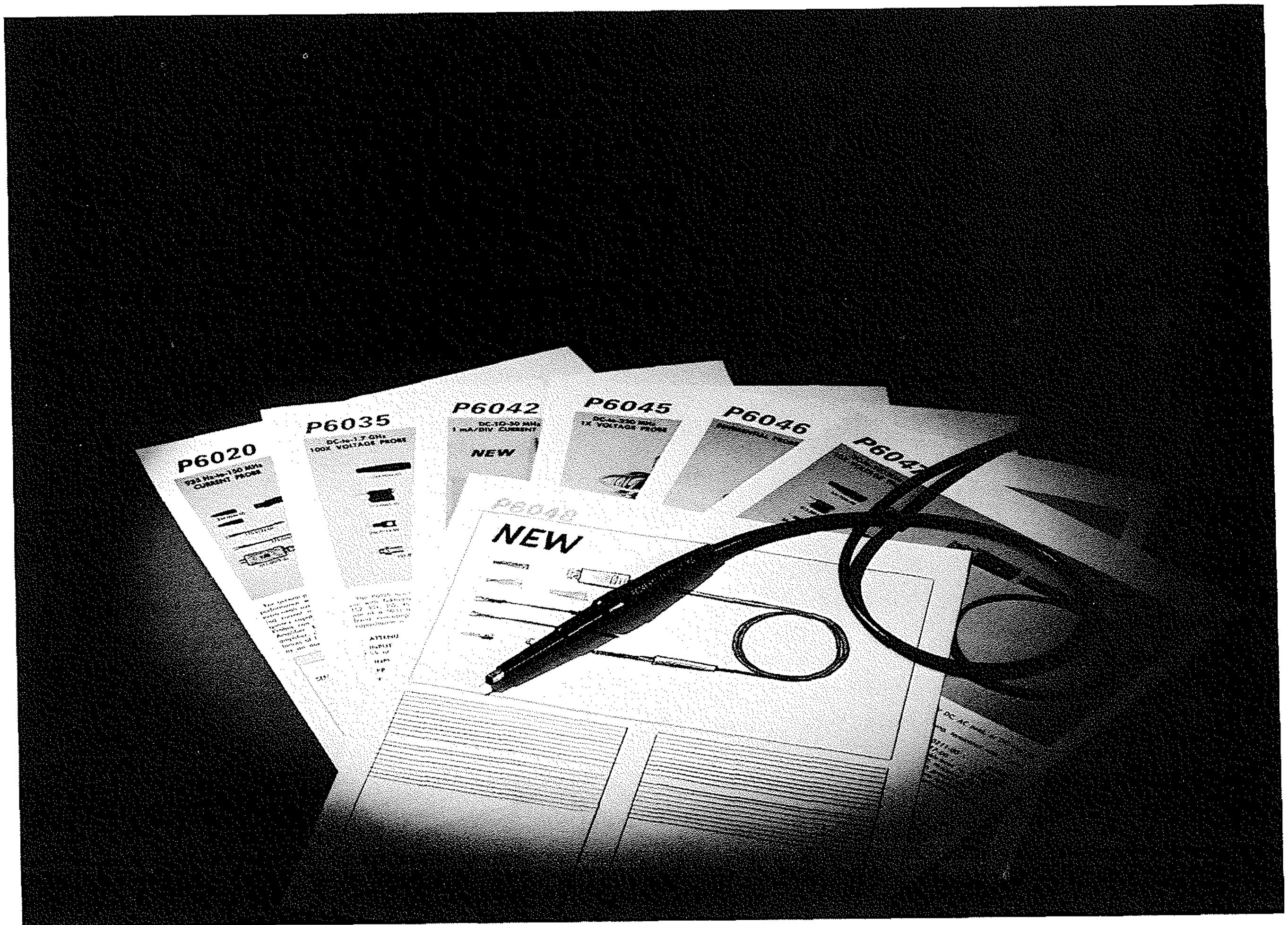




The new P6048 probe is shown next to 6 other high frequency, high performance miniature probes. Designed for use with high performance oscilloscopes, these probes illustrate the full-spectrum measurement capability currently available to the oscilloscope user. See chart on page 5 for additional details.

Plug-On Versatility

CAL HONGEL
Project Manager — Accessories Design

Introduction

Tektronix introduced the plug-in instrument concept with the introduction of the Type 530/540 series oscilloscopes in 1954. This concept developed because the interface between signal source and the cathode-ray tube is often complex and must be adaptable. Oscilloscope plug-in preamplifiers accomplished this interface nicely and so provided greater versatility at a modest price.

Since that time the plug-in concept has spread to counters, spectrum analyzers, function generators and many other instrument lines. Several years ago it became apparent that this same concept could be applied between the input vertical amplifier and the signal source, thus allowing the user more versatility.

Since that time, Tektronix has been engaged in an "across-the-measurement-spectrum" effort to develop

COVER ● Tom Jones, Tektronix photographer, highlights the new SONY/TEKTRONIX Type 323. The Type 512, an instrument of similar characteristics introduced 19 years ago, is shown in the background. See story on page 11.

probes that interface between the many varied signal sources and the vertical inputs of high-performance oscilloscopes. The success of this effort is best measured in the spectrum of Tektronix oscilloscope/probe performance currently available to the oscilloscope user. This concept allows general-purpose oscilloscopes to adapt to many application areas that heretofore required additional plug-ins or special-purpose oscilloscopes.

A case in point is the Tektronix Type 454 Oscilloscope and the high performance probes available for use with it. Two years ago when Tektronix introduced this instrument, two probes were announced, the P6047 passive probe and the P6045 FET probe.

High-Performance Probes

The Type P6047 passive probe provides the Type 454 with 2.4-ns performance at the probe tip and serves as an excellent general-purpose probe for most circuitry because of the 10 MΩ, 10 pF (7 pF @ 100 MHz) characteristics. The P6045 FET probe offers extra sensitivity and still maintains a low input capacitance. Since that time a number of other probes have been developed that truly provide the Type 454 with a full-spectrum measurement capability.

For example, the P6020 miniature current probe with its 200-MHz performance gives the Type 454 the ability to monitor high speed current waveshapes where the source resistance and capacitance are such that a voltage probe causes severe loading.

A high-speed differential probe and amplifier has been developed that provides wideband, high common-mode rejection ratio performance. Differential probe-tip signal processing minimizes measurement errors caused by differences in probes, cable lengths, ground paths and input attenuators. As a result, small high-speed differential signals may now be analyzed on a general-purpose oscilloscope. The P6046 Differential Probe and Amplifier provide the Type 454 with a 1 mV 70-MHz capability that significantly increases the versatility of the instrument.

The P6042 DC current probe is available for use with the Type 454 and while it does not cover the full bandwidth of the instrument, it does provide a unique DC-to-50 MHz current-measuring capability all in one probe. This is a particularly useful tool for many fast semiconductor circuits since fast switching transients, low frequency response, and DC level can all be displayed simultaneously on the same oscilloscope.

New 1 kΩ 1 pF Passive Probe

The latest member to the Tektronix family of high performance miniature probes is the P6048 passive probe system, which extends the measurement capability of the Type 454. The P6048 is a 1000 Ω low impedance passive probe utilizing 100-Ω cable. (A 50-Ω probe system, for example, with the same 10X attenuation has only 500-Ω impedance.) 100-Ω cable is used because studies indicate this is the highest impedance transmission line that has sufficient reliability yet retains small size and flexibility necessary for probe usage. Higher impedance cables do not meet the environmental requirements.

Since all low impedance systems suffer from power dissipation problems, a switchable AC-coupling capaci-

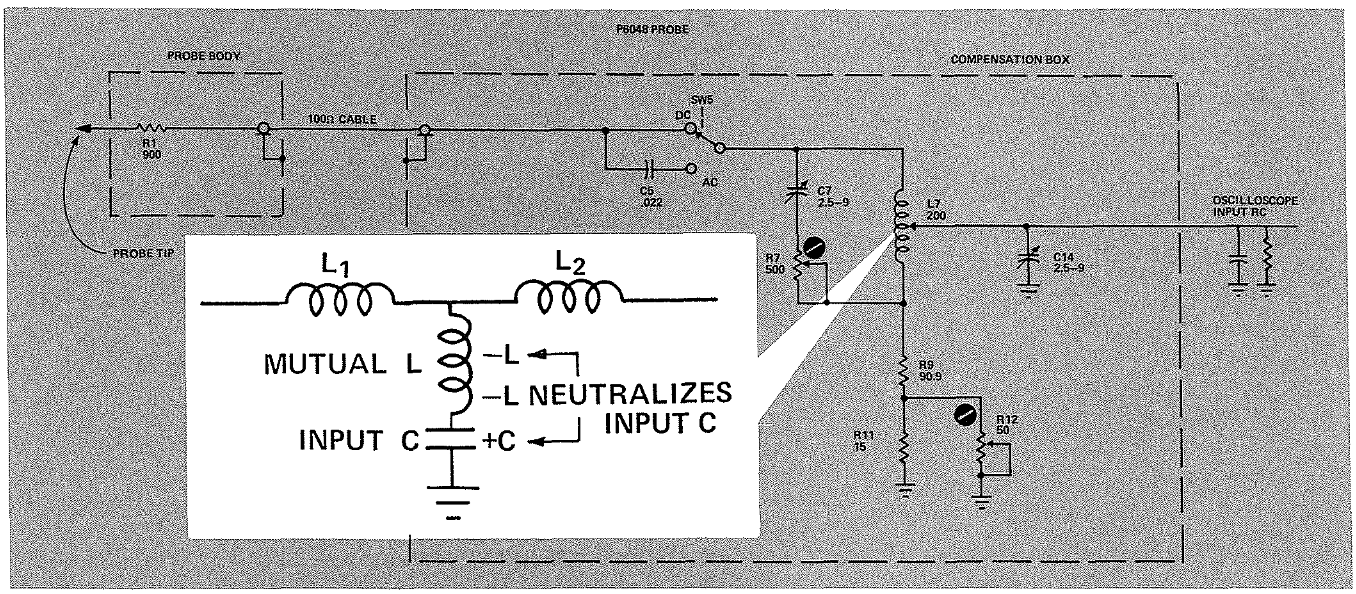


Fig 1. The termination of the P6048 probe is the key to its performance characteristics. The simplified schematic illustrates how the mutual inductance (−L) of the T-coil termination neutralizes the input capacitance (+C) of the instrument. By locating the low-impedance termination in the probe, the general-purpose aspect of the oscilloscope is retained with no sacrifice to the user.

tor is included in the termination box to extend the maximum DC input voltage from 20 V to 200 V. The P6048 design maintains the same input capacitance of less than 1 pF, *even when the probe is AC-coupled,* with a low frequency 3-dB point of 7 kHz.

Size was an important consideration in the design of the P6048 probe. For a high-speed probe to be useful, it must be small enough to probe the circuit under investigation. However, as the probe diameter decreases, the tip capacitance increases. The design of the P6048 is compromised on a 0.3-inch diameter. This allows an input capacitance of <1 pF (typically 0.8) but retains the important small size, so necessary in high-speed circuitry.

50-Ω Systems

Another means of looking at high-speed circuits is to terminate the oscilloscope input with 50 Ω. This permits using high-speed probes such as the P6035 (5 kΩ, 0.6 pF) that work into 50 Ω and can display the 2.4-ns risetime of the Type 454. The Type 454 input characteristics will cause some reflections, but pulse measurement information is valid up to twice the length of the cable time delay used between the probe and scope. An excellent means of optimizing this viewing mode is to insert enough 50-Ω cable between the termination and the probe so the reflection occurs beyond the point of interest as shown in fig 7.

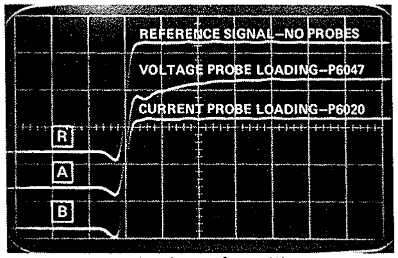


Fig 2. CRT display of oscilloscope under test. Probes are applied to deflection plate circuitry as shown in fig 4.

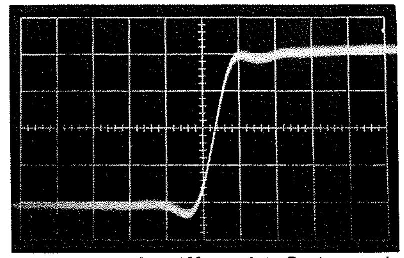


Fig 5. P6046 Differential Probe and Amplifier with Type 454 displays a 4 mV signal (5 ns/div).

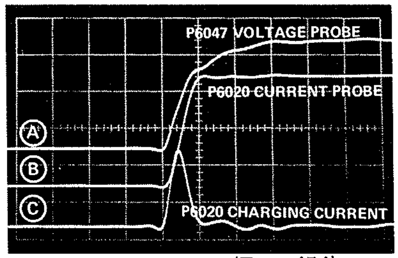


Fig 3. Test oscilloscope (Type 454).

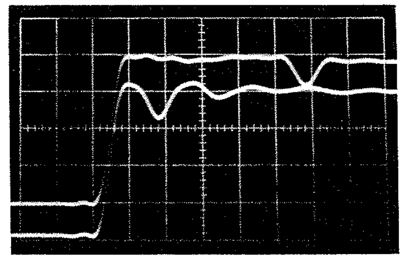


Fig 6. Inserting cable between termination and P6035 probe removes the discontinuity caused by input C from the area of interest (5 ns/div).

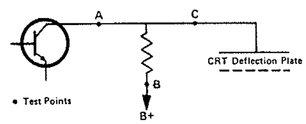


Fig 4. Measuring circuit for figs 2 and 3. Deflection plate circuitry of oscilloscope under test.

Note in fig 3 that the P6020 current waveshape Ⓑ is an accurate representation of the reference signal in fig 2 [B] and does not distort the reference signal [R]. The P6047 loads the signal severely Ⓐ and distorts the probe source as shown in fig 2 [A]. Additional information that only a current probe can display is the initial charging current necessary to charge the CRT capacitance Ⓒ.

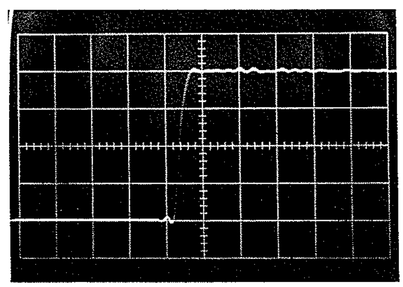


Fig 7. Response of Type 454/P6048 to fast pulse (10 ns/div).

Why are Tektronix real-time oscilloscopes 1 MΩ instead of 50 Ω?

When the Tektronix Type 454 was in the design stage, there was much consideration given to the pros and cons of a 50-Ω versus a conventional 1-MΩ system. The concensus at Tektronix was although a 50-Ω system would be easier to design (1-MΩ attenuators are more complex than 50-Ω attenuators), the customer would have to accept too many compromises for a general-purpose instrument.

Since most oscilloscopes are used as a general-purpose device, a means of increasing the input resistance of a 50-Ω system is mandatory in most measuring situations. The only paths currently available to the user is an FET probe with its inherent extra cost and dynamic range considerations or a passive probe with its relatively low increase in DC resistance.

A second limiting compromise is the limited dynamic range of a 50-Ω system. Both the power ratings of the 50-Ω co nponents and the FET probe elements, all contribute to a system less tolerant of large signal swing and high DC potentials.

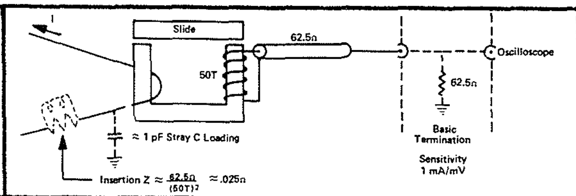
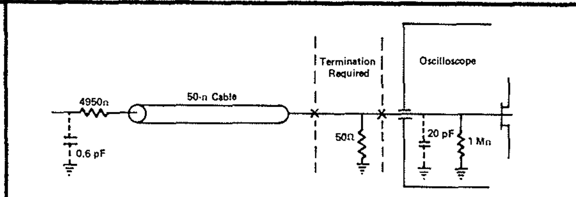
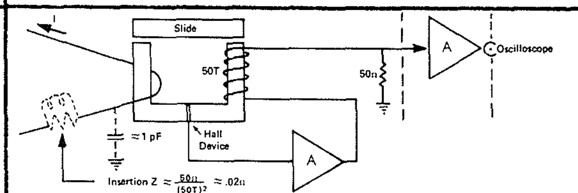
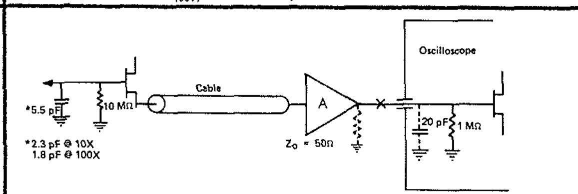
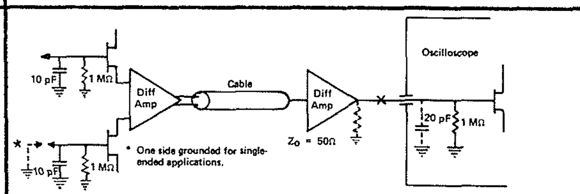
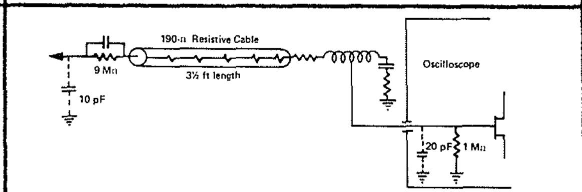
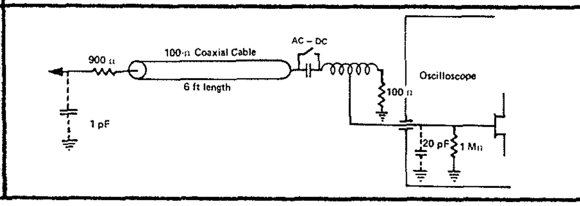
The third compromise is that existing general-purpose probes cannot be utilized. This limits the measurement spectrum severely as most of the probes discussed in this article could not be used.

The chart on page 5 illustrates the prominent features of most popular Tektronix high-performance probes. The probe impedance diagrams will assist the user in selecting the proper probe for his measurement.

Less Than One pF, No Resistive Loading

A case where a high-speed current probe is almost a necessity is where the transistor is a very low-capacitance (0.5—2 pF), high-frequency device working into a high impedance (1—5 kΩ). A transistor with a large collector load and low capacitance presents a particularly difficult measuring circuit. A low impedance passive probe should not be used because the resistive loading could shift the operating level out of range of operation, causing clipping, limiting, or other undesirable effects. Since

Know Your Probe Characteristics

P6020		Very low source loading — less than 1 pF — no resistive loading — insertion impedance of .025Ω — elevated measurements to 500V — sensitivity 1 mA/mV — risetime 1.75 ns — 935 Hz-200 MHz bandwidth.
P6035		Requires oscilloscope terminated in 50Ω — very low input capacitance (.6 pF) — 50Ω cable extends length of probe and moves reflection from input C — risetime 200 ps — DC-1.7 GHz bandwidth — valid for pulse information only.
P6042		Very low source loading — both DC and AC current measurements — sensitivity 1 mA/div — 7 ns risetime — DC-50 MHz bandwidth.
P6045		Good sensitivity (1X) — high DC resistance — low capacitance — interchangable heads: 1X 10 MΩ 5.5 pF, 10X 10 MΩ 2.3 pF, 100X 10 MΩ 1.8 pF — small size — 1.5 ns risetime — DC-230 MHz bandwidth.
P6046		Differential wideband low-level measurements — 1000: 1 CMRR at 50 MHz — 1 mV deflection factor — probe signal paths may be matched to an unusual degree — risetime 3.5 ns — DC-100 MHz bandwidth.
P6047		Fast risetime performance into low source impedance — largest dynamic signal range — rugged — low cost — high DC resistance — least susceptible to overload — small size — 1.2 ns risetime — DC-290 MHz bandwidth.
New P6048		Very low capacitance (<1 pF) — minimum phase shift with frequency — length not critical — no capacitive loading from AC coupling capacitor — small size — loads source with 1 KΩ — low cost — 2.5 ns risetime — DC-140 MHz bandwidth.

Probing Considerations

Select the lowest impedance test point which provides a useful waveform. Although the input impedance of a probe is made as high as possible, it still will always have some finite effect on the circuit under test.

Probe loading effects can be minimized by selecting low-impedance test points. Usually, cathodes, emitters and sources should be chosen in preference to plates, collectors or drains; and inputs to high impedance dividers in preference to mid-points. Circuits with low resistive peaking or compensation often produce displays which are difficult to evaluate properly in high-speed pulse work. It's often preferable to make current measurements than to attempt an accurate evaluation of inductive circuit voltage waveforms because of the effect of the probe input capacitance.

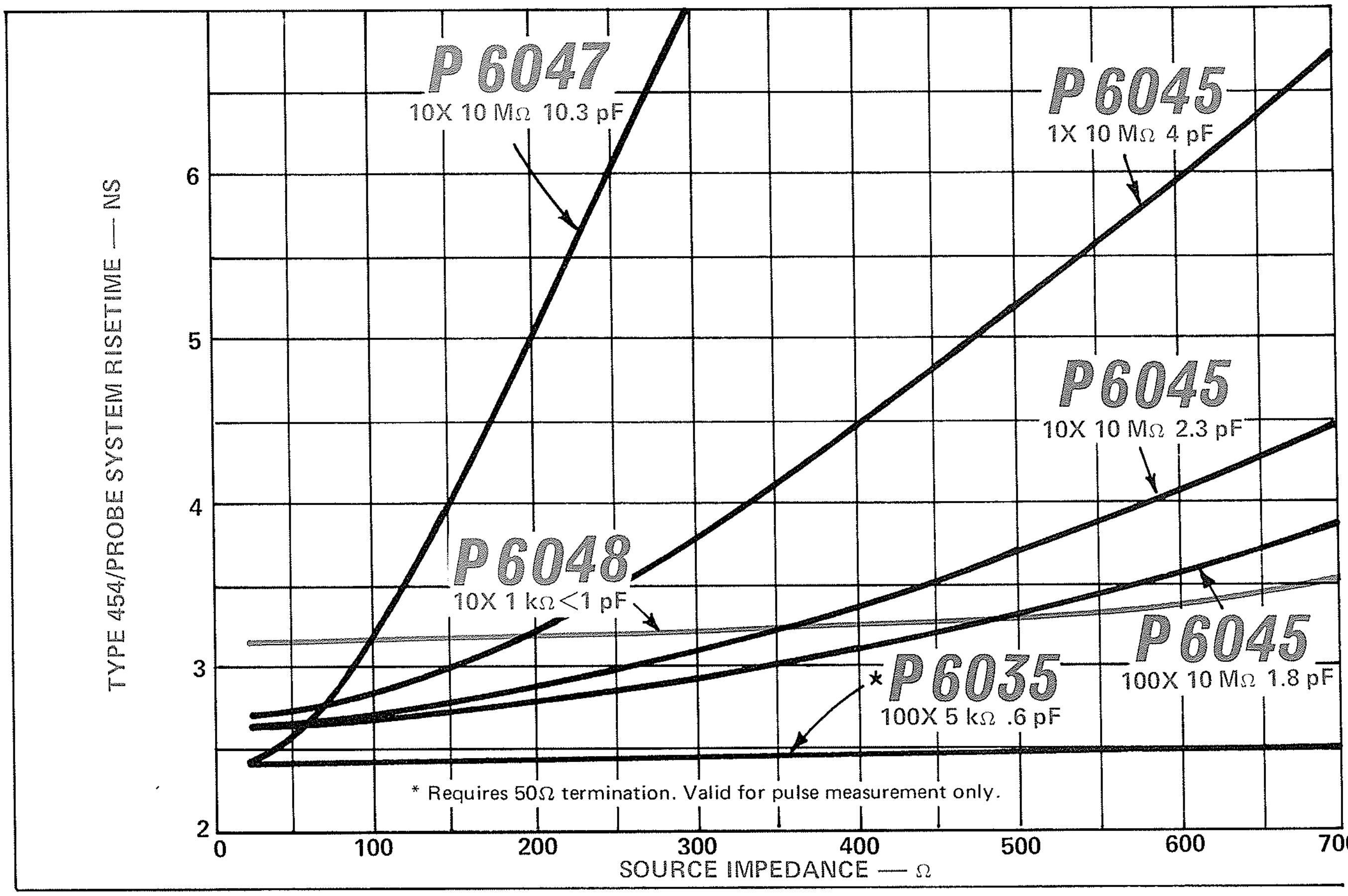
Time-delay differences must be considered, particularly in phase and time coincidence measurements, and differential applications. Low impedance probes minimize these problems and high-speed differential probes are capable of matching probe characteristics to a high degree

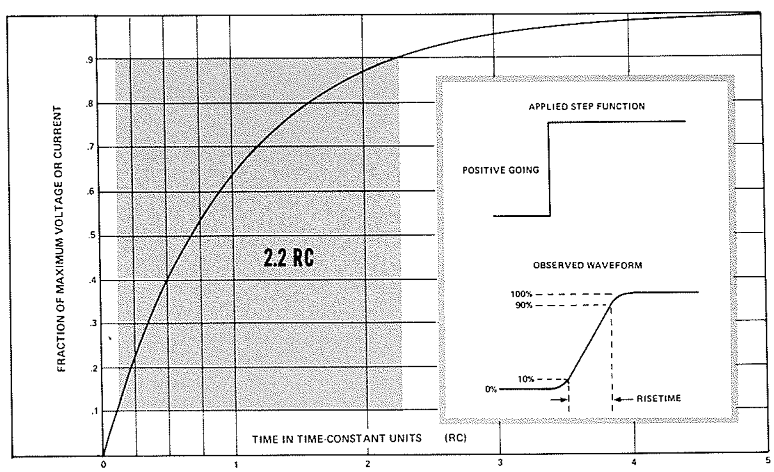
When using low impedance probes keep in mind the resistive loading of the probe. For example, if observing the 1 volt 1%, 250Ω 1% calibrator output of the Type 454 with the 1 kΩ P6048, correct calibration is indicated by a CRT display of 0.8 volts.

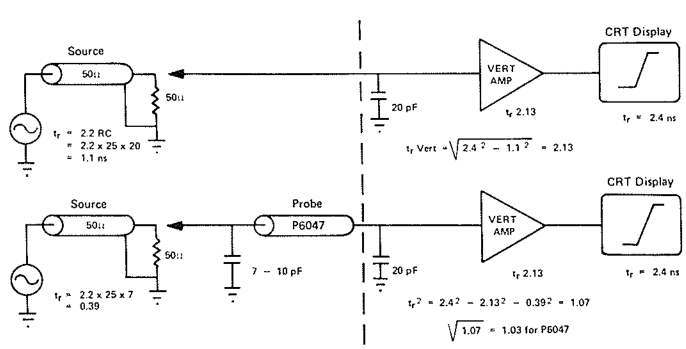
Grounding practices should always be kept in mind, particularly in high impedance probe applications. Using as short as ground path as possible (preferably coaxial adaptor or short bayonet connector) will minimize the effect of series inductance to the probe input.

And, of course, in all probes that have variable compensation adjustments, check your compensation!

Know Your Source Characteristics







Risetime is the time required for a transition from one level to another. For a more useful concept it is defined as the amount of time from 10% to 90% of the two levels. As circuit and pulse speeds increase, the physical limitation at which the risetime can change becomes significant. (It takes a finite amount of time for current to charge the capacitance in order for the change to take place.)

The diagram on the left illustrates the concept of risetime as it is applied to a universal RC curve. Note it is 2.2 RC time constants from 10% to 90% on the RC curve. Thus a fundamental limitation in the formulation of risetime is it cannot be faster than 2.2 RC.

An example of the physical limitations that 2.2 RC can have on a circuit is the risetime of the Type 454. The risetime of the Type 454 without a probe is 2.4 ns. Because the risetime of the Type 454 with the P6047 probe is also 2.4 ns, the P6047 would appear to be a 0 risetime probe. The diagrams illustrate why the 1.2-ns P6047 has this effect on the Type 454. (Although the computed risetime of the P6047 is 1.03 ns, the specified risetime is 1.2 ns).

It is necessary to find t_r vert since 2.2 RC of the source is a significant portion of the display risetime.

$$t_r\text{ display} = \sqrt{t_r\text{ vert}^2 + t_r\text{ probe}^2 + t_r\text{ source}^2}$$

$$t_r\text{ vert} = \sqrt{t_r\text{ display}^2 - t_r\text{ probe}^2 - t_r\text{ source}^2}$$

Once t_r vert is obtained, t_r probe may be found as shown below.

$$t_r\text{ probe} = \sqrt{t_r\text{ display}^2 - t_r\text{ vert}^2 - t_r\text{ source}^2}$$

Note, decreasing the amount of capacitance the source must charge from 20 pF to 7 pF decreases the source risetime limitation by a factor of ≅ 3 (1.1 ns to 0.39 ns). This then allows the addition of an extra element (the probe) with no decrease in observed risetime.

it is a very low-capacitance device, even the 2.3 pF of the FET probe is more than the circuit can stand.

Here a high-frequency clip-on current probe such as the P6020 is an excellent way to make the measurement. This current probe adds approximately one pF (approximately the same capacitance as the 1-kΩ probe), but there is no resistive component and the very low insertion impedance does not disturb the circuit. Further, the probe can be connected to the ground or B+ side of the load resistor, thus isolating the capacitance effect almost completely. Figs 2 and 3 show the P6020 current probe connected in this manner.

The reflection impedance of the P6020 current probe is negligible unless inserted in a low-impedance circuit (below $\approx$ 5 Ω) or using several turns through the slot. (Additional turns are sometimes used to increase the probe sensitivity, but since the inductance varies as the square of the turns, insertion impedance quickly becomes significant.) In the case presented above, where the impedance is 5 kΩ, if you know the collector impedance, you can obtain all the information by current measurement that a voltage probe can obtain. This method almost completely eliminates probe loading as an error factor.

Source Impedance and Risetime

The chart on page 6 clearly shows the effect of source impedance on the oscilloscope display. The P6047 is the high-speed miniature probe that is included with the Type 454 oscilloscope. This particular probe is the passive 10X high impedance probe evolved to the highest state at Tektronix. Note that of all the probes on the chart, the P6047 has the fastest risetime which is 2.4-ns (including the Type 454) at 25-Ω source impedance. A 10 MΩ, 10 pF characteristic (7 pF at 100 MHz) makes it an excellent choice for 2 areas of application. The 10 MΩ resistive component minimizes DC loading and its high speed termination provides a 2.4-ns display when used with a low impedance source (50 Ω). This probe is particularly well-suited for high amplitude signals and is rated at 600 V. It is an excellent choice for a general-purpose probe.

The next curve shows the P6045 field effect probe with 1X attenuation. Its impedance characteristics are 10-MΩ input resistance with 5.5 pF input capacitance. The slope of this curve is flattened out indicating that it is more useful as source impedance increases. This probe is a unity-gain probe which allows a 10× increase in sensitivity (compared to a conventional 10X probe) with less capacitance. A design choice is available, when designing an FET probe, of low noise vs low capacitance. The designer can place an attenuator (usually 3-5X) in front of the FET and sacrifice noise performance for lower input capacitance. The P6045 does not make use of an attenuator in front of the field-effect transistor in the probe and thus excellent noise performance (<1.5 mV at 230 MHz) results. This compromise, while it results in additional tip capacitance, increases the versatility of the probe. Low capacitance performance is still available by using a 10X or 100X attenuator.

The next curve on the chart is the P6045 with its 10X attenuator offering an impedance combination of 10 MΩ and 2.3 pF. Note this curve is appreciably faster than the P6045 1X curve, keeping 3½-ns performance well out into 450-Ω source impedance. Here the usual 10X attenuation factor is present, but the capacitance is reduced to a value of 2.3 pF.

The P6045 with the 100X attenuator presents a 10 MΩ, 1.8 pF impedance to the circuit under test. Note the difference that only 0.5 pF can make in this area of measurement by comparing it to the 10X curve. We now obtain 3.5-ns operation out to nearly 600-Ω source impedance. Also, the curve is now becoming less and less reactive as indicated by the nearly straight line.

The blue line on the chart indicates the recently introduced P6048 passive low-impedance probe. This probe presents the source with 1 kΩ and less than 1 pF input capacitance. This curve is quite flat with increasing source impedance, and is very useful in high-speed circuitry where low source impedance is commonly used.

The P6035 100X probe with 50-Ω termination presents the flattest response of all. This curve is marked with an asterisk since it requires a 50-Ω termination on the front of the oscilloscope. There will be reflections due to the 20 pF input capacitance when used with a fast source, but this is still a very useful means of observing fast pulses. The reflections may be moved away from the point of interest by using additional high quality 50-Ω cable as shown on page 4.

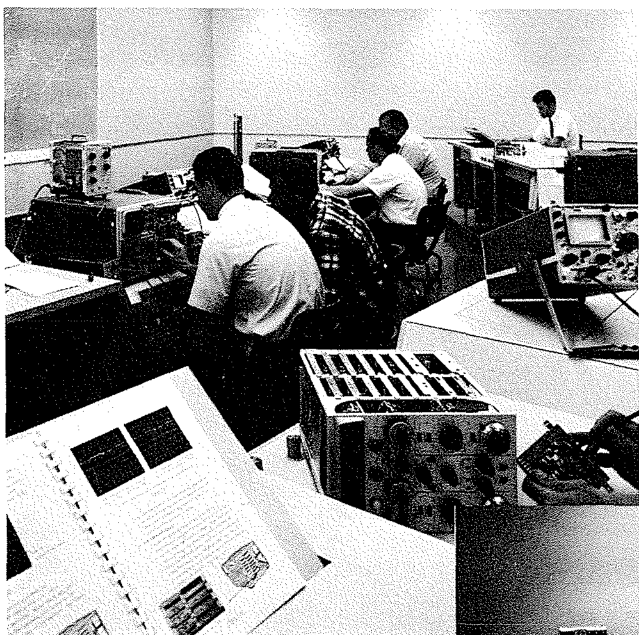
Summary

No single probe discussed in this article is the best for all applications, but all of the probes discussed are good for specific applications. In addition, Tektronix is continually striving to develop additional probe capability to make existing instruments more versatile. It is still necessary, however, for the user to determine the characteristics of his measuring circuit as closely as possible. He may then select from the various probes available to obtain the minimum circuit loading for his measurement.

Customer Training at Tektronix

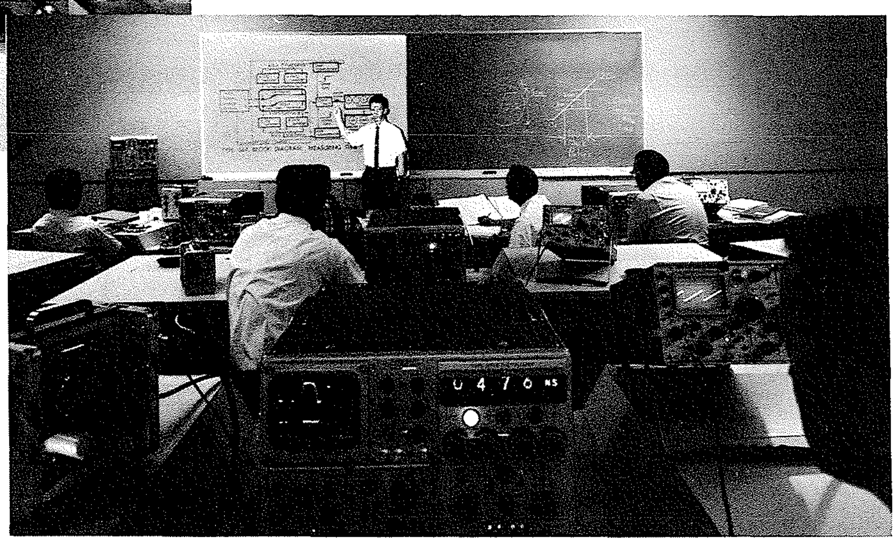
Tektronix field engineers spend a large amount of their time at customer locations teaching the proper operation and maintenance of Tektronix products. In addition, Tektronix field engineers provide local training at the field office to accommodate customers with common requirements. Oftentimes, however, there is a need for in-depth training that cannot be fully accomplished locally. To meet these needs, Tektronix has established a program of factory training which is an extension of Tektronix field engineering services. Customers who participate in this program attend classes at the Tektronix customer training center located in Tektronix Industrial Park in Beaverton, Oregon.

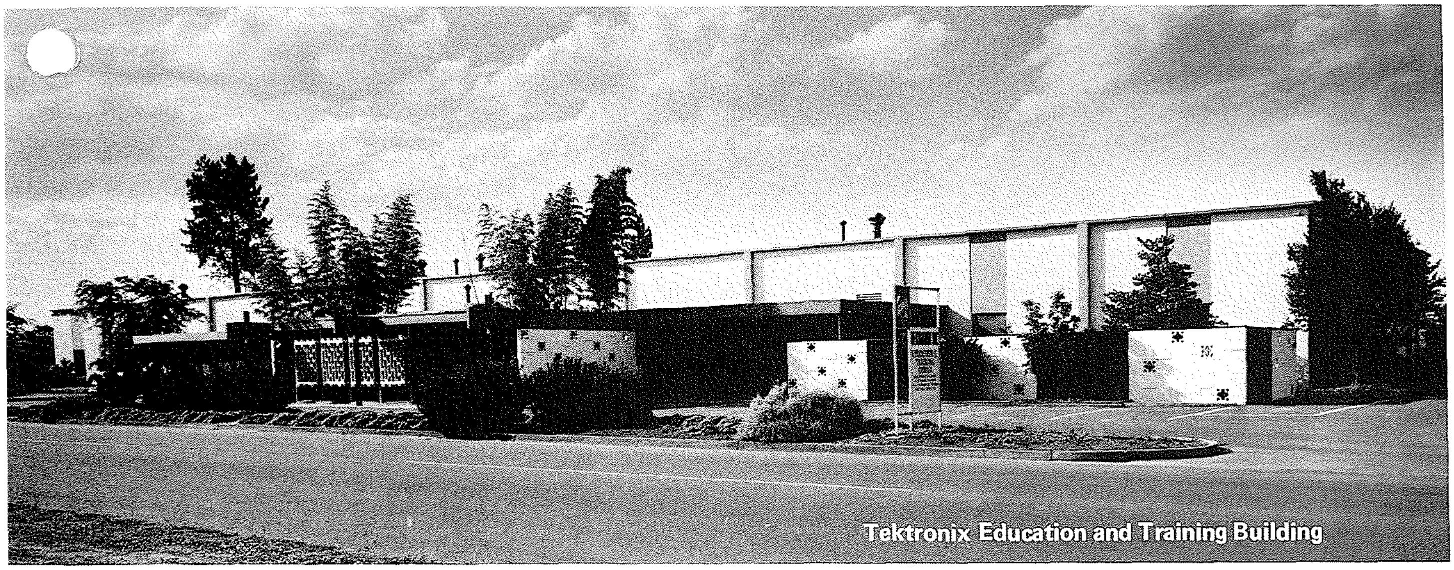
The diverse courses offered vary from 2-4 weeks in length. Where possible, the courses are arranged so the customer may attend 2 or even 3 different consecutive seminars.



Training at Tektronix has always had emphasis placed on the service aspect of Tektronix equipment and, therefore, circuit theory is an important portion of the curriculum. The emphasis on Tektronix training is circuit knowledge and each circuit is described and discussed thoroughly with particular attention on how the various adjustments affect circuit operation. The objective is to familiarize the customer with all the checks, measurements and adjustments necessary for a given instrument. Each phase of each course ends with a theoretical trouble-shooting period, where a group discussion is held to discuss the various problems that specific faulty components could create.

All Tektronix customer courses make extensive use of instruments. The laboratory and classroom are brought closer together with the new Tektronix-designed classrooms shown in fig 1. This unique classroom design allows the student to have a test scope, a scope under test,





and signal generating equipment, all in a classroom environment. The instructor can present theory, instrument demonstration, instrument calibration, movies, slides, etc. without changing rooms. An added benefit is, while the theory of a particular point is being made, the practical considerations may be monitored, since the scope is also present.

The first thing that the student is exposed to in the training is a detailed operator course in which particular emphasis is placed on the function of the knob. Which circuit is the variable in? What does the knob control, and how? Tektronix, throughout the curriculum, relates theory to practical considerations. Thus, when the student encounters problems in his own facility, he has a broad background from which to draw conclusions. The intent of Tektronix customer training is to have the customer trainee proficient enough to train other employees when he returns to his facility.

A staff of 6 full-time instructors ensures thorough coverage with a maximum of individual attention. Films are included in the curriculum and customers are exposed to important topics such as CRT handling, sampling, squarewaves and transmission lines. Tests are held periodically allowing the student to keep aware of his progress.

Informal "buzz" sessions are held where appropriate. For example, if the students are having the sweep circuit presented to them, the instructor might ask that all the students form into groups of two. One student then proceeds to explain the circuit under discussion to the other. If at any time he runs into any difficulty, an instructor explains the problem and he continues. This active participation in circuit analysis does a great deal toward giving the student confidence and retaining the new information.

One of the greatest potential benefits of Tektronix factory training is that it enables the trainees, upon returning from Tektronix, to instruct others in oscilloscope theory. As a result, customers who have technical training programs in their own company or are anticipating need for them in the future, often send an engineer, instructor, or maintenance training specialist to receive this training.

When a customer student successfully completes all the material and passes the final exam, he receives a certificate of completion. This certificate lists all the Tektronix products in which the student is proficient.

There is no cost for Tektronix factory training courses and course materials. The cost of transportation, lodging and meals is the customer's responsibility. Students are usually lodged in downtown Portland where numerous accommodations are available. This central location also provides excellent facilities for the students' after-class recreation. In addition, Tektronix provides a shuttle service between downtown hotels and Tektronix Industrial Park.

To qualify for this program the trainee should have adequate background as indicated below:

1. Knowledge of electronic fundamentals.
2. Experience in calibration of high quality laboratory test equipment (previous contact with Tektronix instruments is recommended).
3. Minimum score of 70% in Tektronix entrance exam.

If you are interested in the Tektronix factory training program, contact your local field engineer for course availability and assistance with lodging. The class schedule for the remainder of 1968 is shown on page 10.

TYPICAL COURSE OUTLINE

TOPIC	OBJECTIVES
Pulse System Technology	Concepts fundamental to oscilloscope technology: pulse circuit theory, RC curves, compensated dividers, risetime vs bandwidth, etc.
Semiconductor Circuit Review	Semiconductor theory of circuits extensively used in oscilloscope systems: differential amplifiers, paraphase amplifiers, emitter followers, etc.
Operators Course	Familiarize the student with instrument capabilities in sufficient detail to instruct others.
Power Supplies	Theory of power supply operation: high and low voltage supplies, regulators, accuracies, tolerances, etc.
Cathode Ray Tubes	Understand the contribution of the CRT: mechanical considerations, unblanking circuitry, etc.
Sweep Circuits	Relate timing accuracy to linear operation of horizontal sweep system: understand Miller Integrator, delaying sweep theory, etc.
Horizontal Amplifiers	Understand contribution of horizontal system to accuracy: X-Y applications.
V Amplifier and Delay Lines	Understand fundamental relationships of sensitivity, stability, bandpass/risetime, circuit theory, etc.
Plug-In Preamplifiers	Acquaint the student with most popular plug-in units, practical explanations of calibration and adjustment checks.
Calibration Instrumentation	Acquaint the student with a variety of special Tektronix instruments used in calibrating instruments: maintenance and trouble-shooting practices.
Laboratory Assignments	Provide the student with working acquaintance of all instruments concerned: discussion of proper adjustment and calibration practices.

CUSTOMER FACTORY TRAINING SCHEDULE 1968

JUL

530/540/580
1A1/82
July 29 — August 16

AUG

Spectrum Analyzer
1L20/1L30/491
August 12 — 30

LABOR DAY — SEPTEMBER 2

SEP

530/540/580
1A1/82
September 9 — 27

454/453/422
Sept 30 — Oct 18

OCT

530/540/550
1A1
October 7 — 25

544/546/547
556/1A1
Oct 14 — Nov 1

Sampling
+
Digital
Oct 28 — Nov 22

NOV

Spectrum Analyzer
1L20/1L30/491
November 4 —22

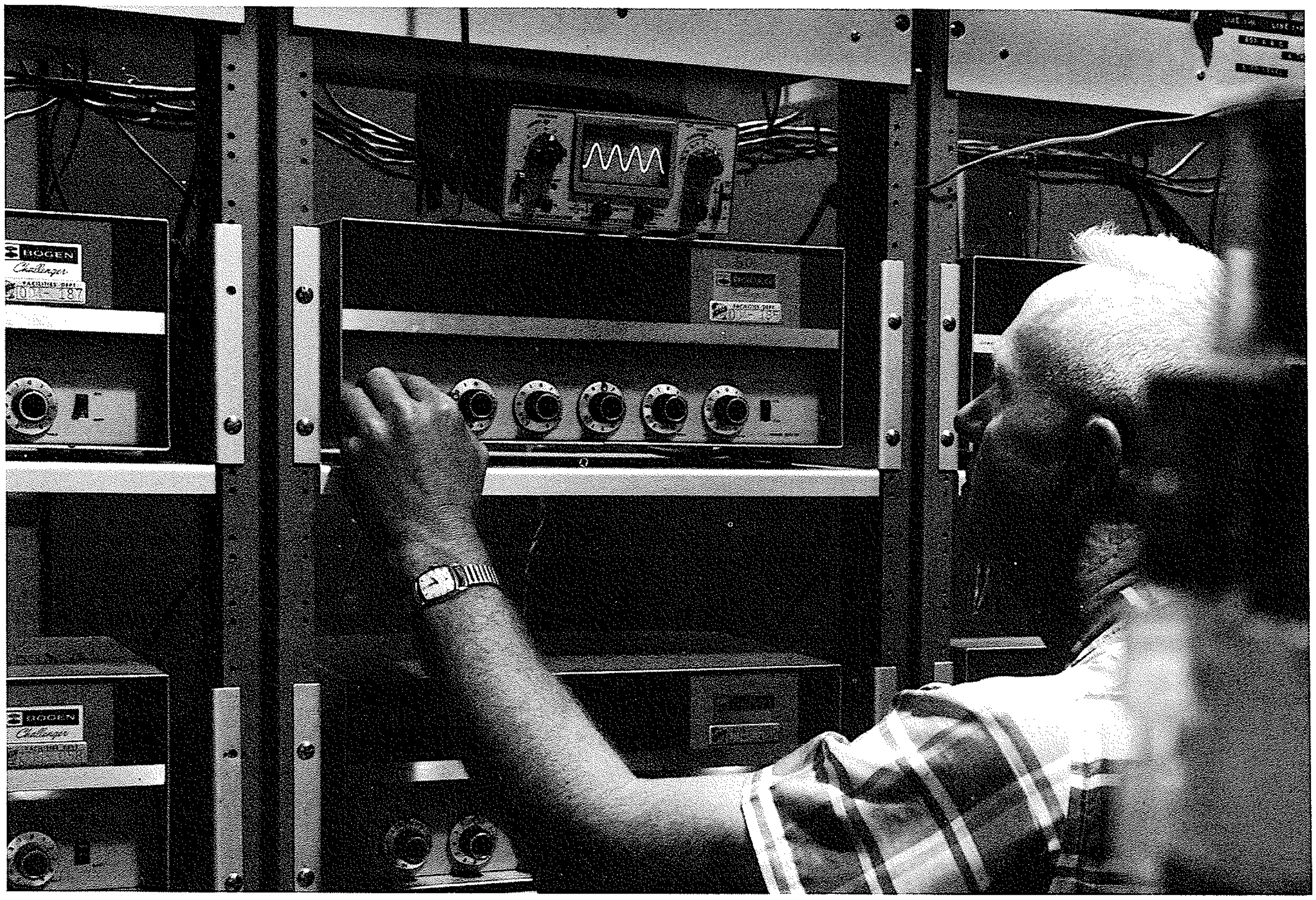
THANKSGIVING — NOVEMBER 28

DEC

530/540/580
1A1/82
December 2 — 20

568/R230
December 2 —13

CHRISTMAS HOLIDAYS



Frank Williams, Tektronix technician, checks an in-plant paging system with the Type 323.

Portable Precision-Redefined

Nearly 20 years have passed since Tektronix introduced the Type 512 DC—2 MHz oscilloscope. At the time it was introduced, in May of 1949, it was advertised as a portable precision laboratory oscilloscope. Its triggered calibrated sweeps and high-gain DC-coupled vertical amplifier (it was the first DC-coupled Tektronix oscilloscope) made it an immediate success and created new standards for oscilloscope performance.

The SONY®/TEKTRONIX® Type 323 makes an interesting contrast to the Type 512, since the electrical characteristics are somewhat similar. Although most Type 512's have long since been retired and replaced with newer Tektronix oscilloscopes, many remain in active use. A closer look at the two instruments shows very clearly the trends and progress of the electronics industry over the past 19 years.

Semiconductors have made possible tremendous savings in weight, power, dissipation, size and reliability. The 7-pound weight of the Type 323 compared with the 53 pounds of the Type 512 is dramatic evidence of this trend. Equally as impressive is the 280 watts of the Type 512 contrasted with the typical 1.6 watts of the Type 323. The overall instrument size has decreased from 4160 cubic inches to 320 cubic inches. In addition, the Type 323 is much more reliable since it is solid-state with the exception of the cathode-ray tube. The chart on page 13 shows other interesting contrasts.

Human engineering was one of the design goals that the Type 323 meets nicely. The Type 323 has only 7 front panel controls. The focus and intensity are located on top of the front panel since they are not used often. This simplifies front panel layout and minimizes accidental moving of controls.

The SONY/TEKTRONIX Type 323 contains the same high quality components and workmanship as Tektronix oscilloscopes and complements the product line nicely. Because the instrument is being marketed by Tektronix (outside of Japan and parts of Asia), it is necessary that the same support exists to ensure that Tektronix can meet the after-sale service commitment. As a result, the instrument manual, spare parts support, etc., are consistent with normal Tektronix practices. The instrument uses plug-in transistors which allow easier and quicker maintenance. In addition, consideration has been given for easy access to circuit boards.

The Type 323 may be powered AC, DC or from its self-contained battery pack. The battery charge rate (full charge or trickle charge) is selectable from the rear panel. The battery pack and charger circuitry may be removed as a unit and operated independently of the instrument. This allows the Type 323 to be powered by a second battery pack while the first is being charged. In cases where the Type 323 is operating from an AC line the battery may be charged at full rate (16 hours) even while the instrument is operating. The 16-hour charge rate ensures that the instrument may be used a full 8-hour day—yet it will be completely charged the next morning.

The Type 323 has a 3-inch CRT that uses a very low-power direct-heated cathode developed by SONY for its 4-inch television sets. The power required is 180 mW and this design contributes to the 2-second warm-up time of the Type 323.

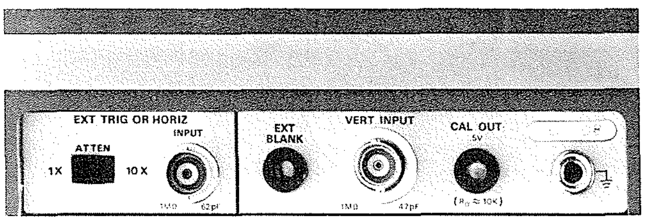


Fig 1. Input and output connections are provided on the left side panel freeing important front panel space for operating controls.

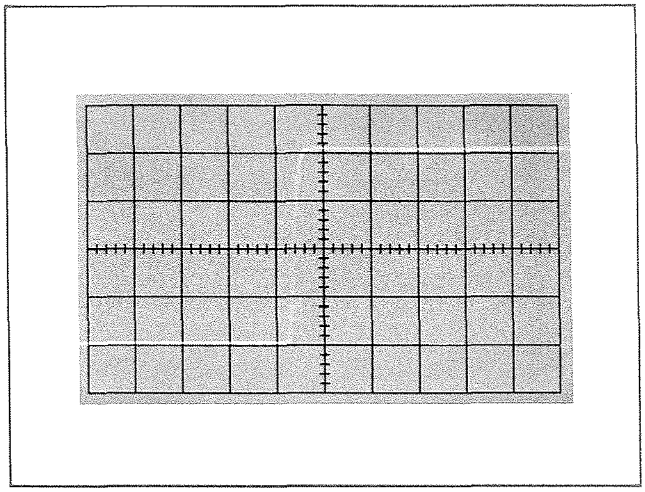


Fig 2. Response of the Type 323 to a fast-rise signal (.5 us/div).

Typical of some of the unique power-saving circuits is the vertical amplifier output stage. A power-saving circuit biases the Type 323 output amplifier at low current and senses signal frequency. When high frequency signals are present, the sensing circuit increases bias so sufficient current is available to charge and discharge the CRT capacitance. In addition, complementary connection of the output transistors (NPN and PNP) minimizes heavy current flow. The output is an exact reproduction of the input, and the technique saves considerable power at high frequencies.

The Type 323 does not have an edge-lighted graticule since power drain was a first-order design consideration. The instrument requires less power, under most operating conditions, than the graticule edge-lighting circuitry used on Tektronix oscilloscopes. As a result a black, internal, non-illuminated graticule is used.

CHARACTERISTICS	TYPE 323	TYPE 512
Weight	Less than 7 pounds	53 pounds
Power	1.6 Watts (typical)	280 Watts
Size (inches)	4-1/4" x 7-1/4" x 10-5/8"	16" x 13" x 22-7/8"
Input RC	1 MΩ 47 pF	1 MΩ 45 pF
Risetime	90 ns (high gain 130 ns)	200 ns (high gain 400 ns)
Bandwidth	DC–4 MHz (high gain DC–2.75 MHz)	DC–2 MHz (high gain DC–1 MHz)
Deflection Factor	10 mV (high gain 1 mV)	150 mV (high gain 5 mV)
Time Base	5 us/div–1 s/div (17 steps)	3 us/cm–.3 s/cm (10 steps)
Magnifier	X10 (fastest sweep .5 us/div)	X5 (fastest sweep .6 us/cm)
Differential Input	No	Yes
Vacuum Tubes	1 (CRT)	44
F. P. Controls	7	22
Environmental	Yes	No
Price	$850	$950

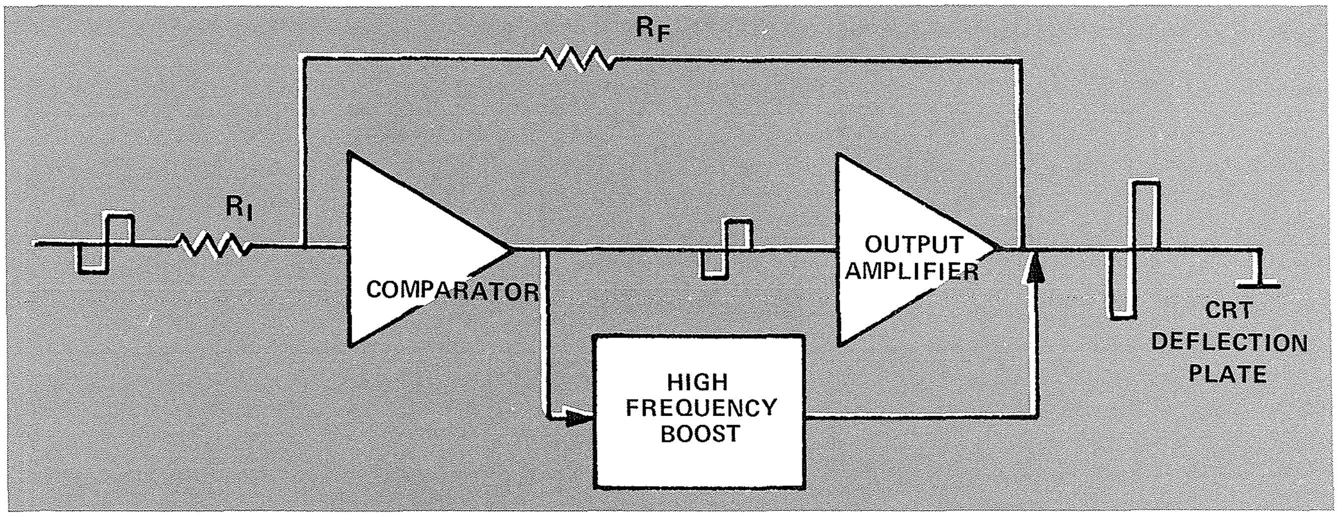


Fig 3. Type 323 vertical output amplifier diagram. The output amplifier is biased at low current to save power, so a high frequency boost circuit is used to supply the required current for high frequency operation. A feedback circuit senses the current the HF BOOST needs to supply for charging and discharging of the CRT capacitance at high frequencies. This unique circuit substantially reduces the power consumption of the Type 323.

The sweep generator provides calibrated ranges from 1 s/div to 0.5 μs/div (with an X10 magnifier). A new automatic trigger circuit is employed that minimizes front-panel space, yet provides versatile trigger operation.

The 4-MHz performance at 10 mV/div deflection factor (2.75 MHz at 1 mV/div) makes the instrument an ideal choice as a field maintenance tool. Its 11 by 8 by 4-inch dimensions and 7-lb weight enable it to go nearly anywhere. The Type 323 is designed to withstand shock, vibration, and wide variations in temperature, altitude, and humidity since SONY/TEKTRONIX engineers realize portable oscilloscopes often encounter adverse environments.

The price of the SONY/TEKTRONIX Type 323 including a P6049 10X attenuator probe with accessories is $850. Further details are included on pages 1-3 in the New Product Supplement to Tektronix Catalog 27 (1968).

SONY® TEKTRONIX®

Sony/Tektronix, a jointly-owned Japanese subsidiary located in Tokyo, Japan, was formed in November of 1964. The rapid growth of the Japanese electronics industry in the early 60's resulted in licensing discussions with several Japanese firms. The result of these discussions led to the formation of a 50-50 joint venture with SONY. Both SONY and Tektronix have cross-licensing arrangements with Sony/Tektronix.

Sony/Tektronix has responsibility for marketing of Tektronix and SONY/TEKTRONIX products in Japan and parts of Asia. The marketing of SONY/TEKTRONIX products in the U.S. and remainder of the world is handled by Tektronix, its marketing subsidiaries, and distributors.

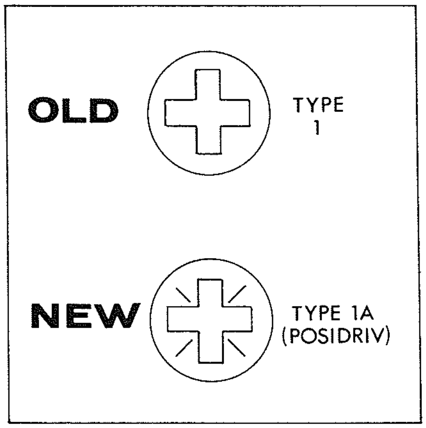
Sony/Tektronix is currently manufacturing several types of Tektronix instruments. These instruments maintain the same high Tektronix quality that is built into Tektronix domestic instruments, but are built exclusively for the Japanese market.

Sony/Tektronix was created with an engineering capability to develop new instruments. This use of the two companies' engineering talent will allow products to be developed that Tektronix or SONY would not develop alone. The Type 323 is the first instrument to be developed by Sony/Tektronix.

Service Notes

Phillips-head screws come with two kinds of slots these days, and the casual observer might never notice it! The newer type slot can be identified by four little lines on the head of each screw, located at the inside corners of the cross. See diagram at right.

The new slots permit screws to be installed with less likelihood of the screwdriver slipping in the slots (camming out) if driven with a new type Phillips screwdriver. The name for the new slot and the new screwdriver is POZIDRIV, a Phillips registered trade name.



Old Phillips screwdrivers will work in the new slots but are more apt to slip. Phillips screwdrivers having the POZIDRIV tip will not fit in the old slots unless they are the wrong (smaller) size. Because screws may be tightened harder using the POZIDRIV slot and POZIDRIV screwdrivers, they may be particularly difficult to remove without the proper tip.

The way to distinguish between an old screwdriver tip and the POZIDRIV bits is that the letters PZD appear on the POZIDRIV bits.

Transistor Troubleshooting Hints

Transistor defects usually take the form of the transistor opening, shorting or developing excessive leakage. The best means of checking a transistor for these and other defects is by using a transistor curve display instrument such as a Tektronix Type 575. If a transistor checker is not readily available, a defective transistor can be found by signal tracing, by making in-circuit voltage checks, by measuring the transistor resistances, or by substituting a known good component.

When troubleshooting with a voltmeter, measure the emitter-to-base and emitter-to-collector voltages to determine whether the voltages are consistent with normal circuit voltages. Voltages across a transistor vary with the type of device and its circuit function, but some of these voltages are predictable. The base-emitter voltage of a conducting germanium transistor is about 0.2 V and that of a silicon transistor is about 0.6 V. The collector-emitter voltage of a saturated transistor is normally 0.2 V. Because these values are small, the best way to check them is by connecting the voltmeter across the junction and using a sensitive voltmeter setting.

If values less than these are obtained, either the device is shorted or no current is flowing in the circuit. If values are in excess of the base-emitter values given, the junction is back-biased or the device is defective (open).

Values in excess of those given for emitter-collector indicate either a non-saturated device operating normally, or a defective (open) transistor. If the device is conducting voltage will be developed across resistances in series with it. If it is open, no voltage will be developed in resistances in series with it (unless current is being supplied by a parallel path).

An ohmmeter can be effectively used to check a transistor if the ohmmeter's voltage source and current are kept within safe limits. 1½ V and 2 mA are generally acceptable. Selecting the 1-k scale on most ohmmeters will automatically provide voltage and current below these values.

If the voltage and maximum output of a specific ohmmeter is in doubt, it should be checked by connecting the test leads to another multimeter before using it.

The table contains the normal values of resistance to expect when making an ohmmeter check of an otherwise unconnected transistor.

Transistor Resistance Checks

Ohmmeter Connections[1]	Resistance reading that can be expected using the R x 1 kΩ range
Emitter-Collector	High readings both ways (100 kΩ to 500 kΩ, approx).
Emitter-Base	High reading one way (200 kΩ or more). Low reading the other way (400 Ω to 3.5 kΩ, approx).
Base-Collector	High reading one way (200 kΩ or more). Low reading the other way (400 kΩ to 3.5 kΩ, approx).

[1]Test leads from the ohmmeter are first connected to the transistor and then the connections are reversed. Thus, the effects of the polarity reversal of the voltage applied from the ohmmeter to the transistor can be observed.

USED INSTRUMENTS FOR SALE

1—Type 1A2, SN 001328. Contact: Marion Paul, WFIE-TV, 1115 Mt. Auburn Road, Evansville, Indiana 47712. Telephone: (812) 425-6201.

1—Type 516, SN 154. Price: $825. 1—Type 551, SN 3247. Price: $1250. Both in very good condition. Contact: Henry L. Gorgas, Exact Electronics, 455 S.E. Second Avenue, Hillsboro, Oregon 97123. Telephone: (503) 648-6661.

1—Type 513D, SN 799. In very good condition. Contact: David Felt, Electra-Design Labs, 4406 Center Street, Omaha, Nebraska 68105. Telephone: (402) 553-4218.

1—Type 524AD, SN 2078. In good condition. Contact: Sid Chodun, 19325 West Nine Mile Road, Southfield, Michigan 48075. Telephone: (313) 353-8070.

1—Type 504, SN 002221. Price: Under $100. In good condition. Contact: Dr. Boyle, Fitzgerald Mercy Hospital, Landsdowne Avenue, Darby, Pennsylvania 19023. Telephone: 586-5020, ext. 2286.

1—Type RM15, SN 002073. Price $500. In good condition. Contact: Bob Burig, 112 Hershey Drive, McKeesport, Pennsylvania 15130. Telephone: (412) 673-4845.

1—Type P Plug-In and 2—Type P6008 Probe Sets. Contact: H. R. Greenlee, 430 Island Beach Blvd., Merritt Island, Florida 32952. Telephone: (305) 853-9542.

1—Type 81 Plug-In Adapter for 580 series, SN 5795. Price: $100. Like new. Contact: Y. J. Lubkin, 84 Beacon Hill Road, Port Washington, New York 11050. Telephone: (212) 286-4400.

1—Type 547. Price: $1,593.75. 1—Type 1A1 Dual Trace Plug-In. Price: $531.25. 1—Type 535A. Price: $1,190. 1—Type CA Plug-In. Price: $233.75. 2—Type 2022 Scope-Mobile® Carts. Price: $234.50. Contact: F. H. Gable, 12808 Coit Road, Dallas, Texas, 75230. Telephone: 239-2611.

1—Type 500/53A. Price: $55.00. 1—Type CA. Price: $125. 1—Type 190B. Price: $150. 1—Type CRT 154-0265-00. Price: $35.00. Contact: Multisonics, Inc., Post Office Box 197, Alamo, California 94507. Telephone: (415) 837-5238.

1—Type 511AD. Price: $50. Contact: Albert Pratt, 114 West Lake View, Milwaukee, Wisconsin 53217.

1—Type 511AD DC-10 MHz. Complete good working order. Price: $195. Contact: Monroe McDonald, 4130 Shorecrest Drive, Dallas, Texas 75209. Telephone: (214) 352-1564.

1—Type 524AD with cart and 5-inch CRT. Price: $600. Used very little. Contact: Padway Aircraft Products, Inc., 11040 Olinda Street, Sun Valley, California. Telephone: 875-1740.

1—Type 545A, SN 27745; 1—Type L Plug-In, SN 9542; 1—Type 1S1 Plug-In, SN 175; 1—Type 1A1 Plug-In; and 2—Type P6006 Probes. Contact: Robert Green, Dielectric Products, Raymond, Maine. Telephone: (207) 655-4555.

1—Type 535A, SN 032925; 1—Type B Plug-In, SN 020369; 1—Type CA Plug-In, SN 065832; and 1—Type 500-53A Scope-Mobile® Cart. Complete package: $2,000. All in excellent condition. Contact: W. N. Rushworth, Purchasing Department, Quebec North Shore and Labrador Railway Company, Sept-Iles, Quebec.

1—Type 536, SN 001509; 1—Type T, SN 001707; 1—Type H, SN 003158; and 1—Type H, SN 002573. Complete package: $700. All in excellent condition. Contact: Mr. Gatecliff, Tecumseh Products, Inc., Research Laboratories, 3869 Research Park Drive, Ann Arbor, Michigan 48104. Telephone: (313) 665-9182.

1—Type 321A, SN 4337. In new condition. Contact: P. C. Miethke, 8910 Santa Monica Blvd., Los Angeles, California 90069.

1—Type 581A, SN 6059; and 1—Type 82, SN 12479. Contact: Carl Bashem, Allen Aircraft Radio, 2050 Touhy Avenue, Elk Grove Village, Illinois 60007. Telephone: (312) 437-9300.

1—Type 514D, SN 2689. In excellent condition with new CRT. Contact: B. G. Carl, 11128 Claire Avenue, Northridge, California 91324. Telephone: (213) 363-1216.

1—Type 502, SN 1221, and 1—Type 502, SN 00817. In good condition. Contact: William Brown, Applied Magnetics Corporation, 75 Robin Hill Road, Goleta, California 93017. Telephone: 964-4881, ext. 55.

1—Type 3S76, SN 3874. Contact: Dr. Charles Ladoulis, Harvard Medical School, 25 Shattuck Street, Boston, Massachusetts. Telephone: (617) 734-3300, ext. 342.

1—Type 561A/3S3/3T77/3A1/3B1/201-2. Contact: Al Nelson, Nelson Instruments, Inc., 1586 South Acoma Street, Denver, Colorado. Telephone: 733-0421.

1—Type C12 Camera with 564 Bezel. Contact: Mr. Class, Lutheran Deaconess Hospital, 2315 14th Avenue South, Minneapolis, Minnesota 55404. Telephone: (612) 721-2933, ext. 222.

1—Type 315D. In good condition. Contact: Bruce Blevins, 176 Barranca Road, Los Alamos, New Mexico 87544.

1—Type 561A/60/2B67. Price: $600. Excellent condition. Contact: Gene Harlen, 465 South 162nd, Seattle, Washington 98148. Telephone: 243-4573.

1—Type 1S1, SN 000643. Price: $975. New condition. Contact: Mr. Gagnon. Telephone: (415) 968-6220.

1—Type 515A, SN 1346. Contact: Michael J. Verrochi, Milton, Massachusetts. Telephone: (617) 698-5490. If no answer, contact: Margie Tanner, Tektronix, Inc., Waltham, Massachusetts. Telephone: (617) 894-4550.

1—Type 517, SN 769, with Scope-Mobile® Cart; 1—Type C. F. probe; and 1—Type B 170 attenuator. Price: $600. Contact: J. B. Taylor and Associates, 1520 Broadway, Oakland, California 94612. Telephone: (415) 832-4056.

1—Type 515A, SN 002588. All mods installed. Telephone: (213) 346-6075 after 6 p.m.

1—Type 310A, SN 21847. Price: $650. In very good condition. Contact: Frank A. Hayes, Red Hill Road, Middletown, New Jersey 07748. Telephone: (201) 671-0271.

1—Type 502, SN 6673. 2—Type P6017 probes. 1—Type P6000 Probe. 1—Type 500A Scope-Mobile Cart. Contact: Dennis Moore, 698 Don Juan Street, Apartment 5, Colorado Springs, Colorado 80908. Telephone: 473-0522.

1—Type 541, SN 6916. 1—Type 53/54C, SN 17265. 1—Type 53/54B, SN 9384. Contact: Carmine Iannucci, WNHC TV, 135 College Street, New Haven, Connecticut. Telephone: (203) 777-3611.

USED INSTRUMENTS WANTED

1—Type 515 or 516. Contact: Enzo Scarton, 133 East Avenue, East Rochester, New York 14445. Telephone: (716) 872-2000, ext. 23050.

1—Type 519. Contact: Oliver Osborne, 15315 South Broadway, Gardena, California 90247. Telephone: (213) 323-2443.

1—Type 515A. State price and condition. Contact: P. Shipp, Professional Instruments Ltd., Box 477, Mount Vernon, New York 10550.

1—Type 190, 190B or 191 Signal Generator. 190B preferred. Contact: Instrument Laboratories Corporation, 315 West Walton Place, Chicago, Illinois 60610. Telephone: (312) 642-0123.

1—Type 540 or 530 series, and 1—Type C Plug-In. Contact: H. R. Greenlee, 430 Island Beach Blvd., Merritt Island, Florida 32952.

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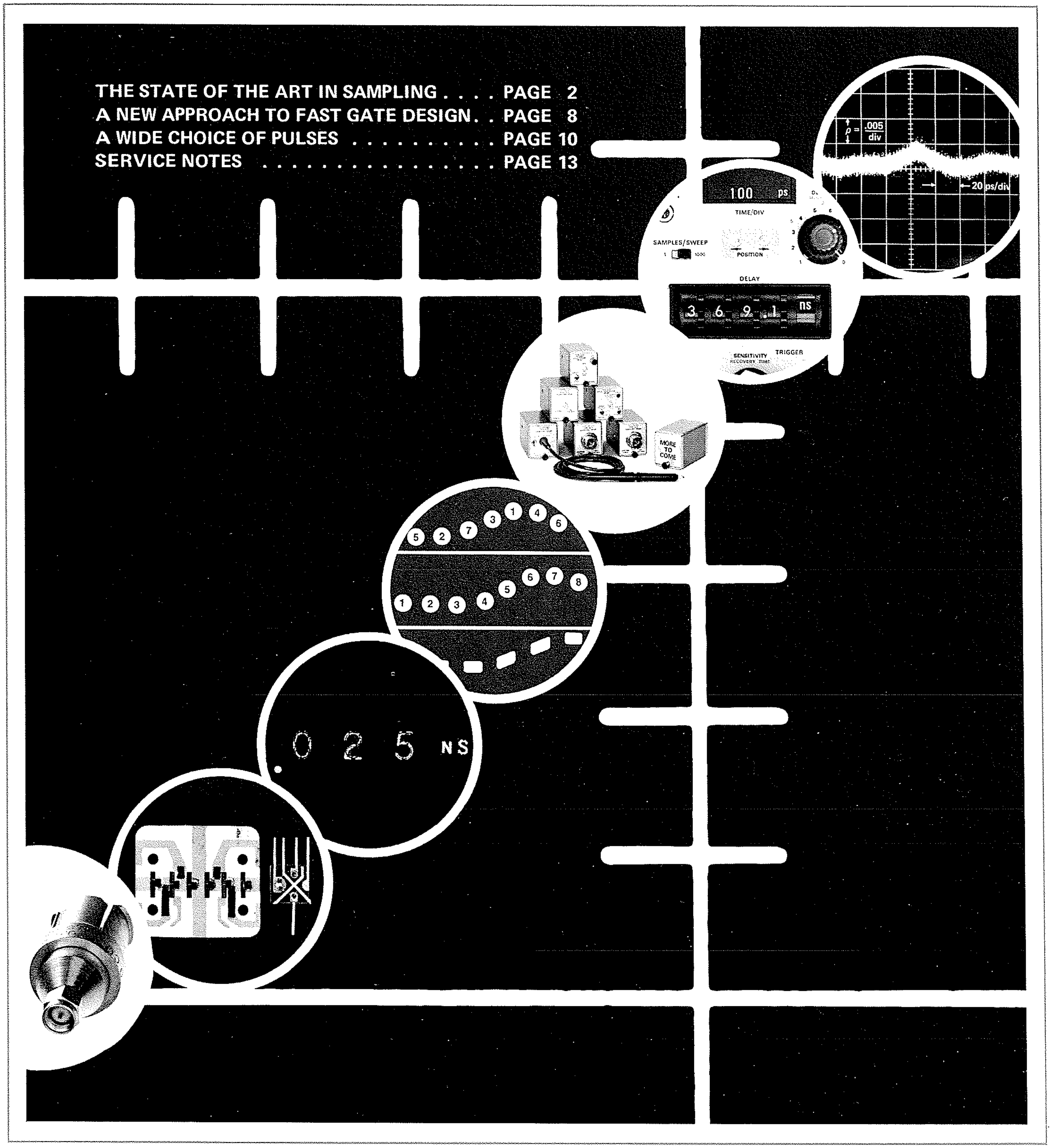
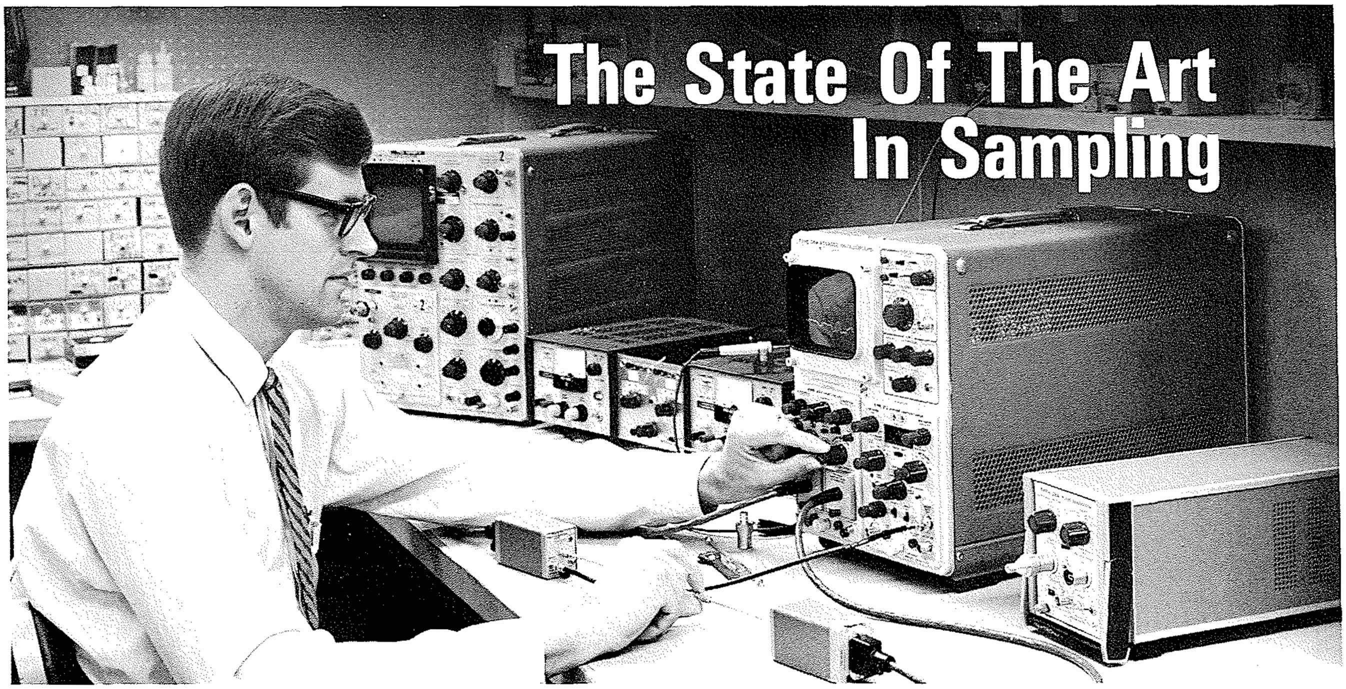


The State Of The Art In Sampling



Al Zimmerman (Sampling and Digital Instruments) checks a connector pair with a high resolution in-line TDR setup. See fig 5b on page 5 for more details.

Development of a 25-ps (14 GHz) instrument, a line of "plug-in plug-ins", and realization of much of the potential of random sampling provide a new criterion for sampling measurements. These new developments in sampling circuitry and sampling packaging have combined to offer the user more versatility than ever before.

Al Zimmerman

Program Manager,
Sampling & Digital Instruments

COVER

Seven characteristics of state-of-the-art sampling are symbolized by samples of an oscilloscope display. From lower left: 3-mm connectors; Tektronix-developed devices (S-4 chip, S-3 chip); 25-ps digital readout; 3 sampling modes (random, sequential, and real-time sampling); the current line of Tektronix sampling heads; digital delay; and 35-ps risetime TDR.

The Type 3S2 Vertical Sampling Unit was announced at IEEE '68 with two plug-in heads—the Type S-1, 350-ps Sampling Head and the Type S-2, 50-ps Sampling Head. At WESCON '68, less than 6 months later, four more heads were introduced: the Type S-3, 350-ps high-impedance Sampling Head; the Type S-4, 25-ps Sampling Head; the Type S-50, 25-ps risetime Pulse Generator Head; and the Type S-51, 1-to-18 GHz Trigger Countdown Head. The latter two special-purpose heads are not capable of producing a display since they contain no sampling gate.

Concurrent with these sampling heads, the Type 285 Power Supply was designed to power the special-purpose plug-in heads in the event both vertical channels are required. Using these components, the user has a number of ways to combine the various heads for the most versatility from his sampling oscilloscope.

A sampling oscilloscope makes use of a great deal of relatively slow-speed signal processing circuitry. The input to the signal processing circuitry is an ideal choice to apply the plug-in idea. These miniature (4½ x 1¾ x 2 inch) sampling heads contain all of the high-speed circuitry which normally make up the front end of a sampling oscilloscope. Use of plug-ins allows the sampling oscilloscope to adapt and interface with much more versatility to the numerous signal sources available.

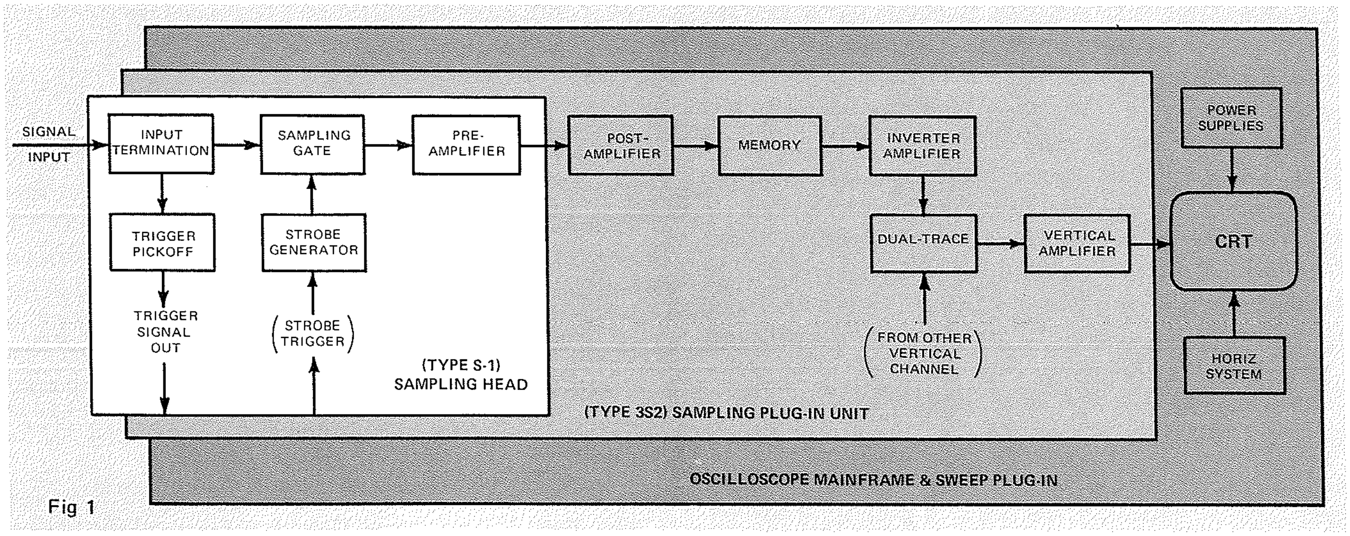
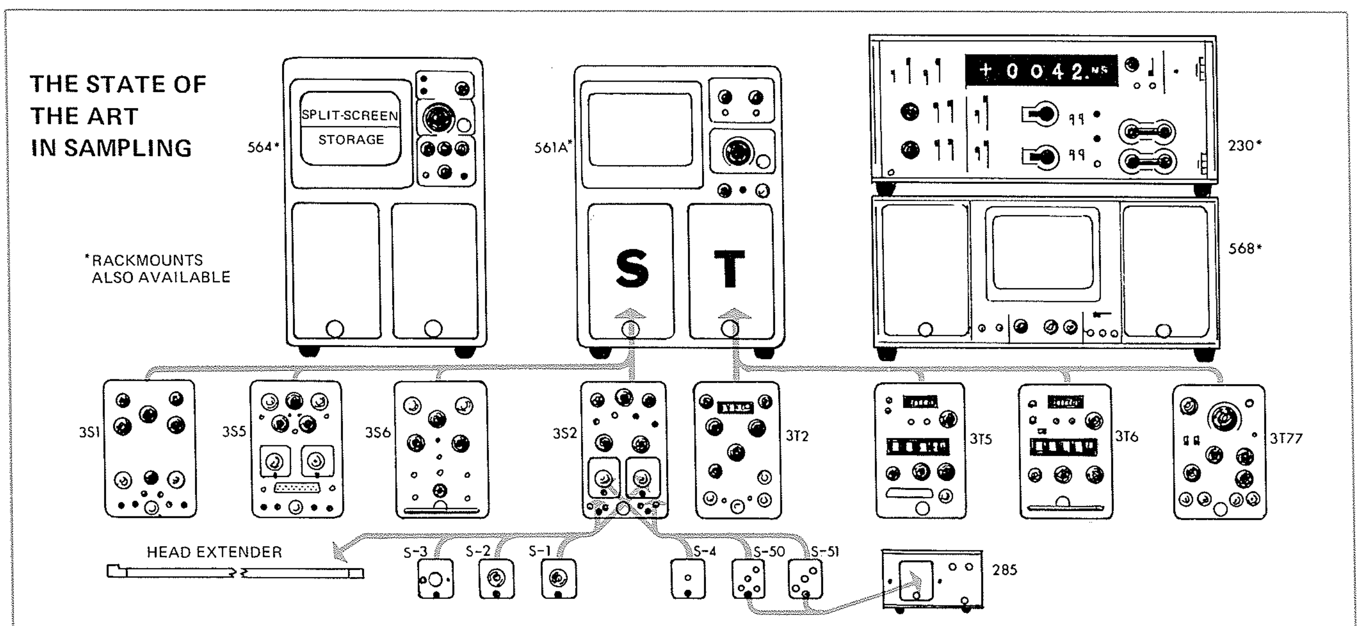


Fig 1

Prior to the sampling head development at Tektronix, a typical sampling unit occupied roughly 75% of its circuitry with the processing of slow speed signals (i.e. sampling-loop amplifiers, memories, dual-trace switching, and the main vertical). As a result, when changing from a 50-Ω general-purpose sampler to a high-impedance sampler, or to a higher speed 50-Ω sampler, nearly 75% of the sampler purchased was redundant circuitry. By creating a module which contains only those circuits which determine the input configurations, noise, sensitivity, and bandwidth of the sampler, these problems have been effectively solved with a degree of adaptability not possible before. This allows a wide range of operational characteristics by changing only the sampling head and *not* requiring the replacement of a complete plug-in vertical sampling unit.

Fig 1 shows how a typical sampling head relates functionally to the rest of the oscilloscope. The nature and extent of the circuitry contained within the sampling head depends on whether it is intended for general purpose, low noise, high speed, 50 Ω, probe type, or other applications (i.e. trigger countdown or 25-ps pulse generator).

Because an individual sampling head represents a relatively small investment, both for the user and in terms of development cost for the manufacturer, there is more incentive to design heads and pursue additional performance trade-offs. The development costs of a sampling head are appreciably less than that of a complete vertical sampling unit. As a result, performance trade-offs may be pursued that were not economically feasible prior to the development of this concept. The table on page 4 shows some of the performance characteristics for the current line of sampling heads.



Sampling heads may either be plugged directly into the larger plug-in unit or may be used remotely at the end of a 3 or 6-foot extender cable. The ability to put the sampling head right at the measurement source allows dual-trace displays of signals originating at different locations—*without* interconnecting signal cables. Cross-talk between display channels is eliminated by the shielding afforded by completely separate sampling heads. The physical independence of the two channels further permits intermixing of head types so performance and input configuration may be matched to the particular measurement requirement. There is no longer the necessity of purchasing a dual-trace sampling unit if only a single-trace display is required.

Signal losses in the cables used to interconnect a system can also be eliminated by using sampling heads on extender cables. This practice can result in significant savings in signal level at frequencies above 5 GHz. For example, both RG8A/U and RG58A/U have losses of well over 1 dB/ft at 10 GHz.

Fig 3 dramatically illustrates the loss in amplitude when a 3-ft coaxial cable transmits a 15-GHz signal. Such losses are minimized by using extender cables and physically placing the individual head adjacent to its source.

Type S-1 Clean Response/Low Noise

The Type S-1 Sampling Head offers excellent transient response, low-noise characteristics, 50-Ω input impedance, and low cost. The Type 284 Pulse Generator and the Type 3S2/S-1 provide the cleanest 350-ps response currently available. Its transient response is specified as +0.5%, −3% or less for 5 ns after transition; ±0.5% after 5 ns (with Type 284 Pulse Generator).

Type S-2 High Speed/Low Cost

The Type S-2 Sampling Head is a 50-Ω, 50-ps risetime unit with 7-GHz equivalent bandwidth. In this unit, the design compromise is faster risetime (at the expense of noise and transient response) for an "economical" price. Unsmoothed noise is 6 mV and the transient response is ±5% for the first 2.5 ns and ±2% thereafter (with Type 284 Pulse Generator).

SAMPLING HEADS

Type	Risetime	Equivalent Bandwidth	Trigger Pick-Off	Noise (Unsmoothed)	Input Z	Input Connector	Price
S-1	350 ps	1 GHz	Yes	2 mV	50Ω	GR874	$250
S-2	50 ps	7 GHz	Yes	6 mV	50Ω	GR874	$300
S-3	350 ps	1 GHz	No	3 mV	100 kΩ 2.3 pF	Probe	$375
S-4	25 ps	14 GHz	Yes	10 mV	50Ω	3 mm	$750

NON-SAMPLING HEADS

Type	Description	Output Connector	Price
S-50	25-ps risetime, tunnel-diode pulse generator	3 mm	$450
S-51	1-18 GHz trigger countdown	3 mm	$425

PLUG-IN VERTICAL UNITS

Type	Remotely Programmable	Physical Configuration	Program Connector	Adjustable Inter-channel Delay	Real Time Sampling	Price
3S1	No	Non Plug-In	None	No	Yes	$1150
3S2	No	Plug-In	None	Yes	Yes	$ 800
3S5	Yes	Plug-In	Front	Yes	Yes	$1450
3S6	Yes	Remote	Rear	Yes	Yes	$1450

PLUG-IN HORIZONTAL UNITS

Type	Type of Sampling	Sweep Delay		Remotely Programmable	Jitter	Price
3T2	Random, Sequential	Up to 5 cm on any time/div		No	30 ps	$ 990
3T5	Sequential, Real Time	999.9 ns in 100-ps increments 9.999 μs in 1-ns increments	Digital	Yes	30 ps	$1550
3T6	Sequential, Real Time	999.9 μs in 100-ns increments	Digital	Yes	30 ps	$1550
3T77A	Sequential Only	Min 100 div/variable		No	50 ps	$ 690

OSCILLOSCOPE MAIN FRAMES

Type	Storage	Digital Readout	Price
561A	No	No	$ 530
RM561A	No	No	$ 580
564	Yes	No	$ 925
RM564	Yes	No	$1025
567	No	Yes	$ 750
RM567	No	Yes	$ 850
568	No	Yes	$ 875
RM568	No	Yes	$ 925

Type S-3 High-Impedance Sampling Probe

The Type S-3 Sampling Head employs a unique design approach for an active sampling probe. A 50-kΩ resistor provides two times attenuation and is designed as an integral portion of the probe. The first stage of the sampling preamplifier (an FET stage) is physically located in the probe itself. These improvements result in a larger voltage signal from the sampler with an improved signal-to-noise ratio.

A portion of this improvement is traded off for other advantages. This approach, however, still has four major advantages. (1) More rugged mechanically. Screw-on attenuators. (2) More rugged electrically. The 50-kΩ series resistance limits the current for diode protection. 100 V DC may be applied to the probe tip. (3) Since the source impedance is isolated by the 50-kΩ resistor, varying the source impedance has much less effect on the sampling bridge than conventional sampling probe designs. (4) The built-in attenuator automatically reduces any kickout that the balanced bridge may still have.

Type S-4 25-ps State Of The Art

The Type S-4 provides state-of-the-art sampling performance with its 25-ps, 14-GHz performance. This unit introduces the first use of a 3-mm (mates with OSM®)† connector used on an oscilloscope. The Type S-4 is specified with less than 10 mV of noise (unsmoothed) and a ±10% transient response as observed with the S-50 25-ps risetime Pulse Generator. Fig. 5 illustrates the Type S-4 Sampling Head and the Type S-50 Pulse Generator Head used in a Type 3S2 for a high-resolution TDR measurement.

The user is assured of more sampling head types evolving because of the relatively low development cost associated with the head. In addition, development times are shorter since only the input characteristics are being changed. These two factors, combined with the development of new devices, offer promise of an even wider line of performance trade-offs in the future. With each advance in measurement technology, new heads can be added quickly to extend performance or convenience features. The current family of existing sampling heads is an excellent example of the speed with which these new heads may be developed.

Random Sampling Eliminates Need For Signal Delay Lines

The introduction of the 3T2 Random Sampling Sweep Unit in 1967 provided the impetus to develop the sampling head concept. Prior to this time, sampling oscilloscopes offering internal triggering used trigger pick-off circuitry and delay lines to develop the necessary pretrigger. Two compromises were involved: (1) There was always some signal degradation since the signal passed through the delay line element; and (2) input

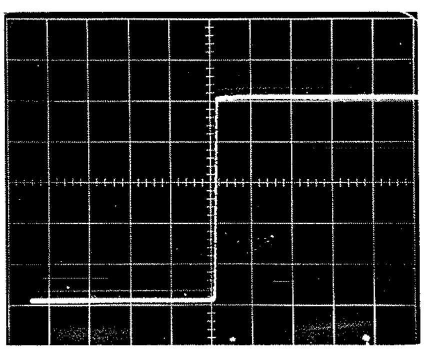


Fig 2. Transient response of Type S-1 and Type 284. Vert: 50 mV/cm. Horiz: 2 ns/cm.

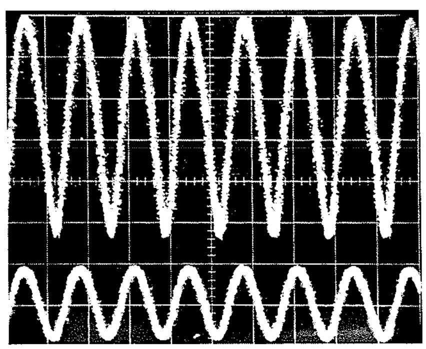


Fig 3. Signal loss due to 3-foot coaxial cable at 15 GHz. Vert: 100 mV/cm. Horiz: 50 ps/cm.

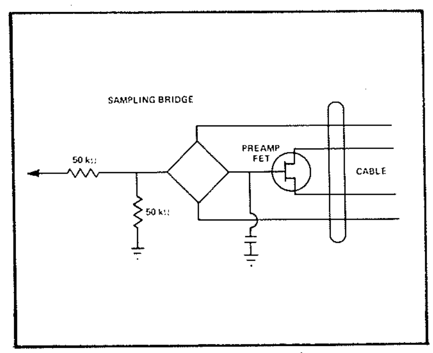


Fig 4. Type S-3 Sampling Head.

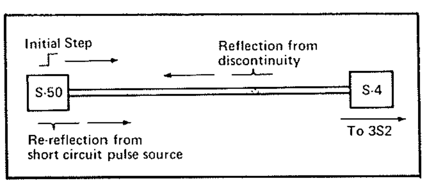


Fig 5a. In-line TDR system.

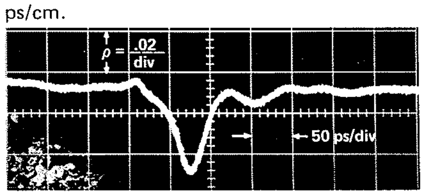


Fig 5b. Discontinuity from connector pair.

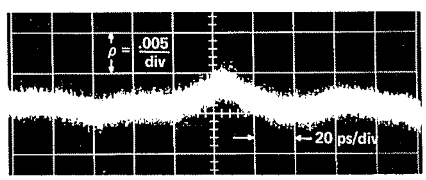


Fig 5c. Maximum amplitude resolution.

Fig 5. The in-line TDR system is particularly well-suited for studying discontinuities in short, high-quality transmission systems. The Type S-50 Pulse Generator propagates the pulse down the test line until it encounters the point discontinuity which reflects energy to the generator. The short circuit source impedance (3 Ω) of the TD generator re-reflects the energy back through the test line into the sampler for observation. Signal-to-noise considerations are optimized since the full 400 mV of the pulse is available. Fig 5c shows an observed ρ (reflection coefficient) of 0.004 which corresponds to a shunt capacitance of 0.008 pF. Fig 5d shows two discontinuities separated in time by 40 ps (80 ps displayed) or a distance of 8.4 mm in a solid Teflon* transmission line.

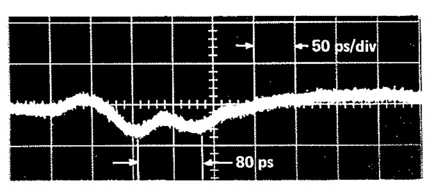


Fig 5d. 40-ps time resolution.

† Registered trademark of Omni Spectra, Inc.

* Registered trademark of DuPont

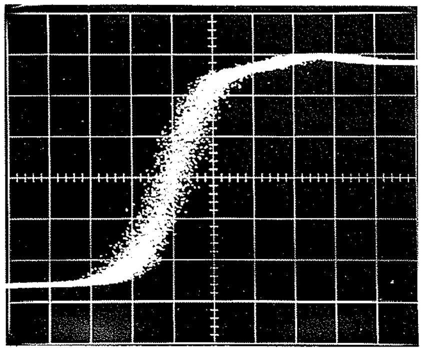


Fig 6. Type S-4 and Type S-50, 35 ps displayed risetime. Vert: 100 mV/cm. Horiz: 20 ps/cm.

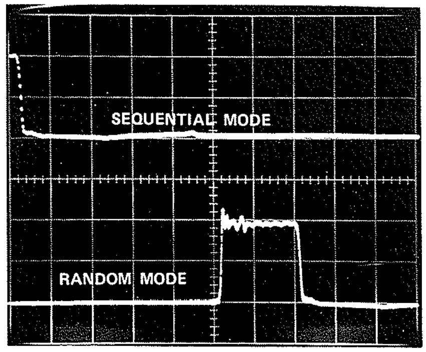


Fig 7. Multiple Exposure. The random mode allows observation of the leading edge without delay lines or pretriggers. Vert:100 mV/cm. Horiz: 10 ns/cm.

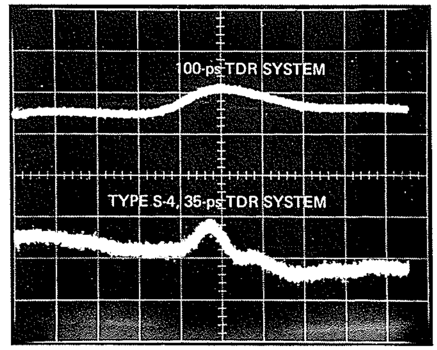


Fig 8. Multiple exposure of 100-ps and 35-ps TDR systems. Vert: 5% (ρ = 0.05)/cm. Horiz: 50-ps/cm.

impedance levels were restricted to a low impedance transmission-line approach since high-impedance delay lines are impractical. As a result, when using 100-kΩ sampling probes, there was no means of internal triggering. In addition, sampling oscilloscopes with risetimes faster than $\approx$350 ps did not offer internal triggering because of the absence of the signal delay line.

The availability of the Type 3T2 Random Sampling Sweep Unit has eliminated these restrictions. Its unique random-sampling circuitry *always* allows observation of points *prior to the triggering transition itself*. Depending on the sweep rate of the display, microseconds, or even milliseconds of time prior to the triggering event can be observed! This is an amount far greater than any conventional real-time oscilloscope can provide. With high-impedance probes, the advantages of internal triggering are present (although a separate trigger probe is required) since the user can monitor points in time before the trigger occurs. At the same time, it is possible to view 25-ps signals with the Type S-4 Sampling Head without pretriggers.

The development of the Type 3T2 Random Sampling Sweep Unit was a major factor in initiating development of the plug-in head concept. Once random sampling had been developed, it was *then* possible to consider a modular design approach without the use of delay lines, and still provide the advantages that internal triggering offers. Eliminating signal delay lines removed a major system bandwidth limitation and contributed markedly to size and weight reductions. At the same time, the problem of aberrations due to skin effect, dielectric losses of the delay lines, and compensation circuits were automatically eliminated.

Variable Interchannel Delay

Variable interchannel delay is a feature of the Type 3S2 Plug-In that has not before been available. The user now has the ability to vary the delay of one channel, ±5 ns, to ensure exact coincidence of time relationships. Minor manufacturing tolerances, probe differences, signal paths, transmission lines, etc., may now be exactly matched to allow more precise time comparisons.

This feature is of particular value when a high-impedance sampling head and a 50-Ω sampling head are used together (cable transit times are different), or when different length extender cables are required. In addition, it ensures optimum X-Y displays when the sampler is used in the A vertical, B horizontal mode.

Digital Sweep Delay

The development of digital delay in a sampling time-base unit, Type 3T5/3T6, offers a new versatility for oscilloscope users. It is now possible to dial in an exact delay over the range of 100 ps—999.9 μs (see fig 10). This delay is generated by incorporating a clock and digital counter to ensure a precise jitter-free display whose stability is not a function of the delay time. This technique allows the Type 3T5/3T6 to maintain its basic 30-ps jitter specification with delays of up to 1 μs.

Programmable Sampling Units

The availability of the Type 3S5 and Type 3S6 Programmable Sampling Units provide a new capability for use with the Type 568/230 Digital Readout System. Plug-in sampling heads present maximum interfacing flexibility when signal sources require a different sampling head. The systems user is assured of maintaining maximum versatility since the systems limitation is basically determined by the sampling head characteristics.

The Type 3S5 and Type 3S6 offer digitally programmable control of deflection factor, DC offset, polarity, and smoothing. 27 program lines using negative logic (true = ground or <2 V — false = open or >6 V) are required to program all measurement functions.

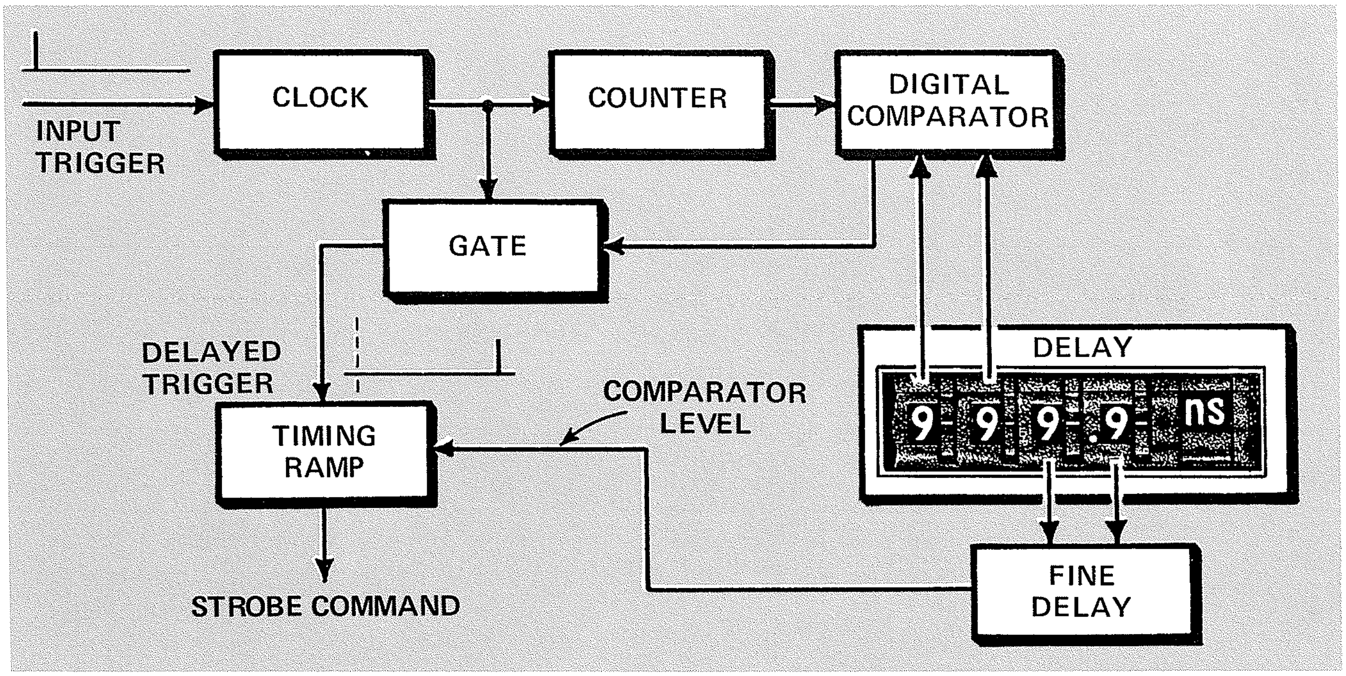


Fig 9. Simplified block diagram of digital delay circuitry.

DIGITAL DELAY RANGE		
Delay Range	Increments	Time/Div
999.9 ns	100-ps	100 ps/div to 500 ps/div
9.999 μs	1-ns	1 ns/div to 1 μs/div
999.9 μs	100-ns	2 μs/div to 500 μs/div

Fig 10.

The Type 3S5 and Type 3S6 have identical electrical characteristics. The Type 3S6 has all connections, including remote sampling heads on the rear panel, while the Type 3S5 provides all connectors on the front panel.

The Type 3T5 and Type 3T6 Programmable Sampling Sweep Units provide a wide range of digitally programmed functions. Time/div, delay time, and samples/sweep are remotely programmable (true = ground or < 2 V — false = open or > 6 V), or controllable from the front panel. The units are programmable over the wide range of 100 ps/div to 500 ms/div in 30 calibrated steps. Real-time sampling is used over the range of 1 ms/div to 500 ms/div.

A new automatic trigger mode has been included in the Type 3T5 and Type 3T6 to eliminate the need for trigger adjustments as trigger amplitudes, repetition rates, risetimes, and pulse widths vary.

The Type 3T5 and Type 3T6 have identical electrical characteristics. The Type 3T5 has a program connector and trigger input on the front panel while the Type 3T6 provides these connectors on the rear panel.

Real-Time Sampling

The Type 3S2 can provide 100 kHz pulses to each sampling head independent of the real-time time base unit. When the Vertical Sampling Unit is switched to the non-sampling position and a conventional time base unit inserted, real-time internal triggering is available. The real-time sampling mode is limited to approximately .1 ms/div since faster sweeps will begin to make the 10μs clock segments objectionable. Thus, signals exceeding 20 kHz are seldom viewed in this mode.

Real-time Sampling offers slower sweep rates with the full bandwidth of plug-in sampling heads. The characteristics of interest this mode offers are:

(1) Slow sweeps with full bandwith

(2) Reduction of random noise through smoothing

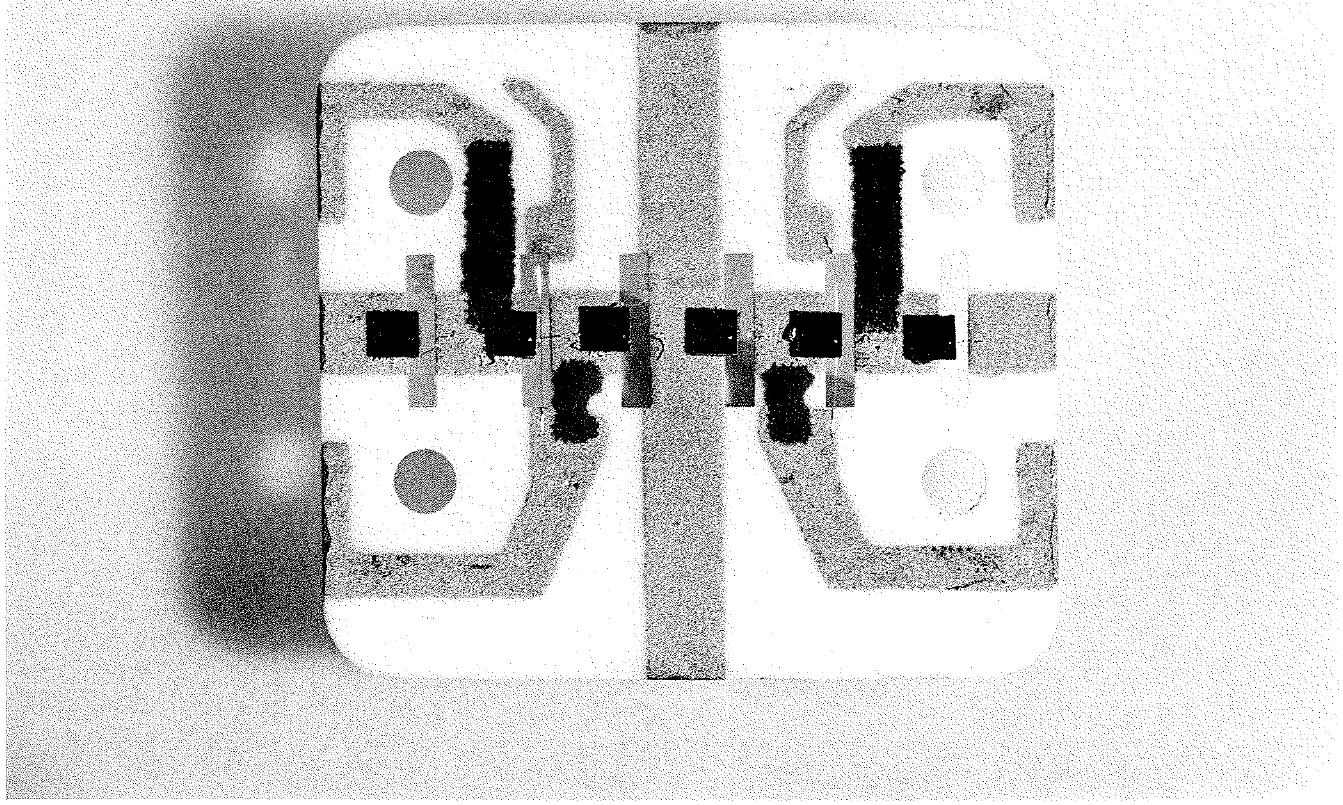
(3) DC offset capability with excellent overload recovery

Conclusion

The sampling head concept has brought a shift in design effort toward the front end of the sampler, where it really belongs. In addition, there has been a reduction in the total number of sampling plug-in units required for the designer to be attentive to the instrumentation needs of tomorrow.

These developments, combined with the options of digital readout, high resolution low-cost storage, random sampling and programmable units, offer the user more versatility at lower cost than ever before.

A New Approach to Fast Gate Design



A unique sampling gate eliminates risetime dependency upon strobe width. This new development offers the highest speed sampling system to date and offers promise for even faster gates.

George Frye
Project Engineer, Sampling

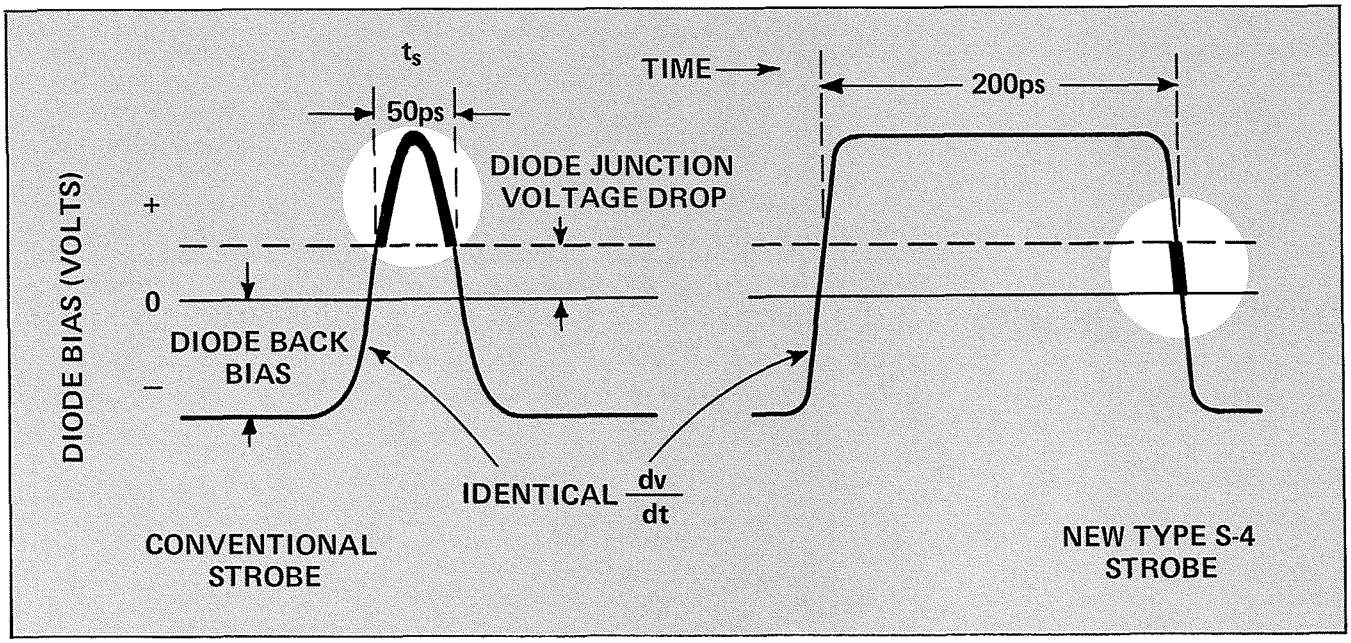
Fig 1 shows a section of delay line with switches inserted at point A and point C. A nonloading voltmeter placed at point B, measures the average of the voltage between the switches when the switch section is opened. When a fast step is applied to the line and the switches then opened, the following observations may be made.

If the step propagating down the line is at point A when the switch opens, 0 volts are observed. If the switches are reclosed and a second observation made at a later time, when the wavefront has reached point C, the voltage is 1. When the step is just entering the switch at point A, we observe 0; if it is just leaving the switch at point C, we observe 1. Thus, we may state that the system 0-100% risetime is determined by the length of the switch section or C-A. Since we know the line has capacitance and voltage, we have effectively "trapped" a quantity of charge (Q=CE). If we now apply this concept to the model shown in fig 2, we can note some very important observations.

The model in fig 2 illustrates a simplified form of the new sampling gate used in the Tektronix Type S-4 Sampling Head. Diodes replace the switches and instead of opening the switches simultaneously, we turn the diodes off one after another. Although it is a balanced system, only one half of the system will be described.

The leading edge of the strobe pulse turns the diodes on and the signal propagates into the conducting diodes and transmission line. The diodes remain on for the duration of the strobe pulse, being turned off by the trailing edge of the wave shape. The strobe pulse is designed to be longer than the transit time between the diodes.

Gate action begins when the strobe trailing edge turns D2 off. At the same time, suppose a signal front enters through conducting diode D1. When the front reaches D2, it is off since the strobe arrived there prior to the front. The signal front reflects and reaches D1 which is now off since the strobe trailing edge has preceded the front. Thus, the signal front has been effectively trapped in the transmission line between the two diodes. Note, however, that the gate characteristics are determined by the strobe trailing edge (only one transition).



The conventional sampling gate must take the diode from a fully-off condition, turn it fully-on, and return it to a fully-off condition. The time between the two fully-off conditions, t_S, is the strobe width and determines the risetime of the system. In the Type S-4 gate, the diodes are fully-on as gate action begins, and only one transition is needed. Risetime is determined by the length of the transmission line as pointed out in the text. The conventional strobe for a fast sampling gate is very narrow since the strobe width determines the system risetime. The Type S-4 uses a wide strobe and minimizes the problems inherent in narrow strobe generators.

In this system, the 0-100% risetime is determined by twice the propagation time between D1 and D2, since both the front and the strobe must traverse the distance.

The important points to note are the following: (1) Only one transition is required for the gate action (gate action occurs from a fully-on diode condition to a fully-off condition). Using one transition offers substantial noise reduction possibilities. (2) The risetime of the system is not dependent upon the strobe width. (3) The propagation time between diodes in this system (8 ps) is much less than the strobe period of approximately 200 ps. (4) Because the diodes currently used may be turned off in 5-10 ps, they do not present a significant risetime limitation.

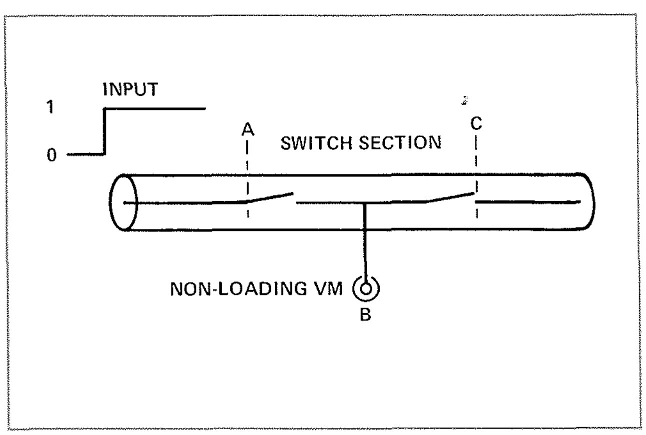


Fig 1. Delay-line section.

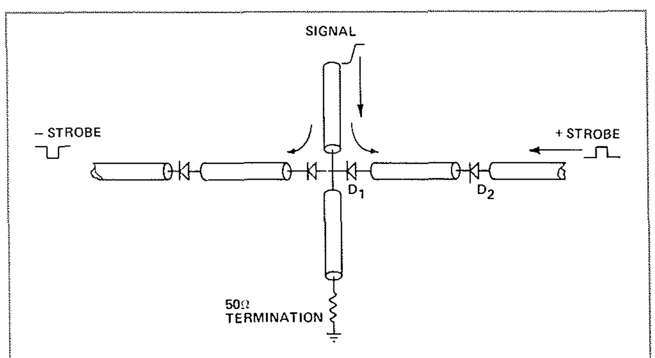


Fig 2. Simplified model of sampling gate for Type S-4.

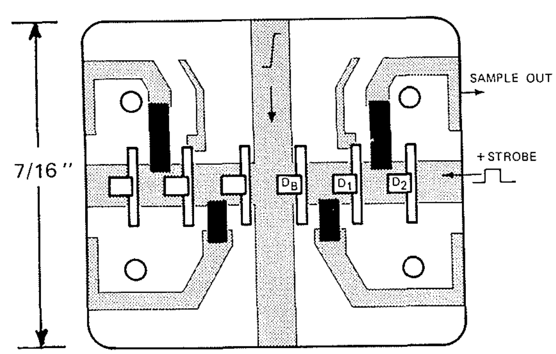
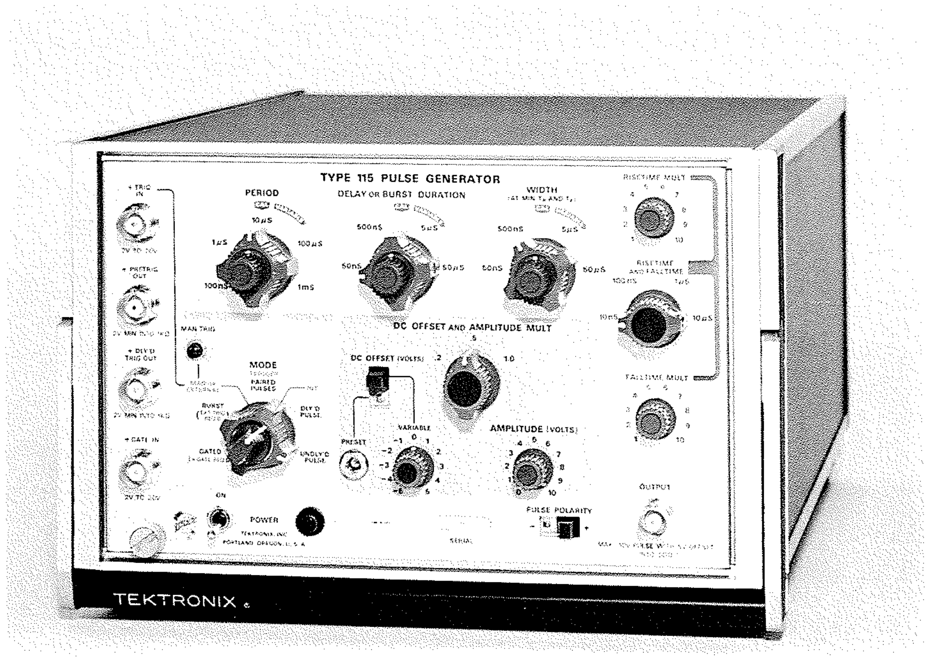


Fig 3. 25-ps hybrid gate. 6 Tektronix-manufactured diode chips are placed on a ceramic substrate. The substrate is formed with slots (0.020) which remove high dielectric constant material near the diodes to reduce shunt capacitance. The diode chips are set in place, extending over the slots, to minimize lead inductance. D_B is in the circuit to correct for signals capacitively coupled through the gate diodes when they are not conducting (blowby).

A Wide Choice of Pulses



Jerry Shannon
Project Manager,
Generators

Tektronix' entry into the medium price general-purpose pulse generator market sets new performance standards, including total peak-to-peak aberrations of less than 3%.

The Type 115 Pulse Generator was designed to meet the continuing requirement for a "clean" pulse generator in the mid-frequency range (100 Hz — 10 MHz). By providing separately variable amplitude, width, period, DC offset, risetime, falltime, and delay functions, the Type 115 offers a wide choice of stable pulse characteristics.

The aberrations of the Type 115 are specified at +3%, —3%, total 3% peak-to-peak. Fig 3, on page 11, illustrates a magnified view of the baseline and pulse top of both positive and negative pulses with each division representing 2% of P-P amplitude. Note, all aberrations are well within the 3% specification.

The Type 115 has variable risetimes and falltimes (10 ns-100 μs) which remain constant while varying pulse amplitude. The amplitude may be varied from ± 10 V (50 Ω) to ± 100 mV without changing the risetime or falltime from its 5% ± 1 ns accuracy specification. In addition, the full range of $\pm$ DC offset is available to the user. A screwdriver preset is located on the front panel to allow DC voltage offset to be preset. A front panel switch offers the choice of variable or preset DC offset.

Considerable attention is given to front panel logic in the Type 115. An example is in the use of the term pulse period instead of pulse repetition rate to be more consistent with time-domain logic. This also helps the user to more quickly determine an error in setup (i.e. width greater than period).

A unique burst mode provides output pulses as shown in fig 9. In this position, the delay control functions as a BURST DURATION control while the PERIOD control determines pulse repetition rate. This mode is convenient since only an external trigger is required to initiate the burst (gate waveshape is not required).

The Type 115 is a solid-state design which ensures optimum reliability and includes a short-proof power supply. Plug-in transistors have been used throughout with the exception of high power transistors that require the chassis as a heat sink. Output protection is a feature of the Type 115 and the output may be subjected to open, short, or inductive surges without damage to the instrument.

The Type 115 has been designed to occupy one-half of a standard 19-inch rack. Two Type 115 Pulse Generators require only 5¼ inches of panel height when used with an optional rack adapter. Thus, the Type 115 is ideally suited for applications where space is at a premium, whether a portion of a complex system, or in bench operation.

The price of the Type 115 Pulse Generator, including a 5-watt 50-Ω termination and cable, is $825. Further details are included on pages 15-16 in the New Product Supplement to Tektronix Catalog 27 (1968).

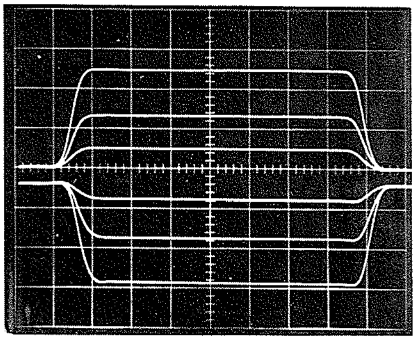


Fig 1. Multiple exposure showing typical aberrations on positive and negative pulses with varying amplitudes. Horiz: 20 ns/cm. Vert: 4 V/cm.

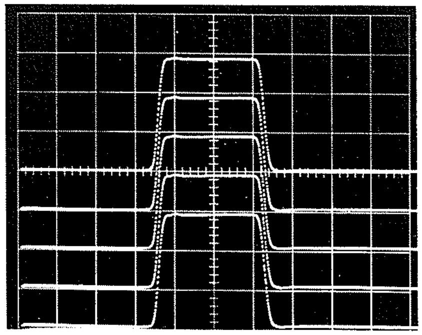


Fig 2. Multiple exposure. 7 V pulse with 10 ns rise and fall showing offset capability of ±5 V in 2.5 V increments. Horiz: 50 ns/cm. Vert: 2.5 V/cm.

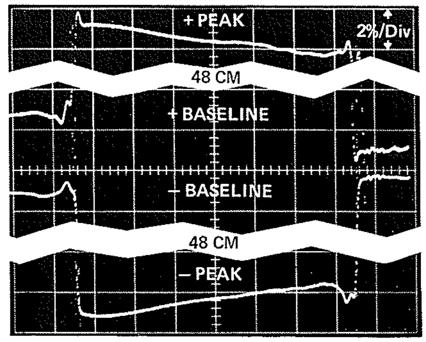


Fig 3. Composite photo illustrates + and -10 V pulses (t_r and t_f 10 ns) with waveform top and baseline each magnified 50 times. Note that all aberrations are well within 3%. Horiz: 2 ns/cm. Vert: 200 mV/cm.

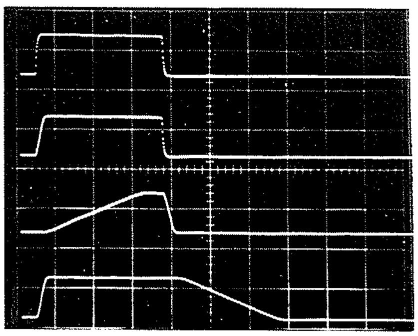


Fig 4. Multiple exposure showing variable risetime and falltime. Horiz: 500 ns/cm. Vert: 10 V/cm.

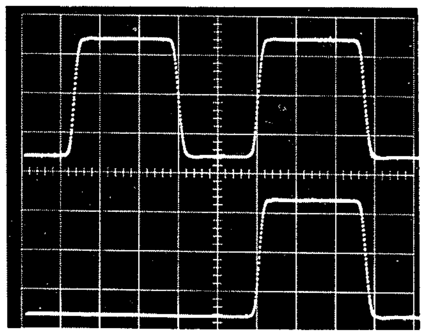


Fig 5. Multiple exposure illustrating PAIRED PULSES (upper) and DELAYED PULSE (lower) modes. Horiz: 50 ns/cm. Vert: 25 V/cm.

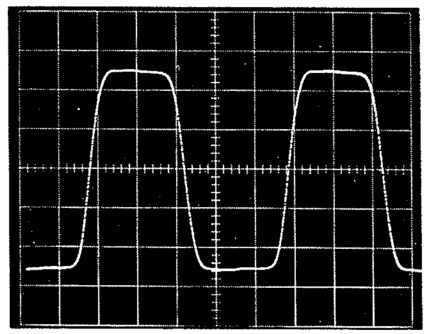


Fig 6. Minimum pulse separation. Horiz: 20 ns/cm. Vert: 2 V/cm.

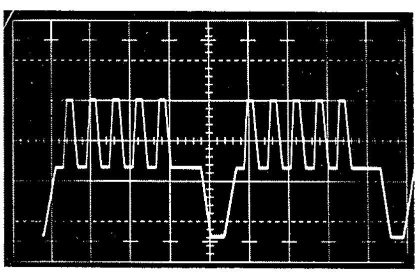


Fig 7. Pulse burst from combined output of two Type 115's. The burst of pulses was triggered by the + delayed trigger from the instrument generating the pedestal. Horiz: 10 μs/cm. Vert: 2 V/cm.

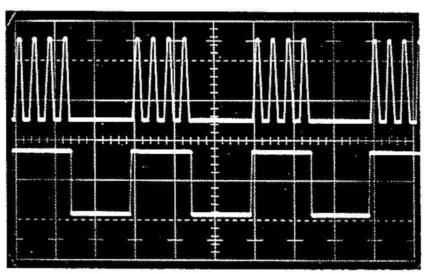


Fig 8. GATED mode. Multiple exposure showing time relationship between external gate input (lower trace) and pulse burst. Horiz: 5 μs/cm. Vert: 5 V/cm.

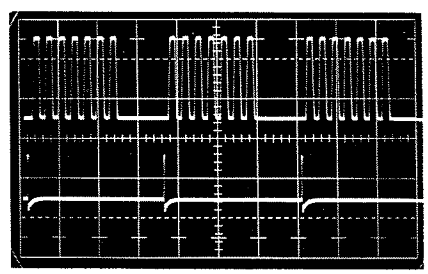


Fig 9. BURST mode. Multiple exposure showing time relationship between external trigger (lower trace) and pulse burst. Horiz: 1 μs/cm. Vert: 5 V/cm.

MIXING PULSE SOURCES

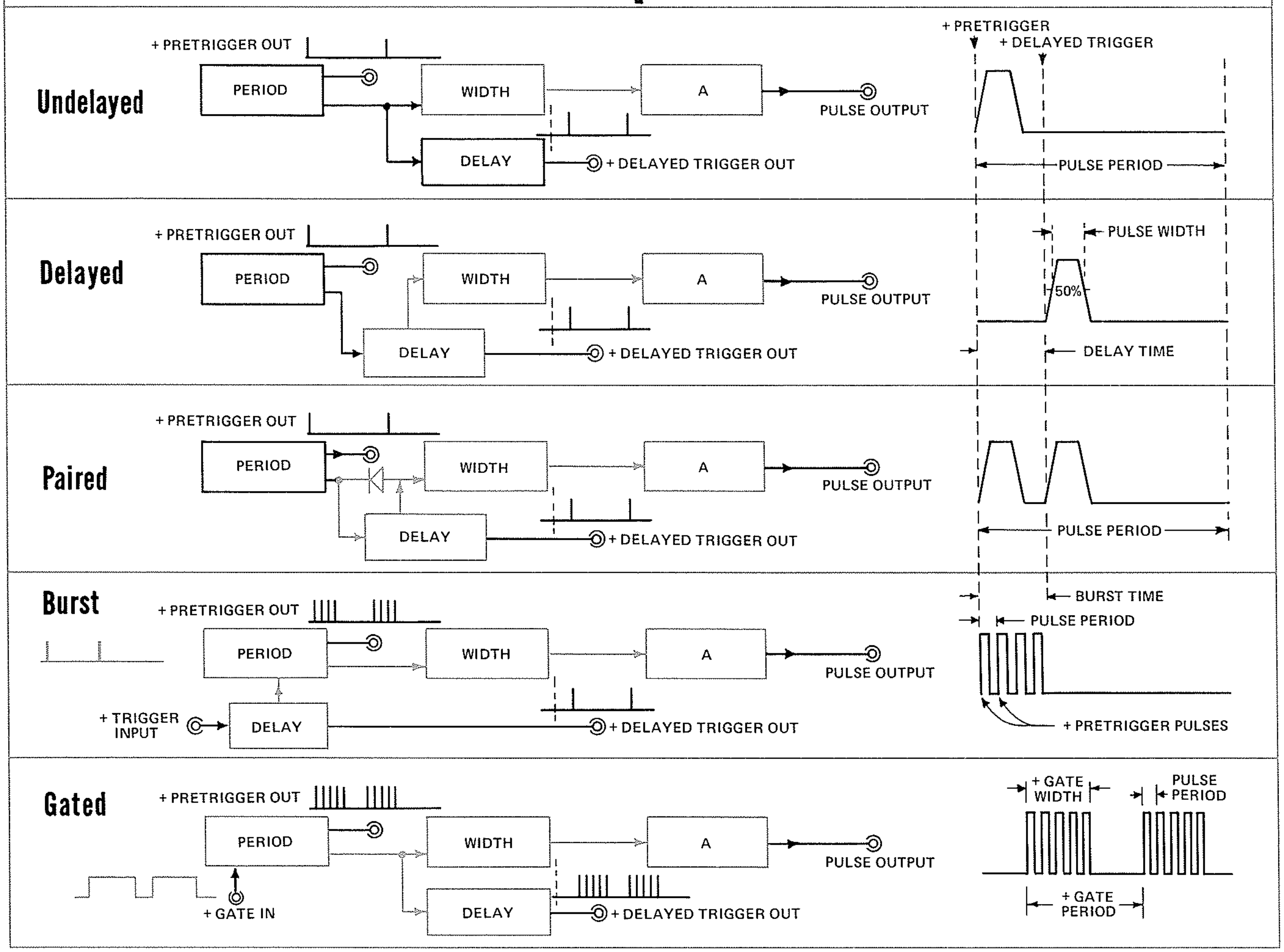
Often it is necessary to mix two or more pulse generators to obtain a desired pulse train. Fig 7 shows one complex waveshape that may be obtained by mixing two Type 115 pulse generators. Three simple rules will minimize problems when mixing sources.

(1) Do not exceed the output voltage specification with the combination of pulse amplitude and offset. (Type 115 specification ±10 V pulse ±5 V DC offset.)

(2) Use .5 multiplier to avoid exceeding the output voltage specification when mixing two generators.

(3) Use multiplier of .5 or .2 (provides back termination) or a power divider to minimize reflections. (Only important with fast risetimes.)

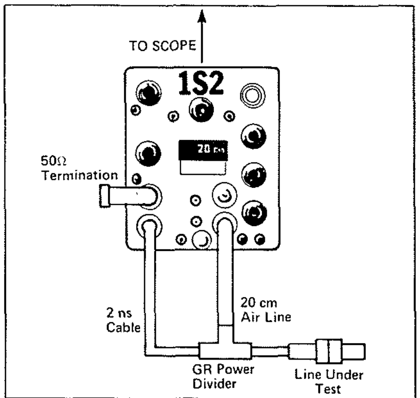
Modes of Operation



TYPE 115 PULSE GENERATOR CHARACTERISTICS

FEATURE	RANGE	GENERAL APPLICATION
AMPLITUDE	±10 V to ±100 mV, 3 ranges continually variable	Threshold determination stimulation, linearity
DC OFFSET	±5 V in 3 ranges continually variable — full range useable with any amplitude setting	Baseline compatible with input requirements
RISETIME AND FALLTIME	10 ns - 100 μs in 4 ranges continually variable	Transient response testing
WIDTH	50 ns to 500 μs in 4 ranges continually variable (duty factor at least 75%)	Duty cycle appropriate for system response
DELAY	50 ns to 500 μs in 4 ranges continually variable	Time-domain control of event
PERIOD	100 ns to 10 ms in 5 ranges continually variable (minimum pulse separation -50 ns)	Frequency of event (clock rate)
GATED	Ext positive pulse required, 2 to 20 V	Generation of pulses coincident with gate duration
BURST	Ext positive trigger required, 2 to 20 V	Generation of pulses during BURST DURATION initiated by ext trigger
PAIRED PULSES	Separated by delay time, recur each period	Resolution between events
EXTERNAL TRIGGERING	Ext positive trigger required, 2 to 20 V	Method of external time reference
SINGLE PULSE	Manual push button	Single-event occurrence
MIXING	See mixing sources on page 11	Algebraic sum of two pulse generators — more complex waveshapes possible
TRIGGER OUTPUTS	+Pretrigger +2 V into 1 kΩ, +Delayed Trigger +2 V into 1 kΩ	Initiate remote timing functions
ABERRATIONS	+3%, -3%, 3% peak-to-peak	More accurate determination of system response

Service Notes



OPTIMIZING SYSTEM RISETIME

The system risetime of a 1S2 may be improved from 140 ps to about 100 ps by a rather simple technique, if you can tolerate a 4-to-1 increase in signal-to-noise ratio. Noise is usually a problem only when trying to see extremely low percentage reflections, and the additional time resolution may be useful in other applications. Rho calibration will also be off by a factor of four.

1. Connect a 20 cm GR air line (017-0084-00) to the ¼ volt step output.
2. Attach a GR power divider (017-0082-00) to the end of the air line.
3. Attach the cable or transmission line to be tested to one branch of the power divider.
4. Attach a short length of high quality cable between the other branch of the GR power divider and one input to the 1S2. (Tektronix 2 ns cable, 017-0505-00, can be used with surprisingly little deterioration of response.)
5. Attach a 50-ohm termination (017-0081-00) to the other 1S2 input.

That's all there is to it.

USED INSTRUMENTS FOR SALE

1—Type 575 Transistor Curve Tracer. In good condition. Contact: Howard Mappen, Molded Electronics, Inc., 459 East Main Street, Denville, New Jersey 07834. Telephone: (201) 625-0299.

1—Type 524AD, SN 2710, and one Cathode Follower Probe. Contact: Mr. Schatz, Bond TV, Hudson Boulevard, Jersey City, New Jersey. Telephone: (201) 333-3112, day; 434-6574, night.

1—Type 570, SN 5508. Price: $500. In excellent condition. Contact: Guy Falcioni, Air Reduction Research Labs, Murray Hill, New Jersey 07975. Telephone: (201) 464-2400, ext. 283.

1—Type 533A/535/541/545. Also, 2—preamps and complete 160-Series Generators. Contact: H. Posner, Pacific Combustion Engineering Company, 5272 East Valley Blvd., Los Angeles, California. Telephone: (213) 225-6191.

1—Type 560, SN 000358. 1—Type 50, SN 000250. 1—Type 51, SN 000268. Contact: Bob Long, Bank Administration Institute, 303 South Northwest Highway, Park Ridge, Illinois 60068. Telephone: (312) 775-5344.

1—Type 2B67 Time-Base Unit. Price: $150. Used 14 months. Contact: T. R. Evans or P. A. Leemakers, Department of Chemistry, Wesleyan University, Middletown, Connecticut 06457. Telephone: (203) 347-4421, ext. 379.

1—Type 504, SN 001387. Used only once; three years old. Contact: James E. Stewart, Electronics, 1308 William Flynn Highway, Glenshaw, Pennsylvania 15116. Telephone: 486-9797.

1—Type CA Plug-In Unit. Price: $125. Contact: Mark Kramer Colortran Industries, 1015 Chestnut Street, Burbank, California 91502. Telephone: (213) 843-1200.

5—Type 533, SN 1075, 001568, 002139, 002136, 002156. 1—Type 561, SN 00992. 1—Type 535A, SN 002184. 6—Type CA, SN 005528, 018803, 013-427, 009277, 013426, 023682. 1—Type 53/54E, SN 2220. 1—Type L SN 007-971. 3—Type H, SN 003170, 003169, 002970. 1—Type TU-2, SN 000791. 2—Type 63, SN 000342, 000341. 2—Type 67, SN 000570, 001118. 1—Type 180A Time-Mark Generator, SN 007-013. Contact: Victor Ferramosca, Computer Systems, Inc., 2042 Westmoreland Street, Richmond, Virginia 23230. Telephone: (703) 353-7856.

1—Type 130 LC Meter, SN 405, with S30 Delta Standard. Price: $125. Contact: Mr. E. Silverman, Oak Park Tool & Die Company, 8726 Northend Avenue, Oak Park, Michigan 48237. Telephone: (313) 547-4688.

1—Type 524D, SN 750. Price: $450. Contact: Ray Swalley, 5544 North 35th, Tacoma, Washington 98407. Telephone: (206) 752-3544.

1—Type 321, SN 001048 with P6022 Probe. Price: $450. Contact: Miss Jensen, Electro-Autosizing Machine Corporation, 140 Woodland Avenue, Westwood, New Jersey. Telephone: (201) 664-5540.

1—Type 532, with CA, B, L, and 1L20 Plug-Ins. Price: $2150 complete. All units perfect and guaranteed. Contact: G. Cecil Translab Inc., 4740 Federal Blvd., San Diego, California 92102. Telephone: (714) 263-2246.

1—Type 514, SN 1545. Contact: Steve Halmo, Nystrom Aviation, 1901 Embarcadero Rd., Palo Alto, California 94303. Telephone: (415) 327-7640, ext. 17.

1—Type 564, SN 2157. 1—Type 3A1, SN 1410. 1—Type 3B4, SN 140, 2—Type P6006. 1—Type P6028. Price: $1450. All in good condition. Contact: James W. Browder, Ryan K. Aeronautical Co., San Diego, California. Telephone: (714) 296-6681, ext. 8247 or 8248.

1—Type 536, SN 260; 1—Type 53/54T. Price: $600. 1—Type 502, SN 2139. Price: $550. 1—Type 504, SN 908. Price: $250. 1—Type 53/54E Plug-In. Price: $75.00. Contact: Eric W. Vaughan, The Superior Electric Company, Bristol, Connecticut 06010. Telephone: (203) 582-9561.

1—Type 310, SN 4978. Contact: COMMSULT, Inc., 3355 Prarie, Boulder, Colorado. Telephone: 444-5900.

USED INSTRUMENTS WANTED

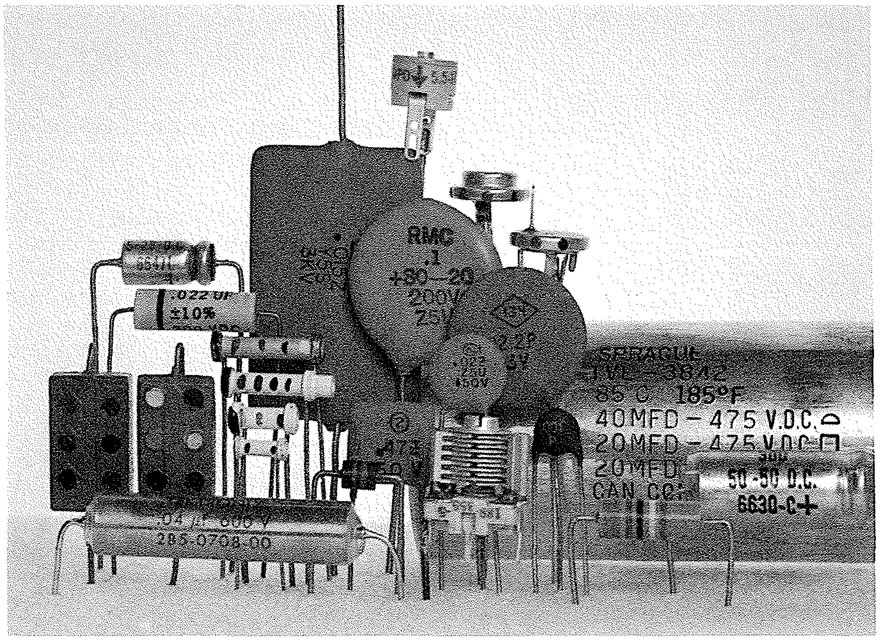
1—Type 585A/82/1A2/1A6. Contact: Mr. Ettinger, Mark Computer Systems, 40 South Mall, Plainview, New York 11803. Telephone: (516) 694-9655.

1—Type 575 Curve Tracer. Contact: Derrick Lindsay, 13 Beechwood Lane, Westport, Connecticut. Telephone: (203) 227-5957.

2—Type S Plug-In Units. In any condition. Contact: Murray Goldstein, Scientific Components, 350 Hurst St., Linden, New Jersey 07036. Telephone: (201) 925-4022.

1—Type 585. 1—Type 82. Contact: Donald A. Paris, 48 East Circle Drive, East Longmeadow, Massachusetts 01028.

Reading Capacitor Codes



There are a number of different color codes for capacitors. The following summary should help you save time in identifying most of the capacitors you encounter. Different marking schemes are used mainly because of the varying needs the different capacitor types fulfill. For instance, temperature coefficient is of minor importance in an electrolytic filter capacitor, but very important in ceramic trimmers for attenuator use. You never find temperature coefficient (T_c) on an electrolytic label, but ceramic trimmers always carry it.

I. CERAMIC DISC CAPACITORS

Often called "discaps" (that's the trademark of one manufacturer), ceramic disc capacitors are available in two categories: temperature compensating or class I, and "high-K" or class II. T_c types usually carry the capacitance in pF's directly. Tolerance may be shown in percent or by letter:

M = ± 20%
K = ± 10%
J = ± 5%
G = ± 2%
F = ± 1%

Temperature coefficient is indicated by P100, which means +100 P/M/° C, or N750 for −750 P/M/° C, NPO for 0 P/M/° C, N030 for −30 P/M/° C, etc. All these T_c's have a tolerance, too. NPO is usually ±30 P/M/° C, with looser tolerance on larger T_c's. T_c tolerance is also looser on very low capacitance parts.

"High-K" types list capacitance the same way (or in μF), and in addition sometimes use a multiplier scheme as follows: 102 for 1000 pF, 473 for 47,000 pF, etc. Capacitance tolerance is shown as above, with the addition of P for GMV ("guaranteed minimum value" or −0, +100%), and Z for −20, +80%. The temperature coefficient of these units is usually not linear, so only the maximum capacitance change due to temperature from the 25° C value is given. This is called the "temperature characteristic", a typical case being "Z5U". This table explains the meaning of the more common temperature characteristic designations.

Temperature range over which characteristic is effective:	Z5:	+10° C to +85° C
	Y5:	−30° C to +85° C
	X5:	−55° C to +85° C
	W5:	−55° C to +125° C
Limits of capacitance change from the room temperature value:	D:	±3.3%
	E:	±4.7%
	F:	±7.5%
	S:	±22%
	U:	+22, −56%
	V:	+22, −82%

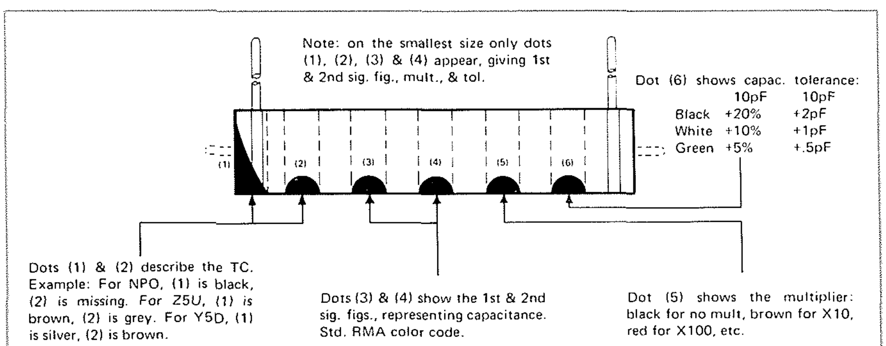
Thus "Z5U" means that temperature can cause the capacitance to increase a maximum of 22%, or decrease a maximum of 56% from the room temperature value, within the limits of +10° C and +85° C.

Whether voltage rating appears on a disc depends on the manufacturer's practice. Most do not include it on their "standard" voltage rating, which is 1000 V for Sprague and RMC, and 500 V for Erie. Other voltage ratings, however, are printed on the capacitor.

High-voltage ceramic discs and plates used at Tektronix are of class II dielectric material, and carry labels similar to the class II discs.

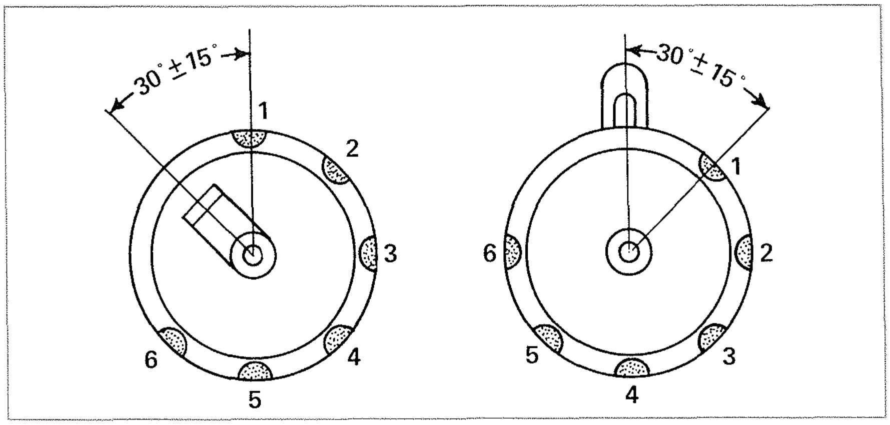
II. CERAMIC TUBULAR CAPACITORS

These units are usually white enamel coated and have parallel radial leads. "Dog bones" come in both class I and class II dielectrics and in several sizes, at least one being too small for a complete code of any kind. The code consists of color dots which show T_c, capacitance, and tolerance. The smallest style shows only capacitance and tolerance, and none can show the capacitance of a close-tolerance part to greater than two significant figures. The more common examples are illustrated below.



III. BUTTON MICA CAPACITORS

The most difficult aspect of understanding the code on these parts is "where do you begin?" The sketch shows that the first dot is keyed to a center terminal lug.



Dot Meaning

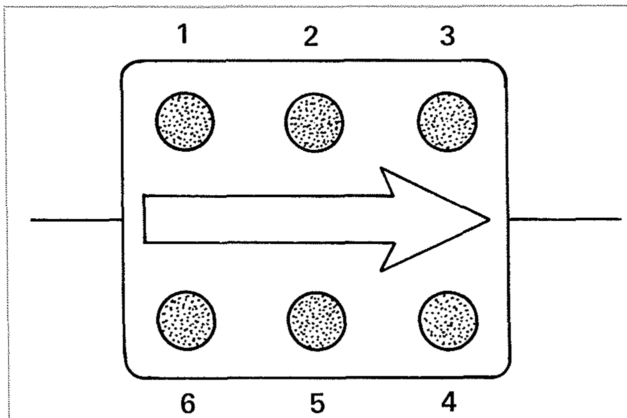
1. Identifier: Black, except omitted where capacitance must be specified to 3 significant figures.
2. Capacitance: 1st significant figure in pF.
3. Capacitance: 2nd significant figure in pF.
4. Multiplier of Capacitance: black = X1, brown = X10, red = X100, etc.
5. Capacitance Tolerance: black = ±20%, silver = ±10%, gold = ±5%.
6. "Characteristic": black (means a temperature coefficient falling somewhere between −20 and +100/P/M/°C.

Note: The dots always read in a clockwise direction.

If the button has no center lug terminals, the manufacturer tries to put the dots more on one side than out on the very edge; thus the code can be seen from one side only.

IV. MOLDED MICA CAPACITORS

Color codes on this type vary, causing much confusion. There are two basically different code schemes, one being "OLD", the other one being the EIA/MIL scheme currently in use. The sketch shows the difference.



EIA STANDARD COLOR CODE

Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

OLD

Dot Meaning

1. Capacitance: 1st significant figure in pF.
2. Capacitance: 2nd significant figure in pF.
3. Capacitance: 3rd significant figure in pF.
4. Multiplier of capacitance.
5. Tolerance: Black = ±20%, Silver = ±10%, Green = ±5%, Brown = ±1%
6. "Characteristic": Brown = B, Yellow = E, Green = F

EIA/MIL

Dot Meaning

1. Identifier: White if per commercial specification, black if per mil specification.
2. Capacitance: 1st significant figure in pF.
3. Capacitance: 2nd significant figure in pF.
4. Multiplier of capacitance.
5. Tolerance: same as "OLD".
6. "Characteristic": same as "OLD".

Note: "Characteristic" in mica capacitors refers to the temperature coefficient and capacitance drift.

Char.	T_C (P/M/°C)	Drift
B	±500	±3% +1 pF
C	±200	±(0.5% +0.5 pF)
D	±100	±(0.3% +0.1 pF)
E	-20 to +100	±(0.1% +0.1 pF)
F	0 to +70	±(0.05% +0.1 pF)

V. DIPPED MICA CAPACITORS

These parts carry a printed label much like that on ceramic discs. They may include the characteristic letter explained in the preceding table at left.

VI. PAPER & FILM CAPACITORS

Aluminum and Tantalum Electrolytic Capacitors: In almost all cases they carry printed or stamped labels consisting of capacitance, tolerance, and voltage rating. Other characteristics are either unimportant or are reasonably consistent in all capacitors of the same kind.

VII. CERAMIC TRIMMERS

The printed-on labels usually show capacitance range and temperature characteristic. TC reads the same as on ceramic discs. The tolerance on TC of ceramic trimmer rotors is much looser than on fixed capacitors, for mechanical reasons.

VIII. AIR TRIMMERS

The same principle applies as in the case of paper and film capacitors. Only capacitance range need be indicated as TC is essentially uniform in this type.

SERVICE SCOPE

October 1968 · Tektronix, Inc., P. O. Box 500, Beaverton, Oregon, U. S. A. 97005

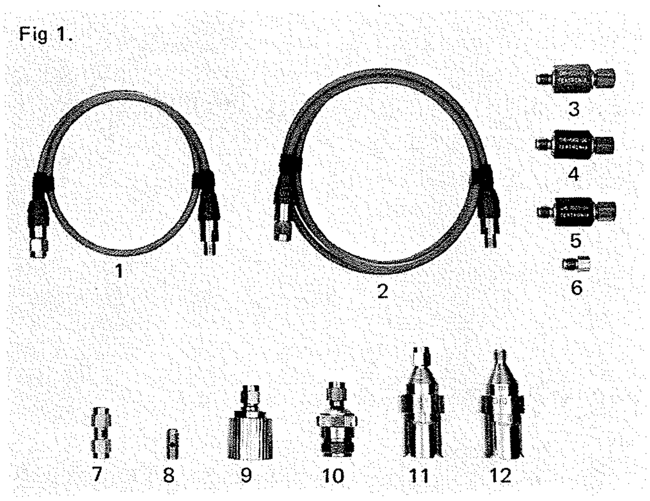
Editor: R. Kehrli   Artist: J. Gorman

This issue of SERVICE SCOPE discusses some of the state-of-the-art developments in sampling technology. Since the development of sampling by Janssen and Michels in 1950, Tektronix engineers have made a number of significant contributions to sampling technology. Listed below are some of the more important developments and the year in which they occurred.

1960 Plug-in sampling unit converts conventional oscilloscope to sampling oscilloscope at modest cost.
1962 High-quality delay lines allow internal triggering and the observation of signal leading edges. Miniature low capacitance, passive probes developed.
1962 Digital readout introduced.
1963 100-ps sampling introduced.
1964 Low-cost, high-resolution storage combined with sampling.
1965 Miniature high-impedance sampling probes introduced.
1966 Wide-range sampling time base introduced, 10 ps/cm to 5 s/cm.
1967 Random sampling eliminates need for signal delay lines. Allows viewing of up to 5 cm before trigger.
1968 New sampling concept developed. 6 plug-in heads introduced. 25-ps sampling with 35-ps TDR. Programmable sampling units, digital delay, and 3 mm connectors.
1969 MORE TO COME!

SOMETHING NEW IN OSCILLOSCOPE CONNECTORS

Fig 1.



NO	ITEM	PN
1	Cable, 2 ns	015-1005-00
2	Cable, 5 ns	015-1006-00
3	Attenuator, 2X	015-1001-00
4	Attenuator, 5X	015-1002-00
5	Attenuator, 10X	015-1003-00
6	Termination, 50 Ω	015-1004-00
7	Adapter, M to M	015-1011-00
8	Adapter, F to F	015-1012-00
9	Adapter, M to 7 mm	015-1010-00
10	Adapter, M to N(F)	015-1009-00
11	Adapter, M to GR	015-1007-00
12	Adapter, F to GR	015-1008-00

A 3-mm (mates with OSM®)* line of connectors is currently stocked by Tektronix. When development of the 50-ps (7-GHz) Type S-2 Sampling Head was completed, studies were undertaken to determine the best connector for higher-frequency sampling oscilloscope designs. As a result, Tektronix has standardized on the 3-mm miniature connector line for higher-frequency developments.

This line of connectors offers the following advantages to the customer: (1) Operation at all frequencies up to 26 GHz. Since the 25-ps S-4 Sampling Head represents 14-GHz response, there is sufficient additional performance so the connector does not present a design limitation. (2) Availability of a full range of adapters and accessories from a number of manufacturers at competitive prices. Adapters are commercially available to adapt to Type N, TNC, BNC, GR, ARC, and OSSM. (3) It is a high-reliability connector because of the following considerations: (a) It is self cleaning, thus it is difficult for gradual signal degradation to occur. At the same time, a time-consuming cleaning process is not required. (b) There are fewer moving parts, so the surface-to-surface contact is better than other connectors available. (4) The VSWR of the 3-mm line is quite good, although not as good as some of the more precise, larger diameter lines. The high-speed sampling gate inherently produces discontinuities that negates much of the value of an expensive, high-precision connector. Therefore, the less expensive, medium precision 3-mm connector seems a good choice. In addition, the VSWR can be improved by inserting a high-quality attenuator, with very little sacrifice to the user. (5) Minimum front-panel space is required.

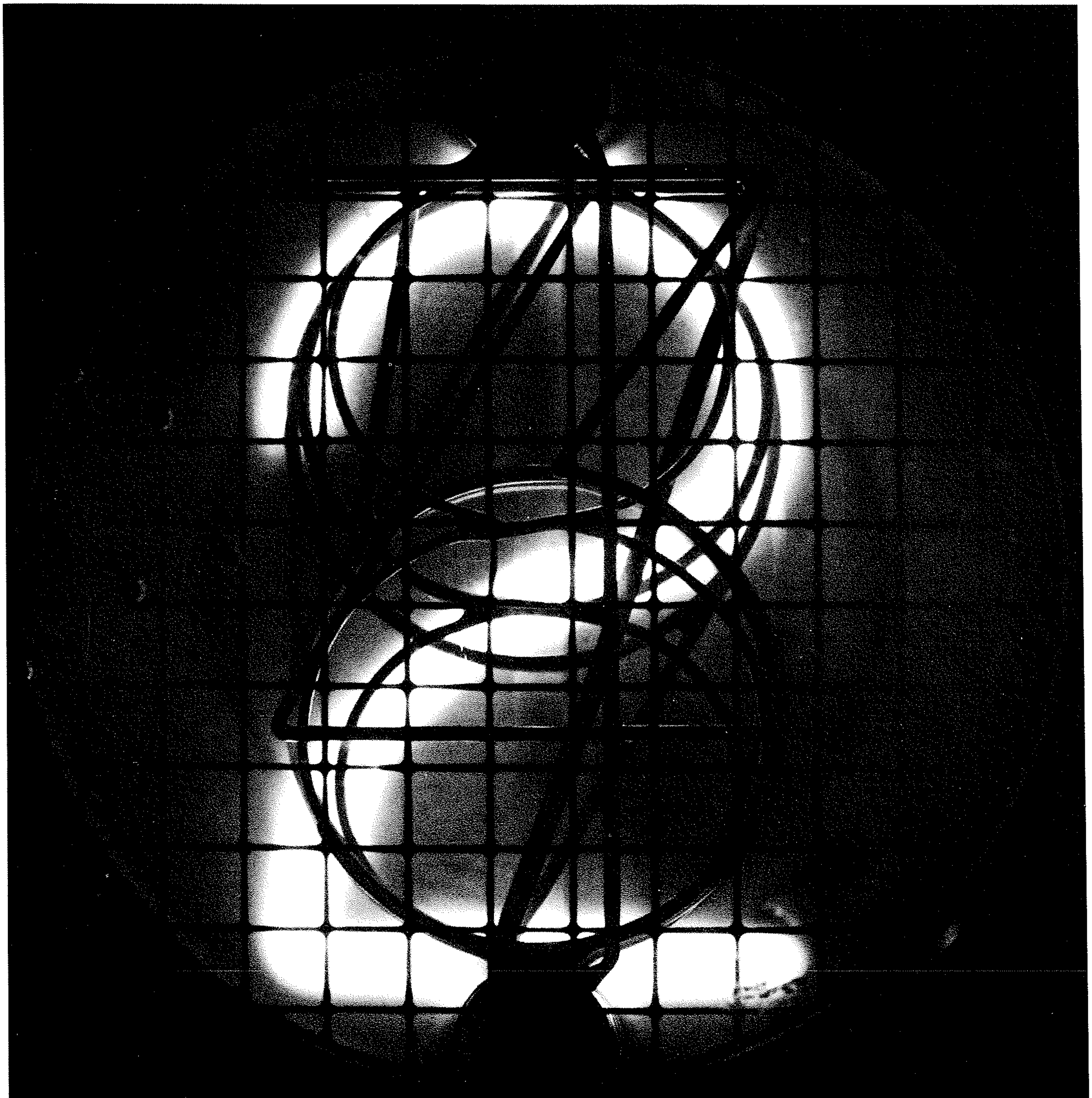
These considerations represent an excellent value connector for the customer. Fig 1 shows the 3-mm accessories currently being stocked by Tektronix.

*OSM is a registered trademark of Omni Spectra, Inc.

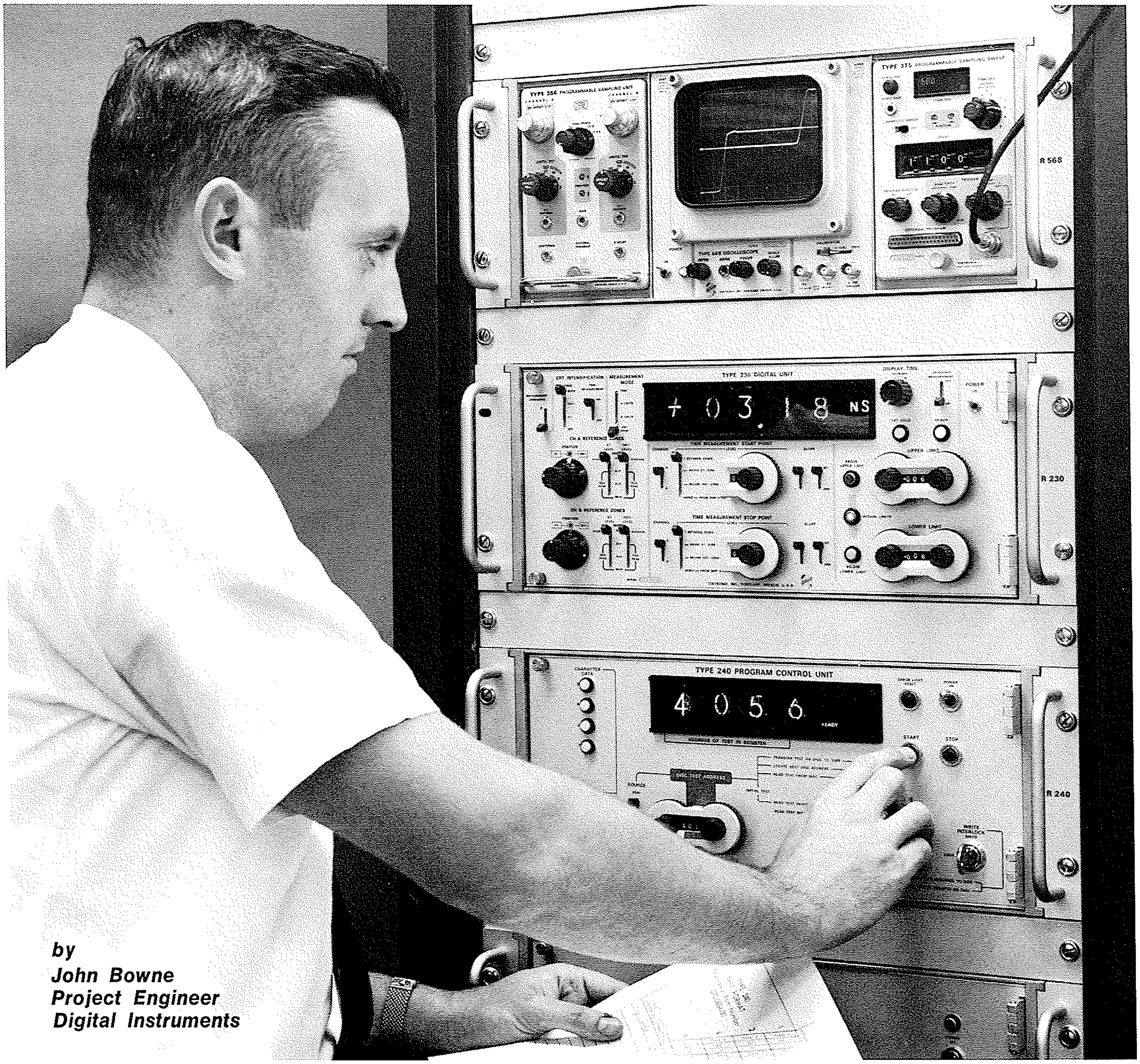
SERVICE SCOPE

NUMBER 53

DECEMBER 1968



Digital Systems Come of Age • Service Notes • Verifying Oscilloscope Performance



by
John Bowne
Project Engineer
Digital Instruments

DIGITAL SYSTEMS COME OF AGE

COVER

The displayed digit 2 is illustrative of the dual-purpose design of Tektronix digital components. These modular components are available: (1) individually, as components of a particular digital system; (2) assembled, as a Tektronix Measurement System (see p 16).

The widespread use of integrated circuits in the electronics industry, and the promise of even greater use in the near future, has focused attention on the need of externally programmable digital systems. To meet these needs Tektronix has developed a family of digital system components that meets IC-testing needs in manual, semi-automatic, or fully-automated measurement systems. Although these system components have been designed primarily with the integrated circuit tester in mind, their flexibility suggests them for many other types of testing.

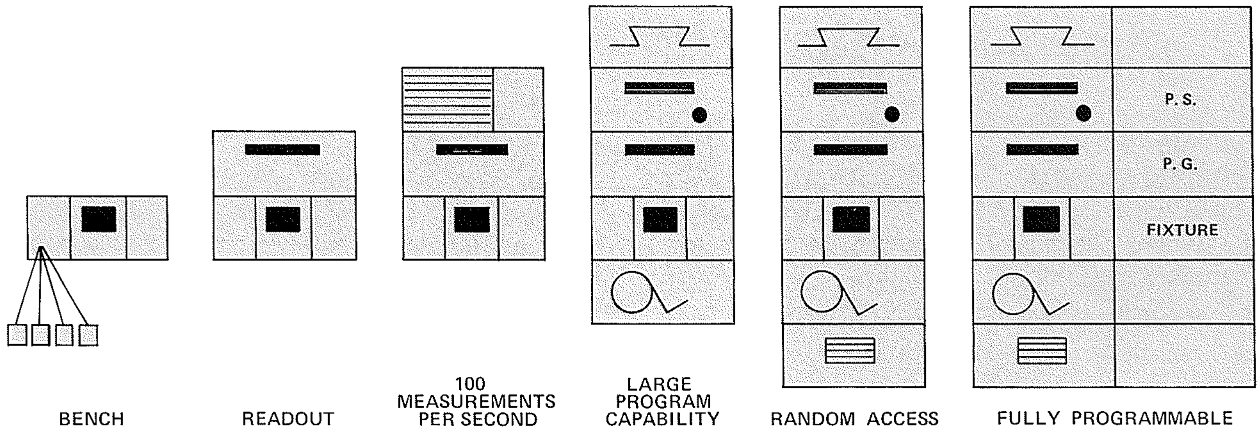


Fig 1. The modular design concept of Tektronix digital system components offers many varied measurement combinations.

Tektronix digital systems are dynamic measurement systems. The basic measurement characteristics are determined by the combination of the sampling sweep unit (Type 3T5, Type 3T6), the sampling vertical unit (Type 3S5, Type 3S6), and the individual sampling head (Type S-1, Type S-2, Type S-3, Type S-4)*. The Type 568 Oscilloscope and Type 230 Digital Unit are then used to digitize and display the information.

A MODULAR DESIGN CONCEPT

A family of modular digital system components offering versatility and expandability eliminates much of the need for special-purpose test equipment. The wide choice of sampling heads combined with this design concept assures the user of a system that can be easily changed to accommodate current needs. In addition, the availability of wide range sampling sweep units (100 ps/div — 500 ms/div with digital delay,) assures the user of a time window with adequate resolution. The ability to upgrade a complete system by replacing only the sampling head provides an inexpensive hedge against system obsolescence.

The Type 230 Digital Unit is the heart of Tektronix systems. In addition, programmable sampling units, programmable pulse generators, sampling heads, and programming devices have been developed. These units serve as building blocks for simple and complex systems. Options such as disc memories, punched tape readers, tape punches, and probe choppers, have also been developed to provide the answer for a wide variety of applications.

Tektronix system components are designed to serve two distinct markets. First, they have been designed to serve as components for the user to combine as he wishes. For example, if a test equipment engineering group is available, Tektronix systems are ideal for use as building blocks for more complex custom testers. Secondly, Tektronix offers digital measurement systems, including the systems engineering necessary for a particular measurement requirement. These systems are composed of Tektronix catalog products with additional equipment such as programmable pulse generators, programmable power supplies, fixtures, equipment racks and other equipment added to them.

Tektronix digital instruments provide digital readout of measurements that may also be displayed in analog form on a CRT. They offer measurement speeds in excess of 100 measurements per second, external programming of nearly all manual operations, and BCD data output (1 2 4 8). They allow dynamic switching time measurements to be made with greater speed, accuracy, and repeatability than a direct CRT measurement.

One of the unique aspects of the current line of Tektronix digital instrument components is the ability to correlate information between development, pilot production, and volume production. The wide choice of Tektronix programming options combined with the state-of-the-art performance provides an economical tester over a wide range of test requirements. For example, a small manual tester in a development phase uses the same basic measurement section as a high-speed production system even though that system is capable of elaborate program branching and a library of 1600 measurements. This uniformity of test conditions eliminates one of the major hazards of changing a device from a development environment into a production environment.

*Al Zimmerman, "The State of the Art in Sampling," Tektronix Service Scope, October 1968, pages 2–7.

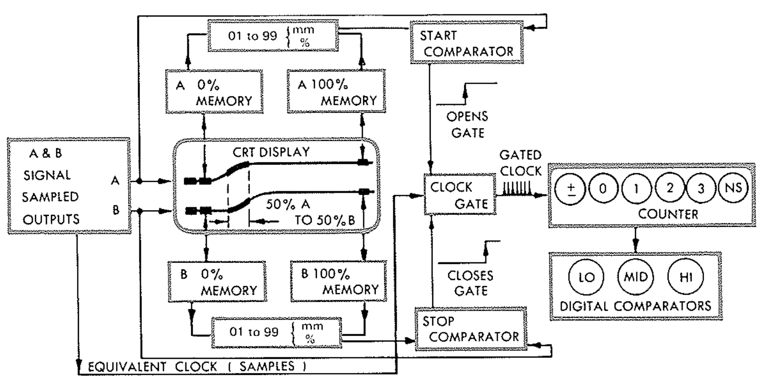
The Type 230 Digital Unit

The heart of Tektronix Digital Systems is the Type 230 Digital Unit which operates in conjunction with programmable sampling units. The diagrams below illustrate how the counts are derived for voltage and time measurements.

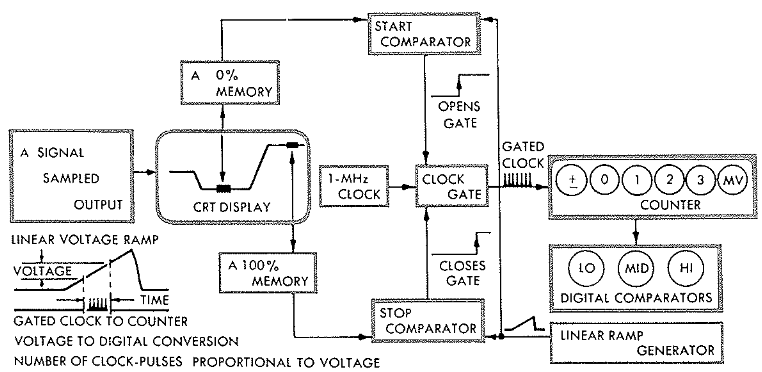
The sampling plug-ins construct a display with each signal repetition contributing a sample. Because the samples per division are accurately controlled, the count of samples between 2 selected portions of a waveform is an accurate measure of the elapsed time. 0% to 100% intensified zones are generated that are variable in .5-cm increments by means of a 20-position switch. By using these zones and the signal delay, the user positions the 0% and 100% zones as desired. After the first sweep, the amplitudes corresponding to the zones are stored in memory circuits. Changes in amplitude automatically re-establish new 0% and 100% memory amplitudes.

In a typical time measurement, digitally selected voltage divider taps between the 0% and 100% memory outputs are set for start and stop timing in 1% (or 1 mm) increments of either waveform of a dual-trace display. The selected percentage reference levels are then compared against the sampled input waveform on the second sweep. Coincidence of the waveform amplitudes with the selected percentage reference amplitudes is sensed by comparators which open and close the clock gate to the digital counter. The CRT display can be intensified for the duration of the measured interval as a reference check. The number of clock pulses are read out digitally in nanoseconds, microseconds, milliseconds, or seconds with decimal points included.

To measure voltage, start and stop comparators gate 1-MHz clock pulses for the period of time that a linear ramp voltage is at values between the 0% and 100% amplitudes. The number of clock pulses is proportional to the voltage between the selected measurement points. Readout is in mV and V with decimal points included.



TYPE 230 Time Measurement



TYPE 230 Voltage Measurement

Incoming inspection is also an application that Tektronix measurement systems handle well. 100% dynamic testing now becomes feasible for incoming inspection of IC's, whether the 15-measurement Type 241 or the 1600-measurement Type 240 with disc option is used. Both cases allow measurement rates of over 100 measurements per second, and as a result component handling sets the maximum test rate in practice.

PROGRAMMING DIGITAL MEASUREMENTS

Once a user has become familiar with the Type 230/568/System (with sampling plug-ins) and has determined that some repetitive testing is required, the Type 241 Programmer is a logical choice. There is sufficient external programming capability to control a Type 230/568/3T5/3S5 and an additional 14 lines for external equipment (159 total lines). The programmer may be used manually or in the automatic sequence modes. Measurement limits may be programmed and out-of-limit conditions can stop the measurement sequence if desired.

A system composed of these units is ideal, both for bench use where similar tests are being conducted often, and for small pilot runs where devices are being characterized.

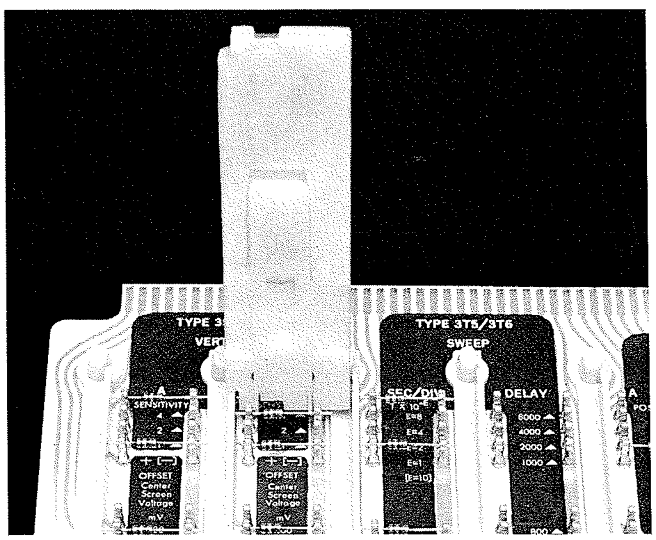


Fig 2. Type 241 program card with diode insertion tool. The card and tool are polarized so the diodes cannot be inserted incorrectly.

To prepare a program the user inserts the diodes provided into special mounting clips on the card with a special tool. Up to 15 different measurements may be programmed for any measurement sequence. The Type 241 also has storage space for 15 additional program cards.

Fig 3 shows a card being programmed for a risetime measurement. Most individual measurements require 15 to 20 diodes to be inserted.

An important feature of all Tektronix externally programmed digital systems is the high-speed program mode of operation. When the system is operating in this mode, the time base runs at a low-sample density of 100 samples per sweep when the instrument is not measuring. During the measurement portion of the sweep, however, 1000 samples are used for greater resolution. This feature eliminates wasted samples and allows testing rates well in excess of 100 measurements/second.

A unique feature of the external program mode is that measurements may be made that can not be performed in the manual mode. The figures below illustrate two such applications. In addition, if printed data output is required, printers are commercially available to connect directly to the Type 230.

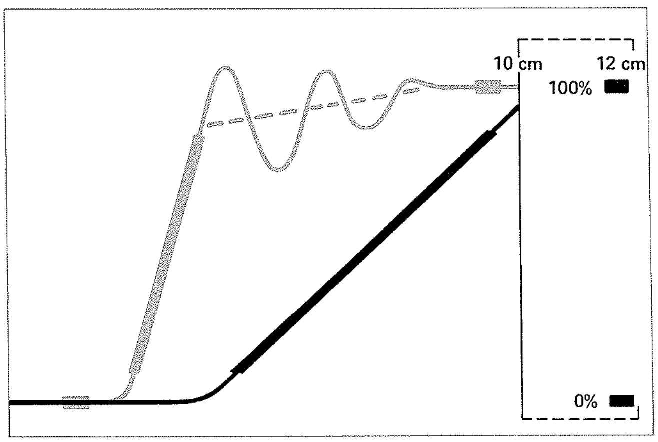


Fig 3. Externally programming the 0% and 100% to 12 cm keeps the memories from discharging after each sweep. A faster sweep may then be used for additional resolution in risetime measurements where ringing or dribble up is present.

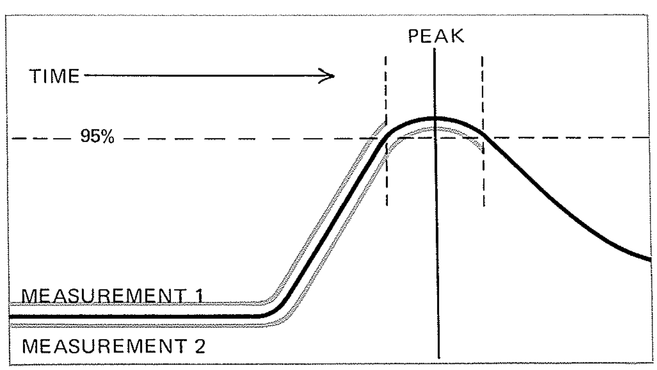
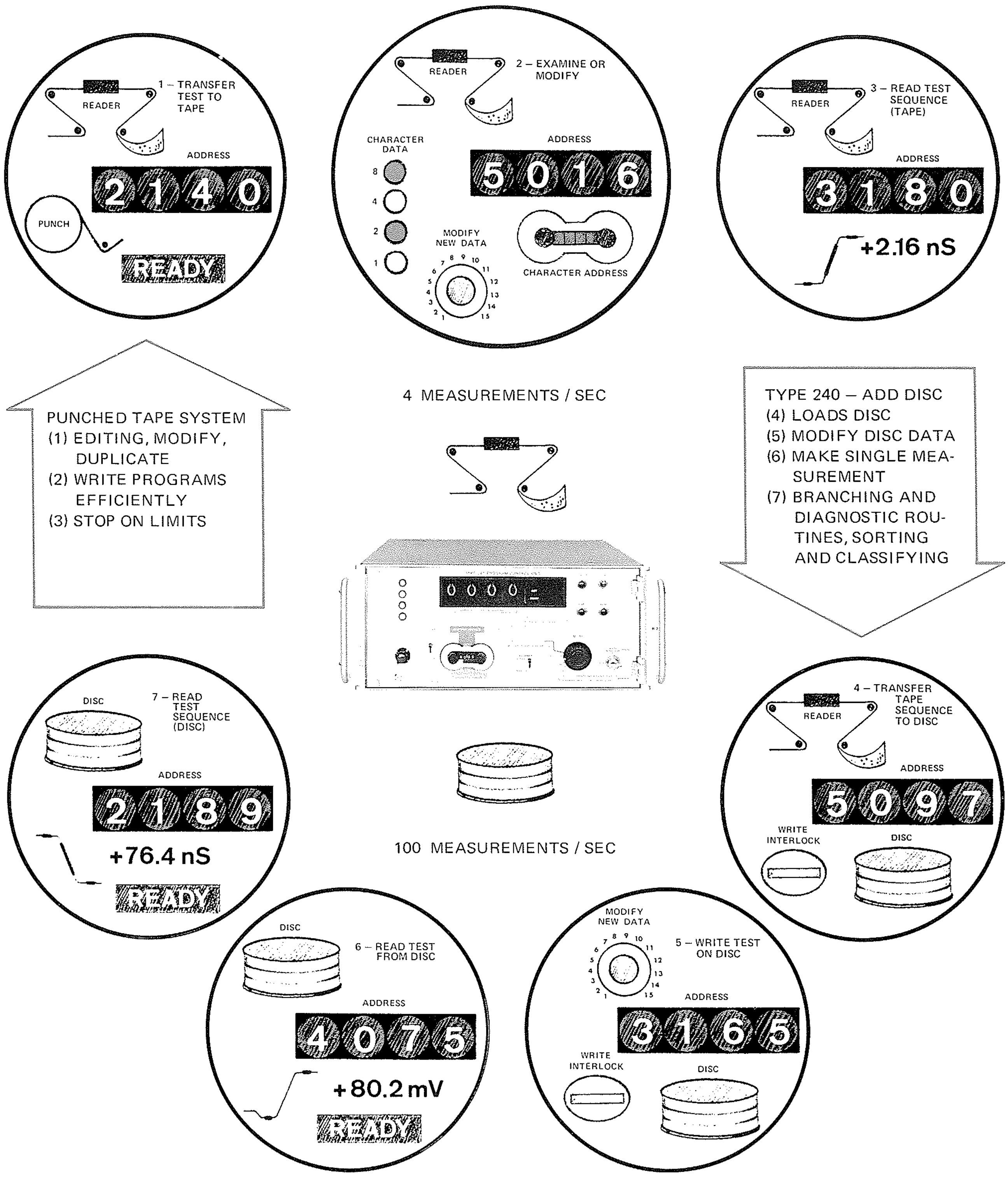


Fig 4. External programming allows inhibiting the counter reset in time-to-peak measurements. Thus two consecutive counts may be added (and divided by two if that line is not in use) to obtain an average value.



PROGRAMMING MODES OF THE TYPE 240. In the tape system above, the reader loads the shift register which allows: (1) a complete program tape to be punched; (2) program characters to be easily modified; (3) a complete measurement sequence to be made. In the disc system the random access disc loads the shift register which allows: (4) load shift register with tape reader and write data on disc; (5) store modified data on disc sector selected; (6) a single measurement to be made and; (7) a measurement sequence to be made (return to ready at sequence end).

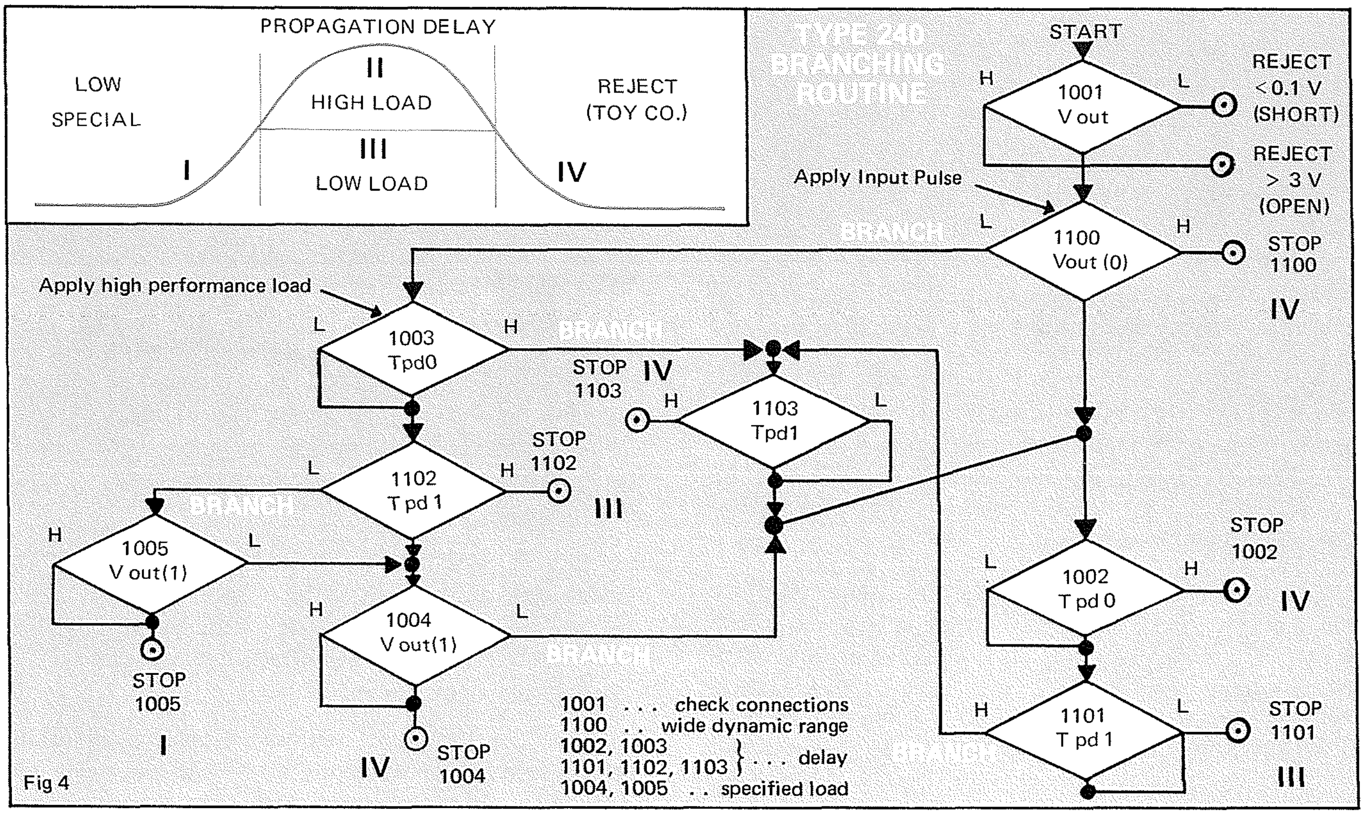


Fig 4

If the programming requirement is for greater than 15 measurements, or if program branching for diagnostic testing is desired, the Type 240 Program Control Unit is the logical choice. The Type 240 is designed to offer a flexible interface between the Type 230 and high measurement-rate systems.

A Punched Tape Reader may be used with the Type 240 for low-measurement rate systems. A maximum measurement rate of 4 measurements per second is available with this technique but the Disc Memory can be added later when programs are "debugged". The Punched Tape Reader is also convenient for loading programs into the Disc Memory.

The optional Tape Punch is used with the Type 240 for generating new program tapes. (Most small computers employ a teleprinter including tape punch that may also be used). If the Disc Memory is used, programs stored in the disc may be transferred to the Tape Punch for permanent storage. The combination of the Type 240 with a Punched Tape Reader offers a versatile systems configuration at a modest price. The Disc Memory can be added when the testing rate of 4 measurements per second is no longer adequate.

The Type 240 is designed to accept program data serial-by-bit from an optional Disc Memory, serial-by-character from an optional Punched Tape Reader, or from an external source. When operating in this manner, the Type 240 acts as a 192-bit shift register which distributes parallel program instructions to the measurement section of the system. In addition, however, it contains the read, write, and control electronics for the optional Disc Memory, optional Tape Reader, and optional Tape Punch.

The optional Disc Memory provides measurement rates in excess of 100 measurements per second and offers sorting, classifying, and diagnostic test routines. The 8-track rotation disc is capable of storing 200 complete measurements per track, thus permitting random access to a library of 1600 independent measurements.

PROGRAMMING LOGIC

Tektronix has standardized on the use of fixed word length for the logic in the Type 240 Program Control Unit. This compromise was chosen because of its efficiency and flexibility in automated testing use. By incorporating an examine/modify mode into the program control unit, the greatest advantages of variable word length are present (i.e. ability to take a previous program and change only those portions of the program that are different). Using fixed word length allows the opportunity to interrupt in the middle of a test sequence (i.e. measurement 21 of a 35-measurement sequence), and check each bit of data. With variable word length it would be necessary to begin at programs

1-20 since portions would be set up at the beginning and not changed after that. An additional benefit is that the test sequence may be changed at will without extensive reprogramming changes.

The advantage of fixed word length to the digital system user is that data can be taken from a disc considerably faster, and any piece of data in all the registers may be monitored easily. The examine/modify mode allows changing the old program, writing it on the disc and punching a new tape from the disc.

The examine/modify mode is an extremely useful mode on the Type 240. When this mode is in operation character data lights indicate the data that is in the shift register. Characters may be selected by character address switches and the characters can then be modified by the modify pushbutton.

One of the inherent advantages of using the Disc Memory with the Type 240 is the ability to branch to a new measurement sequence as shown in fig 4. This then allows reclassifying of the device. This feature is also useful for checking-out of complete boards and assemblies. For example, if a signal is not found at the output, the program changes to a prior stage until the desired response is found. Automatically, the problem has been located to a stage instead of merely being rejected.

One of the most important features of the Type 240 is the ability to error-check all incoming data by means of a parity check. Thus if there is a transmission error it will likely be found before it creates a measurement problem.

The Type 250 Auxiliary Program Unit is designed to provide 192 additional program lines (48-4-bit characters) for use in conjunction with the Type 240. This allows programming of pulse generators, power supplies, fixtures, or other peripheral equipment. Program buffering, including level conversion, level inversion, and D-to-A conversion are also performed by this unit. The Type 250 requires systems engineering and intra-connection wiring for operation. Program assembly cards consisting of shift register cards (serial-to-parallel conversion), and program boards (negative logic, resistance, and conductance) provide for versatile control of programmable functions.

Up to 2 Type 250's may be added to a Type 240 to extend programming capability. When 2 Type 250's are used with the disc memory, then the test format is a fixed word length of 144 4-bit characters and a 1080 measurement library is available.

The modular design of Tektronix digital components offers a wide range of versatility for measurement systems. The ability to upgrade the bandwidth of the system by replacing only the sampling heads ensures a useful testing system after the original test requirements are completed. The ability to add to a system at any time, with a minimum of interfacing problems, assures the user that his tester will not become obsolete.

TEKTRONIX DIGITAL SYSTEM COMPONENTS

TYPE	DESCRIPTION	PROGRAM LINES	PRICE
	DIGITAL AND PROGRAM UNITS		
230	Digital Unit	104	$2965
240	Program Control Unit	192	3750
241	Programmer	159	1950
R250	Auxiliary Program Unit	192	1400
	PULSE GENERATORS		
R116 MOD 703 L	Programmable Pulse Generator	79	2775
R293 MOD 703 M	Programmable Pulse Generator	14	1300
	PLUG—IN UNITS		
3A2	Analog/Digital Unit DC 500 kHz	–	520
3B2	Analog/Digital Time Base Unit 2 μs - 1 s	–	675
3S1	Dual-Trace Sampling Unit	–	1150
3S2	Dual-Trace Sampling Unit*	–	800
3S5	Programmable Sampling Unit*	27	1450
3S6	Programmable Sampling Unit*	27	1450
3T2	Random Sampling Sweep Unit	–	990
3T5	Programmable Sampling Sweep	28	1550
3T6	Programmable Sampling Sweep	28	1550
3T77A	Sampling Sweep Unit	–	690
	SAMPLING HEADS		
S1	350-ps Sampling Head	–	250
S2	50-ps Sampling Head	–	300
S3	350-ps Sampling Head	–	375
S4	25-ps Sampling Head	–	750
	OPTIONAL ACCESSORIES		
Disc Memory	8-Track Disc Memory	–	6600
Tape Punch	Tape Punch	–	1250
Punched Tape Reader	Punched Tape Reader	–	2500

* Accepts two sampling heads

Service Notes

Chuck Phillips, of our factory repair center, passes along the following hints

REPLACING GRATICULE LIGHTS

A boot from an alligator clip makes an excellent bulb remover for graticule light bulbs. It is only necessary to clip a little material from the small end of the boot. Push the boot in so it grasps the end of the bulb snugly. Once the bulb is held firmly, it is only necessary to turn CCW and the bulb is easily removed.

Graticule lights should be replaced when the bulb darkens appreciably or uneven graticule illumination can occur.

Fig 1 illustrates a situation where one bulb was replaced and a dark bulb not replaced. Note the unevenness of the graticule illumination.

Fig 2 is the identical situation with both bulbs replaced.

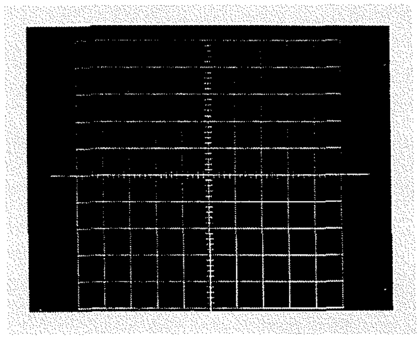


Fig 1. Uneven illumination.

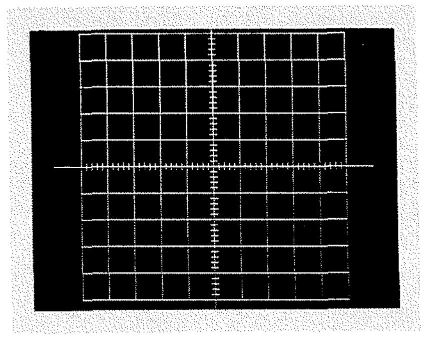
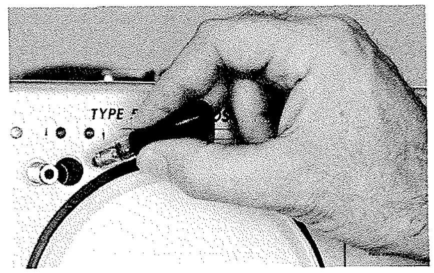


Fig 2. Dark bulb replaced.



INSTRUMENT APPEARANCE

Chuck also suggests that a liquid glass cleaner and furniture wax be available when calibrating equipment. The glass cleaner does an excellent job of cleaning graticules, CRT's, filters, and front panels. The furniture wax restores dull side panels and front panel knobs to a like-new appearance. In order to avoid too much wax Chuck suggests that you spray onto a cotton pad and then do the buffing with the pad. A few moments spent on optimizing the appearance of an oscilloscope can contribute greatly to the overall appreciation of the calibration effort.

USED INSTRUMENTS FOR SALE

1—Type 647 Transistorized Scope, compact, with full-size CRT. Also 10A2 dual trace preamp and 11B2A dual sweep base. Scope rated 50 MHz, updated time base allows steady triggering to 130 MHz. Purchased April 1967, offered at $800. Contact: Mr. John Cone, 775 South Madison, Pasadena 91106. Telephone: days (213) 351-2320, eves (213) 792-5271.

1—Type 532, SN 7302; 1—Q Unit, SN 1206, with extra P7 CRT. Contact: Ken Reeves, Omark Industries/CCI Division, Box 660, Lewiston, Idaho. Telephone: (208) 776-2351.

1—Type 321A. Contact: Dick Bastyr, Research, Inc., Box 6164, Edina Station Minneapolis, Minnesota 55424. Telephone: (612) 941-3300.

1—Type 321A, SN 002605, complete with battery pack, carrying case, probe. Price: $750.00. Contact: Jerry Erickson, Republic Electric & Development Co., 1050 W. Ewing Street, Seattle, Washington 98119. Telephone: AC (206) 284-5200.

1—Type 531 Oscilloscope, SN 21800, new CRT, excellent condition; 1—Type CA Plug-In, SN 40226. Price: $500. Contact: D. Terazawa, Hewlett-Packard Co., 175 Wyman Street, Waltham, Maryland, 02154. Telephone: (617) 894-6300, ext. 334.

1—Type 2A60; 1—Type 3A72; 1—Type 3A1. Contact: Brian Somodi, Meditron Company, Santa Ana, California. Telephone: (714) 541-0468.

1—Type 310A, SN 020673. Contact: Mrs. Minet, 679 W. Glenoaks Blvd., Glendale, California. Office Telephone: (213) 225-6171.

1—Type C-30 Camera. Contact: Mr. John Strapman, Lumidor Products, 2500 W. 6th Avenue, Hialeah, Florida 33010. Telephone: (305) 887-7421.

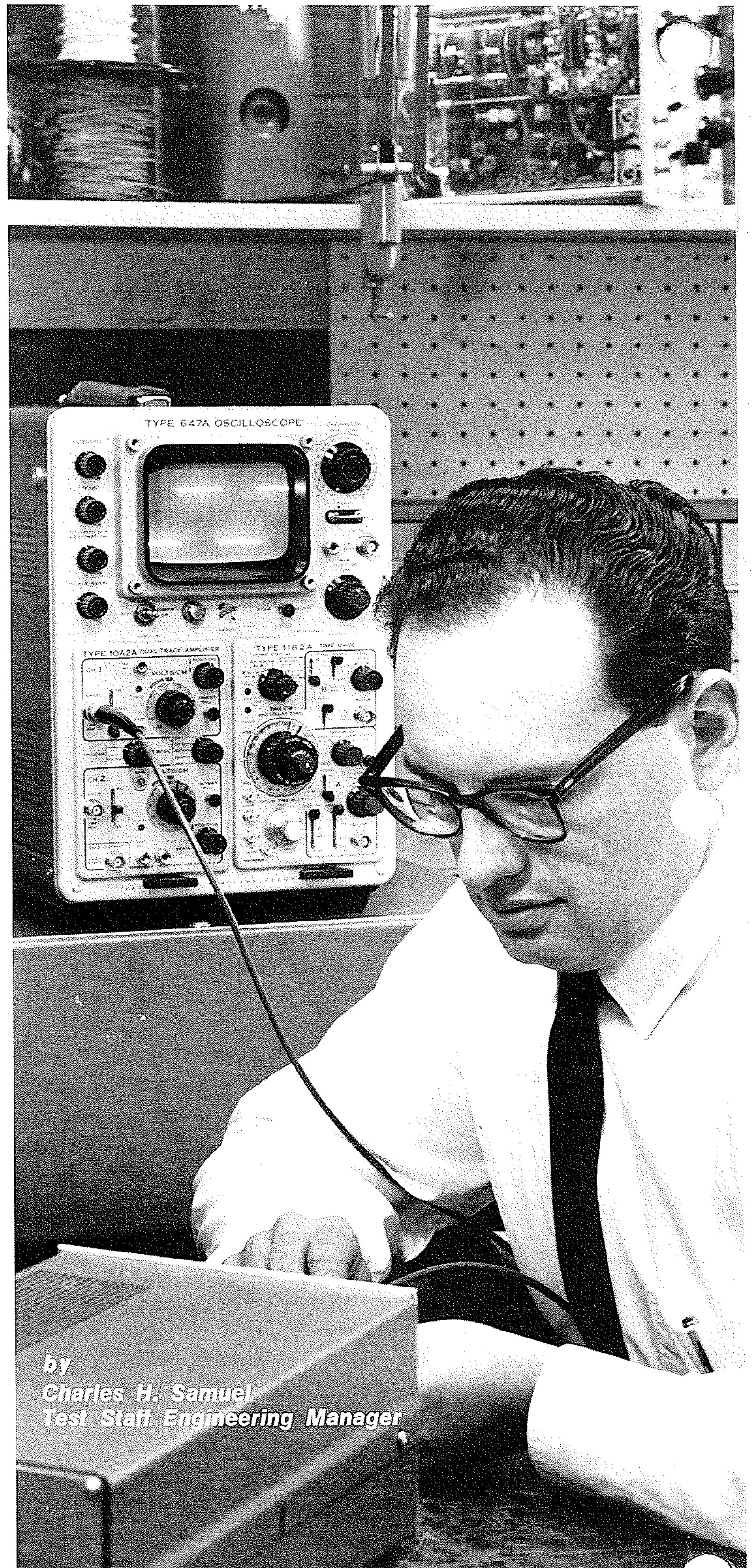
1—Type 190A, SN 6047; 1—Type 180A, SN 7726; 1—Type 107, SN 1722. Contact: Marv Kalor, Instrumentation Services, 957 Winnetka Avenue, North Minneapolis, Minnesota 55427. Telephone: (612) 544-8916.

USED INSTRUMENTS WANTED

Used Tektronix Scope-Mobile® Cart suitable for 514AD or other 5-inch Tektronix Oscilloscopes of similar size. Prefer local replies. Must be reasonable and in good condition. Contact: Dennis Brunnenmeyer, Physicist, Aerojet-General, Building 3003, Box 15847, Sacramento, California. Telephone: (916) 355-3702.

verifying oscilloscope performance

A discussion of the major factors contributing to measurement accuracy



by
Charles H. Samuel
Test Staff Engineering Manager

An oscilloscope, like other electronic test equipment, will not maintain its accuracy indefinitely. Aging of components, drift, environmental conditions and other factors make necessary regular inspections to determine if readjustments are required. Shipping an instrument from one location to another may affect accuracy and in extreme cases may cause instrument failure. Therefore, it is important to check an instrument's performance characteristics periodically to assure accuracy and to determine if calibration is required.

This article provides techniques and background information to verify the more important characteristics of general-purpose laboratory oscilloscopes. For this discussion, "performance check" is determining if a characteristic is within stated limits using a given technique. "Calibration" is adjusting controls or replacing components when a performance check shows limits have been exceeded.

All instruments should have regular performance checks at intervals determined optimum by the user; this interval is largely determined by environment, care in handling, accuracy required and the design of the oscilloscope. (Some oscilloscopes are designed to be highly reliable in adverse environments, while others are designed for laboratory environments.) A regular recalibration generally is not necessary if the performance check indicates that no characteristics are outside their limits.

The measurement methods given here are general ones; when an instrument's instruction manual lists a different method, the method listed in the manual should be used. It must be emphasized that the results of a measurement depend upon the method used and if a single characteristic is measured by two methods, two different results might be expected.

Test Equipment

Selecting the proper test equipment is a most important factor in checking oscilloscope performance. Inaccuracies in test equipment show up as apparent inaccuracies in the oscilloscope under test. As a rule of thumb test equipment should be four to ten times more accurate than the accuracy of the item being tested.[1,2] Resolution capability of the test equipment must also be adequate to insure a measurement not adversely limited by the test equipment. For instance, one would not check a 20 mV ±2% DC voltage source with a voltmeter having a maximum resolution of 1 mV (5% of 20 mV). In some cases it may be detrimental to have test equipment that is "too good" for the measurement being made. For instance, measuring instrument risetime with a step more than 10 times "faster" than the expected risetime can show errors that are due to the waveform used. Tektronix instrument manuals contain a complete listing of the test equipment required for instrument calibration.

Measurement and Nonmeasurement Characteristics

Oscilloscope performance can be broken down into two categories: Those that affect measurement accuracy, such as deflection factors and sweep times, and those that affect performance but don't affect measurement accuracy, such as triggering and writing speed.

In the following, only the most important general-purpose laboratory oscilloscope characteristics have been included. Specific oscilloscopes may have other important characteristics not listed here.

MEASUREMENT CHARACTERISTICS

Vertical Deflection Factors

The vertical deflection factor is the ratio of the amplitude of the input signal to the deflection on the cathode-ray tube, usually given in volts per division of deflection. Measurements of deflection factor accuracy should be made at or below the upper reference frequency discussed under bandwidth (between the two reference frequencies if the amplifier is AC coupled). If a probe is to be used with the oscilloscope, the vertical deflection factors should be checked with the probe in place, as shown in Fig 1.

For each attenuator setting (volts per division) apply a signal with accurately known amplitude to the vertical input of the oscilloscope. The amplitude of this signal should be sufficient to result in 50% to 80% of full graticule vertical deflection (closer to 80% is preferable from the standpoint of resolution on the cathode-ray tube). Carefully measure the deflection on the cathode-ray tube with the graticule and divide the known input voltage by the divisions of deflection. The quotient is the actual deflection factor and can be compared with the stated deflection factor to determine the percent of error. In some oscilloscopes the deflection factor may not be constant throughout the vertical dimension of the graticule. There may be slight errors in the deflection factor due to compression and expansion type nonlinearities. It is possible to check for this nonlinearity by centering a two-division display, then positioning the top of the display to the top of the graticule, measuring any changes in amplitude. Next, position the bottom of the display to the bottom graticule line, checking for any changes in amplitude. This type of nonlinearity usually ap-

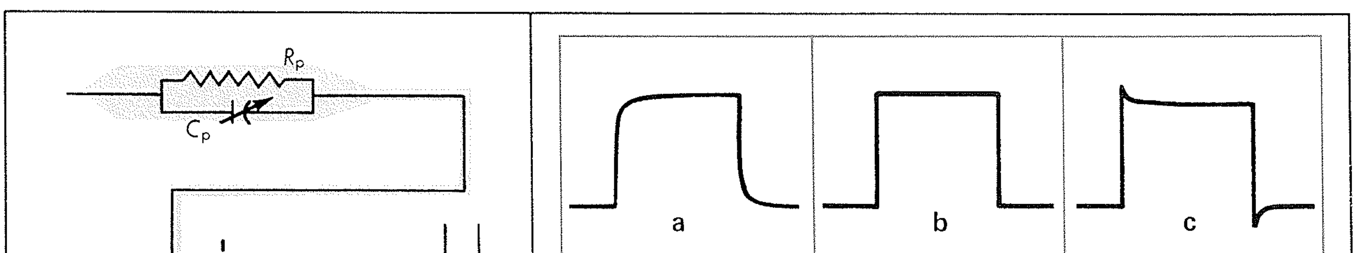


Fig 1. Probe compensation circuitry. Note that when R_pC_p = RC the compensation is correct, and both high and low frequencies are attenuated evenly.
a) Undercompensated display R_pC_p < RC
b) Properly compensated display R_pC_p = RC
c) Overcompensated display R_pC_p > RC

pears only at the graticule extremes. Therefore, if there is a need to make precision measurements with full graticule deflection or with smaller deflections positioned toward the top or bottom graticule limits, any nonlinearity measured should be taken into account.

Horizontal Time-Base Accuracies

Time-base steps are the deflection factors for the horizontal axis of the general purpose laboratory oscilloscope. They are expressed in terms of time per division of deflection. A known accurate time-mark generator is the most convenient signal source for making sweep-time measurements; however, an accurate sinewave generator can be used also. Internal graticules assist greatly in accurate sweep time measurement.

To measure time-base accuracies, apply accurate time marks or a sinewave corresponding to one mark or cycle per graticule division. Position a mark at the graticule line that starts the area to be measured. Next, determine the difference between the graticule line ending the area to be measured and its associated mark, and express this difference as a percentage of the area measured. Due to possible edge nonlinearities, sweep times are typically measured from graticule line 1 to 9 (see fig 2).

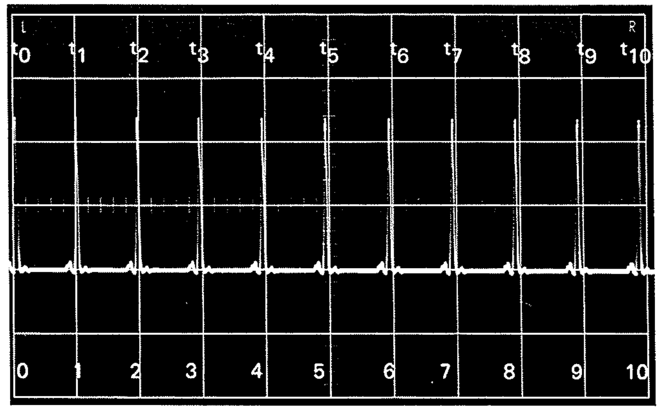


Fig 2. Example of timing 1.25% short.

Example: If the timing is to be measured over the center 8 divisions of the graticule, align t_1 with graticule line 1 and note the position of t_9 in relation to line 9. If t_9 is superimposed with line 9, there is no error; if it misses by 0.1 division, the timing is $0.1/8 = 0.0125$ or 1.25% "long" or "short."

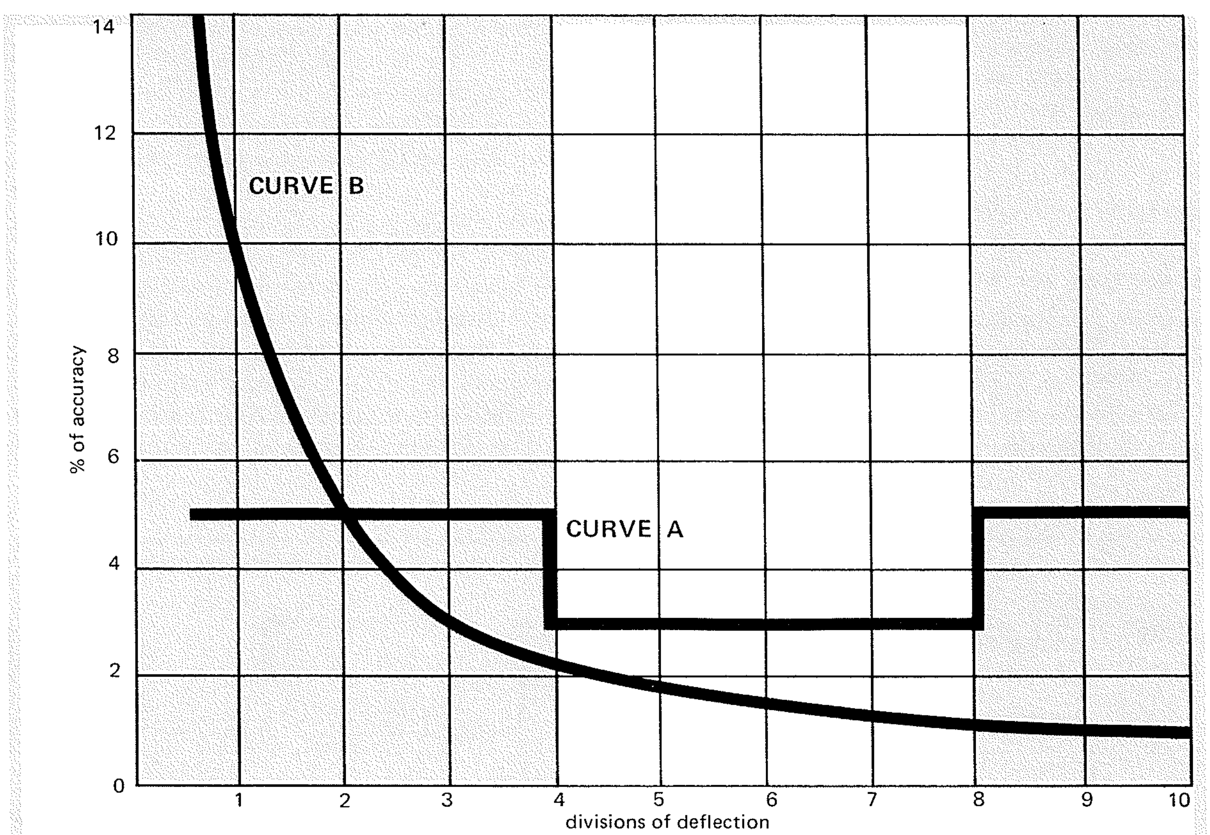


Fig 3. Accuracy vs. length of measured intervals. Note that a measured interval of 4–8 divisions provides optimum display accuracy. The shaded area at left is due to sweep non-linearity and resolution while the area at right is due to CRT non-linearity. Curve A may be shifted downward by optimizing on a single sweep speed and limiting temperature excursions.

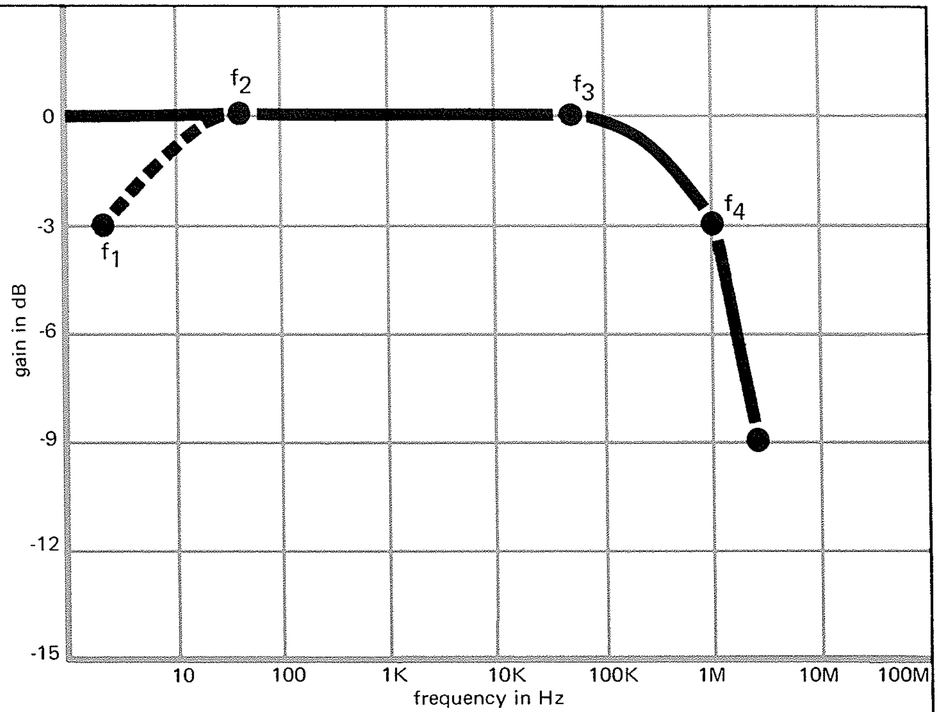


Fig 4. Bandwidth curve for a 1—MHz Oscilloscope. Solid line for DC coupling. Dotted line for AC coupling with a lower bandwidth of 2 Hz.

f_1 — lower bandwidth limit AC (2 Hz)
f_2 — lower reference frequency (2 Hz x 20 = 40 Hz)
f_3 — upper reference frequency (1 MHz/20 = 50 kHz)
f_4 — upper bandwidth limit (1 MHz)

A recent trend is to indicate an accuracy for the time base at different lengths of deflection, thus combining accuracy and linearity measurements. Timing errors, basic linearity errors and errors caused by lack of resolution combine and increase as the length of deflection on the cathode-ray tube face becomes less. For instance, a time base might have a timing accuracy within 3% over any 4 to 8 division segment but if measurements are to be made over less than 4 divisions, accuracy must decrease because of linearity problems and resolution errors. Curve A, figure 3 shows how a sweep with a basic accuracy of $\pm 3\%$ might be described. Assuming an ability for the observer to resolve 0.1 division intervals on the graticule, Curve B illustrates the additional error that can occur due to resolution considerations. The accuracy of any given measurement will be a combination of these two factors. It is possible to get around some resolution problems by measuring to exact graticule lines, using optical magnification, etc.

Bandwidth and Risetime

Bandwidth (bw) and risetime (t_r) are related by a constant in any given oscilloscope. (If the display amplifier has a gaussian response: bw in MHz x t_r in ns $=$ 350.) Therefore, only one of these two characteristics needs to be measured. Risetime can usually be displayed over only a portion of the graticule and the accuracy of the measurement is dependent on sweep timing and resolution. Bandwidth can be measured more accurately, so quite often bandwidth is measured and risetime is calculated based on it.

Bandwidth is defined as the upper and lower limits of the band of frequencies an oscilloscope can display, its gain constant within 3 dB. Bandwidth is measured with a sinusoidal waveform to the first 3 dB down point ($\approx 30\%$) from the amplitude of a reference frequency (30% down rather than -3 dB is used because 30% is more easily read on a conventional graticule).

Bandwidth — Upper Frequency Limit

Apply a sinewave of 1/20 the upper bandwidth limit or less (reference frequency) from a constant amplitude sinewave generator to the oscilloscope vertical input. Adjust controls for a centered display of about 80% of the graticule height. Increase the frequency of the sinewave (its output amplitude must not be changed) until the display is 70% of its amplitude at the reference frequency. This frequency is the upper bandwidth limit.

Bandwidth — Lower Frequency Limit

In a DC-coupled oscilloscope the lower frequency limit is DC and the gain at DC should be equal to the gain at the upper reference frequency, not 3 dB down from it. Also, in a DC-coupled oscilloscope only the upper bandwidth limit may be given; that is, BANDWIDTH: 30 MHz means that the bandwidth is DC to 30 MHz.

An AC-coupled vertical amplifier has a lower frequency limit. To measure this, apply a lower reference frequency sinewave 20 or more times the frequency specified (not to exceed the upper reference frequency) from a constant amplitude source to the vertical input. Adjust controls for a centered display amplitude which is about 80% of the graticule height. Decrease the sinewave frequency until the displayed amplitude is 70% of the lower reference frequency amplitude. This frequency is the lower frequency limit.

In both the upper and lower frequency limit measurements the source impedance and harmonic distortion of the sinewave can have a pronounced effect on the result; these should be as specified by the oscilloscope manufacturer or should be accounted for in the results of the measurement.

Risetime

As noted before, risetime is related to bandwidth and it probably is not necessary to measure risetime if bandwidth is satisfactory. Risetime is a measurement, on the display of a step-function waveform, of the interval between the instants at which the amplitude first reaches 10% and 90% of the reference amplitude (figure 4).

Apply a step-function with a risetime from 4 to 10 times "faster" than that of the oscilloscope to be measured. Measure the time required for the waveform to go from 10% to 90% of its amplitude. If a step function with a risetime less than 4 times "faster" must be used, the risetime of the oscilloscope (t_r scope) can be approximated as follows: $(t_r \text{ scope})^2 = (t_r \text{ measured})^2 - (t_r \text{ step})^2$. Sweep-time inaccuracies and resolution must be accounted for in the measurement.

Amplitude Calibrator Accuracy

Several kinds of amplitude calibrators are provided on general-purpose laboratory oscilloscopes. Their main purpose is to provide a voltage amplitude of known accuracy. The output waveform can be a sinewave but is most commonly a squarewave.

In some calibrators the waveform-producing circuitry can be disabled and the calibrator provides a DC voltage equal to the peak-to-peak value of the normal squarewave output. With this kind of calibrator, disable the waveform-producing circuitry and measure the output voltage with a differential or digital voltmeter. A digital voltmeter with automatic ranging makes it convenient to measure all calibrator output voltages in sequence, quickly. Compare the measured voltages with the labeled ones and determine the percentage error. Return the waveform-producing circuitry to its operating condition. Care should be taken that the voltmeter has the accuracy and resolution for the task, and that it does not present too great a load to the calibrator.

If the calibrator waveform-producing circuitry cannot be disabled, it can be checked with an oscilloscope which has a slideback voltmeter preamplifier. Both peaks of the calibrator's output waveform can then be compared dynamically to the slideback voltmeter's comparison voltage and the calibrator amplitude can be determined. A slightly less accurate method of checking the calibrator amplitude is to first calibrate the oscilloscope for a given display from a known amplitude voltage equal to the nominal calibrator voltage. Remove the known voltage and apply the calibrator voltage and measure it on the calibrated oscilloscope.

NONMEASUREMENT CHARACTERISTICS

Some characteristics of an oscilloscope's performance do not directly affect the accuracy of measurements but determine whether or not a measurement can be made. Two of these are triggering performance and writing speed.

Triggering

Measuring an oscilloscope's triggering performance is mainly a process of applying the proper signals and checking to see that a stable display is possible. Internal triggering is checked by applying signals of the specified amplitude and frequency to the vertical input and monitoring to see that a stable display can be obtained. The same procedure is followed for checking external triggering performance but the signal must be also applied to the external trigger input.

After checking the basic triggering, any special functions can be checked on a performance basis. When using automatic triggering the display should be stable when the specified signal is present and a trace should be displayed when no signal is present. AC, low frequency reject triggering should operate normally at frequencies above a few hundred Hz and only respond to large signals at 60 Hz.

Writing Speed

Writing speed is a figure of merit which describes the ability of a particular camera, film, oscilloscope, and phosphor to record a fast moving trace. Until recently this subject has been surrounded by some mystery. Recent studies indicate that there are measurement methods which are repeatable by most oscilloscope users.[3]

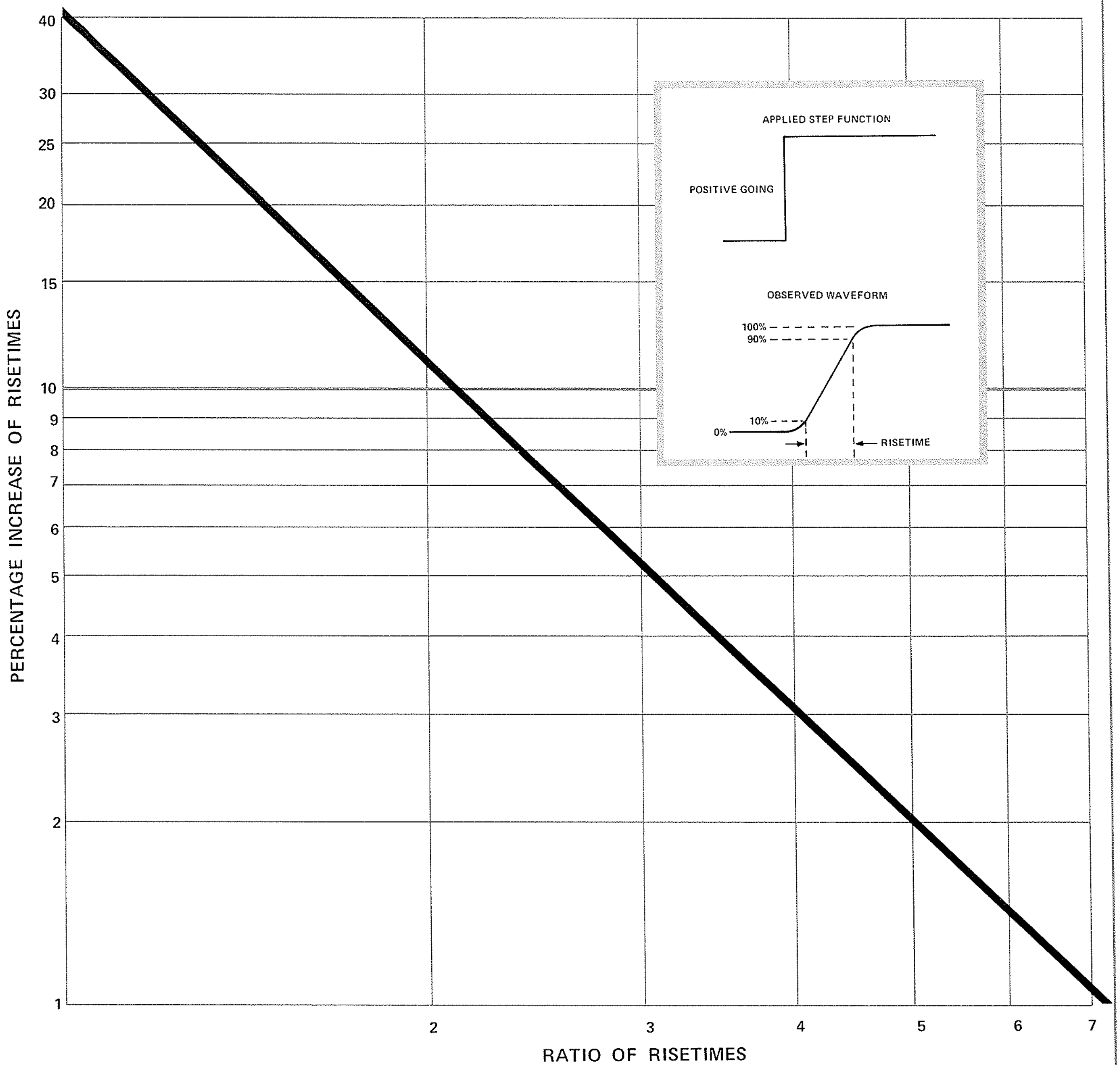


Fig 5. Percentage increase of net risetime vs ratio of risetimes for two cascaded devices. For example, a 2-ns oscilloscope monitoring a 10-ns signal (5:1 ratio) would permit an observation with an error of 2%. Note that if the risetimes are equal the error is 41%.

References

1. Russell, F. C., 'Industry's View of the 10:1 Ratio-of-Accuracy Requirement' 1966 Standards Lab Conference Proceedings p 121-123.
2. 'Calibration Program,' Standards Laboratory Information Manual, February 1968, Naval Inspector of Ordnance, Pomona, California p 1.6-1.7.
3. 'Developing a Writing Speed Specification,' Tektronix SERVICE SCOPE, April 1968 p 2-7.

SERVICE SCOPE

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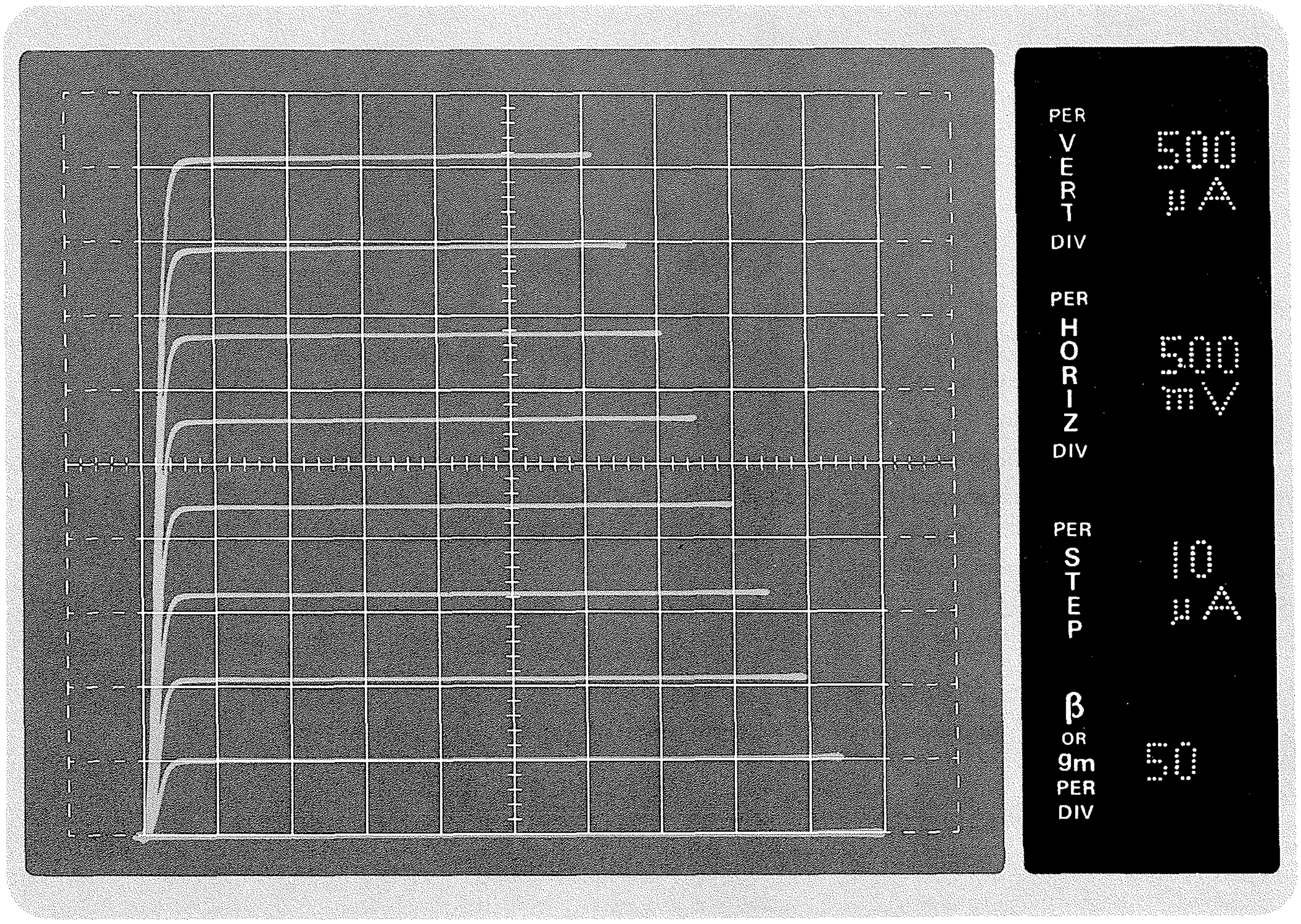
Tektronix Measurement Systems

In addition to digital system components, Tektronix offers Tektronix Measurement Systems. These measurement systems are designed to cover the range of automated dynamic measurements from small "bench" systems to high volume production and incoming inspection testers. Tektronix Measurement Systems use catalog products and add additional equipment such as programmable pulse generators, programmable power supplies, fixtures, and other equipment. Tektronix does the systems engineering to provide the digital measurement system for a particular measurement requirement. In addition, complete "systems" manuals are provided to facilitate servicing and calibration. In the case of the larger systems, Tektronix personnel install and checkout the equipment upon arrival at the customer's location. A test checkout program is provided with each system to assure proper calibration and operation of all system components.

The S-3130 Digital Measurement System is shown above. Full specifications on this, and smaller Tektronix Measurement Systems, are given on pages 27 - 47 of the New Products Supplement to Tektronix Catalog 27 (1968). For additional information contact your Tektronix Field Engineer.

TEKSCOPE

FEBRUARY 1969



A NEW DIMENSION IN CURVE TRACING . . . readout and other advanced features provide new measurement capabilities . . . page 3
SERVICE SCOPE . . . beginning, a guide for localizing instrument problems . . . page 8
AN EXTENDED VALUE . . . 2 new oscilloscopes and 25 plug-ins offer a wide spectrum of performance . . . page 12

TO OUR READERS

WELCOME TO TEKSCOPE. You may have noticed a change in SERVICE SCOPE over the past few issues. Our new name more accurately reflects our continuing effort to provide informative articles, presented in a readable manner, across the whole of Tektronix technology. Each issue of TEKSCOPE will contain articles describing instruments, measurements, and techniques.

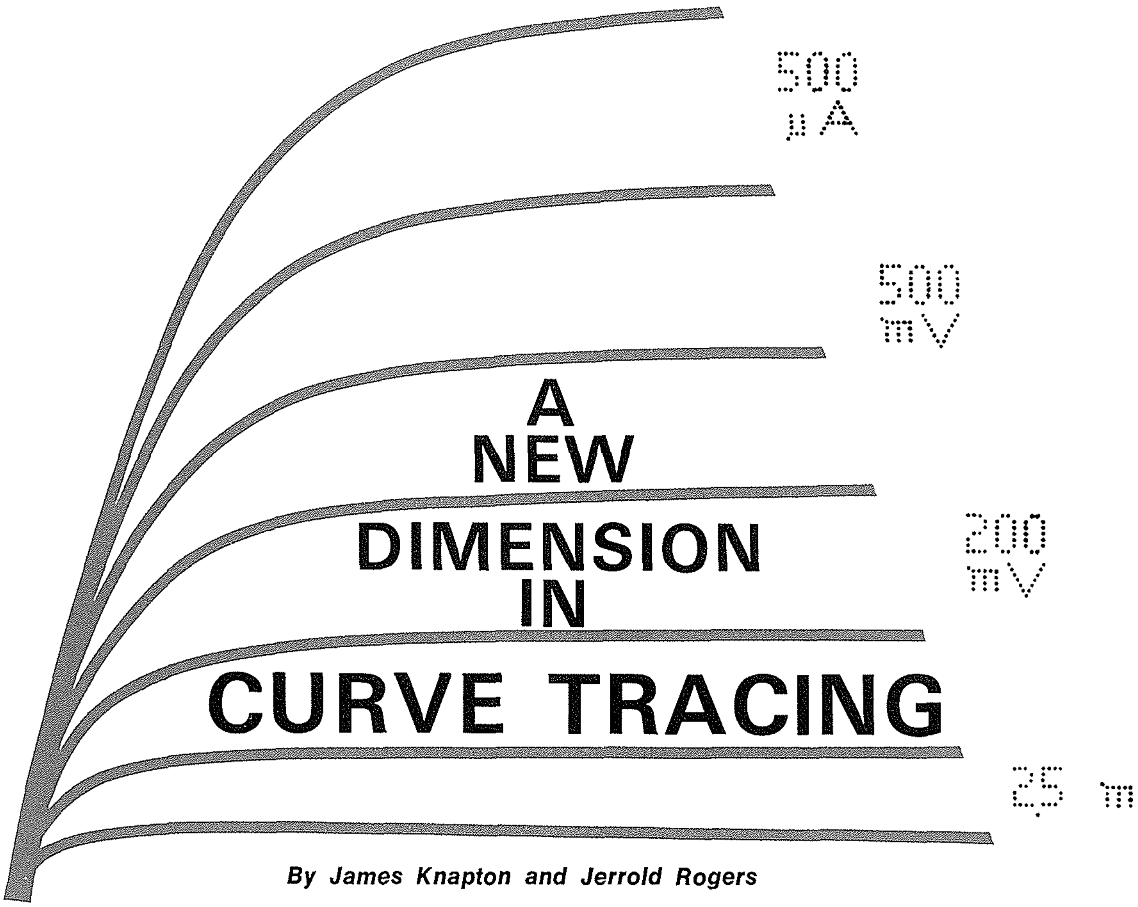
SERVICE SCOPE remains as a feature of TEKSCOPE and will continue to provide information for those responsible for the quality of instrument performance.

We appreciate your interest in Tektronix and welcome your comments on our format.

NOTE: If the address on your issue is incorrect or if you have a friend who would like to receive TEKSCOPE, please call or drop a note to our nearest field office.

COVER: The Type 576 Curve Tracer combines a large-screen CRT with a unique readout capability to provide a new standard for semiconductor measurements (shown actual size).

A NEW DIMENSION IN CURVE TRACING



By James Knapton and Jerrold Rogers

Digital readout of vertical and horizontal deflection factors, step amplitude, and beta/div simplifies curve-tracing measurements substantially. This unique capability, combined with extended measurement characteristics provide an outstanding curve tracer value.

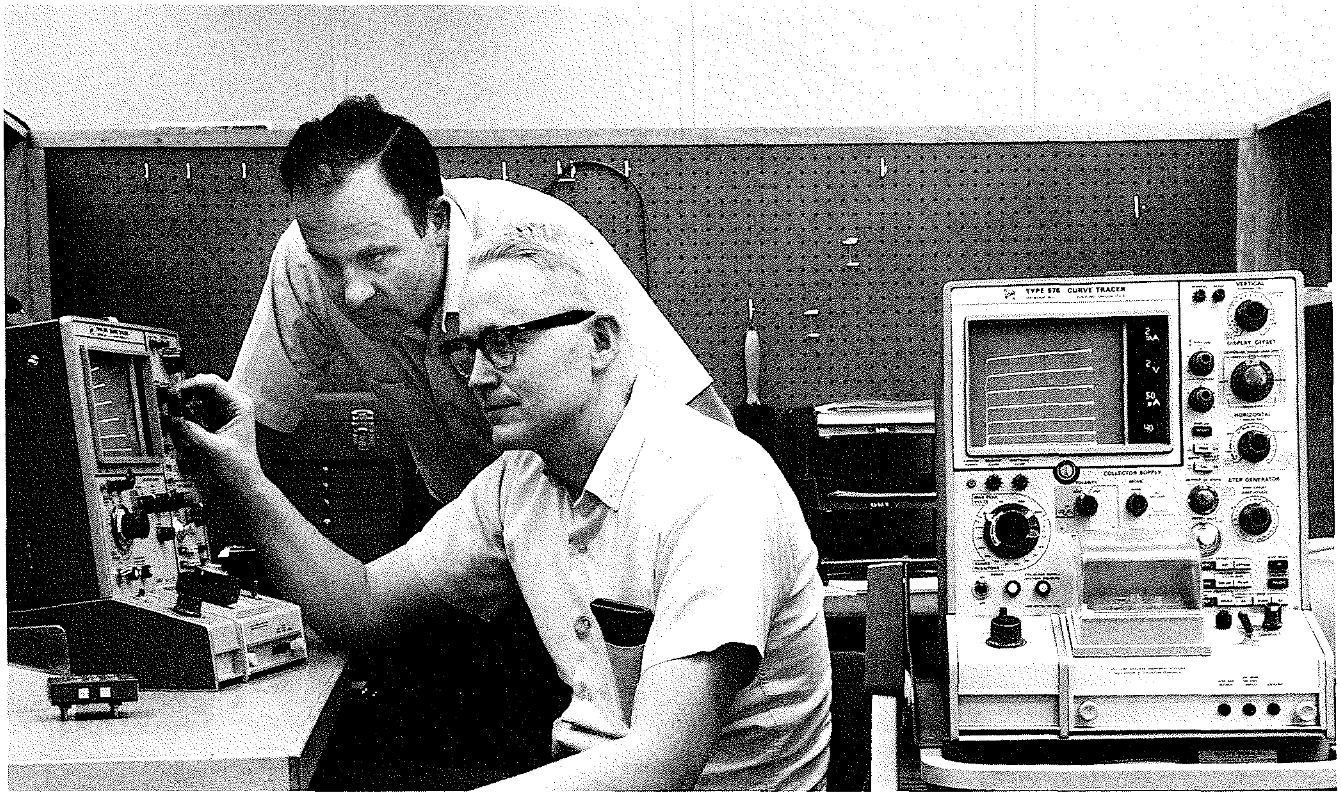
The Type 575 Transistor Curve Tracer was introduced over 10 years ago, when the semiconductor industry was in its infancy. At that time, the Type 575 Transistor Curve Tracer became established as an industry standard. Since that time, semiconductors have improved greatly and semiconductor technology has expanded to include not only transistors and diodes, but tunnel diodes, zeners, FET's, MOSFET's, SCR's, unijunctions, and a number of other useful devices.

The Type 576 is designed to meet the current and future measurement needs for these devices. In addition, the construction techniques utilized allow the instrument to adapt should related measurement needs arise.

The Type 576 is designed with a plug-in test-fixture so that operating characteristics may be changed substantially without affecting the basic instrument. This capability provides the Type 576 with greater flexibility in meeting future measurement requirements.

The most apparent development in the Type 576 is the readout feature. The fiber-optic readout display has been placed adjacent to the CRT where the user normally focuses his attention. Combining readout with the display accomplishes 3 important tasks: 1. The readout takes into consideration magnifiers and multipliers, and especially simplifies operation for new or infrequent users; 2. The necessary information for interpreting curves is automatically included on photographs, eliminating the possibility of incorrect labeling; 3. The simple, but bothersome arithmetic required to compute beta/div and g_m/div is automatically performed, eliminating another potential source of measurement error.

The readout logic, fiber-optic transmission system, and character readout sections have been placed on a single circuit card. This design concept makes it possible for the instrument to be purchased with or without the readout capability.



James Knapton, Project Manager, and Jerrold Rogers, Project Engineer, displaying a family of curves on the Type 576.

PROTECTIVE CONSIDERATIONS

An interlocked cover over the test terminals protects the operator from accidental shock in the 75-V, 350-V, and 1500-V ranges. A red light on the front panel warns the operator when dangerous potentials are present on the collector terminals. A yellow front-panel light informs the operator that the protective box must be engaged in order for the instrument to function properly.

A unique interlocking knob arrangement between the collector voltage ranges and the selectable series resistors offers a device protection feature. These concentric knobs allow the maximum power limit to be preset. As the voltage range is changed, the correct series resistors are automatically inserted to maintain the correct power limit. Six positions are available from 0.1 watt to 220 watts. This feature protects the device under test from overheating and relieves the operator of the necessity of computing which series resistor is required for device protection.

COLLECTOR SUPPLY INCLUDES DC MODE

Different modes have been incorporated into the collector sweep circuitry to provide the instrument with maximum versatility. A normal mode is provided which consists of positive or negative full-wave rectified AC (line frequency). This is the conventional mode for most measurements.

An AC mode supplies an unrectified line-frequency sweep symmetrical about 0 for viewing both forward and reverse characteristics on the same display. This is particularly useful for diode and FET testing since reverse breakdown and forward conduction characteristics may be observed simultaneously.

A DC mode provides positive or negative DC which can be swept manually by varying the variable voltage control from minimum to maximum. In this mode filter capacitors are switched into the collector supply output and the display is composed of a dot at the end of each curve. Manually varying the supply slowly traces out the curves. This mode is of particular interest when measuring low currents where trace looping, caused by device capacitance, limits resolution.

A leakage mode operates in conjunction with the DC collector mode and increases the vertical sensitivity 1000X allowing 1 nA/div displays. In this mode, the Type 576 monitors current into the emitter terminal instead of the collector. The leakage mode provides high-sensitivity displays for observing any two terminals of a device. The 1-nA/div position of this mode provides an excellent means of measuring diode leakage.

NEW DISPLAY CAPABILITIES

One of the most useful features of the Type 576 is the calibrated display offset with magnifier. This function provides 20 half-cm increments of position change (20 5-cm increments with 10X mag). Using this mode, the gain of either the vertical or horizontal deflection amplifier can be increased 10 times. This capability provides a 100-cm display on either axis with the calibrated offset showing precisely which portion of the display is being viewed. Use of display offset also increases accuracy substantially as shown in the figure below. Note that 2% measurements are typical over the largest range of the display area.

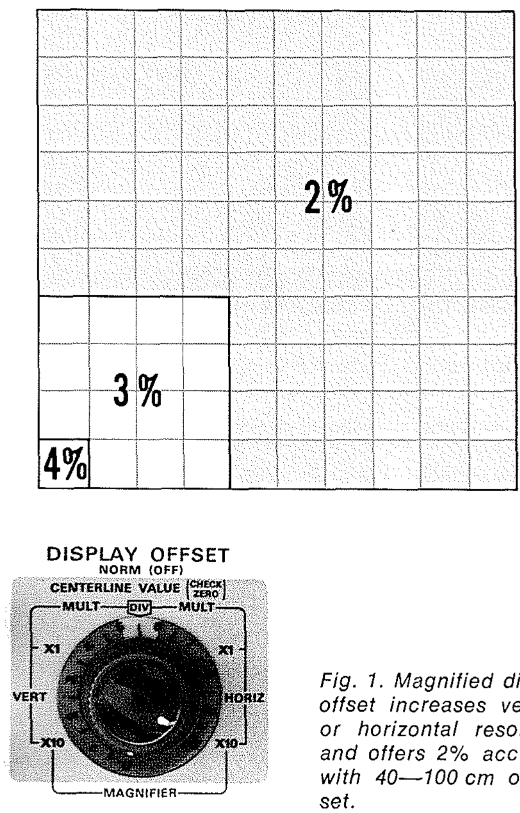


Fig. 1. Magnified display offset increases vertical or horizontal resolution and offers 2% accuracy with 40—100 cm of offset.

Both the vertical and horizontal positioning controls consist of a 5-position switch that positions the origin exactly 5 cm or 10 cm in either direction from normal. In addition, a concentric variable knob provides fine positioning ($\approx$5 cm). The polarity logic automatically positions the origin of the display from lower left corner to upper right corner when the collector sweep is changed from NPN family to PNP family. When switching to AC collector sweep, the origin is automatically positioned to center screen. A display-invert switch is provided for easy overriding of this logic, should it be desired to compare NPN and PNP in the same quadrant.

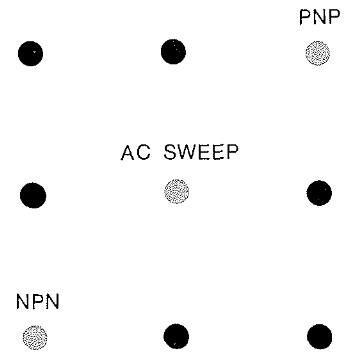


Fig 2. Automatic Display Positioning. NPN, PNP, and AC origins (blue) are automatically positioned when selecting the collector polarity. The detented position knobs (5-cm steps) allow quick positioning as shown above. The variable controls position the origin where desired.

STEP OFFSET PROVIDES NEW VERSATILITY

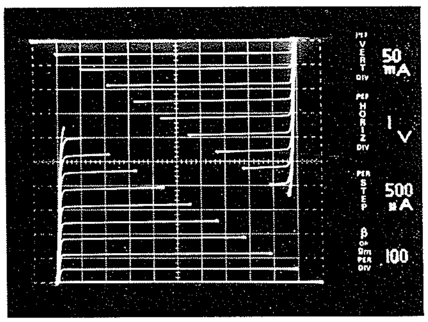
The step generator has been designed for maximum flexibility. A 10-turn calibrated control provides the ability to offset a complete family of steps. The first step may start from any DC level between 0 and 10 times the amplitude of one step. The operator may select the DC offset level to aid or oppose the steps. For example, negative DC voltage may be selected, allowing positive steps to start below the 0 bias point of a FET. By turning the step generator off, the DC offset level provides one curve operation for determining thresholds. This is a particularly interesting configuration since the curve is continuously variable over the wide range of currents and voltages available.

TYPE 576 MEASUREMENTS

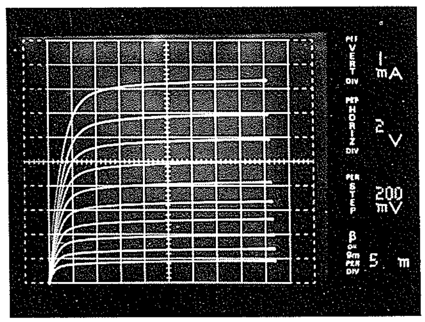
The wide range of base steps, the calibrated step offset, and the pulsed mode of operation provide the Type 576 with a truly versatile base step generator. The multi-mode collector supply (swept, DC, or AC), with its DC—1500 V range allows measurements over a wide spectrum. The vertical and horizontal display amplifiers, combined with the calibrated display offset with magnifier, provide a 2% measurement capability with 10X the resolution of a normal display.

Improved fixturing on the Type 576 extends versatility in making more tests with a greater number of device packages. Dual configurations are easily compared and the **DISPLAY INVERT** feature simplifies comparison of complementary devices. The use of Kelvin contacts in the high-current device adaptors minimizes the effect of voltage drops due to contact resistances. (Kelvin contacts bring the collector and emitter/voltage-sensing leads directly to the device, thus eliminating adaptor-to-test fixture and transistor-to-adaptor contact potentials).

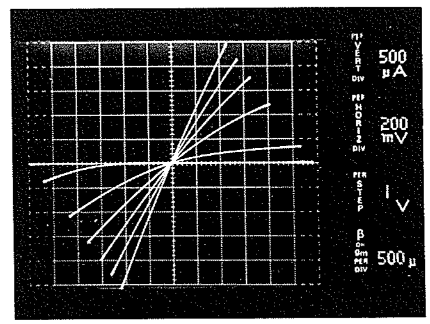
The waveforms below illustrate a few of the measurements that are easily made on the Type 576.



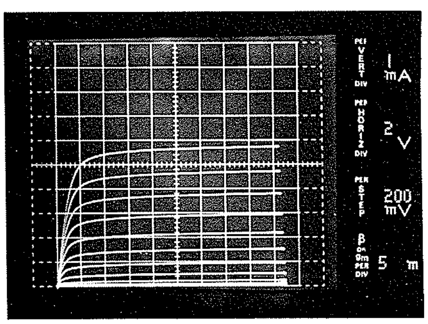
*Double exposure of PNP transistor. Only the **DISPLAY INVERT** was used to reposition the display.*



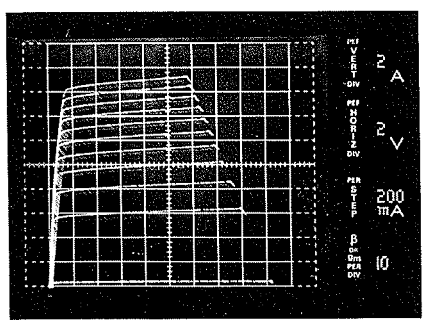
Enhancement and depletion modes of a FET. Opposing DC step offset starts + steps below zero bias point.



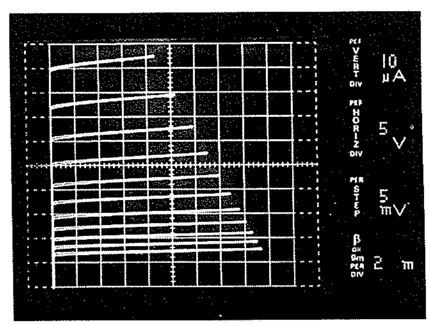
AC sweep permits FET measurements in the resistive region.



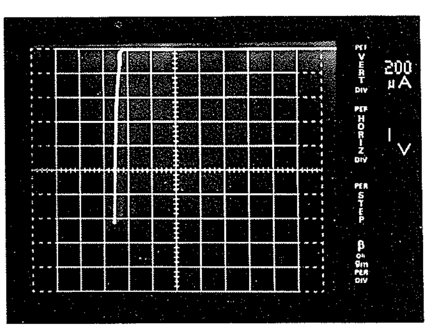
MOSFET drain family in depletion region.



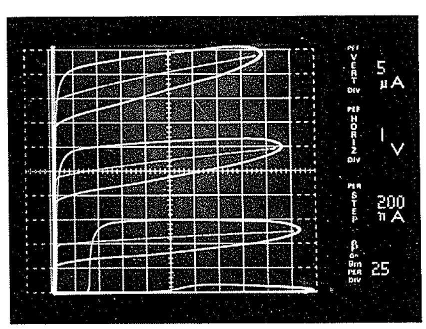
Power transistor with 17 A collector current. The 80-µs pulsed mode with DC collector and manual scan is used.



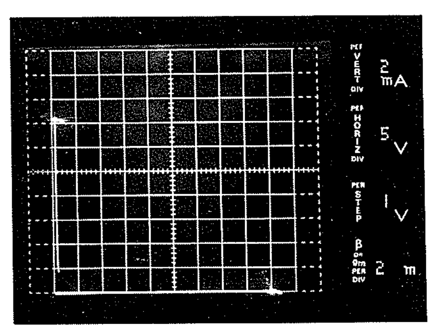
600-mV step offset positions small voltage steps within the transistor active base region.



Display offset with magnifier increases measurement resolution and accuracy. Center line value of 70 V shows zener voltage of 72.6 at 1 mA.



Double exposure. Looping caused by collector-to-base capacitance is eliminated by using the DC collector mode with manual scan (center lines).



SCR measurement in 300-µs pulsed mode measures holding current. Calibrated, variable DC offset allows direct reading of gate-firing potential.

Families of 1-10 digitally selectable steps may be observed. The single family mode normally holds the step generator off and, when triggered, provides one family of curves. Base step rates are NORM (1X the normal collector supply rate which is twice the line frequency), 0.5X and 2X. The wide step amplitude range provides current steps of 200 mA to 5 nA or voltage steps of 2 V to 5 mV. Combining maximum step offset and maximum step amplitudes (AID) provides maximum base voltages to 40 V. The maximum base current is 2 A.

PULSED BASE OPERATION

The Type 576 provides pulsed base operation in which steps are pulsed for either 80 μs or 300 μs selectable from the front panel. In this mode the base drive is applied for only a portion of a cycle and thus, the device is turned on only for short periods of time. This mode automatically connects in the DC mode collector supply to protect the device under test (the fast transitions of the narrow pulses combined with the leakage inductance of the collector sweep transformer could cause a harmful transient). This approach makes it unnecessary to degrade risetime (effective increase in pulse width) and lessen pulse definition. The 300-μs position is useful for checking power transistors while the 80-μs position is useful primarily for measuring small signal transistors at high power. This mode is particularly useful since it allows many devices to be checked without heat sinks. In addition, device characteristics may be viewed at higher power without exceeding safe dissipation limits.

The physical appearance of the Type 576 is unique to the Tektronix product line. Since curve tracers are not generally rackmounted, the front panel was sloped to permit better readability. The "front porch" design provided additional front-panel space and simplified the test fixture plug-in design.

Color has been extensively used on the Type 576 front panel to simplify operation and interrelate controls. For example, black push buttons indicate a single button function which are out for the most common operation, i.e., invert or 0.1X steps. Dark gray is used to denote the common mode of operation in multiple functions, such as zero offset, repetitive family, and base steps. Light gray buttons are used for all other options. Blue is used to relate the display offset relationships; green is used to relate the step generator polarity functions; yellow is used to relate controls for step generator voltage operation; and orange is used to signify the leakage mode setings. This liberal use of color allows the operator to set up individual tests with a minimum of difficulty.

The Type 576 is designed to minimize service problems. Low-voltage power supplies are short-proof and plug-in transistors and IC's are used throughout (including socket-mounted power transistors). Construction is all solid state with the exception of the CRT itself. For further information consult your local field engineer.

576 MEASUREMENT CAPABILITIES

DEVICE	FEATURES
DIODES	1 nA/div sensitivity for leakage measurements — 1500-V collector supply — Kelvin sensing for accurate high-current measurements.
FET's	40 V (step + offset) available for base drive — Step offset allows stepping through zero bias — 1 nA/div sensitivity measures gate leakage — AC sweep allows examination of resistive region.
SCR's	Calibrated variable step offset accurately determines gate firing potential — Holding current may be read directly.
POWER TRANSISTORS	Kelvin sensing for accurate high-current measurements — Pulsed base allows high-current beta measurements without exceeding dissipation limits or requiring heat sinks.
TRANSISTORS	EXTENDED RANGES ON ALL TRANSISTOR MEASUREMENTS — Small steps on top of 600 mV of offset permit observing several voltage driven steps within the active region.
TD's	AC sweep displays forward and reverse characteristics simultaneously.
ZENERS	High-resolution 2% voltage measurements of zener region.

SERVICE SCOPE

TROUBLESHOOTING YOUR OSCILLOSCOPE

By Charles Phillips
Product Service Technician
Factory Service Center

This first article of a series, discusses general techniques for localizing problems to one of the major blocks of an oscilloscope. Future articles will go into more detail on trouble-shooting a major block to pinpoint a faulty stage or component.

The oscilloscope is an excellent tool for self diagnosis. In addition to the CRT display, front-panel indicators (trace-position indicators, trace finders, and pilot lights), and calibrator signals often provide sufficient information to isolate the problem.

Observing the effect of multi-function switches can do much to identify a problem. For example, using the second channel of a dual-trace unit can check vertical circuitry up to the point where switching occurs. In the case of a delaying-sweep or dual-beam oscilloscope, a portion of the circuitry may be used to display information on the oscilloscope itself. Detecting a common problem in all circuits indicates a problem in the power supply.

Switching to the external horizontal input, disconnects the sweep and is a means of determining whether a problem is associated with the horizontal amplifier. At the same time, it can indicate the condition of the unblanking circuitry.

Varying the trigger source switch between internal and external triggering checks the trigger pickoff circuitry. If the sweep will free run by adjusting the stability and trigger level control, additional circuitry may be checked. Comparing operation in different trigger modes can often localize a problem to a specific trigger stage.

Vertical preamplifier plug-in units are a quick way of checking performance to the vertical amplifier input. Once a problem is isolated to a specific plug-in unit, plug-in circuit boards (if used), may isolate the problem even further. Once a problem has been traced to a specific block, a close visual check may pinpoint the problem. Often times burned components or loose leads can be spotted that shorten the trouble-shooting job. Substituting the tubes or transistors offers a quick means of checking a suspected stage. **Always** return the original component to its place if the problem remains.

FRONT-PANEL CONTROLS

The first step in a logical troubleshooting procedure is to preset the front-panel controls in order to be sure that the problem is not an operator problem. It is important to proceed in a logical order (i.e., clockwise) in order not to overlook a control.

All CRT controls may be set to mid-range with the exception of the intensity control. The intensity control normally turns on the CRT at approximately 10 o'clock on a post-accelerator CRT (high voltage at the front of CRT). In the case of the monoaccelerator (high voltage at the base of CRT), the CRT normally turns on at approximately 2 o'clock. These are only approximate figures and will vary from instrument to instrument. A setting much less than these may be insufficient for viewing while a setting much greater may damage the CRT.

The time base should be set to free run, internal triggering, and automatic if there is such a mode. Select a medium speed sweep such as 1 ms/div and select the A or main sweep unmagnified on the horizontal display.

Set the calibrator to a convenient figure such as 1 V. Adjust the vertical sensitivity to 0.2 V/div and select a single channel mode. Position controls and the attenuator balance should be adjusted midrange. In some cases it is convenient to turn the variable gain counterclockwise to lessen the effect of the attenuator balance control.

In the case of a plug-in, be sure that the plug-in is seated tightly and that there is no open connection. Plug-ins that use interlocks are particularly susceptible to this type of problem.

Place the input selector to the DC position and turn off X10 amplifiers if they are available. Substitute a plug-in if an additional one is available.

When troubleshooting a new instrument, take some time to familiarize yourself with the block diagram. Spending a few minutes with the instrument manual can give valuable insight into the particular problem.

THE BASIC OSCILLOSCOPE

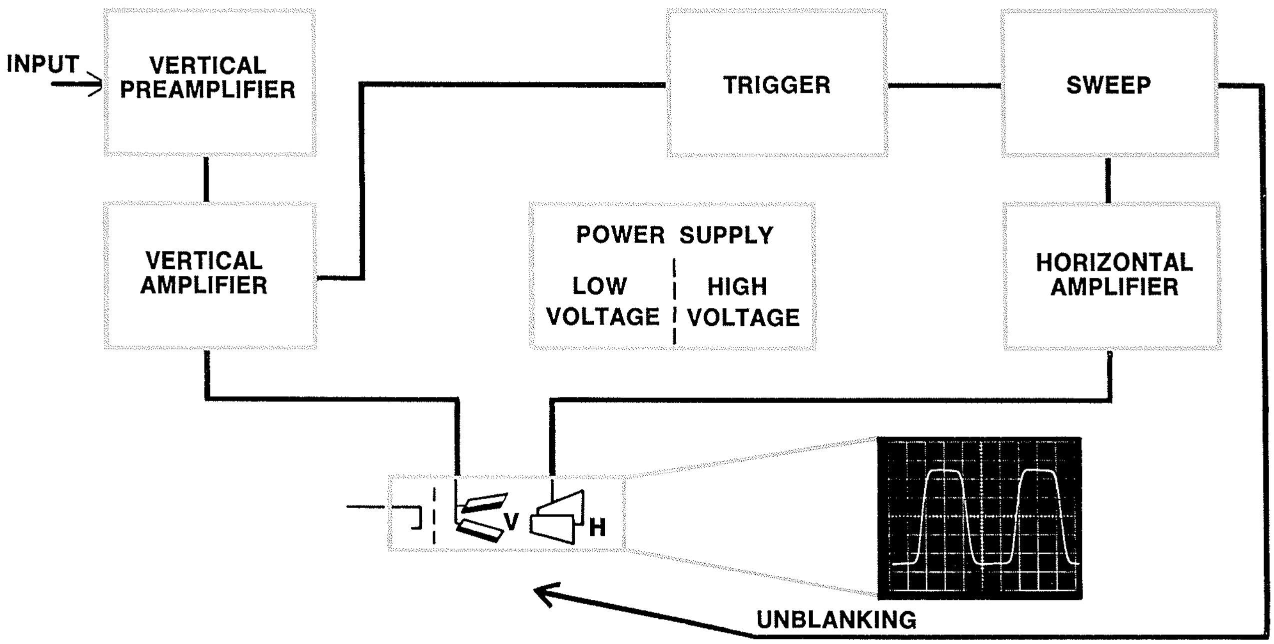
The simplified block diagram at right shows the major components of an oscilloscope. The ability to localize the trouble to one of these blocks is the first step in the troubleshooting process.

POWER SUPPLY

Power supply problems usually affect more than one of the major blocks of a block diagram. If there is no CRT indication, check the line fuse. If this is not the problem, check the power supplies with a voltmeter to determine which supply/supplies are at fault. If the supplies check out, then the problem is probably in one of the other stages. The use of an auto transformer to vary instrument line voltage can quickly verify proper power supply operation.

VERTICAL

When no spot or sweep is seen, use the trace finder or the position indicator to see which direction the spot or sweep is deflected. Use the position controls to see whether the display may be centered. Should the indicator lights show that the trace is deflected off-screen, invert the display. If the display goes off-screen in the other direction, the problem is before the invert switch.



For problems after the invert switch, use a shorting strap, and starting with the CRT deflection plates work stage by stage towards the input amplifier. The stage is working normally when the signal short causes a trace near the vertical center line of the CRT. A defective stage is indicated by the short not centering the trace on the CRT.

Vertical systems containing a plug-in are convenient since substitution may quicken the logical process.

HORIZONTAL

When the oscilloscope has a second sweep, this may be used to see if normal operation can be obtained. A calibrator signal to the external horizontal checks the operation of the horizontal amplifier. If the instrument has a plug-in horizontal, removing the plug-in unit should automatically center the spot. This is of additional assistance with oscilloscopes using deflection unblanking. Deflection unblanking positions the spot off-screen, except during sweep time, and no spot can be seen by overriding the intensity control.

SWEEP

Many instruments have a sweep output connector where the sweep may be monitored. This may give a clue as to where the problem lies. Gate outputs and vertical signal outputs also yield valuable information. Once a display is obtained, the signal should be applied to the input in order to make an approximate check on calibration. When horizontal calibration is off, the vertical calibration should be checked also before attempting to repair the horizontal. If vertical calibration is also incorrect, then the problem is most likely to be in the high-voltage power supply.

TRIGGER

If the instrument has trigger problems, a few simple steps can often determine which stage of the trigger is at fault. Checking operation of trigger circuit in different sources, modes, slopes, and coupling positions will often isolate a problem (for example, the automatic mode normally bypasses the initial trigger stages). Observing the effect of the stability and level controls gives additional information. In checking trigger circuits, always be sure that sufficient signal ($\approx$1 cm) is being applied to obtain a large observable deflection.

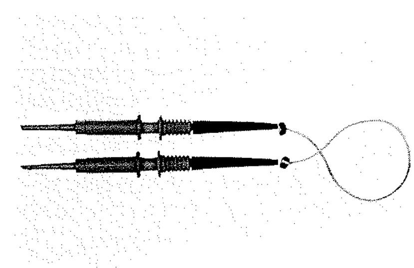
GENERAL

Most problems can be quickly categorized by interpreting results of front-panel controls. If a problem can not be categorized by these steps, then a test oscilloscope can likely determine the faulty stage.

Next: Troubleshooting a power supply

A CONVENIENT TOOL

A shorting strap is one of the most useful troubleshooting tools, as it permits many problems to be quickly pinpointed to a specific stage. A versatile shorting strap can be made by using two Tektronix pincher-tip probes (defective probes are ideal for this) connected together by a short piece of wire. Loop the wire through small ferrite beads (Tektronix PN 276-0507-00 or 276-0511-00 work nicely) as shown in the photo. If ferrite beads are not available, use 47-Ω resistors at each end to dampen oscillations when the strap is used. Alligator clips may be used instead of probe tips but they are much more prone to shorting an adjacent check point.



The strap is used to short the inputs or outputs of complementary stages together. If a stage is defective, applying the short to the input will have no effect on the output.

NEW CONCEPTS BOOKS

Four Circuit Concepts books are presently available. Titles currently in stock are: "Oscilloscope CRT's", 2nd Edition; "Storage CRT's and Circuits", 2nd Edition; "Television Waveform Processing Circuits"; and "Power Supply Circuits", 2nd Edition.

Two of a new series of Measurement Concepts books are completed. The titles currently available in this series are: Information Display Concepts; Semiconductor Device Measurement Concepts.

The material on pages 10 and 11 is taken from one chapter of Semiconductor Devices and is indicative of the content. Other chapters are Bipolar Transistors, Field Effect Transistors, Unijunction Transistors, Signal Diodes and Rectifying Diodes, Zener Diodes, and Tunnel Diodes and Back Diodes.

Should you wish further information on Tektronix Concepts Books, contact your local field engineer.

THYRISTORS (SCR's) AND OTHER PNPN DEVICES

Most of the conductance characteristics of four-layer semiconductor devices can be explored and measured on a transistor curve tracer. The characteristics of principal interest that may be measured are: (1) forward and reverse blocking (breakdown) voltages and currents; (2) the voltage drop at various forward currents for the **on** condition; (3) the gate-terminal turn-on voltage and current requirements for various values of applied anode-cathode voltage; (4) the value of forward current that holds the device in an **on** condition (holding current).

Thyristors are the same kind of semiconductor device as **Silicon Controlled Rectifiers.** The name thyristor is derived from **thyratron,** a gas tube controlled rectifier. The name **Silicon** Controlled Rectifier is to distinguish the solid-state device from the gas-tube device. Thyristors are largely used to control the conduction duty factor of applied alternating voltage, but they do have many other applications. They can be turned on at any time the applied voltage is of the correct polarity but then cannot be turned off until the applied voltage approaches zero volts, or the current which is flowing diminishes to a value that is very low compared to the permissible peak value.

FORWARD BLOCKING VOLTAGE AND REVERSE BLOCKING VOLTAGE

The forward blocking voltage of a thyristor is the voltage that may be applied between cathode and anode before the device switches to have a low impedance—assuming little or no voltage or current is applied to the control terminal and that the polarity of the cathode-anode voltage is correct.

Making a measurement of the forward blocking voltage of a thyristor using a curve tracer is done in very much the same way as measuring the reverse breakdown voltage of a transistor. First the gate terminal is usually either shorted to the cathode terminal or returned to the cathode through a resistor of specified value. In Fig 4-1 forward blocking voltage was measured at 114 volts for 5 μA or forward current at room temperature (Point A). The thyristor is rated to pass no more than 5 μA of peak forward blocking current at 60 volts, the rated peak forward blocking voltage, at a junction temperature of 125°C. A temperature-controlled oven would be needed to conduct the test at 125°C. **Reverse** blocking voltage would be measured in precisely the same way except the polarity of the sweep voltage would be reversed. Fig 4-2 is similar to Fig 4-1 except the applied voltage was increased until the thyristor switched to its **on** state with no gate voltage applied and a different vertical scale factor was used. A current-limiting resistor having a high resistance value was selected to limit the forward current. As the sweep voltage approaches its peak value and Point A is reached, avalanche breakdown occurs at the middle one of the three junctions, and the four-layer device appears to be simply two forward biased PN junctions in series. Current suddenly increases therefore, limited by the series resistance, and the forward voltage drop decreases to a very low value—Point B on the curve. As the sweep supply voltage increases further to its peak value, forward current increases from Point B to Point C. Current then diminishes as the sweep supply voltage drops toward zero. At Point D, not enough forward current remains to hold the thyristor in the **on** condition and current switches off to Point E.

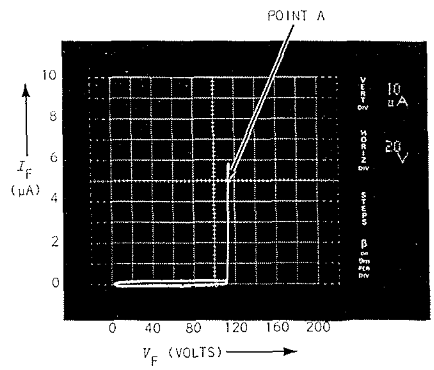


Fig. 4-1. Forward blocking voltage and current 2N5061 thyristor.

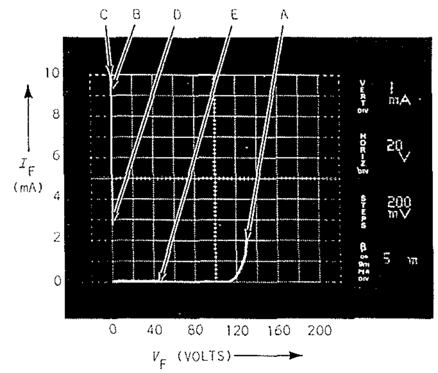


Fig 4-2. Switching conditions, 2N5061, with zero gate voltage drive.

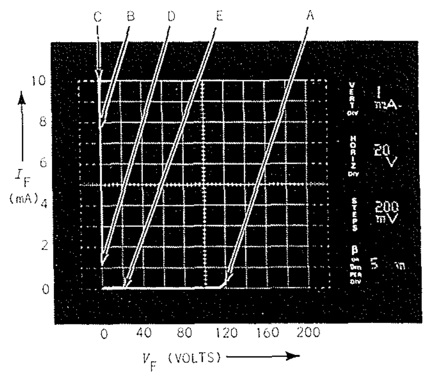


Fig. 4-3. Switching conditions, 2N5061, with small gate voltage drive.

The value of current at Point D is the holding current for that set of conditions. The conditions existing for Fig 4-2 are not a normal mode for operating a thyristor but represent a set of boundary conditions. Forward voltage is not usually applied if it exceeds the rated forward blocking voltage. And some current or voltage is usually applied to the gate terminal to switch the thyristor on. Fig 4-3 is very similar to Fig 4-2; the only difference is that a small steady value of turn-on voltage was applied to the gate terminal for

Fig 4-3. Two important differences should be noted: Switching takes place at a lower voltage and the value of holding current is reduced.

Holding current is usually specified to be equal to or less than some maximum value under stated conditions of temperature, load resistance and anode supply voltage. To select the specified value of load resistance using a transistor curve tracer, both the value of the current-measuring resistor and the selectable series resistor must be considered. Sometimes the correct value may be achieved only by using a third resistor applied at the test terminals. The gate voltage required to switch a thyristor to the **on** state at any given applied anode-cathode voltage can be determined on a Tektronix Type 576 transistor curve tracer. By adjusting the peak supply voltage to the specified amount while the gate terminal voltage is zero, the gate voltage can then be slowly increased until switching occurs and the gate voltage then read from the dial. Go-no go tests can be made by first dialing up the specified gate voltage and observing whether switching occurs or fails to occur. The source resistance for gate voltage drive may be specified. If so, the source resistance can be simulated by adding a resistor of appropriate value in series with the supply.

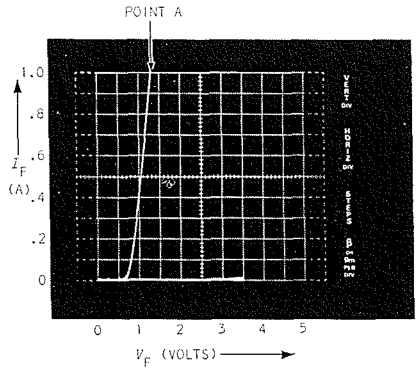


Fig 4-4. Forward conductance, 2N5061. Alternately on and off.

The gate **current** required to switch a thyristor to the **on** state may be tested or measured by means similar to those used for gate **voltage** turn-on measurements.

Fig 4-4 shows the high-current forward-conductance **on** characteristics of the same thyristor as used in the foregoing figures. The forward voltage drop at a current of one ampere is 1.3 volts. The specified maximum is 1.7 volts.

INSTRUMENTS FOR SALE

1—Type 526, SN 1544. Two years old —only a few hours use. Price: $1,500. Contact: D. K. McConnell, General Electrodynamics Corporation, 4430 Forest Lane, Garland, Texas 75040. Telephone: (214) Broadway 6-1161.

1—Type R561A, SN 5909. Contact: Siemens Medical of America, 685 Liberty Avenue, Union, New Jersey 07083. Telephone: (201) 688-5400, Ext. 257.

1—Type 514AD, SN 3955. Best offer. Contact: Mr. Seldon Lazarow, Nortec Computer Dev., Inc., 94 Nickerson Road, Ashland, Mass. 01721. Telephone: (617) 881-3160.

1—Type 2A60; 1—Type 3A72; 1—Type 3A1 Plug-Ins for 564 or 561A Oscilloscopes. Contact: Jack Hatton, The Meditron Company, Santa Ana, Calif. Telephone: (714) 541-0468.

Several Type 533A and various plug-ins. Contact: Henry Posner, Pacific Combustion Engineering Company, Los Angeles, Calif. Telephone: (213) 225-6191.

1—Type L Preamplifier, SN 11107. Contact: Alton Paris, 1789 Kingston Street, Aurora, Colorado.

1—Type 453 Oscilloscope, SN 438. Contact: Kappa Networks, 165 Roosevelt Avenue, Carteret, New Jersey 07008. Telephone: (201) 541-4226.

1—Type 067-0544-00 Calibration Fixture for Type 647, SN 233. New condition. Contact: Mr. Dan Pyko, S. S. Co., Standards Laboratories, 12800 North End Avenue, Oak Park, Michigan 48237. Telephone: (313) 398-2100.

1—Type 514AD, SN 6009. Excellent condition. Scope-Mobile® Cart and accessories. Contact: Mr. Isadore Werlin, 39 Coolidge Road, Medford, Massachusetts 02155. Telephone: (617) NI8-6700 or at home (617) HU8-0520.

1—Type Q Plug-In Unit, SN 2335. Contact: Dave Janicello, Photo-circuits Corporation, 33 Seacliff Avenue, Glen Cove, New York 11542. Telephone: (516) OR6-8000, Ext. 268.

1—Type 543, SN 351. Fully reconditioned. Price: $700.00. Contact: Palmer Agnew, 314 Front Street, Owego, New York 13827.

1—Type 502, SN 007130 with 202-2 Scope-Mobile® Cart. Excellent condition. Contact: Mr. A. W. Smith, Standard Screw Co., P. O. Box 1440, Hartford, Conn. 06102. Telephone: (203) 525-0821, Ext. 455.

1—Type 526, SN 1090. Price: $1,250.00. Contact: Mr. Al Kern, K. H. Q. Inc., 4202 South Regal, Spokane, Wash. 99203. Telephone: (509) KE4-0511.

1—Type 512, SN 766. Price: $75.00. Contact: Mr. Gerry Shefler, Beaverton School District, Beaverton, Oregon. Telephone: (503) 644-3101.

1—Type 67 Time Base Plug-In; 1—Type 72 Dual-Trace Plug-In; 1—Type 561; 2—Type 541A. Contact: J. Rezabek or Johnny Wienkam, Offshore Systems, Inc., 3000 Hicks Street, Houston, Texas 77007. Telephone: AC(713) 869-8241.

1—Type B Plug-In Unit. Price: approximately $80.00. Contact: Mr. Bob Goodman, Clark-Dunbar Company, 325 Jackson Street, Alexandria, Louisiana 71301. Telephone: (318) 443-7306.

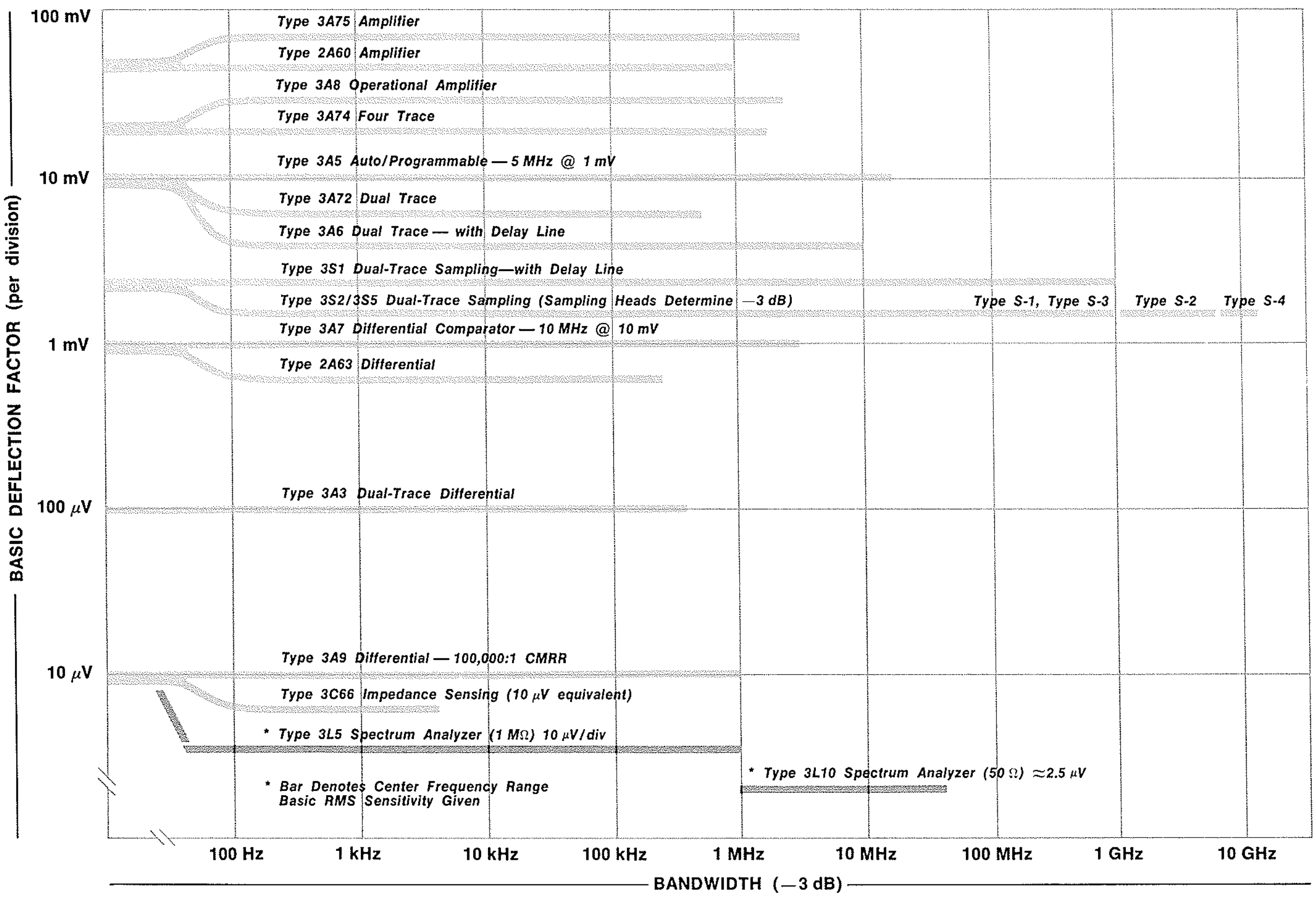
INSTRUMENTS WANTED

1—Type 515A/531A, or comparable scope for personal use. Contact: James Ladd, 5775 Kingfisher Lane, Clarkston, Mich. 48016. Telephone: (313) 332-8111, Ext. 7116. Home: (313) 625-1549.

1—Type 545/555/585 Series, with or without plug-ins. Write giving details and price. Contact: W. D. Van Amburg, CMR #5, Box 1449, APO Seattle 98737.

1 C-12 Camera. Contact: Bob Goodman, Clark-Dunbar Co., 325 Jackson Street, Alexandria, Louisiana 71301. Telephone: (318) 443-7306.

2—Type 201-1 Scope-Mobile® Carts. Contact: Mr. Seldon Lazarow, Nortec Computer Dev., Inc., 94 Nickerson Road, Ashland, Mass. 01721. Telephone: (617) 881-3160.



AN EXTENDED VALUE

By John Durecka

Two new solid-state oscilloscopes, the Type 561B and Type 564B offer improved performance over a wide range of deflection factors and bandwidth.

The advent of the Type 561B/564B marks the second major updating of the 560 Series in the 8-year history of the instrument. 5 years ago, in a significant performance upgrading, the Type 561A became the first Tektronix instrument with an internal graticule. At the same time, the power supplies and CRT were improved to optimize higher frequency instrument performance.

The 25 plug-ins presently available for this series attest to the popularity and versatility of this format. The current updating improves the performance and extends the measurement capability of existing 560-Series plug-ins. The use of plug-in sampling heads now provides DC-to-14 GHz performance. There are currently 17 vertical plug-in units (including 2 spectrum analyzer and 3 sampling units), 4 time-base units, and 3 sampling sweep units. In addition, the Type 565 Dual-Beam Oscilloscope, the Type 568 Digital Readout Oscilloscope, and the Type 129 Power Supply all accept these plug-in units (the Type 565 does not accept sampling plug-in units).

The Type 561B/564B is all solid state with the exception of the CRT. The new power supply design results in improved operation over the specified temperature range. The supplies are better regulated, more stable, and have a lower output impedance. This design holds signal crosstalk through the power supply to a minimum. Short-proof circuitry is designed into all low-voltage power supplies. As a result, low-voltage supplies may be shorted to ground or each other without damage to the instrument. Fig 1 illustrates the principle involved.

The Tektronix line-voltage selector feature is now present on the Type 561B/564B. This feature optimizes instrument performance whether operating at 115 V, 230 V, low line, high line, or mid line.

Power consumption of the Type 564B is decreased to less than 200 watts maximum while the 561B is decreased to less than 180 watts maximum (dependent upon plug-in units used). A major advantage of **this** solid-state power supply design is that most of the power is dissipated in the rear-mounted heat sink. This provides cooler operation of the plug-in units, as well as the main-frame circuitry.

The Type 561B calibrator performance has been significantly improved. The frequency is 1 kHz within 1% and amplitude accuracy is 2% from 0° — +50°C. A 10 mA, ±2% current loop is provided with both a DC and squarewave output to provide a current probe calibration signal.

The calibrator output has been changed from a 1-2-5 sequence to 5 decade steps from 4 mV to 40 V. The new 4-40-400 calibrator sequence chosen presents no fractional division display on any position of the 1-2-5 deflection-factor sequence.

The new calibrator is pictured in Fig. 2. Note that a 40-V DC position is also included so the calibrator accuracy may be checked with an accurate DC voltmeter, DVM, or differential comparator plug-in unit. 2-mV, 20-mV, and 200-mV 50-Ω outputs are available to provide an adequate range for sampling plug-in calibration. The calibrator is designed to be short proof to ground, thus offering additional protection to the instrument.

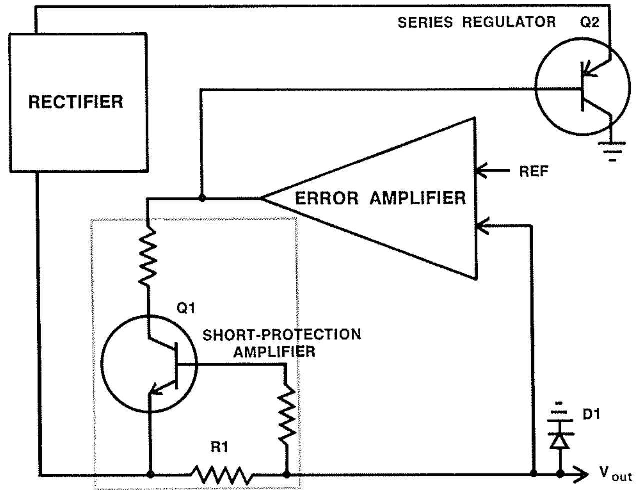


Fig. 1. Short-Proof Protection. Q1 is normally off. When a short demands high current from Q2, the drop across R1 turns Q1 on and reduces the conduction of Q2 to limit the output current. D1 protects from shorting to another supply.

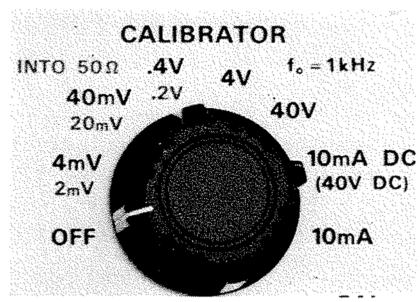
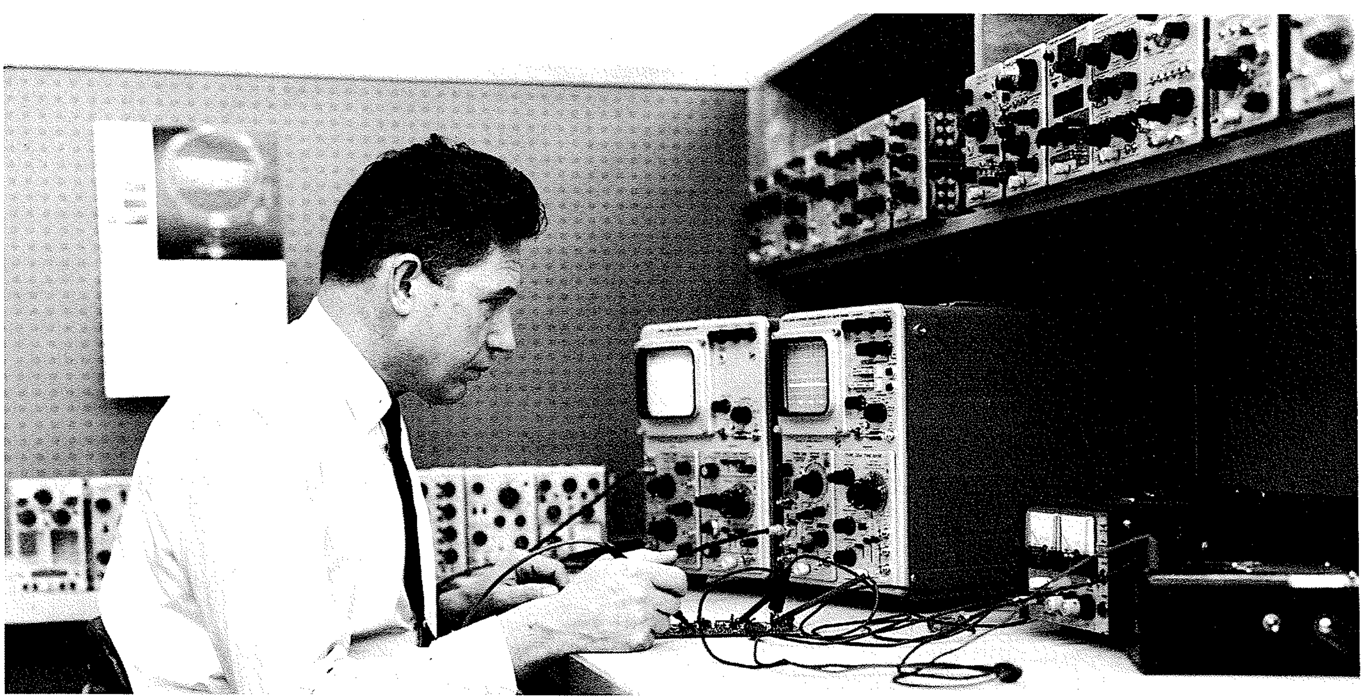


Fig. 2. Type 561/564B calibrator

John Durecka, Project Engineer, monitoring a circuit on a Type 561B and a Type 564B. Some of the 25 plug-in units currently in production are shown in the background.



STORAGE AUTO ERASE

The Type 564B MOD 121N combines Tektronix split-screen bistable storage with automatic erase circuitry. This mode increases the versatility of the instrument since the split-screen displays can be automatically (and remotely) erased after a preselected viewing time of 1-12 seconds. A SAVE mode is also incorporated into the Type 564B MOD 121N. In this position, the auto-erase cycle is interrupted and the stored information is preserved.

Remote operation is also a feature of the Type 564B MOD 121N. A rear-panel connector permits erasing of upper and/or lower half of the split screen from a remote location. In addition, the SAVE function may be controlled by a contact closure to ground.

Designing automatic erase into the 560-Series mainframe presented a difficult design problem, since it was necessary that all previous plug-ins be compatible with the circuitry. As a result, the auto-erase design chosen does **not** lock out the sweep during VIEW and ERASE. The sweep is running during this time, but the trace is blanked at the CRT grid. As a result of this design choice, all time base units, **even those without single sweep capability,** may be used for single-shot or auto-erase storage applications. The automatic-erase controls consist of an extra pushbutton for each half-screen display, AUTO ERASE, a variable VIEW TIME control (1-12 s) with SAVE position, and a rear-panel switch (Signal Triggered Sweep-Erase/Triggered Sweep).

For most applications of sweep speeds faster than ≈0.1 s/div, the Signal Triggered Sweep provides the optimum display. In this mode, an end-of-sweep detector resets the AUTO ERASE circuit and the next sweep after erase resets the logic to store the following sweep. The Erase Triggered Sweep position is useful at very slow sweep speeds to eliminate the waiting time between erasure and completion of the resetting sweep. In this mode, a sweep is initiated immediately after the end of erase. The table below indicates the modes available, limitations, and applications.

10-μV PERFORMANCE NOW AVAILABLE

The Type 3A9, DC-to-1 MHz Differential Amplifier Unit is illustrative of continued improvement in performance available within the 560 Series. Long-term drift of this unit is less than 10 μV/h and displayed noise is ≤12 μV (10 μV/div at 1-MHz bandwidth with a 25-Ω source resistance). The Type 3A9 provides a 100,000:1 CMRR from DC—100 kHz with deflection factors of 10 μV/div to 10 mV/div. Stacking of attenuators decreases the CMRR over the range of 20 mV/div to 10 V/div.

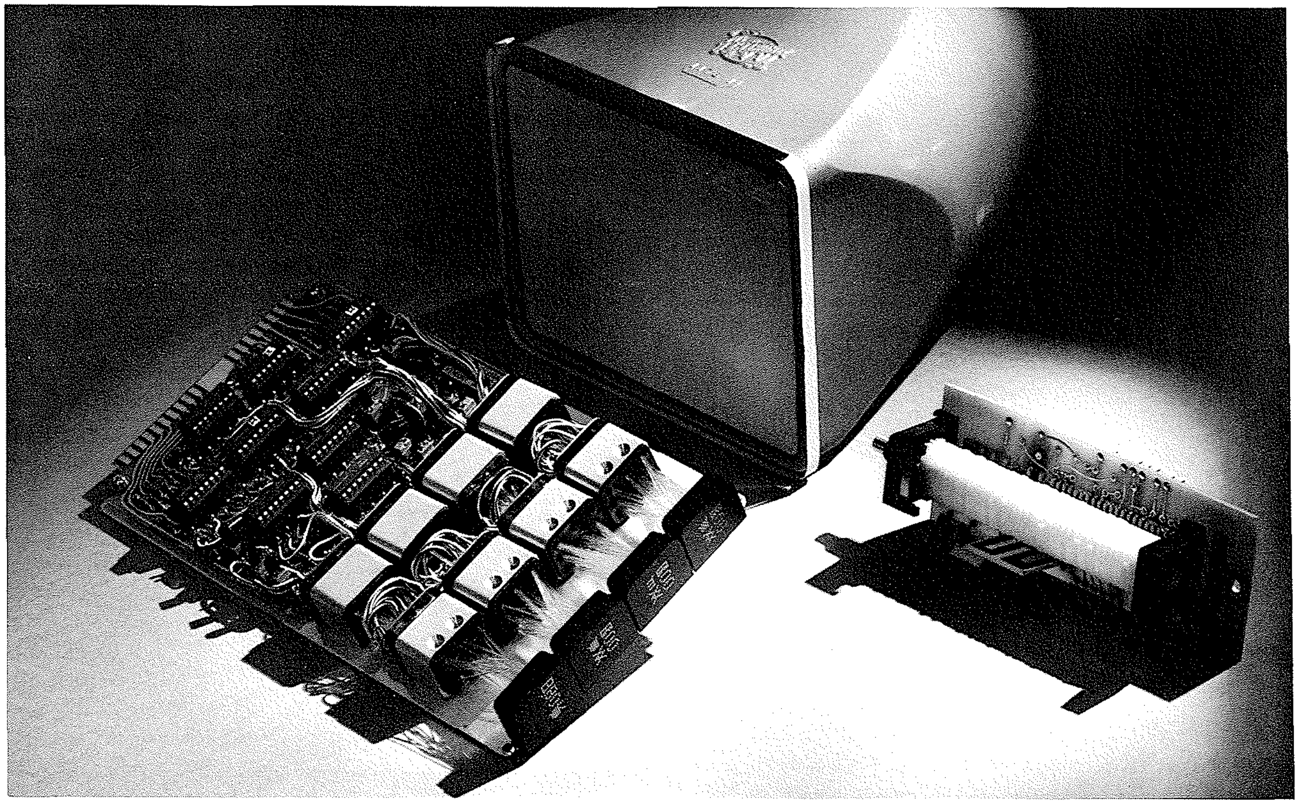
A separate input for a current probe has been provided on the Type 3A9, eliminating the necessity of an external current probe termination. When a P6019 or P6016 probe is used, this built-in termination extends the low-frequency response, providing a bandwidth of 10 Hz to 1 MHz. The convenient color-coded current/div scale allows direct reading of currents from 1 mA/div to 1 A/div.

A DC differential offset provides a variable DC voltage to measure small signal components (voltage or current) over a wide differential dynamic range (1 V-1000 V). The unit recovers to within 0.5% of zero level in less than 10 μs after removal of an applied voltage. Color coding on the front panel indicates at a glance the DC offset range for the various sensitivities. Both upper and lower 3-dB frequency points may be selected to optimize noise attenuation and to provide AC coupling at very low frequencies (0.1 Hz).

The Type 3A9 also provides a front-panel, DC-coupled SIGNAL OUTPUT for recording purposes. The signal is brought out at 1 V/div with a dynamic range of ±5 V, bandpass of DC-to-500 kHz, and output impedance of 100 Ω. An internal potentiometer allows precise adjustment to ground reference. The circuit is capable of driving loads of 10 kΩ and above. For further details on any aspect of the 560-Series Oscilloscopes and Plug-Ins contact your local field engineer.

AUTO ERASE MODES

MODE	OPERATION	USE
Signal Triggered Sweep	**Erasure occurs after viewtime. Sweep can be signal triggered after next retrace.**	**General-purpose sweep displays (0.1 s/div and faster).**
Signal Triggered Sweep (Erase pulse output grounded)	**Display erased at regular intervals at a rate set by viewtime multi-vibrator.**	**No sweep available — X-Y display.**
Erase Triggered Sweep	**Every sweep unblanked—sweep triggered from vertical—viewtime and erase time lost.**	**Slow-sweep, dual-trace displays with alternate erasure remotely controlled. Always at least 1 sweep of data displayed.**
Erase Triggered Sweep (Erase pulse output to external trigger)	**Sweep is triggered at end of erase. No coincidence between sweep starts and signal.**	**Spectrum Analyzer displays (0.5 s/div and slower).**
SAVE	**Interrupts auto-erase cycle.**	**Retains desired information on screen.**



COMPONENT TECHNOLOGY

Many different technologies are pursued within Tektronix to ensure maximum flexibility in design. Some of the significant Type 576 components developed at Tektronix are nearly overshadowed by the more dramatic overall performance of the instrument. These component technologies are responsible for many of the characteristics of the Type 576.

The new rectangular 6.5-inch CRT provides a 10 x 12 cm bright, high-resolution display, and has nearly twice the display area of the Type 575. This use of a large CRT also minimizes operator fatigue when the instrument is used in a production environment.

A high-reliability cam switch has been developed which reduces torque requirements by 50% over conventional switches. The low torque is a result of a more efficient system of actuating contacts. The cam switch has lower frictional drag than conventional switches since less clips are engaged for any switch position. Life tests indicate the life of this switch to be at least twice that of conventional switches used in this application. The switch is mounted on a circuit board which provides space for mounting closely associated components. The basic operation of Tektronix cam switches is much the same as a music box drum. Cam high points contact clips on the circuit board which close the circuit. The manufacture of the switch is applicable to numerically controlled equipment, and thus, the tolerances may be controlled more accurately.

The Type 576 is the first Tektronix instrument to use Tektronix integrated circuits. The use of Tektronix IC's in this application, simplified logic complexity and decreased the cost over the alternative of using commercially available IC's. 9 Tektronix developed and manufactured IC's of 5 different types compose the logic that is required for beta/div computation and lamp driving functions.

Tektronix assembles the optical fibers which transmit light from the lamps to the plastic front-panel display module where the characters are formed. A single card contains the IC decoder computer, lamp drivers, lamps, and display module.

Tektronix resistors, capacitors, transformers, inductors, relays, circuit boards, and plastics are used where necessary to assure the best overall design choice of component. This diversified technology assures the user of dependable components designed to do specific tasks and results in more stable consistent instrument performance.

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Editor: R. Kehrli Artist: N. Sageser For regular receipt of TEKSCOPE contact your local field engineer.

CURVE TRACING DISPLAYS

The Type 576 displays one or more characteristic curves of two and three terminal devices. By applying a constant voltage or current to an input terminal and sweeping the output terminal with a half sinewave of voltage, a single characteristic curve is generated. By applying a stair-step signal (step generator) to the input and sweeping the output terminal (collector supply) once for each successive step up to 10 curves can be displayed. For maximum flexibility, the steps may be current or voltage, positive or negative, and offset by a positive or negative value of current or voltage.

Although the collector sweep is normally a rectified sinewave, it may consist of an unrectified sinewave (simultaneous monitoring of reverse breakdown and forward conduction), or a manually controllable DC potential (eliminates the trace looping effect of the collector-to-base capacitance in low current devices).

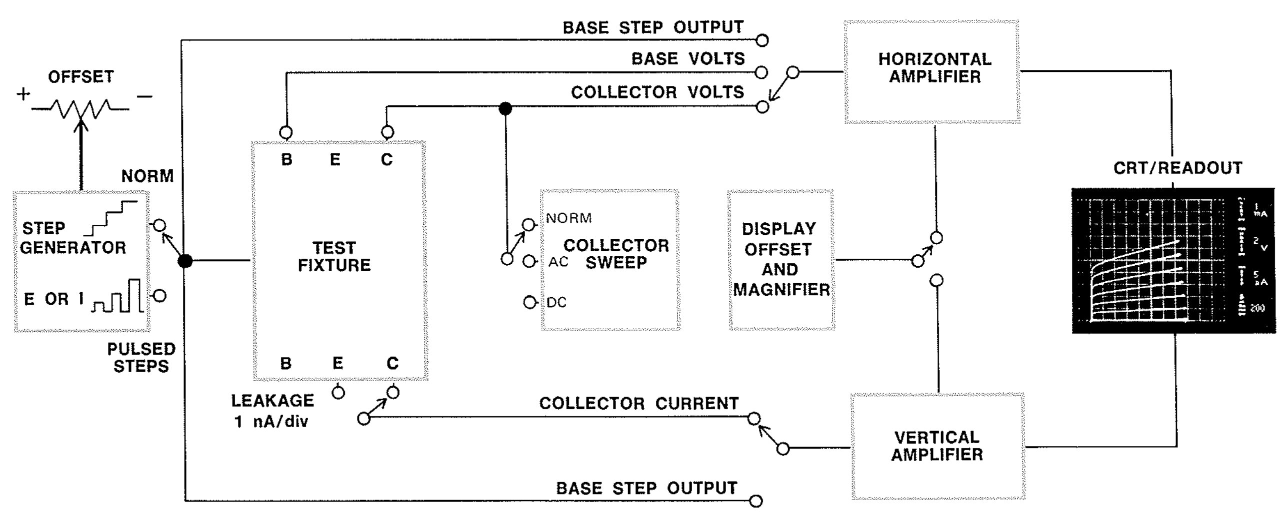
The horizontal amplifier may select base volts or collector volts and the vertical amplifier may select collector current or emitter current (high-gain leakage mode). Both amplifier may select the step generator output.

A display amplifier with magnified offset capability provides display accuracies of up to 2% with either the horizontal or vertical amplifier.

The usual grounded emitter configuration for transistors normally displays collector voltage on the horizontal (or base volts) versus collector current at various drive levels. Grounded base configurations may also be shown.

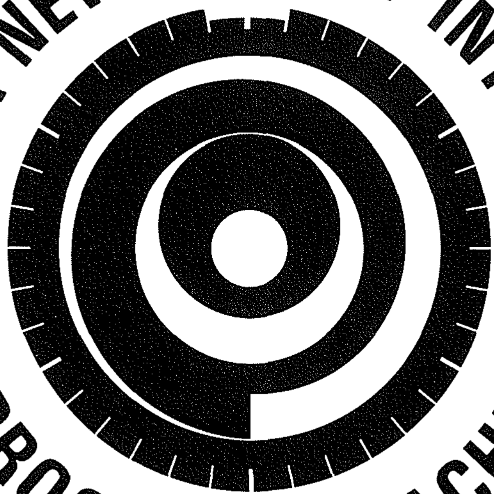
The 576 Curve Tracer is useful for diodes, tunnel diodes, zener diodes, SCR's, small signal and power transistors, FET's, MOSFET's, unijunctions, and other devices. Some of the advantages of curve tracing versus a DC point-by-point measurement are as follows:

1. Irregular characteristics are visible that may be overlooked on a point-by-point basis.
2. The device may be monitored over a wide range of operating conditions.
3. Dependence of one parameter upon another is clearly seen.
4. Changing magnitudes of 2 parameters can be observed simultaneously.
5. Characteristics are obtained quickly and easily.
6. Quick comparison capability—quick permanent record by photography.



TEKTRONIX
TEKSCOPE
APRIL 1969

A NEW INSIGHT INTO RECIPROCATING MACHINERY



By Bill Verhoef

The Tektronix Engine Analyzer System is designed to provide information for effectively evaluating engine, pump, and compressor performance. By using this oscilloscope information, potential problems and trends can be detected and corrective action taken before extensive damage occurs. Preventive-maintenance overhauls may be eliminated or delayed, since the analyzer detects trouble spots without unnecessary downtime. The Engine Analyzer System is also useful as a standard general-purpose laboratory oscilloscope.

COVER
The rotating film disc shown is the heart of the Rotational Function Generator (RFG). When coupled to an engine or compressor, the RFG generates three waveshapes: outer ring — 10°, 60°, and 360° (TDC) markers; second ring — sawtooth ramp; third ring — sinewave with harmonic content (equivalent to piston volume).

4 CHANNELS OF INFORMATION

Tektronix Engine Analyzers offer simultaneous observation of pressure, ignition, vibration, and crankshaft rotation. These quantities may all be observed as a function of time, crankangle, or piston displacement (i.e., P-V diagram). Tektronix Engine Analyzer Systems consist of a Type 561B or 564B oscilloscope, two plug-in units, and a rotational function generator (RFG) with appropriate transducers and cables.

By using the 4-trace electronic switching capability of the Type 3A74 Engine Analyzer Amplifier, one charge amplifier and 3-voltage channels (DC-2 MHz) are available. The operator is provided with new ease in interpreting displays, since all transducer outputs may be monitored simultaneously.

The 564B Split-Screen Storage Oscilloscope is ideal for use with Engine Analyzer plug-ins. Either half of the CRT screen may be independently controlled and used for conventional non-stored displays, or information may be stored on the CRT phosphor up to 1 hour. Storage is particularly convenient when making pressure measurements, since 10 or more engine cycles may be stored on the display and changes detected in pressure. Pre-ignition problems are also readily observed.

PREDICTABLE MAINTENANCE

Vibration pickups, normally piezoelectric crystals mounted on a magnetic base, may be placed anywhere on an engine or compressor to analyze the various vibrations. Operators can thus detect leaking valves, piston blow-by, destructive detonation, excessive cylinder ring wear, and other signs of wear and deterioration.

Ignition measurements are useful for proper engine timing and assist in detection of a wide range of ignition problems. Faulty spark plugs, point arcing and bounce problems, faulty condensors, ignition coils and proper engine timing may all be observed with an ignition probe.

Pressure monitoring allows detecting peak-firing pressures, compression pressures, early or late cylinder firing, and pre-ignition of the engine under test. P-V diagrams determine indicated engine horsepower and overall performance in engines, pumps, and compressors.

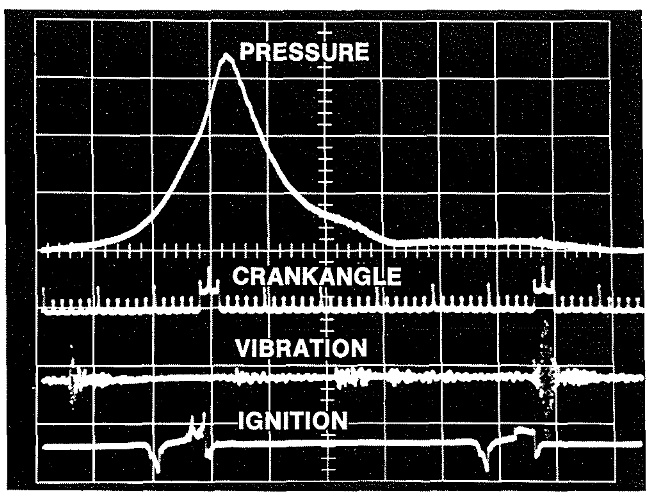
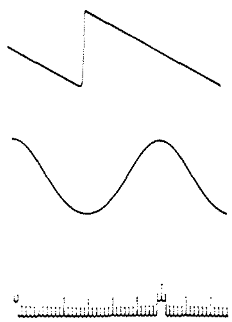


Fig 1. The Tektronix Engine Analyzer System allows simultaneous monitoring of pressure, crankangle, ignition, and vibration.

ROTATIONAL FUNCTION GENERATOR

The Tektronix Engine Analyzer includes a rotational function generator (RFG) that is mechanically coupled to the engine under test and generates 10°, 60°, and 360° crankangle markers. The RFG operates to a maximum of 20,000 r/min* and generates three separate outputs as shown below.



A sawtooth ramp for displays related to crankangle.

A sinewave with approximately 6% second harmonic content to provide piston volume as a function of crankshaft rotation (r/l = 1/4).

Crankangle markers in 10°, 60°, and 360° increments.

Fig 2. Rotational function generator waveshapes.

The various markers (10°, 60°, 360°) have different amplitudes and are displayed in ruler form on one trace. These markers are coupled internally into channel 2 of the Type 3A74 Engine Analyzer Amplifier Unit. A top dead center (TDC) mark is obtained from a magnetic pickup sensing a marker on the flywheel. This magnetic pickup signal is then easily superimposed on channel 2 to coincide with the RFG 360° marker. The RFG volume signal is then aligned with the particular cylinder of interest.

The RFG generates the wave shape necessary for determining piston displacement at any point in the combustion cycle. To accomplish this, the RFG generates a waveform containing 6.35% second harmonic to approximate an r/l ratio of 1/4 (the ratio relates the length of the connecting rod (l) to the radius of the circle described by the rotation of the crankshaft (r), see fig 3). This waveform is then used to generate the V axis for a P-V diagram curve.

*(RPM) Ref IEEE Standard Symbols for Units IEEE No 260 Jan 1965

Most engines have r/l ratios ranging between 1/3.5 to 1/6. The chart below shows the displacement for various values of crankshaft rotation for r/l ratios of 1/6, 1/4, and 1/3.5. Based on a 100-mm displacement, the 1/4 maximum displacement error of the RFG (at 90° of crankshaft rotation) is only —2.15 mm and +0.95 mm respectively. Thus, a variable r/l control is not required.

Once a P-V display is obtained, mean effective pressure can be found as it is proportional to the area within the loop. The mean effective pressure is then used to determine the indicated horsepower of the engine by the formula $HP = \frac{PLAN}{33{,}000}$. In the case of a 4-cycle engine it is necessary to determine the difference between the two loops since one is negative work and the other is positive work.

P = mean effective pressure (lbf/in²)*
L = length of piston stroke (ft)
A = cross-sectional area of cylinder (in²)
N = speed of rotation (r/min) [N/2 (4 cycle)]

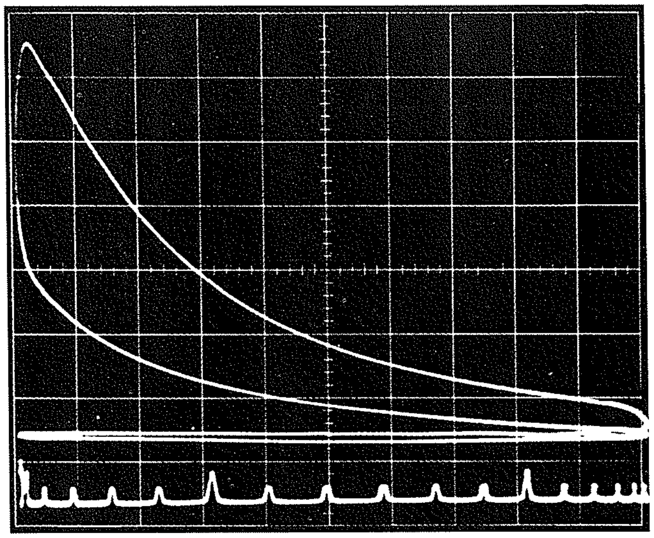


Fig 4. Pressure vs cylinder volume. The area within the loop is the mean effective pressure and may be determined accurately with a planimeter.

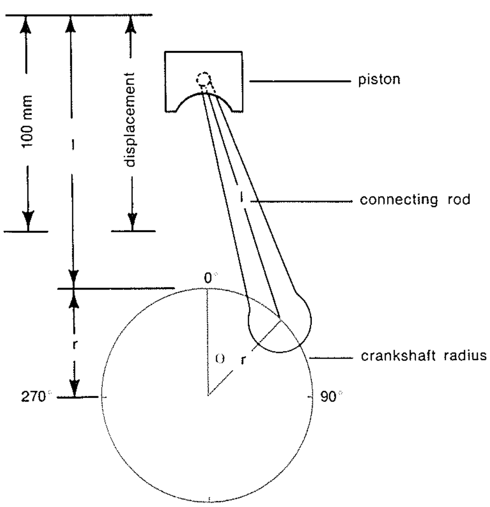
PRESSURE MEASUREMENTS

Pressure measurements are made with the Tektronix Engine Analyzer by using a piezoelectric pressure transducer and a charge amplifier (channel 1 of the Type 3A74 Engine Analyzer Amplifier). 50 feet of special Tektronix designed low-noise cable is used to connect the pressure transducer to the amplifier input. Cable noise is not apparent with the special low-noise cable supplied.

*(psi) Ref IEEE Standard Symbols for Units IEEE No 260 Jan 1965

The low-noise cable, the pressure transducer, and the channel 1 amplifier allow three displays of cylinder pressure to be quickly and easily obtained: (1) Pressure versus crankangle; (2) Pressure versus cylinder volume; (3) Pressure versus time.

The Tektronix Engine Analyzer System measures the charge of the pressure transducer instead of a voltage. As a result, the system is insensitive to variations in transducer or cable capacitance. This feature enables the Engine Analyzer System to use cables as long as 2000 feet, even in the most sensitive position.

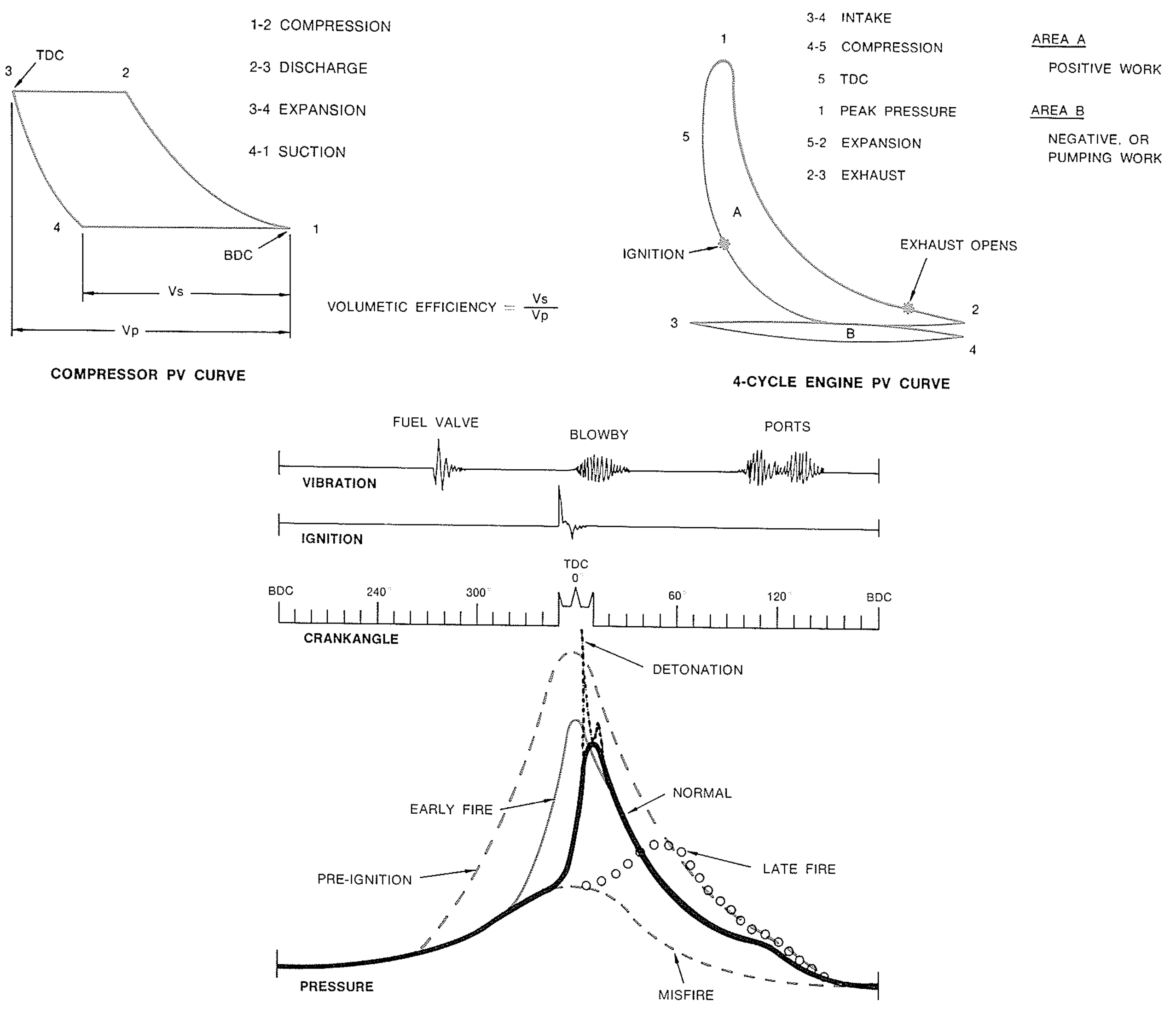


Relationship of Cylinder Volume VS Crankshaft Angle

θ	$\frac{r}{l} = \frac{1}{6}$	$\frac{r}{l} = \frac{1}{4}$	$\frac{r}{l} = \frac{1}{3.5}$
0°	0	0	0
30	7.74	8.3	8.5
60	28.1	29.76	30.4
90	54.2	56.35	57.3
120	78.1	79.76	80.4
150	94.34	94.9	95.1
180	100.0	100.0	100.0

Fig 3. The table above shows the amount of deviation from an r/l of 1/4 as the crankshaft moves the piston from minimum to maximum displacement. Note that the maximum displacement error (90°) at 1/3.5 is +0.95 mm and at 1/6 is —2.15 mm.

ENGINE AND COMPRESSOR BASICS



2-CYCLE ENGINE DISPLAY ILLUSTRATING VARIOUS MALFUNCTIONS

The pressure transducer operates over a range of −40° to +150° C and speeds up to 6000 r/min. The transducer should always be used with a cooling adapter where environmental conditions exceed +150° C. Engine speed must be derated to 1500 r/min when using the cooling adapter, and to 1000 r/min when using the cooling adapter and coupling pipes of 5 to 10 inches.

Special low-noise coaxial cables have been designed by Tektronix with a conductive plastic jacket underneath the braiding. This reduces the cable movement noise by a factor of at least 100 over standard RG58 cable. All coaxial cables are provided with the same BNC connectors as the transducers. As a result there are no problems in interchanging connectors or replacing and repairing cables.

The high-charge sensitivity of the transducer makes the system impervious to cable and connector noise and eliminates resistivity problems caused by dirty connectors. The pressure transducer has a range from 0 to 3000 lbf/in^2 and when used with channel 1 of the Type 3A74 Engine Analyzer Amplifier deflection factors from 1 $lbf/in^2/div$ to 500 $lbf/in^2/div$ are provided in a 1-2-5 sequence. The transducer can stand overload of 9000 lbf/in^2 which enables it to withstand knocks in the transducer access pipes.

The charge amplifier of channel 1 can be set for either LONG ($\approx$4 s) or SHORT ($\approx$0.4 s) recovery time, and is constant in all PSI/DIV positions. The low-frequency response is 0.05 Hz (LONG) and 0.5 Hz (SHORT). Long recovery times are normally selected below 600 r/min, and where critical pressure measurement is required.

VIBRATION MEASUREMENTS

The piezoelectric vibration transducer is capable of 1000 g's maximum acceleration over a range of $-40°$ C to $+150°$ C. 50 feet of the Tektronix designed low-noise cable is provided to connect the vibration transducer to one of the channels of the 4-channel amplifier. The vibration transducer normally provided with a Tektronix Engine Analyzer has a sensitivity of nominally 6 mV/g (4½ mV/g with the 50-foot included cable). Vibration transducers are provided with a calibration chart for the individual transducer. The vibration transducer has a bandwidth of 40 Hz to 15 kHz into the 1 MΩ impedance of the 4-trace amplifier, with a resonant frequency (+25 dB) at approximately 10 kHz.

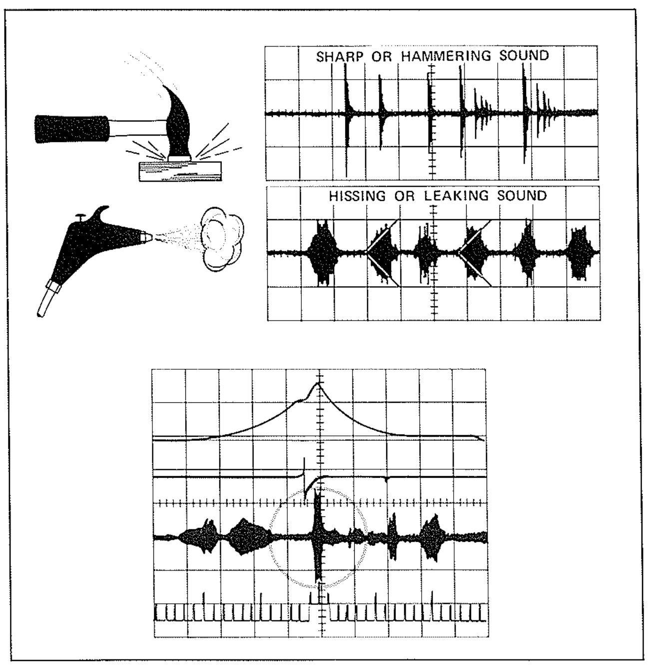


Fig 5. Two basic sounds of interest in engine analysis. The hammering sound has a steep wavefront while that of the leaking sound is much more sloping. The circled area in the bottom photograph indicates a piston slap condition.

The 10-kHz resonant frequency enhances the indication of mechanical shocks (valve closings, loose piston rings), and leaking gases (blow-by). This transducer also aids the operator by filtering out the low-frequency vibrations of lesser interest (below 40 Hz).

IGNITION MEASUREMENTS

The 50-foot low-noise ignition probe consists of a 1000X capacitive attenuator that clamps onto the secondary coil and spark plug wire and presents a signal to the oscilloscope. The exact attenuation of the ignition pickoff is determined by the capacitance between the pickoff and the secondary lead ($\approx$10 pF) and the built-in capacitance of the probe. The probe may easily be calibrated by using a piece of similar cable and the oscilloscope calibrator.

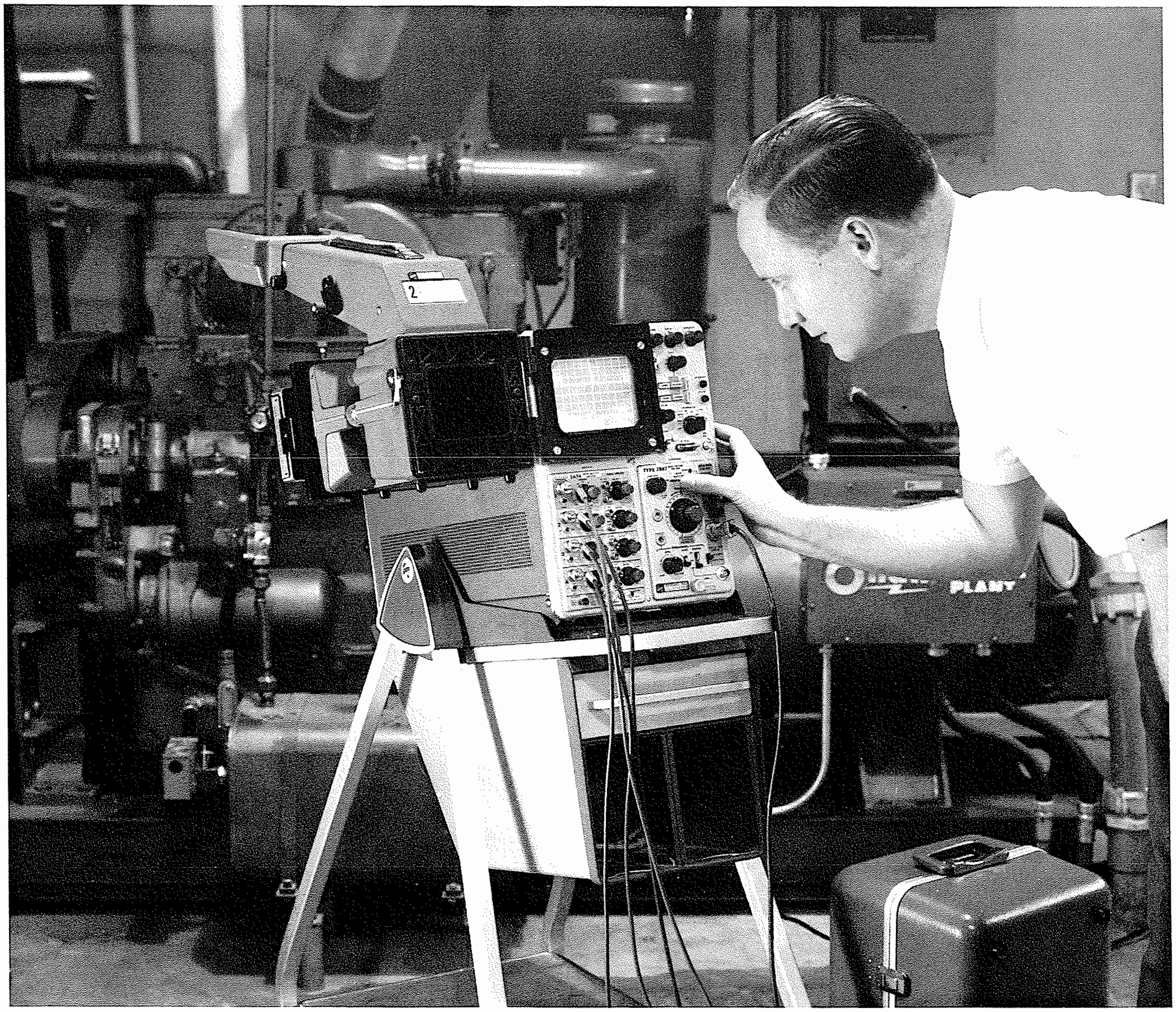
Magnetic pickups are used to indicate the TDC of a piston by detecting a hole or steel stud on the flywheel. The use of magnetic pickups eliminates the inconvenience of timing lights. It is no longer necessary to connect to the high voltage of a spark plug buried somewhere inside the head of a large engine. In addition, there is no large cable capacitance loading the secondary of the ignition system and affecting the timing.

HORIZONTAL DISPLAY

The horizontal display capabilities of the Engine Analyzer are time, crankangle rotation, and piston displacement. The single-sweep mode of the Type 2B67 Engine Analyzer is available for time displays as well as for 2 or 4-cycle engine volume and crankangle displays.

A triangular horizontal modulation signal is provided when no horizontal output is present. This safety precaution prevents accidental CRT phosphor burns. When using the time base the sweep may be triggered externally by the RFG (this connection is built-in), making the triggering insensitive to ignition RFI.

The rotational function generator operates on a photoelectric principle and is a compact lightweight unit with very low rotating torque and a 1:1 ratio. The housing unit is easily rotated for alignment with individual cylinders and has an adjustable dial marked



Bill Verhoef, Engine Analyzer Project Engineer, monitors an Engine Analyzer display.

in degrees to measure the amount of this rotation. A polarity switch is provided, so regardless of crankshaft rotation, the desired crankangle sweep direction is obtained.

SUMMARY

The Tektronix Engine Analyzer System provides valuable information on engine, pump, and compressor performance. The ability to simultaneously monitor pressure, ignition, vibration, and crankshaft rotation provides sufficient information to analyze most problems before extensive damage occurs.

Tektronix manufactures a line of oscilloscope cameras. These cameras all use Polaroid* backs and are ideal for maintaining a history of an engine's performance.

A convenient carrying case is provided which contains all cables, transducers, and accessories required. In addition, space is provided for a planimeter, Polaroid film, timing light, and small tools.

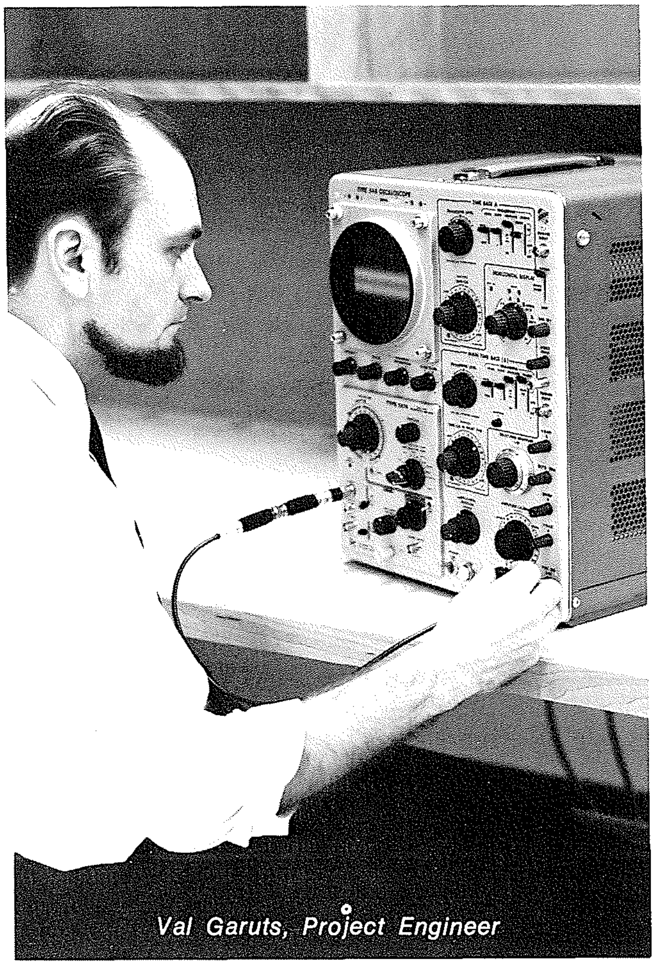
Further information on Tektronix Engine Analyzer Systems is available on pages 178-182 of the Tektronix 1969 Catalog 28, or from your local field engineer. A demonstration is available by contacting any of the 52 field offices serving the United States.

*Registered Trademark Polaroid Corporation

measuring conventional oscilloscope noise

By Val Garuts and Charles Samuel

Noise—random and specific unwanted variations of the trace on a cathode-ray tube (CRT)—is a limiting factor in high-sensitivity measurements with an oscilloscope. The amount of noise visible on a CRT display depends on the oscilloscope's bandwidth, deflection factor setting, the ambient temperature, power line waveform characteristics, and other factors.



Val Garuts, Project Engineer

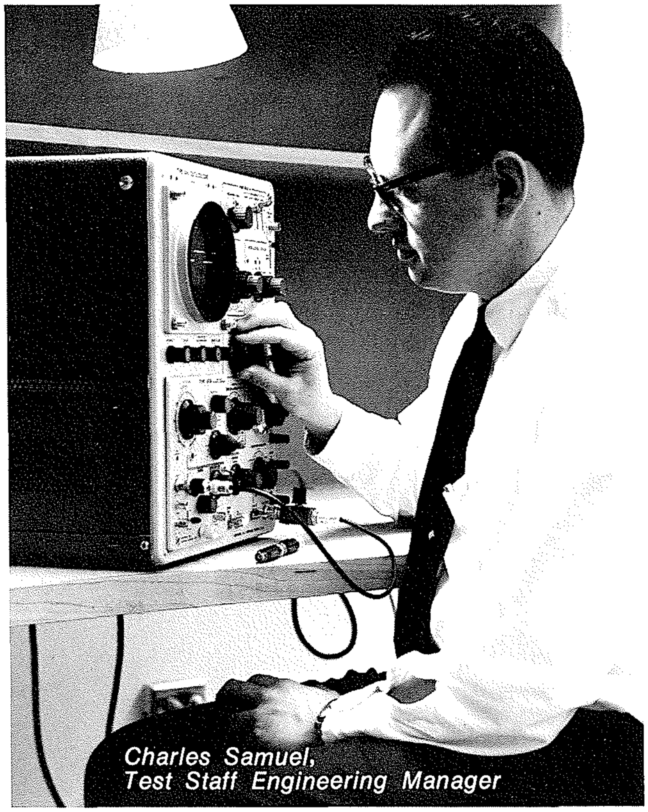
Small amounts of noise usually have little effect on oscilloscope display interpretations. As a result, instruments with less than about 0.2 divisions of noise deflection do not generally have noise performance specified. Instruments with more than 0.2 divisions of noise deflection may have performance areas which are noise limited and thus, a performance specification is required. If the visible noise is much larger than this it may affect measurements made with the oscilloscope.

Three methods to measure and specify noise are presently used on conventional Tektronix instruments:

1. Determine the noise on the display by measuring it at some output point with an RMS voltmeter.
2. Observe the apparent trace width on the CRT.
3. Display a known signal and determine the amount of noise present by tangential measurement (displayed noise).

NOISE MEASURED WITH METER (RMS)

The most repeatable means of measuring noise is with a RMS voltmeter. This method requires access to the signal before it is displayed on the CRT. A calculation is necessary to convert RMS noise to a value corresponding to the CRT observation. The meter *must be* connected to the proper impedance point in the circuit



or the measured noise amplitude will be incorrect. RMS voltmeters are seldom used to describe noise for oscilloscope displays because:

1. Oscilloscope users generally are interested in a specification which can be measured directly from a CRT observation.
2. The complexity of the various sources of noise make it impractical to completely specify noise and difficult to determine where in the circuit to make the measurement.
3. The meter bandwidth will affect the result.
4. Expensive instrumentation is required to verify the specification.

APPARENT TRACE WIDTH

The most convenient method of noise measurement is to determine the peak-to-peak vertical trace width due to noise. Measuring the noise directly at the CRT graticule is also the simplest way to determine the amount of noise present. This requires no extra equipment but is useful only on small amounts of noise deflection where accuracies of ±50% or so are adequate.

Repeatable measurements are difficult to obtain with deflections larger than 0.2 divisions. Different amounts of noise are read at different times and the apparent noise value is changed by ambient lighting and trace intensity. Thus, this method is not adequate for verifying noise performance unless the specification is 0.2 divisions or less. With the apparent trace width method, it is only possible to state that the noise voltage is within a certain value for the time it is observed.

DISPLAYED NOISE

Traditionally, the amplitude of random noise in an amplifier has been stated by an equivalent RMS value of the noise referred to the input. As previously discussed, describing the noise amplitude by stating its RMS value is somewhat unsatisfactory for CRT displays.

Noise interferes with an oscilloscope's usefulness and appears as a visible widening of the trace. This reduces the oscilloscope's ability to display and measure small vertical deflections. A measure of noise-limited resolution may be obtained by noting the vertical signal am-

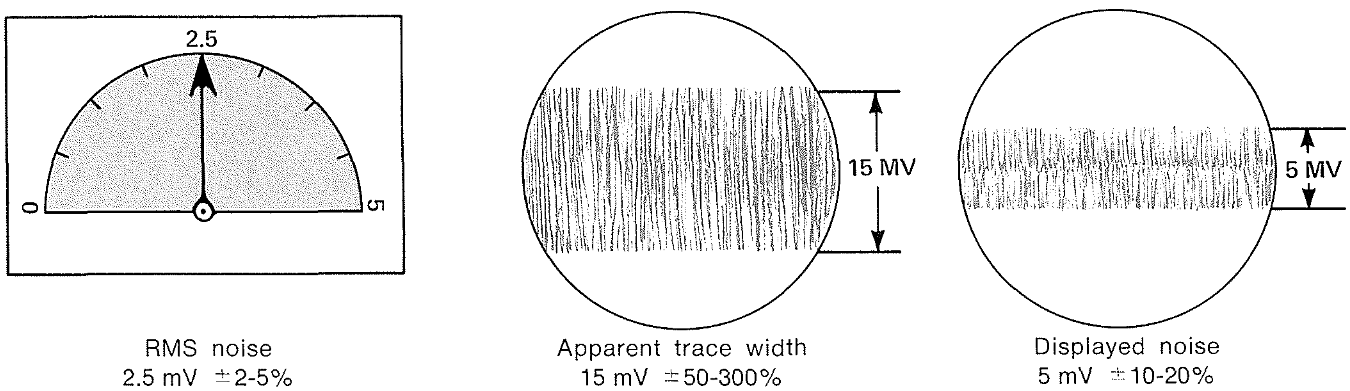


Fig 1. Example illustrating relative amplitudes and accuracies of the three methods used to measure conventional oscilloscope noise at Tektronix.

plitude which will merge two noise traces into one. Noise measured in this manner is defined as displayed noise and is measured by the tangential noise measurement method. This method of stating the noise is more meaningful than the RMS value, since it more closely approximates the actual effect of noise interfering with measurements. It is also much more repeatable than just observing the trace width.

TANGENTIAL NOISE MEASUREMENT

This method is useful with all noise-limited instruments (apparent trace width of 0.2 division or greater). The equipment required is listed below:

1. A squarewave generator, with an internal or external variable attenuator, to produce a frequency 1/10 or less the bandwidth of the oscilloscope.
2. A precision (e.g., ±1%) 100X attenuator.
3. Necessary terminations, cables, etc.

By following the steps below, the displayed noise is easily measured.

1. Set up equipment as in fig 2.
2. Adjust the oscilloscope sweep controls for a free running sweep at about 0.2 ms/div. Adjust the oscilloscope intensity control for comfortable viewing; also adjust the focus and astigmatism concontrols if necessary. The setting of the CRT controls is not particularly critical. Any intensity which produces comfortable viewing may be used and sweep time can have any value that does not produce flicker.

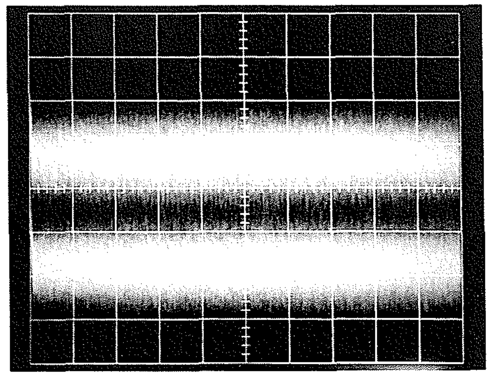


Fig 3. Initial setup for tangential noise measurement.

3. Set the oscilloscope vertical volts/division to the deflection factor where the noise is to be measured, and apply the signal from the test setup shown in fig 2. Adjust the squarewave amplitude so two bands of noise can be observed on the CRT, see fig 3.
4. Reduce the squarewave amplitude till the two noise bands merge (the point where the darker band between the noise bands just vanishes), see fig 4. The final amplitude adjustment should be made slowly, since the observer may adapt to the pattern and tend to observe a residual dark band where none is observable a few seconds later. A total adjustment time of 1 minute is typical.
5. Remove the 100X attenuator from the squarewave path, change the oscilloscope deflection to

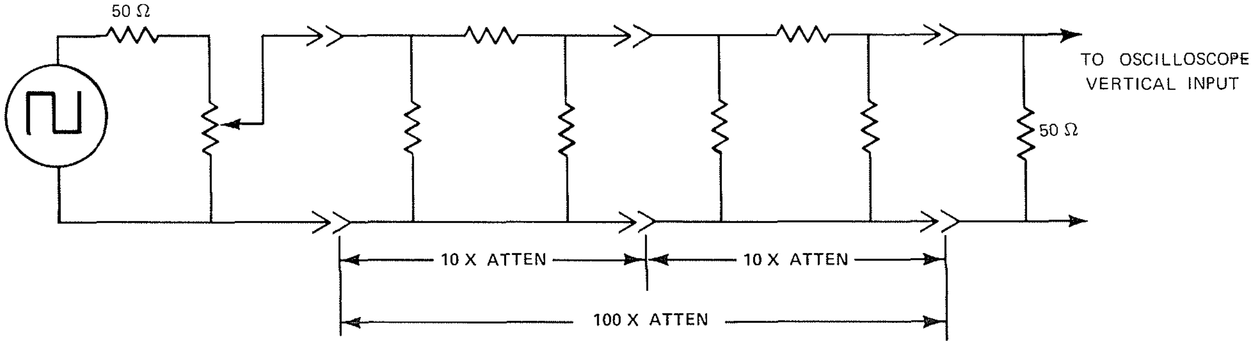


Fig 2. Equipment setup for measuring displayed noise.

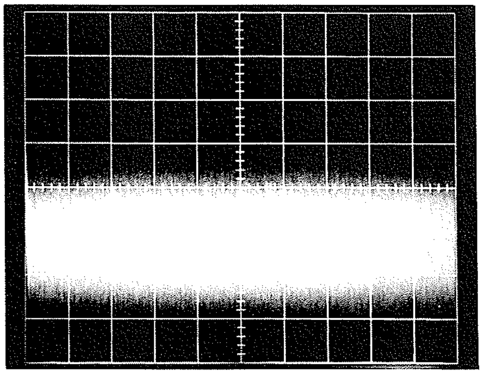


Fig 4. Final Adjustment. Dark band between the noise bands has just vanished.

a suitable value, and measure the squarewave amplitude. Divide this amplitude by 100 to obtain the amplitude of the displayed noise.

RELATIONSHIP TO RMS VALUE

For the very common case of a Gaussian noise amplitude distribution (e.g., thermal resistance noise), tangentially measured displayed noise has a simple relationship to RMS noise: displayed noise $\approx$2X RMS noise. A common situation where these relationships do not hold is for essentially Gaussian noise mixed with a comparable amount of single-frequency signal (i.e., hum).

ACCURACY AND REPEATABILITY

The repeatability of the tangential method is relatively unchanged by changes in trace intensity or ambient lighting. The measurement accuracy depends primarily on the user's ability to detect small differences in the brightness of two adjacent regions. This difference threshold depends upon the absolute brightness of the regions, the brightness relative to background, the closeness of the regions (rate of change of brightness with dimension), the absolute angular size, and other factors. Under optimal conditions, brightness differences as small as 2% can be seen; a 50% brightness difference is always easily perceived. Experiments indicate a 20% brightness difference may be perceived by most operators since conditions such as size, absolute brightness, and relative brightness are under the operator's control. Statistical analysis of independent measurements indicate that 99% of all observations should lie within 20% of the mean of all observations.

The relationship of the three measurement methods described was determined by experiment. Values were determined for the conversion factors described in the following 2 equations:

Noise measured with a RMS meter X conversion factor 1 = displayed noise.

Displayed noise X conversion factor 2 = apparent peak-to-peak trace width of noise band.

Five observers made measurements on each of 13 Tektronix Type 545B/1A7A Oscilloscopes. They made judgments of the amplitude of the noise band observed, measured the RMS noise with a meter at the signal output connector of the Type 1A7A, and measured the displayed noise by the method just described. These observations were tabulated and the conversion factors were determined. These conversion factors indicated that the following relationships are valid for conventional oscilloscopes:

$$\textbf{Displayed noise} \approx \textbf{2 RMS equivalent noise}$$

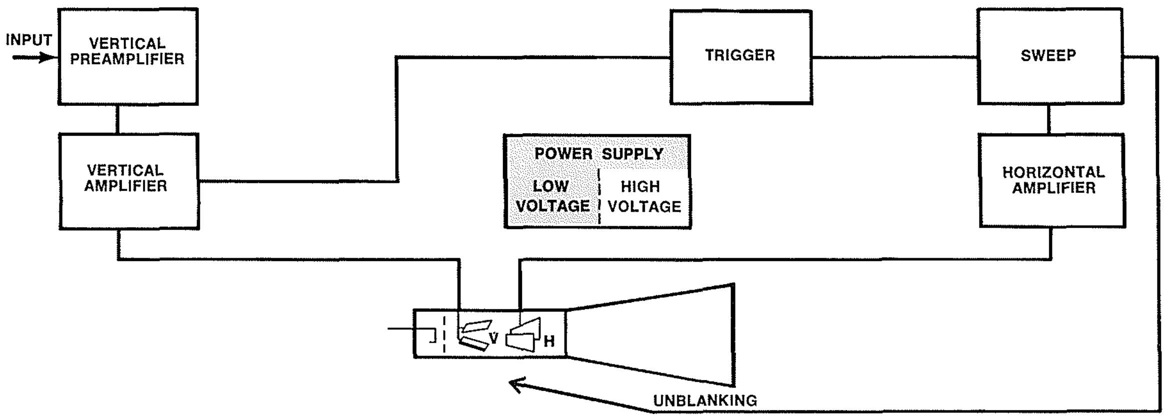
$$\textbf{Displayed noise} \approx \frac{\textbf{apparent trace width}}{\textbf{3}}$$

Note that the visible effects of random noise on a CRT display (apparent trace width) is approximately 6 times the RMS noise value.

CONCLUSION

A tangential noise measurement requires a minimum amount of equipment and offers an accuracy of approximately ±20%. The mean of 5 observations should be accurate to ±10%, provided a particular observer has no fixed bias. In comparison, the accuracy of the apparent trace width measurements may vary several hundred percent. The RMS meter is slightly more accurate than the displayed noise technique but requires more care and additional equipment to make an accurate measurement. As a result of these conclusions, all new Tektronix conventional oscilloscopes specify displayed noise performance by the tangential method of measurement discussed.

SERVICE SCOPE



TROUBLESHOOTING THE POWER SUPPLY

By Charles Phillips
Product Service Technician
Factory Service Center

This second article in a series discusses troubleshooting techniques for Tektronix power supplies. The February TEKSCOPE discusses localizing problems to a major block of an oscilloscope.

The power supply is the most fundamental block of an oscilloscope. The performance of the instrument is only as good as the condition of the power supply. The following information will assist in checking and obtaining the optimum performance from Tektronix power supplies.

For effective troubleshooting, examine the simple possibilities before proceeding with extensive troubleshooting. The following list provides a logical sequence to follow while troubleshooting:

1. Check control settings.
2. Check associated equipment.
3. Thorough visual check.
4. Check instrument calibration.
5. Isolate trouble to block.
6. Check voltages and waveforms.
7. Check individual components.

Incorrect operation of all circuits usually indicates trouble in the power supply. Check first for correct voltage of the individual supplies. However, a defective component elsewhere in the instrument can appear as a power-supply trouble and may also affect the operation of other circuits. A short circuit in any regulated supply may cause the output level of all supplies in the instrument to drop to zero until the short is removed. If the output level of all the supplies is incorrect, check that the Line Voltage Selector Assembly is set for the correct line voltage and regulating range.

Most Tektronix manuals list the tolerances of the power supplies. If a power-supply voltage is within the listed tolerance, the supply can be assumed to be working correctly. If outside the tolerance, the supply may be misadjusted or operating incorrectly. When testing for shorts or overloads, remove the loads from the output filter. Check the resistance of each to segregate which load is causing the short or overload. Next, look in the defective circuit for connections from the power supply directly to ground. Diodes and potentiometers are a good place to start.

CHECKING POWER SUPPLY REGULATION

Connect the oscilloscope under test to a variable auto-transformer. Turn off the sweep and calibrator, and monitor the individual supplies with a 1X probe, AC-coupled to the test oscilloscope. Begin with the reference supply since other supplies are related to this reference. Adjust the variable auto-transformer to the point where the supply goes completely out of regulation, noted by a large increase in ripple. Next, increase the line voltage to the point where the supply pulls into complete regulation, and note the voltage. This point is the low-line regulation voltage (low-line regulation is checked in this manner because of the regulator tube characteristic of holding gain when heated). Next, increase the line voltage to the point where the supply starts to go out of regulation. This point is the high-line regulation voltage. Fig 1 illustrates the various line conditions normally encountered.

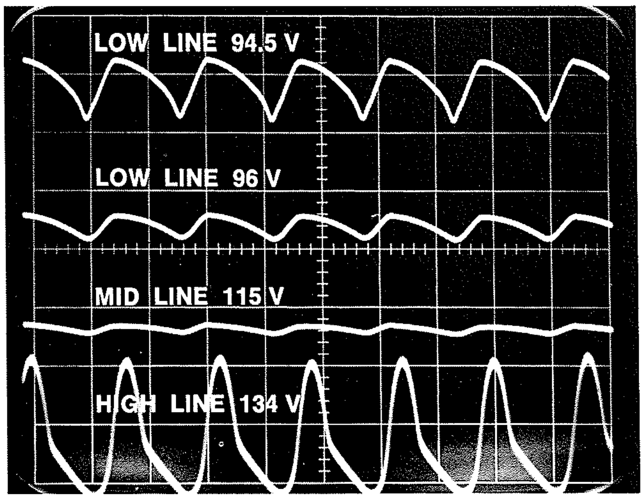


Fig 1. Regulation indications of a typical tube-type power supply.

POWER SUPPLY NOISE

A power supply voltage with noise or microphonics can often be located by rapping softly with a finger. The finger acts as a convenient, reasonably uniform reference when checking for noise. It is often helpful to turn the oscilloscope upside down or on its side and then recheck. This will usually show up loose connections.

RESISTANCE MEASUREMENTS

In tube type instruments (where stacking of supplies is common) the supply resistance will start at ≈2-3 kΩ in the reference supply and increase with each supply. Note—if a supply reads low (500 Ω or so) reverse your meter leads. Some voltage supplies employ a diode at the output and the low reading may be the resistance of the diode. If there is any doubt, consult the instrument manual and check the circuit schematic.

The same technique works with solid-state supplies, although the resistance values are lower. Solid-state power supplies, because of their lower impedance qualities, have supply resistances as low as 25-50 Ω.

Silicon diodes can usually be checked in the circuit and typically read ≈2 kΩ in one direction. When a power supply diode fails it usually will be either a dead short or open. If an in-circuit check leaves doubt as to the condition of a supply, lift one end of the diode to be sure of the reading. Most silicon power supply diodes read ≈2 kΩ or ≈2 MΩ, depending on direction of current flow.

DIFFERENCES IN TRANSISTOR SUPPLIES

Solid-state supplies are more and more common in present day electronic equipment. The following points summarize the major differences between vacuum tube and solid-state supplies:

1. Lower output impedance. As a result, solid-state supplies have lower output ripple—usually on the order of 2 mV.
2. Resistance of supplies is typically lower but checking is the same due to stacking of supplies.
3. Supplies may be checked for shorts immediately after power is applied (no time delay relays).

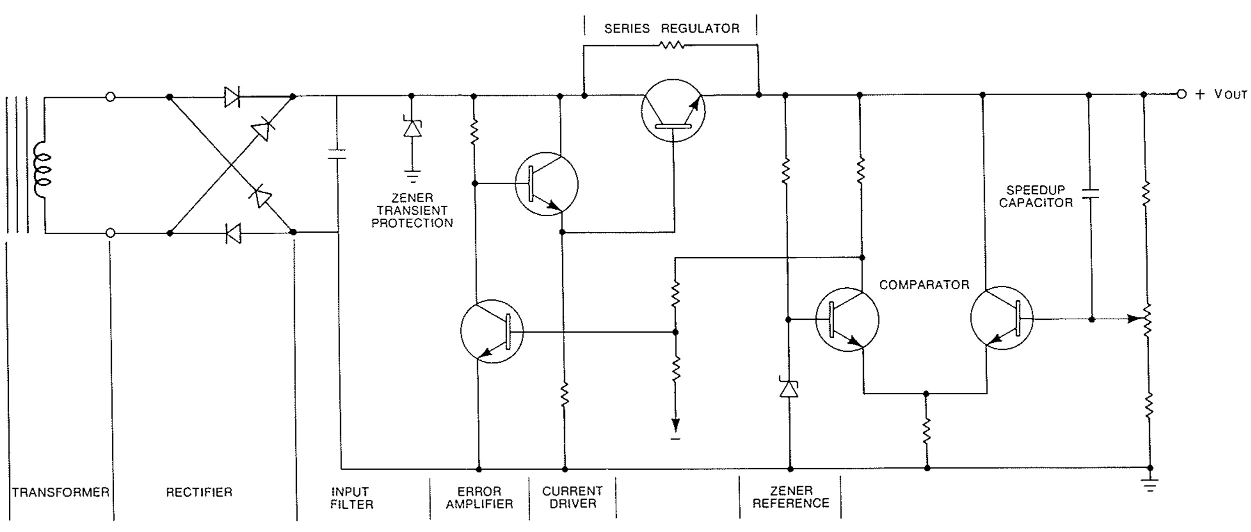


Fig 2. Simplified schematic of solid-state power supply.

4. Less problems with regulators because of less heat dissipation.
5. Varying line voltage does not provide as much information on regulation in a solid-state supply. Use a hair dryer to heat the power supplies, then cool with an aerosol circuit coolant to determine if a supply is faulty. This technique simulates the ambient conditions the supplies encounter over a longer period (2 or 3 hours) than the auto-transformer test. Often this check will indicate a heat sensitive device early and eliminate the need to recalibrate portions of the instrument twice.

COMMON POWER SUPPLY PROBLEMS

1. Fuse blows when power is applied—shorted diode in bridge.
2. Fuse blows when time delay relay closes—overloaded output.
3. Excessive ripple—divide by 10 for approximate solidstate values.
   (a) 50 mV to 1.5 V—comparator, speedup capacitor
   (b) 1.5 V to 8 V—output filter
   (c) 8 V or more—input filter
4. Off tolerance—leakage speedup capacitor (lift one end, change both output voltage setting resistors).
5. Poor regulation:
   at 117 V line—weak compartor
   at 105 V line—weak regulator
6. Noisy output—noisy comparator or regulator, noisy output voltage setting divider, noisy tube or poor connection.

NOTE

Power transformers, manufactured in our plant, are warranted for the life of the instrument. If the power transformer is defective, contact your local Tektronix field engineer for a warranty replacement. Be certain to replace only with a direct replacement Tektronix transformer.

IMPROVED BNC ATTENUATORS

A significant improvement in performance has been incorporated into a new series of BNC attenuators and terminations available from Tektronix. The new design features improved VSWR, greater bandwidth, increased reliability, and extended power ratings (see chart below).

SPECIFICATIONS	OLD	NEW
Power Rating	1 watt	2 watts
VSWR — 250 MHz	(1.1 - 100 MHz)	1.1
VSWR — 500 MHz		1.2
Attenuation Ratio	+ 2% - DC	+ 2% - DC
	+ 3% - 100 MHz	+ 3% - 500 MHz

These new accessories are shorter in length and lower in cost and are available in the following configurations: 50-Ω feedthrough terminations (white); 50-Ω 2X attenuator (red); 50-Ω 2.5X attenuator (white); 50-Ω 5X attenuator (green); and 50-Ω 10X attenuator (brown). In addition, a 5 watt 50-Ω feedthrough termination (black) is available.

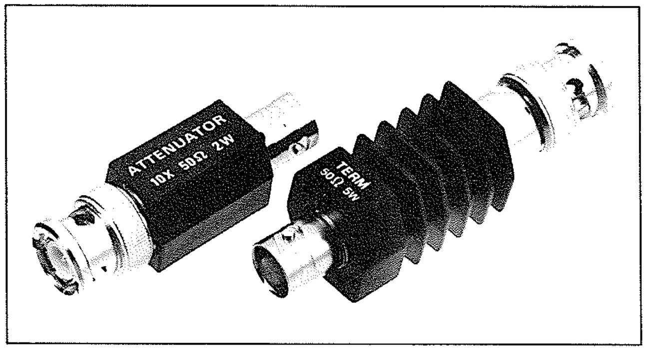


Fig 3. New two-watt attenuator and five-watt termination.

TEKTRONIX WIRING COLOR CODE

All insulated wire and cable used in the Tektronix instruments is color-coded to facilitate circuit tracing. Signal carrying leads are identified with one or two colored stripes. Voltage supply leads are identified with three stripes to indicate the approximate voltage using the EIA resistor color code. (See fig 4). A white background color indicates a positive voltage and a tan background indicates a negative voltage. Note—older Tektronix instruments may use a black background to indicate a negative voltage. The widest color stripe identifies the first color of the code.

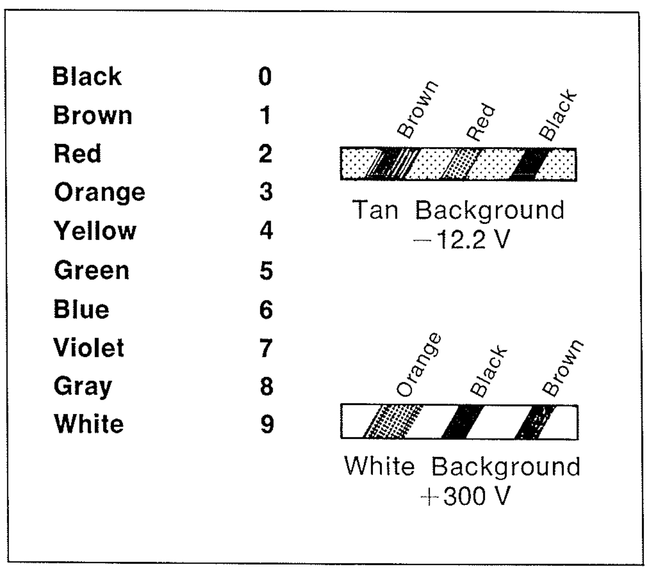


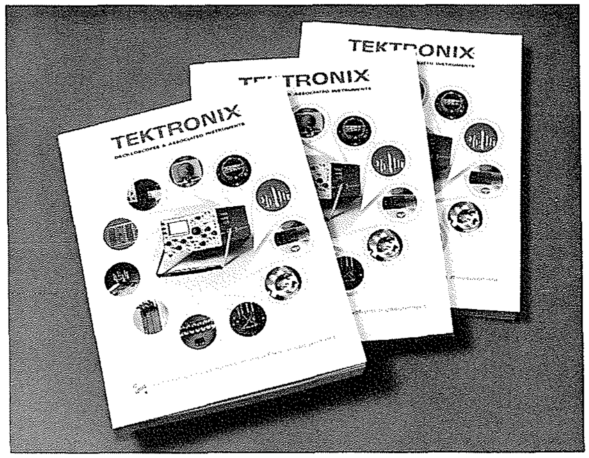
Fig 4. Tektronix color-coded insulated wire.

1969 TEKTRONIX CATALOG

The new 1969 Tektronix Instrument Catalog 28 has been distributed to the mail list and your copy should now have reached you.

Over 40 new Tektronix products have been added since mailing of Catalog 27. The catalog includes a new functional index in the rear and an expanded reference section in the front.

If you have not yet received your 1969 Tektronix Catalog, contact your local field engineer.



INSTRUMENTS FOR SALE

1—Type 122 Low Level Preamplifier. Good condition. Contact: Mr. Ed McKenna, Mechanical Engineering Department, University of Colorado, Boulder, Colorado 80302.

1—Type 203, Model A, Scope-Mobile® Cart for 561A, with plug-in carrier. Contact: Mr. Kian Miradadian, 7020 Atwell, Houston, Texas 77036. Telephone: (713) MO7-5067.

1—Type 514AD, SN 139 in excellent condition. Latest mod kits and flat face tube. Price: $275. Contact: Mr. George L. Garton, 3576 Texas Street, San Diego, California. Telephone: (714) 460-4509.

1—Type 524AD, SN 5715. Contact: Mr. George Groth, Jampro Antenna Co., 6939 Power Inn Road, Sacramento, California 95828. Telephone: (916) 383-1177.

1—Type 561A, SN 20580; 1—Type 3S1, SN B090795; 1—Type 3T77A, SN 5463; 1—Type P6034; 1—Type P6035. Price: $2,250. All in excellent condition. Contact: Judy Masters, Sudmier Enterprizes, Inc., 1527 W. El Segundo Blvd., Gardena, California 90249. Telephone: (213) 754-2821.

1—Type 545B, SN 236; 1—Type W; 1—Type P6019, with 134 Amplifier. Contact: E. Schwab, 8 Chatham Place, Huntington, Long Island, New York 11743. Telephone: (516) 864-8725.

1—Type 535-S2, SN 5737; 1—Type CA Dual-Trace, SN 017641. Price: $600 sold as a unit. Contact: James Hooper, Argonaut Insurance Company, 250 Middlefield Road, Menlo Park, California 94025. Telephone: (415) 326-0900 Ext. 44.

1—Type 422, SN 10685 (Mod 125 without battery pack). Price: $1400. 1—Type 310A, SN 20903. Price: $500. Contact: A Zandbergan, Northern Radio, 4027 - 21st Avenue West, Seattle, Washington 98199. Telephone: (206) AT 4-0534.

1—Type 512, SN 1016. Price: $125. Contact: Larry Keyser, Econolite Division, 3644 Albion Place North, Seattle, Washington 98103. Telephone: (206) ME 3-2159.

1—Type 80/P80 Vertical Plug-In Probe with 5 attenuators, SN 003904. Price: $125. 1—Type 81 Plug-In, SN 3149. Price: $85. Contact: A. Barron, 1122 Brunswick Way, Santa Ana, California 92705. Telephone: (714) 540-1234.

1—Type 535A Oscilloscope. Two Scope-Mobiles®, Models 500/53A. Used moderately. Price: $1,200. Contact: Miss Cannon, Biochemical Procedures, 12020 Chandler Blvd., North Hollywood, California 91607. Telephone: (916) 766-3926 Ext.36.

1—Type 515; 1—Type 516. Good condition. Contact: Robert Galbraith, 11513 Bar Harbor Place, N. E. Albuquerque, New Mexico 87111. Telephone: (505) 264-6468 (work); (505) 298-9590 (home).

1—Type 541A, SN 022675; 1—Type B Plug-In, SN 019056; two probes. Contact: Alvin Walker, Electro of Arizona, 4025 N. 6th Street, Phoenix, Arizona 85012.

1—Type 545A; 1—Type D; 1—Type CA; 1—Type 160A; 1—Type 161; 1—Type 162; 1—Type 163. Contact: Intectron, Inc. P. O. Box 584, Waltham, Massachusetts 02154. Telephone: (413) 891-4114.

1—Type 310A, SN 21847. Price: $450. Very good condition. Contact: Frank A. Hayes, Red Hill Road, Middletown, New Jersey 07748. Telephone: (201) 671-0271.

1—Type 585 Oscilloscope, SN 002799; 1—Type 80, SN 003456; 1—Type P80 Probe; 1—Type L Plug-In Unit, SN 019918; 1—Type 81 Adapter, SN 005-006. Price: $1000 for entire package. Instruments recently factory calibrated. Contact: Mr. Art Godsen, Maritime Communications, 4210 Lincoln Blvd., Venice, California. Telephone: (213) 397-7705.

1—Type RM561, SN 717; 1—Type 2A63, SN 4463; 1—Type 3B3, SN 131. Will consider separate sales. Contact: Mr. Russ W. Johnson, Ball Brothers Company, P. O. Box 1062, Boulder, Colorado 80302.

INSTRUMENTS WANTED

1—Type 545/CA or equivalent. Contact: Mr. Jerry Cowan, Sperry Rail Service Division Automation Industries, Shelter Rock Road, Danbury, Connecticut 06810. Telephone: Office (203) 748-9243, Home (203) 868-2252.

1—Type 585 with Type 82 Plug-In. Contact: Donald A. Paris, 48 East Circle Drive, East, Longmeadow, Massachusetts 01028. Telephone: (413) 525-2333.

1—Type S Plug-In. Contact: Dr. T. S. Chu, Electronic Sciences Department, Southern Methodist University, Dallas, Texas. Telephone: (214) 363-5611 Ext. 2221.

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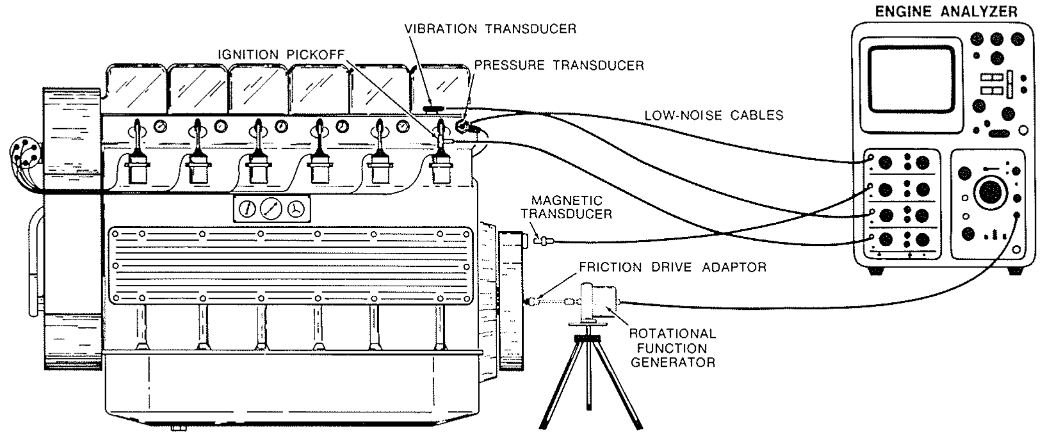
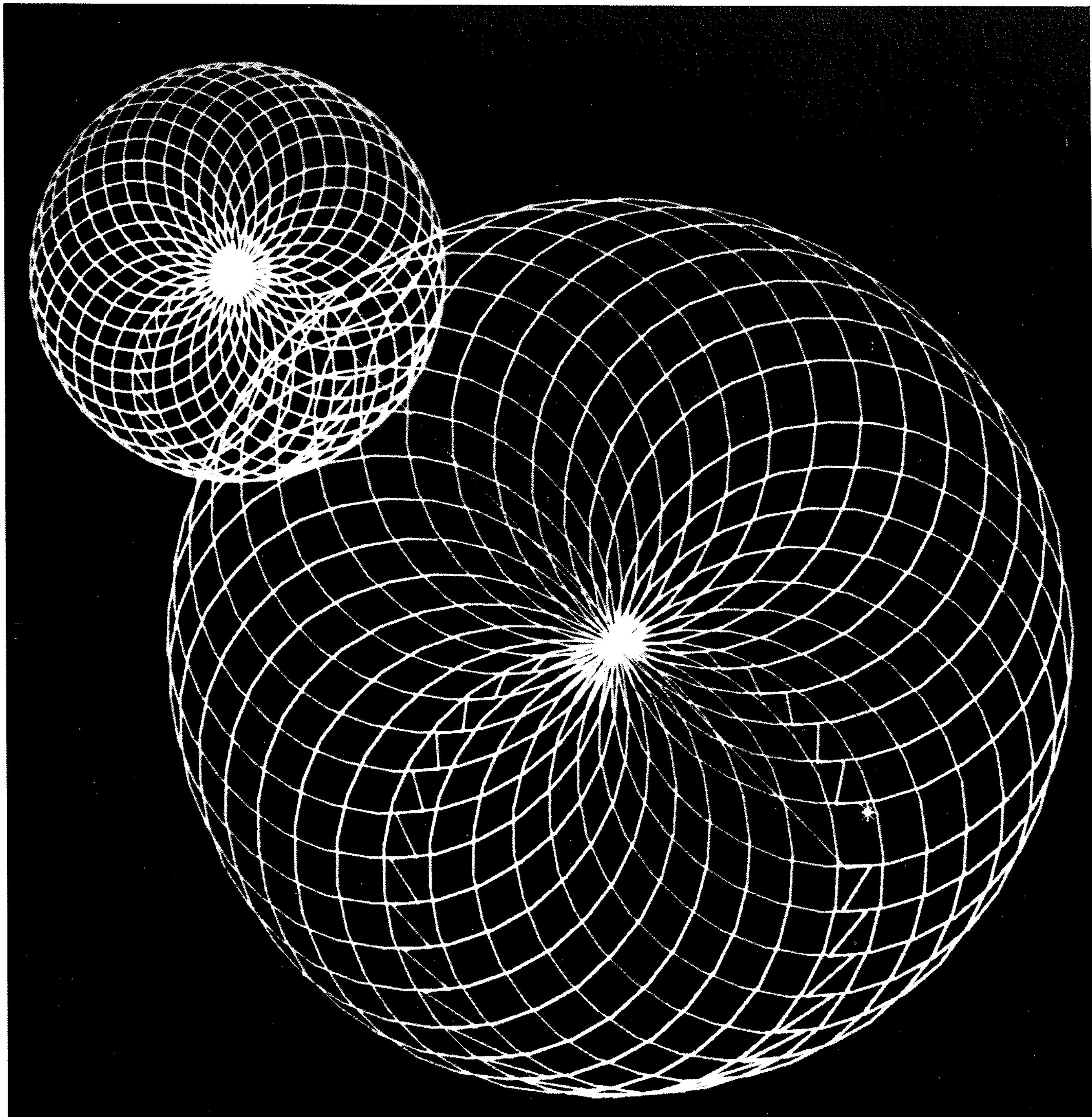
ENGINE ANALYSIS



DISPLAY	APPLICATION
Pressure-Time	*Observe many combustion cycles to measure variations in peak pressures, rate of pressure rise, and r/min.*
Pressure-Volume (Compressors, Pumps)	*Evaluate performance of suction and discharge valves, compressor capacity, ring action, volumetric efficiency, and overall compressor, and pump operation.*
Pressure-Volume (Combustion Engines)	*Evaluate engine performance, cause of horsepower variation, measurement of efficiency, compression ratio, capacity, power balancing, and horsepower.*
Pressure-Crankangle	*Observe engine events (valve openings and closings, ignition or pre-ignition, etc.), against the crankangle at which they occur. Four-trace oscilloscope displays vibration, pressure, ignition, or any desired combination of curves required to evaluate compressor and engine performance.*
Vibration Analysis	*Detect, locate, and identify defective parts to uncover destructive detonation, improper valve functions, piston slap, improper function of compressor valves, worn valve cams, carbon buildup, blow-by, leaking valves, ring damage, blower bearings, engine cylinder run-in, and other malfunctions.*
Ignition Analysis	*Proper timing of engine, evaluation of breaker point gapping, point arcing, point bounce, low and high resistance in secondary circuits, spark plug condition, shorted primary, coil condition, etc.*

TEKSCOPE

JUNE 1969



A New Look in Information

1 Low-Cost Graphics

2 Offline Editing

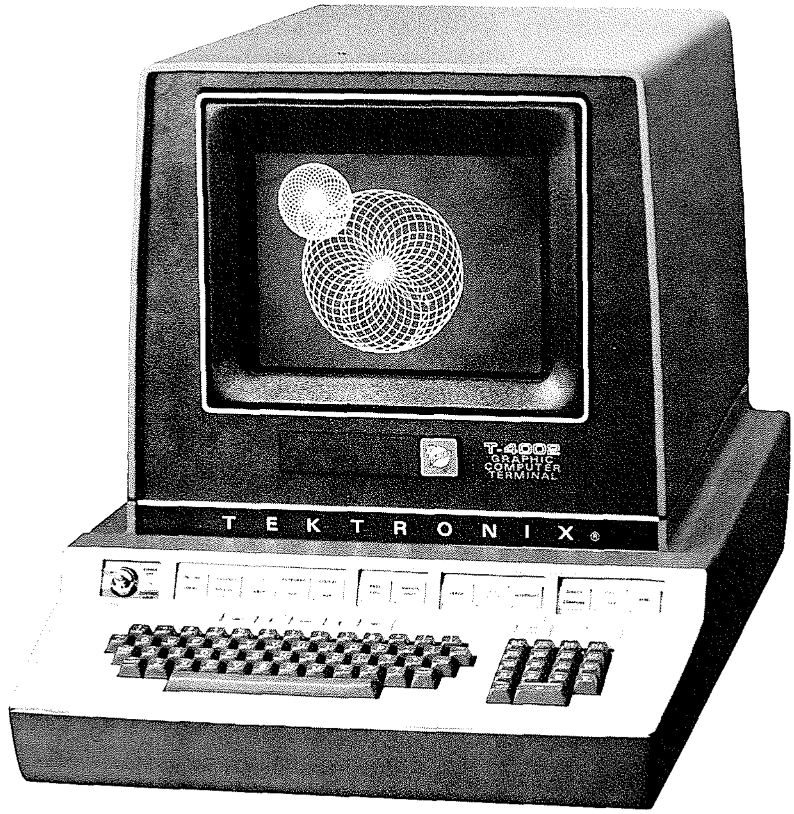
3 Storage Basics

4 Scan Conversion

COVER
Circle on circle program. This graphic display is formed when the locus of the centers of circles form a circle.

Five years ago Tektronix introduced the Type 564 low-cost, direct-view bistable Storage Oscilloscope. Many customers involved in computer readout projects found this instrument to be the best overall compromise for a computer readout device. Since that time customer interest in this area has resulted in the formation of an Information Display Division. The June issue of TEKSCOPE discusses some of the significant developments of this new Tektronix technology.

Display



1 Low-Cost Graphics

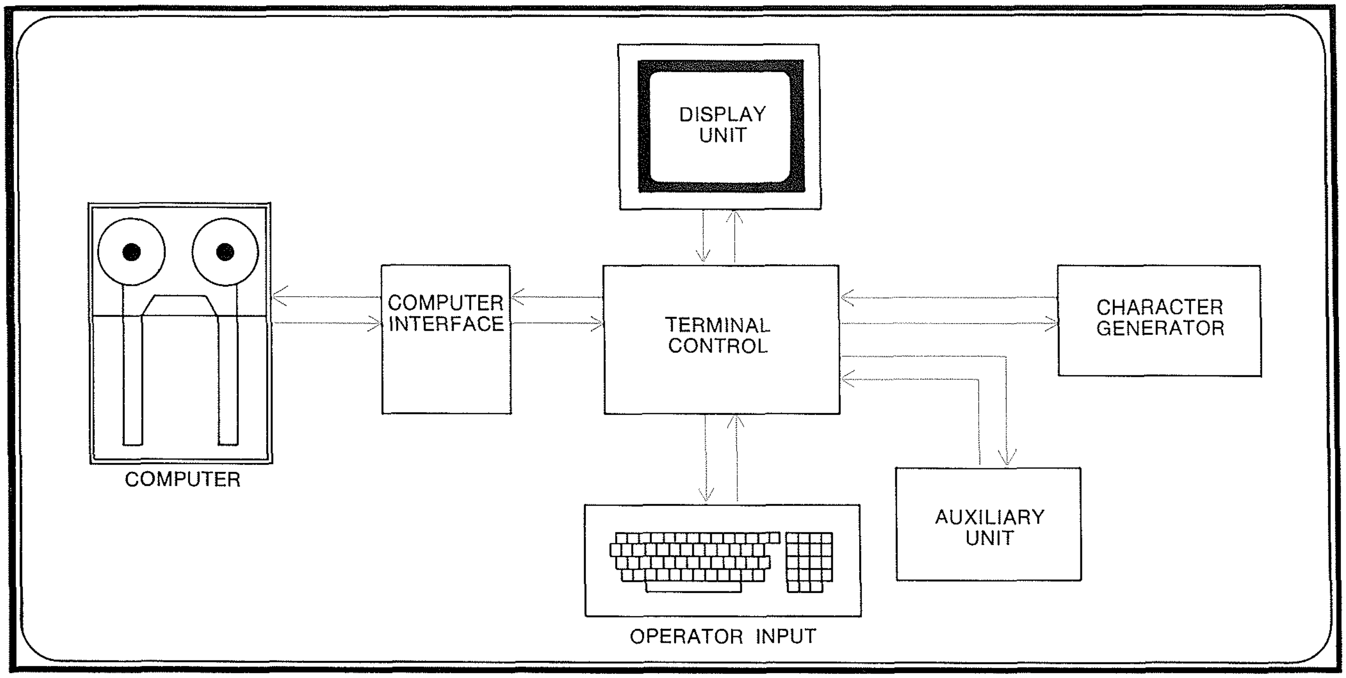
A new low-cost graphic computer terminal is capable of presenting high-information content messages at speeds of up to 2000 characters per second. For the first time, low-cost (less than $9000, including interface) complex graphic and high-density alphanumeric displays are possible. This breakthrough in information display technology allows users to now consider graphic displays where cost has been prohibitive in the past. The Tektronix T4002 Graphic Computer Terminal offers greater information content at approximately one third the price of other graphic systems.

The Tektronix Type T4002 Graphic Computer Terminal is a completely self-contained, desk-top information system which provides a high-resolution, flicker-free display with both high-speed complex graphic and high-density alphanumeric capability. Its unique direct-view storage tube eliminates the requirement for a separate refreshed memory and minimizes the information rate requirements of the data source. With no display refreshing circuitry, the annoying flicker associated with most refreshed displays is also eliminated. The new data is written only once and data can therefore be sent to the terminal at a convenient rate of up to 2,000 characters per second.

The direct-view bistable storage tube provides most of the economic advantage of this type of system. The slower speed allows the use of software for much of the data formatting and data control functions. In addition, the analog character generator, with its characteristic of high-accuracy and low-slew rate, contributes to the low-system cost.

To ensure maximum flexibility, the terminal uses a standard control and input signal interface that is compatible with the following Tektronix Display instruments.

Type 601 . . . . (5-in storage monitor)
Type 602 . . . (5-in high-resolution monitor)
Type 611 . . . . (11-in storage monitor)
Type 4501 Scan Converter (large-screen TV display)



T4002 GRAPHIC COMPUTER TERMINAL BASIC BLOCK DIAGRAM

A solid-state, data-entry keyboard and the visual display of high-resolution alphanumerics and graphics provide a truly interactive system. No longer is the user required to obtain his information from columns of data or lists of numbers. The low cost of this graphics system allows managers to now obtain trends quickly and easily. Information may now be summarized in graphs, electrical circuits drawn, flow diagrams developed, etc.

The T4002 is designed to use existing software as much as possible. TTY teletype interface is provided to allow complete compatibility with common existing teletype terminals. Thus, the user who is connected into a time-share service or computer with a regular teletype can connect the terminal with no change in software. Note: There may be a teletype-speed limitation unless the computer interface is modified to eliminate the time delays for TTY teletype. Once this high-speed link is available, however, the full capabilities of the Tektronix Type T4002 may be utilized.

Four modes of display are selectable on the Type T4002: (1) Alphanumeric, (2) Point plotting, (3) Incremental plotting and (4) Linear interpolation plotting. A fixed grid of 1024 x 780 calibrated addressable points are available in any of the three graphic modes.

The three modes of graphic displays selectable on the T4002 are discussed at right. Programs that have been developed in any of the three modes mentioned below will generally be suitable for use with the Type T4002 with only minor modifications.

1. Point Plot: The point-plot mode generates a display by providing a separate address for each point and then plotting it. Although there is no restriction on where the point is placed, this mode is inefficient because of the amount of bits required to draw a graphic display.
2. Incremental Plot: Incremental plot mode is widely used by mechanical plotters. The display is generated by providing an address for the beginning point. The next point must be adjacent in one of eight directions and may be printed or not printed. This incremental technique saves data bits compared to the point plot mode.
3. Linear Interpolation: The linear interpolation mode provides a beginning and ending address. A line is then generated between the two points. This vector-type display allows smoother lines to be drawn since the beginning and ending points are the only points that must be on the fixed grid. Because minimal data is required to draw graphics, this mode is particularly appropriate when sending over phone lines.

One of the greatest advantages of the computer terminal is the fact that programming is made so much easier and quicker. When writing and "debugging" programs, a teletype readout is slow enough that the programmer often loses his train of thought. The mind usually thinks much faster than a teletype can print out program elements. The tremendous speedup of the T4002 with its quick readout allows a rapid input back into the system. Thus, ideas and changes are applied without delay and the effects may be immediately observed. This interactive display capability is particularly important when developing graphics programs since there is little delay from program development to program observation.

The T4002 Graphic Computer Terminal basically consists of a display unit, terminal control, character generator, keyboard module, input/output interface and auxiliary unit.

The 11-inch, flicker-free display (6½ x 8¼-inch screen) accommodates 37 lines of alphanumeric characters of 85 symbols each, permitting more than 3000 characters to be displayed. Resolution is equivalent to 300 x 400 line pairs.[1] Stored information may be erased in less than 0.5 second.

The terminal control provides timing logic, data buffers, interconnection logic, function decoding, scratchpad control, D/A converters and plot logic for the character generator, keyboard and auxiliary module. All the data is routed and priorities determined by the Terminal Control.

The character generator provides a complete set of USASCII[2] printable characters with both upper and lower case, numbers and special symbols. In addition, two sizes of characters are under program control.

The control panel is designed for ease of operation with panel controls held to a minimum with automatic control functions. In addition to the standard keyboard with 96 USASCII characters and 32 control characters, the following functions are provided.

ON LINE/LOCAL—Controls status of terminal.

TRANSMIT/RECEIVE—Indicates status of data transmission.

TTY/ASCII—Permits selection of keyboard code.

1. Refer to April 1968 Service Scope "Direct-View Bistable-Storage CRT Resolution
2. USA Standard Code for Information Interchange

INPUT—Permits selection of KEYBOARD and/or AUXILIARY.

OUTPUT—Permits selection of DISPLAY and/or AUXILIARY.

PAGE FULL—Indicates full page and stops computer information (when input is available).

MARGIN SHIFT—Choice of four-margin positions.

ERROR—Indicates communication or echoplexed character error.

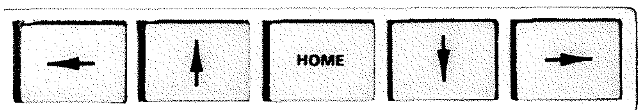
DATA RECEIVED—Indicates when computer makes display entry.

INTERRUPT—Stops transmission.

FORMAT CONTROLS—Cursor indicator in alphanumeric mode.

VIEW—Switches display from a hold mode to a view mode for 1 minute.

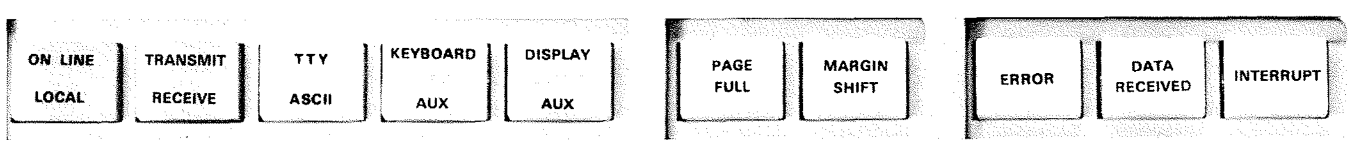
ERASE—Erases the display.

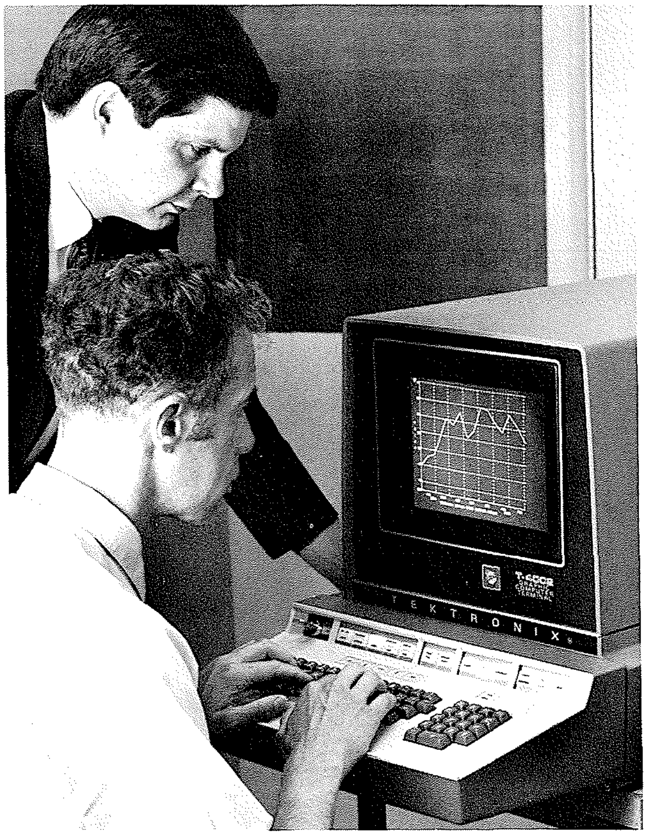


The format controls determine the positioning of the cursor. The adjacent VIEW and ERASE button allow holding or changing of the stored display. These seven buttons differ from the control functions in that they do not go to the computer, but into the display. Thus, formatting the location on the display does not disturb the output from the computer. The HOME button returns the cursor to a fixed reference.

Color-lighted buttons are used to simplify operation and to alert the operator of the terminal status. By pushing a button, the status can be changed. Five colors are used with the following logic.

- Green — On Line — Normal Operation.
- Blue — Local or Auxiliary.
- White — Status (completion of operation).
- Amber — Incomplete Operation — Error may occur unless corrective action is taken.
- Red — Operator action is required.





Stu McNaughton, Project Engineer, and Ernst Massey, Mechanical Engineering Manager, discuss a graphic display on the T4002 Graphic Computer Terminal.

Two interfaces are currently available for the T4002 Graphic Computer Terminal. The Type 4801 (parallel interface) interfaces with the DEC PDP-8 family of computers; the Type 4802 (serial data communications interface) interfaces with Bell System Type 132, Type 201 and Type 202 Data Sets and other EIA compatible modems or high-speed data systems. Both interfaces permit alphanumerics and all graphic modes to be sent over normal ASCII communication circuits.

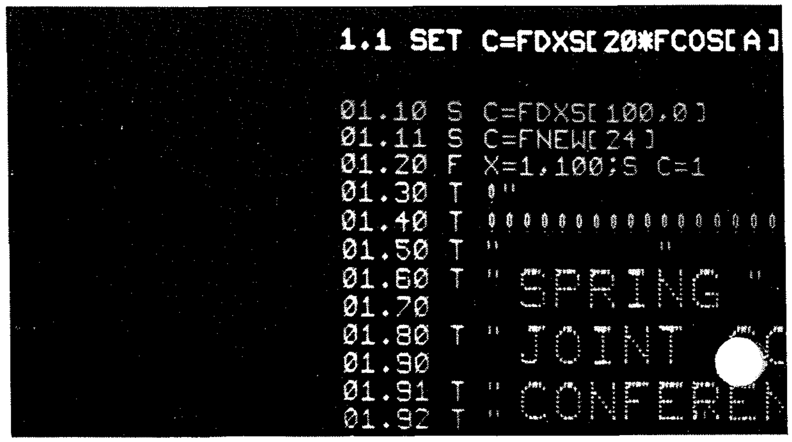
The T4002 is designed to accept an auxiliary plug-in module to expand future capability. Inputs to peripheral gear and outputs from peripheral gear such as teleprinters, tape readers and magnetic recorders are feasible.

The T4002 offers a substantial improvement over electromechanical teleprinters in speed, noise of operation, and flexibility in the formatting and editing of data. These advantages, combined with a complex graphic capability, provide a complete versatile system for less than $9000 (including interface). For further information on Tektronix Information Display products, refer to pages 276-293 of the Tektronix 1969 Catalog 28, or consult your local field engineer.

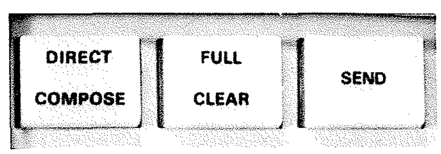
2 Offline Editing

John Griffin, Project Manager, Information Display Electronics

The large-screen storage tube used in the T4002 has a number of advantages for graphic and alphanumeric displays. The tube is rugged, low-cost, has flicker-free operation, and is capable of very high information density. Because the Tektronix storage tube stores the information in analog form (a series of lines and/or dots on the screen) the information is not stored in discrete locations in coded form.



The new offline editing feature of the T4002 Graphic Computer Terminal incorporates a scratch-pad memory of a one-line (84-character) discrete memory. This memory is used in conjunction with a small refreshed area at the top of the tube. The information is in numeric form and thus the user can edit the text before sending the information to the computer as a one-line message block. Information may be updated and verified, corrected if necessary before it is sent to the computer.



Use of the electronic scratch pad is as follows: The COMPOSE button is pressed to change operation from DIRECT to COMPOSE. At this time the refreshed scratch pad area is displayed and the characters in the buffer memory are presented in one line across the top of the tube.

Information may be changed in one of several manners. The CLEAR button clears the text from the buffer and the cursor reverts to the left-hand edge of the refreshed area (point of entry of next character). The desired text is typed in and entered into the buffer and appears in the scratch pad area. (When editor-buffer capacity is reached, the FULL button is lighted to alert the operator). Once the message is complete, pressing the SEND button sends all of the text to the computer as though it were coming from the keyboard.

Fig. 1. The 84-character refreshed memory shown below, allows text to be quickly and easily corrected and edited before being sent to the computer.

This operation offers two advantages. First, text is edited and you know it is correct before you send it; second, it allows you to send a burst of text (i. e., one complete line as opposed to a number of individual characters) which minimizes the transmission time of the machine.

The scratch pad buffer is also convenient for incorrect messages. If the message is not correct the first time typed, editing is accomplished as follows: The keyboard is backspaced until the cursor is located where a change is desired (the scratch pad cursor consists of an underline so as not to obliterate the dot matrix of the character block).

Once the cursor is at the desired location you have one of two options: a) Delete the character. b) Insert a character before the character designated by the cursor. Striking the DELETE button removes the character from the buffer and you have one character less. If you wish to insert a character, you simply start typing characters and they will be inserted just before the character which has the cursor underneath it. Fig. 2 illustrates these editing operations.

When the editing is finished the SEND button is pressed

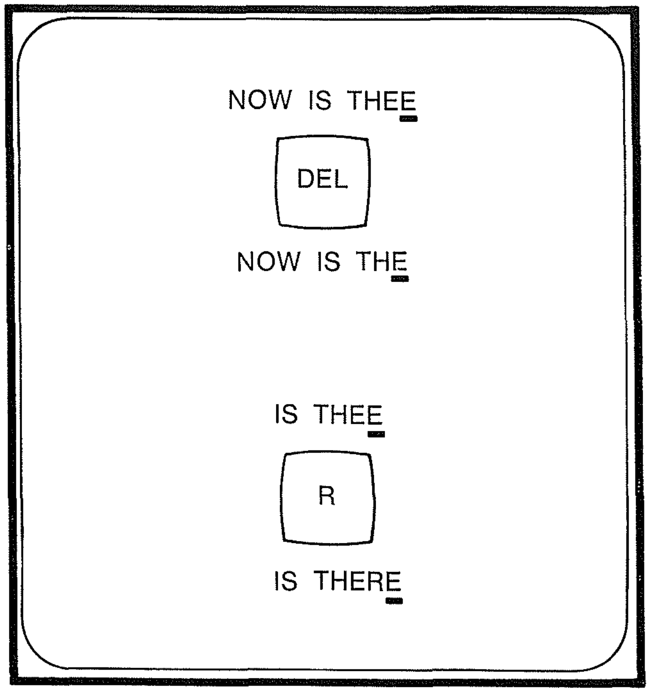


Fig 2. Characters are deleted by striking the DEL button and inserted (before the character designated by the cursor) by striking a character button.

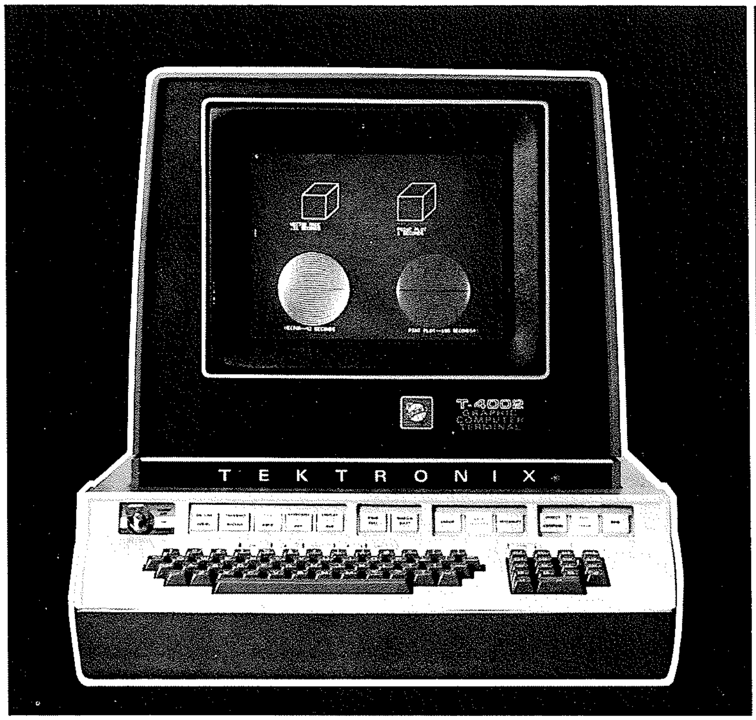
and the information is sent to the computer as a block of data. Pressing the SEND button automatically returns the terminal to the DIRECT mode and it is necessary to return it to COMPOSE to edit the next line.

Another point of interest is that the text buffer is not erased by the SEND command. Therefore, if an error is encountered in transmission, the entire text buffer could be sent out to the computer again, simply by striking the COMPOSE and SEND buttons.

Scratch-pad operation combines many of the advantages of refreshed terminals with the advantages of the direct-view storage tube. The result is a low-cost remote terminal well suited for text editing applications. Scratch-pad operation is particularly desirable where relatively unskilled operators require information over a time-share network, e.g., parts information and parts drawing applications where a very small amount of input must be accurate.

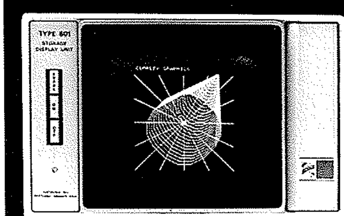
A second area of scratch-pad usage is when the terminal is used as a remote "batch" device. Such a use requires updating of information in computer files. The information that is being sent to the computer is the updated information and must be correct. Therefore, it is desirable to compose and verify the entire entry before sending it to the computer.

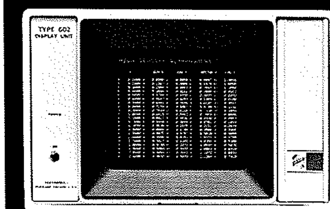
THE TEKTRONIX FAMILY OF INFO



T4002 GRAPHIC COMPUTER TERMINAL

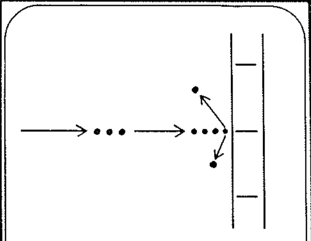
TYPE 601 STORAGE
DISPLAY UNIT ↓



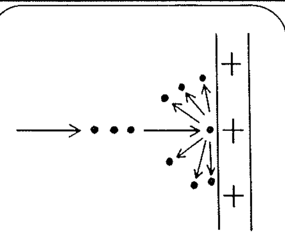


TYPE 602 ↑
DISPLAY UNIT

3 Storage Basics



Slow electrons dislodge few secondaries. The material, gaining electrons, charges negative.



Fast electrons dislodge many secondaries. The material, losing electrons, charges positive.

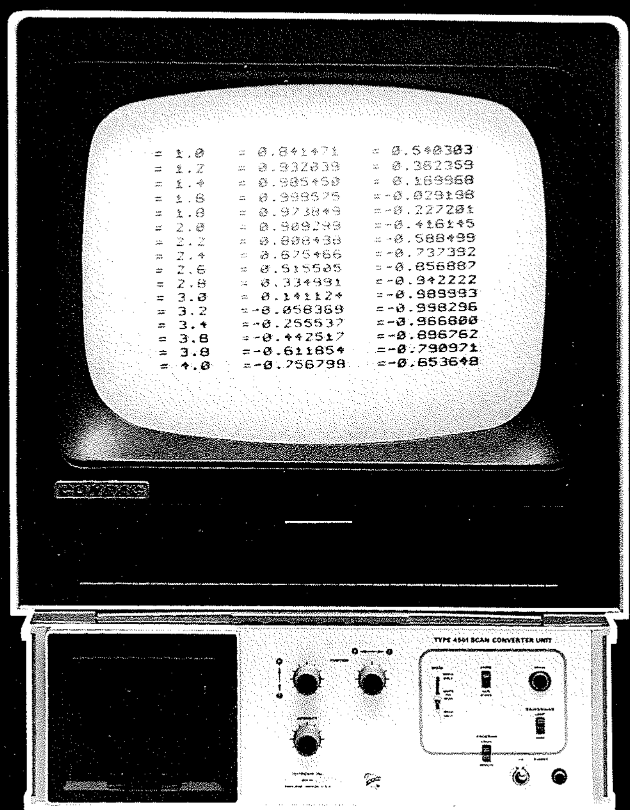
The Tektronix direct-view bistable storage tube (DVBST) is based on a secondary emission principle. When a stream of primary electrons strikes the phosphor target, secondary electrons are dislodged from the phosphor surface. As the potential increases, each primary electron displaces more than one secondary electron, resulting in the material charging positive.

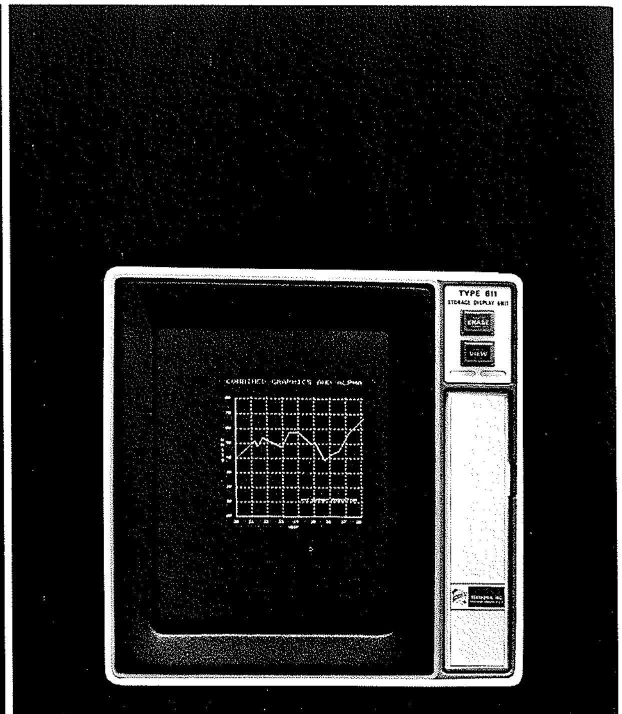
In addition to the normal CRT writing guns, flood guns are used to cover the complete phosphor screen uniformly with low-velocity electrons. A conductive transparent face plate under the phosphor completes the circuit and allows storage to take place.

The normal writing gun bombards the phosphor screen with a beam of high-speed focused electrons. The beam writes and also dislodges great numbers of secondary electrons. The written surface where the waveform is traced out loses electrons and charges positive.

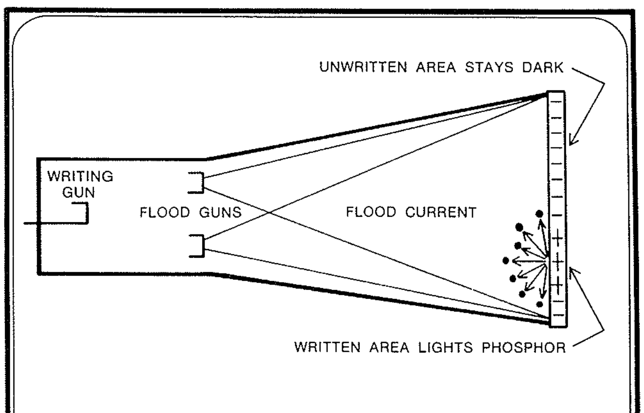
MATION DISPLAY INSTRUMENTS

TYPE 4501 SCAN CONVERTER





TYPE 611 DISPLAY UNIT



Flood gun electrons hit unwritten areas too closely to light phosphor and the target charges negative. The positively charged written area attracts electrons at high speed keeping the phosphor lit and dislodging enough secondaries to hold the area positive.

By using the flood-electron guns, the display may be stored. The flood guns emit low-velocity electrons over the whole CRT-screen area. The electrons strike the unwritten area too slowly to jar loose many secondaries. As a result, these areas merely collect electrons until they are driven negative and can attract no more current.

The latent image where the beam has written attracts flood electrons at such a velocity so each entering primary dislodges sufficient secondaries to hold the phosphor target positive. Thus, the written area neither gains nor loses electrons but remains positively charged and continues to attract flood current. As a result of this equilibrium, the trace is stored.

This is the basis for all Tektronix direct-view bistable storage tubes. The same flood current that holds the background dark also holds the written trace bright.

Tektronix bistable storage tubes provide a medium for the conversion of analog inputs into TV format. These bright displays are ideal for individual or group viewing under high-ambient light conditions.

The heart of the Tektronix Type 4501 Scan Converter is a Tektronix-developed storage tube which acts as a graphic memory. A composite video output is provided for convenient viewing on large-screen television monitors and receivers. Single events stored on the CRT or dynamic displays of changing information may be scan-converted into TV format.

The Type 4501 Scan Converter Unit may be looped through a number of monitors for viewing at multiple remote locations. The Type 4501 output signal is suitable for mixing with another TV signal to create a picture that is an overlap of two signal sources. For example, an active TV camera output could be superimposed with information scanned from the Type 4501.

4 Scan Conversion

Scan Conversion is a term which has been applied to several processes used to transmit images between two systems which are electrically incompatible, e.g., radar PPI to TV or PAL TV to NTSC TV. Although the basic principle is not a new one, modern techniques and components have made it possible to apply the principle in new ways.

Once the analog input information is stored on the Type 4501 CRT, the input source may be removed. The stored image is then continuously scanned and displayed on TV monitors, until erased on command (200 ms). The tube also operates in a nonstorage mode where dynamic displays are desired. Resolution is equivalent to 100 x 125 stored line pairs and dot writing is less than 8 μs.

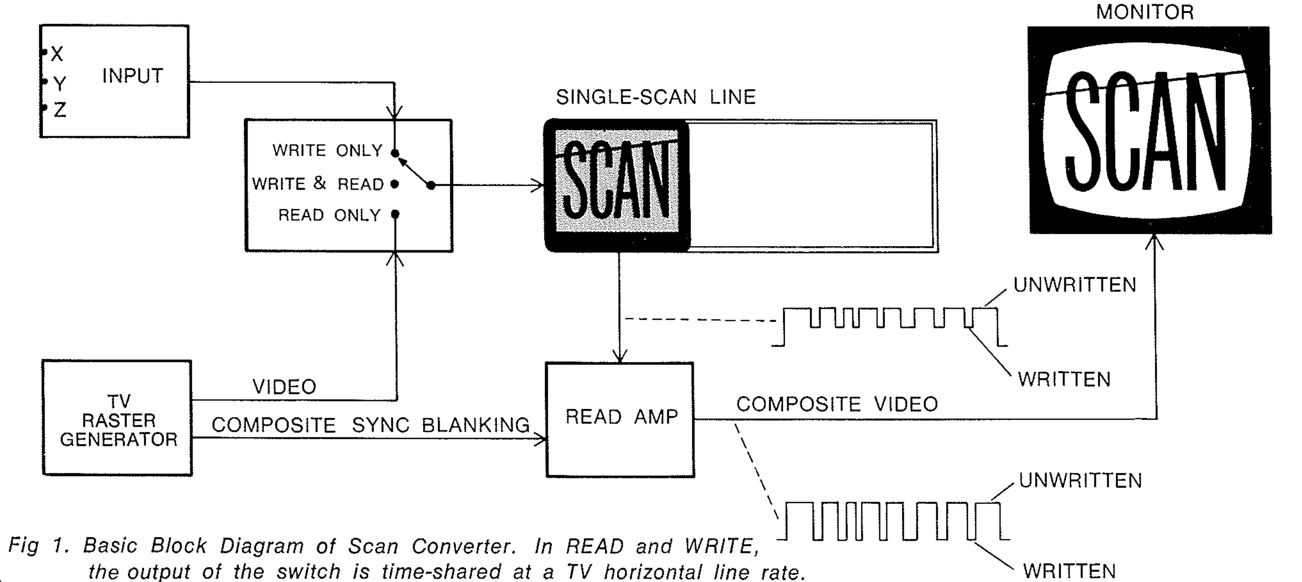


Fig 1. Basic Block Diagram of Scan Converter. In READ and WRITE, the output of the switch is time-shared at a TV horizontal line rate.

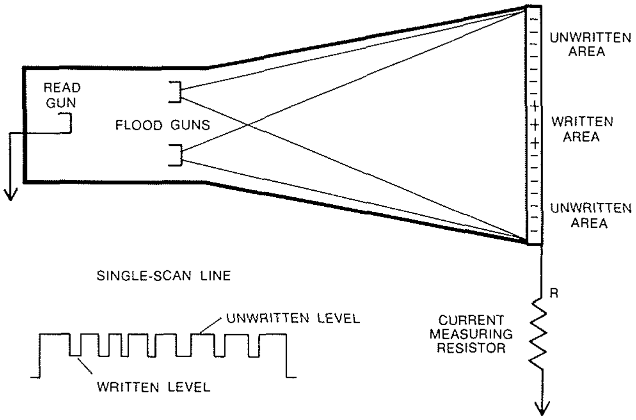


Fig 2. Read mode of basic scan converter. By measuring target current, written and nonwritten points may be differentiated.

Scan conversion is accomplished in the following manner. The storage target is raster-scanned by the CRT writing beam (read beam). The diagram in Fig 2 shows the basic circuit used to detect changes in voltage between written and nonwritten points as a read-gun raster scans the target.

A line is scanned as follows. When the raster line starts, the read beam is turned on and voltage across the current measuring resistor is developed. In the case of a nonwritten area that is negatively charged, current flows away from the target causing a voltage shift positive. When the read beam strikes a point that has been written positive, less current flows in the monitoring circuit. This causes the voltage shift to be less positive than when reading a nonwritten point. After a series of scans, a complete TV picture is developed.

Scan conversion then, consists of the following sequence: writing the target; monitoring the current fluctuation; processing these in the video amplifier; and mixing the video signal with sync and blanking to form a composite video signal (conforms with EIA (or CCIR) standards). Additionally, the composite video modulates an RF signal to allow the user to drive Channel 2, 3 or 4 of any TV set.

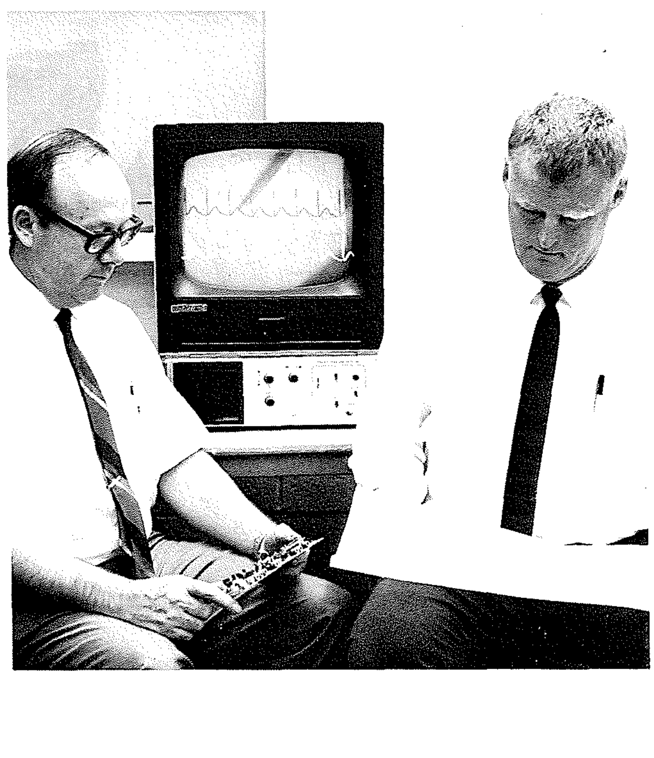
The CRT writing beam is used for both writing information and raster scanning in the WRITE AND READ mode. In this time-shared mode, writing is done during retrace of the raster (8 μs out of 63.5 μs) and information may be added to the display while the TV display is active. A WRITE ONLY mode provides no readout (monitor is blank) but allows observation of signals incompatible with beam time sharing. A READ ONLY mode is also provided. New information cannot be written on the storage target in this mode.

A LIGHT-DARK BACKGROUND switch is provided to change composite video polarity. This is particularly convenient when mixing the scan converter output with another video signal. The user can select the proper background to display his information most clearly.

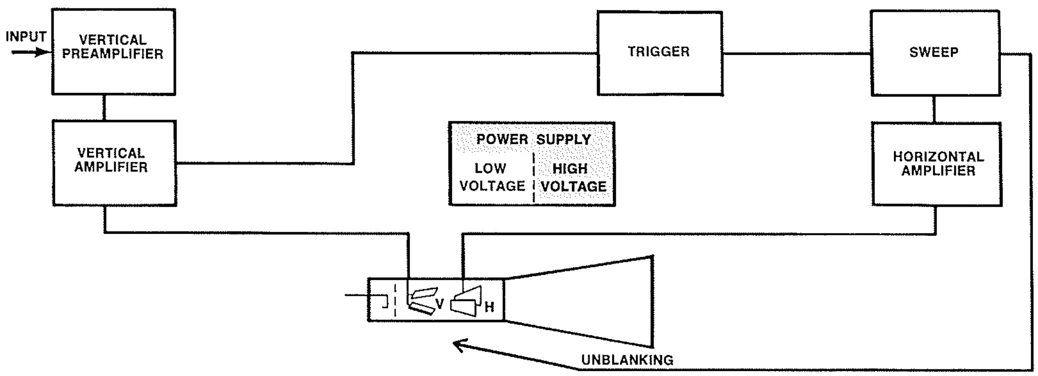
The Type 4501 Scan Converter was developed primarily to provide more flexibility in displaying information. By designing a basic unit that converts X-Y-Z inputs into TV format (EIA 525/60 or CCIR 625/50 scan rate selectable internally), the user can select the particular display best suited for his use. Differential inputs and 10-MHz bandwidth (X and Y) ensure versatile performance. In addition, two rear-panel remote program connectors provide external programming of major functions.

The price of the Type 4501 Scan Converter is $2200. For further information, refer to pages 290-293 of Catalog 28 (1969) or consult your local Tektronix field engineer.

George Edens, Project Engineer, and Chuck Gibson, Systems Manager, discuss a point of interest on the Type 4501 Scan Converter. The composite display on the monitor is composed of a camera video signal and two scan converter outputs.



SERVICE SCOPE



TROUBLESHOOTING THE HIGH-VOLTAGE SUPPLY

By Charles Phillips
Product Service Technician
Factory Service Center

This third article in the series discusses troubleshooting techniques for Tektronix high-voltage power supplies. The two previous articles available are: "Troubleshooting Your Oscilloscope", February TEKSCOPE: "Troubleshooting the Power Supply", April TEKSCOPE.

The high-voltage supply is fundamental to oscilloscope/CRT performance. Cathode-ray tubes require DC operating voltages much higher than those provided by conventional power supplies. To eliminate large vacuum tubes, bulky and dangerous capacitors and heavily insulated transformer windings, most Tektronix high-voltage power supplies use voltage multipliers to generate high voltages with a considerable savings in cost and space.

By using a frequency of approximately 60 kHz instead of 60 Hz, the required filter capacitor values are reduced by a factor of 1000. Thus, small and relatively inexpensive disc capacitors (0.02 - 0.03 μF) can be used instead of expensive 20-μF capacitors. A class C oscillator usually develops the 40-60 kHz voltage that supplies the primary winding of the high-voltage transformer.

Satisfactory regulation is achieved in most high-voltage supplies by controlling the amplitude of the high-frequency oscillator output. It is important to remember that CRT circuits are very low-current circuits and, as a result, are susceptible to leakage paths.

TYPICAL HIGH-VOLTAGE PROBLEMS

High-voltage power supply problems are usually indicated by one of the following CRT symptoms:

1. No intensity on CRT display.
2. Full intensity on CRT display.
3. No control over intensity and/or focus of CRT display.
4. Incorrect vertical and horizontal calibration.

The control-grid supply is normally 100 V more negative than the cathode supply. If these two supplies for some reason decrease their bias, the high-voltage supply can draw sufficient current to drive it out of regulation. The intensity control varies the bias of the CRT.

Most Tektronix cathode-ray tubes will cut off when the grid is approximately 65 V more negative than the cathode. If the tube is weak, you can never get down below the cutoff point of the tube.

Modern general-purpose oscilloscopes may have either a transistorized solid-state high-voltage supply (e.g., septupler) or the more common vacuum tube trippler high-voltage supply. Some of the more common troubleshooting symptoms are listed below.

1. Inability to turn off the intensity is often caused by a weak rectifier diode in the control-grid supply. If vacuum tube high-voltage rectifiers are used, check visually for filament glow. All the filaments in a properly functioning supply will glow with approximately the same intensity. A bright glow usually indicates a weak tube.

   A control grid to cathode short in the CRT will exhibit similar symptoms. To check for the latter, remove the socket from the CRT and note if the CRT bias changes. If the bias changes, then the loading is caused by the CRT load. The CRT filament supply should also be checked to insure that the problem is not caused by leakage in the filament transformer.

2. No brightness with normal intensity control settings, but slight intensity as the control is moved further counter clockwise, usually indicates a weak rectifier diode in the cathode supply. Similar symptoms will be present if no unblanking is being received from the time-base generator, or in the case of a very gassy CRT. A gradual increase or decrease in intensity are symptoms of weak rectifier diodes in either the control grid or cathode supplies. Note: Grid and cathode vacuum rectifier diodes should be replaced at the same time to prevent differential aging problems.

3. No high voltage is commonly caused by loading (one or more of the secondary supplies is causing the oscillator to not run). To pin point the problem, break the feedback loop by removing the error amplifier stage. In most high-voltage supplies this step will cause the oscillator to free run at a frequency slightly higher than normal. If the oscillator still does not free run, then the problem is probably due to loading of the transformer by one of the secondary loads. By lifting the anode of the rectifiers in the secondary supplies, these stages may be eliminated. (Only the most positive anode need be disconnected in the high-voltage anode supply.) If the oscillator now oscillates, it is only necessary to put back the supplies one at a time to find which one is causing the loading. For example, if this procedure led to a problem in the grid supply, then the next step would be to check for resistance measurements from the intensity control to ground. A good idea is to remove the CRT socket to see whether this has any effect on the circuit symptoms. It is possible for a short in the CRT or extremely gassy tube to load one of the other supplies sufficiently to affect proper oscillator action.

   Typical resistance value in the grid circuit is 4 - 5 MΩ to ground. This holds true for almost any spot that you measure in the circuit. If the components check out properly, it is quite probable that the problem is in the high-voltage transformer and that one of the windings has a leakage path to the core.

Problems in the high-voltage anode supply sometimes show up as insufficient high voltage. Check the output filter capacitors and the anode coupling capacitors. Weak high-voltage rectifiers will also indicate insufficient high voltage. A poor connection at the CRT anode connector can show up as jitter in the sweep or poor regulation. Note: All solder joints on high-voltage chasses should have smooth surfaces. Any protrusions may cause high-voltage arcing, particularly at high altitutdes.

Some of the more recent Tektronix oscilloscopes have a control called the CRT bias control. This adjustment is sometimes used as a maximum intensity control to allow the user to protect his CRT. When the instrument is adjusted in this manner and the intensity is limited, dimness problems may occur at the faster sweep speeds. If there is a brightness problem with a cathode-ray tube, check to be sure that the CRT-grid bias is properly set.

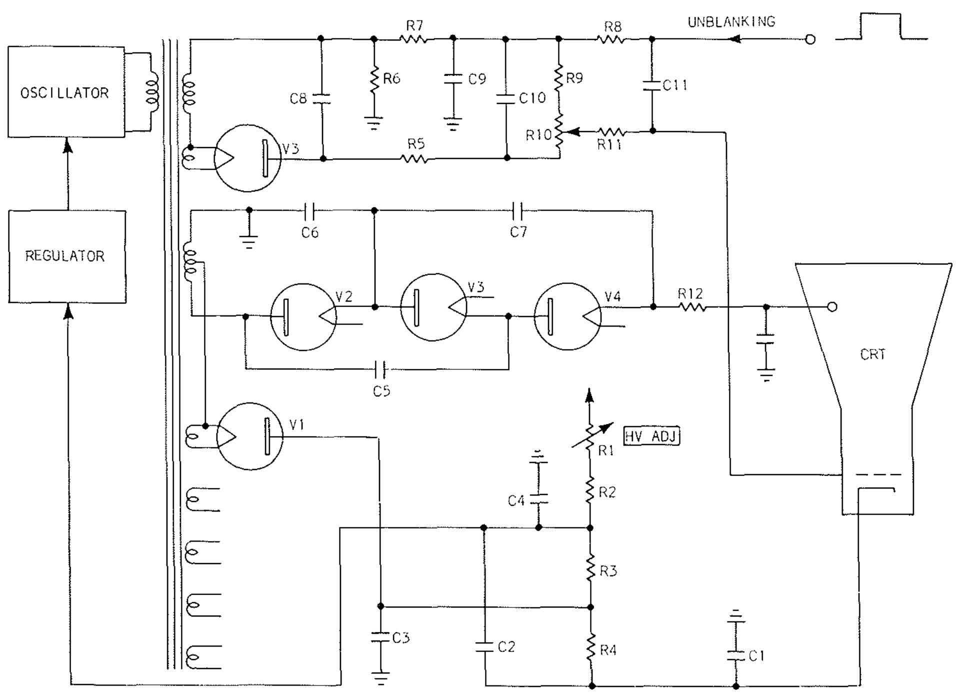


Fig 1. Simplified Schematic of Typical High Voltage Power Supply.

Intensity modulation (blank spots or uneven trace intensity) is often caused by heater-to-cathode leakage in the oscillator, the neons in the CRT-grid circuit, or leaky coupling capacitors in the unblanking circuitry. These symptoms are often seen when high-voltage tubular capacitors have been replaced with disc capacitors. The frequency is usually about 10 kHz or less (related to oscillator frequency) and the problem is present at any sweep speed.

CRT CONSIDERATIONS

Gassy CRT's may be identified by their "double-peaking" characteristic. When the CRT is cold, there are normally two very pronounced spots where the CRT turns on. As the intensity control is advanced CW, the trace comes on (usually dimly), decreases in intensity and then increases somewhat normally to the CW extreme. Once a tube begins to display this characteristic, a self-destructive process has begun and it is only a matter of time until the tube must be changed. Gassy CRT's also often exhibit poor focus and brightness characteristics, and static charge phenomenon. Static charge problems typically may be caused by dirt and if this characteristic is noted, the CRT face and cover should be thoroughly cleaned.

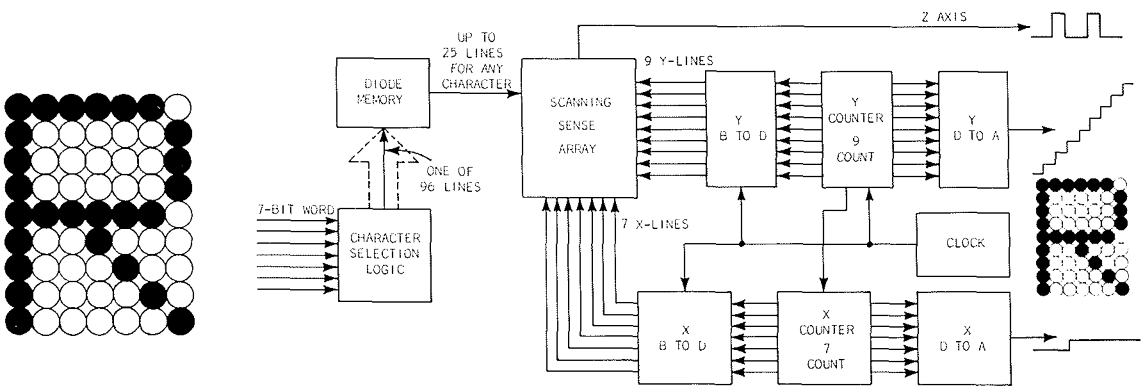
A problem similar to static charge is sometimes caused by the CRT-gun support rods becoming charged. This rod charge may sometimes be eliminated by deflecting the electron beam completly off-screen horizontally, turning the intensity full CW and varying the position control rapidly from the upper extreme to the lower extreme. After a few moments, the rod charge should be dissipated.

NEW CONCEPTS BOOKS

Four new concepts books are now available from your Tektronix Field Engineer. The new titles are: "Digital Concepts"; "Oscilloscope Trigger Circuits"; "Spectrum Analyzer Circuits"; and "Television Systems Measurements".

"Digital Concepts" discusses the binary number system, Boolean algebra, nand gates, nor gates, flipflops, implementing logic functions, implementing logic circuits using integrated circuits, counting circuits, counter readout circuits; "Spectrum Analyzer Circuits"—components and subassemblies, filters, amplifiers, mixers, oscillator and RF attenuators; "Oscilloscope Trigger Circuits"—trigger circuits, input triggering signals, pulse generators, delaying and delayed sweeps and triggered delayed sweep; "Television Systems"—cameras, television tape recorders, telecine, signal switching, transmitter, video distribution system, components of video waveform, measurements requirements, analysis of video transients, color -bar waveform analysis, multiburst test waveform and picture-waveform analysis.

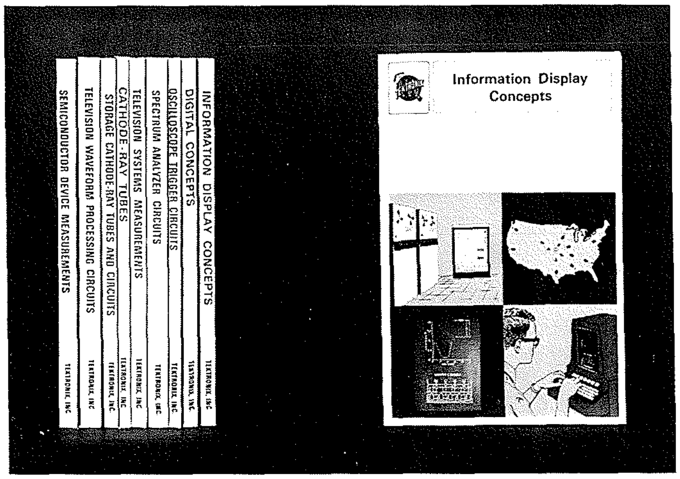
Information Display Concepts will be of special value to those interested in the Tektronix Information Display instruments discussed in this issue of TEKSCOPE. Material covered includes local computer peripherals, time sharing, programming, digital data transmission, computer display terminals, terminal output devices, digital-to-analog and analog-to-digital converters and vector and character generators, characteristics and specifications of direct-view bistable storage tubes and display-unit circuit design considerations.



Dot Character Generator

A character is generated by stepping the beam through 63 positions that make up a 7 x 9 dot character rectangle. When a character line is activated the appropriate diodes in the diode memory conduct. When the inputs from the X and Y B-to-D converters coincide with this information, a pulse turns on the Z axis. X and Y D-to-A converters output the appropriate voltage to step through the 7 x 9 dot matrix.

The block diagram on page 14 is taken from page 80 of "Information Display Concepts" and illustrates the major blocks that make up a dot character generator. The character generator used in the Tektronix Type T4002 Graphic Computer Terminal is of this basic configuration.



Other titles currently available are: "Oscilloscope CRT's", 2nd Edition; "Storage CRT's and Circuits", 2nd Edition; "Television Waveform Processing Circuits"; Power Supply Circuits", 2nd Edition; and "Semiconductor Device Measurement Concepts".

Should you wish further information on Tektronix Concepts Books, contact your local field engineer.

INSTRUMENTS FOR SALE

1—Type T Plug-In Unit, SN 002323. Price: $125. Contact: Mr. David Luce, Melville Clark Associates, 8 Richard Road, Cochituate, Massachusetts. Telephone: (617) 655-0906.

8—Type 533 with Plug-Ins. 2—Type 533A with Plug-Ins. Excellent condition. Sell or trade. Contact: Mr. Ralph Harris, Nuclear-Chicago Corporation, 333 East Howard Avenue, Des Plaines, Illinois 60018. Telephone: (312) 827 4456.

1—Type RM41A, SN 1065 with Type K Plug-In Unit, SN 13424. Price: $475. Contact: Mr. Melvin A. Holznagel, Route 4, Box 273A, Sherwood, Oregon 97140. Telephone: (503) 625-7121.

1—Type N Plug-In Unit, SN 00931. Like new. Price: $150. Contact: Cal-State Electronics Company, 5222 Venice Boulevard, Los Angeles, California 90019. Telephone: (213) 933-8187.

1—Type RM16, SN 001029. Price: $450. Contact: Mr. Leon Lacabanne, 3904 East 44th Street, Minneapolis, Minnesota 55406.

1—Type 422 with AC supply, complete with accessories. Less than 40 hours use. Price: $1200. Contact: Mr. Dave Hailey, Reece Corporation, 200 Prospect Street, Waltham, Massachusetts 02154. Telephone: (617) 894-9220.

1—Type 514D, SN 2561. Sell or trade for smaller scope. Price: $400. Contact: Mr. Pfalzer, Hoover Electric Company, Port Columbus, Columbus, Ohio 43219. Telephone: (614) 235-9634.

1—Type 422, with AC Supply, SN 3551. Less than three years old, used less than 30 hours. Price: $1000. Contact: R. Edward Stemm, Inc., 17W480 Lake Street, Addison, Illinois 60101. Telephone: (312) 279-2440.

1—Type 517A. Contact: Mr. Bruce Blevins, 176 Barranca Road, Los Alamos, New Mexico 87544. Telephone: (505) 668-4458.

1—Type 545B/CA, 535A/CA, RM529, 561A; 1—Type 3A6, 3A74, 3B3; 2—Type 515A; 1—Type A, B, D, H, S, R Plug-In Units. 1—Type TU-2 Test Load Plug-In Unit; 1—Type 107; 1—Type 111; 1—Type 181; 122 Amplifier. Contact: Mr. Posner, Pacific Combustion Engineering Company, Los Angeles, California. Telephone: (213) 225-6191.

1—Type 526, SN 00967. Price: $1000. 1—Type 261 Coax Switch. Price: $350. 2—Type 262 Programmer. Price: $695 each. Contact: Mr. Stewart Ex, Stewart Enterprises, 14827 Cohasset, Van Nuys, California. Telephone: (213) 873-7672 or (213) 786-7672.

1—Type 504, SN 001667. Price: $395. Contact: Mr. Jack Snow, General Design, Inc., P. O. Box 116, Melbourne, Florida 32901. Telephone: (305) 727-3191.

1—Type 317. Unused since reconditioning in Tektronix Service Center. Contact: Mr. William Wersing, Williams Laboratories, Inc., 125 Northview Road, Ithaca, New York 14850.

1—Type 175. One year old, never used. Contact: Mr. Earl Stridde, Skil Corporation, 5033 Elston Avenue, Chicago, Illinois 60630. Telephone: (302) 286-2000 Ext. 341.

1—Type B Plug-In Unit, SN 021854. Brand new condition. 1—Type 1A7 Differential Unit, SN 001830. Contact: Mr. Irv Sieger, General Resistance Division Chronetics, Inc., 500 Nuber Avenue, Mount Vernon, New York 10550. Telephone: (212) 292-1500.

1—Type 531; 1—Type 53/54C Plug-In Unit; 1—Type 202 Scope Mobile®; 1—100X, 2—10X, 1—1X Probes and Polarized Viewer. Good condition. Price: $950 complete. Telephone: (213) 422-1942.

1—Type E Plug-In Unit, SN 006618. Price: $120. Contact: Mr. Bob Goodman, Clark-Dunbar Company, 325 Jackson Street, Alexandria, Louisiana 71301. Telephone: (318) 443-7306.

INSTRUMENTS WANTED

Oscilloscope for personal research. Reasonable price. Prefer Plug-In versatility. Contact: Mr. C. S. Levine, 1002 Campbell Avenue, West Haven, Connecticut 06516. Telephone: (203) 934-6287.

1—Type C12 or C27 Camera. Contact: Mr. Bob Goodman, Clark-Dunbar Company, 325 Jackson Street, Alexandria, Louisiana 71301. Telephone: (318) 443-7306.

Usable Type 519 DC-to-1 GHz Oscilloscope. Contact: Professor Edward M. Eyring, Department of Chemistry, University of Utah, Salt Lake City, Utah 84112.

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TEKSCOPE

Volume 1 Number 3 June 1969

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DEVELOPING AN "INFORMATION AGE" TECHNOLOGY

THE BEGINNING . . . . Bob Anderson, inventor of the first simplified bistable, direct-view storage tube.

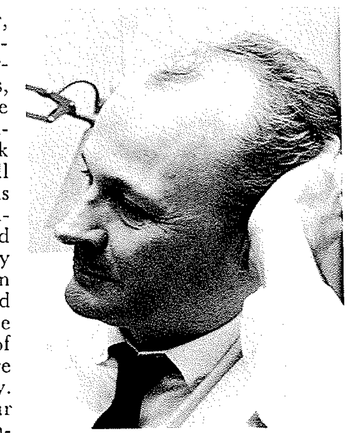
The art of inventing is a fusion of the imaginative and the practical.

The first step is in the realm of the practical, and typically consists of the identification of a specific and worthwhile need. This identification may come directly out of problems which are well recognized in existing devices, or may come out of the recognition of a previously unvoiced need.

The second step is in the realm of the imaginative, and consists of dreaming new dreams of better ways to reach the objective. At this stage, the untried uncertain conjecture is often the precursor of invention, for you cannot be truly new by building entirely on old and certain knowledge. There is no compromise with finished history—you either have something which differs from past knowledge, or you have no invention.

The third stage is again in the realm of the practical, and consists of experimental selection, verification and extension of the new concepts, and then the implementation through development, design, production and sales, which will involve many essential contributors besides the inventor.

All of these steps are equally important in the sense that, like the serial links of a chain, none can be omitted and still bridge the gap from "conception to contraption". However, the truly new idea is one of the more scarce commodities. The man who says "ideas are cheap" identifies himself as one who is not making his living and his career out of his ability to conceive new ideas. For the career inventor who takes the consequences of the ideas which fail, good ideas are crucial, scarce and most expensive—not cheap.



To the beginning inventor, I would offer these comments. Cultivate a deliberate sensitivity to problems, leading you to form a large and explicit backlog of unfilled needs. Then, think deeply about how you will select problems from this reservoir for your most intensive efforts. You will need to be working on many problems, and well chosen ones, since you will succeed so seldom. Do not scorn the imaginative, but be proud of your dreams, since they are at the source of creativity. Do not hesitate to use your own personal aids to the imaginative process, such as conjectural "bull sessions", graphic aids to visualization and information gathering activities. Do not be dismayed at those who persistently and critically ask why you need these procedures, for they are not equipped to understand your answer.

Be encouraged when an expert tells you that your concept is unworkable (if his reasons are vague), because he is really telling you that the novelty of your concept has taken him by surprise, and you are getting close to an answer.

Success often comes soon after such predictions of failure.

THE FUTURE . . . . C. Norman Winningstad, Information Display Manager.

Today, the general population still has little contact with the computer. Although many paychecks and bills are computer prepared and processed, there is little direct contact between man and machine. Even engineers and scientists usually interface the computer through a stack of cards or a programmer.

Often, companies with computer installations are disillusioned because information needed for decisions is not readily accessible from the computer. How many times have you had to wade through the pages of the weekly printout, vainly searching for what you want? If computer information was quickly and easily accessible, man could enter the "Information Age".

The remote computer terminal allows entry into the Information Age. Bring the information to the man! At Tektronix, we believe we have an excellent solution. Since one picture is worth 10,000 words, we are proposing graphic computer terminals rather than just alphanumeric terminals. We did not invent the idea of graphics, but Anderson's invention led us to a practical, economic solution to graphics. We feel we are performing a "pump priming" operation.

There is little now in existence in operational information systems for several reasons. Software, compatible communications language and terminals all need to evolve further. Now that the key item of reasonable-cost terminals is here, the others will follow quickly. Software development is proceeding rapidly, especially among the time-sharing services. The ASCII code is close to a universal language.

The main point here is compatible business procedures. Let's not use business in the broad sense of purposeful human activity, but confine it to the communication of information. Accountants, for example, are used to scanning columns of figures, and develop the skill of reading trends from numbers. They would prefer to express the numbers graphically, but until recently, it was not economically feasible to obtain graphical results. Almost everyone today operates his business in alphanumerics simply because typewriters, teletypes and computer printers cannot do graphics and humans take too long to generate a graph. Wouldn't you like to have a PERT chart available to you, up-to-date on a daily basis for your individual projects? Or any Standard and Poor's stock performance chart updated daily?

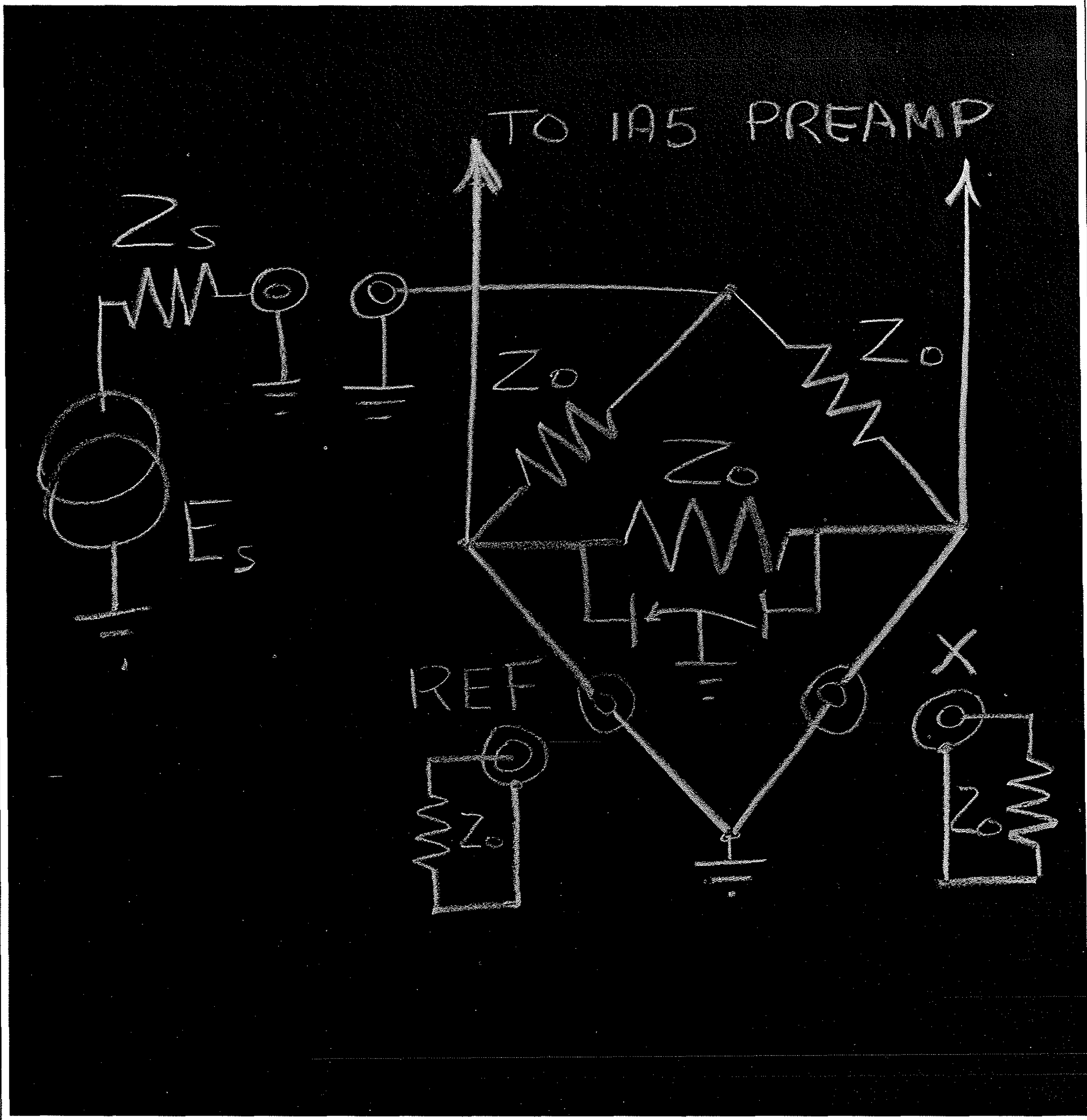
Low-cost graphics, and the availability of mass data bases will fundamentally change the way we do business. From education to medicine, from engineering to housekeeping—nothing will ever be the same.

We are proud to be among the pump primers!

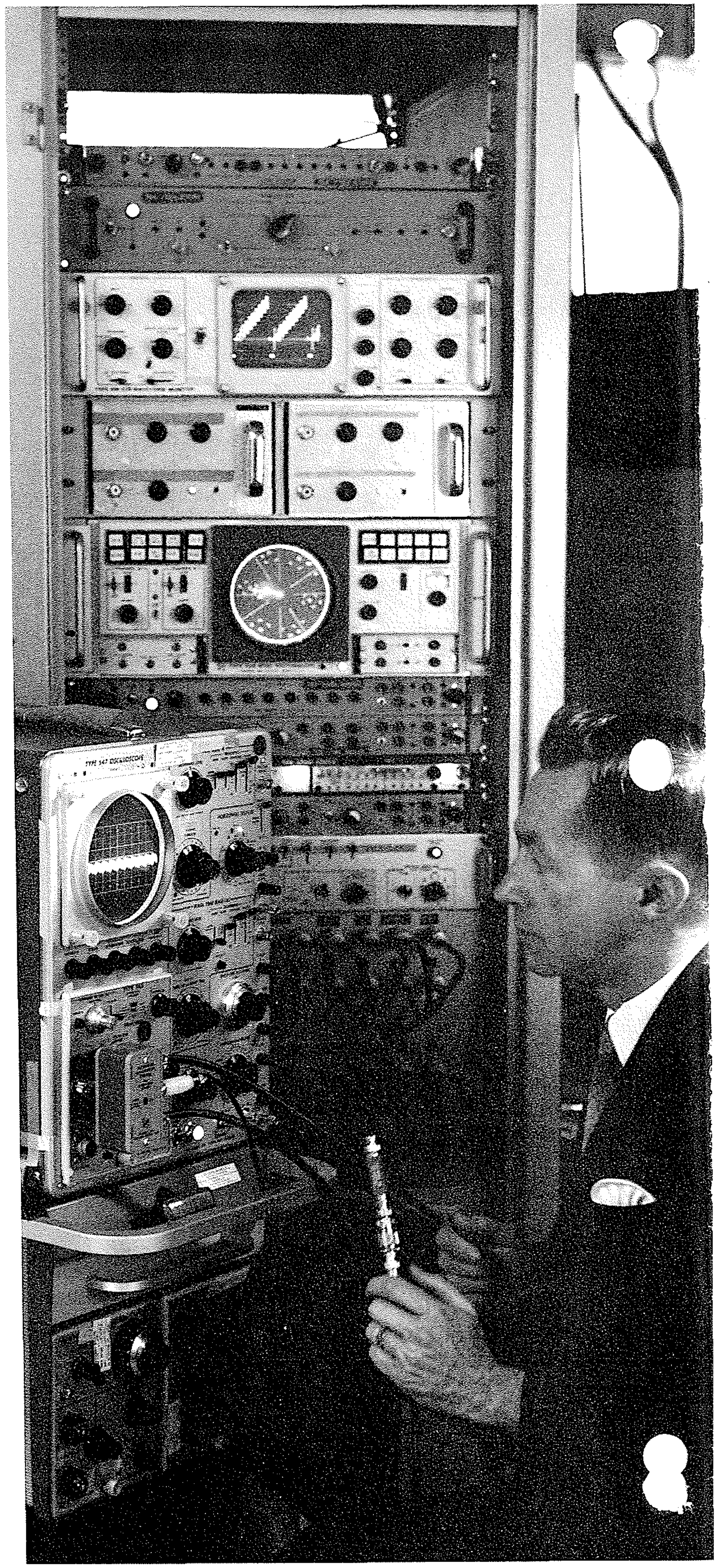
TEKTRONIX

TEKSCOPE

AUGUST 1969



measuring return/loss



Return-loss measurements are a powerful tool for quickly indicating the extent of an impedance mismatch or a discontinuity in a video transmission system. The use of a 1-mV, DC-10 MHz differential preamplifier as an error detector allows direct observation of system performance over the complete video bandwidth.

Return-loss techniques accomplish basically two types of measurements. The simplest is the verification of the performance specifications of instrumentation.

The second area of interest for return-loss measurements is looking into long cable systems that may have a number of monitors, distribution amplifiers, etc., bridging the line. Return-loss can give the user a good measurement of the degradation contributed by each component of the video transmission system, including coaxial cable condition.

As a result, with proper test signals applied, return-loss measurements provide indications closely related to picture impairment.

COVER The Tektronix Return-Loss Bridge consists of a basic 75-Ω Wheatstone Bridge with a 1-mV, 10-MHz Type 1A5 differential amplifier null detector. *See story on page 2.*

At left: Charles Rhodes, Program Manager of Television, Low Frequency, and Medical Instrument Engineering, measures return loss.

Modern color TV broadcasting studios require that a number of monitors, processing amplifiers, distribution amplifiers, VTR's, oscilloscopes, and other equipment all be driven by a signal passing down a relatively long length of coaxial transmission line. In some cases, since the signal may pass several times through the same type of amplifier, a large cumulative error can result if the amplifier provides an incorrect source or load impedance to any frequency component of the video signal.

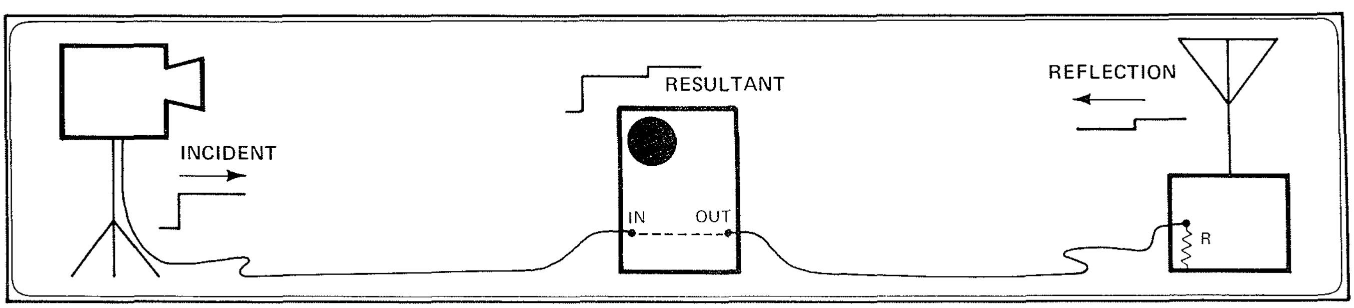
When coaxial transmission lines feed a number of different instruments, the method of making connections is important. For this reason, a loop-through technique is often used since transmission of wide-band video signals must be on constant impedance transmission lines. The impedance characteristic of the cable is critical to transmission quality and shielding requirements dictate that coaxial cables be used. If the input impedance, coaxial connectors and cable used within each instrument were perfect, no measurable effect upon the transmission would occur. Unfortunately these parameters are not perfect so a figure of merit of the quality of video transmission systems is important.

Looping a signal through an instrument means a portion of the transmission path the signal traverses is now within the instrument. Therefore, it is necessary to know what effect this additional signal path contributes to the overall video system. Because a connection must be made to the center conductor, an incorrect impedance can cause a mismatch and cause energy to be reflected. Ideally, the termination should be an impedance exactly equal to the characteristic impedance of the line to prevent reflections and match the two impedances in magnitude and phase.

If the two impedances are not matched, standing waves on the line produce erroneous voltage or current readings. Fig 1 illustrates a case where a camera is located 100 feet from a monitoring point. The coaxial cable runs from the camera, loops through the monitoring point and is terminated at the transmitter. If the transmission line is not perfectly impedance matched at the receiving end, energy will be reflected back. The monitoring point will observe the instantaneous sum of the camera signal and the signal reflected from the termination. Therefore, the signal measured at the monitoring point may differ considerably from the signal measured at the termination. As an exaggerated example, suppose an oscilloscope were displaying the signal at a point of minimum voltage—a minimum caused by relatively high standing wave ratio on the line. A second oscilloscope located 46 feet (¼ wavelength at 3.58 MHz) from the first will observe a drastically different display.

A typical transmission segment might consist of the connectors and cable (including loop-through facilities) connecting two active elements. The last point in the segment is the termination resistance into which the energy is delivered. Since the line effectively ends when a signal encounters the input impedance of an active element, information cannot be obtained beyond that point. Thus, a television transmission system is measured segment by segment. Return loss measures the amplitude and phase of the reflections developed from impedance discontinuities. Reflections can occur whether the discontinuity is in the line itself or caused by an instrument bridging the line.

Fig 1. The oscilloscope views the instantaneous sum of the incident and reflected signal.



For many years the effects of an impedance mismatch have been discussed in terms involving reflection coefficient (ρ), a standing-wave ratio (SWR), characteristic impedance of the transmission line (Z_o), and termination impedance (Z_t).

Transmission line theory develops the concept of a "reflection loss" which is derived from the reciprocal of the coefficient.

$$\rho = \frac{\text{Reflected Voltage}}{\text{Incident Voltage}}$$

Reflections are created because of impedance mismatch. Therefore, the reflection coefficient may also be expressed in terms of characteristic impedance and termination impedance.

$$\rho = \frac{\text{Reflected Voltage}}{\text{Incident Voltage}} = \frac{Z_t - Z_o}{Z_t + Z_o}$$

In the past few years, European and Australian TV engineers have referred to the term "return loss" (reflection loss). Return loss is being used by Tektronix and other manufacturers of video equipment to specify the performance characteristics of inputs and outputs of 75-Ω TV equipment. By definition, "return loss" is 20 $\log_{10}$ of the reciprocal of the reflection coefficient.

$$\text{Return loss, dB} = 20 \log_{10} \frac{Z_t + Z_o}{Z_t - Z_o} \frac{\text{(Incident Voltage)}}{\text{(Reflected Voltage)}}$$

Note that an open and short circuit will both produce a return loss of 0 dB, while a perfect impedance match results in a return loss of ∞ dB.

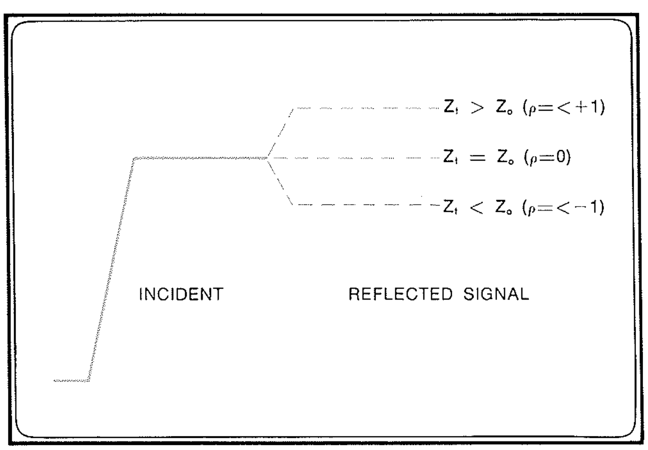


Fig 2. An incorrect termination impedance causes a reflection whose amplitude is proportional to the size of the mismatch.

TEKTRONIX RETURN-LOSS BRIDGE

The Tektronix Return-Loss Bridge consists of a simple Wheatstone Bridge with three fixed 75-Ω resistors and two removable 75-Ω resistive terminations mounted on matched cables. The capacitor across the center of the bridge permits balancing of stray capacitance from the bridge arms to ground. This configuration offers a matched load to both the signal generator and the reflected wave from the unknown impedance. The test signal is applied to the top of the bridge (one side is grounded to allow single-ended testing), and the error signal is measured across the output terminals. The rugged passive components are mounted in a compact housing for attachment to the Type 1A5 Differential Unit.

The error signal is processed by the Type 1A5 Differential Unit which acts as a balanced detector. This unit, when used with the Tektronix Return-Loss Bridge provides DC-10 MHz performance at 1-mV deflection factor. This preamplifier, which works into any of the Tektronix Type 530, 540, 550 and 580* Series Oscilloscopes, is the heart of the measuring system.

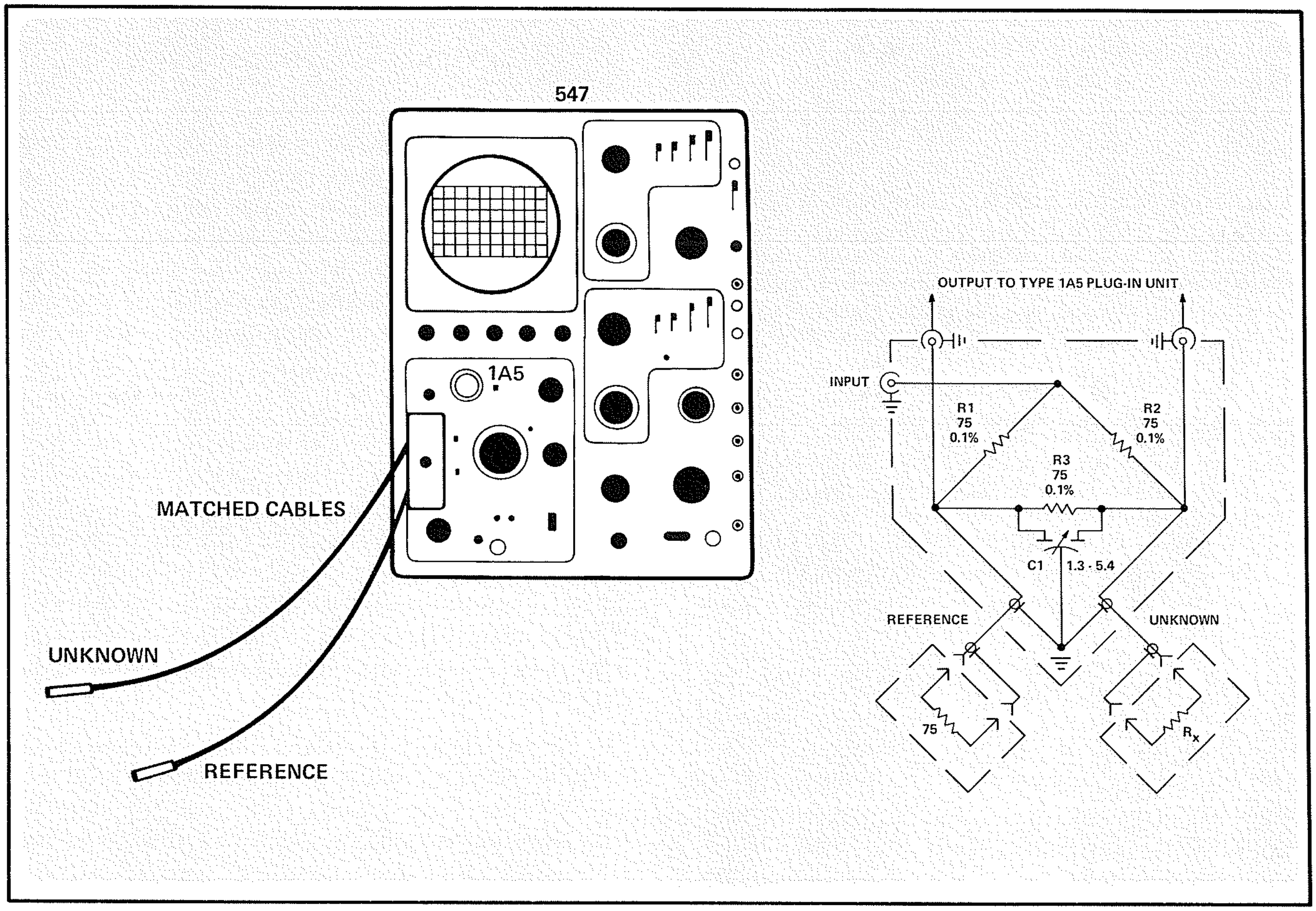
The Tektronix Return-Loss System is specified at −54 dB over the full 10 MHz bandwidth of the system. Since 46 dB is equivalent to an impedance discontinuity of less than 0.5%, the bridge provides more resolution than is usually required.

Use of the Tektronix Return-Loss Bridge is quite simple. Once the bridge is balanced, the UNKNOWN termination is removed and the cable is applied to the device under test. If the device employs a loop-through input, the UNKNOWN termination should be used to terminate the device. The oscilloscope deflection thus obtained is a measure of the amplitude and phase of the reflected signal. The amplitude describes the severity of discontinuity (return loss) and the phase indicates the nature of the reactance.

Amplifier input impedances sometimes change depending whether the power is on or off. When a part of the termination impedance of an amplifier is the input impedance (as is often the case) then the input impedance of the amplifier will probably vary with power on or off. Thus, equipment must be checked under power-on and power-off conditions. This is particularly important with semiconductor equipment.

Return-loss measurements are also convenient for measuring output impedance. It is only necessary to connect the unknown arm of the bridge, and the output imped-

*Requires Type 81A Adaptor.



ance may be compared against the bridge reference resistor. This allows quick determination of incorrect output impedance at some frequency in the video band. By checking *both* the input impedance and output impedance of video distribution amplifiers, additional information is obtained about the video transmission system.

Many users will prefer to use a swept frequency oscillator to check their systems and will check each frequency in which they are interested. The only problem with this approach is that correlation of frequency information to picture impairment is difficult. Steady-state performance is not easily related to picture impairment. Although all the amplitude information is present, no phase information is available. Unless the amplitude frequency characteristic and the group envelope delay characteristic of the sytem are both known, time-domain testing with pulses is required for the additional phase information. In time-domain testing, it is possible to relate a picture impairment to the measured return loss. In sinewave testing, there is little relation between test results and picture impairment.

PICTURE IMPAIRMENT DISTORTIONS

TV distortion problems may be conveniently categorized into three broad time domains: field-time distortion, line-time distortion, and short-time distortion.

Field-time distortion may be observed using a square wave at the field frequency, i.e., 50-60 Hz. The frequency range of this distortion is limited to a few hundred hertz since at that point the energy content is small and lost in the noise. Included in this test range are the simple ohmic discontinuities, AC-coupling networks, DC impedance matches of long pieces of cable and termination resistors. Field-time distortions are indicated by a non-uniform brightness at the top or bottom of the screen.

Line-time distortions are the most easily visible picture impairments. Distortions that occur at 15-500 kHz rate and that appear across a line, show up as very ap-

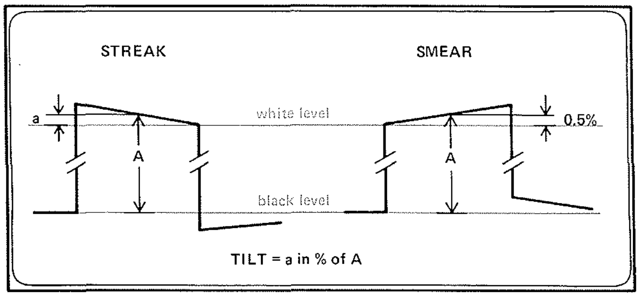


Fig 3. Common line-time distortions. An overshoot or undershoot of less than 0.5% is apparent to an observer viewing a monitor.

parent streaks or smears. As little as 0.5% tilt in a 15 kHz luminance signal can be easily seen by anyone looking at their receiver from across the room. (see Fig 3.)

Coaxial cables have significant losses in this frequency band so the video signal is generally degraded at this point. Transmission line losses, then, show up as a smear in the picture.

Short-time distortions may be considered as those distortions that occur in the last octave of frequency response of the video channel (approx 2-4 MHz). Overshoot, ringing, and rounded vertical transistions result in a soft-looking picture lacking sharp definition. This distortion is all controlled by the phase and frequency response between 2-4 MHz. A fast rise square-wave pulse at 15 kHz may be used, but it is usually more convenient to use a pulse source in which the amount of energy between 2-4 MHz is large compared to the system noise (e.g. $\sin^2$ pulse). Thus, a high rep rate signal is appropriate since you are only looking at the few hundred nano seconds around transient occurrence.

A transmission system should be tested as close to its operating voltage level as possible. A defective input amplifier may have very good return loss with a 50-mV input, but have poor performance at 1 V. If, for example, there is very low collector voltage on an input emitter follower, the collector-to-base junction could be driven into the forward bias region with a large signal. Or, overdriving an operational amplifier changes return loss drastically. Since the reason a system is being checked is to detect possible problems, test the system in such a manner as to most closely simulate actual operating conditions.

One of the major strengths of return-loss techniques is that the system is not being overtested. The bridge is excited only with those test signals which, when distorted, result in picture impairments. It does not shock-excite the system by applying frequencies that are of no interest. It basically monitors the reflected energy that is not absorbed in the load as it should be. Although the bridge tells the exact nature of the impedance discontinuity, it gives no time information as to where, physically, the fault lies.

One of the inherent advantages of a return-loss bridge is that standard television test signals may be used as a source. Thus, sine-squared, pulse and bar window, multiburst and color-bar generators all serve to provide information across the video system. In addition, sine-wave oscillators, swept frequency oscillators and square-wave oscillators may all be used as sources. By choosing the proper signals, the impedance characteristics may be specified across the complete video bandwidth. Note: The return loss specified on Tektronix instruments is *always* the worst return loss of any portion of the band.

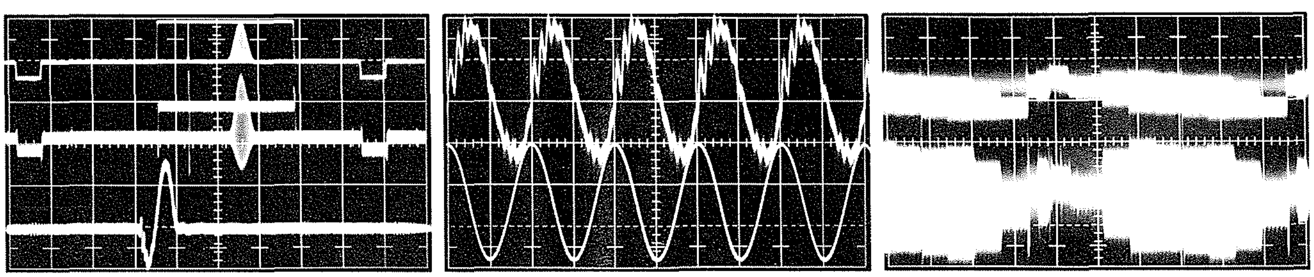
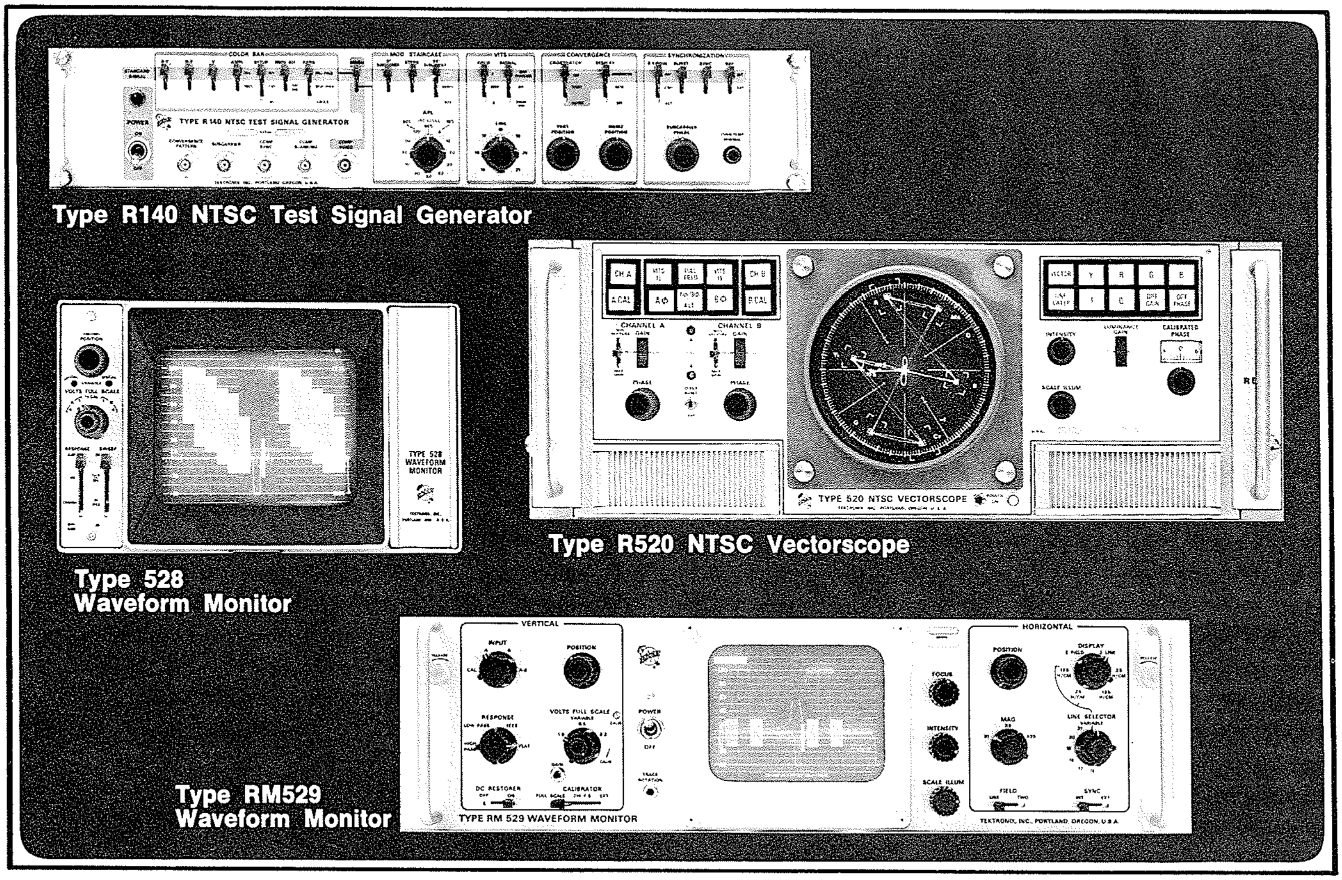


Fig. 1. Upper—T and 20T $\sin^2$ pulse and bar input: 0.5 V/cm. Center—Differential display: 1 mV/cm. Note that the $\simeq$54 dB return loss of the bar (line time) is less than that of the $\simeq$48 dB pulses (short time). Z_t is $>$ Z_o and 1/500 mismatched or $\simeq$75.2 Ω. Lower—T pulse magnified and repositioned. The initial negative portion indicates a shunt C condition. Fig. 2. Upper—Differential display of subcarrier: 1 mV/cm. Lower—Single ended display of reference input: 0.2 V/cm. The return loss is 45 dB (0.56/0.003). By externally triggering, the upper signal is shown to be lagging 90° indicating a shunt C situation (leading 90% would indicate series L). Fig. 3. Upper—Return loss of a TV monitor with switchable termination in 75-Ω position ($\simeq$48 dB). Lower—Return loss increases substantially when reversing IN and OUT connections ($\simeq$39 dB). Both displays: 1 mV/cm.



TEKTRONIX INSTRUMENTS WITH RETURN-LOSS SPECIFICATIONS

An excellent source for return-loss measurements is a Pulse and Bar Window Generator. This pulse source contains sufficient information to check for all three categories of distortions. Pulse and Bar Window Generators have large energy components at field-frequency, line frequency, and band edge (short-time distortion) all at the same time.

Another source that works well for return-loss testing is a sine-squared pulse of T to 2T. The T pulse has zero frequency response at 8 MHz with 0.5 energy at 4 MHz while the 2T pulse has frequency response points at 4 MHz and 2 MHz respectively. As a result, these sources are ideal for short-time distortion testing. Sin^2 pulse and bar testing is useful for checking line-time distortion since the $\sin^2$ bar signal will not ring in a properly tuned system (when used for line distortion testing, the leading edge is neglected). An auxiliary 50 or 60 hertz square wave should be used for field-time distortion checks.

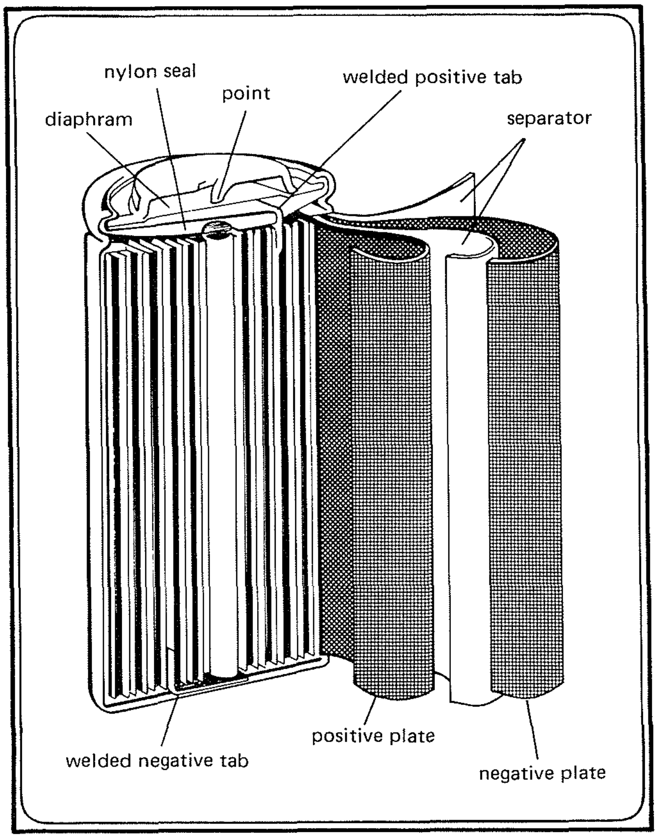
A color-bar generator (e.g., Tektronix Type 140 NTSC and Type 141 PAL Test Signal Generators) provides a good signal for return-loss checking. The white reference pulse of 6-7 microseconds duration gives a good indication of line-time distortions. The large amount of energy at the color subcarrier frequencies provide information on short-time distortions. In addition, the split-field signal of the Type 140 gives a fair indication of field-time distortion.

Sine-wave generators are also useful with a return-loss bridge. One of the virtues of a sine-wave generator is that a great deal of energy may be generated at a single frequency. In the case where it is necessary to override a large adjacent radio transmitter source, a return-loss bridge could be used. By decreasing bridge sensitivity and raising the level of input source, the strong noise source can effectively be "overpowered". This technique is quite difficult with $\sin^2$ generators or color-bar generators, since it calls for a much larger than normal amplitude.

Return-loss measurements provide the video transmission line user with an accurate measure of reflections due to impedance discontinuities. By choosing the proper signal source, impedance characteristics may be measured across the complete video bandwidth.

For reference consult: (1) E. Friedman and F. Davidoff, "The Video Return-Loss Bridge" J. SMPTE, Aug. '68. (2) F. Davidoff, "Status Report on Video Standards" IEEE Video Signal Transmission Subcommittee 2.1.4, June '69.

nickel cadmium battery review



Cross-section diagram of a typical coiled electrode sintered plate cylindical cell.

The widespread use of rechargeable cells in electronic instrumentation provides a new accessibility in the use of modern instruments. This article points out some parameters of concern to the battery-powered instrument user.

The following explanation applies specifically to the sealed "C" and "D" Nickel-Cadmium (NiCd) cells used by Tektronix to power the Types 321A, 323, 410 and 422 Mod 125B. For the purposes of this review, a "battery" consists of one or more cells.

BASIC PRINCIPLES

Nickel hydroxide is the active material of the positive plates in nickel-cadmium batteries. Cadmium is the active material of the negative plates, and the electrolyte is usually a water solution of potassium hydroxide or sodium hydroxide. The use of an alkaline electrolyte allows use of a nickel screen or a sintered nickel plate to retain the active materials. This type construction reduces the corrosion of the electrode structure by the alkaline electrolyte to an extremely low rate and contributes to the long life associated with NiCd cells. The drawing illustrates the construction of a typical nickel-cadmium cell.

SEALED VS UNSEALED CELLS

The major differences between sealed and unsealed NiCd cells are that sealed cells use a minimum amount of electrolyte and a gas permeable separator, while unsealed cells use an excessive amount of electrolyte and a separator material that is nonpermeable to gas.

Oxygen generated in sealed cells during overcharge (see section on OVERCHARGE) is recombined and causes heat dissipation at the end of the charge cycle. In unsealed cells, oxygen is liberated without generating heat.

Sealed NiCd cells need little maintenance, are efficient at high discharge rates, accept long-term overcharging and operate in any position over a relatively wide temperature range. For these reasons, all Tektronix portable oscilloscopes use sealed NiCd cells. All following information pertains to sealed cells only.

DC-powered Oscilloscopes manufactured by Tektronix which use NiCd sealed cells. Pictured are the Type 321A (DC 6-MHz), Type 410 Physiological Monitor, Type 323 (DC 4-MHz) and Type 422 Mod 125B (DC 15-MHz).

CHARGE CAPACITY AND EFFICIENCY

The energy rating of cells and batteries is usually specified in Ampere Hours (Ah). Energy ratings of the "C" and "D" size NiCd cells currently in Tektronix instruments are specified at 1.5 or 1.8 and 4.0 Ah respectively. Actual Ah capacity of new cells can be as much as 30% greater than the specified value. This fact should be allowed for when considering charge times.

Charge efficiency is defined as the ratio of the recoverable charge to the original charge expressed as a percentage. It is normally close to 100% except at the end of the charge cycle when oxygen is liberated. An exact efficiency is not usually specified because of self-discharge. To allow for both charge efficiency and self-discharge, recharge Ah must be 120 to 130% of the charge capacity.

SELF-DISCHARGE

Self-discharge occurs continuously whenever a cell has remaining charge. The major factors contributing to self-discharge rate are temperature, material impurities and the state of charge. At 45°C, self-discharge can be 5 times greater than at room temperature and as much as 15 times greater at 60°C. Immediately after charging is completed, self-discharge starts to reduce the stored energy. A fully charged NiCd cell may lose 10 to 15% of capacity within the first 24 hours. After the initially high energy loss, the rate decreases to less than 1 per cent per day or 10 to 15% per month. Thus, when maximum operating time is required, the batteries should be charged until immediately before use. Once full charge is reached, the battery may be maintained at full charge by trickle charging to offset self-discharge.

CHARGE RATE

In most Tektronix instruments, the sealed nickel-cadmium cells are charged with constant current at a C/10 rate. (1.5 Ah cells are currently being introduced which will recharge at C/6.) A C/10 charge rate means the charging current is one-tenth of the Ah rating.

EXAMPLE: If C = cell capacity in Ah and 10 = number of hours for full discharge, then for a 4.0 Ah cell, C/10 rate is

$$\frac{4.0\text{ Ah}}{10\text{ H}} = 400\text{ mA.}$$

A specific charge rate for each cell type is adopted because it is typically the maximum recommended rate at which that cell type can be overcharged without damage or significant reduction in cycle life.

CHARGE TIME

To take account of charge efficiency it is recommended that 120 to 130% of the charge capacity be inserted to insure a full charge. At the C/10 rate, this implies charging for 12 to 13 hours to reach the specified Ah capacity. (14 to 16 hours takes account of the possibility that a new cell will have more than the rated Ah capacity.)

	RATED Ah		HIGH Ah	
	120%	130%	140%	160%
C/10	12 hrs	13 hrs	14 hrs	16 hrs
C/6	7.2 hrs	7.8 hrs	8.4 hrs	9.6 hrs

OVERCHARGE

Overcharging is the technique of deliberately applying more than 100% rated charge to the cells, and is the best way to bring cells to a balanced state of charge.

Because oxygen is evolved from the positive nickel plate during overcharge, it is mandatory to the design of the sealed cell, that capacity to absorb oxygen be provided. If the overcharge rate is not too large, i.e., C/10, an equilibrium condition is reached such that oxygen is recombined to form cadmium hydroxide at one plate as fast as it is being liberated at the other. In fact, both plates are provided with capacity to absorb oxygen, since during reverse charge, oxygen is liberated at the opposite plate. Overcharge energy is dissipated as heat and there is a tendency to dry out the cell electrolyte if overcharge is continued for long periods. Electrolyte loss will proportionally reduce cell life. All cells approved for use in Tektronix instruments will tolerate overcharging for an accumulated total of several weeks during their lifetime without this factor being the major cause of cell end-of-life.

When a number of cells are operated in series, charge imbalance occurs. To reduce the possibility of one or more cells going into reverse charge towards the end of the discharge cycle, charge balancing is recommended. The recommended method of charge balancing is to deliberately charge for a longer period of time than is necessary to reach maximum Ah rating. In other words, overcharge the battery. Balancing is recommended once a month or every 15 charge/discharge cycles by charging for about 50% longer than the normally recommended time.

TRICKLE CHARGE

When trickle charge techniques are attempted to take a discharged battery up to full charge, most of the energy is spent combating self-discharge. Therefore, trickle charging for a time that calculations suggest would result in full charge, may only raise the charge to 30 or 40% of its maximum value. Thus, trickle charging cannot fully charge batteries, but does provide a useful method of maintaining full charge.

When battery operation is not required for several days or weeks and the battery is fully charged, trickle charge makes up the energy lost through self-discharge and and maintains the battery in a fully-charged condition.

DISCHARGE

Operating time is a function of the load current represented by the instrument, the actual Ah capacity of the battery, the operating temperature and the depth of the discharge chosen. All Tektronix instruments provide an indication when these endpoint voltages are reached. (e.g., front-panel warning light or battery condition indicator.) *Caution: It is important that operation be terminated within* 15 *minutes of the time when the endpoint voltage is reached to avoid possible damage to the cells.* Discharging below end point voltage is a major cause of cell damage, particularly when considered together with charge imbalance.

REVERSE CHARGE

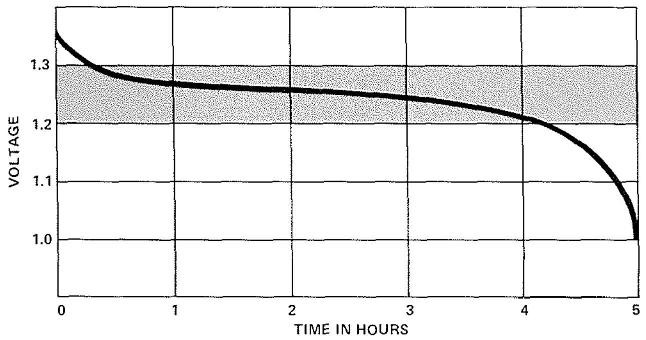
Reverse charging occurs when a low cell in a series is discharged beyond the point where it reaches 0.0 V. From this point the remaining cells in the series supply charge current to the low cell, but with reversed polarity.

A certain rate of reverse charge is not damaging to a cell, but at higher rates, undesirable consequences occur. A battery passes through three stages in reverse charge. First, it will exhibit a 0.2 V barrier potential for a considerable charge. Second, it will rise to 0.7 V when hydrogen and oxygen begin to evolve without combining within the cell, so that the internal pressure increases. Third, it will come to full reverse charge with considerable hydrogen being evolved and with a potential as high as 1.5 V. At this stage the relief valve may vent, releasing gas and some electrolyte. The relief valves on some of the cells we use vent at six atmospheres (100 psi) and do not reseal.

Ability to exceed the reverse barrier potentials is a function of reverse current. At C/20, no damage is likely. At C/10, there is perhaps a 1% chance of exceeding the first barrier potential. At C/5 and above, however, damage is likely. Some types of cells that have vented can be detected by a white deposit around the relief valve.

VOLTAGE CHARACTERISTICS

The best means of currently determining the condition of cells is to measure their individual voltages accurately. Because the no-load voltages can be misleading, voltages should be measured while operating the instrument. First, establish that no cells are short circuit (zero) by measuring the individual cell voltages. Then, check that the charge current is correct for that instrument. Next, overcharge the battery by charging for approximately 24 hours. Individual cell voltages should be measured again on load after operating the instrument for one hour. Any cell differing by more than 50 mV from the majority is suspect and should be examined and perhaps replaced. Whenever a cell is replaced, the battery must be overcharged to balance the capacity.



Typical voltage characteristic for a single cell discharged at a C/5 rate. Normal operation usually lies within the band.

BATTERY LIFE

In Tektronix instruments, terminating discharge between 1.04 and 1.19 V/cell, (90% discharge), 500 to 600 charge/discharge cycles can be expected before "end of life". End of life is defined to be when the recoverable Ah capacity has fallen to 80% of the specified value. This does not mean that the cell is unusable after this time.

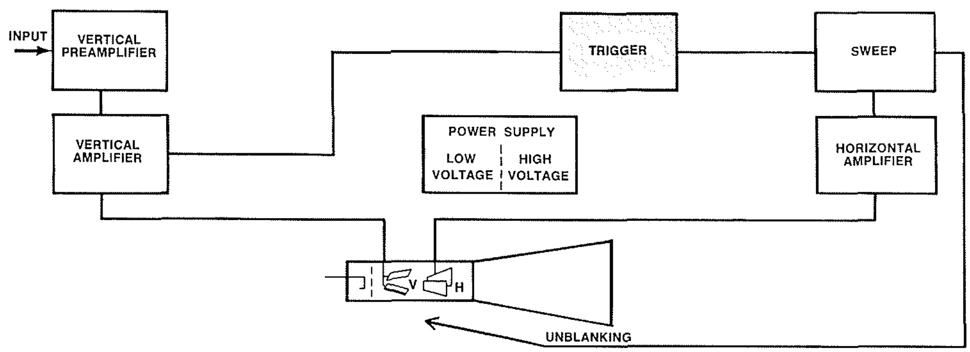
A cell can be stored in either a charged or uncharged condition for extended periods of time. At room temperature, a cell would be expected to have a shelf life of three to five years, although a cell which has been stored for this length of time could not be expected to exhibit maximum cycle life.

In the event of a catastrophic failure of one cell in a relatively new battery, there is no reason why the single cell should not be replaced, providing the recommended charge balancing procedure is carried out after installation of the new cell.

The older the cells are, the less justification there is in replacing individual cells because the resulting pack is no better than the worst remaining cell. Bearing in mind the age of the cells and what proportion are defective, a logical decision can be made as to whether individual cells or the whole battery should be changed.

Users need not be concerned about the differences in charge state between the battery and the new cell if the repaired battery is charged for a period of time that will bring the weakest cell to full capacity.

SERVICE SCOPE



TROUBLESHOOTING THE TRIGGER CIRCUITS

By Charles Phillips

Product Service Technician, Factory Service Center

This fourth article in a series discusses troubleshooting techniques in the trigger circuits of Tektronix instruments. For copies of the preceding three TEKSCOPE articles, please contact your local field engineer.

For effective troubleshooting, examine the simple possibilities before proceeding with extensive troubleshooting. The following list provides a logical sequence to follow while troubleshooting trigger circuitry:

1. Observe CRT display characteristics.
2. Check control settings.
3. Isolate trouble to block.
4. Thorough visual check.
5. Check voltages and waveform.
6. Check individual components.

Tektronix trigger circuits are designed to respond to a wide variety of input signals. Since many of these input signals are unsuitable as sweep-initiating triggers, signals are first applied to a trigger circuit where they are converted to pulses of uniform amplitude and shape. Thus, regardless of the input signal configuration, it is possible to start the sweep with a pulse that has constant amplitude and risetime. The trigger circuitry allows the operator to start the sweep on either slope of the waveform, select any voltage level on the rising or falling slope of that waveform, and filter out selected frequencies of the input signal for greater ease and repeatability in triggering.

The triggering of the general purpose oscilloscope may be broken down into five basic parts: (1) vertical amplifier trigger pickoff circuitry, (2) input coupling circuitry, (3) input amplifier, (4) trigger pulse generator, and (5) automatic triggering circuitry.

The trigger pickoff circuitry acts as a buffer to keep trigger circuitry from changing the operation of the vertical amplifier, yet pass the amplified vertical signal to the trigger circuit with minimum distortion. Input coupling circuitry allows selection or rejection of various frequency components of the triigger signal. The input amplifier provides gain to assure the trigger pulse generator of sufficient input for proper circuit operation. The automatic triggering circuitry used in older Tektronix instruments eliminated control of coupling and level and provided a baseline in absence of signal at a 50-hertz rate. The automatic triggering used in the more recent Tektronix instruments provides all normal trigger functions as well as a bright baseline in the absence of a trigger signal.

Although trigger circuits vary in their complexity and sophistication, the essentials are the same in all instruments. Nearly all Tektronix trigger circuits use a Schmitt Multivibrator for the trigger pulse generator. Most trigger circuits incorporate a trigger sensitivity control to permit adjustment of the minimum size signal to which the circuit can respond. Fig 1 illustrates simplified block diagrams for vacuum-tube circuits and solid-state circuits. Individual trigger circuits vary but all circuits make use of some of the basic functions listed below.

CONTROLS AND ADJUSTMENTS

Front-panel controls used in conjunction with the internal controls are typically:

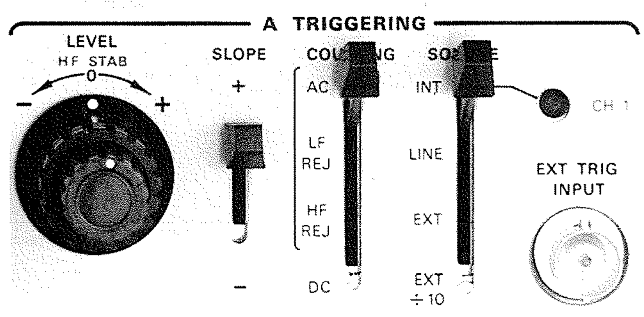
1. SLOPE (+, —)
2. COUPLING (AC, AC LF REJ, AC HF REJ, DC)
3. SOURCE (INTERNAL, EXTERNAL, LINE and PLUG-IN or CH 1)
4. TRIGGER LEVEL
5. MODE (NORM, AUTO, SINGLE SWEEP)
6. STABILITY

The basic internal adjustments of a modern oscilloscope are the following:

1. Trigger level centering adjust—controls trigger circuit symmetry to enable all coupling modes to work properly with the slope switch.
2. Internal trigger DC level adjust—allows the center of the LEVEL control to be set exactly to 0 volts in the DC mode.
3. Trigger sensitivity—controls the minimum signal response—minimum sensitivity limited by noise.

When troubleshooting trigger problems, a few simple steps can often determine which stage of the trigger is at fault. Checking operation of trigger circuit in different sources, modes, slopes, and coupling positions will often isolate a problem. Observing the effect of the stability and level controls gives additional information. In checking trigger circuits, always be sure that sufficient signal is being applied to obtain a large observable deflection. (≃1 cm)

Varying the trigger SOURCE switch between INTERNAL and EXTERNAL triggering checks the trigger pickoff circuitry. Comparing operation in different trigger modes can usually localize a problem to a specific trigger stage (e.g., noting a difference in operation of the trigger circuit in AUTO or NORM may suggest the faulty stage).



Typical Oscilloscope Triggering Controls

Once the problem has been traced to a specific block, a close visual check may pinpoint the problem. Substituting tubes or transistors offers a quick means of checking a suspected stage. Always return the original component to its place if the problem remains.

When troubleshooting a new trigger circuit, take some time to familiarize yourself with the block diagram and schematics. Spending a few minutes with the instrument manual can give valuable insight into the particular problem.

TRIGGER OPERATION

A simple, convenient general method to check proper trigger circuit operation is to apply a calibrator signal to the oscilloscope. Using the INTERNAL trigger source, adjust the controls and vertically center at least 1 cm of calibrator signal on the CRT display. Set the triggering LEVEL control to zero and place the coupling control in the AC LF REJECT position (called AC-FAST on some oscilloscopes). This is

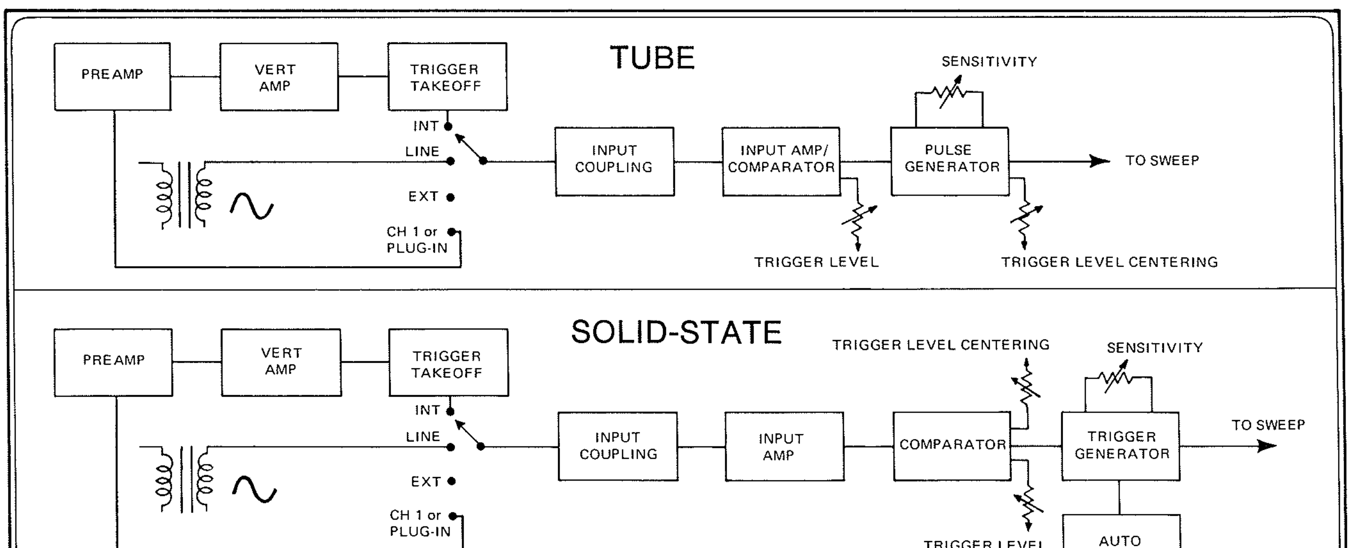


Fig 1. Typical block diagrams for tube and solid-state trigger circuits.

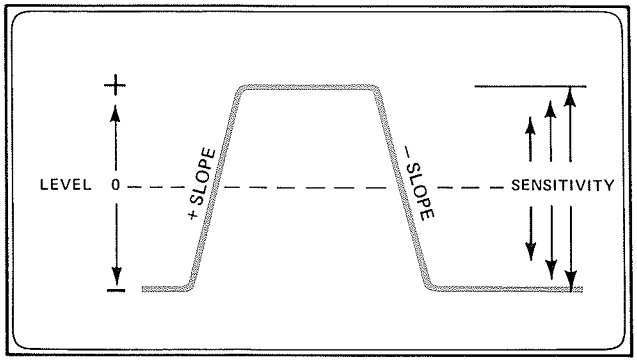


Fig 2. The sensitivity adjust determines the minimum circuit response (in mV). The trigger level centering assures proper slope and level operation in all coupling modes.

typically the most difficult position in which to make trigger adjustments. If the circuit functions properly in this position, you can be assured that the circuitry is good. Set the sweep speed for the appropriate speed to observe 5-10 cycles of the square wave signal. Preset the trigger sensitivity (if there is one) to midrange. Note: If the instrument has a STABILITY control, adjust the control until the trace free runs and then backoff the adjustment 10-15°.

Adjust the trigger level centering for proper switching as the slope switch is switched from + to −. Decrease the signal amplitude slowly, continually adjusting the trigger level centering control, until switching occurs while changing POLARITY. If a problem develops, try changing the tubes or transistors in the comparator and the trigger generator or pulse generator stages. Continue this procedure until the signal amplitude is decreased to 4 or 5 mm.

Next, apply the signal to the external input source and adjust the trigger sensitivity until the scope triggers on + and − SLOPE with 200 mV of input signal. Check to be certain that the scope will not trigger on either polarity at 100 mV. Caution: Do not adjust the trigger sensitivity to be overly sensitive or the oscilloscope may respond to noise pulses. In addition, tube circuits normally age in such a manner that the circuit becomes more sensitive with age. Once the trigger sensitivity is properly set, then the triggering level centering may be more finely adjusted.

Next, select the AC (sometimes called AC-SLOW) position of the COUPLING switch and note whether polarity remains correct. (A problem here usually indicates the large coupling capacitor is defective.) With 0.5 cm of signal, place he COUPLING switch in DC and adjust the internal trig DC adjust for a stable display. Note: Because of signal attenuation in the DC position, approximately twice as much signal is required as in the AC position. In the DC-coupled mode, any movement of the front panel POSITION control will act as a change in DC level and interfere with circuit adjustments. Once a stable display is obtained, check for proper circuit operation in both positions of the POLARITY switch.

TRIGGER PROBLEMS IN TRANSISTOR CIRCUITS

Troubles in the auto-multi block are indicated when triggering with a signal is normal, but there is either no trace or a blinking trace in the automatic mode. This usually indicates a defective or leaky transistor. If a free-running trace is present with signal input conditions, disable the auto-multi block to confirm proper operation of the NORM mode.

A problem in the trigger generator is usually indicated by NO triggering capability. The most common problems in the trigger generator are TD's and transistors. The TD, as well as the transistors, may be checked using a Tektronix Type 575 or 576 Curve Tracer. Defective gating diodes in the Trigger Generator show up as an inability to trigger on one slope. If the problem appears to be a free-running display with no trigger capability in either slope (AUTO mode), the bifilar transformer should be checked. If trigger operation is erratic in HF SYNC, suspect a slow-switching TD.

Comparator stage problems are usually indicated by insufficient range of the variable controls. If this condition arises, change the transistors to determine if the problem is devices or circuitry. If switching of devices unbalances the circuit in the opposite direction, replace the device(s) as they are unbalanced.

TRIGGER PROBLEMS IN TUBE CIRCUITS

If the trigger input stage has a vacuum-tube input, a leaky stage will show up as drift in adjustment. Leakage may be easily checked by monitoring the input to the trigger amplifier/comparator from the triggering level circuit and then switching the SOURCE from INT to EXT. A shift of more than 200 mV indicates excessive leakage.

If triggering is erratic near 0 on the trigger level, but control is okay at other points, suspect a defective trigger LEVEL control. If erratic triggering on small signals is noted in INT, the internal trigger pickoff path should be checked for excessive noise.

No trace without input in the AUTO mode (other triggering normal) indicates a weak Pulse Generator tube. If the problem is a bright trace without input the STABILITY and PRESET should be checked for proper operation and adjustment.

NOTE: If possible, use aged tubes or allow tubes to age-in several hours before final realignment for most stable adjustment.

NEXT: Troubleshooting the Sweep

INSTRUMENTS FOR SALE

3—Type 535, SN 5342; SN 10979; SN 1326. Price: $960 (Each.) 1—Type 545, SN 5292. Price: $1,125. 4—Type 53/54B, SN 6626; SN 7334; SN 5460; SN 7713. Price: $75. (Each.) 1—Type 111, SN 000262. Price: $150. 1—Type T, SN 001240. Price: $100. 1—Type 180A, SN 6269. Price: $110. All equipment is in good working order. Contact: Teletek Enterprises, P. O. Box 118, Carmichael, California 95608.

1—Type 564, SN 006132. 1—Type 3A72, SN 005718. 1—Type 2B67, SN 015969. Contact: Mr. Stan Lindberg, Anocut Engineering, 2375 Estes Ave., Elk Grove Village, Illinois 60007. Telephone: (312) 437-5400.

1—Type 533A. Never used. 1—Type CA. Approximately one year old. 15—Type RM529. Never used. Contact: H. D. Addington, WATL TV, 1810 Briarcliff Rd., Atlanta, Georgia 30329. Telephone: (404) 633-4111.

1—Type 422, AC Model, SN 3551. Under three years old. Used less than 30 hours. Can ship in original foam container. Price: $1000. Contact: R. Edward Stemm, Inc., 17W480 Lake St., Addison, Illinois 60101. Telephone: (312) 279-2440.

1—Type 545/1A2. Extra plug-ins Types D; K; 81 adapter. 127 plug-in power supply. Scope cart, calibration instruments 84 and 180A time-mark generator. Instruments were used in calibration business and are in perfect condition. Contact: Fred Bell. Telephone: (213) 429-3739.

Several Type 517A. Without power supplies. Several kinds of CRT's. Contact: Mr. Bruce Blevins, 176 Barranca Rd., Los Alamos, New Mexico 87544. Telephone: (505) 668-4458.

1—Type 1L20, SN 1285. One year old. Only used once. Contact: Mr. Stan McWhinney, Canadian Electronics Ltd., P. O. Box 2330, Edmonton, Alberta, Canada. Telephone: (403) 429-4981.

2—Type 513D, SN 1933 and SN 668. 2—Type 514D, SN 2795 and SN 3025. Price: $250. (Each.) Crating extra, F.O.B. our plant. Contact: Arenberg Ultrasonic Laboratory, 94 Green St., Jamaica Plain, Massachusetts 02130.

1—Type 514AD, SN 4188 with stand. Good condition. Price: $349. Contact: Mr. Wally Cheesman, Glencourt Electronics, 3508 Nob Hill Blvd., Yakima, Washington 98902. Telephone: (509) 452-0166.

1—Type 323. Good condition. Contact: Kalman Isaacs, 1805 Strahle St., Philadelphia, Pennsylvania. Telephone: (215) 742-3179.

1—Type 561A. 1—Type 3A6. 1—Type 2B67. Scopes are approximately two years old. Price: $850. (Entire unit.) Contact: De Frees Leasing Company, Tiburon, California. Telephone: (415) 435-1107.

1—Type 535, SN 1482. 1—Type CA, SN 002884. Both in very good condition. Price: $600. (Entire unit.) Contact: Mr. Phillip Dooley, 308 McBroom St., Barstow, California 92311. Telephone: (714) 587-0651.

1—Type 512. Price: $125. Contact: Mr. James W. Boynton, 10 Pennsylvania Ave., Yonkers, New York 10707.

1—Type 317. Good working condition. Price: $600. Contact: Mr. Laurence C. Keeler, Greb X-ray Company, 1412 Grand Ave., Kansas City, Missouri 64106.

1—Type 513D. Price: $250. 1—Type 514D. Price: $200. 1—Type 110. Price: $395. 1—Type 53/54K. Price: $95. 1—Type 53/54E. Price: $95. 1—Type 53/54B. Price: $85. 1—Type 531. Price: $495. 1—Type 535A. Price: $750. 1—Type 541. Price: $695. Contact: Mr. Frank A. Aamodt, KFMB TV Channel 8, San Diego, California. Telephone: (714) 232-2114.

2—Type 561A/67/72. Price: $630. (Each.) 1—Type 503. Price: $395. Contact: Mr. Carl Wasson, Micromatic Hone Corp., P. O. Box 192, Berne, Indiana 46711. Telephone: (219) 589-2136.

1—Type 531, SN 5429. 1—Type 53/54G, SN 2189. Scope has trigger "preset" and power supply rectifier modifications. Contact: Mr. John Unruh, Jr., 1722 East Rose Ave., Orange, California. Telephone: (714) 633-3450.

1—Type 531A, SN 20404. Price: $575. 1—Type B, SN 20936. Price: $90. 1—Type 543, SN 962. Price $675. 1—Type CA, SN 59106. Price: $150. 1—Type G, SN 6948. Price: $110. 1—Type 202-1. Price: $85. Contact: Mr. Don Wickland, Ferroxcube Corp., 5455 South Valentia Way, Englewood, Colorado. Telephone: (303) 771-2000.

2—Type 122, SN 2970 and SN 04335. Price: $60. (Each.) 1—Type 160A, SN 2663. Price: $90. 3—Type 161, SN 2077; SN 2449 and SN 2638. Price: $60. (Each.) 1—Type 162, SN 2977. Price: $60. 3—Type 163, SN 723; SN 1670 and SN 1779. Price: $60. (Each.) Excellent condition. Contact: Mobil-scope, Inc., 17734½ Sherman Way, Reseda, California 91335. Telephone: (213) 342-5111.

1—Type 565, SN 2704. Like new. Price: $1,350. Contact: Mr. R. Wittich, Hydrocraft Corp., 648 Main St., Westbury, New York 11590. Telephone: (516) 333-2640.

1—Type 547, SN 5800. 1—Type 1A4, SN B061261. 1—Type 202-2 Scopemobile. Contact: Mr. Rupenthal, Circle Leasing Corp., 126 W. Vermont St., Indianapolis, Indiana 46204. Telephone: (317) 634-3557.

1—Type 3A1 Plug-In. Contact: Mr. Jim Reidy, University of Michigan, Physics Dept., Randall Laboratories, Ann Arbor, Michigan. Telephone: (313) 764-5248.

1—Type 524AD, SN 1874. With probes and filter hood. Good condition. Price: $500. Contact: Mr. E. R. Jones, 1250 Ross St., Plymouth, Michigan. Telephone: (313) 453-4649.

1—Type 535A, SN 18406. 1—Type B, SN 017780 Plug-In. 1—Type P, SN 001387 Test Fixture. Contact: Harvey Smith, 981 North Virginia, Covina, California 91722. Telephone: (213) 332-2660 or (213) 286-5477.

1—Type RM16, SN 1029. Price: $425. Contact: Leon Lacabanne, 12207 Ridgemont Ave., W., Minnetonka, Minnesota 55343. Telephone: (612) 544-1981.

1—Type 422. 1—Type 3A6. 2—Type 564. 1—Type 3B3. 1—Type 201-2. 1—Type 3B4. 2—Type 3A74. Several miscellaneous probes. Contact: Mr. Ron Maytin, K&M Electronics Company, 109 Hopkins Place, Baltimore, Maryland 21201. Telephone: (301) 685-3140.

1—Type 1L30, SN 000152. Contact: Al Lockwood, Ogden Technology. Telephone: (408) 739-5900.

INSTRUMENTS WANTED

1—Type "M" Unit. Preferably three to four years old with UHF Connectors. Contact: Steve Allen, 328 Braniff Bldg., Dallas, Texas 75235. Telephone: (214) 357-9461.

Oscilloscope for personal use by Electrical Engineering Student. Prefer Plug-In versatility. Contact: C. S. Levine, 1002 Campbell Ave., West Haven, Connecticut 06516. Telephone: (203) 934-6287.

1—Type 109 Pulse Generator. Also wanted, a Type 113 delay line. Write giving details and price. Contact: Bruce Weitermann, 4549 North 38th St., Milwaukee, Wisconsin 53201.

1—Type 545 or 545A or equivalent. Prefer Type CA Plug-In. Contact: Dr. F. M. Vallese, 340 Ridgewood Ave., Glenridge, New Jersey 07028.

1—Type 1A1. Contact: Harvey Smith, 981 North Virginia, Covina, California 91722. Telephone: (213) 332-2660 or (213) 286-5477.

1—Type 1S2. Contact: Al Lockwood, Ogden Technology, Telephone: (408) 739-5900.

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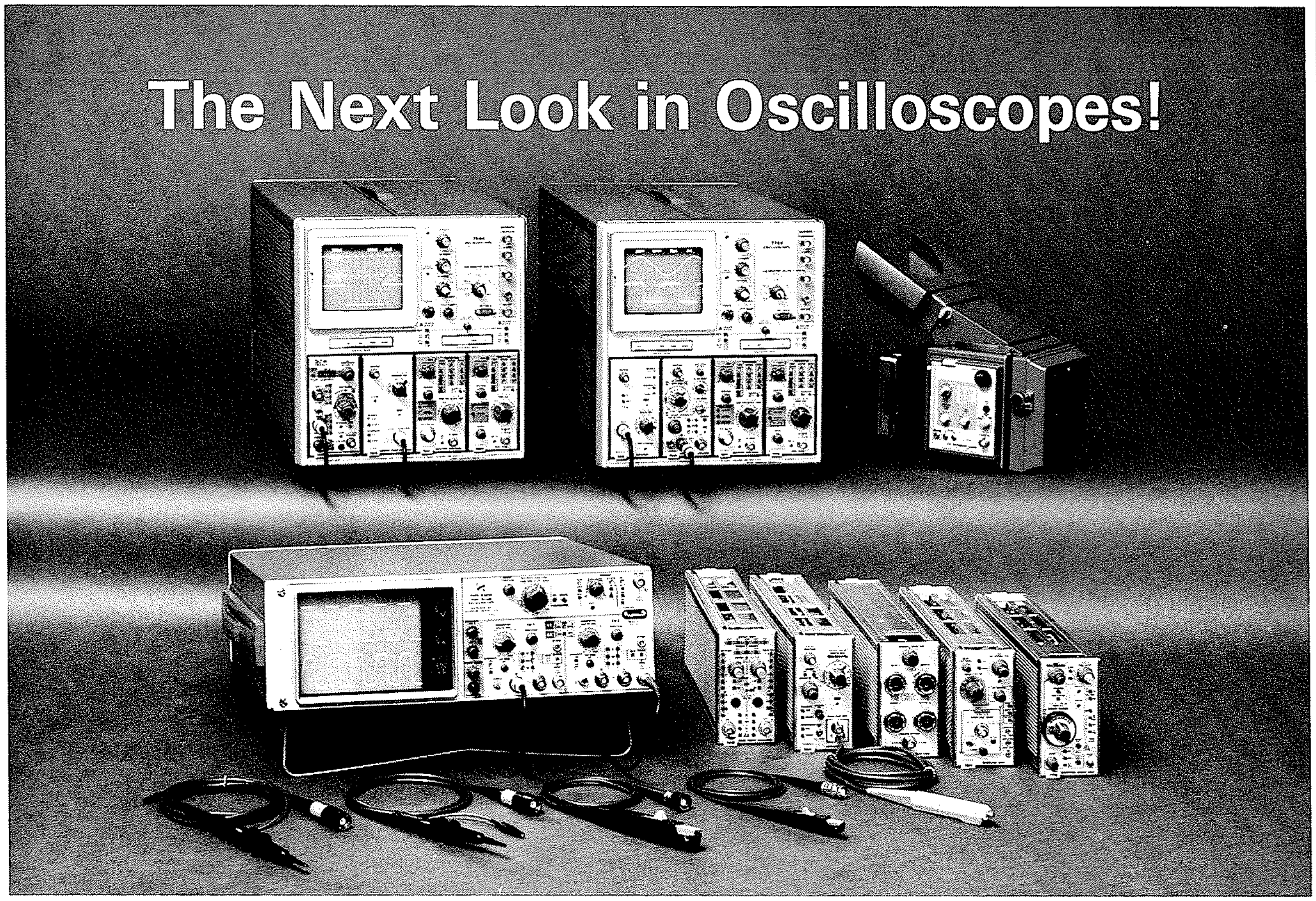

SCALE FACTOR READOUT

Control settings, probe attenuation values, and magnifier settings are all taken into consideration and electronically read out in the CRT viewing area. A > symbol is provided for uncalibrated settings and a ↓ symbol denotes vertical channel polarity inversion.

TWO NEW MAINFRAMES

90-MHz or 150-MHz performance capability with readout is provided. Both the 7504 and 7704 accept four plug-ins and employ mainframe switching for vertical and horizontal versatility.

13 NEW PLUG-INS

The initial 13 plug-in units provide dual trace (4 trace with 2 units), differential, differential comparator, low C FET probe and amplifier, AC current probe amplifier, and wide-band conventional amplifier performance. Versatile time-base plug-in units provide a new ease in triggering and sweeps up to 2 ns/cm are available. Sampling units that accept sampling heads provide additional versatility and the sampling time-base available provides a 10 ps/div sweep.

NEW CAMERA SYSTEM

The C-50, with its electronic shutter, eliminates much of the film waste normally associated with oscilloscope photography. Range finder focusing is combined with a trace-brightness photometer to simplify and improve oscilloscope photography.

NEW LARGE SCREEN OSCILLOSCOPE

More than 50% greater viewing area (over an 8 x 10 cm display) is available in the Type R5030. This advanced design 10 μV, 1 MHz dual-trace oscilloscope also provides a fiber optic display of scale factor readout.

ADVANCED COMPONENT TECHNOLOGY

This new generation of Tektronix oscilloscopes makes extensive use of Tektronix developed and manufactured components to provide the user with the most reliable components currently available. Low torque cam switches, miniature illuminated push buttons, relays, custom integrated circuits, ceramic cathode ray tubes, and a number of other unique components contribute to superior instrument performance.

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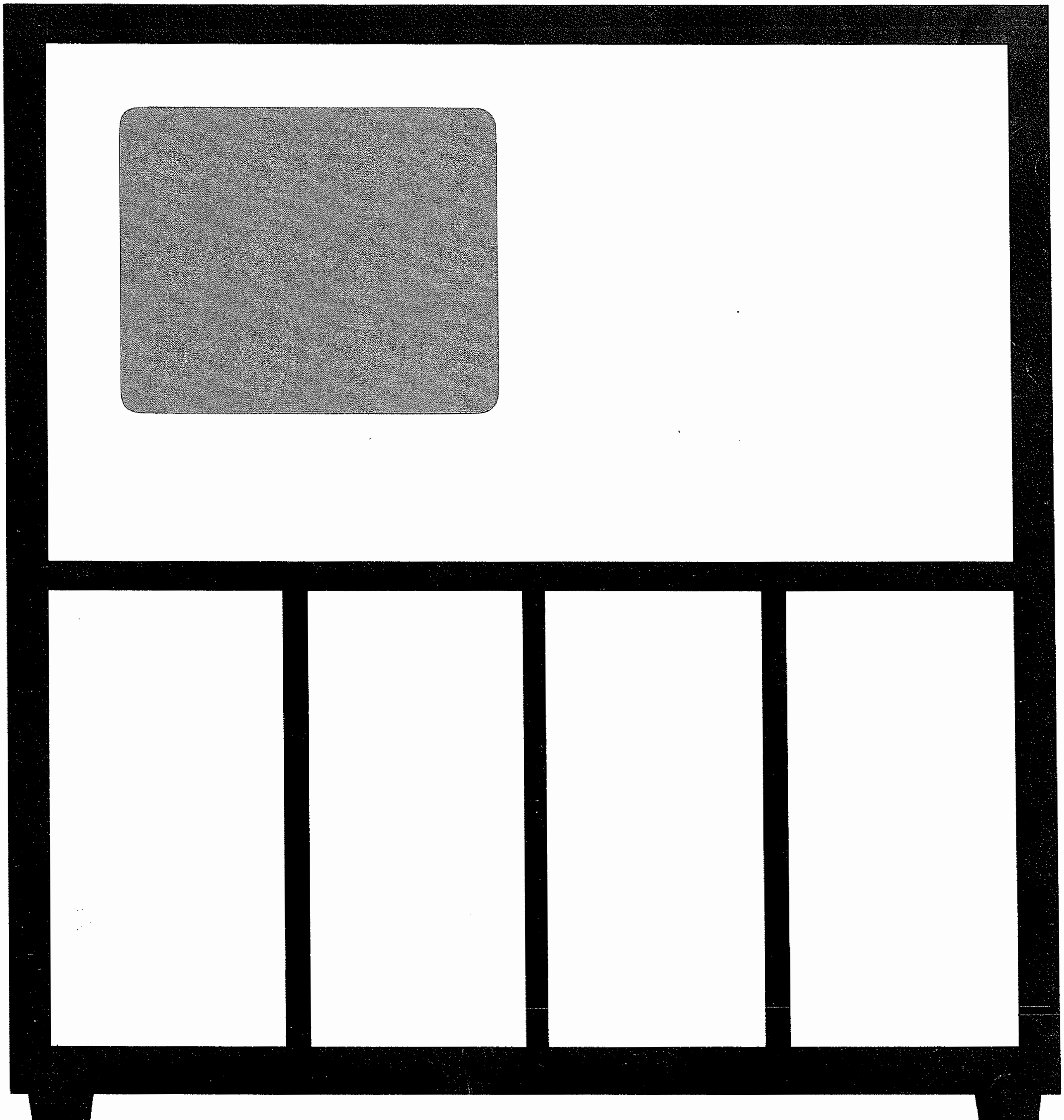
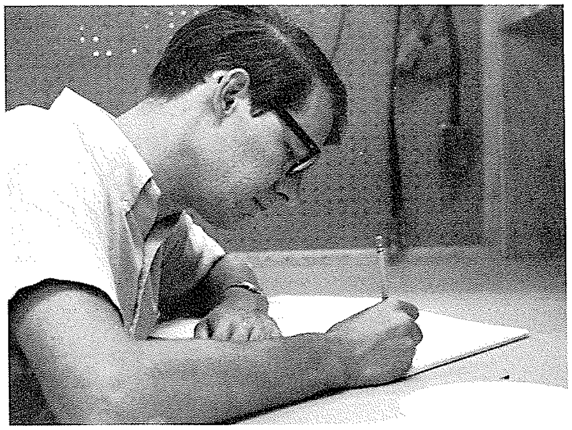
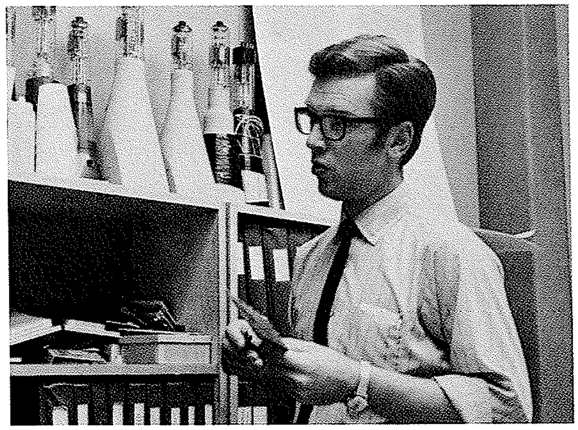
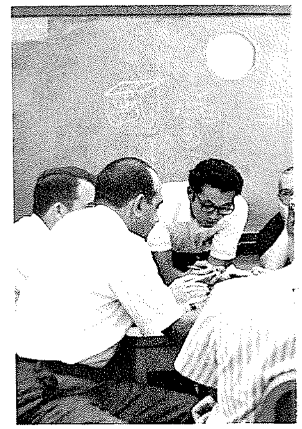
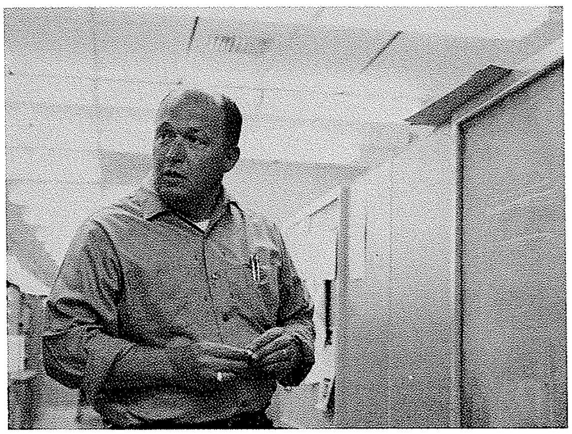
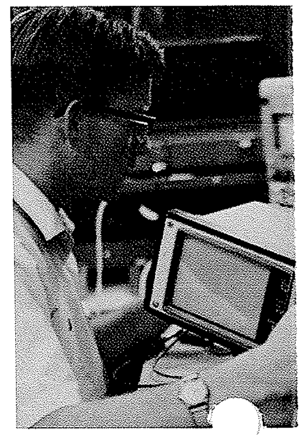
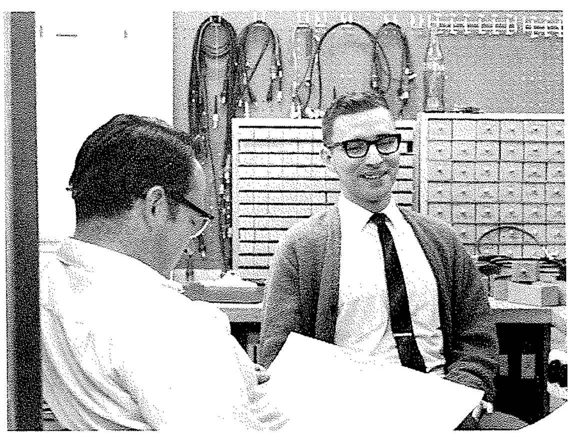
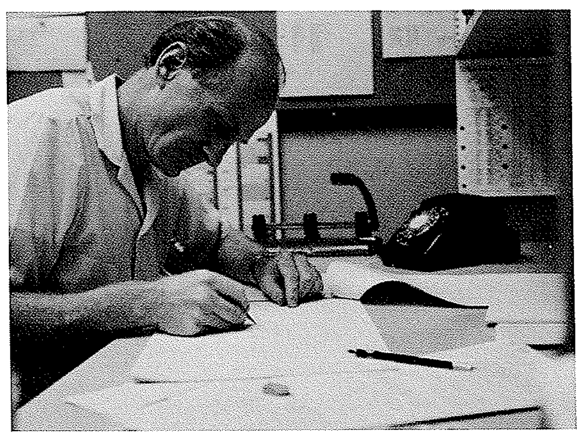
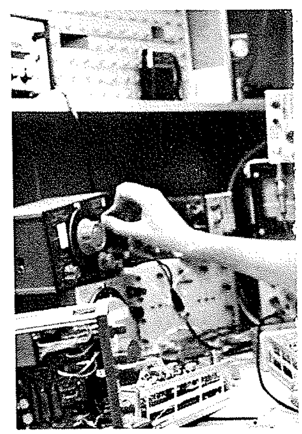
TEKSCOPE

OCTOBER 1969

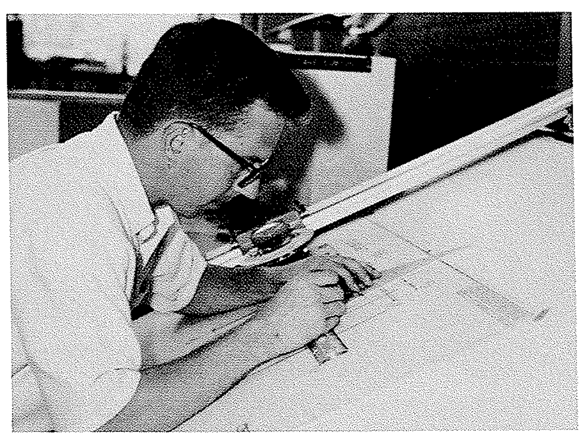
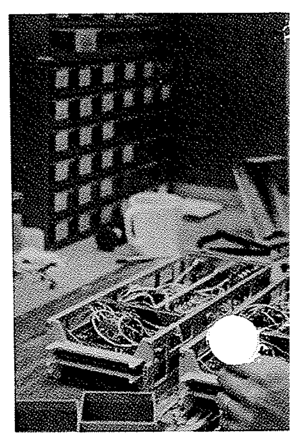


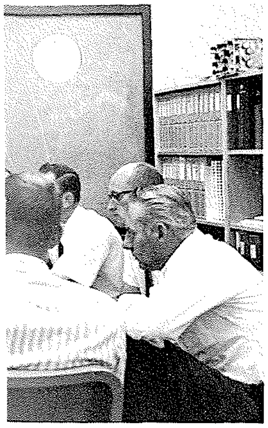





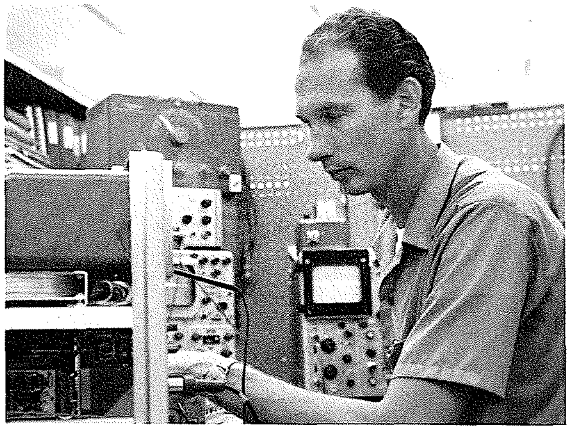
NEW GEN

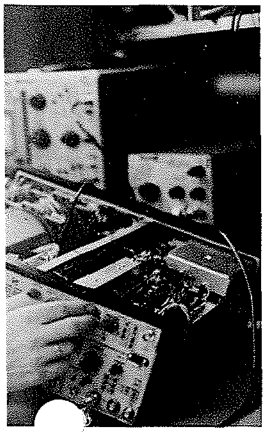
October TEKSCOPE focuses on some of the more unique aspects of our new generation of oscilloscopes. The cover symbolizes the bold new concepts embodied in these instruments . . . . Pictured within these pages are a few of the individuals involved with the myriad of problems associated with developing a totally new product line. . . . . Future articles in TEKSCOPE will deal with some of the more specific measurement capabilities of these sophisticated designs . . . .

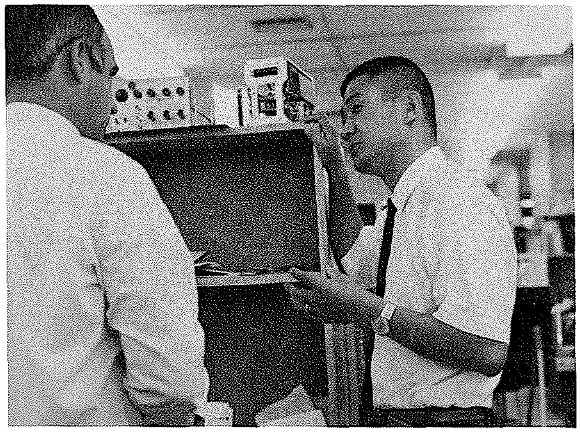



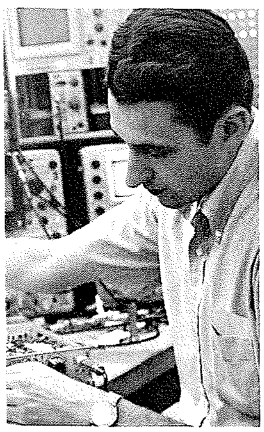


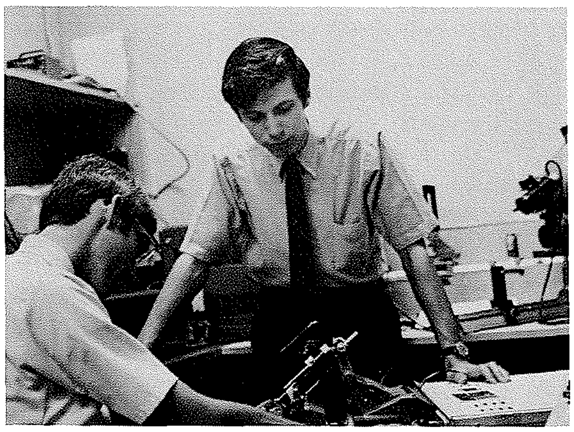


Over 15 years ago Tektronix introduced the plug-in concept with the introduction of the Type 535 Oscilloscope. The instrument accepted any one of four plug-ins and for the first time allowed the user to quickly adapt a single oscilloscope to observe many varied signal sources. Oscilloscope plug-in preamplifiers provided high-gain, wide bandwidth, differential, and dual-trace performance, and provided great versatility at a reasonable price. Since that time the spectrum has widened to include 14 other oscilloscopes with 30 additional plug-ins, and all are compatible. Storage, sampling, time-domain reflectometry, spectrum analysis, and a number of other advancements have all been incorporated to expand the versatility of the concept.





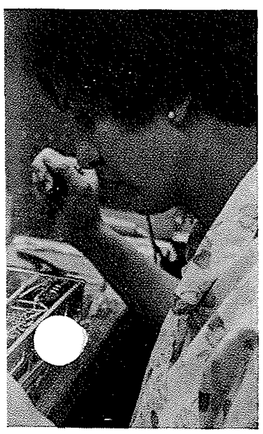


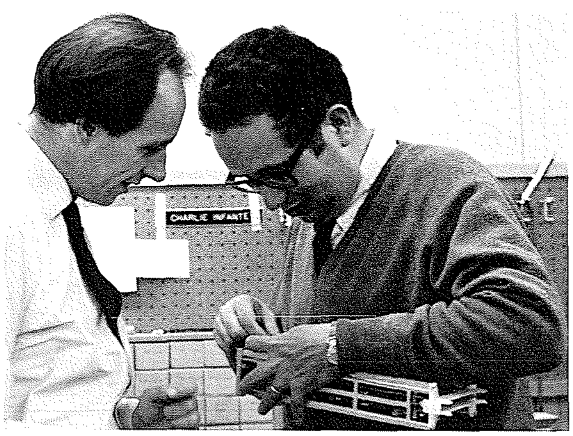


The NEW GENERATION is a term used by those who have participated in the development of a new concept in oscilloscope design. To the men and women of Tektronix, who have labored with their many varied skills to convert these thoughts into reality, it will always be the NEW GEN.

The NEW GEN has taken the best efforts of a large segment of the Tektronix development population. The beginnings were over five years ago when a small task force first began studies of a product line designed for the future with optimum versatility. Over 20 years of oscilloscope experience and accumulated skills have interacted with these studies to result in the new 7000-Series and 5000-Series Oscilloscopes. New components have been built as well as new facilities to produce them. Over two years of intensive engineering development precedes the introduction of these instruments. The results are the *finest* oscilloscopes available based on today's most advanced technology.

This issue of TEKSCOPE can only tell the beginning of the New Generation evolution. The future, we believe, will be even more exciting.





INTRODUCING THE NEW GENERATION

The 7504 and 7704 with their array of 13 plug-ins are the vanguard of a new oscilloscope line designed with an unprecedented degree of flexibility in anticipation of future requirements. Each instrument accepts up to four plug-ins and can display its output in a wide variety of ways. Blank plug-in panels are available to cover the unused panels if four plug-ins are not required initially.

The new plug-in oscilloscopes are designed to be the most expandable line of oscilloscopes ever developed. Thought has been given to probable technical developments in both components and instruments, and every effort has been taken to ensure the future compatibility of these designs.

The 13 plug-ins provide an overall measurement capability exceeding that of any other plug-in oscilloscope. 5-mV performance at 150 MHz with a full 8-cm scan, 5-mV four-trace performance at 105 MHz, are just two of the features currently available only in the 7000 Series.

The two plug-in oscilloscopes are identical in front panel appearance. The major differences are in the vertical amplifier, the low voltage power supply, and the cathode ray tubes. The 7504 with appropriate plug-ins provides up to 90 MHz bandwidth performance, while the 7704 has 150 MHz capability.

Possibly the most dramatic feature of the new instruments is the readout capability. Auto scale-factor readout is a standard feature of both oscilloscopes and automatically provides a display of vertical and horizontal sensitivity. By providing the correct scale factors on the face of the CRT, the operator is relieved from simple but bothersome mental calculations. Plug-in knob settings are read out on the CRT screen by means of a unique character generator which time-shares the CRT beam with the normal oscilloscope display.

Magnifier settings and probe attenuation are automatically taken into consideration. Therefore, the operator always reads the value at the probe tip at the correct sweep speed. Should plug-in polarity be inverted, an indication (↓) is given. If any knob becomes uncalibrated, a greater than symbol (>) will precede the quantity. A photograph will include both the analog display and alphanumeric data, eliminating the possibility of incorrect labeling.

A new trigger circuit is featured in the new oscilloscopes that greatly simplifies trigger operation. The peak-to-peak auto trigger circuit detects the peak-to-peak excursions of the displayed waveform, stores the value in the peak-to-peak memories, and matches the range of the level control to the range of the displayed signal. With the trigger in the peak-to-peak auto position, the operator can go through the maximum excursions on either slope and never reach an untriggerable position on the control knob.

Switching in the 7000 Series is accomplished in the mainframe of the oscilloscope. Five vertical mode push buttons and four horizontal mode push buttons determine which plug-in outputs will be displayed. Twenty possible combinations of vertical and horizontal operating modes are provided for maximum versatility. This design choice allows comparison between any two vertical channels to enable comparison of signals with significantly different characteristics. For example, sampling (50 Ω) and conventional (1 MΩ); wide bandwidth and high sensitivity; differential comparator and current probe; dual trace and dual trace for four-trace operation are all easily accommodated in the appropriate plug-ins. In addition, as higher performance or special performance plug-ins are developed, they may be used with a more conventional unit.

The center two compartments are designed so they may be devoted to sampling capability, spectrum analysis, or

X-Y display. This allows a signal to be observed in a conventional manner while simultaneously monitoring a sampling display, frequency display, or X-Y display of the identical phenomenon.

Switching is also provided between the two horizontal plug-ins to provide sweep-switching capability. In addition to ALT, a CHOP mode is provided which is convenient when observing two displays of greatly different repetition rates. This mode also provides dual-beam capability up to approximately 20-μs/div sweep speed.

Placing the plug-in interface before the oscilloscope amplifier provides a number of important advantages. For maximum versatility, we have chosen a plug-in output of 25 mV/div at 0 volts in a 50-Ω environment. This convenient interface will allow us to take the maximum benefit of new developments in components and in signal conditioning. In addition, as future oscilloscopes evolve, changes in display sensitivities are easily accommodated with the buffering vertical amplifier.

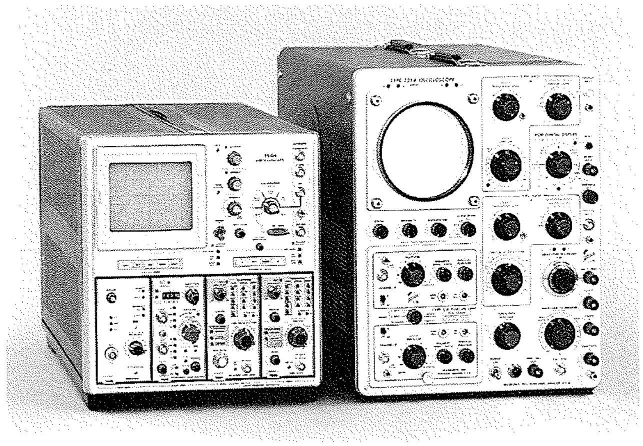
Although this design choice increases the initial price of the oscilloscope, it decreases the price of each plug-in. With the vertical amplifier in the oscilloscope, it is not necessary to build an output amplifier for each plug-in and this saving may be passed along to the customer.

The 150-MHz 7704 utilizes a "high efficiency" power supply which eliminates the bulky iron-core transformer and heat sink and eliminates any necessity for a fan. This new supply dissipates approximately 60 watts com-

7-SERIES PLUG-IN PERFORMANCE

AMPLIFIER	BANDWIDTH 7704	BANDWIDTH 7504	MIN DEFL FACTOR	PERFORMANCE FEATURED
7A11	150 MHz	90 MHz	5 mV/div	Low-capacitance FET Probe Amplifier
7A12	105 MHz	75 MHz	5 mV/div	Dual-channel Amplifier
7A13	100 MHz	75 MHz	1 mV/div	Differential DC Offset, High-Freq. CMRR Amplifier
7A14	50 MHz 105 MHz	45 MHz 75 MHz	1 mA/div	AC Current Probe Amplifier (2 current probes)
7A16	150 MHz	90 MHz	5 mV/div	Wide-bandwidth Conventional Input Amplifier
7A22	1 MHz		10 μV/div	DC-Coupled, High Gain Differential Amplifier
*7S11	350 MHz - 14 GHz depending on Sampling Head		2 mV/div	Sampling Amplifier *Sampling head required
**7M11	2 GHz (175 ps)		X2 atten	**Passive Dual Delay Line Unit

TIME BASE	FUNCTION	MAX SWEEP RATE	TRIGGERING FREQ. RANGE
7B50	Delayed Sweep & Ext. Amp	5 ns/div	DC - 100 MHz
7B51	Delaying Sweep		
7B70	Delayed Sweep & Ext. Amp.	2 ns/div	DC - 200 MHz
7B71	Delaying Sweep		
7T11	Random, Sequential & Real-Time Sampling	10 ps/div	DC - 12.4 GHz



7000 Series and Type 535A. Four plug-in capability and auto scale-factor readout are distinguishing characteristics of the new instrument line.

pared to 140 watts that a conventional supply would dissipate. Use of this new supply removes approximately 12 pounds from the weight of the instrument, providing a 200-W power supply in a 10-lb package.

The instruments make extensive use of color coding to simplify front panel logic for the operator, and improve user interface. In addition, proper front panel component selection has assisted in attaining this goal.

The new R5030 is a dual-beam differential oscilloscope providing 1-MHz, 10-μV performance in a 6½-inch CRT. The instrument makes use of a fiber-optic readout display adjacent to the CRT area. A separate current mode is provided to accept a current probe (1-mA sensitivity) with no external termination being required.

The instrument is designed for simple operation and uses color coding extensively. Depressing a push button changes the display from a dual beam Y-T to a single beam X-Y display for additional versatility.

Unique to this instrument is a LOCATE function associated with the time-base magnifier. When depressed, the time base is returned to an X1 magnification position and the area which will be magnified is intensified. The magnifier, which is direct reading on the auto scale-factor readout offers five positions of magnification on the time-base switch. The locate feature allows the operator to easily pick out where on the trace he has chosen his magnified sweep.

For further information on all of these new Tektronix instruments, consult your local field engineer. Complete information is given in the August 1969 New Products Catalog Supplement.

READOUT

Since an oscilloscope display is basically a graph, it is logical that the axes be labeled with the scales used, to simplify interpretation of both displays and photographic records. The calibration of this system is accomplished with a coding system that extends to the probe tip and is carried through the plug-in interface. Thus, the oscilloscope takes on the characteristic of a true quantitative instrument.

The 7000 Series introduces a dramatic new system of readout inexpensive enough for oscilloscope use. As oscilloscope displays may present several traces at different sensitivities and sweep speeds, a versatile system is required. A fully integrated electronic character generating system has been developed which timeshares the cathode ray tube with all regular functions. The result is a system which collates within the CRT area all the important parameters of the measurement.

The symbols are 3-mm high and 2-mm wide with spacing 0.3 mm between words. Eight words are possible, four in the upper CRT area and four in the lower CRT area. The intensity of the readout display is adjustable by a front panel control and may be switched off if desired.

The character is written in 9.8 μs. The display rate is 71.5 Hz, independent of the amount of data. The fractional time taken out of the display is proportional to the number of symbols displayed (0.1% per symbol) and has little effect on the intensity of the normal display.

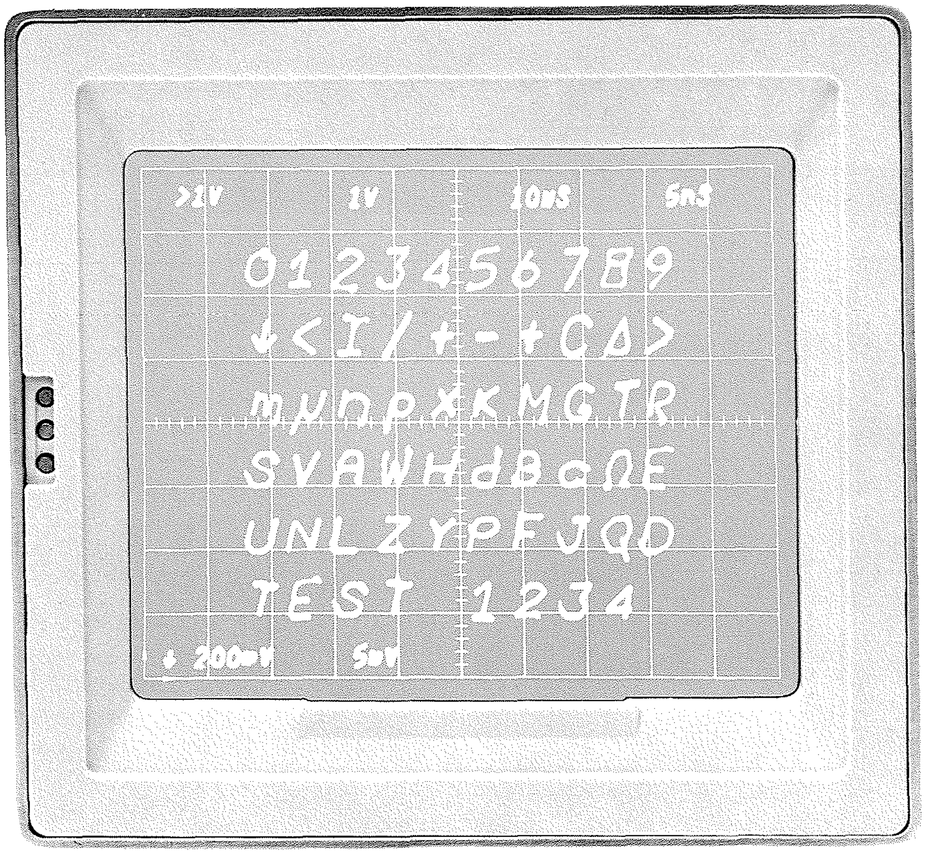
The system uses 14 Tektronix bipolar integrated circuits (the equivalent of some 6000 active devices) and is contained on a 4½ x 5-inch circuit board. The heart of the system is the novel character-generator proper. Utilizing two new circuit principles, ten symbols are packaged in each 65-mil square die, fabricated by the standard planar process. A total of five dice provide a basic 50-character font, but changes in the style of the character (italicization, aspect ratio, size, etc.) are readily made externally. To generate a new set of symbols, it is only necessary to change one mask in the process—the pre-ohmic mask. Since this step is near the end of the process, wafers can be processed in common up to this point.

Each circuit is a complete system, requiring only a power supply and a scanning voltage to produce characters on the CRT. The characters are selected directly by applying a current to one of ten selection pins. The outputs appear from "free" collectors and thus any number of packages may be connected in parallel. The outputs correspond to the scanned X- and Y-values of the complete symbol, and require no further processing. Addressing is performed by currents on column-select lines and row-select lines. The column-select current is in the range 0 to 1 mA, and the character size is directly proportional to it; thus, it is simple matter to generate a display having mixed symbol sizes.

Each symbol is composed of seven strokes, but unlike prevalent seven-stroke generators, the break-points of the strokes may be placed at any one of several hundred locations. In addition, the strokes may have virtually any length and angle, permitting high-quality symbols to be generated by a small number of co-ordinate pairs. Each of the eight break-points consists of an X-co-ordinate and a Y-co-ordinate (no Z-axis information is required to generate the symbol), and these are defined by the number of emitters connected through the pre-ohmic holes in the oxide. A total of 1440 emitters are used in the co-ordinate section of the circuit. This use of multiple emitter-areas as precise current-splitting elements is the first of the features that enabled Tektronix to achieve the high packaging density.

The second feature is found in the method devised for scanning symbols. A simple sequential pulsing of the eight co-ordinates would produce only an eight-dot display. A smooth scanning from one point to the next is required to trace out the character fully. This is achieved by using a resistive ladder network connected to the bases of the co-ordinate-forming transistors.

Multiple exposure. This photograph illustrates a typical auto scale-factor readout at top and bottom. Note the uncalibrated scale of Channel 1 and the polarity inversion of Channel 2. The 50-character font provided is also shown enlarged for clarity, in the center of the photo.



A triangular input waveform smoothly sequences through the co-ordinate pairs, and by proper network biasing produces an X- and Y-current waveform corresponding to the symbol. Scanning rates can be anywhere from DC to a megahertz.

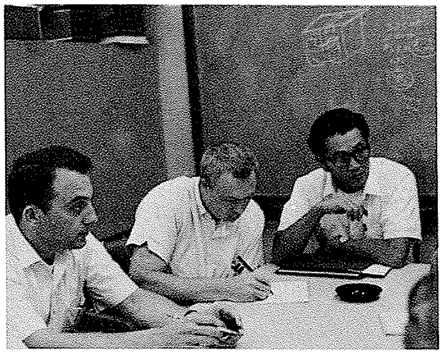
Much of the flexibility of the system stems from the data coding techniques used. Instead of using the usual binary codes, a time-multiplexed multi-level analog current code was adopted, in which the data is divided up into eleven 100-μA levels at 250-μs intervals. Since the symbols are stored in a matrix of ten rows (some correspond to the stored instructions, and some are spares) by ten columns, two lines are needed to convey the data out of the plug-in. Data is encoded in the plug-in by switch-closures and resistors. Decoding is accomplished on the readout board by integrated A-D convertors (one IC for row and one for column data) which then address the matrix.

Apart from the increased data-handling capacity (some 10^{160} combinations are possible for the readout system), a more subtle advantage results from the use of an analog current code: data can be modified systematically by the addition or subtraction of levels. For example, one of the instructions controls the number of zeros that follow the first digit of a scaling factor.

Each higher level adds a zero, until two zeros are displayed. The next level causes zeros to be dropped and the prefix (n, μ, m, etc.) to be shifted a factor of 1,000. Consequently, responding to the addition of attenuator probes is a simple matter.

Each word may have up to 10 symbols, although typically there are between 2-5 symbols per word. The symbols are normally written without redundant spaces, but spaces may be called for in the code, if desired. In addition to the scale factor, provision is made for indicating inverted polarity (↓) and not calibrated (> symbol) preceding labeling.

A special "identify" feature is included to determine which scale factor goes with which trace. Depressing the IDENTIFY button replaces the appropriate scale factor with IDENTIFY and deflects the identified trace up a few millimeters. This feature is available on all the new plug-ins and is also present on the new probes introduced.



COMPONENTS

The new generation of instruments would not have been possible without the extensive component development program embarked upon by Tektronix component engineers. Early in the program it was recognized that commercially available components would be much too restrictive; so simultaneous development programs were initiated in integrated circuits, rotary and push-button switches, relays, and thick film attenuators. At the same time, efforts were launched in developing the "mother-board" etched circuit board concept along with the required interface connectors.

The results of these efforts are the prime factors in the ability to introduce the R5030 and the 7000-Series. For example, auto scale-factor readout would not have been possible without custom integrated circuit design, since the price and size would have been prohibitive. Much of the versatile switching that characterizes the 7000-Series is also accomplished with custom IC's.

Tektronix Integrated Circuits are widely used in new generation oscilloscope circuitry. Seventeen different integrated circuits are included in the new instrument designs and allow performance that would otherwise be unattainable. The ability to custom-design IC's permits instrument features that would otherwise be prohibitively expensive. The ability to use the best logic for a given job, instead of relying on logic designed for other applications, results in a more versatile, logical instrument at a more economical price.

Tektronix switch engineers developed the small reliable rotary cam switch to replace bulky multiganged rotary switches. Two basic sizes have been developed. One incorporates a 0.83-inch drum diameter and is available in up to 28 positions. The other is 0.454 inch in diameter and is available in up to 12 positions. In the case of the R5030, two 12-position cams and a 28-position cam are linked together with a clutch to provide a direct reading magnifier and direct reading external horizontal amplifier on the same knob as the TIME/DIV control. This novel configuration simplifies the front panel logic and conserves front panel space.

Rotary cam switches provide the following advantages:

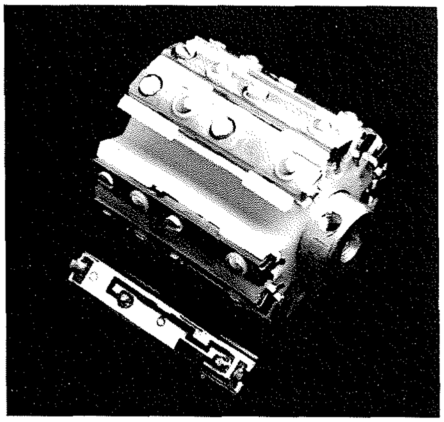
1. Lower and more controllable torque. A cam switch may be turned without a knob. Thus a smaller diameter knob may be used allowing more efficient use of front panel space.
2. Higher reliability and longer contact life.
3. More accurate control of tolerances since cam manufacturing uses numerically controlled equipment.
4. Wiring to the switch is more direct. "On board" wiring may be used since no separate wiring harness is required.

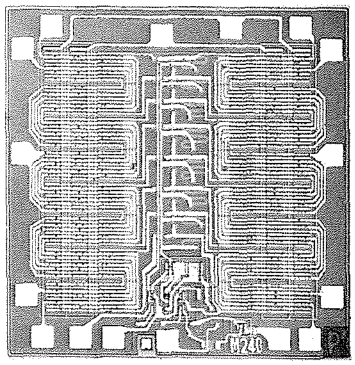
New miniature push buttons indicate the status of various functions and replace many of the larger switches used in previous designs. The basic family of push-button switches is provided in rows of 2 through 10 positions. Most configurations require only one lamp to light any button in a row.

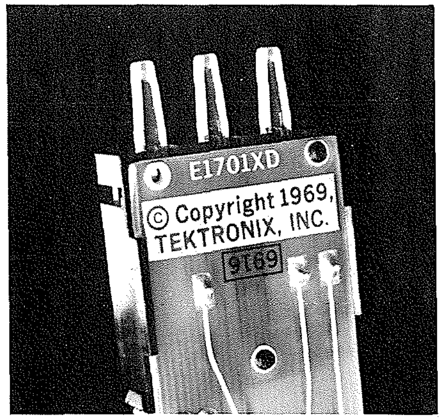
Depressing a push button causes the rear beveled edge of the button to obtain light from the lamp at the end of the rows. The light is then transmitted to the front of the transparent button. The push-button switches are mounted on an etched circuit card that contains the appropriate circuitry. The lamps used are rated at 50,000 hours at full power with even longer life at partial power.

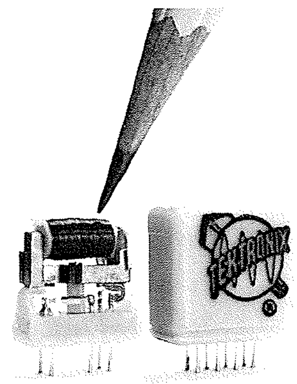
These small switches require less inward travel than other commercially available switches. Since the holes in the casting are quite small, the switch design also creates less of an EMI problem than the older larger switches.

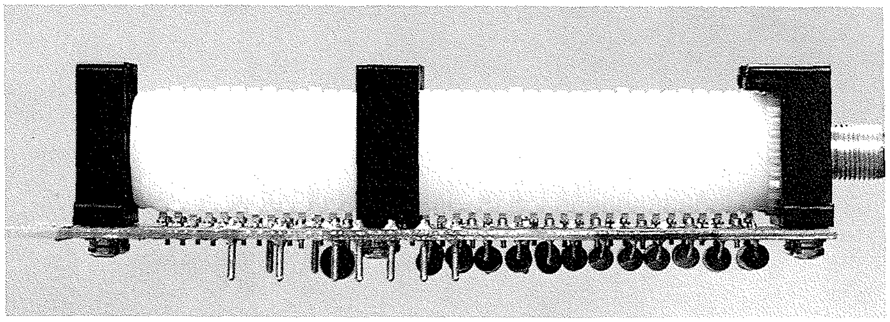
The new Tektronix instruments make extensive use of relays and relay switching. As there were no inexpensive miniature relays on the market, Tektronix engineers developed a 200-mW double-pole, double-throw











Some of the Tektronix components used in new generation instruments. Clockwise from upper left: thick-film drum attenuator, character-generator IC with 1440 emitters, miniature lighted push-button switch, miniature relays, and rotary cam switch.

sensitive relay. From this basic design, there are currently 16 variations including a single-pole, single-throw version, a magnetic latch version, and a bifilar wound center tap latch version.

Tektronix relays are generally designed to plug into a socket that is flow soldered to the etched circuit board, assuring quick and easy servicing. These low-capacitance miniature sensitive relays have less leakage than semiconductor switches and are much more tolerant of transient voltage considerations.

A new potentiometer design contributes to operator convenience and saves front panel space. The design uses a 3:1 reduction drive to improve the resolution of the triggering control. By combining this potentiometer with a relay, the slope is automatically changed as the level control passes 0° and 180°. The development of this feature provides a new ease in oscilloscope triggering and contributes to the human engineering of the new instruments.

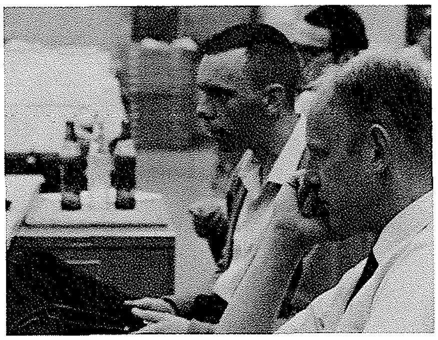
A "push-push" switch design was developed to switch variable controls in and out of the circuit. The small switch, which conveniently solders to a circuit board, is used wherever a variable function might uncalibrate an oscilloscope.

Thick film technology permitted the drum attenuator design for the 7A16 Amplifier and allows this unit to provide 5 mV sensitivity with 150 MHz bandwidth in the 7704.

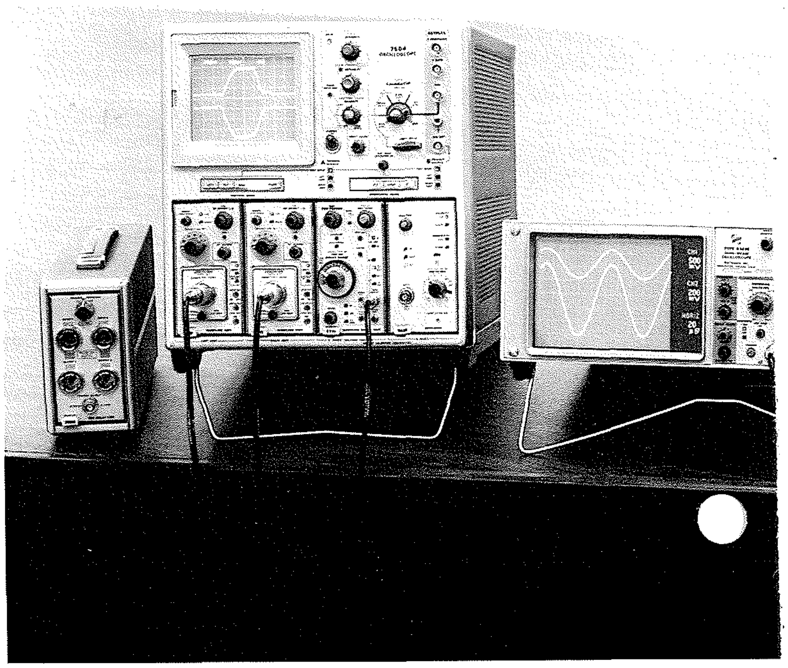
The drum attenuator design consists of a ceramic chip for each attenuator position. The chip consists of two resistors whose value is determined by the amount of thallium oxide and glass fired onto the chip. Although stray capacitance is still a factor, it is constant and controllable, and once compensated it remains the same. The attenuator design incorporates subminiature butterfly trimmers formed of small round ceramic discs with a deposited silver film to allow compensation and standardization.

Each attenuator position has its own attenuator without switching in stacked resistors. As a result, inductance, feedthrough, and crosstalk are held to a minimum. In addition, the process lends itself well to tight tolerances since the resistors may be easily trimmed to 0.1%. The result makes possible a very clean, fast plug-in amplifier with a 1 MΩ and 15 pF input impedance.

Thick-film techniques are also used for the high resistance dividers in the high voltage supplies of the 7504, 7704, and R5030.



HUMAN ENGINEERING



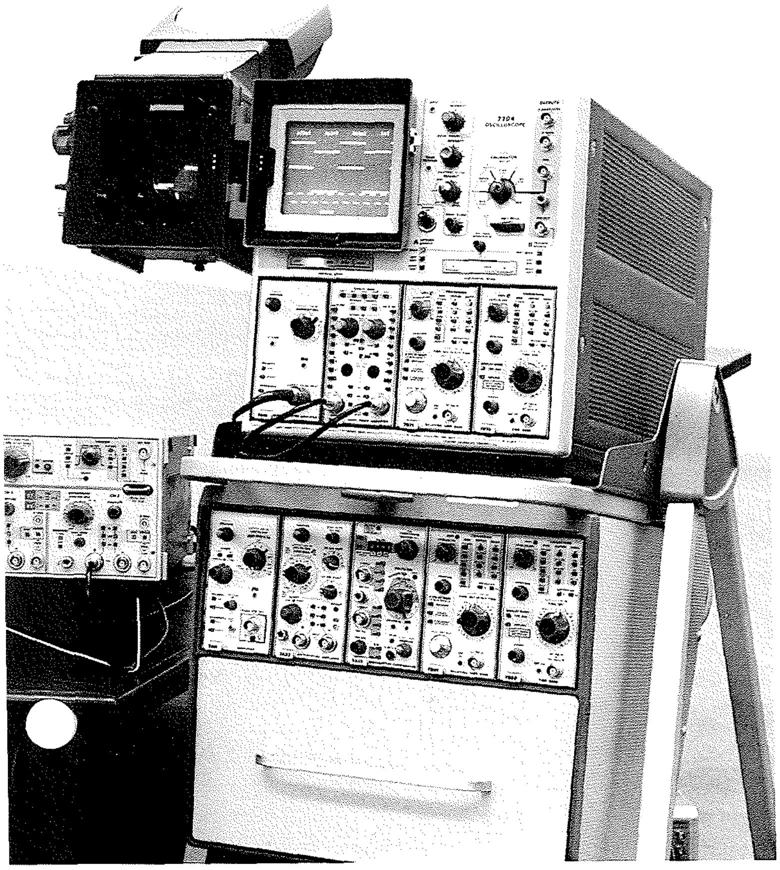
The new generation design concept of Tektronix instruments has provided the ability for the front panel to keep pace with circuit miniaturization developments. Portable oscilloscopes such as the Type 453 were designed in appreciably smaller packages by using solid-state techniques. Front panel controls, however, made no significant size reduction since essentially the same components were being used. Once the choice of plug-in size for the 7000-Series was determined (2⅝" W x 5" H x 14¼" L), it became evident that commercially available rotary switches would no longer do the job. The same problem was present with lever switches and the push buttons available.

As a result of a joint effort between component development engineers, circuit engineers, mechanical engineers, and industrial design engineers, suitable Tektronix components were developed. Once these new components were available, it was then possible to design an instrument front panel considerably different than before. The result is the radically new and logical front panel layouts of the 7000-Series and the R5030.

The miniature lighted push buttons were designed to eliminate function selector switches and rotary switches wherever possible. Rows of miniature lighted push buttons quickly indicate the status of all controls where a choice must be made.

The push-button spacing has been given considerable attention. Since the finger is oval, not round, vertical and horizontal requirements are different. The curvature of the finger and how far you have to push determines the minimum spacing of the buttons. This spacing has been closely calculated and as a result, there is more finger space than is present in commercially available push buttons used in the Type 184. These self-cancelling push buttons are one of the greatest contributors to the simplified front panel logic of these new instruments.

A logical and consistent use of front-panel color coding identifies specific functions and simplifies front-panel logic. The following colors have been assigned to assist the user in oscilloscope operation:



The NEW GENERATION of Tektronix instruments and accessories.

Black (and gray) is neutral and is used for all general nomenclature and controls. It is also used for grouping similar kinds of things (e.g. signal outputs on the mainframe of the 7000-Series). Varying shades of gray are used to denote various logical sub-groups.

White indicates status and normal operating conditions (e.g. push-button lights and whether A or B intensity control affects the display).

Blue is assigned to the display mode function. For example, the display mode of the plug-ins and the mainframe switching is coded in blue. The user knows that he must make a decision in each area where he sees blue.

Green is assigned to triggering functions. A subtle difference is that in the sampling instruments a green outline is used instead of the normal solid color block. This indicates the triggering does not go through the mainframe, and thus the operator need not bother with mainframe controls.

Yellow is used for notes of caution or unusual operating functions. As an example, yellow is used to indicate the restricted sensitivity (1 — 50 mV) available in the electrometric mode ($R \simeq \infty$) of the 7A13 Differential Comparator Amplifier.

Orange is used for exclusive functions on a given instrument (e.g. current inputs on the R5030).

Red is exclusively assigned to controls that will uncalibrate the instrument and indicates that an inaccurate measurement is possible. Thus, when a variable control is in use, the red color band of the knob (as well as the readout on the display) warns the user that the instrument is in an uncalibrated position. Depressing the knob removes the red from the front panel, recesses the knob flush with the outer control, and returns the instrument to a calibrated display. If an uncalibrated display is desired, a slight push on the knob releases the red variable knob and the user regains variable control of the function.

This new component simplifies front panel logic and guards against unintentional non-calibrated displays. Its use allows seldom used controls to essentially disappear when not in use.

Color-coding has been extended to include concentric knob color and lettering style. If concentric knobs are used for similar functions (e.g., offset—fine, coarse), the knobs are identical in color. If concentric knobs are used for dissimilar functions (e.g., focus and intensity), the knobs are dissimilar in color.

The same logic is used for labeling. Outline lettering is used to relate to the light gray inner knobs and normal black lettering is used to relate to the dark gray outer knob. In the case of similar functions, the inner control is in smaller lettering than the outer knob nomenclature.

We, at Tektronix, feel that a major breakthrough has been achieved in simplifying front panel understanding. Although this first Tektronix offering of our new products provides more flexibility than ever before, we think the improvement in human engineering will make them even simpler to operate. One thing is certain. A great deal of thought, discussion, and effort has gone into the final design choices. If acceptance is as we expect, future designs will all be compatible in their logic. As new designs evolve, less and less effort will be necessary for the user to easily understand and use the capabilities of his Tektronix instruments.

CONSTRUCTION

All three new instruments make use of front and rear panel castings connected by aluminum extrusions. The oscilloscope plug-in compartment is designed with no dividers for maximum future flexibility. The modular power supplies are located behind the plug-in compartment on cables for easy access. The R5030 power supply is located at the right rear of the instrument and is accessible via a swingout heat sink.

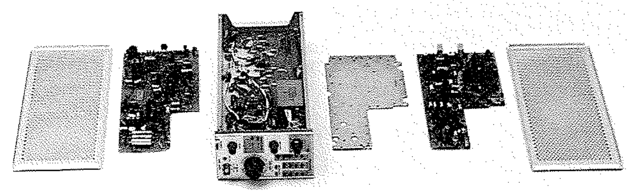
Plug-in construction consists of a front casting, aluminum extrusions top and bottom, a plastic rear panel, and a circuit board. The central "motherboard" contains the circuitry and forms the connector of the plug-in. This connector then plugs into the female connector at the rear of the plug-in compartments and provides the interface to the oscilloscope amplifiers. The circuit board connectors have been specifically designed for low insertion and withdrawal forces to provide a reliable connection with long life characteristics.

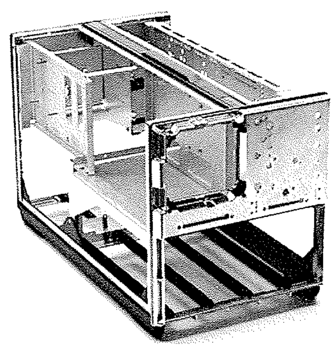
Extensive use is made of new 0.025 square gold-plated pins. Female clips on the end of wires clip directly to the gold pins. Where possible, plastic clips containing multiple connectors group wires together for easier servicing. The use of long pins permits stacking of boards when component density is high. This technique provides good accessibility and ease of maintenance and contributes to a neat overall instrument appearance. The format also provides for easier automatic pretesting and faster instrument assembly.

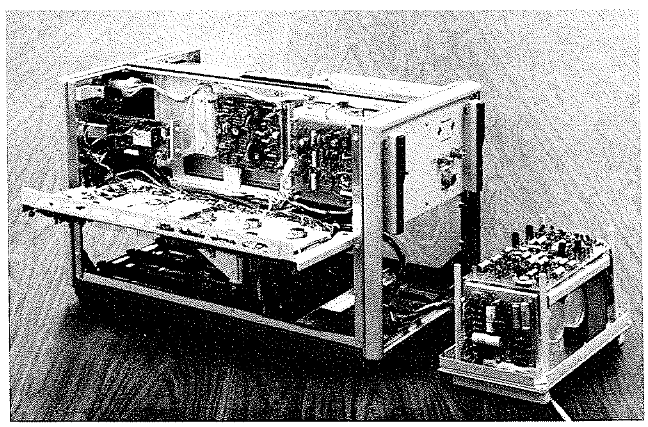
Gold-plated glass epoxy circuit boards are used to ensure maximum reliability. Features such as plated-through holes, built-in test points, and transistor and IC sockets all combine to enhance maintainability.

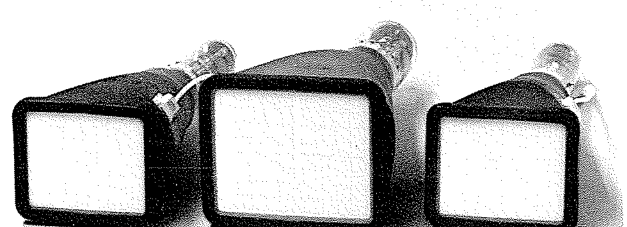
Eletromagnetic Interference requirements have been taken into consideration and are a standard feature in the plug-ins. The 7000-Series oscilloscopes are designed to be convertible to meet EMI specification by a special set of side panels. This feature guards against obsolescence in the event of stricter EMI regulations.

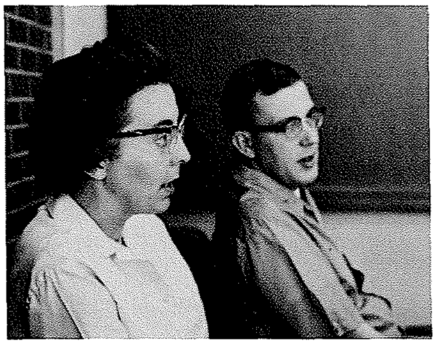
Top to bottom: construction of a typical stacked plug-in unit; basic structure of casting, extrusions, and chassis; 7704 with modular high-efficiency power supply extended for servicing; the three new CRT's developed for the New Generation instruments.











CATHODE RAY TUBES

The heart of any oscilloscope is the cathode ray tube. The ceramic post-deflection accelerator CRT's developed for the Tektronix 7000-Series Oscilloscopes offer significant improvements over CRT's currently available. The 8 x 10 cm viewing area provides a large bright display with high writing speed. Both the 7504 and 7704 can easily record an 8-cm single-shot photo of their risetime, using standard Tektronix P31 phosphor, without employing film fogging techniques.

The new Tektronix CRT's use a frame-grid construction. Frame-grid CRT's employ scan expansion and provide a very good compromise of deflection sensitivity and writing speed. Because frame-grid conductors run only in the vertical direction, electron-beam transmission is nearly 50% greater than most mesh construction tubes. The result is a high writing-speed tube with very good linearity and sensitivity (e.g., the 7704 CRT vertical sensitivity is $\simeq$ 3.3 v/cm) over a full 8 x 10 division scan.

Good horizontal sensitivity is achieved by placing the frame grid as far forward as possible into the post accelerator field. This causes the field lines to curve around the front of it sufficiently that the effect on the electron beam is similar to a curved horizontal plane. Thus many of the advantages of a mesh are obtained with few disadvantages.

Tektronix CRT's are designed to provide single-shot writing speeds sufficient to record a transient at the risetime limit of the instrument. Writing speed is specified with no film fogging using P31 phosphor, the optimum phosphor for general purpose viewing and long-life characteristics.

The 7504 CRT is operated at 18 kV and provides a specified minimum writing speed of 2500 cm/μs (with C-51 camera) using Tektronix standard P31 phosphor with no film fogging.

The 7704 CRT is operated at 24 kV and provides a specified minimum writing speed of 3300 cm/μs (with C-51 camera) using Tektronix standard P31 phosphor with no film fogging. This photographic writing speed is more than twice that of the Type 454 with P31 phosphor (identical camera systems).

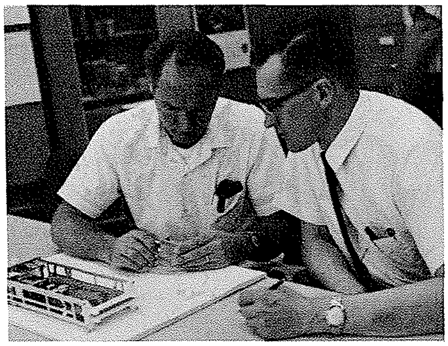
The 7704 incorporates a special face plate design to ensure that X-ray radiation is attenuated well below the TV standard recommended by the National Council on Radiation Protection and Measurement (100% duty cycle raster with full intensity). In addition, circuitry has been included to limit the maximum possible high voltage to keep the specification well within this figure.

The R5030 CRT is a dual beam 6½-inch ceramic monoaccelerator CRT. This unique tube provides a full 8 x 10 div (div = 1.27 cm) coverage for both electron guns with deflection defocusing better than 1.5 to 1 on any axis. The large divisions provide 50% greater viewing area than conventional 8 x 10 cm designs. The tube provides a bright high-resolution display which minimizes operator fatigue.

A novel dynamic geometry circuit maintains excellent geometry in this tube over the wide extended deflection angles. An additional deflection element is placed between the two sets of vertical deflection plates and corrects the beam at the deflection extremes (i.e. upper edge of lower gun display and lower edge of upper gun display). The correction voltage minimizes geometry problems providing an excellent overall geometry.

The new Tektronix tubes employ a new female type neck connector for the deflection elements that is essentially flush with the glass. As a result, tubes may be removed without worrying about the pins catching and bending, or breaking off. A new male connector on the deflection leads simplifies CRT replacement.

The ceramic construction provides greater strength, lighter weight, and improved internal graticule edge lighting. This construction technique also allows tighter tolerances and decreases development time, due to our well-developed ceramics technology.



ACCESSORIES

The probes and accessories developed for the new generation of Tektronix instruments embody the same philosophy as the instruments themselves. Thus, new probes have been designed to automatically provide the correct scale factors and ensure that the auto scale-factor readout represents the sensitivity at the probe tip.

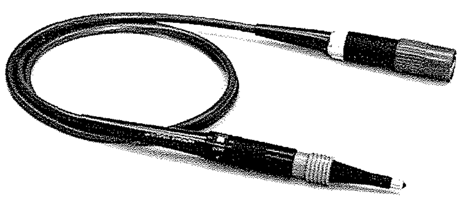
For example, an FET probe was designed as an integral part of the 7A11 FET Probe/Amplifier. By incorporating two stacked attenuators and a temperature compensated FET amplifier in the probe itself (<0.8 in^3) it is possible to relay switch the attenuators from the front panel. A miniature relay had to be developed to fit into the nose of the probe to switch the two 20X high speed, high impedance attenuators.

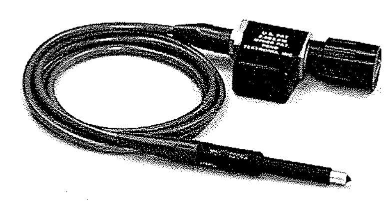
The result is an FET probe that is small in size with no bulky amplifier to mount to the oscilloscope and which cannot be made to clip or limit the signal on the CRT by an incorrect combination of input attenuator and plug-in sensitivity. Thus, the operator is freed from concern with manual plug-on attenuators and dynamic signal range over the complete range of 5 mV/div to 20 V/div. If the signal can be positioned or offset to fall within the viewing area, the amplifier is operating linearly. The sensitivity at the probe tip may be read directly from the front panel or from the auto-scale readout.

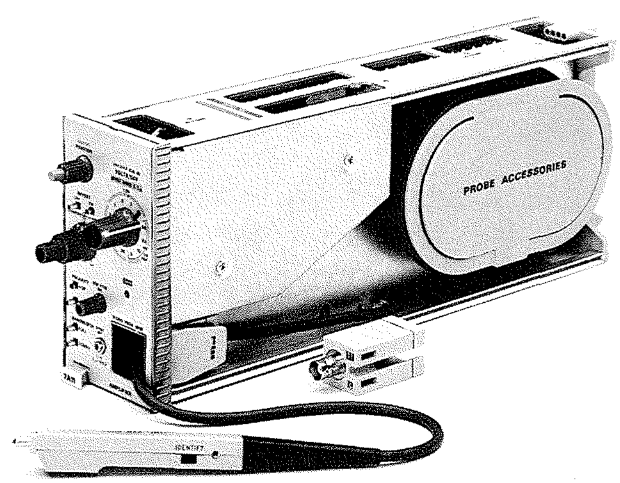
A second mode of operation is provided via a BNC connector on the front panel. When the full capability of the system is not required, the probe is stored internally and is accessible via a front panel BNC connector. Storage space for probe accessories is also provided within the plug-in.

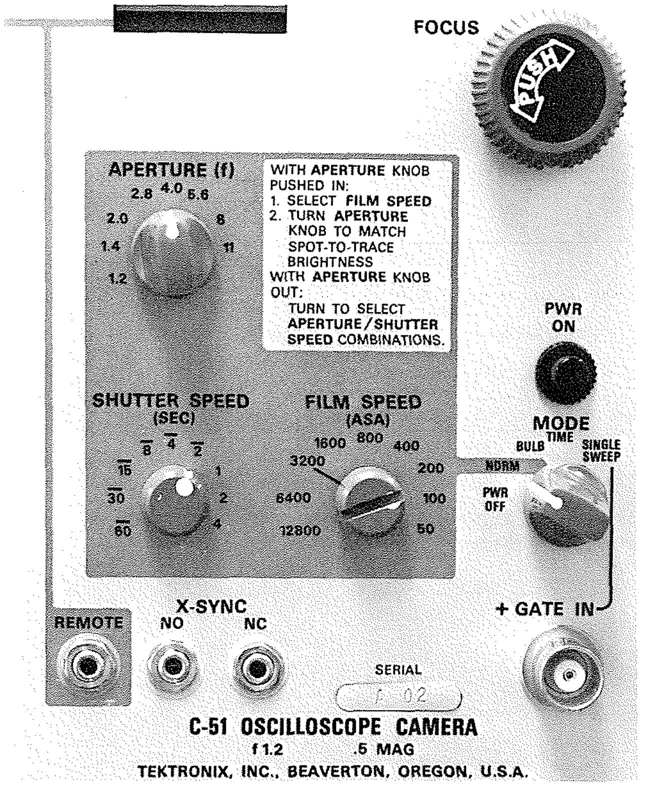
The 7A11 FET/Probe Amplifier provides 150 MHz bandwidth (2.4 ns risetime) in the 7704 and 90 MHz bandwidth (3.9 ns risetime) in the 7504. The capaci-

The 7A11 Probe/Amplifier and the P6052 and P6053 probes offer new versatility in probe usage. Each probe is coded to ensure the correct readout, regardless of attenuation used, and contains a push-button trace-identify feature.









The C50/51 camera offers a new ease in waveform photography. When used with auto scale-factor readout the user is assured of recording the essential information of his oscilloscope display.

tance is a function of the attenuators and is 5.8 pF from 5 mV to 50 mV/div; 3.4 pF from 0.1 V to 1 V/div; and 2.0 pF from 2 V to 20 V/div. When the front-panel BNC connector is used, approximately 1 pF is added to the input capacitance.

All 7-series amplifier plug-ins are equipped with special signal input connectors. These consist of a BNC connector with a concentric outer ring that is connected to the readout circuitry. The amount of resistance between the outer ring and ground determines the attenuation factor to be used by the auto scale-factor readout. For example, a 10X probe has a 13 kΩ resistance connected between the outer ring and ground. In addition, when the ring is shorted to ground the circuitry acts as a trace identifier and shifts the trace on the screen.

Two new coded passive probes are currently provided. The P6052 is a DC-30 MHz dual-attenuation probe designed for low-frequency applications. A sliding collar on the probe barrel selects 1X or 10X attenuation and a push button provides a trace-identify feature. The P6053 is a miniature 10X probe designed for the Tektronix 7-Series amplifier plug-in units. The probe has a risetime of 1.2 ns (290 MHz bandwidth) and also provides a push button for trace identification.

Two compact semi-automatic cameras have been developed for use with all Tektronix 7000-Series Oscilloscopes. The C-50 (f/1.9, 1:0.7) and C-51 (f/1.2, 1:0.5) differ only in the lens system. Both cameras provide rangefinder focusing to assure correct focus for every exposure.

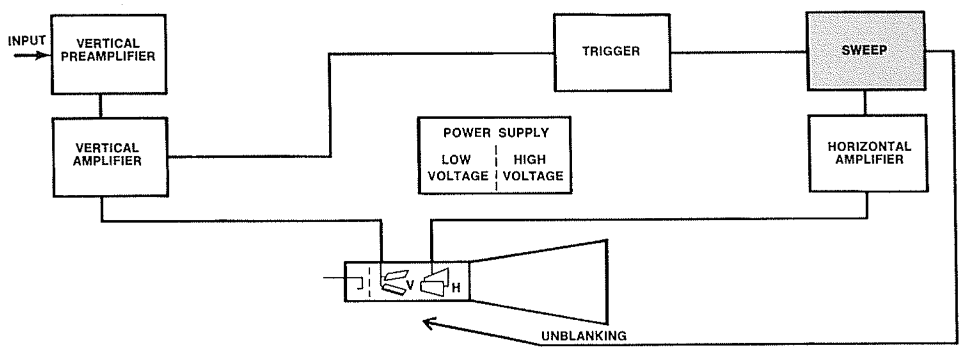
By depressing a spring-loaded focus control, two light bars are projected on the CRT screen. The operator turns the focus control until the bars merge, and when the control knob is released, the camera is locked in focus.

Both cameras use electrically controlled shutters and provide a trace brightness photometer to determine the correct exposure. The operator sets the ASA index, depresses the f knob until the photometer brightness matches the trace intensity and releases the f knob. The camera will now automatically track to keep the same exposure if either the f knob or shutter speed is changed. A shutter open lamp is lighted when the shutter is open at shutter speeds of 1/8 second or slower, and in the TIME and BULB modes. Power for the camera is obtained through the oscilloscope bezel so that no external power cord is required.

The SINGLE-SHOT mode offers the operator additional features. When the SHUTTER push button is depressed, the shutter opens and the camera provides a reset pulse to arm the oscilloscope sweep. If the +GATE is connected to the camera, the shutter control circuit will close 5 seconds after the sweep has occurred. The light then extinguishes to alert the operator that the shutter is closed.

A new Scopemobile® Cart is specifically designed to accommodate 7000-Series Oscilloscopes. The Type 204-2 features 9 tiltlock positions, holds 5 plug-ins and provides a large drawer for storage. A locking mechanism on the Scopemobile goes through the oscilloscope mainframe securely fastening the instrument to the tray.

SERVICE SCOPE



TROUBLESHOOTING THE SWEEP CIRCUITS

By Charles Phillips
Product Service Technician, Factory Service Center

This fifth article in a series discusses troubleshooting techniques in the sweep circuits of Tektronix instruments. For copies of the preceding four TEKSCOPE articles, please contact your local field engineer.

Tektronix sweep circuits are designed to develop a linear sawtooth voltage over a wide range of sweep times. Linear sawtooth voltages ensure that the waveform passes through a given number of volts during each unit of time. The sawtooth rate of rise (or fall) is set by the normally calibrated TIME/DIV control. This sawtooth voltage is then processed in the horizontal amplifier and applied to the plates of the CRT, resulting in the horizontal deflection of the electron beam.

As a result, the cathode-ray beam is swept horizontally to the right through a given number of graticule divisions during each unit of time—the sweep rate being controlled by the TIME/DIV control. In this manner, a baseline is produced that is proportional to discrete amounts of time (determined by the TIME/DIV control). By measuring the distance between two different horizontal points on the CRT display a time difference reading may be easily made.

Delaying sweep oscilloscopes are quite common and provide two separate complete sweep systems. The first, or delaying sweep, provides a delayed sweep trigger just prior to the moment when the signal of interest occurs. Generally, a 10-turn multiplier dial used with the TIME/DIV control provides a continuously variable sweep trigger and initiates the delayed sweep at the desired time. Delaying sweep oscilloscopes provide both increased measurement resolution and accuracy.

Modern time-base generators generally consist of five main circuits: a sweep gating multivibrator, a Miller runup (or rundown circuits (sawtooth generator and disconnect diode), holdoff circuitry, sweep lockout circuitry, and automatic sweep generator circuitry. In addition, the sweep circuit provides the unblanking signal to the CRT and often a sawtooth and/or gate output on the instrument panel.

Sweep generators make use of operational amplifier techniques to obtain their required linearity. As a result, if circuit problems appear, they are sometimes difficult to troubleshoot because of the feedback loops involved. Usually the feedback loop must be broken in order to localize the circuit problem.

When troubleshooting an oscilloscope sweep circuit, examine the simple possibilities before proceeding with extensive troubleshooting. The following list provides a logical sequence to follow while troubleshooting sweep circuitry.

1. Observe CRT display characteristics.
2. Check control settings.
3. Isolate trouble to block.

4. Thorough visual check.
5. Check voltages and waveform.
6. Check individual components.

When troubleshooting sweep circuits, free run the sweep to be certain that the trigger circuitry is not inhibiting sweep operation. Gate and sawtooth output connectors provide a quick check of circuit operation and may provide a clue to the problem. If no outputs are observed, check to be certain that trigger inputs are gating the sweep gate circuits.

Holdoff and feedback operation may be checked by monitoring the cathode of the holdoff circuit. Check to see if the cathode of the holdoff cathode follower follows the action of the sweep length control. A similar check is to vary the stability control while monitoring the lockout multivibrator cathode. These two blocks comprise most of the feedback path and if their cathode follower action is inoperative, the problem is quickly localized.

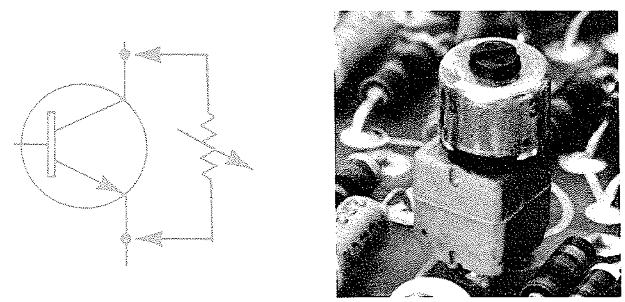
TECHNIQUES

A Tektronix Type 575 or Type 576 is very useful to check tunnel diodes in the circuit (in most cases). If there is any doubt of device performance, one end may be lifted. Connect test leads directly across the TD. Set the vertical sensitivity on the 576 to cover the sensitivity of the diode under test and the horizontal to .1 V/div. (Typical TD's have a horizontal switching voltage of $\approx$½ volt.) The waveform is not exactly like an out-of-circuit check, but in most cases, it indicates whether the TD is working properly. This procedure prevents mechanical strain or excessive heat from being applied to the TD. The photos below show an in-circuit and out-of-circuit check being made on the same TD. Interaction caused between the test leads and the circuit will sometimes produce a cluttered trace, but switching can nearly always be detected.

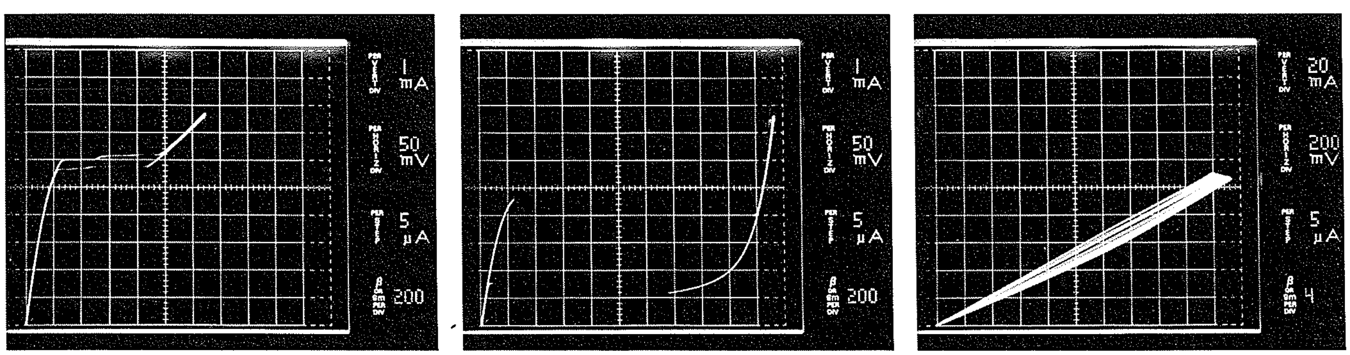
Noisy resistors can also be checked dynamically (with power off on instrument under test) on a Tektronix Type 576. Connect test leads from the sockets on the 576 to the resistor under test. Use the emitter test lead for the low point of the resistor under test and the collector lead for the high point. With the collector sweep in "+" polarity, dial in the proper amount of voltage. (If you don't know how much voltage to use—turn the instrument on and check the voltage drop across the resistor with a meter first.) Next, set the horizontal and vertical switches on the 576 to display the waveform on screen. Noisy resistors will show as an intermittent or broken line. The photo below shows a defective resistor that appeared normal with an ohmic check.

Often it is necessary to start the sweep gating multivibrator manually. If the sweep does not run, ground the collector of the sweep gating multivibrator (e.g. Q504 in a Type 453) and monitor the collector of the sawtooth sweep rundown circuit. This should cause the sweep to rundown and let you troubleshoot in a normal manner.

Breaking the feedback loop is often helpful in large operational amplifiers. One technique that can be used is to pull the transistor from the reset emitter follower and ground the emitter terminal (e.g. Q543 in a Type 453). A sweep should occur each time the point is grounded. Or remove the reset multivibrator (e.g. Q585 in a Type 453) and apply an external positive DC voltage at the collector terminal to "brute force" the sweep to run. (The Type 576 is again convenient for this application.) Often a 10-kΩ minipot connected as shown will work nicely and will plug right into the transistor socket. This is a convenient method since the internal voltage from the collector supply may be used as the voltage source.



A minipot connected into a transistor socket as shown is a convenient way to "brute force" the sweep.



Series of waveforms illustrating the use of the Type 576 Curve Tracer as a versatile troubleshooting tool. Left: In-circuit TD check. Center: out-of-circuit TD check. Right: Noisy resistor.

Another technique is useful when timing delaying sweep oscilloscopes. The horizontal display is set for A delayed by B with A sweep free running. Start with the fastest B sweep where A can be run 100 times faster than B. This will make each cm equal to 0.1%. Set the delay time multiplier to 8.95. This will move the 9th marker to center screen for 0% tolerance.

Each cm to the left of center screen now equals —.1% error and each cm to the right equals +.1% error. Start with time marks of the same speed as the B sweep. If the 9th marker shows up on screen, the error can be read directly + or — from how far it is from center screen. Decrease sweep speeds (A and B) by 1 switch setting until each range of the delayed sweep is checked. When two markers show up on screen, it is time to switch the time-mark source to the next lower decade to match the B-sweep TIME/CM setting. If the pulse is off-screen, use the delay time multiplier to position the pulse on screen and read the number of minor divisions that it takes. Each minor division is equal to 0.1%.

TYPICAL SWEEP TROUBLES (TUBE)

1. Sweep shortens at faster sweep speeds.
   Check: The sawtooth output cathode follower may be loading the circuit. Remove the sawtooth cathode follower and note whether the problem disappears. If the trouble is not in this stage, then check the output stage of the horizontal amplifier.

2. Sweep non-linear at the left side of the CRT.

   Check: Faulty holdoff circuit operation may be causing the problem. Check holdoff cathode follower for gassy tube or improper circuit operation.

3. Sweep shortens on right side of the CRT when sweep is triggered.

   Check: An open diode in the positive trigger clipper circuit may inhibit positive clipping of the sweep gate input and cause premature rundown of the sweep.

4. Sweep tends to free run at different sweep speeds when triggered at other speeds.

   Check: Preset stability is misadjusted or lockout multivibrator circuit operation is weak.

5. Sweep will not run by itself, but will start when shock excited (i.e., rotating the TIME/CM switch).

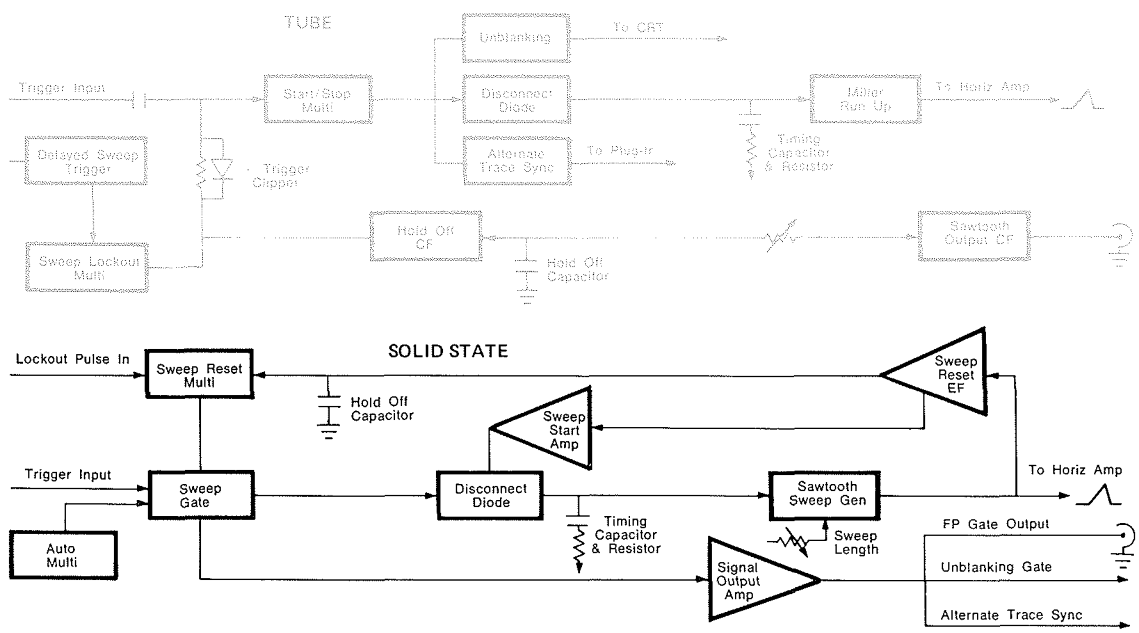
   Check: Start-stop multivibrator circuit failure will show these characteristics. Check the tube and circuitry. Off-tolerance precision (1%) resistors in this circuit will sometimes cause this problem.

6. Sweep non-linear or inaccurate at slow sweep speeds. (In extreme cases, spot may stop part way through the sweep.)

   Check: Disconnect diodes should be tested. Check for proper operation by starting the sweep, and then removing the disconnect diode and see if problem clears itself. The sweep will run for one sweep and stop. Replace diode and repeat procedure if necessary to get a better look. If this procedure clears up the problem, the disconnect diode is faulty (leaky or gassy).

7. Sweep non-linear at some TIME/CM settings; normal operation at others.

   Check: Miller runup circuit may be leaky. Check for gassy Miller tube.



8. Sweep timing off at several of the slower sweep speeds (below 1 ms/div).

   Check: Suspect precision timing resistors. Many older oscilloscopes used brown A-P resistors on the sweep timing switches. These resistors changed value with age and should all be changed.

9. Delayed sweep operation, normal; delaying sweep operation, normal but cannot obtain triggered delayed sweep when using both sweeps.

   Check: Suspect weak or defective delayed sweep trigger amplifier.

10. Sweep timing accuracy long in the .1, .2, and .5 ms/div range.

    Check: Unsolder one end of the small padder capacitor in parallel with the .001 μF timing capacitor located on the A sweep timing switch and monitor timing. If timing is improved, remove the small capacitor.

11. Erratic starting of sweep.

    Check: Noisy resistor in sweep start-stop circuit or poor connection of high voltage anode lead can cause this problem.

12. Erratic sweep operation, sweep start is not erratic.

    Check: Noisy or heater cathode leakage in disconnect diode may cause this problem.

TYPICAL SWEEP TROUBLES (TRANSISTOR)

The operation of transistorized sweep circuitry is generally similar to the tube type circuitry. Some additional specific checks that may be useful are:

1. Sweep inoperative.

   Check: Check the sweep gate transistor and the sweep TD. If these operate properly, then check the fixed divider at the input of the sweep reset multivibrator for proper value.

2. Sweep inoperative.

   Check: If normal troubleshooting doesn't produce a trace (see techniques), check the sweep length circuit. A diode failure or bad switch contact in the sweep length circuit may cause an inoperative sweep.

3. Sweep timing error at different sweep speeds.

   Check: Gallium-arsenide diodes used in the sweep disconnect circuit may be defective. Replace if necessary.

4. Sweep jitter.

   Check: Gallium-arsenide diodes used in the sweep disconnect circuit may be defective. Replace if necessary.

USED INSTRUMENTS FOR SALE

1—Type 526, SN 1544. Price: $1295. Contact: Donald K. McConnell. General Electrodynamics Corp., 4430 Forest Lane, Garland, Texas 75040. Telephone: (214) 276-1161.

1—Type 514D. Excellent condition. Price: $400. Contact: Dr. William Carr, Southern Methodist University, Dallas, Texas 75222. Telephone: (214) 363-5611, extension 2221.

1—Type 524AD/202-1, SN 7750. Two years old. Price: $1000. Contact: Dave Sanders or Charlie Henry, American Microwave & Communications, 203 Stephenson Avenue, Iron Mountain, Michigan 49801. Telephone: (906) 774-2923.

1—Type 422. New. Price: $1,250. Contact: Ellsworth M. Cochran, 7805 Laurel Ave., Cincinnati, Ohio 45243.

1—Type 514D, SN 1348. Excellent condition. Price: $250. Contact: Robert Bartell, RD 2, P.O. Box 31, Kingston, New York 12401. Telephone: (914) 331-9019.

1—Type 545 with D plug-in unit. Price: $1,100. Contact: Dr. J. McConn, Cornell University, Division of Biological Sciences, Savage Hall, Ithaca, New York 14850. Telephone: (607) 275-4809.

1—Type 535A. 1—Type 545A. Several plug-ins for 530/540 Series. 1—Type 515A. 1—Type 575. Contact: Harry Posner, Pacific Certified Electric. Telephone: (213) 225-1584.

1—Type 3A72, SN 4690. Price: $200. 1—Type 53A. Price: $35. Contact: Mr. Myhre, Mission Engineering, Inc., Hiawatha, Iowa 52233. Telephone: (319) 393-2253.

1—Type 310A Contact: Don Pagan, Varian Data Machines, Irvine, California. Telephone: (714) 833-2400.

1—Type 310A, SN 014771. Price: Best offer. Telephone: (415) 326-6200 Extension 2619.

1—Type 551,, SN 3247. Excellent condition. Price: $1350. Contact: Wayne Hunter, Exact Electronics, Hillsboro, Oregon 97123 Telephone: (503) 648-6661.

1—Type 551, SN 002812. 1—Type CA, SN 027013. 2—Type B, SN 011852 and SN 018247. Will sell as a unit for $700. Contact: Jim Rogers, Pacific Assemblers, 4500 Campus Dr., Suite 524, Newport Beach, California 92660. Telephone: (714) 540-0030.

1—Type 454 with cart. Approximately one year old. Perfect condition. Price: $2500. Contact: Robert Crawford, 124 West 86th St., New York, New York 10024. Telephone: (212) 787-6715.

1—Type 321, SN 003443. Has batteries. Price: $400. Contact: Evans Wheeler, 539 South Raymond Ave., Pasadena, California 91101. Telephone (213) 449-5650.

1—Type 533A, SN 4859 with Type B Plug-In, SN 19959. Excellent condition. Used 100 hours. Price: $675. Contact: Henes Manufacturing Co., 4301 East Madison St., Phoenix, Arizona 85034.

Sampling dual-trace and time-base plug-ins for 560 series. 1—Type 3S76, SN 408. 1—Type 3T77, SN 437. 2—Type P6032. All like new condition. Purchase date 4/31/62. Contact: Burr-Brown Research Corp., Tucson, Arizona 85706. Telephone: (602) 294-1431.

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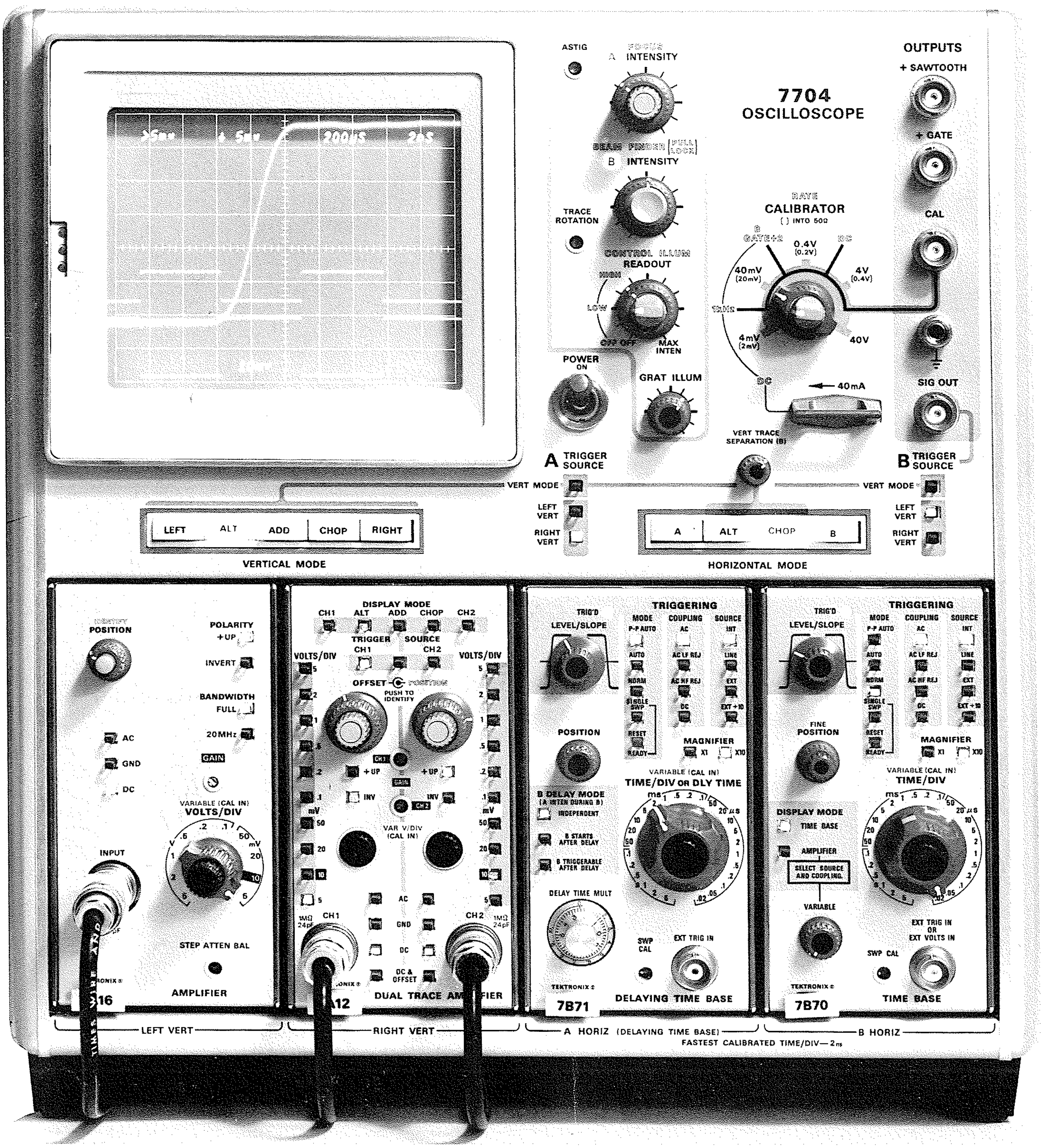

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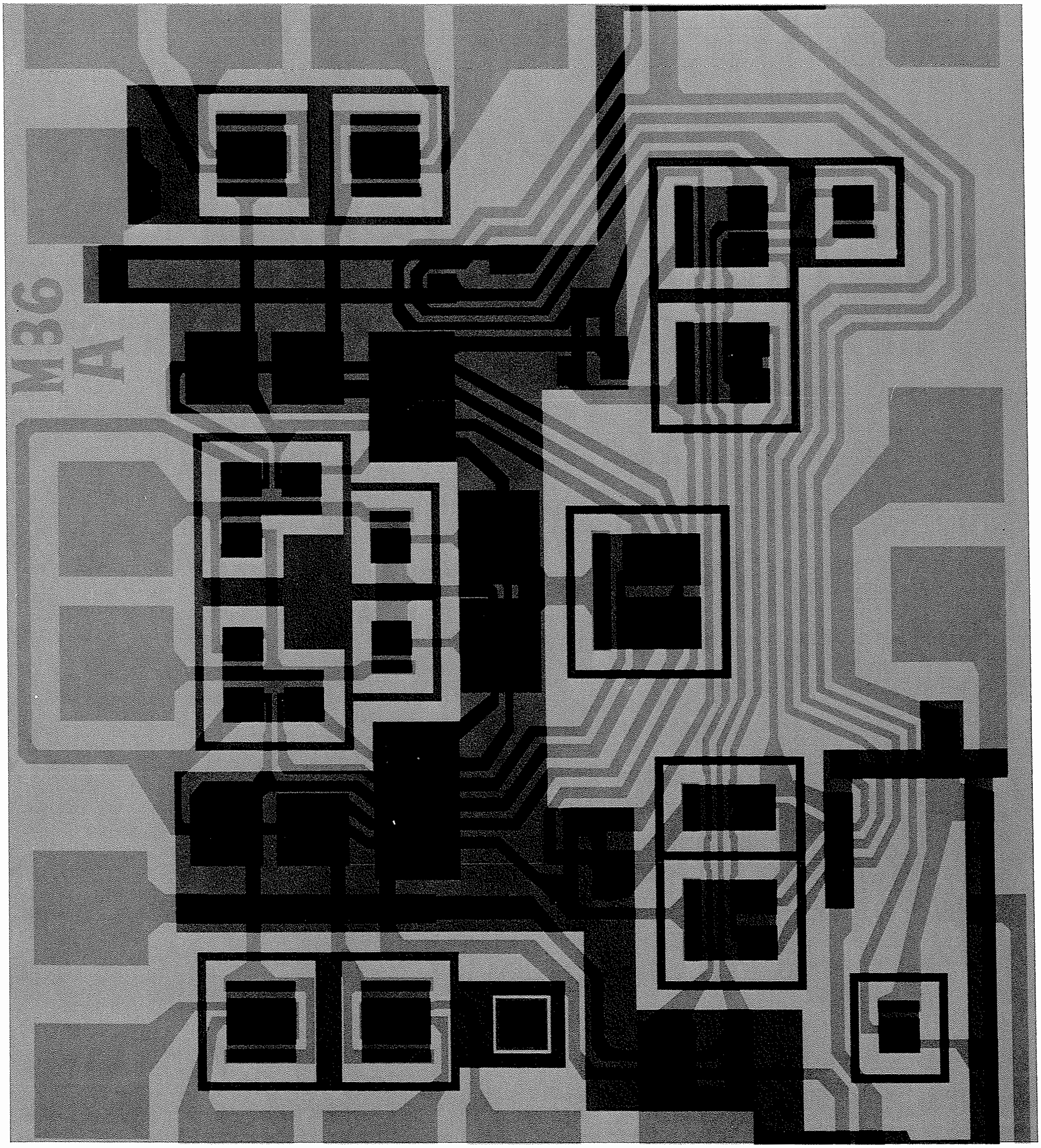
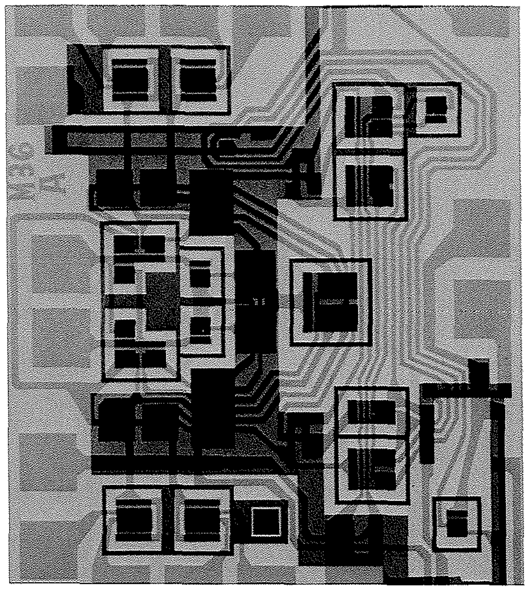


New Logic for Oscilloscope Displays • **Basic Logic Review** • **Service Scope**



a new logic for oscilloscope displays

Placing the mode switching function in the oscilloscope mainframe, where it logically belongs, greatly enhances the flexibility of the plug-in concept. This new development, coupled with an instrument design that accepts up to four plug-in units and provides an 8 x 10 cm display, offers unprecedented versatility in oscilloscope performance.

The new Tektronix 7000 Series provides the most versatile oscilloscope switching to date. Historically, vertical switching has taken place in the plug-in instead of in the oscilloscope. By placing the switching capability in the mainframe, many of the typical limitations are overcome and a number of advantages are available. No longer is the user limited to a choice of any one of two or three dual-trace plug-in units. A wide selection of multi-trace options is provided, since switching is between plug-in units and therefore performance parameters may vary greatly. Thus, the user can select the two vertical plug-ins most appropriate for his measurement, and *still* have multi-trace performance.

COVER—The composite mask of the MO36 Channel Switch IC symbolizes the versatility provided by the mainframe switching capability of the 7000 Series. See back cover.

MAINFRAME LOGIC

There are 20 possible combinations of VERTICAL MODE and HORIZONTAL MODE switch settings. The total number of possible display configurations is multiplied further by: (1) the variety of plug-ins available for use with this instrument (i.e., voltage amplifiers, current amplifiers, sampling units, etc.), (2) the interchangeability of plug-ins (i.e., an amplifier or time-base unit can be installed in either of the vertical or horizontal compartments or both) and (3) the capabilities of the plug-in units which are used in these instruments (e.g., a dual-trace vertical unit can be used in either of the two single-channel modes, in either dual-trace modes, or added algebraically; a delaying time base may be used either for a normal sweep or for delayed sweep). The table at right illustrates the combinations available for single-channel vertical and horizontal units used in the conventional Y-T mode.

The mainframe logic accepts the plug-in outputs and time-shares the CRT to provide the appropriate display. Thus, the operation of each plug-in is continuous and independent. The mainframe sequentially selects and applies plug-in outputs to the vertical and horizontal deflection plates respectively. The time interval and sequence in which plug-in outputs are displayed depends on which combinations of display modes are used.

The basic system is set up to sweep-slave the middle two plug-ins and the outer two plug-ins together (VERT MODE—ALT and HORIZ MODE—ALT or CHOP).

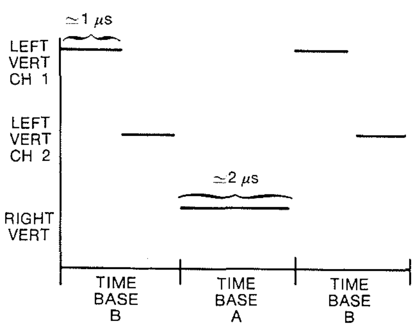
SWITCHING LOGIC

VERTICAL MODE	HORIZONTAL MODE	SOURCE OF DEFLECTION	DISPLAY
LEFT	A B	Vertical—single unit; horizontal—single unit.	Single-trace.
	ALT CHOP	Vertical—single unit; horizontal—two units.	Dual-trace—independent dual time-base—simultaneous DELAYING and DELAYED sweep.
ALT	A B	Vertical—two units; horizontal—single unit.	Dual-trace.
	ALT CHOP	Vertical—two units; horizontal—two units. Sweep slaving between LEFT VERT and B HORIZ plug-ins and RIGHT VERT and A HORIZ plug-ins.	Dual-trace—independent "dual-beam" operation—X-Y, Y-T—dual-trace delaying sweep—dual-beam X-Y (CHOP ONLY).
ADD	A B	Vertical—algebraic summation of two units; horizontal—single unit.	Single-trace—algebraic addition of two or more signals—dual-trace delaying sweep—raster capability.
	ALT CHOP	Vertical—algebraic summation of two units; horizontal—two units.	
CHOP	A B	Vertical—two units; horizontal—single unit.	Dual-trace.
	ALT CHOP	Vertical—two units; horizontal—two units.	Four-trace—each vertical displayed at two sweep speeds—dual-beam X-Y.
RIGHT	A B	Vertical—single unit; horizontal—single unit.	Single-trace.
	ALT CHOP	Vertical—single unit; horizontal—both units.	Dual-trace—independent dual time-base—simultaneous DELAYING and DELAYED sweep.

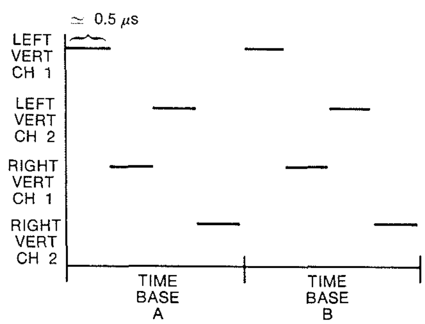
Thus, the right vertical plug-in is displayed at the sweep rate of the A horizontal plug-in and the left vertical plug-in is displayed at the sweep rate of the B horizontal plug-in (non-delayed sweep only). One reason for this particular choice is to allow for the possibility of multiple width plug-ins for the future. Since there are no vertical dividers in the plug-in compartment, maximum future flexibility is provided.

For delayed-sweep operation, a different display sequence occurs. First, the LEFT VERT unit is displayed at the sweep rate of the time-base unit in the A HORIZ compartment (delaying sweep) and then at the sweep rate of the time-base unit in the B HORIZ compartment (delayed sweep). The vertical display then shifts to the RIGHT VERT unit and is displayed consecutively at the delaying and delayed sweep rate. The figures below show three of the possible switching configurations.

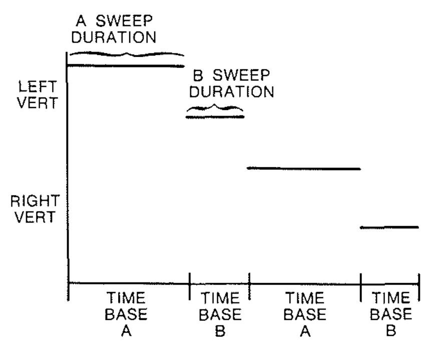
The CHOP HORIZ mode provides a display that has not been possible before. In this mode, the outputs of the A and B horizontal plug-ins are continuously switched and displayed on the CRT. If the two horizontal plug-ins are time bases, then the CHOP mode displays both at what appears to be the same time. The chopping is not normally discernible since the sweep switching occurs nonsynchronously with the sweep.



VERTICAL MODE—ALT HORIZONTAL MODE—CHOP
ONE DUAL-TRACE (CHOP) AND ONE SINGLE-CHANNEL PLUG-IN
TWO TIME-BASE PLUG-INS (CHOP)



VERTICAL MODE—CHOP HORIZONTAL MODE—CHOP
TWO DUAL-TRACE VERTICAL PLUG-INS (CHOP)
TWO TIME-BASE PLUG-INS

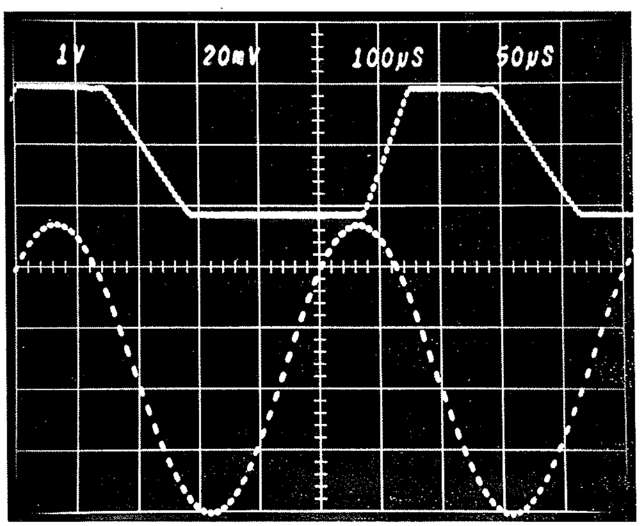


VERTICAL MODE—ALT HORIZONTAL MODE—ALT
TWO SINGLE-TRACE VERTICAL PLUG-INS
TWO TIME-BASE PLUG-INS (DELAYED-SWEEP OPERATION)

Three of the many possible switching configurations are shown above.

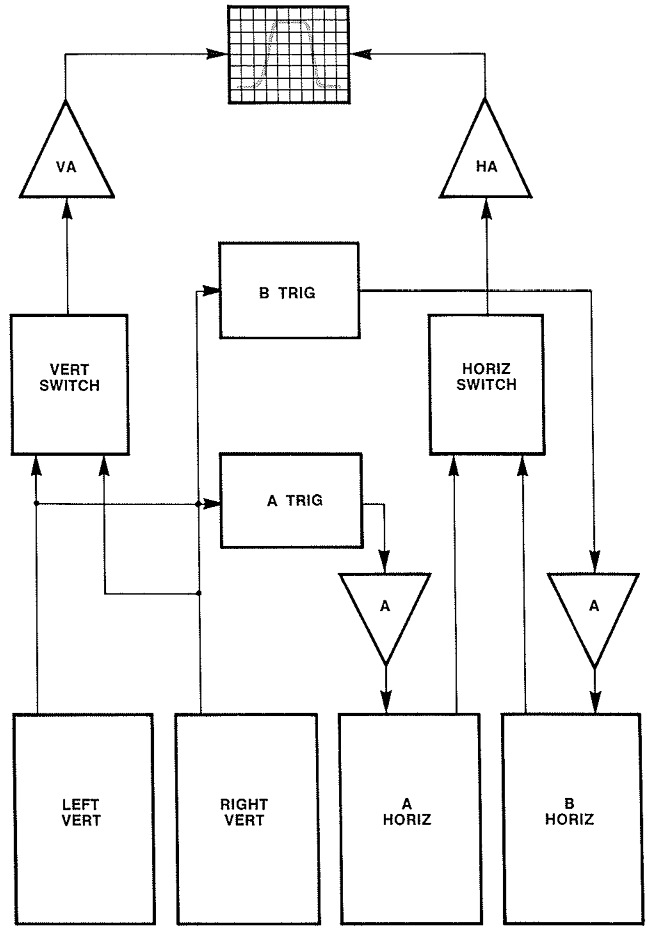
The CHOP horizontal configuration provides the ability to obtain an equivalent dual-beam single-sweep capability. The maximum sweep speed limitation is dependent upon the horizontal chop rate. Since the horizontal chop rate requires a 2-μs segment for each plug-in and the vertical chop rate requires $\simeq$ a 0.5-μs segment, the fast sweep limitation is basically the horizontal chop rate. Thus, two simultaneous single events may be monitored at sweep speeds as fast as 50 μs/div. The photo below illustrates this capability.

A second advantage of the CHOP horizontal configuration is that the intensity level of different sweep speeds may be more closely matched. Because the sweep-speed ratios may be quite diverse (2,500,000,000:1 is available in calibrated sweeps with the 7B70 Time-Base Unit), the Alternate mode in many cases can have too great an intensity level difference to display the faster sweep. Chopping, however, helps a great deal to balance the different sweep intensities.



The horizontal CHOP mode monitors two independent single-occurrence events ***simultaneously*** *and provides a dual-beam capability to approximately 50 μs/div.*

Selection of internal trigger signals for both sweeps is provided on the front panel. For most applications, these switches can be set to the VERT MODE positions. This position is the most convenient since the internal trigger signal is automatically switched as the VERTICAL MODE switch is changed or as the display is electronically switched between the LEFT VERT and RIGHT VERT plug-ins in the ALT position of the VERTICAL MODE switch. It also provides a usable trigger signal in the ADD or CHOP positions of the VERTICAL MODE switch, since the internal trigger signal in these modes is the algebraic sum of the signals applied to



The unique mainframe switching of the 7000 Series provides a new versatility in signal and triggering processing.

the vertical plug-in units. This technique prevents the time base from triggering on the vertical CHOP signal. The VERT MODE ensures that the time-base units receive a trigger signal regardless of the VERTICAL MODE switch setting, without the need to continually change the trigger source selection.

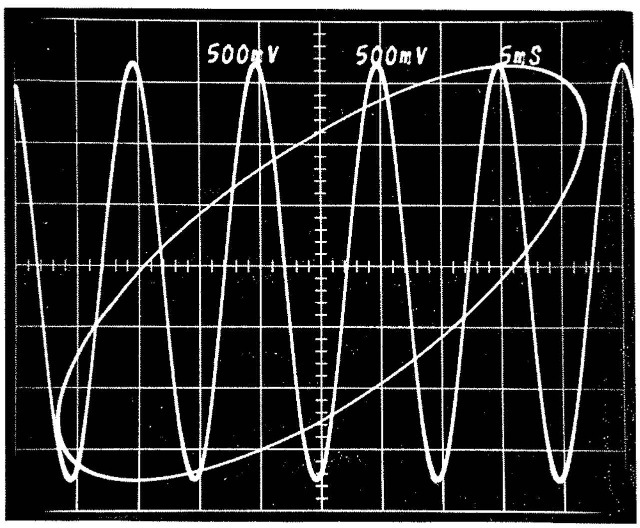
If correct triggering for the desired display is not obtained in the VERT MODE position, the trigger source for either the A HORIZ or B HORIZ time-base unit can be changed to obtain the trigger signal from either the LEFT VERT or RIGHT VERT plug-in. The internal trigger signal is obtained from the selected vertical compartment whether or not the plug-in in that compartment is selected for display on the CRT.

One of the most unique aspects of the NEW 7000 Series is the ability to simultaneously use different methods of analyses. Thus, the identical signal can be observed both X-Y and Y-T. A sampling display (X-Y or Y-T) may be compared against a high-impedance conventional display, and a raster display (T-T) may be displayed *simultaneously* with an X-Y or Y-T display, or both.

A unique Z-axis configuration available on 7000-Series instruments enhances this multiple display capability. Two inputs are provided for maximum user versatility in Z-axis modulation applications. HIGH SPEED requires 60 volts peak-to-peak to provide trace modulation over the full intensity range from DC to 100 MHz (7704). HIGH SENS requires only 2 volts peak-to-peak to provide full intensity range from DC to 2 MHz.

Three outputs are provided on the front panel of the 7000 Series. A positive sawtooth output provides a sample of the sawtooth signal from either of the plug-in time bases. The rate of rise of the signal is approximately 50 mV/div into a 50-Ω load or approximately 1 volt/div into a 1-MΩ load.

The + GATE output provides a positive-going rectangular output pulse from either A or B time base, on the delayed gate from an A delaying time-base unit. The amplitude of the + GATE is approximately 0.5 volts into 50 Ω or approximately 10 volts into 1 MΩ.



The 7000 Series allow simultaneous use of different methods of analyses. Thus, both X-Y and Y-T presentations may be monitored to obtain additional information from the display.

The SIG OUT connector provides a sample of the vertical deflection signal. The source of signal is determined by the position of the B trigger source. In the VERT MODE position, the output signal is determined by the setting of the VERTICAL MODE switch. In the ALT position of the VERTICAL MODE the output signal switches between vertical units along with the CRT display. CHOP and ADD both provide a composite signal output. The output voltage into 50 Ω is approximately 25 mV/div of the CRT display. Into a 1-MΩ load, the output voltage is approximately 0.5 V/div. The bandwidth of the output signal is determined by the combination of plug-in and oscilloscope. The 7704 and 7A11 or 7A16 provide a DC-60 MHz vertical signal output capability.

AMPLIFIER PERFORMANCE

The initial offering of 13 plug-ins contains 7 amplifier units (including a sampling amplifier). Up to four amplifier units may be displayed (dual X-Y displays), but the most common configuration is two amplifier units in the LEFT VERT and RIGHT VERT compartments. The wide range of units available include wide-band amplifiers, dual-trace amplifiers, differential comparators, current probe amplifiers, and high gain differential amplifiers.

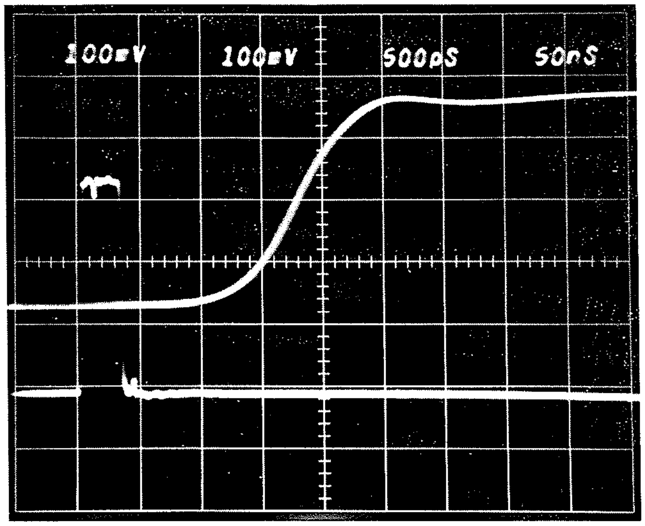
The basic accuracy of most amplifier units is specified at 2% over the temperature range of 0° to 50° C. The exceptions to this are 1½% for the differential comparator unit and 3% for the sampling amplifier unit. All amplifier units contain an INVERT position and an IDENTIFY button which deflects the trace slightly and identifies the appropriate Auto Scale-Factor Readout area.

An X-Y compensation option is available for applications requiring precise phase measurements. The option consists of a network to compensate for the differences in vertical and horizontal delays allowing phase shift to be adjusted to less than 2° from DC to 2 MHz.

The 7A11 amplifier is a new concept in high input impedance (1 MΩ) amplifier FET probe design offering 5-mV, 150-MHz performance in the 7704 and 5-mV, 90-MHz performance in the 7504. Capacitance is a function of the attenuators and is 5.8 pF from 5 mV to 50 mV/div; 3.4 pF from 0.1 V to 1 V/div; and 2.0 pF from 2 V to 20 V/div. One volt (±) of DC offset is provided as well as an output jack for monitoring of the offset voltage.

A unique captive probe design that is an integral portion of the plug-in allows a design much easier to use than present FET probes. Two stacked attenuators and a FET amplifier are contained in the probe and are relay-switched by the front-panel VOLTS/DIV control.

The result is a FET probe that is small in size with no bulky amplifier to mount to the oscilloscope. The probe cannot be made to clip or limit the signal on the CRT by an incorrect combination of input attenuator and plug-in sensitivity. The operator is thus freed from concern with manual plug-on attenuators and dynamic signal range. If the signal can be positioned or offset to fall within the viewing area, the amplifier is operating linearly. The sensitivity at the probe tip may be read directly from the front panel or from the auto scale-factor readout on the CRT.



Lower trace—conventional display. Upper trace—sampling display provides increased time resolution.

A second mode of operation is provided via a BNC connector on the front panel. When the full capability of the system is not required, the probe is stored internally and is accessible via a front panel BNC connector. In this mode, approximately 1 pF is added to the input capacitance.

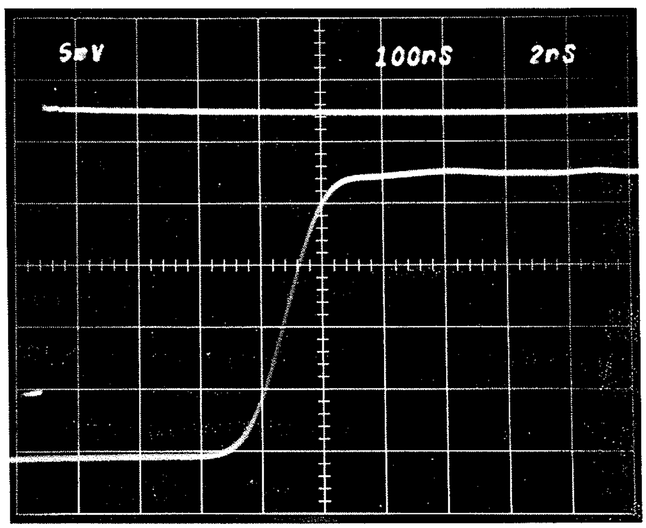
The 7A12 is a 1-MΩ, 5-mV dual-channel plug-in amplifier that is the basic building block for two, three and four-trace operation. The 7A12 provides 105-MHz performance in the 7704, and 75 MHz in the 7504, with an accuracy of 2% over the 5-mV/div to 5-V/div deflection factor range. In addition to the 5 display modes (Channel 1, ALTERNATE, CHOP, ADD, Channel 2), a trigger source allows selection of either Channel 1 or Channel 2. An additional position is included for operator convenience. In this position, the trigger source is automatically locked to the display mode. Thus, when Channel 1 is selected as the display mode, Channel 1 is automatically selected as the trigger source. The only exception to this is in CHOP, where the triggering is the same as in the ADD mode.

A feature new to dual-trace operation is the volts DC offset provided to allow ±1000 cm of offset on all ranges for both channels. Thus, the user can make DC-coupled measurements of low-amplitude signals that "ride" on DC levels. This DC offset makes the 7A12 truly a versatile instrument.

The 7A13 is a differential comparator plug-in amplifier that incorporates a number of performance features in the same instrument. As a conventional 1-MΩ input impedance amplifier, the 7A13 maintains constant bandwidth (100 MHz in the 7704, 75 MHz in the 7504) over a 1 mV/div to 5 V/div deflection factor range. A 5-MHz bandwidth position is provided to minimize noise in the lower frequency applications. As a differential amplifier, the 7A13 maintains its conventional features, and provides a CMRR of 20,000:1 from DC to 100 kHz, decreasing to 1000:1 at 10 MHz.

The 7A13 features an in-line digital readout of comparison voltage. The decimal point for the comparison voltage is coded by the probe in use and automatically indicates the correct voltage as referenced to the probe tip. The ±10 volts of offset provides an effective 10,000-centimeter display on the 1 mV/div range, of which any 8-cm "window" can be displayed.

A V_c REF button applies the comparison voltage to both input gates. The "null" is established using V_c instead of a ground reference, and results in a simplified method of obtaining a zero reference.



The 7704 and the 7A16 Amplifier provide a 5-mV, 2.4 ns capability. Note the excellent long-term and short-term response characteristics.

The 7A14 is an AC current probe amplifier which provides constant bandwidth (dependent on the current probe and mainframe) over the 1-mA/div to 1-A/div calibrated deflection factor range. Both the P6021 and P6022 AC current probes may be used with the 7A14. A special BNC input connector senses the type of current probe, and switches in the proper internal compensation circuit. An invert switch on the plug-in allows an inversion of the current waveform and eliminates the need to physically reverse the probe.

Two current probes are presently offered for use with the 7A14. The P6021 is optimized for low-frequency response. It has a lower −3 dB point of 30 Hz and an upper −3 dB point of 45 MHz in the 7504 and 50 MHz in the 7704. The P6022 is designed for high-frequency response. The lower frequency −3 dB point is 250 Hz with an upper −3 dB point of 75 MHz in the 7504 and 105 MHz in the 7704.

The 7A16 is a wideband amplifier with a deflection-factor range of 5 mV/div to 5 V/div. 150-MHz performance is provided in the 7704 and 90-MHz performance in the 7504. The unit provides a 1-MΩ, 15-pF input and employs a thick-film drum attenuator for excellent frequency response. Bandwidth is selectable at FULL or 20 MHz for user convenience.

The 7A22 is a high-gain differential amplifier with 10-μV, 1-MHz performance characteristics. The displayed noise (tangentially measured) at full bandwidth is held to 16 μV. Drift is held to less than 5 μV/min and 10 μV/h. Both HF −3 dB points and LF −3 dB points may be selected from the front panel to reduce the displayed noise for any given measurement. An offset feature provides ± 1 volt at small deflection factors, ± 10 volts midrange, and ± 100 volts at large deflection factors. The CMRR of the instrument is 100,000:1 from DC - 100 kHz.

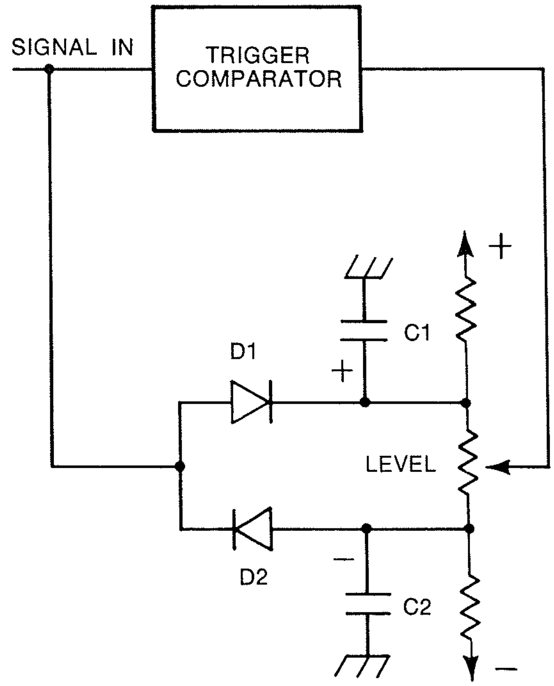
TIME-BASE PERFORMANCE

Four time-base units are presently available for use in the 7000-Series Oscilloscopes. All four make extensive use of push buttons for simplified operation. For the most commonly used mode, it is only necessary to depress the upper push button in each row. Twelve push buttons control MODE, SOURCE, and COUPLING. The 7B50/51 were primarily designed for the 7504 and the 7B70/71 were primarily designed for the 7704. The primary differences between the 7B50/51 and 7B70/71 are maximum sweep speed and trigger bandwidth (5 ns, 100 MHz or 2 ns, 200 MHz). The plug-in front panels are identical except for the fastest sweep speed range. Any time base may be used in any mainframe although maximum calibrated sweep speed may become a factor. For example, the 2-ns position of the 7B70/71 would not be calibrated if used in the 7504. A notation on each mainframe labels the fastest calibrated TIME/DIV.

The 7B50 and 7B70 are typically used as delayed-sweep units and also contain provision for external horizontal operation, 25 mV/div or 250 mV/div.

The 7B51 and 7B71 are typically used as delaying-sweep units and contain delay-time multiplier circuitry with a jitter specification of 1 part in 50,000.

A new trigger circuit is featured that greatly simplifies trigger operation. The peak-to-peak auto trigger circuit detects the peak-to-peak excursions of the displayed waveform, stores the value in the peak-to-peak memories, and matches the range of the level control to the range of the displayed signal. Should the amplitude change, the memories will automatically respond. Thus, positive triggering is ensured for all positions of the LEVEL/SLOPE control regardless of signal amplitude. In addition, trigger level and slope are incorporated into one control with the slope being relay-switched as the LEVEL/SLOPE control passes through 0° and 180°.



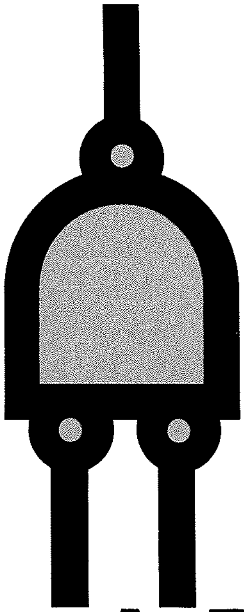
The repetitive signal input forward-biases the peak detectors (D1 and D2) and allows peak-to-peak memories C1 and C2 to become positively and negatively charged, respectively. This level is impressed across the LEVEL control and allows full sensitivity for all amplitudes of trigger signal within the sensitivity limits.

With the trigger in the peak-to-peak auto position, the operator can go through the maximum excursions on either slope and never reach an untriggerable position on the control knob.

The 7S11 Sampling Amplifier, the 7T11 Sampling Time-Base Unit, the 7M11 Dual Delay-Line and a complete line of sampling heads provide a complete sampling capability. The ability to mix conventional displays against sampling displays offers a unique new measurement capability. The 7S11 accepts any one of five plug-in sampling heads to cover the impedance/bandwidth spectrum from 1 MΩ/350 MHz to 50 Ω/14 GHz. In addition, the random sampling mode of the 7T11 allows the triggering event to be displayed without pretrigger or delay lines. February's TEK-SCOPE will discuss in detail the performance of these new sampling instruments.

The Tektronix 7504 and 7704, with their initial complement of 13 plug-ins, represent an excellent investment for the future and a hedge against obsolescence. Placing the mode switching capability in the mainframe results in a new standard of oscilloscope versatility and performance.

For further information on the Tektronix 7000 Series refer to the August 1969 New Products Supplement and consult your local Tektronix Field Engineer.



A BASIC LOGIC REVIEW

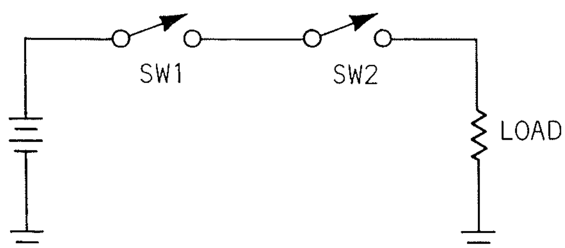
The latest Tektronix instruments are using digital logic functions extensively. This review is a brief discussion of the common symbols and terms used to explain some of the basic logic functions.

All new Tektronix instruments are standardizing on the use of positive logic. Positive logic refers to the use of a 1 to represent the true or more positive level and a 0 to represent the false or less positive level (0 volt). A convenient method of converting the HI-LO logic convention to a 1-0 notation is to disregard the first letter of each state. Thus:

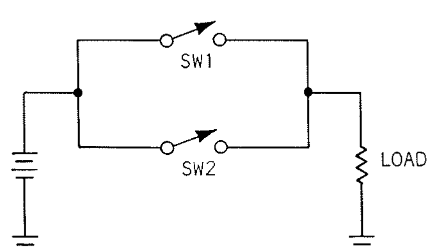
HI = 1
LO = 0

Input/output (truth) tables are used with logic diagrams to show the input combinations which are of importance to a particular function, along with the resultant output conditions. The tables can be given either for an individual device or for a complete logic stage.

The basic logic circuit is the AND gate. The AND gates contain two or more inputs and a single output. The output of an AND gate is HI only when all of the inputs are at the HI state. A LO signal on any of the input terminals produces a low signal at the OUTPUT. Thus, the AND gate performs the logical operation of producing a true output signal only when all the input signals are simultaneously true. The circuit drawing illustrates a circuit in which no voltage is delivered to the load unless both switches are closed.

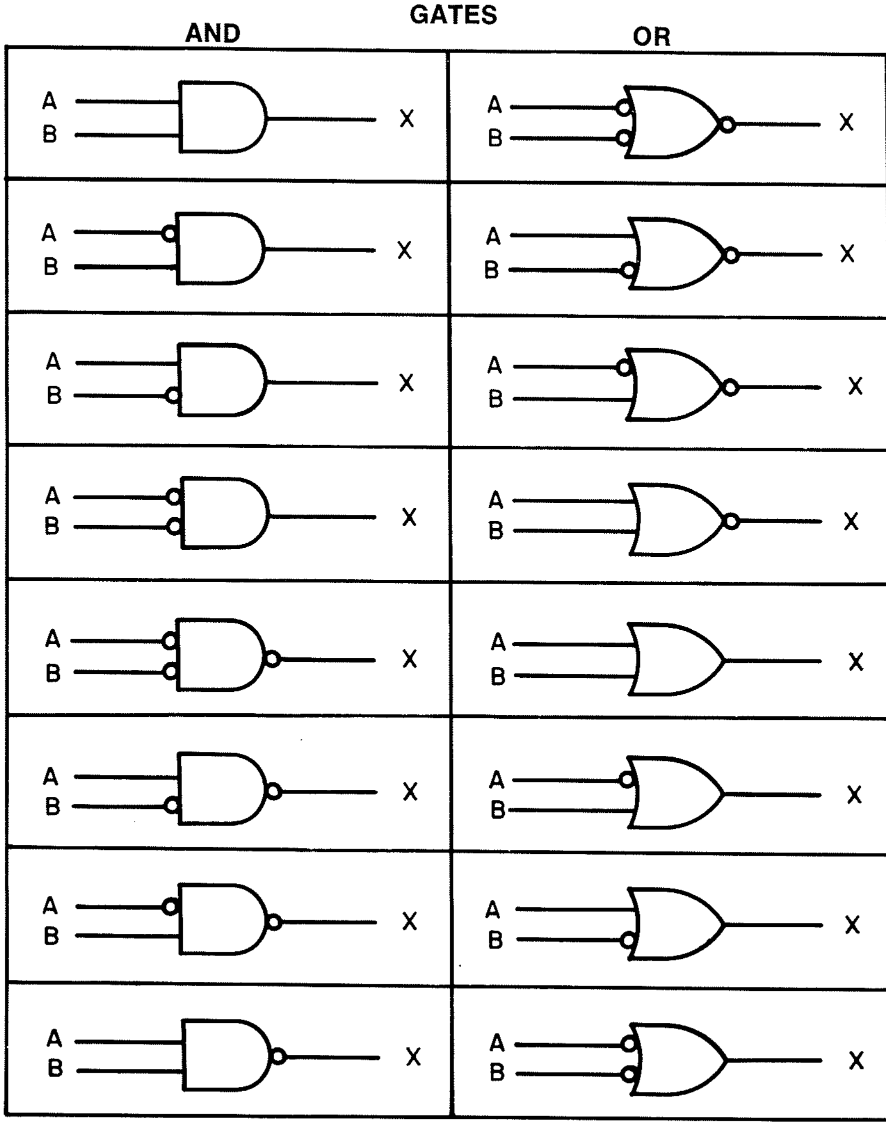


A second basic logic circuit is the OR gate. OR gates contain two or more inputs and a single output. The output of an OR gate is HI when one or more of the inputs are at the HI state. Thus, the OR gate performs the logical operation of producing a true output for the time duration that one or more of its inputs are true, and a false output for the time durations in which none of its inputs are true. The circuit drawing illustrates a circuit in which voltage is delivered to the load where either or both switches are closed.



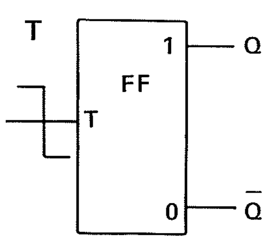
BASIC LOGIC DIAGRAMS

GATES

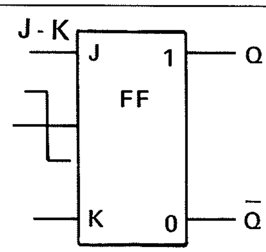


A	B	X
HI	HI	HI
HI	LO	LO
LO	HI	LO
LO	LO	LO
HI	HI	LO
HI	LO	LO
LO	HI	HI
LO	LO	LO
HI	HI	LO
HI	LO	HI
LO	HI	LO
LO	LO	LO
HI	HI	LO
HI	LO	LO
LO	HI	LO
LO	LO	HI
HI	HI	HI
HI	LO	HI
LO	HI	HI
LO	LO	LO
HI	HI	HI
HI	LO	LO
LO	HI	HI
LO	LO	HI
HI	HI	HI
HI	LO	HI
LO	HI	LO
LO	LO	HI
HI	HI	LO
HI	LO	HI
LO	HI	HI
LO	LO	HI

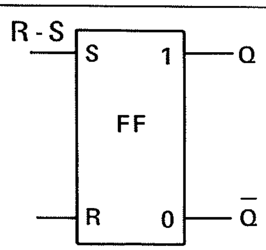
FLIP-FLOPS



Input Condition before trigger pulse		Output Condition after trigger pulse	
Q	$\bar{Q}$	Q	$\bar{Q}$
LO	HI	HI	LO
HI	LO	LO	HI



Input		Output	
J	K	Q	$\bar{Q}$
LO	LO	No change	
LO	HI	LO	HI
HI	LO	HI	LO
HI	HI	Complement	



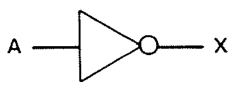
Input		Output	
R	S	Q	$\bar{Q}$
LO	LO	No change	
LO	HI	LO	HI
HI	LO	HI	LO
HI	HI	Undefined	

FLIP-FLOP INPUTS

SET .... Shown by the letter S
RESET (or CLEAR) .. Shown by the letter R
TOGGLE .... Shown by the letter T
J and K ..... Shown by the letters J and K
DELAY .... Shown by the letter D

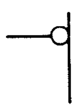
Cut along dotted line.

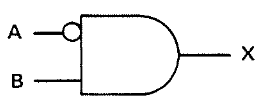
The inverter amplifier is a device with one input and one output that is used to invert the sense of the signal. The output of an inverter provides the complement of the input. Thus, the inverter amplifier performs the logical operation of not producing a true output (HI) for the time duration that the input is true.



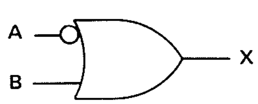
A	X
LO	HI
HI	LO

Logic diagrams make extensive use of the LO-state indicator. A small circle at the input or output of a symbol indicates that the LO state is the significant state. The absence of a circle indicates that the HI state is the significant state. For example, an AND gate with LO-state indicator at the input is shown below. The output of this gate is only HI when the A input is LO and the B input is HI. A second example is the OR gate shown with a LO-state indicator at the A input. Note that the output of this gate is HI if either the A input is LO or the B input is HI.



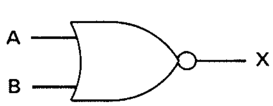


A	B	X
LO	LO	LO
LO	HI	HI
HI	LO	LO
HI	HI	LO



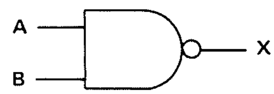
A	B	X
LO	LO	HI
LO	HI	HI
HI	LO	LO
HI	HI	HI

A NOR gate is functionally equivalent to an OR gate followed by an inverter. The NOR gate fulfills the logical function of producing a HI at the output only when all the input signals are simultaneously LO. A HI applied to any input results in a LO output.



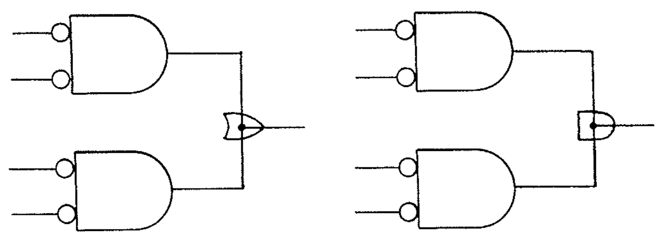
A	B	X
LO	LO	HI
LO	HI	LO
HI	LO	LO
HI	HI	LO

A NAND gate is functionally equivalent to an AND gate followed by an inverter. The NAND gate performs the logical function of producing a LO at the output only when all the input signals are HI. The inverted output of the NAND gate provides level restoration in addition to performing a logical function.

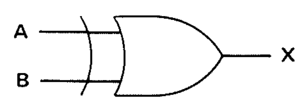


A	B	X
LO	LO	HI
LO	HI	HI
HI	LO	HI
HI	HI	LO

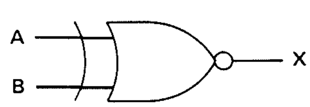
Occasionally, circuits can be combined according to AND (or OR) function simply by having the outputs connected. This configuration is called a phantom OR (sometimes called a wired OR). Two examples are presented below.



An EXCLUSIVE OR gate produces a true output when the input states are not identical. The output is false if the inputs are identical. Thus, the EXCLUSIVE OR gate fulfills the logical function of producing a HI if one and only one input is LO. A second configuration of the EXCLUSIVE OR (COINCIDENCE) produces the complement.



A	B	X
LO	LO	LO
LO	HI	HI
HI	LO	HI
HI	HI	LO



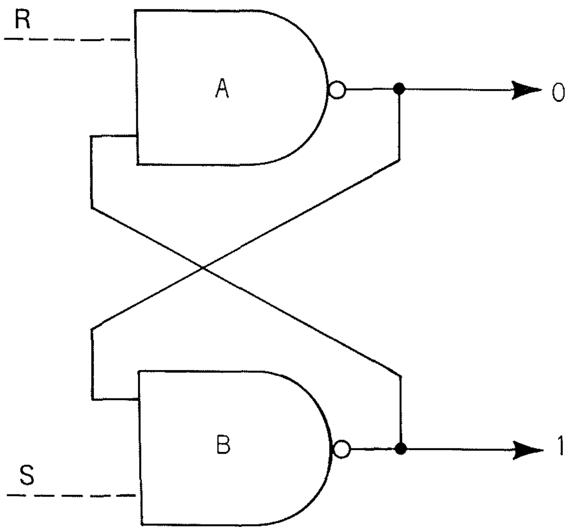
A	B	X
LO	LO	HI
LO	HI	LO
HI	LO	LO
HI	HI	HI

The flip-flop is a bistable device with one or more inputs and two outputs which performs the logical operation of storage. A flip-flop is a bistable circuit that will remain in its last state until an input causes it to change into its output state. Because of this ability to store a bit of information, the flip-flop is the basic building block in digital logic. The state of the flip-flop is available on the output line and a particular flip-flop is generally identified by which function is stored within it. Nearly all flip-flops have a second output line on which the complement (e.g., $\overline{Q}$)

of the stored function is available. The other terminals of a flip-flop are input terminals and may receive either level or pulse signals, depending on the particular circuit.

A basic flip-flop can be drawn using two NAND gates connected as show below. To understand operation, assume the two inputs shown as dotted lines do not exist. When power is applied, opposite states will appear on the outputs.

For example, assume that the output of gate A is LO. This LO will be applied to the input of gate B whose output will then become HI. When this HI is applied



to the input of gate A, a LO will remain on the output of gate A. Thus, the gates are latched into a stable state.

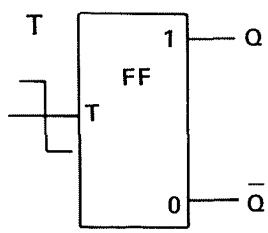
Next, connect R and assume it is HI. The state of the gates can be changed by applying a LO to input R. The flip-flop flips to the state where A is HI and B is LO. (NAND gate—if either input is LO, the output is HI.) Since the input of A is now LO from gate B, there is no way to return to the original state through the use of R. The LO input will now keep the output of gate A HI, regardless of the R input state.

By connecting S, the state of the flip-flop can be changed by applying a LO to the R or S where output is LO and the flip-flop is fully controlled. Thus, a basic flip-flop consists of two NAND gates with outputs cross-coupled to the inputs.

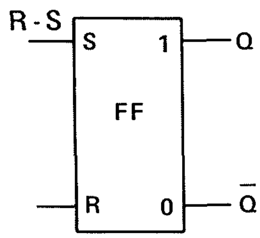
Flip-flops may be either clocked or unclocked. In a clocked flip-flop, the outputs respond to the inputs only when clocked. In an unclocked flip-flop, the outputs respond to the inputs as the inputs change.

A common configuration is the toggle flip-flop (TFF). The TFF is a bistable device with one input line and two output lines which changes states from one stable state to the other state with each trigger. Either or both of the complementary outputs may be used. A major shortcoming of the TFF is that the state of the FF after a trigger is applied cannot be accurately known unless the present state is known.

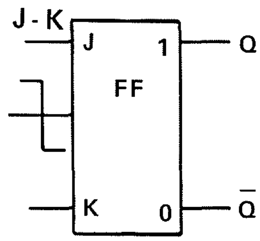
Another common FF is the set-reset flip-flop (RS FF). The RS FF is a bistable device with two input lines and two output lines. The output lines are complementary and change states in response to the states at the input. Two rules for R-S flip-flops are "set to 1 and reset to 0". Set to 1 means an input signal to the set terminal switches the circuit to a known condition (HI). Reset to 0 means that an input signal to the reset input switches the flip-flop to the opposite condition (LO). Inputs at both the R and S inputs are forbidden since the device can never be in both states simultaneously. The R-S flip-flop is used in logic situations which do not include the possibility of simultaneous set and reset inputs.



Input		Output	
Condition before trigger pulse		Condition after trigger pulse	
Q	$\bar{Q}$	Q	$\bar{Q}$
LO	HI	HI	LO
HI	LO	LO	HI



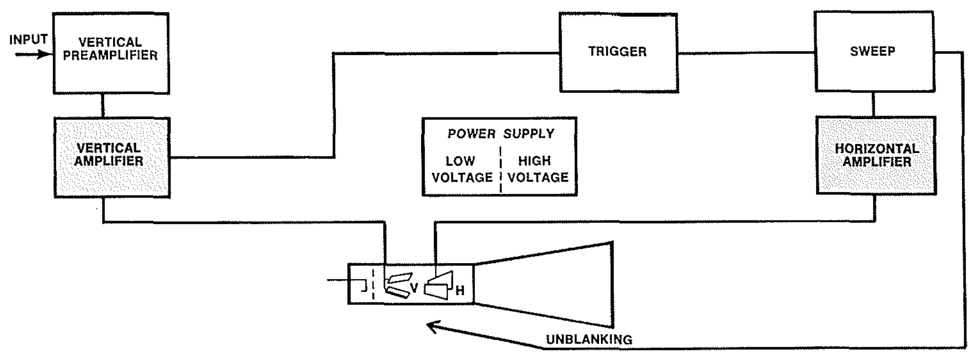
Input		Output	
R	S	Q	$\bar{Q}$
LO	LO	No change	
LO	HI	LO	HI
HI	LO	HI	LO
HI	HI	Undefined	



Input		Output	
J	K	Q	$\bar{Q}$
LO	LO	No change	
LO	HI	LO	HI
HI	LO	HI	LO
HI	HI	Complement	

The J-K flip-flop has no ambiguous states and is a commonly used configuration. The J-K flip-flop has two inputs and two outputs. When a HI is applied to the J, the flip-flop is switched to the HI state. With a HI at K, the flip-flop is switched to the LO state. If HI's are applied to both the J and K terminals, the FF switches to its complement state. Many J-K flip-flops are supplied with two or more J inputs and two or more K inputs. As a result, frequently one J and one K input are connected together for use as a clock input.

SERVICE SCOPE



TROUBLESHOOTING THE AMPLIFIERS

By Charles Phillips
Product Service Technician, Factory Service Center
Contribution by Dave Colbert

This fifth article in a series discusses troubleshooting techniques in the vertical and horizontal amplifier circuits of Tektronix instruments. For copies of the preceding four TEKSCOPE articles, please contact your local Tektronix Field Engineer.

For effective troubleshooting, examine the simple possibilities before proceeding with extensive troubleshooting. The following list provides a logical sequence to follow while troubleshooting both the horizontal and vertical amplifier circuitry:

1. Observe CRT display characteristics.
2. Check control settings.
3. Isolate trouble to block.
4. Thorough visual check.
5. Check voltages and waveform.
6. Check individual components.

Note: **Always** return the original component to its place if the problem remains.

GENERAL

Neon indicator lights and trace finders usually provide sufficient information to indicate which side of the vertical or horizontal amplifier is causing the trouble, or whether both sides are. If the trace-finder button brings the trace back on the screen, then by varying the position control we can observe whether we have position control on both sides. If we have position to one side only, this will tell us that we have an unbalance in one of the amplifiers. If we have no position, then it could be a defective stage completely.

If a vertical or horizontal amplifier is badly out of balance, a clip lead can be used to short the collectors of the output transistors (or plates of output tubes) to ensure that the spot is centered. (The deflection plates themselves may be shorted to verify the true electrical center of the instrument.) The shorting strap is then moved to the base (or grid) of the output stage and the amount of difference in the spot position noted. The position difference indicates the amount and direction of unbalance in the output stage. By applying this technique, stage by stage back to the input, the amount of unbalance may be determined. Switch the input transistors of the output amplifier when the unbalance is over 0.5 centimeter. A defective stage is indicated by the shorting strap not centering the trace on the CRT. It's a good idea to switch transistors around to obtain an unbalance less than that figure. This will ensure a well balanced vertical system and minimize compression or expansion.

The Type 576 Curve Tracer presents a convenient way to locate difficult problems in push-pull or complementary circuitry. The AC Collector Mode is ideal for comparing the impedance of various circuit points against similar impedance points. Any substantial difference in displays indicates a probable incorrect circuit impedance for the test point. Use sufficient voltage to turn on nearby junctions for maximum insight into the test circuit. Open and shorted diodes are easily found this way as well as much more difficult conditions, including in-circuit leakage problems. Be certain that the power is OFF on the scope under test.

This approach is useful whenever suspected stages may be compared against a known good stage. The technique is particularly valuable when troubleshooting feedback circuitry. By setting the initial display to approximately a 45° positive slope, meaningful comparisons can be quickly made.

A convenient method of determining which component in a string is noisy is to use a differential comparator unit. Usually, if such a problem is observed single-ended, it is difficult to localize the faulty resistor. By monitoring the problem differentially and bucking out the voltage, the noisy component is quickly and easily located. The same technique will often work to a lesser degree with add algebraic or ordinary differential amplifiers.

HORIZONTAL AMPLIFIERS

The horizontal amplifier develops a push-pull version of the input ramp from the time-base generator. These simultaneous positive and negative going ramp voltages are then applied to the right and left horizontal deflection plates, respectively, causing the CRT spot to move across the screen. Thus, equal increments of distance represent equal increments of time, and the sweep can be calibrated.

Many horizontal amplifiers include magnifier circuitry that decreases the amount of negative feedback and increases the gain accordingly. Such magnifiers are usually X5 or X10 and effectively increase the sweep rate by that amount. Most oscilloscopes also provide an external input to the horizontal amplifier. In this position, the internally generated sawtooth is disconnected and an external signal may be connected to the external horizontal input terminal. Often a compensated 10X attenuator is used with the external horizontal circuitry to provide a wider range of signal inputs.

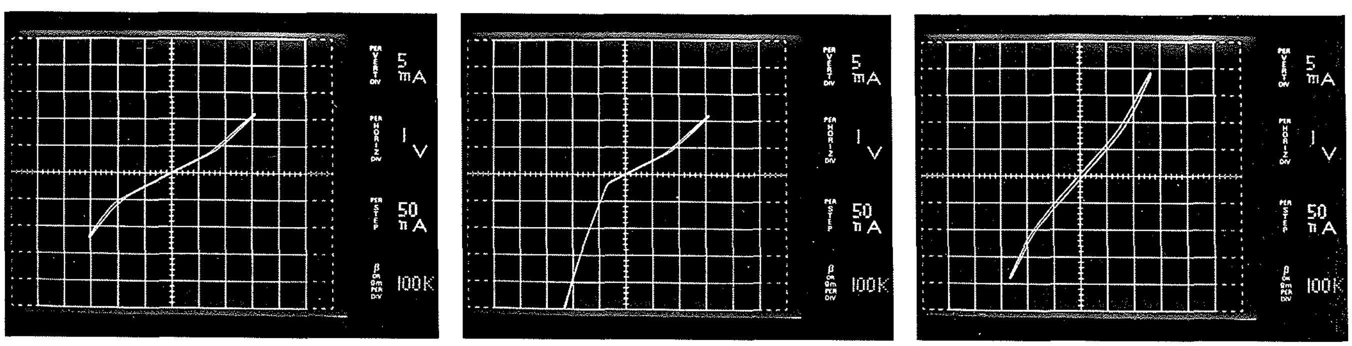
When the oscilloscope has a second sweep, this may be used to check for normal operation. A calibrator signal to the external horizontal input checks the operation of a portion of the horizontal amplifier. If the instrument has a plug-in horizontal, removing the plug-in unit should automatically center the spot. This is of additional assistance with oscilloscopes using deflection blanking. Deflection blanking positions the spot offscreen, except during sweep time, and no spot can be seen by overriding the intensity control.

Switching to the external input disconnects the sweep and is a means of determining whether a problem is associated with the horizontal amplifier. At the same time, it can indicate the condition of the unblanking circuitry.

VERTICAL AMPLIFIERS

The vertical amplifier develops a push-pull version of the input signal from the vertical preamplifier. These simultaneous positive and negative going amplified signal voltages are then applied to the upper and lower vertical deflection plates, deflecting the CRT spot as it traverses the screen. Thus, an accurate amplified reproduction of the original signal is displayed on the CRT. In addition, many oscilloscopes provide a vertical signal output which allows the amplified signal to drive other devices.

No stage where distributed amplifiers are used should contribute more than 2-mm unbalance. In addition, tubes should be switched so the total unbalance of the distributed amplifiers does not exceed 2 mm. Never mix different brands of distributed amplifier tubes. If a distributed amplifier tube fails and a replacement is needed, the trigger pickoff tube makes an excellent aged replacement. The trigger pickoff tube may then be replaced with a different brand.



Comparing similar impedance points can often locate troubles when other techniques fail. In-circuit impedance checks: Left, normal operation of the emitter circuit side of a paraphrase amplifier; Center, opposite side of the same paraphrase amplifier with open emitter; Right, shorted emitter.

TYPICAL HORIZONTAL PROBLEMS

Problem: Sweep shortening at fast sweep speeds. Nonlinearity and sometimes sweep compression to the right.

Solution: This problem is typically caused by an open collector (or plate) load to one of the stages. An open decoupling resistor will also cause this problem.

Problem: Compression or expansion of the sweep as it is positioned from one side to the other.

Solution: This problem is typically caused by the diode network between the bases (or grids) of the amplifier. Check for leaky diodes.

Problem: Horizontal shift exceeds 1 cm as line voltage is varied from 105-125 V.

Solution: Change tubes or transistors.

Problem: Horizontal sweep control center position is shifted and control is nonlinear.

Solution: Check for an open circuit in the center tapped plate load resistors of the output amplifier.

Problem: Nonlinear sweep.

Solution: Gassy HF capacitance driver tube. A faulty input CF tube may also cause a similar problem.

Problem: Insufficient HF timing range and gain or position effect.

Solution: Check the horizontal output amplifier for weak tubes.

Problem: Position range off-centered.

Solution: Check the input compensated divider of the input CF.

TYPICAL VERTICAL PROBLEMS

Problem: Unbalance greater than 0.5 cm.

Solution: Switch tubes to bring within 0.5 cm of electrical center. **NOTE—TURN OFF POWER WHEN SWITCHING INPUT TUBES.**

Problem: No internal triggering capability.

Solution: Open plate load inductance of trigger pickoff amplifiers.

Problem: Bump in display 0.25 μs from beginning.

Solution: Check for open or defective termination network.

Problem: DC shift.

Solution: Check to be sure that the plate load resistor is correct for the brand of tubes being used. (Resistor value varies with tube manufacturer other than original.) If the problem still remains, check the filter capacitors.

Problem: Cathode-Interface—front end of pulse varies as line voltage is varied from 105-125 V.

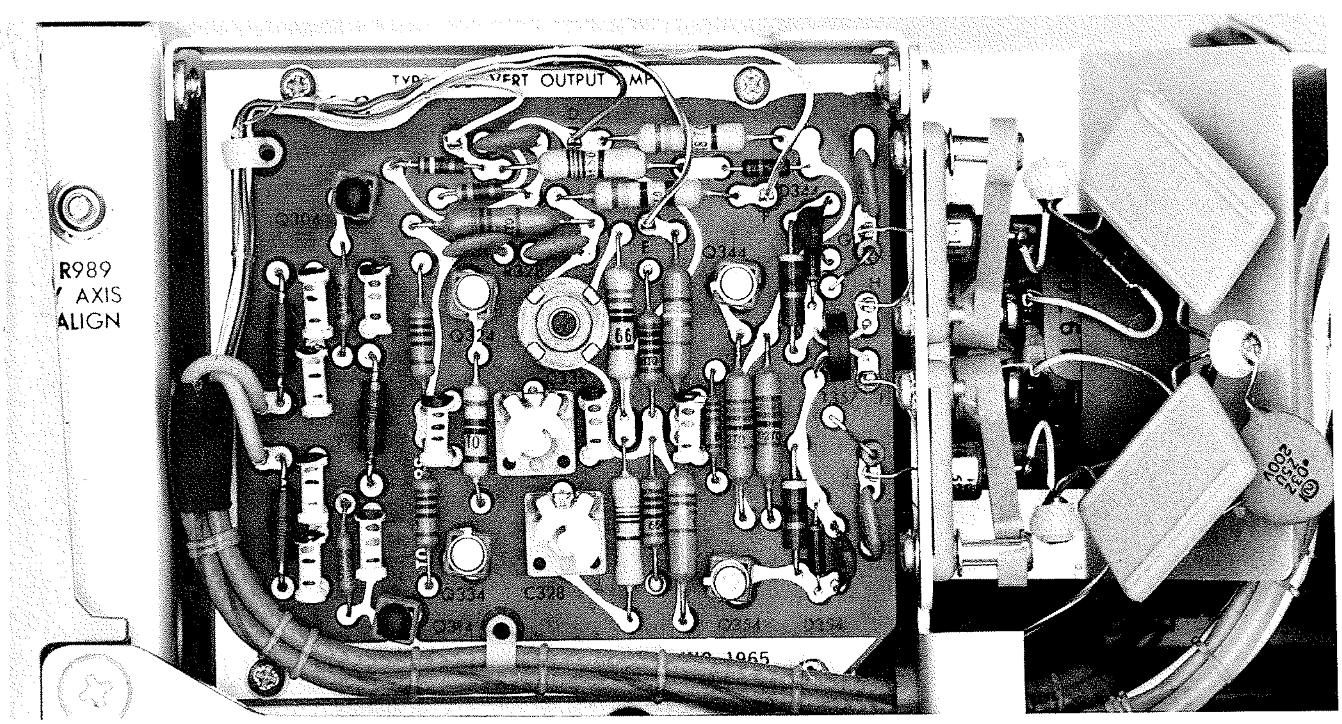
Solution: Replace input tubes. If problem still remains, retube the distributed amplifier.

Problem: Overshoot and ringing.

Solution: Check collector load resistor for out-of-tolerance components. If problems remains, check gain potentiometers. Non-Tektronix made gain pots may not have the right amount of inductance.

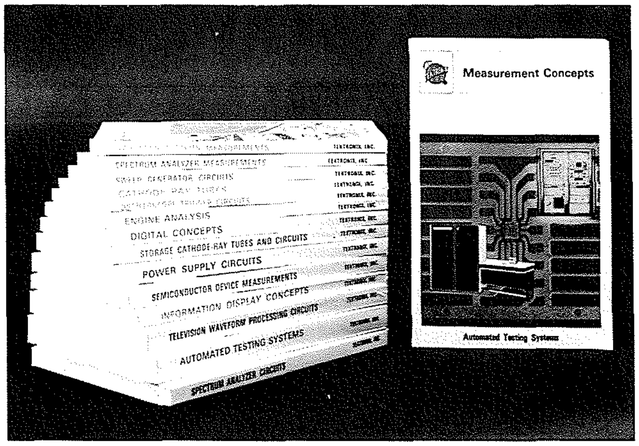
Problem: Compression.

Solution: Check diodes in base circuits for a shorted diode.



Type 422 Vertical Amplifier circuit board. Note that transistor sockets are used where possible for servicing convenience.

NEW CONCEPTS BOOKS



Four new titles have been added to the concepts series of books published by Tektronix. A total of 14 concepts books are now available from your Tektronix Field Engineer. Eight circuit concepts books and six measurement concepts books are presently in print.

"Sweep Generator Circuit" is the addition to the circuits concepts series and discusses sawtooth waveform characteristics, the gated clamp-tube generator control circuit, bootstrap sweep generators, Miller integrators, and sweep generator control circuits.

Three new titles are available in the measurement concepts series: "Spectrum Analyzer Measurements", "Engine Analysis", and "Automated Testing Systems". "Spectrum Analyzer Measurements" discusses concepts of RF spectrum tuning, RF modulation systems, spectrum analyzer terms, spectrum analyzer characteristics and their relationships, spectrum analyzer functional considerations, CW signal measurement, amplitude-modulation measurement, single-sideband measurements, pulsed RF carrier measurements, swept frequency measurements, fluid velocity measurements, and waveform analysis. "Engine Analysis" consists of ignition systems, ignition waveform analysis, magnetic transducers, rotational function generators, vibration transducers, and pressure transducers. "Automated Testing Systems" discusses the memory and control blocks (data disc, punched tape, tape readers and perforators, the Type 240 program control unit, the Type 250 auxiliary program unit, and the Type 241 programmer unit); the measurement block (sampling review, the Type R568 oscilloscope—Type 3S6 vertical and Type 3T6 sweep, the Type 230 digital unit, testing systems options); the stimulus block (the Type R116 programmable pulse generator, the Type R293 programmable pulse generator and power supply, and programmable power supplies); and the fixture block, a discussion of fixturing and problems.

INSTRUMENTS FOR SALE

1—Type 535A, SN 24917 and 1—Type CA, SN 30061. Price: $1,225. 1—Type 535A, SN 25772 and 1—Type CA, SN 30364. Price: $1,225. 1—Type 545, SN 8225 and 1—Type B, SN 14320. Price: $1,200. Recently reconditioned and recalibrated. Contact: Mr. Weiss, Communications Radio, 150 Jerusalem Avenue, Massapequa, New York 11758. Telephone: (516) 798-7342.

1—Type 661/4S1/5T1A. Good condition, small amount of use. Contact: Carl Gruber or Dr. Hixson, Electrical Engineering Dept., South Dakota School of Mines and Technology, East St. Joe Avenue, Rapid City, South Dakota 57701. Telephone: (605) 394-2291.

1—Type 535, SN 489. 1—Type L, SN 010273. 1—Type 53C, SN 730. 1—Type G, SN 006777. Contact: Mr. E. Thomas, The Budd Co., 12141 Charlevoix, Detroit, Michigan 48215. Telephone: (313) 822-7000 Ext. 229.

1—Type 561A/3A3/2B67. Used only 20 hours. Price: $1,400. Contact: Dick Hahn. Telephone: (914) 232-5891.

1—Type CA, SN 38575. Price: $150. 1—Type T, SN 2782. Price: $150. Contact: William H. Greenbaum, V.P., Unilux, Inc., 48-20 70th Street, Woodside, New York 11377. Telephone: (212) 651-2258.

1—Type 422, AC Model. Used less than 25 hours. Price: $1,000. Contact: J. M. Edelman, M.D., 4550 North Boulevard, Baton Rouge, Louisiana 70806. Telephone: (504) 927-3553.

1—Type 575. Three years old. Will calibrate prior to sale. Price: $900. Contact: L. M. Buckler, Intech, Inc., 1220 Coleman Ave., Santa Clara, California 95050. Telephone: (408) 244-0500.

1—Type 524D, SN 1186. In operating condition. Best reasonable offer. Contact: Jerry Berger, Minneapolis Moline, 301 Ninth Avenue South, Hopkins, Minnesota 55343. Telephone: (612) 935-5181 Ext. 306.

1—Type 575, SN 010866. Three years old. Price: $950. Contact: Mobilscope, Inc., 17734½ Sherman Way, Reseda, California 91335. Telephone: (213) 342-5111.

1—Type 422, SN 003693. Good condition. Price: $1000. Contact: Robert Blessing, National Supply Company, Drawer H, Gainesville, Texas 76240. Telephone: (817) 465-2811.

1—Type 514, SN 2907. 1—Type 517, SN 280 with Duty Cycle Limiter Modification. Contact: R. A. Kern, Link-Belt Div. of FMC Corp., P. O. Box 346, Indianapolis, Indiana 46206. Telephone: (317) 632-5411 Ext. 337.

1—Type 575, SN 002669. Reconditioned. Price: $850. Contact: Mobilscope, Inc. 1734½ Sherman Way, Reseda, California 91335. Telephone: (213) 342-5111.

1—Type 545B, SN 2529. 1—Type 1A1, SN 2029. And 015-0062-00 TV Sync Separator. Price: $1,750. Contact: Robert Brown, Everett Cablevision, 2507 Broadway Avenue, Everett, Washington 98201. Telephone: (206) 259-3171.

1—Type 1A1. Price: $400. Contact: Mr. Dean Maloney, 832 Busse Highway, Park Ridge, Illinois 60068.

1—Type 575 Mod 122C, SN 12941. One year old. Price: $995. Contact: Alfred Gomez, Computer Components International, Inc., 3804 Burns Road, Palm Beach Gardens, Florida 33404. Telephone: (305) 842-4216.

1—Type 545S6, SN9388. Price: $900 or best offer. Contact: Mr. M. Stepanski, Deltron, Inc., Wissahickon Avenue, North Wales, Pennsylvania 19454. Telephone: (215) 699-9261.

INSTRUMENTS WANTED

1—Type 515A or 516. Any condition. Contact: Ray Harland, Route 1, Box 745A, Escondido, California 92025. Telephone: (714) 746-4584.

1—10 to 20 MHz scope, either single or dual channel. Contact: John Ricker, 1570 Meade Street, Denver, Colorado 80204. Telephone: (303) 623-6002.

1—C-12 Camera. Contact: Mr. Dean Maloney, 832 Busse Highway, Park Ridge, Illinois 60068.

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TEKSCOPE
Volume 1 Number 6 December 1969

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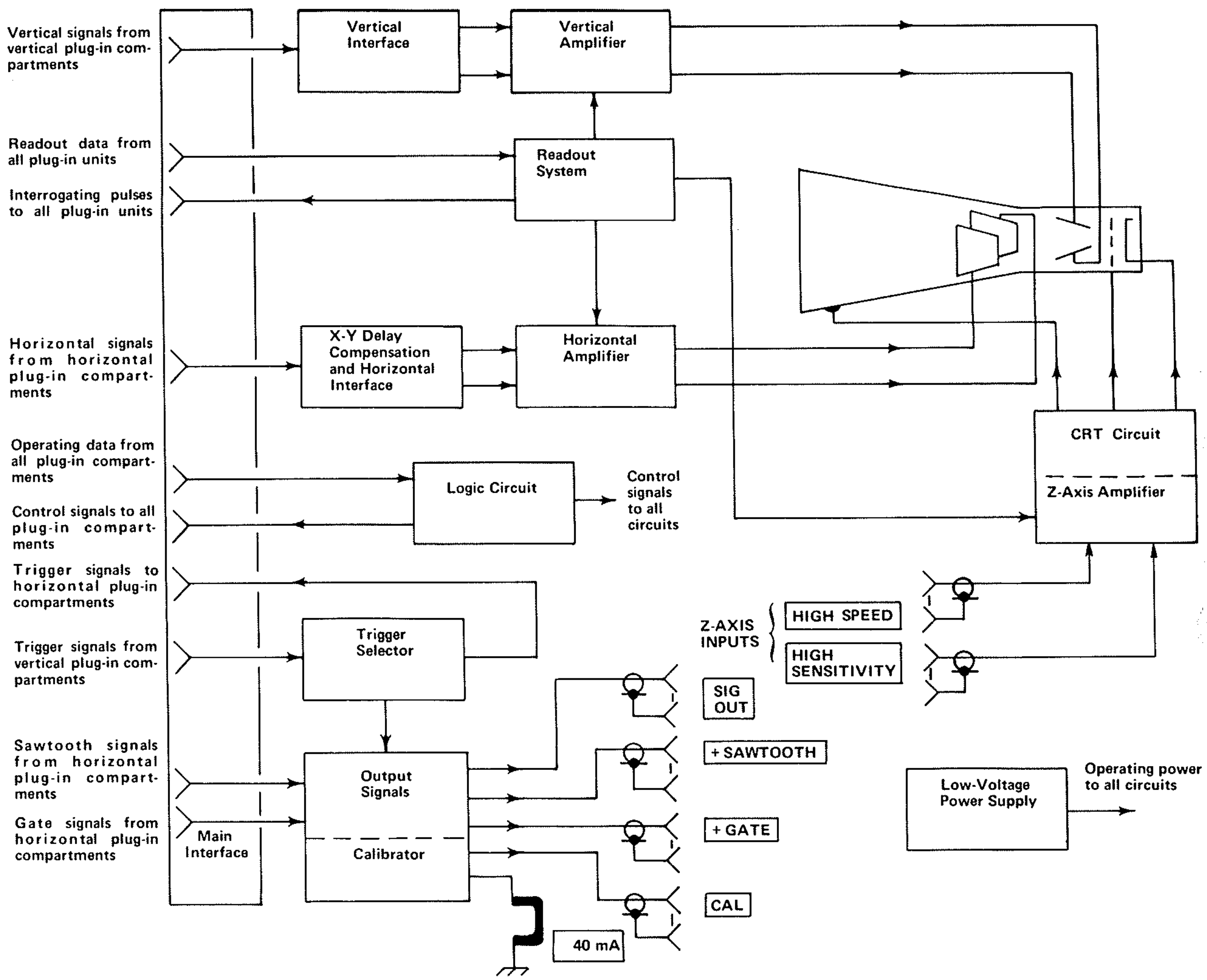
Editor: Rick Kehrli Artist: Nancy Sageser For regular receipt of TEKSCOPE contact your local field engineer.

7000-SERIES BLOCK DIAGRAM



The Tektronix developed and manufactured M036 Channel Switch IC was developed to fill the need for a fast, clean switch with good isolation characteristics. The switch is housed in a 14-pin, dual-in-line package and is the key to much of the versatility of mainframe switching in the NEW 7000 Series. One M036 is used in both the Vertical Interface and Horizontal Interface and two are used in the Trigger Selector block.

The channel switch selects one or mixes two analog input signals in response to a digital input. In its simplest application, it is a double-pole, double-throw selector of one of two balanced input signals. Its more sophisticated role is in providing signal steering in dual-trace vertical and horizontal amplifiers.

The MO36 is designed for two balanced input signals of 25 mV/division into 50 Ω per side (0.5 mA/div). Side-to-side diodes are included inside the IC for limiting the differential voltage swing of the output. The risetime of the switch is less than 1 ns and switching time is 20 ns maximum. The IC is also very clean from chopping transients.

1968-1969 TEKSCOPE INDEX

BACK ISSUES—Although some back issues of listings in this index are out-of-print, most issues are available upon request from your local Tektronix Field Engineer.

CHRONOLOGICAL INDEX

SERVICE SCOPE

TEKSCOPE

TEKSCOPE LABEL INSIDE →

SUBJECT INDEX

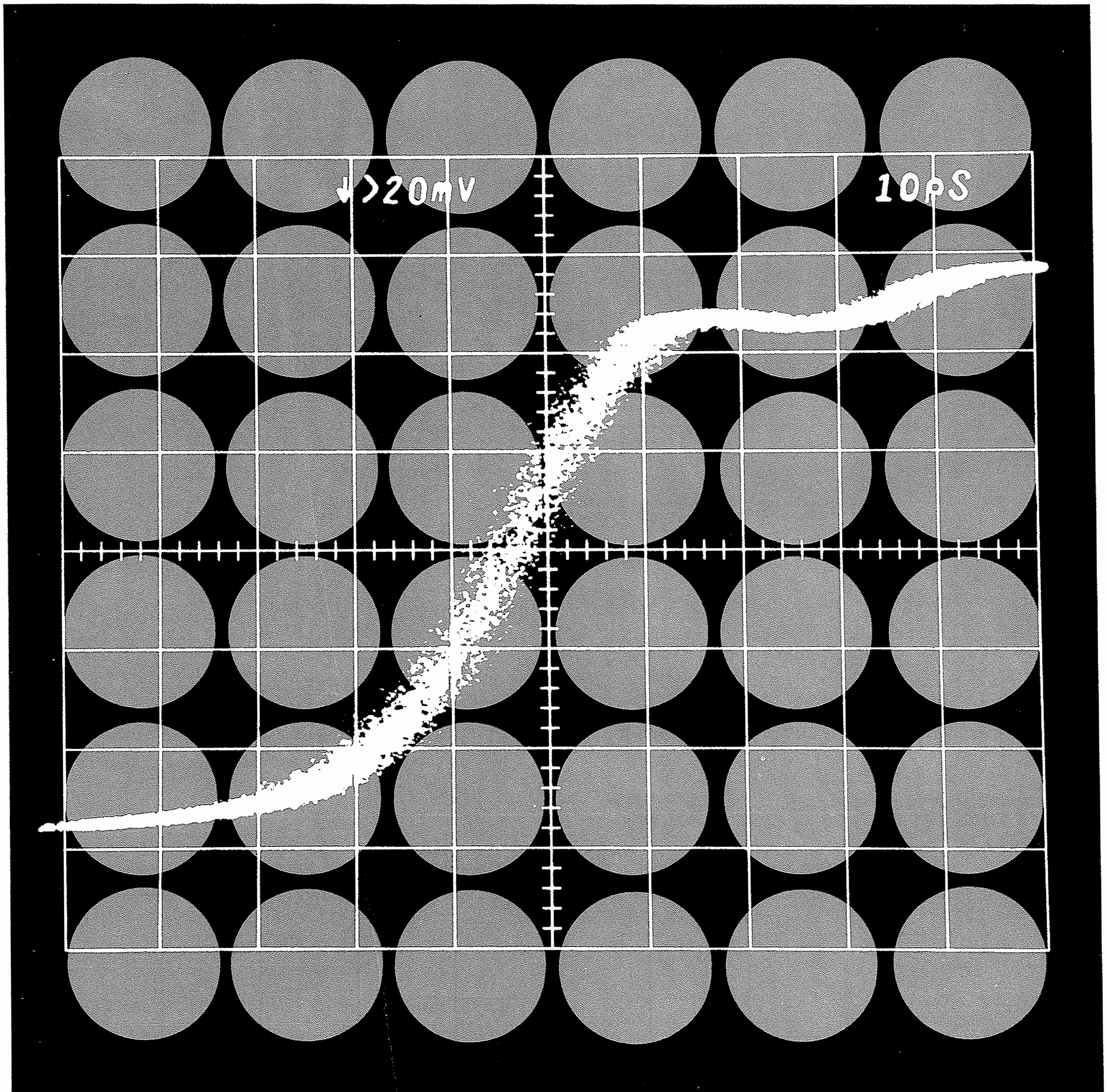
TEKSCOPE LABEL

Peel off the protective cover and apply your TEKSCOPE vinyl label to the spine of a three-hole loose-leaf binder. You now have a reference home where your TEKSCOPES and your index may be conveniently filed.

SUBJECT INDEX (SERVICE INFORMATION)

TEKSCOPE

FEBRUARY 1970



Al Zimmerman, Program Manager, and George Frye, Project Engineer, confer over a 7T11 Time-Base Unit.

Measuring Jitter with a Sampling Oscilloscope

By Al Zimmerman

The oscilloscope is a useful tool for measuring time jitter between two different but repetitive events. The **sampling** oscilloscope is particularly well-suited for these measurements because of its extremely fast sweep rates and low internal jitter. Jitter measurement resolution to within a few picoseconds may often be achieved.

COVER—The excellent jitter performance (less than 10 ps) is clearly shown on a randomly sampled fast rise display.

Typical examples of time jitter measurements include:

(a) Measuring the inter-period jitter of a repetitive signal source.

(b) Measuring the pretrigger-to-pulse jitter of a pulse generator.

(c) Determining the uncertainty of threshold crossing detectors (comparators) due to noise, etc.

(d) Verifying the oscilloscope's jitter specs.

SOME TERMINOLOGY

"Noise" is the term we shall use to describe a random broadening of the oscilloscope trace in the vertical direction, while "jitter" will be used to describe a random broadening in the horizontal direction. In the sampling oscilloscope, the apparent trace broadening occurs as individual display dots are misplaced along one or both axes.

The causes of noise and jitter are many and varied. Some are truly random, or aperiodic, in nature while others are uniformly periodic. Unless the noise or jitter source is synchronous or very nearly synchronous with the oscilloscope sweep rate (or scanning rate in a sampling oscilloscope), even periodic causes such as hum or RF often *appear* to result in random dot displacements. No matter how many or what the causes are, the result is a statistical distribution of dots along either a vertical or horizontal cross-section of the trace.

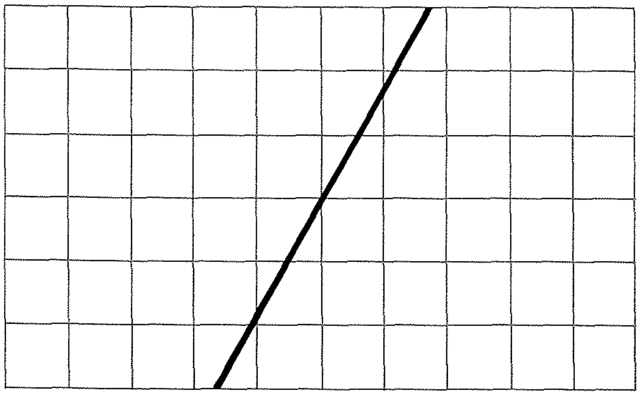
NOISE AND JITTER INTERACTION

When it comes to measuring jitter, a problem arises when noise is also present since these separately-caused effects tend to interact in the display. See drawing 1. *A sloping waveform will suffer both a vertical broadening and a horizontal broadening from either noise or jitter.* While one may always observe noise independently by displaying a horizontal baseline, the analogous operation for a completely independent jitter observation is impossible. In practice, jitter measurements with an oscilloscope must either *reduce the effect* of noise to the point of insignificance in the display *or* the jitter measurement *must be corrected* to remove the effect of noise.

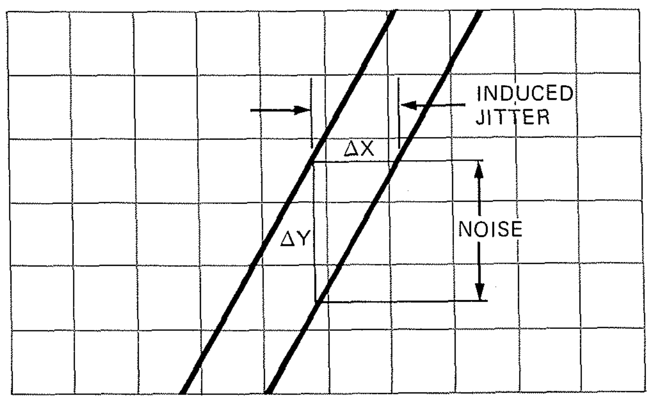
The *first approach* requires a large dV/dt for the input signal relative to vertical volts per division divided by horizontal seconds per division in the oscilloscope display. This produces a steep slope and may provide the required independence of noise and jitter in the display. Either the risetime of the available signal, the risetime of the oscilloscope, or the permissible signal amplitudes may impose the ultimate limit on the dV/dt which may be displayed, however.

It must also be noted that a large signal should be used relative to the inherent noise level of the oscilloscope. *Simply turning up the vertical sensitivity (volts/div) to get a steeper slope does NOT reduce the interactive effect of noise upon jitter.* Anything done to increase the signal-to-noise ratio DOES reduce the effect—at *ANY* sensitivity setting.

The *second approach* to a solution for this problem involves a subtractive correction to the observed jitter based on measurements of waveform slope and noise. Before we describe how to make such a correction, however, we need to look further into the question of how to measure the observed jitter from a noisy, jittery trace.



Drawing 1. No noise.



Drawing 2. Jitter induced by noise.

THE HUMAN FACTOR

A significant problem which plagues both noise and jitter measurements is the subjectivity of display interpretation. Different people find it difficult to agree on the same reading from the oscilloscope screen. The problem is due to the "skirts" on the gaussian or near-gaussian dot distributions encountered. When asked to describe the boundaries or limits of such a distribution, one person will tend toward a peak-to-peak interpretation which includes *all* the dots while another person will discount the more widely scattered dots and consider only the central portion of the distribution. Since most people seem to tend toward the latter interpretation; it is difficult to specify or to describe such a display with much precision.

MEASURING NOISE

In the April '69 issue of TEKSCOPE, a "tangential trace" technique was described for measuring noise displayed on a conventional (non-sampling) oscilloscope. The same technique can be used for measuring noise on a sampling oscilloscope. A typical setup is shown below.

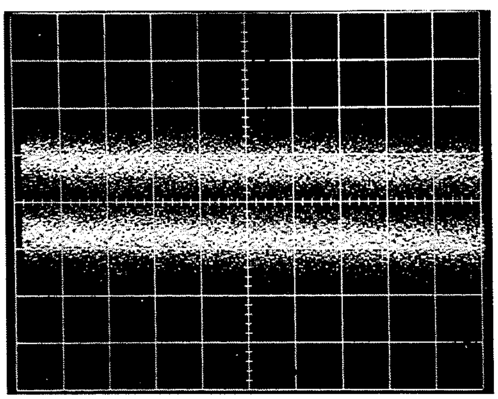


Photo 1. Initial setup for tangential noise measurement.

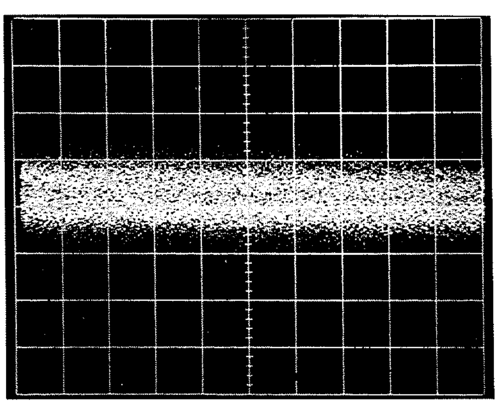


Photo 2. Final adjustment. Dark band between the noise bands has just vanished.

In this technique, two traces are produced by adding a slow squarewave to the vertical signal and adjusting the square-wave amplitude to achieve "tangency" of the two traces. It can be shown for a gaussian distribution, that tangency is achieved when the squarewave value (N_{SW}) is exactly *twice* the RMS noise value.* It can also be shown (see chart 1) that the displayed noise value (N_D) which contains 90% of the dots is approximately *three times* the RMS noise value (N_{RMS}). From these relationships the following statement is derived:

$$N_D \cong 3N_{RMS} = 3/2\ N_{SW}$$

*Garuts, Val., "A Simple Method for Measuring Preamp Noise," Tektronix Engineering Instrument Specification Guidelines.

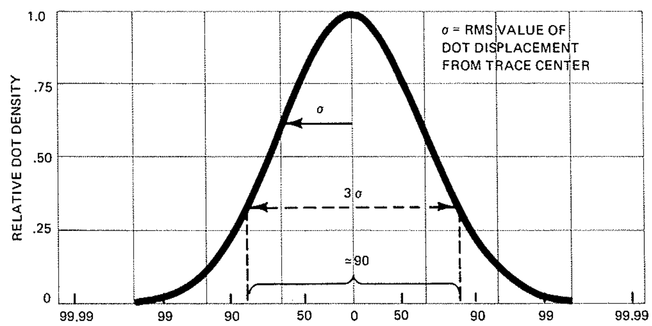
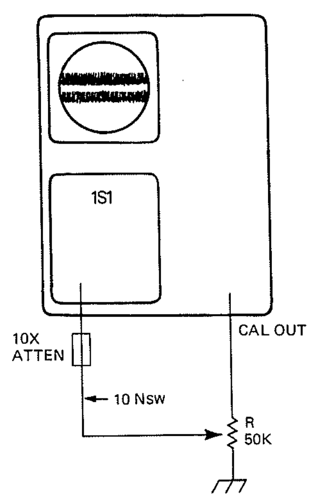


Chart 1. The percentage of dots contained with a cross-section of a trace is approximately 90% (3 σ).

MEASURING NOISE (N_{SW})

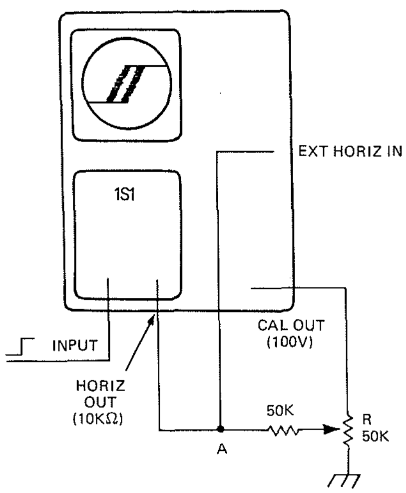


MEASURING JITTER

Several techniques similar to the tangential-trace method for measuring noise have been suggested for measuring the horizontally summed effects of time jitter and and noise which we shall simply call "observed jitter". One of these techniques is shown below (J_{SW}). Here a square wave is added to the slow speed horizontal signal causing the displacement of a fast-rising portion of the display. The square-wave amplitude is again adjusted to achieve tangency, but this time its value must be in terms of the resulting time displacement of the tangent traces. This is most easily done by switching to MANUAL SCAN on the sampling sweep and observing the effective time displacement caused by the square wave alone. The resulting jitter relationships are:

$$J_D \cong 3J_{RMS} = 3/2\ J_{SW}$$

MEASURING JITTER (J_{SW})



CORRECTING FOR NOISE

It must be emphasized that the display-jitter measurement described *includes* a contribution due to vertical noise. If one wishes to describe the *time jitter* independently from the induced contribution from noise, it will be necessary to subtract out this contribution. Thus, noise-corrected time jitter (J_{NC}) may be easily found

$$J_{NC} = \sqrt{J_D^2 - \left(\frac{N_{SW}}{\text{slope}}\right)^2}$$

where the slope is simply $\Delta Y/\Delta X$ of the waveform in the display. All values shown include approximately 90% of the displayed dots along a vertical or horizontal cross-section.

CORRECTING THE MEASUREMENT

Since the jitter introduced by the oscilloscope itself (J_O, usually less than 20 ps) may be a significant part of the observed jitter, it may be desired to make a similar subtractive correction for it as well. Oscilloscope jitter may be determined by viewing the triggering event directly and then making a noise correction as described above. The complete formula for time jitter corrected for noise and scope jitter (J) then becomes:

$$J = \sqrt{J_D^2 - \left(\frac{J_{SW}}{\text{slope}}\right)^2 - J_O^2}$$

Using the techniques discussed, the effects of noise and human interpretation may be reduced to allow repeatable jitter measurements to within a few picoseconds with a sampling oscilloscope.

PROCEDURE FOR DETERMINING NOISE AND JITTER

N_{SW}

1. Adjust R for tangency.
2. Remove the 10x attenuator (applying the squarewave signal directly.)
3. Measure the trace separation in volts directly on the screen. (E_{SEP})
4. N_{SW} (in volts) $= \frac{E_{SEP}}{10}$

J_{SW}

1. Adjust R for tangency of the two step transitions.
2. Set 1S1 to MAN SCAN.
3. Measure the squarewave amplitude at A. (E_{TAN})
4. Adjust R for 8 cm deflection.
5. Again measure the squarewave amplitude at A. (E_{8CM})
6. J_{SW} (in seconds) $= \frac{E_{TAN}}{E_{8CM}}$ x (Time/Div) x 8

Basic Sampling

A brief description of the three major modes of sampling

Three new sampling units are the building blocks for sampling performance with the Tektronix 7000 Series. The 7S11 Sampling Unit accepts any one of 5 sampling heads that cover the measurement spectrum from LF, high Z (350 MHz, 1-MΩ input) to HF, low Z (14 GHz, 50-Ω input). The 7T11 Sampling Time Base provides random, sequential, and real-time sampling displays and covers the range of 5 ms/div to 10 ps/div. A built-in VHF synchronizer provides the ability to view 12.4 GHz signals without requiring additional equipment. The 7M11 is a dual 75-ns delay line unit designed for the viewing of triggering events in low repetition rate applications.

The use of random sampling permits the user to observe *prior to,* coincident with, or after the displayed signal without sacrificing display lead time. Thus, the random sampling oscilloscope provides an important measurement capability that conventional oscilloscopes do not provide (i.e., look ahead of the triggering point).

The timing circuitry used in the 7T11 uses a time measurement rather than a time programming process for horizontal sample positioning in equivalent time. That is, the horizontal position of the dot on the screen is determined by the measurement of the time interval between strobe and trigger. The same process is used in both Random and Sequential operation, with only the method of strobe timing changing between the two modes. The staircase generator now never drives the CRT directly—it is only used as a reference source of voltage.

Two major advantages are achieved by this method:

1) Improved timing linearity, especially at the start of the slewing ramp; starting transients in the slew ramp show up as dot position nonlinearities instead of timing nonlinearities.

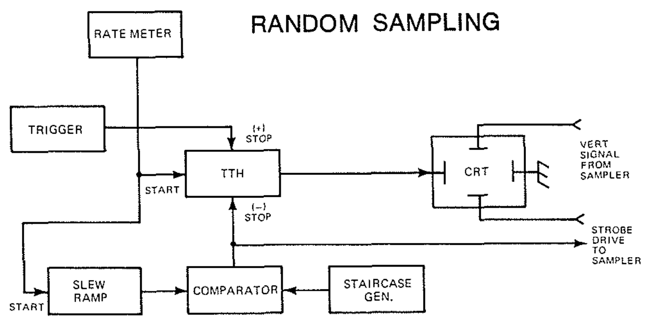
2) Reduced display jitter. Comparator noise that results in strobe jitter shows up as dot jitter, not display jitter. The display jitter displayed becomes a function of the noise level of the integrator circuit used for the time measurement plus the few picoseconds of jitter in the trigger recognition and strobe drive circuits. This new development provides a display jitter specification of less than 10 ps.

The Random Sampling process is composed of two basic operations:

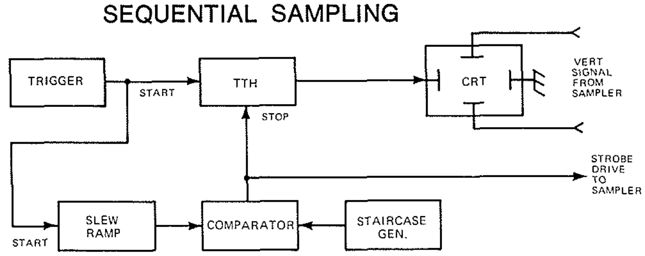
1. Originating the sample pulses randomly distributed in a time window around the part of the signal to be displayed.

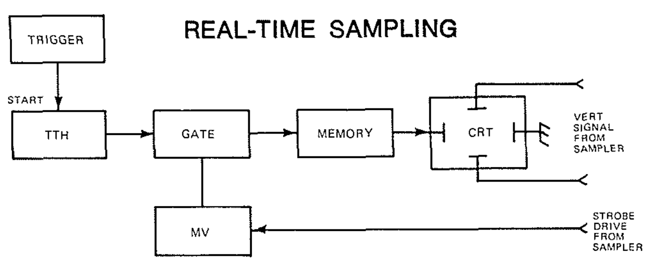
2. Constructing a pulse display by deriving two analog signals, representing X and Y coordinates, from a series of those samples.

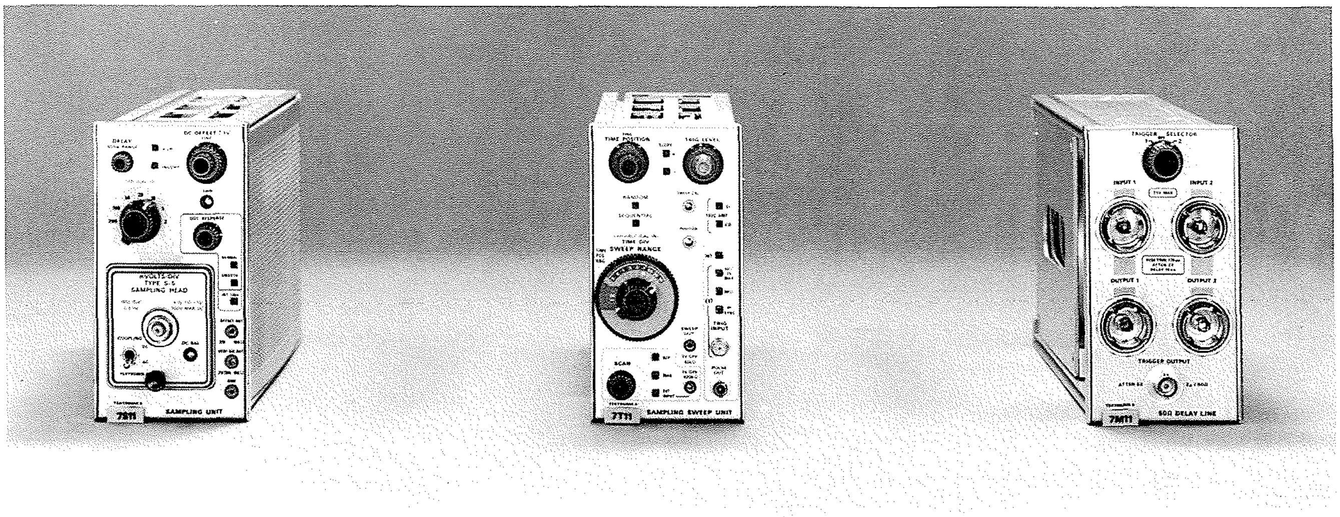
To originate sample pulses, the ratemeter measures the trigger rep rate and starts the slew ramp to generate samples within the time window. The Time-to-Height Converter (TTH) includes two stop inputs, one + and one —. When the ratemeter produces a start command at a programmed time before the predicted arrival of the Trigger event, the Slew Ramp runs and produces a strobe when a comparison with the staircase is made. (Note—There is no fixed time between the slew ramp and the next trigger signal.) The TTH does not initially make any output excursion, because the + input signal equals the — input. If the trigger arrives first, a + stop command occurs and the TTH runs negative until a



SEQUENTIAL SAMPLING







Three versatile new Tektronix Sampling Units. From left: 7S11 Sampling Amplifier, 7T11 Sampling Time Base, and the 7M11 Dual Delay Line.

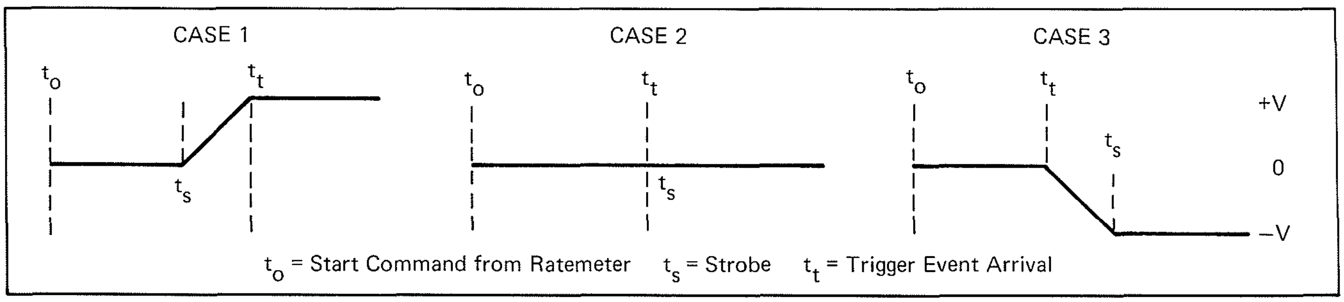


Fig. 1. Random sampling time relationships. Case 1 illustrates the condition where the strobe occurs before the trigger. Case 2 illustrates the condition where the strobe and trigger are coincident. Case 3 illustrates the condition where the strobe occurs after the trigger.

strobe drive pulse and — stop command comes from the comparator. The dot is then deflected to the right of the center on the CRT. If the Trigger and Strobe events both happen simultaneously, the TTH. produces no change in output voltage. If the Strobe occurs before the trigger, then the TTH runs positive and the dot moves to the left a distance proportional to the time difference. The ratemeter provides maximum display dot density by gathering the samples around just that section of the waveform that is used for the CRT display.

The samples which fall outside the time window do not have any contribution to the display construction and are kept as few as possible. If too many samples fall outside the time window, an error signal is generated to improve the ratemeter "guess". This ensures that the horizontal signal tracks with the staircase over the average of many samples.

In sequential sampling, the sampler is programmed to produce strobes when commanded by the 7T11. The block diagram shows a TTH added to the standard sequential sampling time-base. A slew ramp is used as is a staircase generator and comparator. The major differences from conventional sampling circuitry is that the staircase generator does not drive the CRT directly. Instead the strobe drive from the comparator occurs at a programmed point in time. The TTH then measures the difference in time between the Trigger and Strobe drive events and places the dot on screen at a position corresponding to that point in time where the strobe actually occurred (which may not be exactly the same as where it was programmed to occur). The ramp rates of the TTH and the slew ramp are equal.

The basic block diagram for real-time sampling is very similar to that of a standard real-time oscilloscope. The arrival of a trigger starts the timing ramp, or TTH. The Sampler is programmed to free run. When a strobe occurs, the Real-Time Multivibrator (MV) fires, causing the gate to conduct. The Memory tracks along with the TTH ramp until the gate quits conducting. It then remains at that level until the next strobe arrives.

The width of the Memory gate strobe sets the lead time ($\simeq$3 μs) of the instrument. The display appears as a series of dots starting from the left-hand side of the screen. For each triggering event, one sweep across the screen is produced with each dot spaced about 20 μs from the preceding one.

Specifying Product Performance

By Rich Nute

The basic purpose of specifying product performance is to allow comparisons with competitive products or other methods of measurement. This article discusses the reasons for specifications and explains some of the criteria for Tektronix specifications.

WHY SPECIFY?

Specifications arise from the need to describe products as clearly as possible. When a product provides a measurement capability, the user must know, first, what functions it performs, and second, how well it performs those functions.

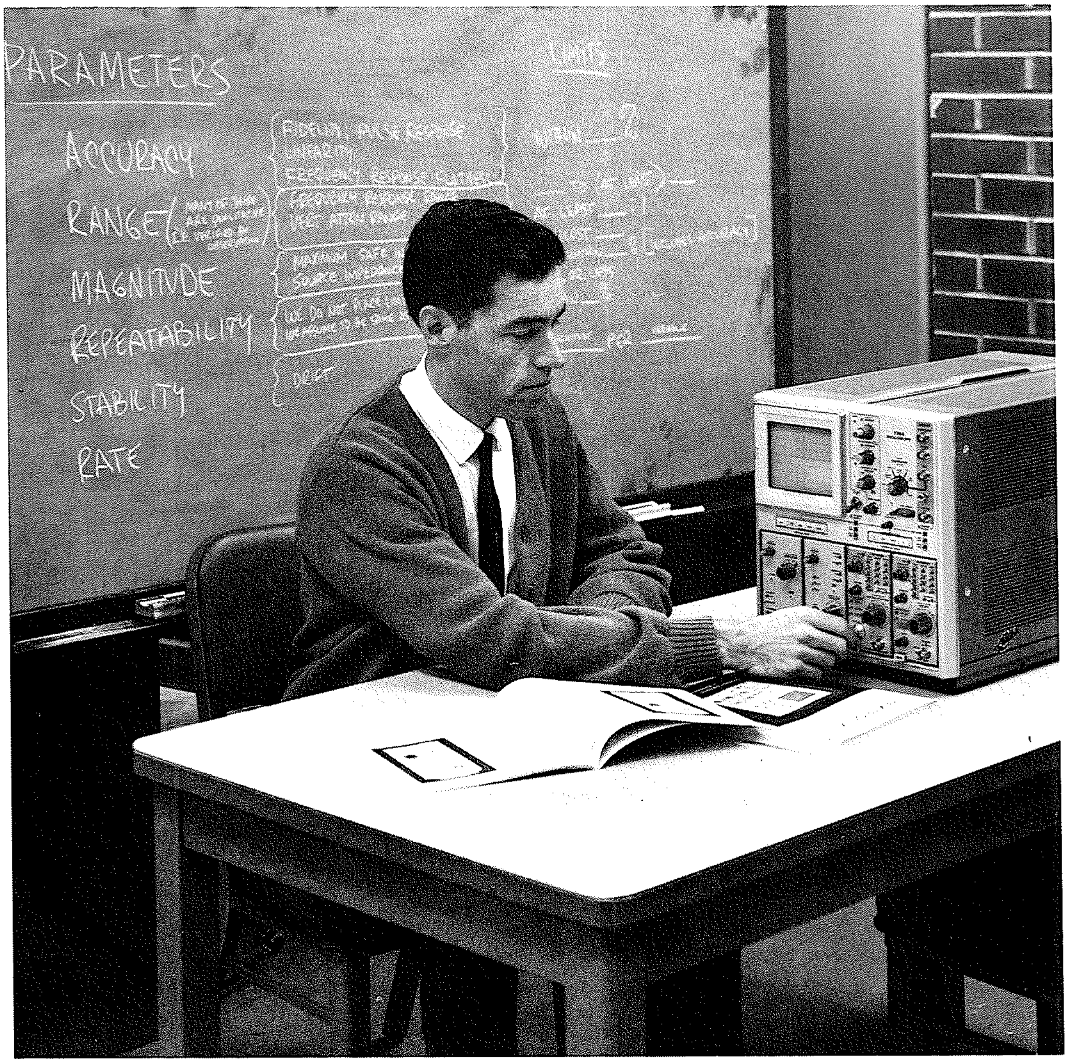
The oscilloscope is a tool that measures amplitude as a function of time. The tool is chosen based upon the user's needs for amplitude and time measurement. Thus, we need to know both the functions and how well it performs. We specify that the user can determine (1) whether a given product can make his measurements, and (2) whether the measurement can be made with the desired accuracy.

WHAT IS A SPECIFICATION?

A specification is a series of statements listing the functions of a product and describing how well those functions are performed. The specification describes the product, but it differs from other descriptions: It is absolutely factual, and subjective modifiers are avoided. We don't say "good stability" or "wide range". These are subjective expressions—How good is "good" stability for circuit design applications? "Wide" bandwidth oscilloscopes used for computer design are quite different from "wide" bandwidth oscilloscopes for TV service work.

Specifications provide no judgements to simplify the information contained in them. Each statement carries equal weight with all other statements. No prior judgement is made that one statement is more important than another. The bandwidth statement of an oscilloscope vertical amplifier gets the same emphasis as does the sweep output statement. The specification is a technical, impersonal statement objectively describing functions and performance.

A specification is an assertion which claims to be true. Therefore, a specification statement must be verifiable. Verification is an essential part of every specification. The verification procedure should be implied by the specification statement. Tektronix instruction manuals contain a performance check section which describes in detail how to verify *all* specification statements.



Rich Nute, Component Evaluation Manager

SPECIFICATION STATEMENTS

Specification statements fall into two major categories: function and performance. In designing (and using) a specification, functions must be described before performance may be described.

A qualitative statement describes the functions of a tool. Most instrument functions are represented on the front panel of a measuring instrument. For example, an oscilloscope dual-trace vertical amplifier mode switch indicates functions. Channel 1, Alternate, Added, Chopped, and Channel 2 are mode descriptions that provide essential function information. Verification of qualitative specification statements is made by observation—the instrument either possesses these qualities (functions) or it does not. Qualitative statements describe the controls and functions of the instrument.

A quantitative statement defines the performance of the tool. Performance is determined by how well a given function does its job. The vertical system of an oscilloscope displays signals at 5 mV/div—function. Its accuracy is 3% of 5 mV/div—performance. Verification of quantitative specification statements is made by measurement—a comparison with a standard. Performance statements provide a figure of merit for comparison of measurement tools, and, therefore, are the more important of the two kinds of specification statements.

A quantitative statement consists of two parts: A definition of the characteristic being specified, and the value assigned to that characteristic. In other words, a parameter and its limits.

PARAMETERS

A parameter is an arbitrary constant to which values (limits) may be assigned. There are relatively few real parameters used to specify analog oscilloscopes, but these are used over and over again in describing performance. For example:

PARAMETER	EXAMPLE
Accuracy:	Vertical deflection factor accuracy. Time-base accuracy.
Range:	DC offset range. Frequency response range.
Magnitude:	Sensitivity. Sweep output amplitude.
Stability:	Drift with temperature.
Repeatability:	This parameter is not usually specified for oscilloscopes. (Repeatabilty is sometimes erroneously assumed to be the same as accuracy.)
Rate:	This parameter is not directly specified for oscilloscopes; an example is sweep repetition rate, but this is usually implied by specifying sweep hold-off time.

Often, specifications are unclear because of poorly defined parameters. Avoiding vague specifications is a prime consideration in designing a product specification.

The most crucial test of a specification statement is to ask, "How can this be verified?" If the parameter cannot be measured or interpreted without further definitions and qualifications, then it cannot be useful. The specification must describe the products as clearly as possible.

LIMITS

Associated with each parameter is a set of limits, high and low. In a specification, the limits define the bounds of performance. The vertical deflection factor accuracy (parameter) is within 3% (performance limits) of indicated deflection factor. The limits of a parameter are described with words such as:

Within 3% of indicated value
7 ns or less
At least 150 MHz

In this way, we define the performance limits of a product.

However, the word "limits" can be taken in two ways. In one sense every product has performance limits. It doesn't do all we want it to do. An oscilloscope may be limited to 50-MHz frequency response. In a different sense, vertical deflection factor may be accurate within 3%. Because this limit is specified, the oscilloscope is an accurate measuring tool of known performance.

ERRORS

No product does its job perfectly. There are always errors introduced by the measuring tool. Errors are usually expressed as a percentage. Whenever percentage is used, the question must always be asked, "Percentage of what?" Though not expressly stated, it is implied to be "of indicated deflection factor". Or, we can turn this around and say that the signal may be 3% different than measured.

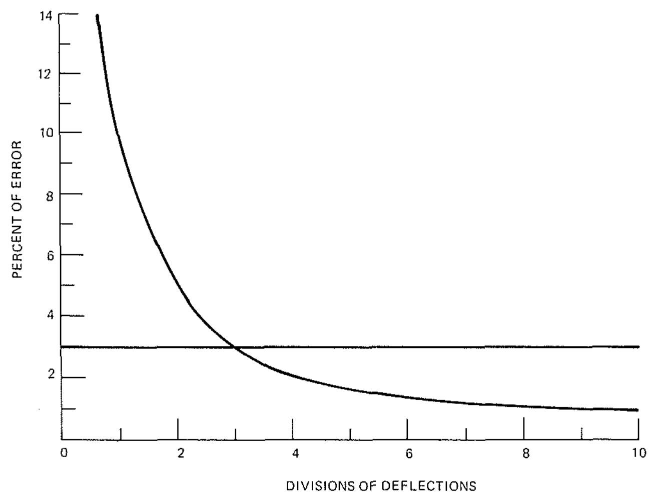


Fig. 1. The straight line indicates a cumulative error while the curved line indicates a discrete error.

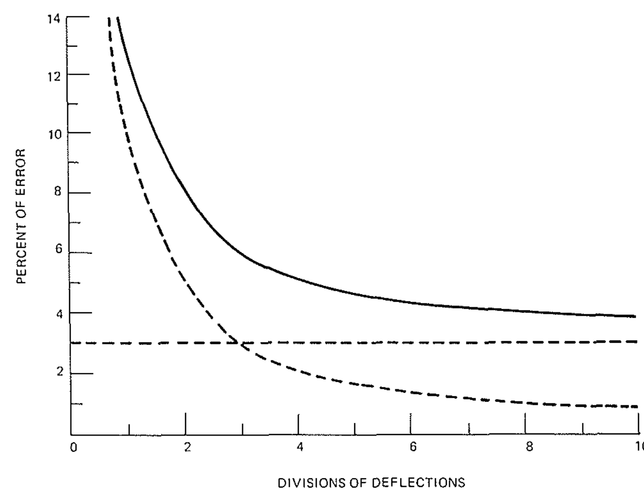


Fig. 2. Combined cumulative and discrete errors.

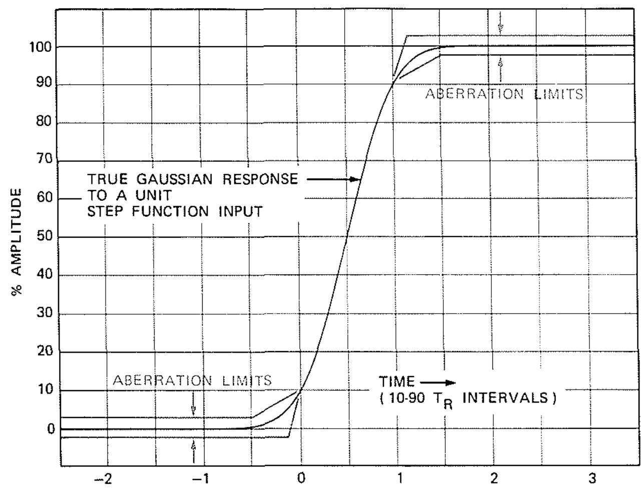


Fig. 3. Typical Oscilloscope Step Response.

Errors are of two types, cumulative and discrete. A cumulative error is expressed as a percentage of indicated value. An oscilloscope time base contains cumulative errors. No matter what sweep speed is used, the error is a constant, e.g., 3% of indicated value.

A discrete error is expressed as a magnitude. When reading values of a signal on the CRT, the center of the trace is uncertain. If the trace is 0.04 divisions wide, then this is a constant error. For a time-interval measurement of 0.4 divisions, the error is 20%. For a time-interval measurement of 8 divisions, the error is 1.0%. For a discrete error, the percentage error changes with magnitude.

Oscilloscope sweep delay specifications combine both cumulative and discrete error statements. Accuracy statements take the form "within 1% and 0.02 multiplier divisions".

Even with this rigorous approach to designing specifications, some statements are still not clear because of the lack of a standard for comparison. Oscilloscope step response is an outstanding example. Even if there were a perfect step from which to measure step response, there is no mechanism to clearly convey the deviation from that perfect step. If aberrations are 3% or less, a useful picture is still not conveyed since many different responses are possible within the band provided.

In spite of efforts to be as complete and thorough as possible in designing a specification, it is the responsibility of the user to interpret specifications. Specifications are written as independent functions—that is, each statement should stand by itself, regardless of other functions. As a result, all electrical statements are true over the entire specified temperature range.

A specification must compromise statements for the sake of clarity and assume that the user can determine the modifying conditions of other specification statements. When vertical deflection factor accuracy is specified within 3%, we do not qualify this statement as a function of frequency. The frequency response of an oscilloscope is defined at its —3 dB point, which is a 30% error in deflection factor accuracy. The user must put these two pieces of information together and determine that the oscilloscope exceeds its 3% accuracy limit well below its —3 dB frequency.

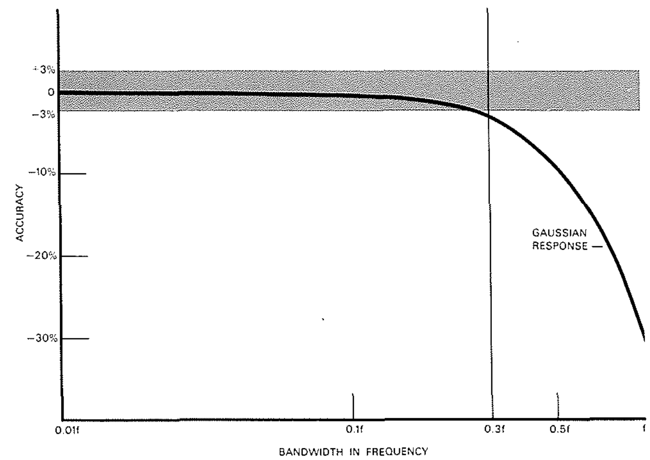


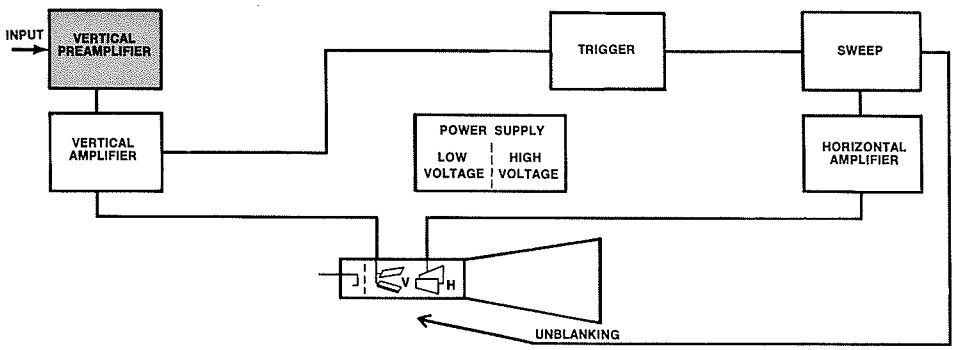
Fig. 4. Oscilloscope Frequency Response. Note that 3% deflection accuracy is exceeded far below the —3 dB point.

Specifications have both positive and negative connotations. We specify because we want to call attention to a particular measurement capability—for example, accuracy. Conversely, we must specify negative attributes of oscilloscopes to keep the user from assuming an error does not exist.

No oscilloscope has perfect step response. Therefore, if we say aberrations are within 3% of the input signal, there is a negative connotation about performance. Thus, limits define both intended performance (accuracy) and unintended performance (aberrations).

At Tektronix, everyone is concerned about specifications because the specifications describe and characterize the product. The ideas presented here are the result of the contributions of Tektronix people—Design Engineers, Calibrators, Manual Writers, Advertising Writers, Field Engineers, and Customers.

SERVICE SCOPE



TROUBLESHOOTING PREAMPLIFIERS

By Charles Phillips
Product Service Technician
Factory Service Center

This sixth article in a series discusses troubleshooting techniques in the preamplifiers of Tektronix instruments. For copies of the preceding five TEKSCOPE articles, please contact your local field engineer.

Substituting vertical preamplifier plug-in units is an excellent means of checking performance to the vertical amplifier input. Once a problem is isolated to a specific plug-in unit, plug-in circuit boards may isolate the problem even further. Once a problem has been traced to a specific block, a close visual check may pinpoint the problem. Often, burned components or loose leads can be spotted that shorten the troubleshooting job. Substituting the tubes or transistors offers a quick means of checking a suspected stage. **Always** return the original component to its place if the problem remains.

In the case of a plug-in, be certain the plug-in is seated properly and that there is no open connection. Plug-ins that use interlocks are particularly susceptible to this type of problem. Place the input selector to the DC position and turn off X10 amplifiers if they are available.

When troubleshooting a new instrument, take some time to familiarize yourself with the block diagram. Spending a few minutes with the instrument manual can give valuable insight into the particular problem.

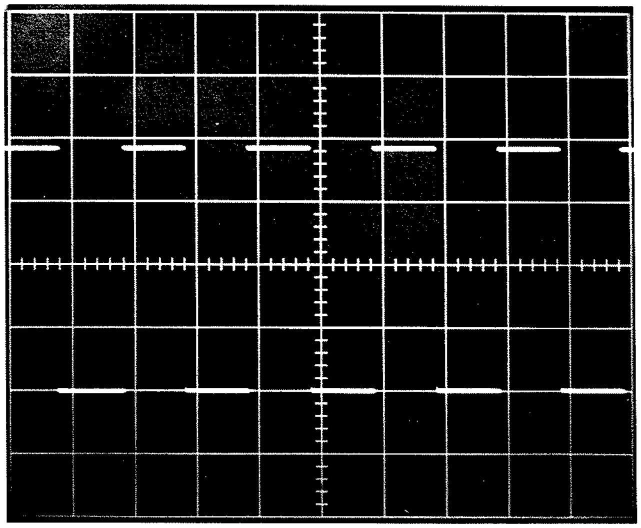
When no spot is seen, use the trace finder or the position indicator to see which direction the spot is deflected. Use the position controls to see whether the display may be centered. Should the indicator lights show that the trace is deflected off screen, invert the display. If the display goes off screen in the other direction, the problem is before the invert switch.

For problems after the invert switch, use a shorting strap, and starting with the output stages of the preamplifier, work stage by stage towards the input amplifier. The stage is working normally when the signal short causes a trace near the vertical center line of the CRT. A defective stage is indicated by the short not centering the trace on the CRT.

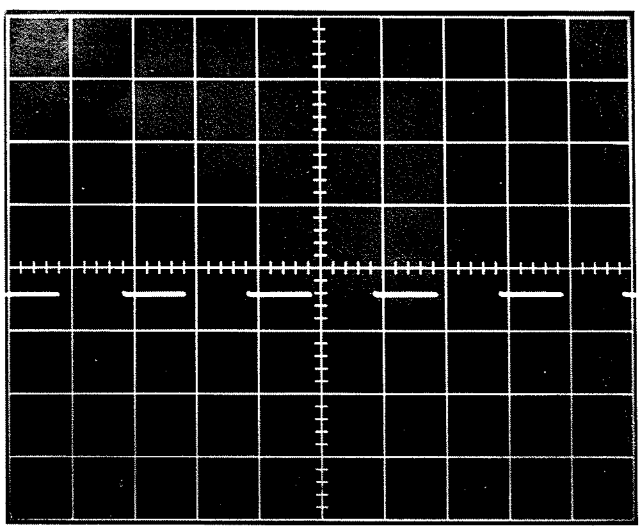
If the amplifier is well-balanced, the position control will be close to midrange when the trace is centered. If a problem exists, switch the output stages to obtain balance near the potentiometer midrange point.

Select output tubes or transistors so that the trace may be positioned off screen in both directions.

Set the calibrator to a convenient figure such as 1 V. Adjust the vertical sensitivity to 0.2 V/div and select a single channel mode. Position controls and the attenuator balance should be adjusted midrange. In some cases, it is convenient to turn the variable gain counterclockwise to lessen the effect of the attenuator balance control.



Attenuator error with 4 div of deflection (2½% per mm).



Attenuator error with 10 div of deflection (1% per mm). Centerline reference.

Good balance is particularly important in multi-trace instruments. For example, good balance is indicated by both traces of a dual trace being within a centimeter of center screen. It's often wise to switch tubes or transistors until A is the upper trace and B is the lower trace (when all controls are centered). In general, when tubes are replaced by raw tubes, be certain to operate the instrument overnight and rebalance.

A technique that may be used to optimize attenuator accuracy is to apply 10 centimeters of CRT deflection and use the oscilloscope as a null detector. This method is particularly valuable on oscilloscopes with limited vertical scan. By using the center line as a reference, DC couple a signal 10 times the attenuator setting on the straight-thru attenuator position.

For example, at 50 mV/div, apply a 500-mV signal to the input. Position the trace so the upper portion of the waveform is aligned with a convenient vertical reference. Check each attenuator position for deviation always keeping the ratio of signal to attenuator 10:1. Under these conditions, each mm of CRT display is equal to 1% error. This method provides much greater resolution since CRT characteristics (geometry, compression, expansion, edge defocusing, etc.) do not enter into the measurement accuracy. After the attenuator ratios are checked for proper values, then gain can be set.

Problem: Microphonic noise that appears when switches and controls are moved. A simple consistent method of checking microphonics is to rap the instrument at the top of the front panel firmly with the palm of your hand.

Solution: Tubes are the most common offenders. Replace as required. If a control or switch is noisy, spray a good contact cleaner directly on the contacts. For noisy potentiometers, use a hypodermic needle and insert one drop on the shaft, contact, and seams. Do not remove the potentiometer covers. In the case of intermittent problems, rotate the instrument in 90° increments and make the above microphonic check on each axis.

Problem: Grid current gain error on DC measurements. If grid current causes a 4-cm signal reference to shift 2 mm, the error is 5%. Check by selecting a reference line on the most sensitive attenuator position. Terminate the input with a 50-Ω termination and keep within 2-mm maximum trace shift.

Solution: Replace input tube to correct this problem.

Problem: Input cap leakage causes the trace to go off screen when operating in the AC mode with a DC voltage applied. For example, at 5-mV sensitivity when checking power supply ripple, 50 mV of leakage will cause the display to be positioned off screen. To check for cap leakage, go to the AC position and center the trace at 50 mV/div sensitivity. Apply ≃500 V to the input and see how far the trace moves.

Solution: The capacitor should be replaced if trace shift exceeds 50 mV.

Problem: Input capacitance range incorrect. It is important that all attenuator ranges have an equal RC so the probe doesn't have to be re-adjusted as the volts/div is changed. When calibrating—if you have dual channels, you want both channels to match.

Solution: Physical arrangement of the input coupling cap can alter the capacitance range of the adjustment if needed. If a capacitance normalizer isn't available, one channel input C can be set to midrange and a 10X probe used to compensate the other dividers.

Problem: Position balance and range. If amp is balanced, the position control will be close to midrange when trace is centered and this will allow the position control to move the trace off screen in either direction.

Solution: Switch output stages to get proper balance.

Problem: Spike on front end of fast rise pulse that cannot be adjusted out. (Cathode interface.) Because DC filaments are used in nearly all plug-ins, varying line voltage does not change the pulse leading edge as it does in an oscilloscope amplifier.

Solution: Replace output amplifier tubes or plate load resistors.

Problem: Tilt on chopped waveshape exceeds 1 mm.

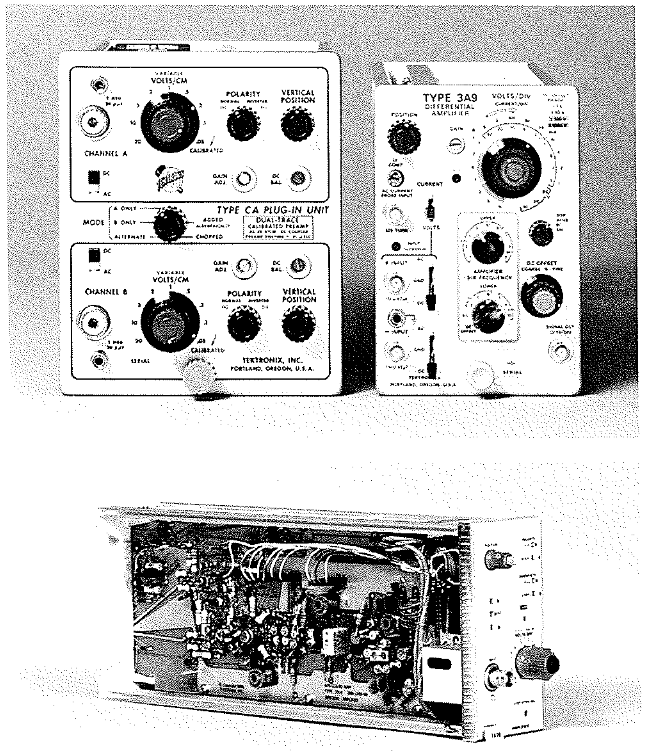
Solution: Select balance amplifier tubes (or transistors) for minimum tilt. Check for leakage in one or more of the switching diodes.

Problem: Interactive trace display, trace is displaced as other trace is positioned across it.

Solution: Check for leaky diodes in switching circuit.

Problem: Bandpass of each channel of a multi-trace unit does not match.

Solution: Select input cathode followers or switch for match.



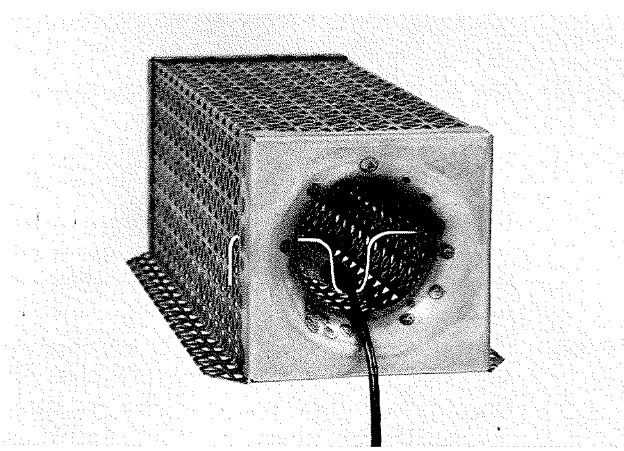
Tektronix plug-in preamplifiers are manufactured in several different configurations. Upper—Letter-Series and 560-Series Plug-Ins. Lower—New 7000-Series Plug-In.

SOLDERING IRON SAFETY TIP

Here's a convenient tip to prevent light weight pencil soldering irons from continually falling on the floor. The small 15-watt irons now commonly in use for circuit board work often fall from their holders when their cord is brushed.

Take a 6-inch piece of 14 or 16 gauge wire and place a U-shaped bend in the center of the wire. A little experimenting will quickly find the optimum wire shape to securely hold the iron in place. Adjust the wire so the iron must be lifted to be removed from its holder. Attach the wire to the holder with two right angle bends at the extremes of the wire.

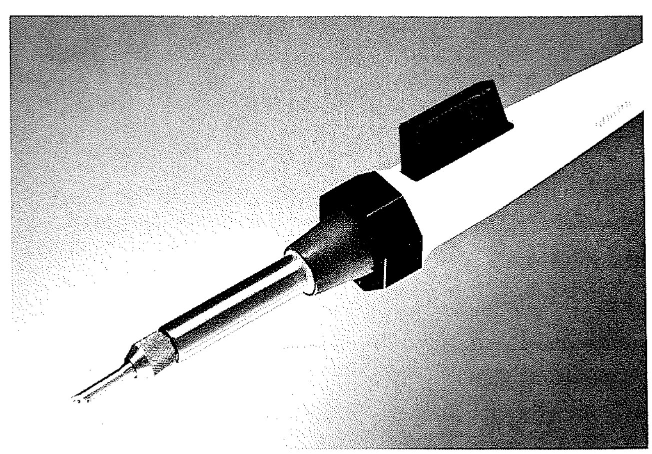
The same technique will also work for the larger 25 and 40 watt irons.



NEW SOLDERING IRON DESIGN

New soldering irons are currently available that are particularly convenient for your circuit board work. The model shown utilizes a built-in solder remover and makes use of special tips with holes in them. The solder is drawn into the tip as the bulb is depressed, thus simplifying the repair job.

An additional advantage of this design is that when removing components from printed circuit boards the hole in the tip provides a convenient method of straightening the ends of the wire. Thus, the component can be removed neatly and cleanly with minimum interference with the board.



USED INSTRUMENTS

INSTRUMENTS FOR SALE

1—Type 547, SN 4975. 1—Type 1A1, SN 13860. 1—Type 202-2. All in excellent condition. All for $2,000. Contact: Sterling Bradley, 717 Goodyear, Irving, Texas 75060. Telephone: (214) 255-7071.

1—Type 535, SN 11516. 1—Type K, SN 012282. Price: $525. Contact: John Phelps, General Electric Co., Electronics Park, Bldg. 9, Rm. 117, Syracuse, New York 13201. Telephone: (315) 456-3763.

1—Type 316. Perfect condition. Price: $400. Contact: N.C. Planning Dept., Fenn Mfg. Co., Fenn Road, Newington, Connecticut 06111. Telephone: (203) 666-2471.

1—Type 63, SN 283. Factory reconditioned. Used approximately 8 months. Price: $100. 1—Type 2B67, SN 25788. Used approximately 8 months. Price: $200. Contact: Roger Kloepfer. Telephone: (517) 487-6111, Ext. 231.

1—Type 1A1. 1—Type 1A2. 1—Type 516. All instruments are about 1 year old. Contact: Lee Merritt, Interactive Data Systems, 17785 Skypark Circle, Irvine, California 92664. Telephone: (714) 549-3329.

1—Type 453, SN 28439 with Type P6010. Never used. Price: $1,400. Contact: Mr. George Patterson. Telephone: (313) 663-8791.

1—Type 3A7 Plug-In, SN 513. New. Contact: Marty Husmann, Eastman Kodak Co., 925 Page Mill Road, Palo Alto, California 94304. Telephone: (415) 327-7200.

1—Type R543B, SN 00910 with Type H, SN 015509. Like new. Price: $1000. Contact: Terry Wilson, Communications Contact, Inc., 618 National Avenue, Mt. View, California 94040. Telephone: (415) 961-1480.

1—Type 3A9. Contact: George H. Halsey, 45 Foundry Avenue, Indiana, Pennsylvania 15701. Telephone: (412) 463-7446.

1—Type 514D. Excellent condition. Price: $300. Contact: D. D. Brunnenmeyer, 2533 Clear Lake Way, Sacramento, California 95826. Telephone: (916) 363-2730.

1—Type 546, SN 002286 with CA plug-in. Three months old. Price: $1850. Will deliver within 100 mile radius. Contact: Mr. Porter Schultz, Box 247, Aptos, California 95003. Telephone: (408) 722-4177.

1—Type 502A, SN 206670. Price: $700. 1—Type 502, SN 5769, modified to a 502A. Price: $700. Contact: Mr. Herbert Grams, Lawson Co., 2011 West Hastings, Chicago, Illinois 60608. Telephone: (312) 226-5300, Ext. 340.

1—Type 323, SN 300822. Price: $900. Contact: Melvin A. Holznagel, Route 4, Box 273A, Sherwood, Oregon 97140. Telephone: (503) 625-7121.

1—Type 1A7A, SN 20351. Price: $450. Contact: Wilhelm F. Kartak, 10720 S. W. Fonner, Tigard, Oregon 97223. Telephone: (503) 639-4568.

1—Type 561A. Approximately 5 years old. Price: $600. Contact: Mr. R. C. Dodds, 4932 Glacier, San Diego, California 92112. Telephone: (714) 287-1280.

2—Type 535A, SN 32495 and SN 32335. Both with CA plug-ins. Price: $830. (Each). Contact: d b Electronic Enterprises, 13526 Pyramid Drive, Dallas, Texas 75234. Telephone: (214) 241-2888.

1—Type 502A, SN 26362. Price: $750. Approximately 2 years old, in good shape. Contact: Cort Platt Metrology, Inc., 126 Jackson Avenue North, Hopins, Minnesota 55343. Telephone: (612) 935-1441.

1—Type 503, SN 008159. Price: $550. Includes table and miscellaneous accessories. Contact: Wesley Wilson, Jr., Wesley L. Wilson Company, 5938 West Montrose Avenue, Chicago, Illinois 60634. Telephone: (312) 282-5535.

1—Type B, SN 018696. Excellent condition. Contact: J. P. Stein, Emcee Electronics, Inc., P. O. Box 32, 177 Old Churchmans Road, New Castle, Delaware 19720.

1—Type 514D, SN 1163. Price: $300. Contact: Mr. Leonard Valle, 3143 Mildred Street, Wayne, Michigan. Telephone: (313) 722-2185.

1—Type 535A, SN 24917. Price: $1000.
1—Type 535A, SN 25772. Price: $1000.
1—Type CA, SN 30061. Price: $225.
1—Type B, SN 14320. Price: $100.
Contact: Mr. Charles Weiss, Communication Radio, 150 Jerusalem Avenue, Massapequa Park, New York 11762.

1—Type 575, SN 010888. Excellent condition. Contact: Jack Cannon, EE Dept., Vanderbilt University, Nashville, Tennessee 37203. Telephone: (615) 254-5411.

1—Type 514 AD, SN 3708. 1—Type 512, SN 3286. 1—Type 315, SN 2207. 1—Type 531/53A, SN 1714/597. 1—Type 531/53B, SN 3366/1736. 1—Type 531/53B, SN 619/2672. 1—Type 121. Contact: Fred Muessigmann, Watson Instrument Co., 446 Lancaster Avenue, Malvern, Pennsylvania 19355. Telephone: (215) 647-3777.

1—Type N, SN 335. 1—Type 280, SN 246. Recently completely recalibrated and are in very good condition. Contact: Mr. Warren Herne, Teledyne, Inc., Crystalonics Div., 147 Sherman St., Cambridge, Massachusetts 02140. Telephone: (617) 491-1670.

1—Type 576, SN 004583. Excellent condition, used very little. Completely recalibrated. Price: $900. Contact: Carrier Corp., Carrier Parkway, Syracuse, New York 13201. Attn: Jack Fields. Telephone: (315) 463-8411, Ext. 3365 or 3366.

INSTRUMENTS WANTED

1—Used 3B3 Time Base Unit. 1-2 years old. Contact: Roger Kloepfer. Telephone: (517) 487-6111, Ext. 231.

1—Used 611 Oscilloscope. Contact: Mr. R. H. Roberts, Dallas Cap and Emblem, 2924 Main Street, Dallas, Texas 75226. Telephone: (214) 742-4511.

1—Type 647A with plug-ins. Consider Type 647 if very reasonable. Any condition. Contact: John H. Cone, 775 South Madison, Pasadena, California 91106. Telephone: (213) 792-5271 noon to midnight.

1—Type 519. Contact: George Lichterman, R. E. Goodheart Co., Inc., P. O. Box 1220, Beverly Hills, California 90213. Telephone: (213) 272-5707.

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TEKSCOPE

Volume 2 Number 1 February 1970

Customer Information from Tektronix, Inc., P. O. Box 500, Beaverton, Oregon, 97005
Editor: Rick Kehrli Artist: Nancy Sageser For regular receipt of TEKSCOPE contact your local field engineer.

1970 CUSTOMER FACTORY TRAINING SCHEDULE

The curriculum for the Tektronix Customer Training Center in Beaverton, Oregon, is listed below. Courses vary in length from 2-4 weeks and are provided at no cost for customers passing the Tektronix Entrance Exam. For further details on the Tektronix factory training program, refer to the August, 1968, Service Scope pages 8-9. For additional information and course availability, consult your local field engineer.

454/453

January 12-23
March 16-27
June 1-12
August 17-28
November 2-13

454/453/422

January 12-30
March 16-April 3
June 1-19
August 17-September 4
November 2-20

Spectrum Analyzer
491/1L10/1L20/1L30

May 4-15
October 5-16

Spectrum Analyzer
491/1L10/1L20/1L30/1L5

May 4-22
October 5-23

530/540

February 2-13
April 13-24
September 14-25
November 30-December 11

530/540/545B/1A1/W

February 2-20
April 13-May 1
November 30-December 18

530/540/550/1A1

September 14-October 2

544/546/547/556/1A1

April 13-May 1
August 17-September 4

Storage
549/564B

June 15-26

561B/3A6/3B3

February 23-March 6
July 27-August 7

561B/3A6/3B3/565/564B/2B67

February 23-March 13
July 27-August 14

Sampling
561B/3S2/3T2

May 4-15
October 5-16

Sampling
561B/3S2/3T2/1S2

May 4-22
October 5-23

Sampling
561B/3S76/3T77A

March 23-April 3
September 14-25

Sampling and Readout
561B/3S76/3T77A/6R1A

March 23-April 10
September 14-October 2

Sampling and Readout
568/3S6/3T6/230/241

February 16-March 6
June 8-26
November 30-December 18

647A/11B2A/10A2A

August 3-14

585A/82

July 6-17

585A/82/545A/1A1/W

July 6-24

New Generation
7704/7A12/7A16/7B70/7B71

November 30-December 18

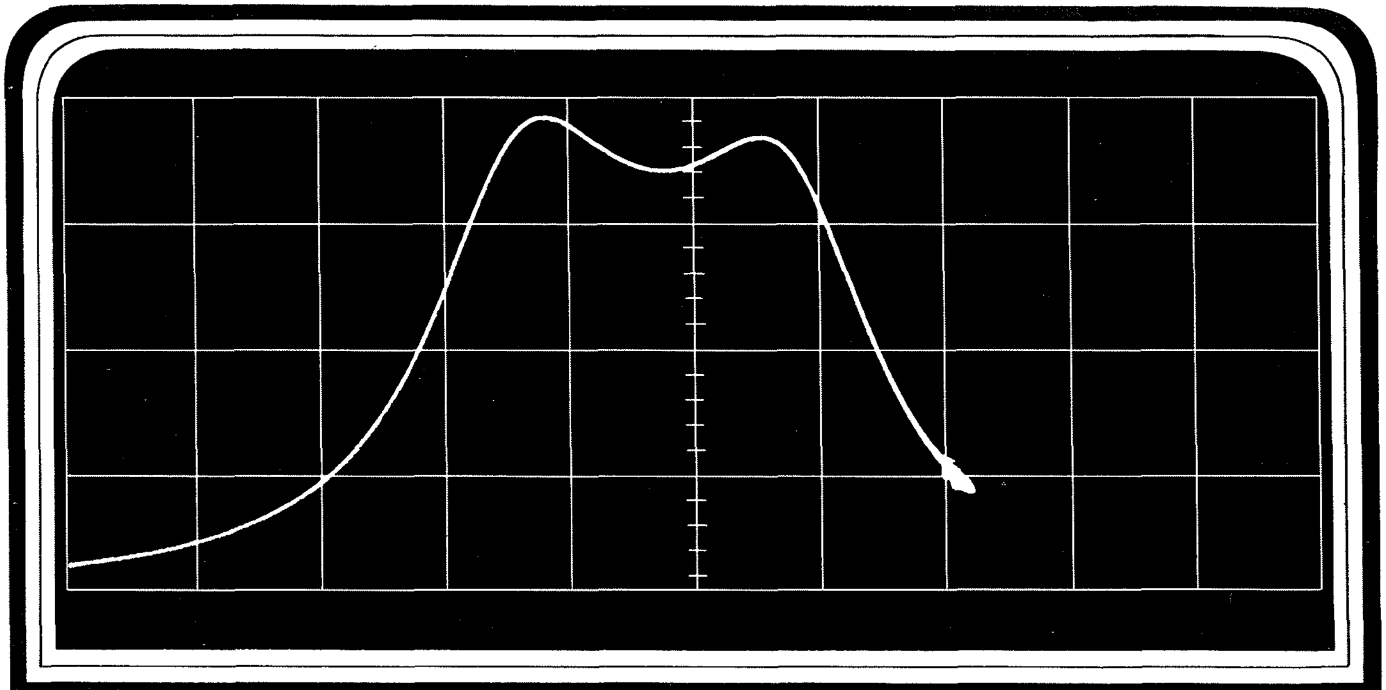
S-3130 Digital System

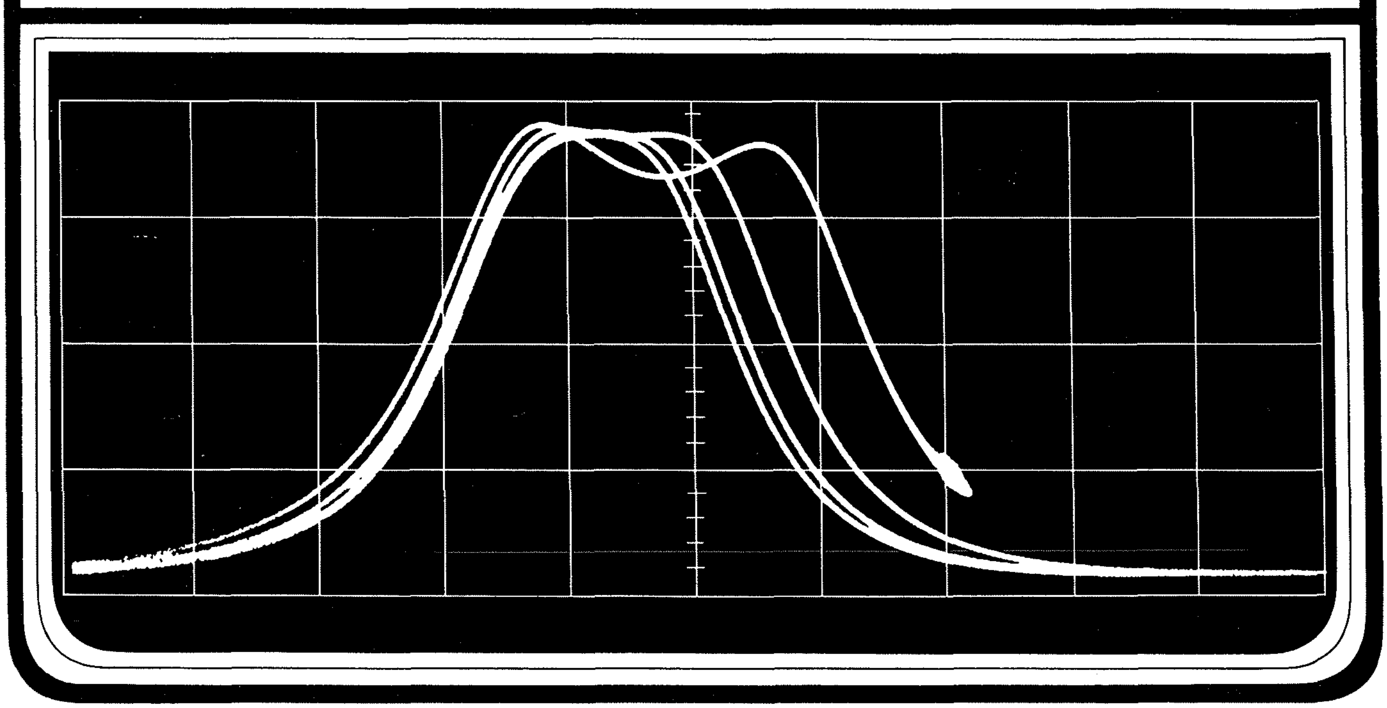
January 12-February 6
March 9-April 3
April 13-May 8
July 6-31
September 14-October 9
October 19-November 13

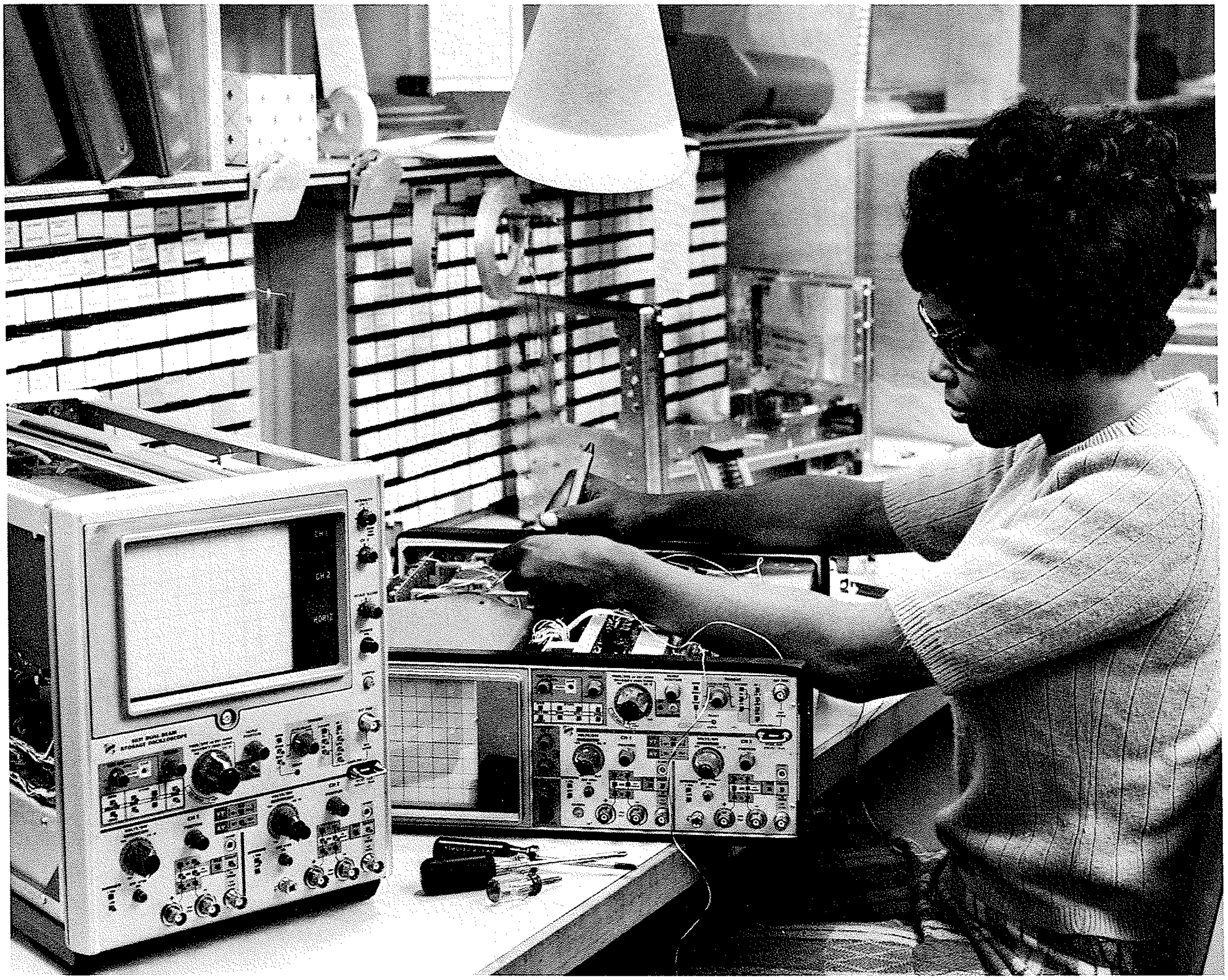
TEKTRONIX

TEKSCOPE

APRIL 1970







A DUAL-BEAM FAMILY

Now both dual-beam storage and non-storage oscilloscopes are available with large screen and auto scale-factor readout. Measurement ease and accuracy are increased by human engineering and performance features.

COVER—Long-term changes in a voltage controlled filter response curve are plotted by both beams of the 5031 Split-Screen Storage Oscilloscope. This instrument is holding and simultaneously displaying "history" as new information is recorded and erased.

LARGE SCREEN AND READOUT

The new, 50% larger screen area plus scale-factor readout displays more information than previously possible. These unique features provide new measurement ease in this complete family of dual-beam oscilloscopes. All six instruments have a display area of approximately 10 x 12.5 centimeters. The internal graticule is scaled in an 8 x 10 division format on the 6½-inch dual-beam

A cabling change is installed by Prototype Technician, Sandra Lowe. Superior construction starts early in Tektronix instruments.

CRT and the large-screen area of the 5030 and 5031 oscilloscopes allows generous separation of displays. For example, a display of two waveforms, each occupying 4 centimeters, will be separated by 2 centimeters.

This dual-beam series uses no time sharing as is required in a dual-trace instrument. The possible errors in time correlation between traces in dual-trace alternated modes are eliminated and true simultaneous dual displays are established. No resort to special control setups and trigger sources is necessary. Each independent beam has its own vertical amplifier and separate intensity control, and one time base drives both beams simultaneously.

The 5030/5031 Series uses fiber optic readouts to ease interpretation of deflection factors for both visual observation and photographic recording. The large fiber optic readout panel (located just to the right of the CRT) places each scale factor in the logical place; where the operator is looking. The user is not distracted by searching for scale factors near the knobs where most instruments locate this information.

Each readout is activated by the amplifier and timebase controls that affect changes in calibration and modes of deflection. Voltage, current and time units are *all* automatically selected by the same switches that control the internal circuitry used for these three modes. The automatic display of scale factors includes indication of an uncalibrated condition during the use of a variable time or deflection sensitivity control. When an operator wants to use a variable control, he pushes the recessed control causing it to pop out to an active position. An active variable will be indicated by a greater than sign (>) just to the left of the appropriate readout. A second push removes the > sign from the readout and restores calibrated operation.

The user will see a crisp, high-resolution display over the full screen for both beams, as a sharp presentation is maintained at varied intensity settings with no adjustment. There are no front panel focus or astigmatism controls to contend with. Deflection defocus is less than 1.5 to 1 on any axis. To assure display accuracy, an additional deflection element has been added to the CRT. This element is driven by an active geometry circuit that corrects geometry dynamically with beam position information.

CONTROL LOGIC

A versatile, single-beam instrument has many modes of operation. A versatile, dual-beam scope should have more modes than a single-beam unit. The 5030/5031 Series has this mode versatility, but it does not add complexity to the operator's tasks.

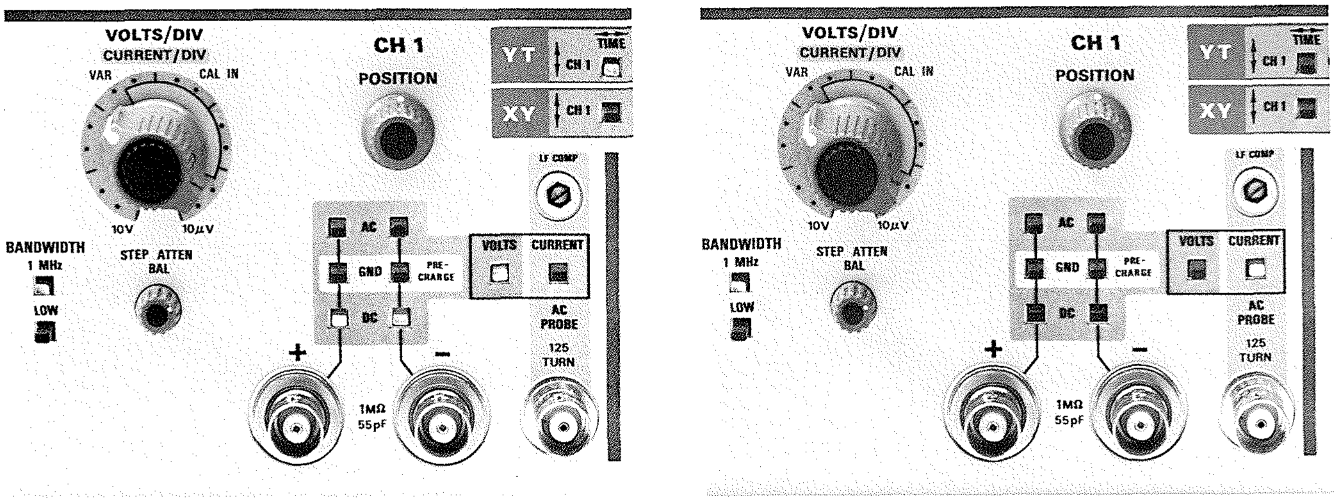
Instrument design evolves over a period of time and reflects the original objectives and inspirations of the people involved. This design effort in the 5030/5031 Series is reflected by the logic of each control and the grouping of controls. The operator using these controls gets results quickly and without ambiguity. The design effort in the 5030/5031 Series has produced fewer controls, each with maximum usability and simplicity, while increasing the number of operational modes.

Operating modes are not always easily identified in some instruments. A control can mislead an operator when it is not in use. If a control looks no different, active or inactive, the user may be uncertain as to what mode is really in use. The 5030/5031 instrument group positively identifies the mode in operation. The user does not sense any ambiguity of control meaning when making measurements with this series.

Four methods of identification are used in the 5030/5031 Series:

1. The CRT Display
2. Panel Indicator Lights
3. The Fiber Optic Readout
4. Illuminated Push Buttons

Panel lights are common to many instruments. The usual applications of scope panel lights are in warning indicators such as "uncal". The 5030/5031 Series uses only one panel light, the magnifier "on" indicator. The important indication of "uncal" has been moved from the panel to the display area where it logically belongs. The use of a variable control places a greater than sign (>) where the user needs it, in front of the appropriate fiber optic scale-factor readout.



Mode Identification

Push buttons quickly establish the mode needed for a measurement. Illumination of the push buttons activated complete the identification of mode.

An example of mode identification and control usage is revealed by a look at the front panel and the display area. Channel 1 and Channel 2 are readily switched from a voltage to a current mode. When operating in a *voltage* configuration, the push-button switches in use will be illuminated and the scale-factor readout will indicate voltage units. Pushing the *Current* button will extinguish illumination of all switches unique to voltage, change the scale-factor readout to current units, and illuminate the current button. Switches common to both current and voltage remain illuminated when active after mode change.

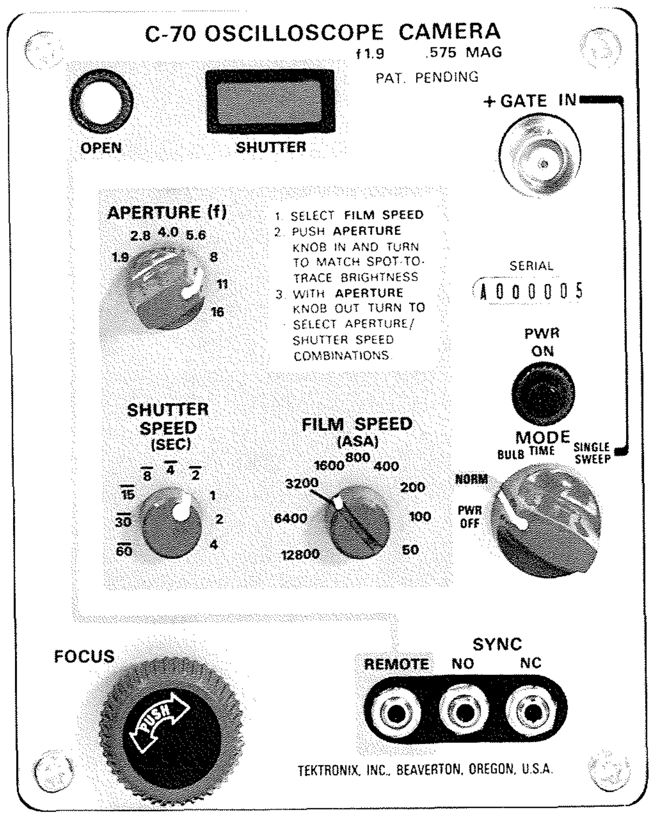
Scale-factor readout, control illumination and color keying allows the new user of the 5030/5031 Series to rapidly feel at home because ease has been designed into this dual beam measurement system.

NEW CAMERA EASE

Reduction of photographic errors and adjustment effort have been achieved in a new camera. Prior to the introduction of all the new Tektronix cameras, waveform photography could require considerable trial and error setup efforts. Several new approaches have been incorporated in this new camera series to minimize focus and exposure errors.

The C-70 is designed for the 5030/5031 and other Tektronix instruments with 6½-inch CRT's. The C-70 does not require a focus plate. This camera uses two adjustable bars of light projected onto the CRT to simplify adjustment. Alignment of the light bars with one focus control quickly sets the camera for sharp results.

With an easy adjustment of a projected photometer spot to match the trace intensity, the C-70 camera user can set the correct lens opening for proper exposures. This photometer spot is new to oscilloscope cameras and plays an important part in the quick and error-free setup of all the new Tektronix cameras. After setting exposure, any subsequent adjustment of shutter speed or f-stop, automatically adjusts the complementary control to maintain correct exposure value.



The C-70 Oscilloscope Camera adjustments are made here. Correct exposure and sharp focus are quickly set with no film waste.

TIME BASE AND TRIGGER

Any YT display requires a stable location of the T_o reference. This point is established by triggering. Early triggered-sweep instruments required five distinct steps to establish a triggered time base and the desired T_o point.

Step 1. Set Sweep Stability

Step 2. Select Trigger Source

Step 3. Select Trigger Coupling

Step 4. Select Trigger Slope

Step 5. Set Trigger Level

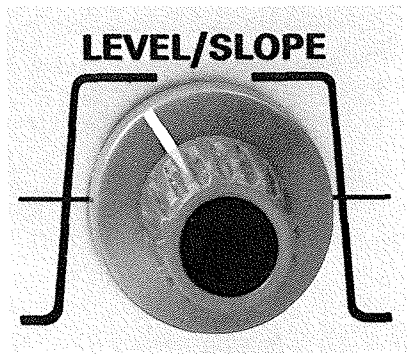
If the operator was inexperienced or rushed, he encountered difficulties. Even when he strived for optimum front panel control settings, he could be frustrated by marginal performance resulting from component aging effects and improper internal adjustment.

An ideal scope would automatically establish T_o without resorting to control use. Circuit design would eliminate aging effects and the need for internal adjustments. Tektronix engineering efforts in the 5030/5031 Series have resulted in a significant step towards an ideal triggering and time base system.

After selection of source and coupling, most scopes require slope selection with a separate single-pole, double-throw switch. Then, the operator searches for a point for sweep start on the trigger waveform. This is commonly done by varying a trigger level control over a fixed voltage range to provide a comparator with an input that is equal to the desired trigger point on the incoming waveform.

Oscilloscopes ordinarily provide some form of automatic operation based on a zero comparison voltage. This allows triggering on all signal levels including low level noise and other sources of display jitter. When level selection is provided along with automatic operation, a level can be selected that eliminates noise triggering. The level selected may also exceed a triggerable point causing loss of stable display.

The 5030/5031 Series features fully automatic, hands-off triggering. After a source is selected, activation of the new PEAK-TO-PEAK AUTO mode will present stable displays on virtually all triggerable waveforms without adjustment. The simplified triggering of the 5030/5031 Series is the result of two lines of parallel development aimed at usability. One—a simplification of control; two—the minimization of internal adjustments and aging effects.



This one knob selects both slope polarity and triggering level.

The Peak-to-Peak mode uses the trigger signal itself to set the limits of triggering level. Peak detectors set the upper and lower DC voltages available to the level selector so that the level control cannot select a trigger point above or below the available trigger signal amplitude.

The 5030/5031 instruments, when operated in the Peak-to-Peak Auto mode, can be set for any trigger point from peak negative through peak positive. Simple rotation of the continuous 360° turn Level/Slope control selects all the possible level and slope triggering points. The user cannot exceed the trigger level range and he does not have to stop to select slope. Slope is "selected" by relays at the 6 and 12 o'clock positions of the trigger/slope control. In the absence of a triggering signal, the time base will "free run" to provide a high-duty-cycle, bright baseline.

The Peak-to-Peak Auto mode control is activated by pressing a push-button switch located with the other trigger push buttons in a color grouped area of the panel. All active mode controls are illuminated.

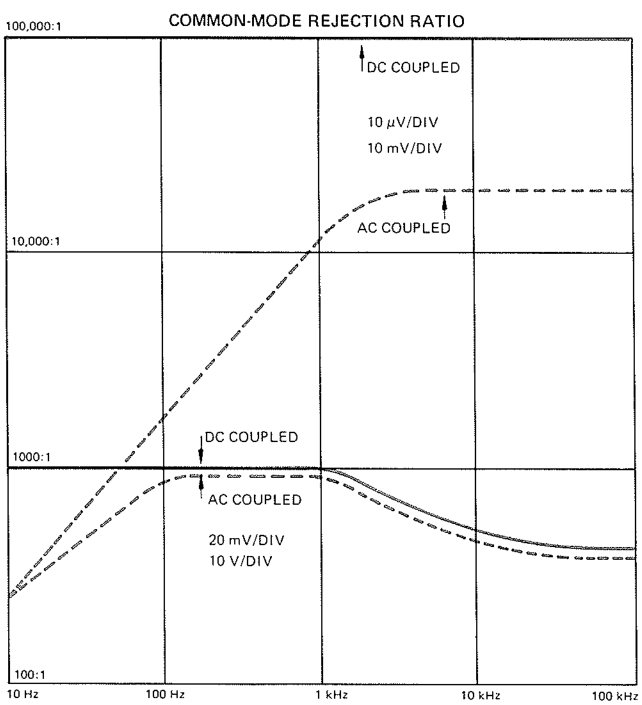
Two unique Tektronix integrated circuits and six transistors perform all functions of triggering and time base generation. Only two adjustments are required to calibrate the time base and center the trigger level recognition response. The built-in circuit stability minimizes time base and trigger problems.

TEN MICROVOLTS PER DIVISION

An instrument with 10 microvolts per division sensitivity must reflect concern with the low-level measurement environment. Noise and drift in the display must be minimized. The amplifier must be capable of rejecting unwanted common-mode signals that often exceed the desired input in amplitude. While being used, its own operational requirements must not detract from the user's measurement efforts.

This series has a tangential noise specification of less than 15 microvolts in voltage modes and less than 200 microamps in current modes. Trace stability is excellent and is specified as less than 10 microvolts or 0.1 divisions per hour after 2.5 hours warm up. Less than 5 microvolts per minute drift is achieved after only one hour warm up.

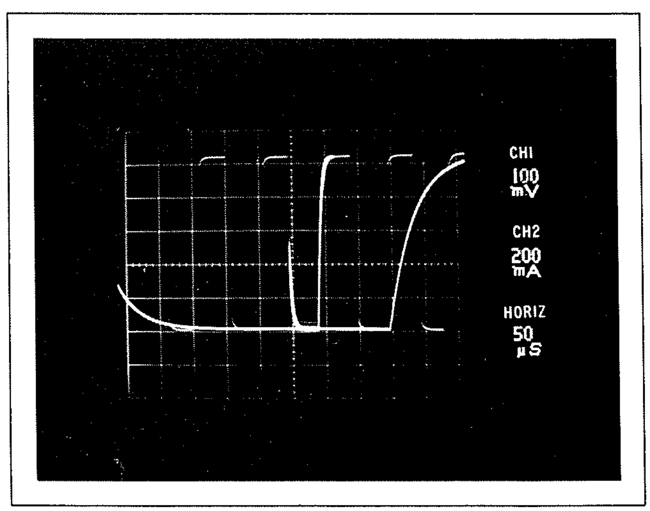
Common-Mode Rejection, a vital specification of a differential amplifier, must be considered over a range of input voltages at varying frequencies. The 5030/5031 instrument group maintains at least a 100,000:1 ratio when DC coupled up to 100 kHz at 10 microvolts per division to 10 millivolts per division. The ratio is still at least 500:1 at 100 kHz when AC coupled at 20 millivolts per division to 10 volts per division. The same attention to the circuit design that resulted in excellent noise and drift performance has achieved excellent CMRR. Another feature representative of the attention to operational ease in this series removes a common annoyance from AC coupled operation. An input capacitor can often cause a trace drift-in period before a measurement can be made. When operating in the sensitive ranges, the charging of the input capacitor from a test point may require a long wait for the trace to stabilize. The necessary charge time can now be eliminated by using the *Precharge* Position of the vertical input. This will allow the input coupling capacitor to charge during the base line zero volts reference check. Use of the AC push button after precharge will now present a drift-free trace.



Specified Common Mode Rejection Ratios of both Channel 1 and Channel 2.

NEW MAGNIFIER DISPLAY

A novel approach to identifying magnified sweep display is included in the 5030/5031 instruments. Magnification is an expansion of a portion of a time-base display by increasing the gain of the horizontal amplifier. In either of the "Mag On" or "Mag Off" conditions, what is centered horizontally in the display area should be the same. This centering is an identification aid common to most scopes. To further aid the operator in identifying the location of the magnified display in time on the unmagnified display, a special LOCATE button is provided. Pressing this button will restore an unmagnified time base when operating "Mag On" with an *Intensified* portion that identifies the location of the portion of the sweep magnified.



The intensified area of the slower display identifies the time interval magnified. The faster display is that time interval expanded by magnification. Double exposure is used to represent this feature photographically.

5030/5031 Series Displays

YT Dual Beam	Channel 1	Voltage vs Time or Current vs Time
		and
	Channel 2	Voltage vs Time or Current vs Time
XY Dual Beam	Channel 1	Volts vs Volts or Current vs Volts
		and
	Channel 2	Voltage vs Volts or Current vs Volts
XY Single Beam	Channel 1	Volts vs Channel 2 Volts or
	Channel 1	Current vs Channel 2 Volts or
	Channel 1	Current vs Channel 2 Current or
	Channel 1	Volts vs Channel 2 Current
Z Axis		Both beams have separate inputs that function in all modes.

XY

Oscilloscope users usually think first of a voltage-vs-time plot (YT) when selecting an instrument. This display is the most used mode. YT usefulness is the reason that most scopes are designed primarily to achieve optimum performance in that mode. XY modes in most instruments are usually compromised in X-axis performance because of YT considerations. Sensitivities, bandwidth, phase characteristics, control logic usefulness are often less than that found in the Y-axis.

The XY mode in the 5030/5031 Series is treated as equal in importance to a voltage-vs-time (YT) display. The user has available at a touch a 10-μV per division differential X-axis amplifier with the same characteristics as the Y system. This X-axis amplifier is the Channel 2 amplifier switched into X-axis by a push button. Channel 2's X-axis performance is equal to Channel 1's Y-axis characteristics. In the XY mode, phase difference between X and Y is only 1° at 200 kHz and is still better than 4° at 1 MHz.

An unusual mode available in this line of instruments is the plot of two variables against a third. Channel 1 and 2 are plotted against a common X-axis amplifier with 20 millivolts to 500 millivolts per division sensitivities in 1, 2, 5 steps. Activation of this separate X-axis amplifier is a function of the time-per-division control. This combined control use eliminates the need for separate controls for X-axis mode selection. Inadvertent selection of a voltage X-axis is prevented by a positive press activated clutch. Any use of X-axis modes is clearly indicated to the user by control illumination and automatic scale-factor readout.

DUAL-BEAM STORAGE

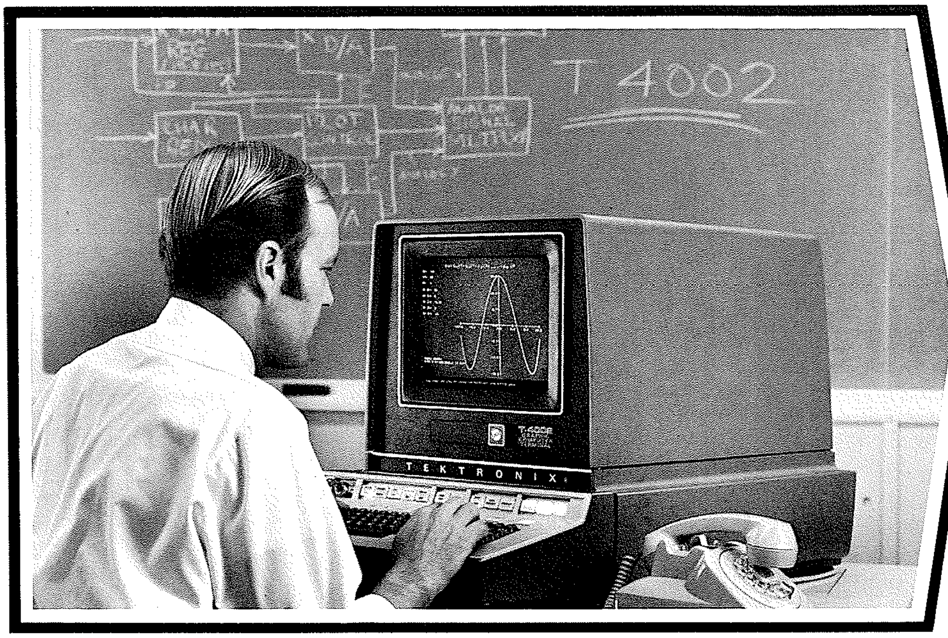
The 5031 and R5031 are the new storage scopes in the 5030/5031 Dual-Beam Family. They feature all the modes of the non-storage instruments (5030 and R5030) plus Tektronix bistable storage. Tektronix features such as split screen and long-term storage at full stored intensity are prominent in this pair of instruments. Stored writing speed is specified as greater than 20 divisions per millisecond.

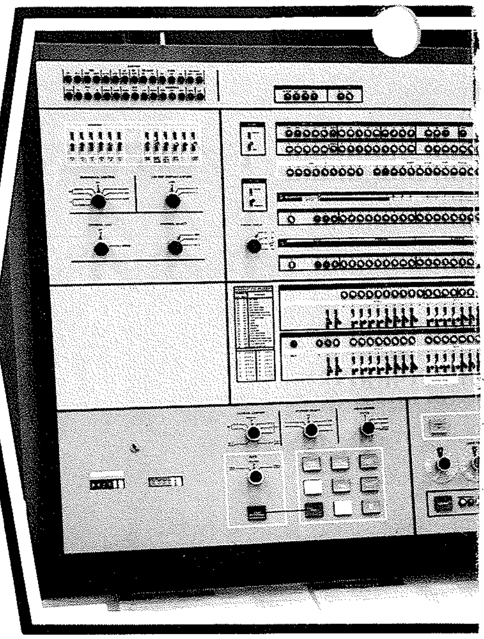
The split screen allows Tektronix storage tubes to store a representative or standard waveform on one half screen while tracing other repetitive information in a conventional non-stored mode for comparison on the other half screen. Another split screen use is for the display of a signal, single-sweep stored and periodically automatically erased on one screen area, while the other area is used to store several displays. This creates a short-term "history" of what has happened. The inclusion of auto erase, remote erase, as well as front panel erase for each screen area multiplies storage application possibilities.

The AUTO ERASE mode is often used to monitor changing information while looking for some significant display worth saving. The user may desire to stop auto erase action and view a particular stored display. Pressing the VIEW control "saves" the stored display for a long term look.

When using an oscilloscope to plot time in periods of 10 milliseconds or greater, flicker becomes a viewing factor. Storage scopes can present a flicker-free display by operating in store and auto erase after sweep modes. Since the time needed to erase becomes a significant factor in such displays, the 5030/5031 Series storage scopes have reduced erase periods to 2 milliseconds. No information is lost during this erase because the period is usually shorter than sweep retrace times.

Each screen can be separately or individually erased automatically or remotely from an electrical input, as well as manually from the front panel, or remotely by use of an optional accessory.





DATA COMMUNICATION BASICS

by Emory Harry, Tektronix Field Engineer

The high rate of information transfer possible with the T4002 Graphic Computer Terminal places increasing emphasis on the considerations of using *voice-grade* data communication channels. Further development of techniques currently available offers promise of much higher data rates in this basic communication building block.

BAUD VS BIT

A bit (BInary digiT) is a digit (0, 1) in a numbering system with a base of two. The term baud refers to a unit of signaling speed. Baud is usually defined as the reciprocal in time of the shortest code element. ONLY under one set of circumstances (all code elements equal in time with two level signaling) are bit rate and baud identical. Although they are often used interchangeably, if the code elements are not equal in time or if multi-level signaling is used, significant differences may exist.

Data Communication is normally considered to be communication of anything other than voice or video. In the United States, over 2,000 common carriers offer communication facilities and services for the transmission of voice, data, video, facsimile, telemetry, etc. These companies are regulated by federal (interstate), state (intrastate), and in some states, municipal agencies.

The tariff structure is very complex and it is usually necessary to contact the sales office of the local common carrier to determine the exact charges for the service you require. Differences between intrastate tariffs and interstate tariffs vary widely throughout the country, and thus, the wise user looks closely at all alternatives in designing a Data Communication System.

Several grades of communication channels are presently available for data communication.

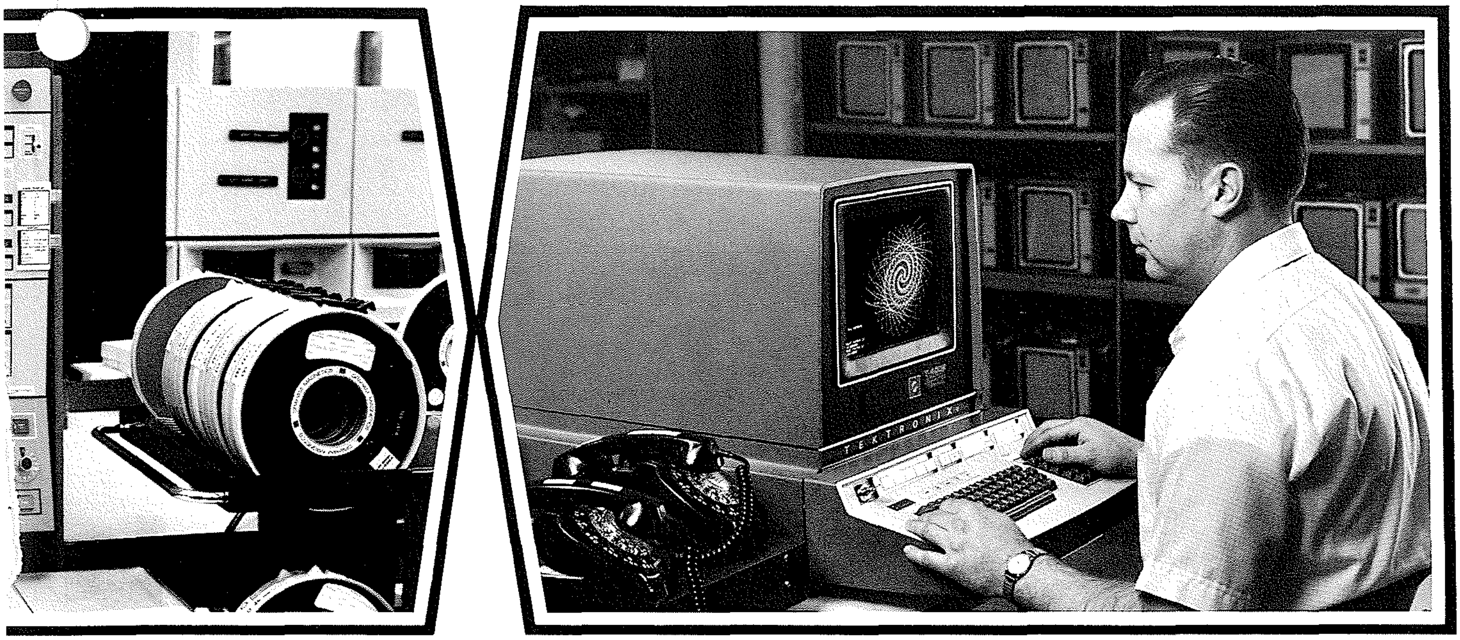
Telegraph Grade Channels — 45 to 75 Baud

Sub Voice Grade Channels — 110 to 600 Baud

Voice Grade Channels — 300 to 2400 Baud

Broad Band Channels — up to about 1 Mega Baud

There are two basic types of voice grade channels: DDD (Direct Dial Distance) and Leased (Private). The bandwidth is similar (300 Hz to 3000 Hz), but other characteristics differ measurably. Leased lines avoid local central office switching equipment and are much less subject to noise. Several levels of line conditioning are usually available on leased lines to compensate for the undesirable characteristics such as envelope delay, frequency distortion, etc. Although line conditioning is more expensive, higher transmission rates are possible. 9600 Baud is currently practical on voice-grade, conditioned, leased lines.

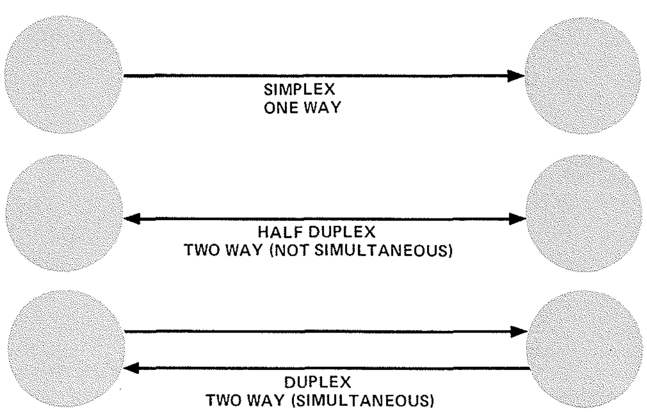


The Tektronix T4002 Graphic Computer Terminal provides interactive displays in a time-sharing environment. At left, Emory Harry in a classroom application. At right, Ken Nordling checks a graphic mode.

BASIC COMMUNICATION

Communication channels may be categorized as simplex, half-duplex, or full duplex. These transmission modes refer basically to whether the channel can transmit data in one direction only, one direction at a time, or both directions simultaneously as shown in the drawing. A two-wire circuit may be used for full duplex operation by employing frequency division multiplexing (a different portion of the channel's frequency spectrum is used to transmit in each direction).

Full duplex or half-duplex does not mean that the channels are symmetrical or of equal bandwidth in both directions. If the data transmitted in one direction is originating from a keyboard, the slow transmission makes it wasteful to divide a voice grade channel equally. Modems are available which transmit full duplex at the rate of 110 bits per second in one direction (keyboard) and 1200 bits per second in the opposite direction (computer).



Basic Data Transmission Methods

Supervisory Channel describes a very low bandwidth reverse channel that is used only to send control information. This Supervisory Channel is sometimes as slow as five bits per second. A channel which transmits data in one direction and supervisory information simultaneously in the other is not normally considered full duplex.

Echo-plexing is not another mode, but its operation is similar. Echo-plexing describes the operation whereby data is transmitted in one direction and is then turned around and sent back to its source for verification. Echo-plexing is being employed if data is sent out from the terminal keyboard, goes to the computer or interface, and then is sent back to the terminal where it goes to the character generator and is displayed. If an error occurs in communication, the operator detects it since the letter on the display is different from the keyboard input.

Echo suppressors are used in long distance transmission to reduce the effects of channel discontinuities on voice communication by introducing attenuation in the line opposite to the direction which the voice is traveling. Echo suppressors are switched by voice detectors, and should be out of the circuit when data is being transmitted. They can be switched out of the circuit by transmitting energy solely in the band from 2000 Hz to 2250 Hz. After the switching, transmission may utilize the entire frequency spectrum of the channel, but if energy is interrupted, the echo suppressor is automatically switched back into the line.

SERIAL VS PARALLEL

Transmission of data falls into two basic categories: serial and parallel transmission. In parallel transmission, several code elements are transmitted simultaneously through individual channels. For example, a five-level teletype code would require five separate channels; a seven-level ASCII code would require seven channels. Using multiple voice-grade lines provides a very high data transfer rate, but for most purposes, this approach is excessively expensive. The same results can be achieved by frequency-multiplexing a single voice grade channel and using a separate portion of the frequency spectrum for each code element. However, because perfect filters are not attainable, frequency multiplexing wastes bandwidth. Parallel transmission is not practical for terminal applications unless the transmission distance is very short, making it unnecessary to use telephone lines.

In serial transmission, the code elements are sent sequentially with each element occupying its own time slot in a form of time multiplexing. Although serial transmission normally requires more expensive hardware, the cost is more than offset by the fact that a single communications channel can be used. Serial transmission results in a much lower rate than is possible with multiple channels in parallel transmission.

Data transmission may be further divided into two categories: asynchronous and synchronous. Asynchronous transmission is used by most devices whose code elements are not generated uniformly in time. For example, the data rate output at a keyboard is a function of the speed at which the operator types.

When using asynchronous (start/stop) transmission, extra elements are sent with the data to identify and synchronize it. An extra element or bit is sent ahead of the data bits (start bit) and either one or two bits are sent after the data bits (stop bits). The group of bits that form each character has no definite time relationship with the previous or succeeding group of bits.

When transmitting synchronously, the characters have a definite time relationship to one another. Normally, a character is sent immediately after the preceeding character with no time lag between them. This type of transmission is generally more practical for devices that generate a continuous flow of data.

In synchronous transmission, it is necessary to periodically interrupt the data flow to send synchronizing information. Because the ratio of synchronizing bits to data bits is much lower in a synchronous system, the information transfer rate is proportionally higher. Codes have been developed that are self-synchronizing and require no synchronization bits to be transmitted, but these codes are not commonly used because of the expensive hardware required.

The T4002 can be used with modems (modulator demodulators) designed for either synchronous or asynchronous operation. When employing a synchronous modem, however, start and stop bits are still required.

MODULATION TECHNIQUES

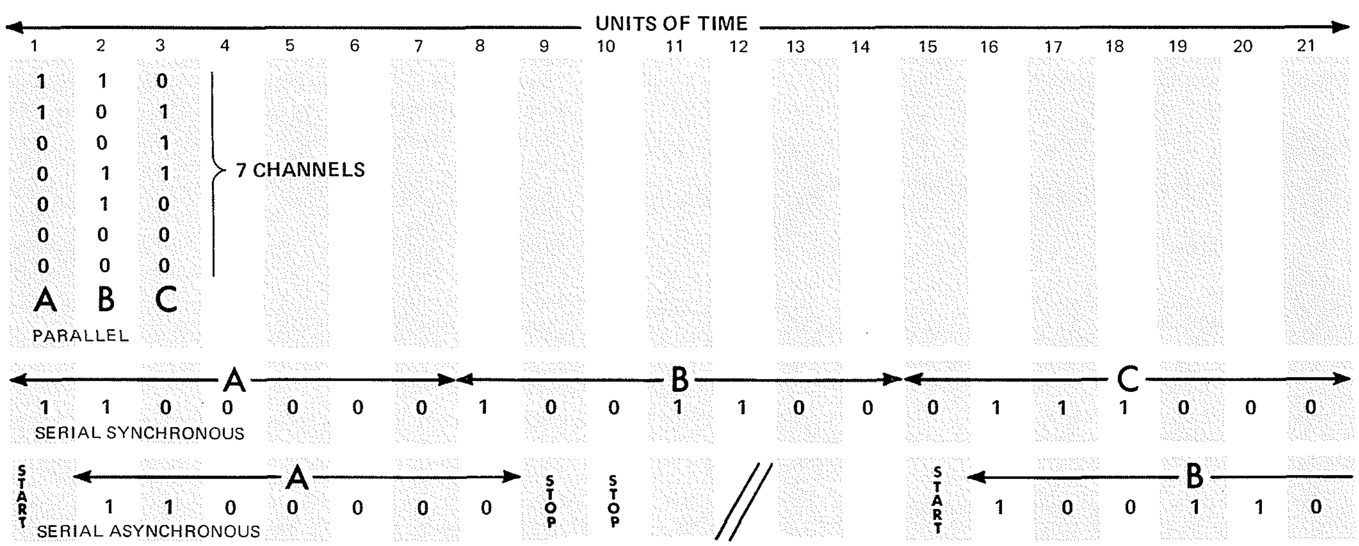
Modems are necessary to efficiently transmit data since the basic transmission medium, telephone lines, is not ideally suited to the transmission of data. The bandwidth of a voice-grade channel is normally from about 300 Hz to about 3 kHz. Modulation maximizes data transmission rate while minimizing the effects of noise, distortion, etc.

A number of considerations are important when selecting the type of modulation. Error control, equipment cost and complexity, available bandwidth, signal-to-noise ratio of channel, and type of code, all enter into the modulation system selection. Amplitude, frequency or phase modulation may be used, with some systems combining these techniques.

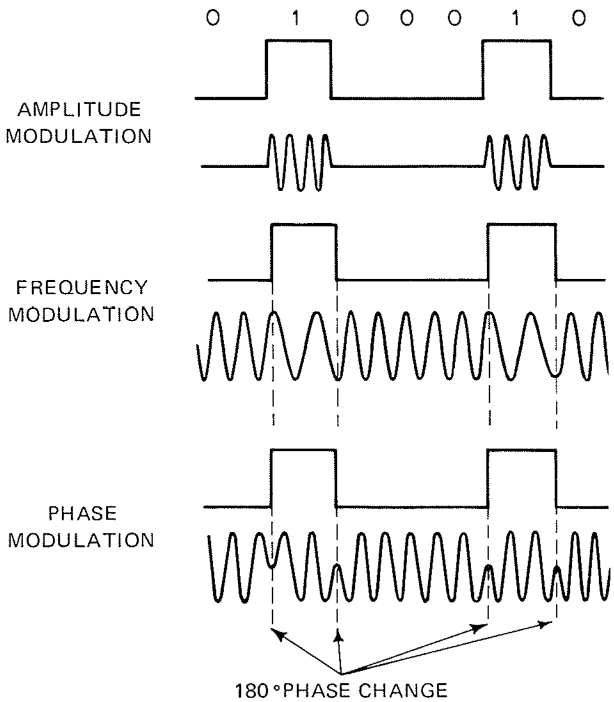
Frequency modulation, where frequency varies as a function of input code, is used on many lower-speed modems. Usually, a specific type of frequency modulation called frequency shift keying (FSK) is used in which one frequency represents a binary zero and another represents a binary one.

Many of these modems are designed to cradle the telephone handset and are called acoustic couplers. The signal is acoustically coupled from the telephone handset to a transducer in the modem, rather than the connection being made physically. Though this approach is convenient for low-speed communications, high-speed communications require a different approach.

Amplitude modulation, where amplitude varies as a function of input code, is used on many higher speed modems. Usually,a specific type of amplitude modulation called vestigial sideband is used.



Basic Communication Methods



Basic Modulation Techniques

Phase modulation is used on many of the higher speed synchronous modems, e.g., the Bell 201 Series. These multilevel modems generally do not employ more than four levels (each 90° of phase representing a level) because of noise and distortion limitations. When four increments of 90° are used, each level represents a two bit pair called a dibit. The Bell 201 Series that transmits four dibits (00, 01, 10, 11) is capable of data transmission rates of 2400 Baud. As the number of levels goes up, the modem becomes increasingly complex and expensive and the amount of line conditioning becomes impractical.

Modems are available which have their own adjustable conditioning or equalization networks. In addition, others are available with automatic equalizers which allow the modem to adjust to changing line conditions. As the degree of sophistication increases, however, so does the cost of the hardware.

Many variations and combinations of these three basic forms of modulation may be used in the future.

MULTIPLEXING

Multiplexing is a term used to describe the techniques used when combining several signals for transmission through a single channel.

Frequency multiplexing is the most common method in data communications. It is characterized by shifting of signal spectra so that no two spectra overlap. Shifting is usually accomplished by heterodyning. For example, a single voice grade channel can be divided into two frequency bands, one from 500 Hz to 1400 Hz and another from 1700 Hz to 2600 Hz. This creates two effective channels that can be used to send data in both directions simultaneously. Each channel uses less than half of the original bandwidth since a guard band is necessary between channels because of filtering limitations.

Time multiplexing is characterized by the interlacing in time of input data samples. Much less of the original bandwidth is lost using this technique than with frequency multiplexing because the time between channels can be very short.

Other forms of multiplexing such as Linear Addition Multiplexing, Orthogonal Multiplexing, and Polarization Multiplexing may all find wider use in the future.

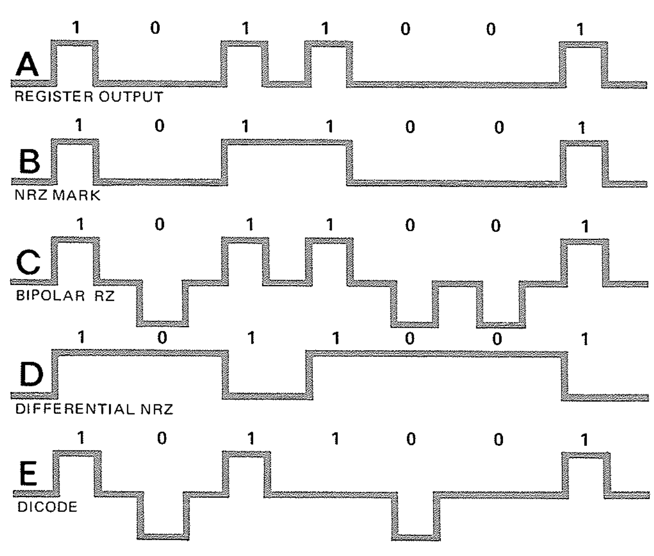
BIT CODING TECHNIQUES

A wide range of techniques are currently available for coding bits. Assume that a series of 7 bits has 4 true and 3 false bits. A, B, C, D, and E are five different bit coding methods that might be employed. Each technique (and the many others that are not represented) have characteristics which will make them desirable in one application and not in another.

Sequence A illustrates the pulses at the output of a computer register. In most FSK modems, the train appears as B where 1 is transmitted at f1 and 0 is transmitted at f2. The modulator shifts between frequencies depending on whether the bit is 1 or 0. This technique is sometimes called NRZ Mark (Non-return to Zero Mark). (One and zero have long been referred to in telegraphy as mark and space.) Note that there are fewer transitions in a given length of time and thus bandwidth is conserved.

C is a code that might be used if more synchronization information is required than is inherent in B. In C, there are always 2 transitions made in each unit of time. This code is usually called bipolar RZ (Return to Zero).

D is a code where bandwidth is of major consideration. A transition is made for each logic "1." This code is normally called differential NRZ.



Bit Coding Techniques

E is a code where a bipolar bit occurs on each new series of pulses. Each time the bit changes from 1 to 0 or 0 to 1, a pulse, either negative for 0 or positive for 1, is sent. This code is good for conserving bandwidth if long series of 1's or 0's are anticipated.

There are many different bit coding schemes that offer advantages and disadvantages depending upon the application. Bandwidth, synchronization, cost of coding and decoding hardware, and power consumed are all important characteristics of any system chosen.

CHARACTER CODING

A large number of character coding schemes are currently used, such as the Baudot, EBCDIC, and ASCII Codes. The most universal code is the USASCII (United States American Standard Code for Information Interchange) shown in the diagram, 7 bits with 128 permutations. These codes are generally termed quiet channel codes as they are designed for channels with relatively high signal-to-noise ratios.

Error detecting and error correcting coding techniques are accomplished by adding redundancy to the code. The amount and type of redundancy designed into a code is usually determined by how serious the effect of errors is. If the data is perishable, a large amount of redundancy may be designed into the code. In most computer terminal applications, where the channel is a phone line, the major source of errors is the operator, not the hardware, and thus, little redundancy is designed into the standard Data Communication code. Usually, a single parity bit is added to each character which makes the total number of bits in the character either odd or even. This allows most errors to be detected, but not corrected. When poorer signal-to-noise ratios are encountered, or when it is necessary to correct as well as detect errors, more sophisticated coding techniques are employed. One such technique is simply the addition of more than one parity bit.

Adding additional parity bits allows a larger number of errors to be detected, or permits the same number with a lower signal-to-noise ratio. When parity bits are added in sufficient numbers, the correction of most errors is feasible. Of course, the higher the level of error control, the higher the cost and the lower the information transmission rate.

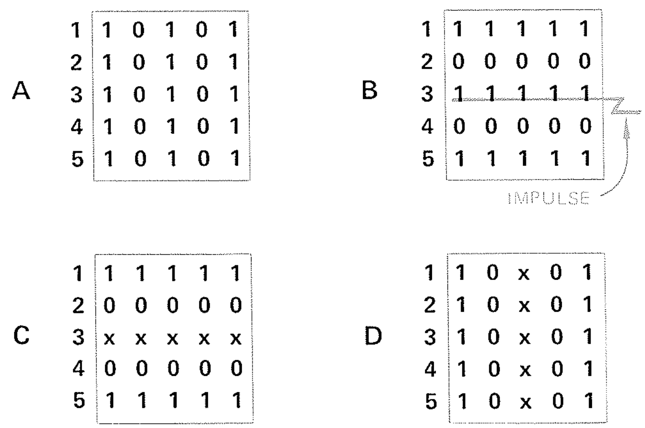
b_7 b_6 b_5 →					0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
Bits b_4	b_3	b_2	b_1	COLUMN → / ROW ↓	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	FS	,	<	L	\	l	¦
1	1	0	1	13	CR	GS	–	=	M	]	m	}
1	1	1	0	14	SO	RS	.	>	N	^	n	~
1	1	1	1	15	SI	US	/	?	O	_	o	DEL

USASCII Code

INTERLACING

This is a term which is used to describe a technique which is similar to time multiplexing and is used to effectively normalize impulse noise, a form of noise that is the largest source of data communication errors. Each character (7 bits, if the code is USASCII) plus 4 parity bits is stored in some form of storage device such as a flip-flop register. When as many characters are stored as there are bits in the code, in this case 11 characters, then the information is read out, but not as it was stored. One bit from each of the eleven characters is transmitted. For example, bit one from each of the eleven characters is sent together, then bit two from each of the eleven characters, until all 121 bits are sent. If an impulse should occur during transmission that would normally destroy one character, now only one bit from each character is lost and the one-bit error can be detected and corrected.

This is a very effective technique, particularly if multiple parity bits are also transmitted so that error detection and error correction are both possible at the receiving end. The technique is not as useful for asynchronous as for synchronous transmission.



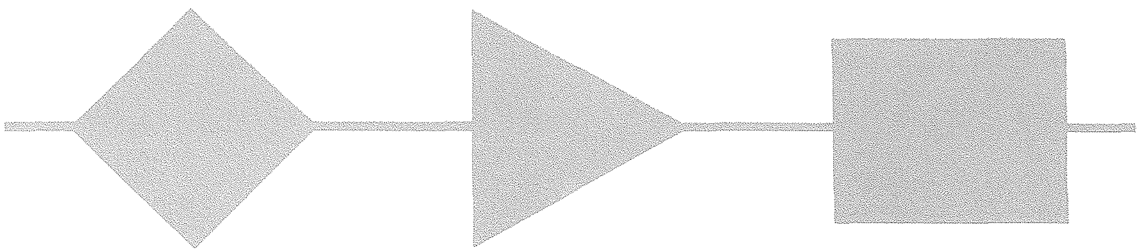
Five words are read in horizontally (A). The five words are scanned vertically and transmitted as in B. If a noise impulse strikes word three, the data appears as C when received. Vertical scanning C constructs five words with one error bit (D). If the code has sufficient redundancy, the original words (10101) can be reconstructed.

STANDARDIZATION

Attempts have been made at standardizing on a universal code. This code is the ASCII Code, American Standard Code for Information Interchange. The USASCII discussed earlier is that which has been found to be the most universally accepted. The ISO (International Standardization Organization) has proposed both 6 and 7 bit character sets for international information processing interchanges.

The Electronic Industries Association Standard RS232B (Interface Between Data Processing Terminal Equipment and Data Communications Equipment) is a standard which specifies such things as connector type, pin assignments, voltage levels, impedance, etc. EIA RS232C is a new standard which attempts to make compatible RS232B and the CCITT (Consultative Committee for International Telephone and Telegraph) Standards.

SERVICE SCOPE



Troubleshooting Sampling Systems

By Charles Phillips
Product Service Technician, Factory Service Center

Confidence and knowledge enable a service technician to complete his services with best results. Confidence in servicing sampling scopes is sometimes prevented by unnecessary awe of subnanosecond region instrumentation. With normal preparation, you will find much of your knowledge and experience with real-time scopes is of direct value when working on these "fast" scopes.

This article will discuss adjustments and troubleshooting in vertical systems with particular emphasis on the *Sampling Loop.* All Tektronix Sampling Oscilloscopes* use an error or difference detecting technique. Since they use this technique, you will find a similarity in the various sampling systems. These similarities allow us to work in this article with a "composite sampling scope" and make some generalized statements about samplers. These generalizations should not be used in place of specific information included in your instrument's instruction manual. That manual's calibration section should be your source of specific adjustment information. Your Tektronix Field Engineer can aid you further with your individual requirements.

A display visible on screen is the most valuable aid available to you. Here are a few ideas on getting that trace.

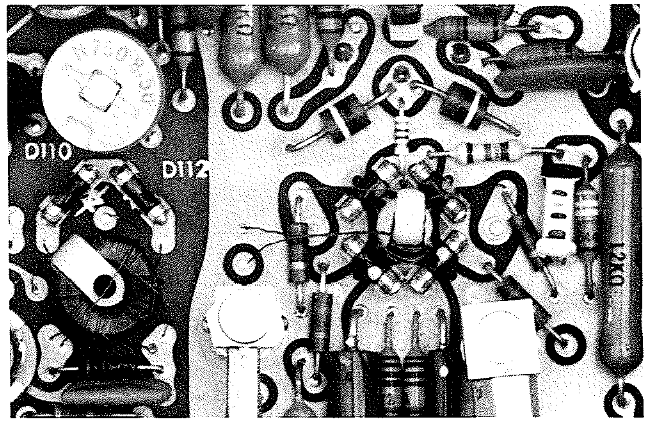
*N unit exception.

> *Sampling Notes* and *Sampling Oscilloscope Circuits* by John Mulvey are two publications available from your Tektronix Field Engineer that are valuable sources of sampling facts.

We should start with the output of the vertical system. Output circuitry is straightforward. It amplifies the output of the *Sampling Loop* to drive the vertical deflection system. It can be isolated from the Sampling Loop by sliding the NORM/INVERT switch to its center. This blocks the input to the output circuits and will allow you to localize the off-screen problem to the "loop" or the "output".

After you have the "output" functioning, set the NORM/INVERT switch to NORM. If no trace is on screen, you should suspect the loop. Try the following:

1. Apply a 25-kHz squarewave of approximately 300 mV to the input. Use 200-mV/div sensitivity.
2. Free run or trigger the time base and use about 10 dots per division, zero the offset (use meter at output jack) and the *Position* control should bring the display on screen. If the position control does not do the job, center it at about 12 o'clock.
3. If step 2 does not produce a display, vary each of the internal adjustments in the "loop" and sampling gating pulse generator full range, one at a time, remembering the original settings. If an adjustment does not reveal a display, return it to its original setting and proceed to the next one. If any adjustment brings the display on screen, attempt to achieve a correct response by using your manual. If all adjustments fail, leave them in their original position and proceed to the troubleshooting information.



Here's where most of the fast action occurs. A four-diode bridge makes the sub-nanosecond voltage sample. The two-diode memory gate accepts processed sample and holds the information for CRT vertical deflection.

SOME INFORMATION ON ADJUSTMENTS

The section of the sampling system that is located within the *Sampling Loop* has the most effect on waveform, risetime, aberrations, and vertical trace position. The adjustments we will discuss often interact and may appear to have the same function. This interaction and similarity of results on screen should be explored to get the "feel" of the system. This "feel" cannot be derived from any written material.

No harm will result if you try extreme range combinations of the adjustments. By this exploration of extreme settings, you rapidly build confidence by gaining knowledge and experience.

Memory

Memory Balance—Purpose: To adjust for no trace shift when "smoothing" (front panel) is operated. Effect: See purpose.

Memory Gating Pulse Width—Purpose: To allow memory to respond to the full input signal. Effect: Will cause "rounded corners" of signal at one extreme (gain <1) or oscillation (gain >1).

Amplifier

Loop Gain—Purpose: To adjust for maximum signal to the memory. Effect: Will cause "rounded corners" of signal at one extreme or oscillation at the other. May also be located in the memory.

Dot Response—Purpose: A front panel adjustment to maintain a loop gain of 1 after internal adjustments have been set. Effect: Similar to loop gain (very evident when using a random sampling system).

Smoothing—Purpose: A front panel control for minimizing noise. Effect: Similar to loop gain, but usually its effect varies from unity gain to less than 0.5 gain.

Sampling Gate

Sampling Gate Volts—Purpose: To set voltage across gate diodes, normally about 2 volts for proper display risetime and dynamic range. Effect: Risetime is changed as adjustment is made.

Sampling Gate Balance—Purpose: To neutralize trace shift as mV/div switch is rotated. Effect: See purpose.

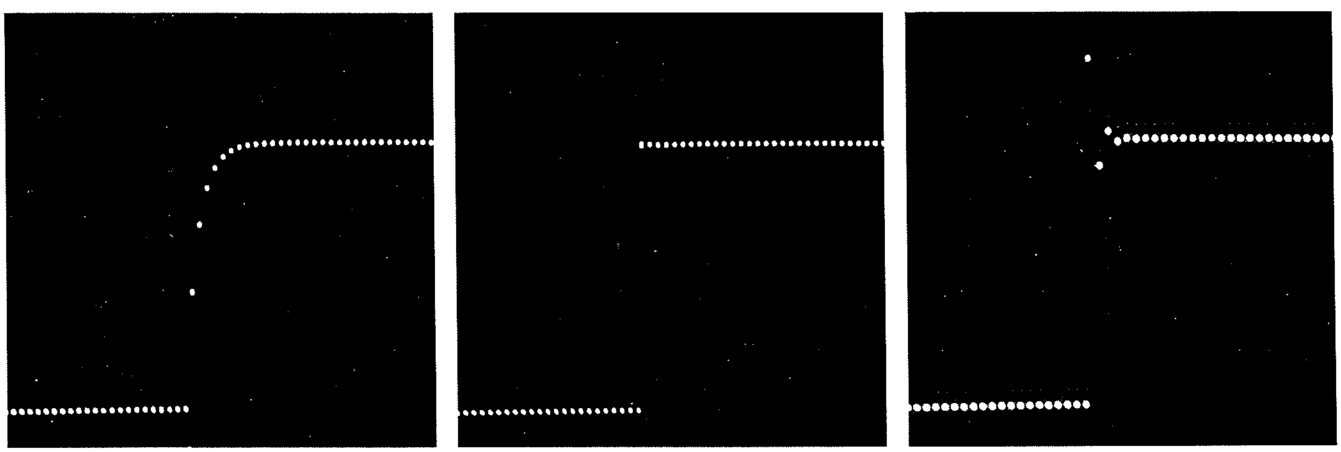
Blowby Compensation—Purpose: To neutralize capacitance in the sampling gate. Effect: Will change aberrations in the 2-μs interval after risetime.

Strobe Pulse Generator

Snap-off Current—Purpose: Adjusts strobe pulse for best resulting display risetime. Effect: Has the most significant control over risetime.

Avalanche—Purpose: To drive the sampling strobe source with minimum noise and jitter. Effect: In addition to noise and jitter effect, there are some risetime effects.

All the adjustments in the loop and strobe generator will have some loop gain effects. It is usually worthwhile to recheck for unity gain using your manual information after completing adjustments.



The sampling gate is unable to fully charge the amplifier input capacity with one sample. Feedback after the gate completes the charging process. Adjustments in the "Loop" produce (1) less than full charge (gain <1) (2) full charge (gain $= 1$) (3) more than full charge (gain >1).

SOME SOLUTIONS

Problem: Dot transient response difference between plus and minus signals.

Check: If more than 10% difference, sampling gate should be replaced.

Problem: Baseline shift with change of trigger frequency.

Check: Set front panel controls for a free-running trace at 2 mV/div (or highest sensitivity). Change time/div through entire range. Trace shift should be less than 2 divisions. If more, the sampling gate diodes should be interchanged. Replace diodes if necessary.

Problem: Memory slash (vertical elongation of dot at low trigger rates).

Check: Trigger sweep at 10 Hz; if slash is more than 0.6 divisions, interchange memory diodes or replace them. Other sources of slash are tubes and FET's.

Problem: Noise, microphonics, level changes, gain changes.

Check: Sampling gate diodes seated with proper clip tension. Grounds solidly made, soldered properly and mechanically tight. Input connectors tight. Input 50-Ω resistors should not be discolored and should be within ±1 Ω. Nuvisor socket should have sufficient tension in tab slots for good grounds.

Problem: Display tilt.

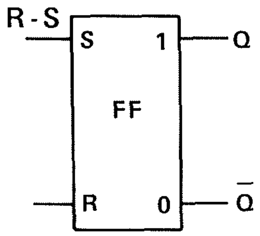
Check: If problem is most noticeable at about 1 MHz, the sampling gate is most suspect. Try blowby adjustment, then gate diodes. If interaction between both channels is noticeable, especially at certain positions on screen, check output amplifier tubes and channel switching diodes.

BREAKING THE LOOP

The feedback in the Sampling Loop can be disabled to further localize problems. Isolation of the memory can be easily accomplished by lifting one end of the memory gating diodes. Some instruments use built-in clips for resistor insertion for isolation. If this provision is made, see your instruction manual.

The sampling gate may be isolated by disconnecting the center arm of the sampling gate balance. This will allow you to check for proper voltages around the gate circuits. You may wish to remove the diodes to check for proper bridge voltage before replacing the gate diodes.

CORRECTION



Input		Output	
R	S	Q	$\bar{Q}$
LO	LO	No change	
LO	HI	HI	LO
HI	LO	LO	HI
HI	HI	Undefined	

Frankly, our truth tables are a pack of lies! In the December Issue, the article "A Basic Logic Review" had a mistake in the R-S Flip-Flop Truth Table. A corrected table is shown above. Our thanks to our readers for notifying us and our apologies for not detecting it.

The Editor

INSTRUMENTS FOR SALE

1—Type 511AD. In operating condition. Contact: Bruce Blevins, Box 2012, Socorro, New Mexico 87801. Telephone: (505) 835-5555.

1—Type 514AD. Good condition. Will accept reasonable offer. Contact: M. R. Sparks, 104 Ward Street, Oxford, North Carolina 27565.

7—Type 535A/CA. 1—Type 543B. Other 530/40 Series with plug-ins. Contact: Mr. Posner, Pacific Engineering Company. Telephone: (213) 225-6191.

1—Type 547, SN 11965. 1—Type 1A1, SN 24603. Both brand new. Contact: Mr. G. Schneider, Space Electronics, 40 Cottontail Lane, Irvington, New York 10533. Telephone: (914) 591-8681 or 8774.

1—Type 1A1, SN 016111. 1—Type 1A2, SN 006740. 1—Type 516, SN 004789. Contact: Bob Smith, Interactive Data Systems, P. O. Box A-O, Irvine, California 92664. Telephone: (714) 549-3329.

1—Type 516. Just calibrated and in excellent condition. Price: $600. Contact: Heinz Frederick, Data Products Corp., 6219 De Soto Street, Woodland Hills, California 91364. Telephone: (213) 887-8219.

1—Type 581, SN 966. 1—Type 82, SN 7944. 1—Type C-40, SN 10639. Reconditioned by Tektronix one and one half years ago. Lot Price: $1900. Contact: Ken Marich, Stanford Medical Center, Room 230, Stanford, California 94304. Telephone: (415) 321-2300 Ext. 6071.

1—Type 546/1A1. Good condition, small amount of use. Price: $1900. Contact: Don R. Green, Ferson Optics, P. O. Box 629, Ocean Springs, Mississippi 39564.

1—Type 575 Mod 122C and 1—Type 202-2. Used approximately 30 hours. Price: $1000. Contact: Mrs. Wainwright, I-Tel Corp., 10504 Wheatley Street, Kensington, Maryland 20795. Telephone: (301) 946-1800.

1—Type 545, SN 15990. 1—Type CA, SN 9652. Price: $1250. Contact: Les, 575 South Barrington, Apt. 202, Los Angeles, California 90049. Telephone: (213) 472-0882.

1—Type 541, SN 693. Best offer. Contact: Mr. Greg Jigamian, Hanson Hawk, Inc., 20327 Nordhoff St., Chatsworth, California 91311. Telephone: (213) 882-9600.

4—Type RM503, SN 001848; SN 001651; 00905; and SN 001866. Price: $450 each. Contact: Stuart Ex, 14827 Cohasset, Van Nuys, California 91405. Telephone: (213) 786-7672 or 873-7672.

INSTRUMENTS WANTED

1—Type 2B67 Time Base. Contact: F. O. Wiseman, T. B. Woods & Sons Co., Chambersburg, Pennsylvania 17201. Telephone: (717) 264-7161.

Printed in U.S.A. 3/70 A-2423

TEKSCOPE

Volume 2 Number 2 April 1970

Customer Information from Tektronix, Inc., P. O. Box 500, Beaverton, Oregon 97005
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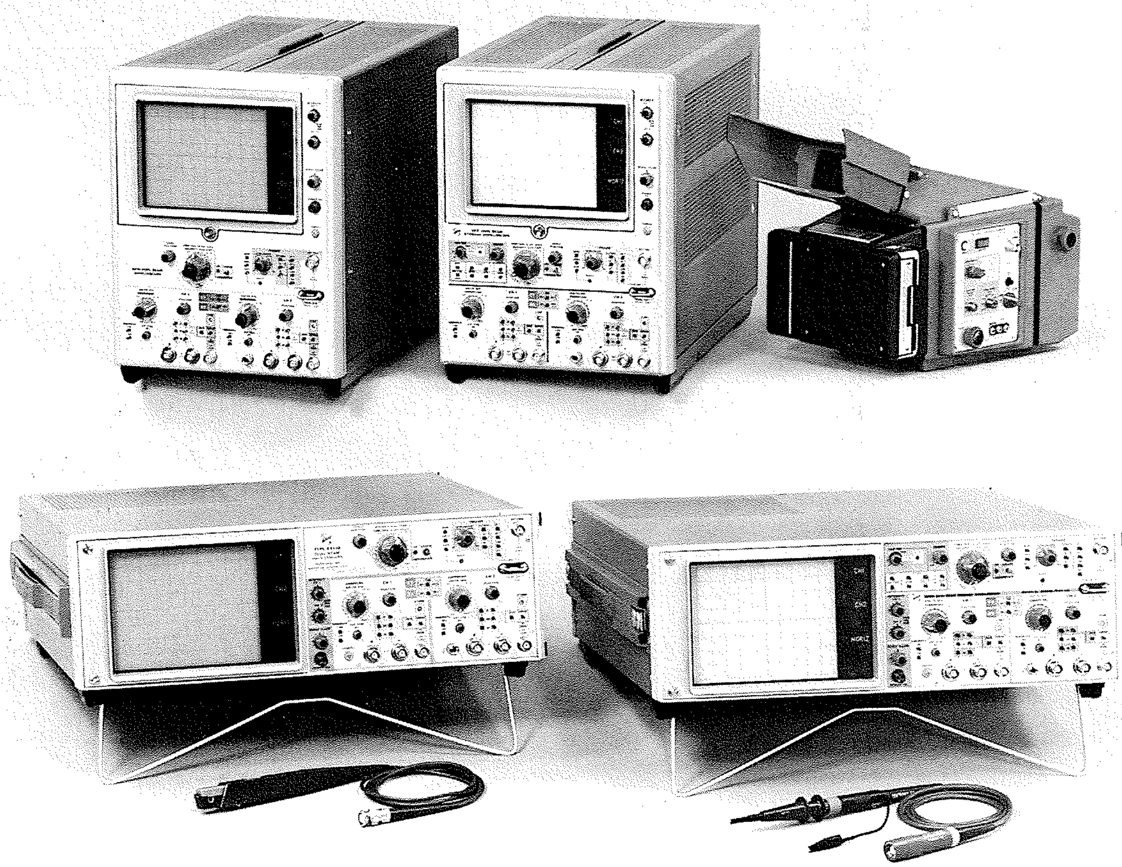


A DUAL-BEAM FAMILY

SCALE FACTOR READOUT

Control settings, probe attenuation values, and magnifier settings are all taken into consideration and electronically read out in the CRT viewing area. A > symbol is provided for uncalibrated settings.

NEW CAMERA SYSTEM

The C-70, with its electronic shutter, eliminates much of the film waste normally associated with oscilloscope photography. Range finder focusing is combined with a trace-brightness photometer to simplify and improve oscilloscope photography.

NEW LARGE-SCREEN OSCILLOSCOPE

More than 50% greater viewing area (over an 8 x 10 cm display) is available in the 5030/5031 Family. 1-MHz dual-beam oscilloscope also provides a fiber optic display of scale-factor readout.

ADVANCED COMPONENT TECHNOLOGY

Tektronix oscilloscopes make extensive use of Tektronix developed and manufactured components to provide the user with the most reliable components currently available. Low torque cam switches, miniature illuminated push buttons, relays, custom integrated circuits, ceramic cathode-ray tubes, and a number of other unique components contribute to superior instrument performance.

NEW DUAL-RANGE ATTENUATOR PROBE

The P6052 is easily switched from X1 to X10 attenuation. Probe attenuation factor is sensed and automatically controls scale-factor readout to display total system deflection factor.

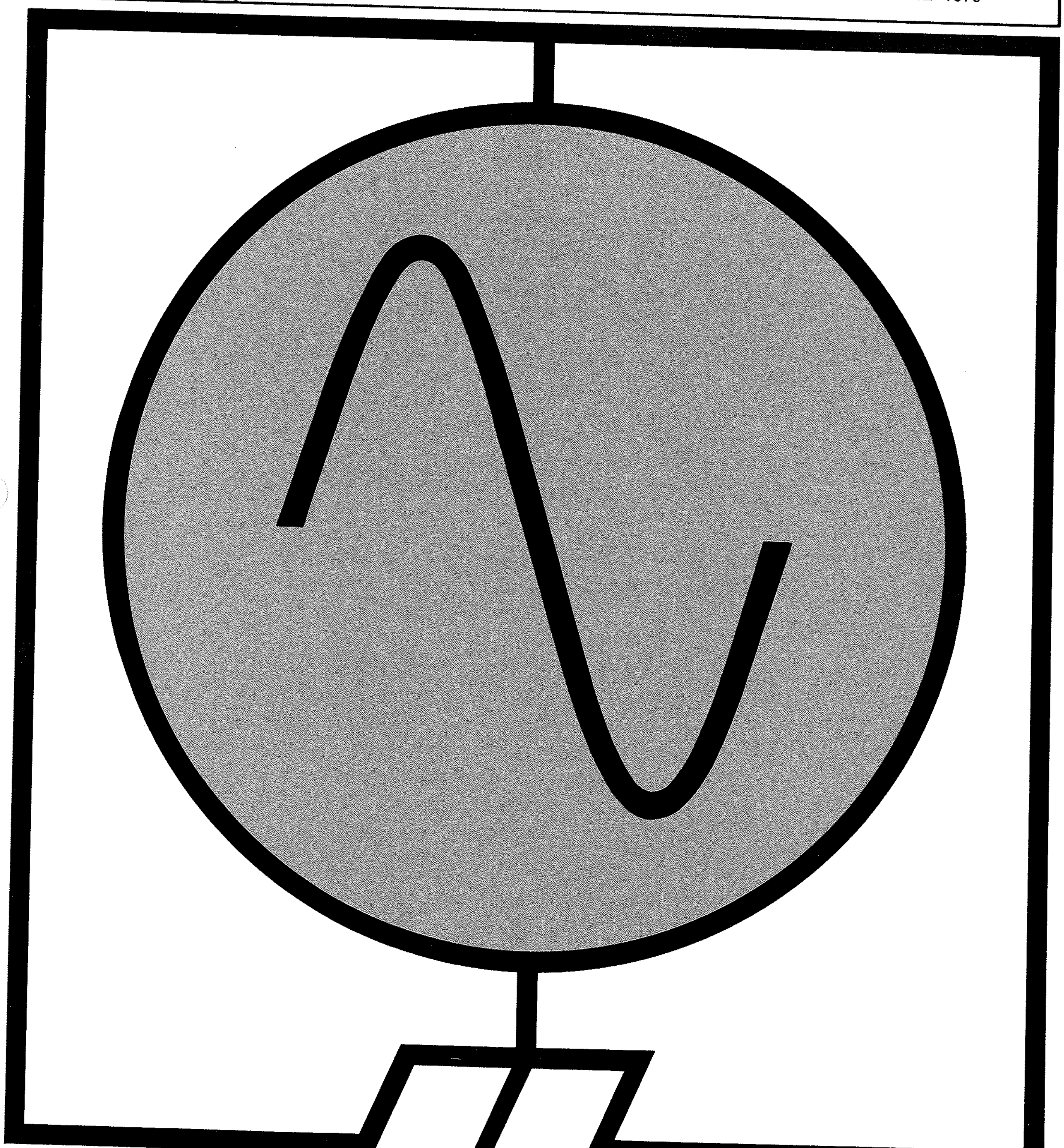
CURRENT PROBE

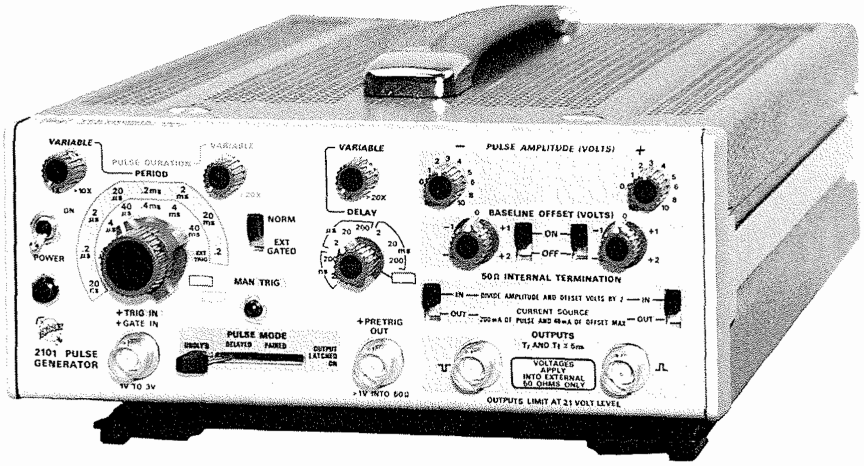
The P6021 current probe is used without adapter or external amplifier to allow easy current waveform display.

TEKTRONIX

TEKSCOPE

JUNE 1970





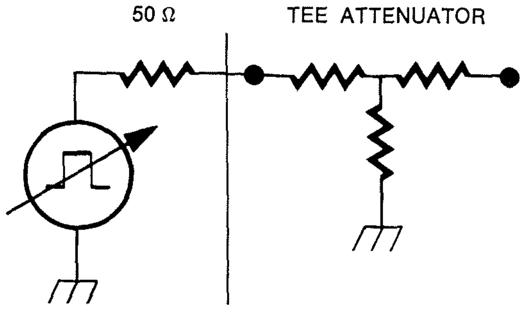
tektronix signal sources

Oscilloscopes and pulse generators are very closely associated. Pulse generators are essential in calibrating the oscilloscope. Pulses are formed in many oscilloscope circuits. The measurement of pulse parameters is the primary purpose of the time base oscilloscope. Tektronix has long been engaged in the design and manufacture of pulse and other signal sources.

A new general purpose pulse generator, the Tektronix 2101, has recently been announced. This instrument is easy to operate and yet will produce a wide variety of pulses. This article will look at 2101 performance and some aspects of pulse source application.

The 2101 may be divided into two major operating sections: Gated Power Output and Gate Timing. This two section approach follows a concept of pulse generation by gating DC power supplies. The 2101, of course, has an AC powered internal DC supply. This supply is the ultimate source of output power. It should not be confused with the output power sources mentioned hereafter.

COVER—Do you see a symbolic CRO or a Signal Source symbol? If you see both, the activities of Tektronix in two separate, but closely related, instrumentation fields are symbolically joined.



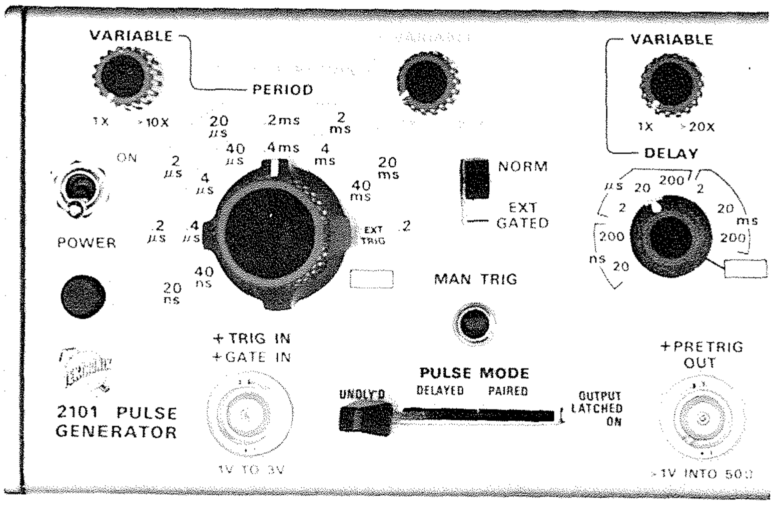
When using most pulse generators, it is good practice to use higher amplitude outputs with external attenuation whenever minimum aberrations at very low amplitudes are needed.

The 2101 has two power output connectors. A pair of variable amplitude current sources are operated in parallel to each output connector. In each pair, one supply contributes plus or minus 40 mA for **offsetting** the pulse starting level or baseline. The other supply controls **pulse amplitude** by adding up to 200 mA to the **offset current.** Each output has an identical offset supply, but the pulse amplitude supply is of positive polarity in one pair, negative in the other. When the 2101 is operated LATCHED ON, the pulse supply is turned on and "pulse" duration is long. So long that until the Mode is changed, the 2101 is actually a direct current power supply.

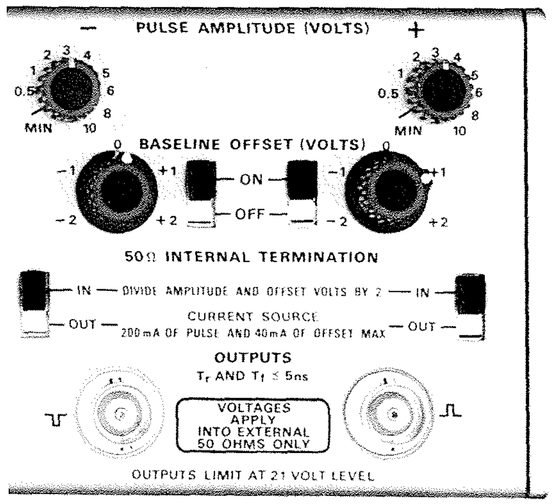
Pulse risetime, falltime, overshoot, droop, and other aberrations are primarily caused by the output supply circuits. A gated transistor actually controls the amplitude of the output pulse current. This device is optimized to produce minimum aberrations at 50% amplitude. These aberrations are less than 3% at full output amplitude in the 2101. Since all pulse generators tend to produce larger relative aberrations at low variable amplitude settings, the user should know how to minimize aberrations. Whenever low amplitude, clean pulses are needed, it is good practice to use high amplitude settings and external attenuators for best results.

GATE TIMING

Period, Duration, and Delay are all gate timing functions. In the 2101 all three functions are internally generated. External sources of these functions may be used in combinations with internal timing signals to provide additional control of gate timing. The 2101, with external control, can produce bursts of pulses and pulse periods locked to an external time reference.



"GATING"

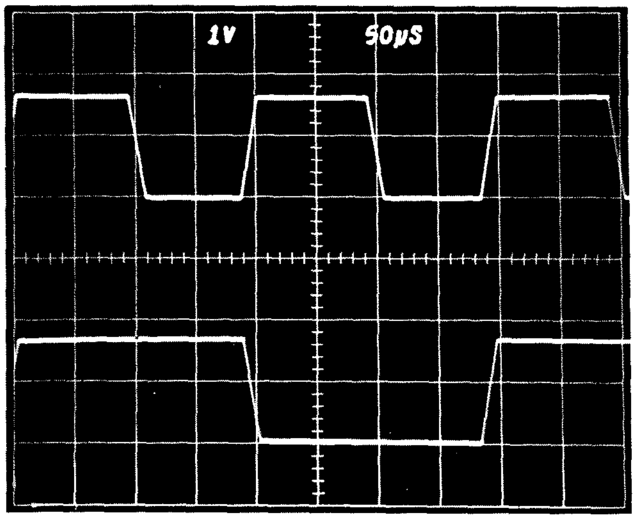


"POWER SUPPLY"

The latest Tektronix Pulse Source can be divided into two operating sections. With OUTPUT LATCHED ON the "power supply" outputs direct current. In all other modes the "power supply" is "gated" to produce pulses.

PROTECTION AGAINST ERRORS

The DURATION and PERIOD controls of the 2101 interlock to prevent improper duty factor combinations. Duty factor is the ratio of duration to period. Duration must always be less than period. The DURATION and PERIOD controls rotate independently in any less than one duty factor control set up. If either control sets up a duty factor condition approaching one, the two controls lock and rotate together.



Duration can change period. This double exposure shows the inadvertent doubling of period by misuse of a duration control. Both traces are produced with period set to 100 μs. The lower trace has "doubled" period as duration (width) was rotated beyond 100 μs. Protection against inadvertent period doubling is a feature of the 2101.

Pulse generator output circuit destruction can occur if protection is not built in. The 2101 protects itself from shorting loads by being designed as a current source. Over voltage protection from inductive kicks and other load developed excess voltages is furnished by diode protection. Because it is protected, the 2101 can be safely coupled to any passive load.

2901 TIME MARK GENERATOR

The new 2901 is one of the most convenient sources of accurate timing signals. Twenty time signals are available from 2 nanoseconds through 5 seconds, all based on a 10 MHz ± 20 ppm crystal controlled oscillator. Push buttons select individual time marks or combinations of time marks over a 0.1 microsecond through 5 second range. All timing signals are conveniently available at amplitudes of at least 0.3 volts into 50 Ω. For Z axis and other applications where large amplitudes are needed 25 volt into 1 kΩ markers of either polarity can be produced. These large markers can be used individually or in combination over the 1 microsecond through 5 second range.

A novel feature allows the 2901 to count down from external reference signals. Custom markers for radar or time signals for other purposes can be easily produced. Any two volt signal from 50 kHz to 10 MHz will provide the sufficient reference drive. Time reference signals lower than 50 kHz reference may be used if the rate of rise is >1 volt per microsecond for two volts. The 2901 extends the external reference time period up to 50,000,000 times.

In addition to pulse time marks; 2, 5, 10 and 50 ns period sine waves are generated. Frequency multiplication of the 10 MHz internal reference signal assures the time accuracy of this group of timing signals. In addition to the regular time mark and sine wave outputs a set of eight positive pulses is available for triggering or other uses. These pulses are selected in decade steps from 0.1 microseconds to 1 second. The trigger output amplitudes are at least 0.5 volts into 50 ohms or one volt into 1 megohm. This compact, bench or field instrument is a useful secondary standard wherever ac power is available. Extensive use of integrated digital circuits in the 2901 Time Mark Generator minimize the possibility of miscount and simplify maintenance and reduce calibration time.

This precision time or period source produces sixteen timing pulses by digital countdown. Maximum countdown ratio is $5 \times 10^{+7}$ from an internal precision source. The 2901 will also accurately countdown external signals.

OTHER SIGNAL SOURCES

114, 115, and R116

Tektronix manufactures **20** signal sources in addition to the 2101 Pulse Generator and the 2901 Time Mark Generator. Two of the instruments, the 114 and 115, can be classified as general purpose pulse generators.

The economical **114** is designed for laboratory and production test applications. The broad operating range of this instrument makes it well suited for those use areas where economy and versatility are paramount.

Independently variable rise and fall times allow the **115** to meet many transition time test requirements. Rise or fall is adjustable from a fast 10 nanosecond up to a slow 100 microseconds. Delay functions include paired pulses and externally triggered bursts. Compactness plus very useful performance features enable the 115 to be used as stimulus in IC and other logic testing.

The programmable **R116** is similar to the 115 in specifications. This rackmounted pulse generator is the unit selected for use in the Tektronix **S3130** and **S3150** Automated Test Systems. The R116 may be operated manually from conventional front panel controls.

R116 PROGRAMMABLE PULSE CHARACTERISTICS

Risetime	10 ns to 100 μs
Falltime	10 ns to 100 μs
Period	100 ns to 110 ms
Duration (width)	50 ns to 550 μs
Delay	50 ns to 550 μs
Burst Time	50 ns to 550 μs
Amplitude (50 Ω)	0.4 volts to 10 volts
DC Offset	—5 volts to +5 volts
Polarity	Positive or negative

CALIBRATION SOURCES WITH OTHER USES

A group of Tektronix generators were designed to meet the exacting requirements of oscilloscope calibration. The precise performance of these units make them well suited in other applications where similar qualities are required.

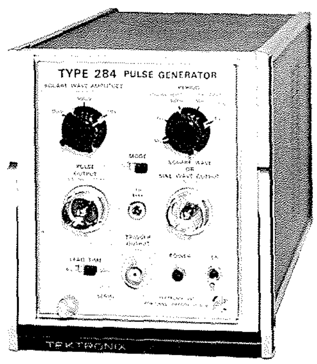
In addition, when you need results to be close to or better than instrument specifications, a calibration instrument available for daily use can be insurance against errors and wasted efforts. The 106, 191, and 184 are calibration instruments often used outside the calibration laboratory.

The **106** provides simultaneous positive and negative-going output transitions with ≥ 1 ns risetime into 50 Ω. Minimum aberrations make 106 waveforms ideal for verifying oscilloscope transient response. This instrument is also useful in diode recovery, core testing, digital, analog design and other applications.

Type **191** is a variable-frequency sine wave generator whose output maintains constant-amplitude over the entire frequency range of 350 kHz to 100 MHz. Amplitude is held constant during frequency variations by continuous sampling of the output voltage. Both output amplitude and frequency are calibrated.

The Type **284** Pulse Generator is very useful for verifying the performance of sampling oscilloscopes. This generator offers, in one small instrument, all of the signals required to check the risetime, vertical deflection factors, and horizontal sweep rates. A pre-trigger is provided for non-delay line systems.

In addition to checking the transient response of sampling oscilloscopes, the 70 picosecond, pulse output is an excellent 50 Ω signal source for TDR measurements. The Type 284 is available in a cabinet version, or modified for rackmounting in standard 19-inch rack.



Television Test Signals

If you have ever had your television picture roll, you probably have seen a VITS. In that dark area between pictures, a horizontal line or two may have a set of dots, a series of various levels of grey, or a series of luminance changes. These are VITS or VERTICAL INTERVAL TEST SIGNALS. Vertical Interval Test Signals are one of a group of test signals used by broadcasters and networks to verify system quality.

The composite television signal is an extremely complex, analog signal requiring fidelity in every stage from camera to home receiver. Without attention, each of the many processing and transmission stages will take a little information out of the signal. The cumulative effect through many stages can be significant. Since small degradations are difficult to analyze subjectively on picture monitors, the broadcast industry uses test waveforms and oscilloscopes instead. These test waveforms are based on the special character of the camera signal, the bandwidth limitations of the TV channel and the problems of interaction of color and black and white signals.

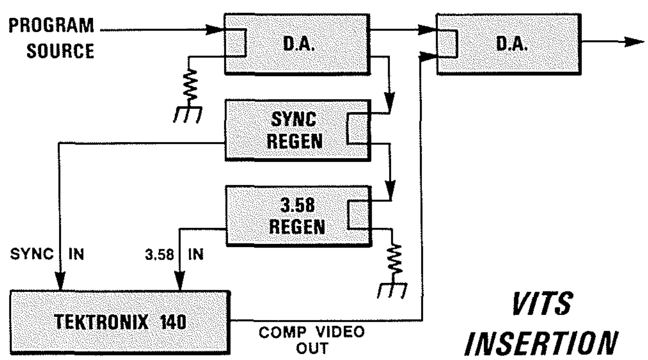
The Tektronix 140 NTSC Signal Generator is a source of several precise test waveforms for measuring chrominance and luminance interactions. These interactions are one of the major problems that occur when nonlinearities exist anywhere in a TV system. The 140 generates three test signals for measuring the effects of these nonlinearities. One waveform is the **Modulated Stairstep;** five equal steps of luminance modulated with 3.58 MHz chrominance. The chrominance amplitude is equal to the luminance riser amplitude. In TV systems Chrominance Phase and Gain can **differ** with luminance level. The measurements made with **Modulated Stairstep** are called **Differential Gain** and **Differential Phase.** Variations on these measurements include inserting the modulated stairstep on every fifth line with the other four lines held at a variable level of luminance. These levels are changed to simulate varying average picture level (APL) conditions.

Another effect that can be measured with a 140 is called **Luminance Cross Modulation.** This is the effect of various chrominance levels on luminance. For some years the phase of chrominance was considered to be the only critical parameter for true hue reproduction. The color signal, however, does have a luminance component. If the luminance component is changed (distorted) in amplitude, the viewed effect is often subjectively judged to be a phase (hue) distortion. To test for **Luminance Cross Modulation,** the 140 provides a second waveform, a variable luminance level modulated by three levels of chrominance. The luminance, after demodulation, is measured on a waveform monitor for distortions of level caused by chrominance.

Color bars are widely used for a quick check of picture quality. A trained observer who sees minor color differences on a picture monitor display of color bars can make measurements with a vectorscope. With a vector display he can quickly measure errors of amplitude and phase for each color bar. Eight bars are generated; white, six colors, and black. Each color bar is generated in the order of its luminance value.

Color Bars and Modulated Stairstep signals are normally used in off-the-air testing. When program material is being broadcast, the two signals can be used as VITS. Since the Vertical Interval Test Signal occurs during the time used for vertical blanking, it does not conflict with any picture being transmitted. The VITS is a quantitative signal that can be analyzed at any point from camera to receiver. All interested parties use the VITS to verify the quality of what he is receiving and what his system is adding to or subtracting from the transmitted picture.

The 140 can add color bars or modulated stairstep to program material. For VITS Insertion the 140 can serve as the MASTER SYNC source or can be slaved to program sync. If program composite sync and subcarrier are not separately available, we recommend the set up below.



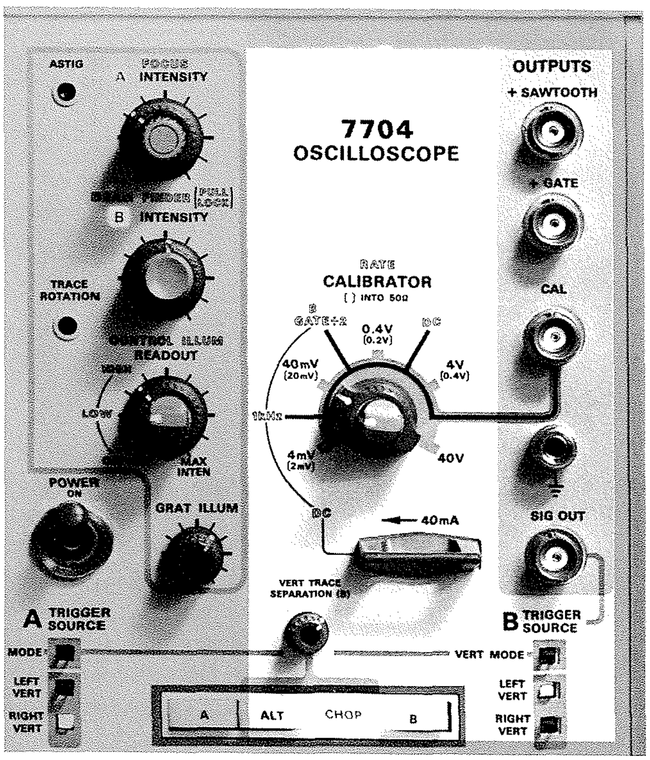
140 VITS insertion with program material.

CONCEPT BOOKS

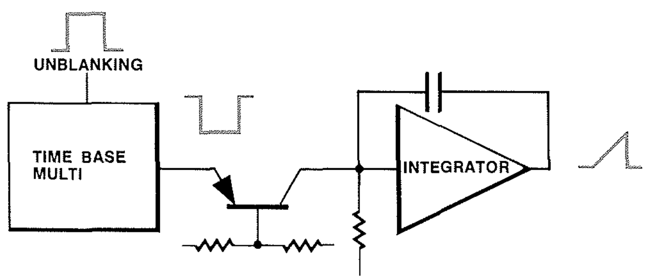
Tektronix has published two paper bound books in the CONCEPT SERIES containing television information. These are available at nominal cost from Tektronix. TELEVISION SYSTEMS MEASUREMENTS by Gerald Eastman discusses measurement techniques used in the television broadcast studio. TV SYSTEM MEASUREMENTS can be ordered using part number 062-1064-00. TELEVISION WAVEFORM PROCESSING CIRCUITS, part number 062-0955-00, by the same author, describes the circuit concepts of Tektronix wavefrom monitors and vectorscopes.

the 7000-series oscilloscopes as signal sources

A substantial portion of an oscilloscope is often available as signal sources. These sources are outputs of vertical amplifiers, time base generators and the calibrator. These outputs are normally thought of as *auxiliary* to most scope applications. Knowledge of how they work and their characteristics extend the usefulness of your scope beyond routine work.



The panel area of a 7704 has four signal source outputs from seven generators and amplifiers.

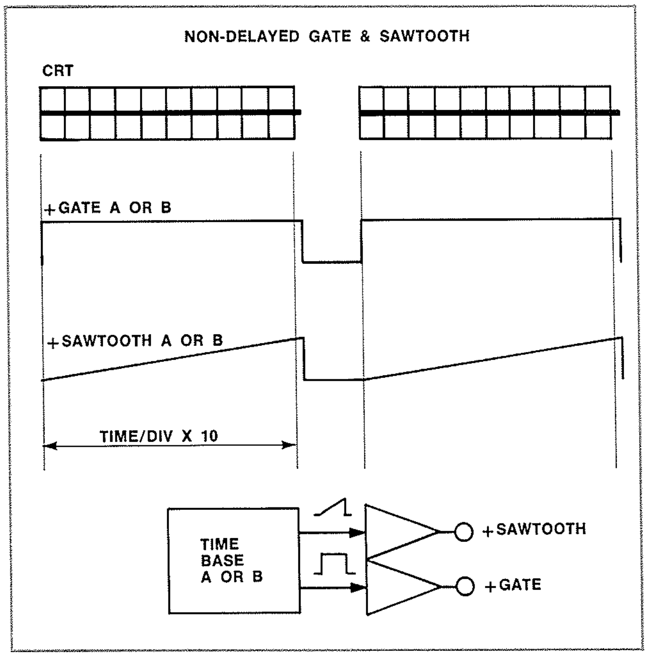


This is how a time base produces the gate for unblanking and the sweep sawtooth. The same gate and sweep sawtooth can drive, gate or control devices external to the scope.

The 7704, 7504, and the new 7503 have four signal outputs: SAWTOOTH, + GATE, CALIBRATOR, and VERTICAL SIGNAL OUT. The SAWTOOTH and + GATE each originate in time base circuitry; the CALIBRATOR independently produces squarewaves but may be driven by a time base gate. The VERTICAL SIGNAL OUT is derived from the vertical amplifier. An examination of each source in detail follows.

SAWTOOTH AND + GATE

Both gate and sawtooth are produced by time base generators for unblanking the CRT and sweeping the deflection system. A multivibrator produces the gate. This

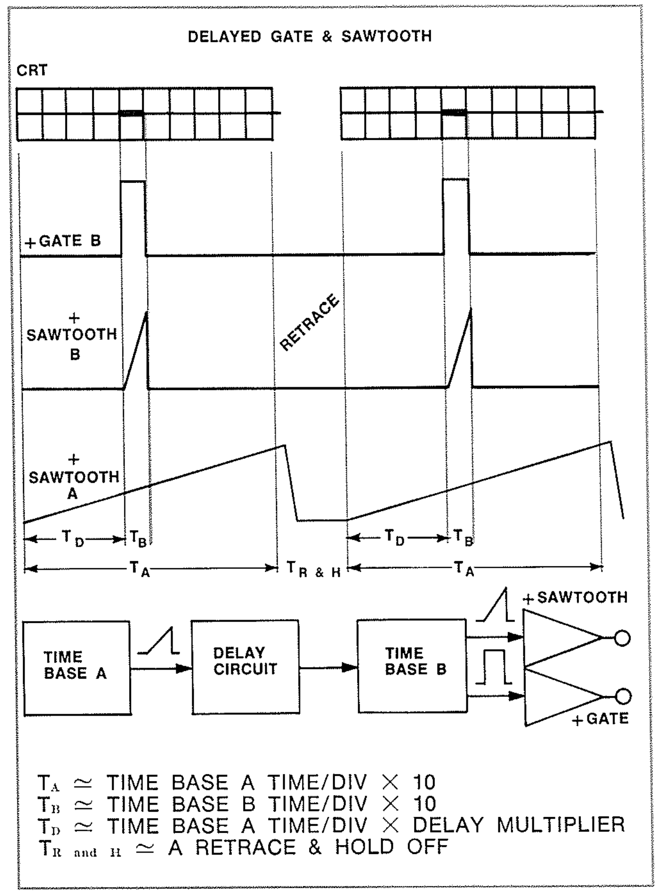


multivibrator may be triggered or internally caused to free run producing a gate that is integrated, generating a sawtooth for time base deflection. A portion of the sawtooth separately resets the multivibrator. The duration of all time base waveforms is determined by sawtooth rate of change and the reset voltage level of the multivibrator. Duration of gate and sawtooth is therefore directly controlled by the TIME PER DIVISION control. Duration and sweep length in time are, for practical purposes, identical. TIME PER DIVISION times ten divisions approximately equals duration of the + GATE and + SAWTOOTH.

Period of both sawtooth and gate will be duration plus retrace and hold off time. Hold off is a built in interval before the next waveform cycle can occur. It is very significant at fast sweep rates, but becomes inconsequential for medium to slow sweeps. In most cases, the user may use 10 X TM/DIV as an approximation period. It is well worth while to use a second oscilloscope to fully understand the full effects of the *source scope's* controls on its own outputs.

In the 7704, 7504 and 7503 the + GATE can be set as a delayed gate. This is a gate initiated at a selectable time after a delay time base starts. In the 7704 and 7504 a delayed sawtooth can also be produced. The duration of the delayed waveform is determined by the delayed time base TIME PER DIVISION control.

Gates and sawtooths have controllable time relationships with the display and can be used to initiate externally generated events, control swept systems, and provide versatile waveforms for other applications. An example of how the sawtooth may be used is shown on page 13 of this issue.



CALIBRATOR

The 7000-Series Calibrator has the following purposes:

1. Verification of deflection factor accuracy for both voltage and current.
2. Response compensation signal for both voltage and current probes.
3. Verification of mid-range time base accuracy.

Voltage probes have a required compensation adjustment in the range of 500 microseconds. For this reason, the Calibrator in the 7000-Series has a one kilohertz squarewave output. Current probes require longer duration waveforms for adjusting compensation. The 7000 Calibrator provides such signals by using the period of Time Base B divided by two to generate gate periods beyond four minutes. This long period provides a useful waveform for measuring long time constant effects in other circuits. For example: Long duration step waveforms are useful in detection of low frequency bandwidth problems.

7000-SERIES OUTPUT CHARACTERISTICS

+SAWTOOTH OUTPUT

LOAD	RATE OF RISE	PEAK
50 Ohm	50 mV/Div	≥500 mV
1 Megohm	1 V/Div	≥10 V
Short	≥1 mA/Div	≥10 mA

Output Source Impedance 950 Ω ± 2%

+GATE

LOAD	OUTPUT VOLTS	RISETIME
50 Ohm	0.5 V ± 10%	≤20 ns
1 Megohm	10 V ± 10%	—

VERTICAL SIGNAL OUTPUT

LOAD	OUTPUT VOLTS
50 Ohm	25 mV/Vertical Div ± 10%
1 Megohm	0.5 V/Vertical Div ± 10%

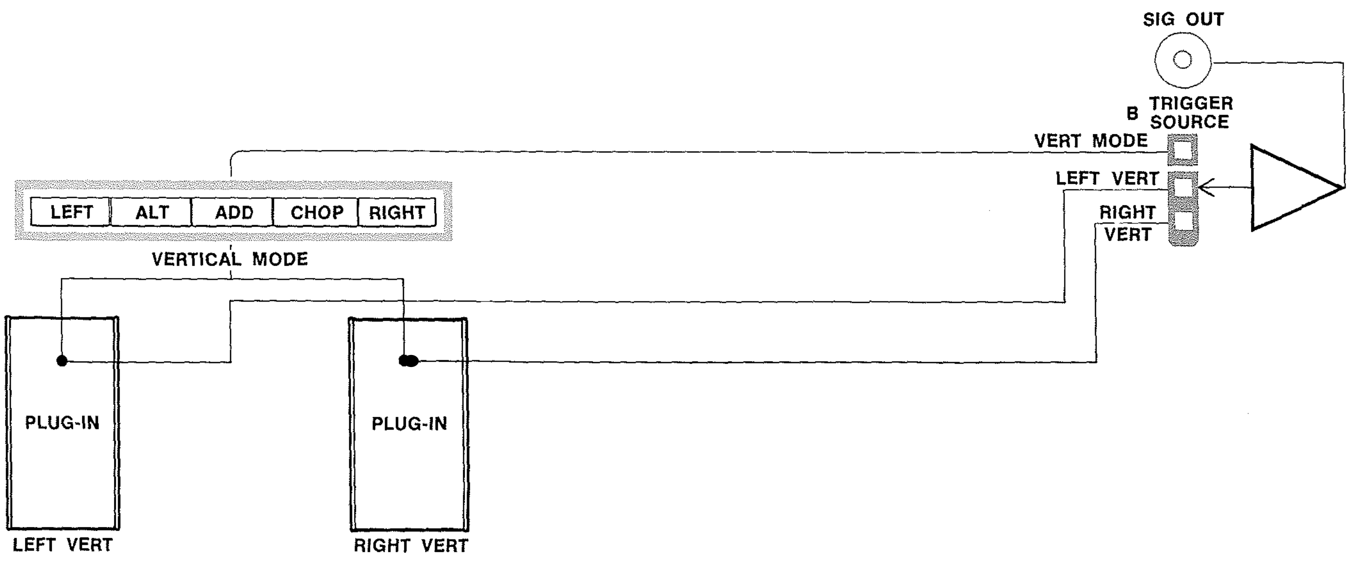
Source Impedance 950 Ω ± 2%

VERTICAL SIGNAL OUTPUT

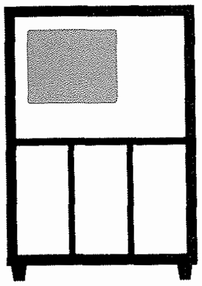
A wide variety of amplified and/or mixed signals may be produced by the SIG OUT circuitry. To fully utilize all possibilities, you must understand the relationship of vertical controls and vertical time sharing to the composite waveform produced.

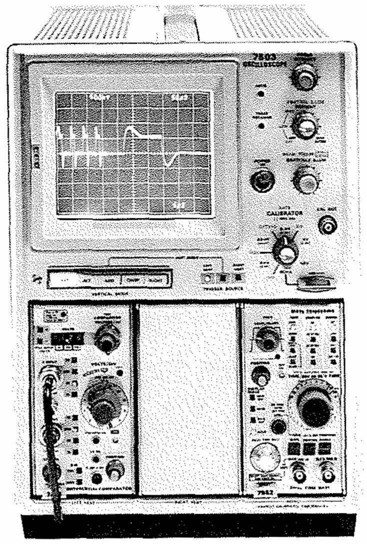
The vertical amplifier signal selected by the **B TRIGGER SOURCE** switch is the signal available at the SIG OUT connector. The character of that signal is affected by several factors. The dc level is directly affected by vertical positioning controls. A measurement should be made of the output level to determine what vertical position should be used if the output dc level is important. Absolute signal voltage out is determined by the vertical deflection factor. For example, the output at 10 millivolts per division deflection factor will be twice that at 20 millivolts per division. Any signal causing off-screen deflection may produce amplitude distortion. Any time shared output will lose information during the switching time. Time sharing, algebraic addition, deflection factor and vertical position all affect the character of the signal out.

The SIG OUT may be used to drive auxiliary devices such as counters, provide composites of two or more signal inputs, or selectively gate a signal on and off.

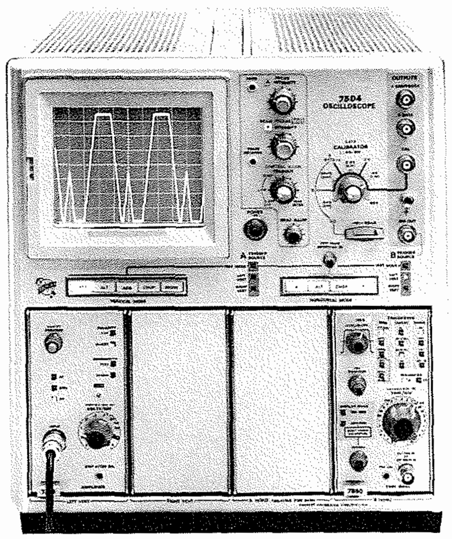


These 7000-Series push button selectors determine which plug-in signal is amplified and available at the SIG OUT connector. The same "Time Shared" signals driving the CRT are available at the output when B Trigger Source is in VERT MODE. The LEFT VERT or RIGHT VERT buttons of the B Trigger Source switch selects one of the two plug-ins as the output signal source.





turning easily from one thing to another



Oscilloscope Versatility By Addition

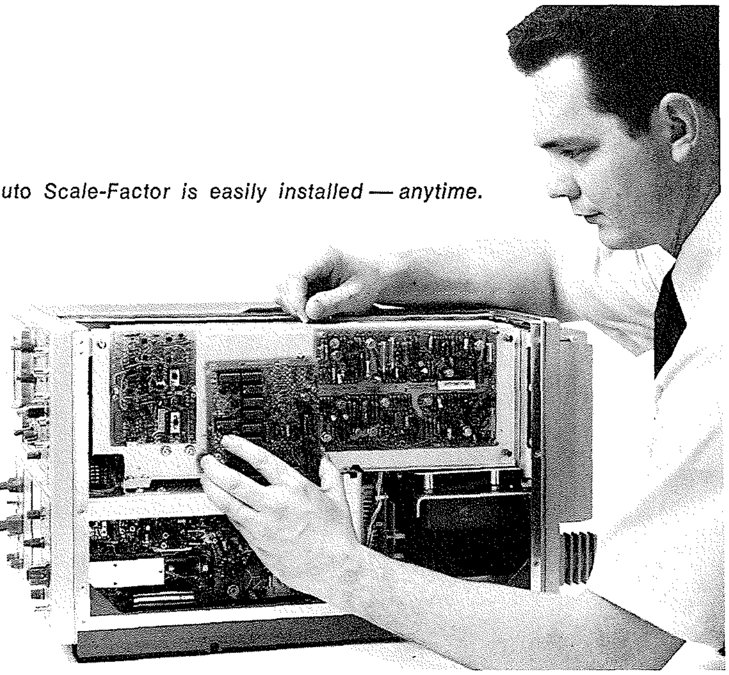
Versatile is a much used word. Repetition of the word has reduced its meaning, but it is still the best one word description of a general purpose instrument. The title of this article, taken from Webster's, is the meaning of versatile that fits the Tektronix 7000-Series. The 7000-Series has new ways to meet your future measurement needs.

The ability to turn easily from one performance characteristic to another has long been associated with plug-in substitution. Since substitution is so firmly established, it is easy to overlook the possibility that plug-in substitution **only** is a limited concept. Limited, if all that is possible is a change from one performance feature to another.

Change of oscilloscope vertical amplifier characteristics was featured in the Tektronix 112 external amplifier 20 years ago. This "outboard" amplifier converted the 10 MHz, 30 millivolt per division, 514 oscilloscope to something else: A 5 millivolt per division, differential input instrument. The outboard approach was soon overshadowed by plug-in methods of substitution. That innovation was introduced by the Tektronix 530/540 Series. Plug-ins were a major contribution in the early 50's. Easy substitution of state of the art, high performance features protected the future value of the plug-in oscilloscope. Substitution was simple and could be done any time. The value of easy substitution by plug-in change immediately became a sought after oscilloscope feature. Performance change by plug-in substitution was extended to horizontal systems with the introduction of the 536, 561, and 647.

Selection of a general purpose oscilloscope is a long term commitment and the instrument selected must serve your needs for many years. It is certain that more features will be required, but precisely what features will be needed is uncertain. Since plug-ins are a proven way to substitute features, when adapting to new measurement needs a plug-in scope is certain to be considered. To meet future needs more completely, the 7000-Series allows the **ADDITION** as well as the substitution of features.

The ability to **ADD** features is built into the 7000-Series oscilloscope. For example: The mainframe circuits will function without plug-ins. Addition of a plug-in time base and plug-in amplifier will create a fully functional oscilloscope. Even when the other one or two plug-in compartments are empty!



Auto Scale-Factor is easily installed — anytime.

Since the present three 7000-Series scopes are fully functional with only two plug-ins you can have a complete single or dual trace, delaying sweep instrument by using just two plug-ins. Plug-in capacity is reserved for future **additional** performance. When it is needed, performance can be easily added to the plug-in features already in use. Attractive blank panels are available to use in the plug-in compartment reserved for future needs.

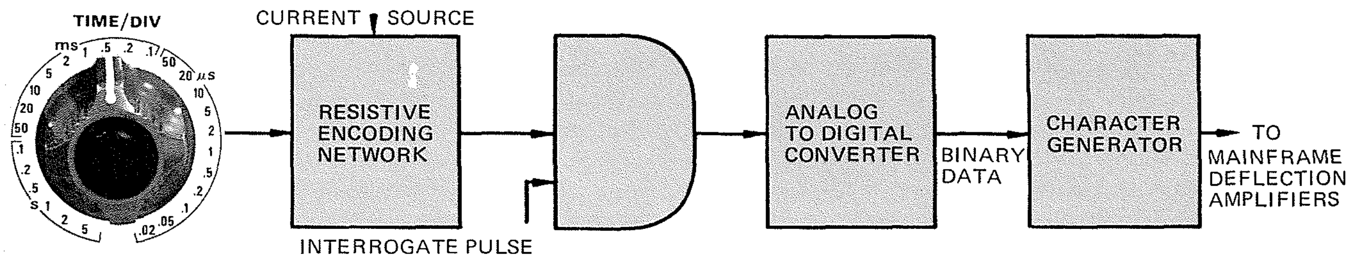
There are currently three oscilloscopes in the 7000-Series family: The four plug-in compartment 7704 with DC to 150 MHz performance, the four plug-in compartment 7504 with DC to 90 MHz performance, and the new 7503 featuring three plug-in compartments and DC to 90 MHz performance.

AUTO SCALE-FACTOR READOUT

The Tektronix Auto Scale-Factor Readout process, very much simplified, involves an analog encoding of plug-in control settings, pulse interrogation of that analog information, A to D conversion, and character generation controlled by the converted data, time shared into the scope's output amplifier. The logic used in the process of Auto Scale-Factor Readout is located either on the plug-in or the plug on character generator board. Because the mainframe does not have the Auto Scale-Factor circuitry hard wired in, a scope user can readily reserve capacity for its future addition. Two or three plug-ins in an Option 1 7000-Series mainframe* is a high performance scope today and an excellent investment in the future. This starter approach, without Auto Scale-Factor Readout, allows advanced scope performance today at minimum cost. Option 1 reserves capacity for future AUTO SCALE-FACTOR READOUT with no cost penalty.

The 7000-Series Readout includes 50 characters. The CRT display can include up to 8 words of 10 characters each. Two words are controlled by each plug-in in use. Complete sets of Scale Factors for voltage, current and time plus symbols and words for polarities, greater than and identify are generated as appropriate.

*Listed in the 1970 Catalog on page 34 as OPTION 1.



SIMPLIFIED AUTO SCALE-FACTOR READOUT

SERVICE SCOPE

TROUBLESHOOTING SAMPLING SYSTEMS PART II

By Charles Phillips

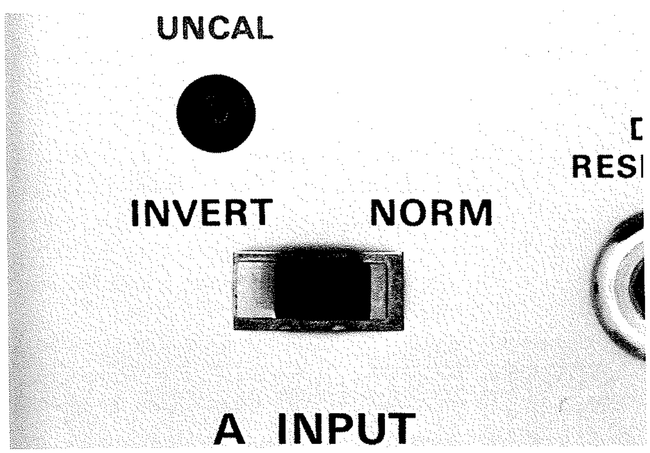
Product Service Technician, Factory Service Center

In the last issue, we covered the vertical circuitry of a "composite" Tektronix Sampling Oscilloscope. This issue discusses troubleshooting the typical horizontal system of that scope.

A spot or trace on screen is very useful in analyzing and finding problems in any scope. To eliminate the effects of most vertical problems, slip the NORM/INVERT switch to its center. A trace or spot will be centered vertically except when the vertical output circuits are defective. Use the horizontal position control to verify that the horizontal deflection amplifier is functioning.

In the absence of a trace, rotate the trigger sensitivity control. If no time base appears, switch to a manual scan mode. In manual scan, a variable DC voltage is substituted for the staircase equivalent time base. The manual scan should plot a horizontal line.

After you have established that the horizontal amplifier and staircase circuitry are operating, set the NORM/INVERT switch to NORM. Now let's proceed to the trigger circuitry. Regenerated trigger pulses should appear at the front panel trigger output connector or at the input to the fast ramp stage if the trigger circuit is operative. Use the trigger sensitivity control over its full range until trigger waveforms appear.



Slide switches of this type "break before make". This allows the troubleshooter to select a mid-range break position that opens the input to the output amplifier.

We now proceed to the fast ramp and comparator. With the regenerated trigger operational, a timing ramp of short duration should be generated. At the input to the comparator, a slewing ramp waveform should appear on a test scope. This slewing waveform verifies operation of the fast ramp and comparator. When the staircase is not functioning, the manual scan may be substituted for the staircase to analyze the fast ramp and comparator.

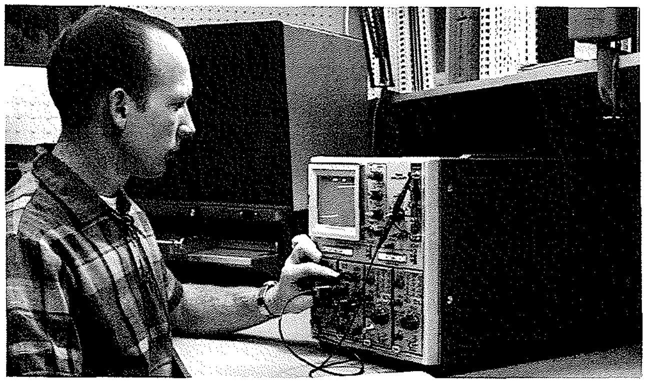
GENERAL TROUBLESHOOTING TECHNIQUES

The techniques used in troubleshooting sampling circuits are generally the same as for any other circuit. You should know the function of front panel controls and how the circuits work. In any malfunctioning circuit, transistors and tunnel diodes are the most suspect components. Here are some of the techniques that we have found helpful in locating defective components.

If you have a unit that is intermittent or drifts, routine checks may reveal no problem. Use a small, portable hair dryer to apply heat to the area where a problem is suspected. Then cool that area with spray-type, circuit cooler. The quick change in temperature will normally cause a defective component to malfunction severely. In many cases, the component will open or short. Locating the defective part should then be easy.

Elusive intermittents are often nailed by using circuit cooler and a hair dryer.

Some tunnel diode troubles are hard to detect. For example, the sampling system may operate, but the operation is not "normal". Triggering insensitivity, display jitter, balky time base operation all may be caused by a sluggish tunnel diode. A Tektronix 576 or 575 Curve Tracer is a very valuable instrument for identifying marginal tunnel diodes and transistors. A sluggish tunnel diode develops excessive voltage before switching. A slower "turn on" voltage than normal results. A good tunnel diode will switch at about 100 mV. A sluggish tunnel diode can develop 200 mV or more before switching.

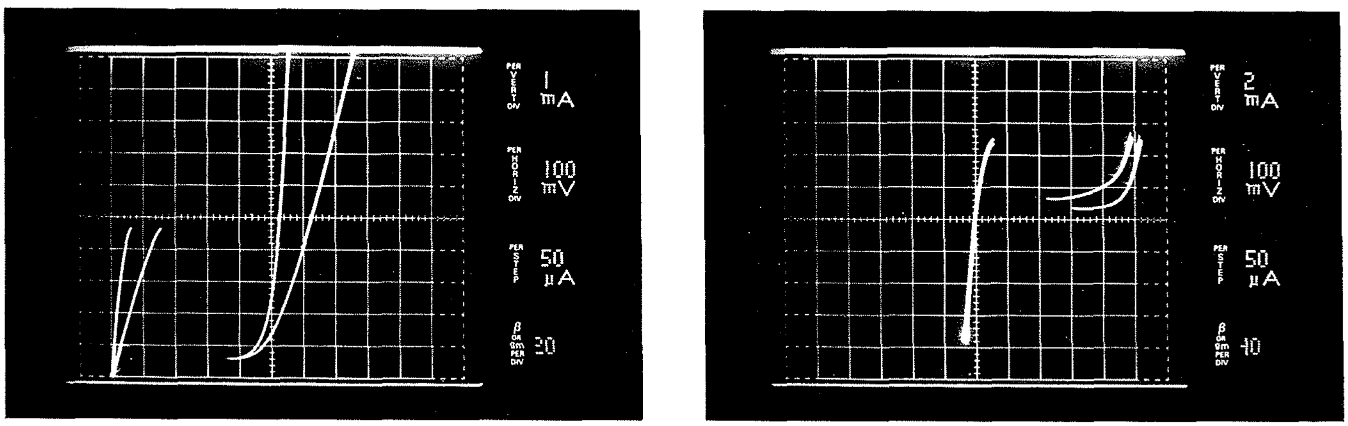


Chuck Phillips uses the 7504 Oscilloscope Sawtooth to verify correct TD performance.

Other methods of testing tunnel diodes are helpful where no curve tracer is available. The sawtooth output from a scope may be used to drive the tunnel diode to determine its switching point.

The sawtooth on a 7000-Series scope is a handy tunnel diode test signal. 10 mA or less TD's may be checked by placing them across a probe from ground lead to tip. The tip is then touched to the sawtooth output. The resulting display will show the voltage across the TD in the vertical axis. Each horizontal division will represent approximately one milliampere. A good 4.7 mA device will switch between the fourth and fifth horizontal division and develop about 500 mV. Caution: Some other scope sawtooth outputs are not current limited; a limiting resistor must be used.

Go, No/Go tests may be made with the multimeter. With power on, an in circuit voltage measurement across a tunnel diode should read 200 to 600 millivolts. A reading of 0 volts or substantially greater than 600 millivolts is a good indication of a shorted or open tunnel diode.



Marginal Tunnel Diodes are quickly detected with Tektronix 576 Curve Tracer. In the left photo, the "good" TD switches at 4.7 mA and 60 mV. The "poor" unit develops 160 mV before switching at 4.7 mA. The right photo shows "acceptable" waveforms made with the AC position of the 576. The AC Mode is a full sinewave sweep mode useful in making quick diode checks. It eliminates the need to observe diode polarities. (Photos are double exposed.)

PROBLEMS & CHECKS

Horizontal Amplifier

Problem: Position control will not move trace or positioning range is not normal.

Check: A. Sweep centering adjustment for proper centering.
B. Output stage for unbalance.

Problem: Display compression or expansion.

Check: A. Output stage.

Staircase Generator

Problem: Sweep starts at a different point on screen than it does in the manual scan position.

Check: A. Staircase DC level adjustment.
B. Output stage tube, nuvistor, or transistor.

Problem: No single sweep operation when in the single sweep mode.

Check: A. Tunnel diode stage in staircase circuitry.

Fast Ramp

Problem: Sweep nonlinearity at beginning of trace.

Check: A. For proper adjustment of the comparator.
B. Comparator tunnel diode.

Problem: Slashing between dots or other indications of improper blanking or unblanking.

Check: A. Transistors in the staircase inverter circuit.

Problem: Time base calibration changes with different values of trigger sensitivity.

Check: A. Transistor at input of the fast ramp where the regenerated trigger signal is applied.

Problem: Center of time base is nonlinear.

Check: A. Nuvistor or transistor in sweep calibration adjustment stage.

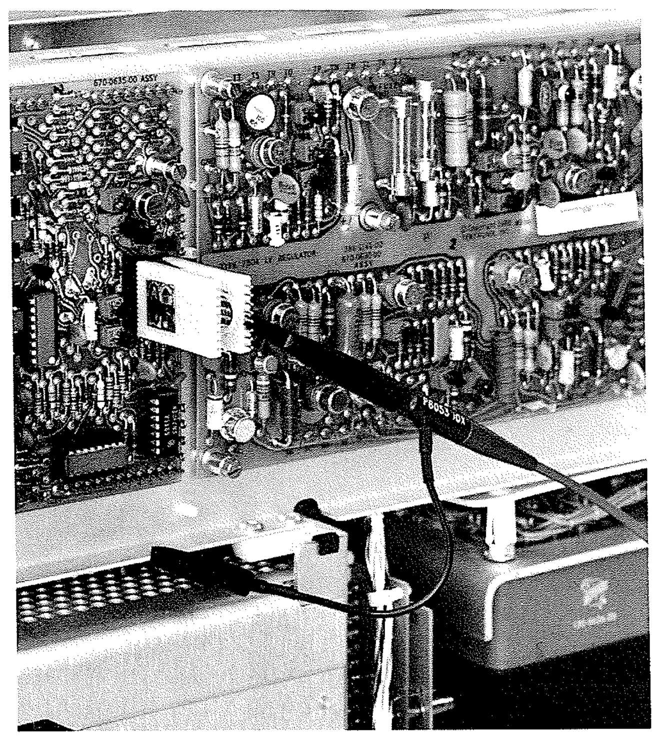
USEFUL IC TOOLS

Integrated circuits are showing up everywhere. Here are several handy IC handling tools available through your *local suppliers.*

The first item is particularly useful in removing TO5 case devices. This tool, manufactured by The Ephrata Tool Co., has tips that grip the TO5 case securely for pulling out of sockets or boards. This tool also has a handy set up for trimming TO5 leads neatly and easily.

Integrated Circuit Test Clip manufactured by AP Incorporated snaps over a 16 pin line like a clothes pin. It provides accessible test points and can help you pull suspect IC out of sockets and boards. Two sizes are available: 0.3 inch #923700 and 0.5 inch #923702.

Trimming individual leads on integrated circuits and transistors is a nuisance. This Ephrata cutter does the job with less effort.

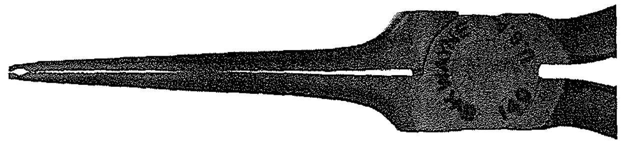


Dual in-line integrated circuits often lack convenient probe test points. The AP, Inc. test clip simplifies the probing job.

MODIFIED AND DO IT YOURSELF TOOLS

From time to time, we mention tools that are commercially *available through local suppliers.* These tools are mentioned as a service to people who are concerned with the responsibility of insuring instrument quality.

We occasionally mention standard tools modified to ease a particular job. These tools will also be readily available from your local suppliers and you can make the modification.



Sampling gate diode characteristics are critical to sampling system performance. It is generally best, for that reason, not to touch the body of the diode while performing any checks or replacements. If you do touch them, don't be overly concerned; they probably will be still okay.

A long-nose pliers may be easily modified to facilitate insertion and removal of gate diodes without touching them with your fingers. Grind out a groove on each jaw near the tip and you will have a handy device to use in tight spaces. The long-nose pliers that you modify should be of a type that does not normally develop high, crushing pressures at the tip. A type with jaws almost as long as the handles is good.

Occasionally, you will find an adjustment in a spot where a long, flexible screwdriver would be handy. A simple and easy to make tool has been used to advantage by some of our people. Take a 12 inch length of number 14 buss wire, flatten the end and slip a piece of spaghetti over all but the ends. Take a small knob (of a type used on small shafts) and fasten to round end of the "screwdriver" shaft. You now have an insulated tool to use in recessed narrow areas for low-torque adjustments.

INSTRUMENTS FOR SALE

3S1, 3T77A $1700. William McPerson, Powers Wire Products, 10180 E. Valley Blvd., El Monte, California 91731. (213) 283-0321.

531 with 53/B Plug-In. $500. Chuck Frederickson, Univac Fed. Systems Division, 475 No. Prior Avenue, St. Paul, Minnesota 55104. (612) 645-8511, Ext. 3308.

525. $550. Mr. L. R. Roche, Dyna Technology, Inc., Sioux City, Iowa 51102. (712) 252-1821.

547, 1A1. Scope-Mobile Cart. $1950. George Payne, 806 Third Avenue, Sweet Home, Orgeon 97386. (503) 753-8482.

517A. Henry Thomas, Electronics Department, McAllen High School, 2021 LaVista, McAllen, Texas 78501.

310A. $600. Tom Fisher, Standard Communications, 620 E. 219th Street, Torrance, California 90502. (213) 775-6284.

107. Price open. Mike Brady, Instrumentation Services, 957 Winnetka Avenue North, Minneapolis, Minnesota 55427. (612) 545-8916.

517. $1000. 514D. $100. Dennis R. Menges, FMC Corporation, 220 South Belmont Avenue, Indianapolis, Indiana 46206. (317) 632-5411.

547, 1A1, 1S1. All for $3000 or individually. Palmer Agnew, 314 Front Street, Owego, New York 13827.

3B4. $300. Mr. Moss, Eastwood Industries, 1101-11 West Armitage Avenue, Chicago, Illinois 60614. (312) 472-8662.

190B. $275. Bob Lightner, Audio Supply, 81 North Atlantic, Cocoa Beach, Florida. (305) 783-3062.

545S6. $900. Mr. M. Stephanski, Deltron, Inc., Wissahickon Avenue, North Wales, Pennsylvania 19454. (215) 699-9261.

575, Mod 122C. $900. Jack Fields, Carrier Corp., Carrier Parkway, Syracuse, New York 13201. (315) 463-8411, Ext. 3365 or 3366.

547, 1A1, 111. Mr. Tibol, Semi-Elements, Inc., Saxonburg Blvd., Saxonburg, Pennsylvania 16056. (412) 265-1581.

661, 4S2, 5T1A, $2000. John McAlpine, Linear Accelerator Lab., University of Saskatchewan, Saskatoon, Saskatchewan. (306) 343-4511.

545 with plug-ins 53/54C, 53/54L, M. $750. D. K. McDonald, Electronic Systems, P.O. Box 20391, Denver, Colorado 80220.

454 with extras. $2200. Hull Industries, Santa Monica, California (213) 451-2215.

LC130, 317, 503, 515, several 530/540 Scopes with plug-ins. Henry Posner, Pacific Combustion Engineering Co., 5272 E. Valley Blvd., L.A., California 90032.

561B, 3S2, 3T2, Two — S2 heads. Wilmar Electronics, 2103 Border Avenue, Torrance, California 90501. (213) 320-6565. Price for all units — $2250.

3T77. $325. 3S3. $750. Al Nelson. (303) 733-0421.

180 Time Mark Generator $150. Plug-In Units, 53C $95, 53/54K $75, "S" $50, 545 $850. Jim McKim, 5601 Del Cerro Blvd., San Diego, California 92120. (714) 583-4076.

561, Plug-Ins 2A61, 2B67, $650. Paul F. Fitts, Innovatek Enterprise, Smithfield Road, Millerton, New York 12546. (914) 373-9122.

INSTRUMENTS WANTED

555. Henry Thomas, Electronics Department, McAllen High School, 2021 LaVista, McAllen, Texas 78501.

570. Chris McIntyre, 13 Laurel Village, Beaufort, South Carolina 29902.

422. George Rademacher, Jr., Georges Mfg. Corp., 9915 Pacific Avenue, Franklin Park, Illinois 60131. (312) 625-5868.

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TEKSCOPE

Volume 2 Number 3 June 1970

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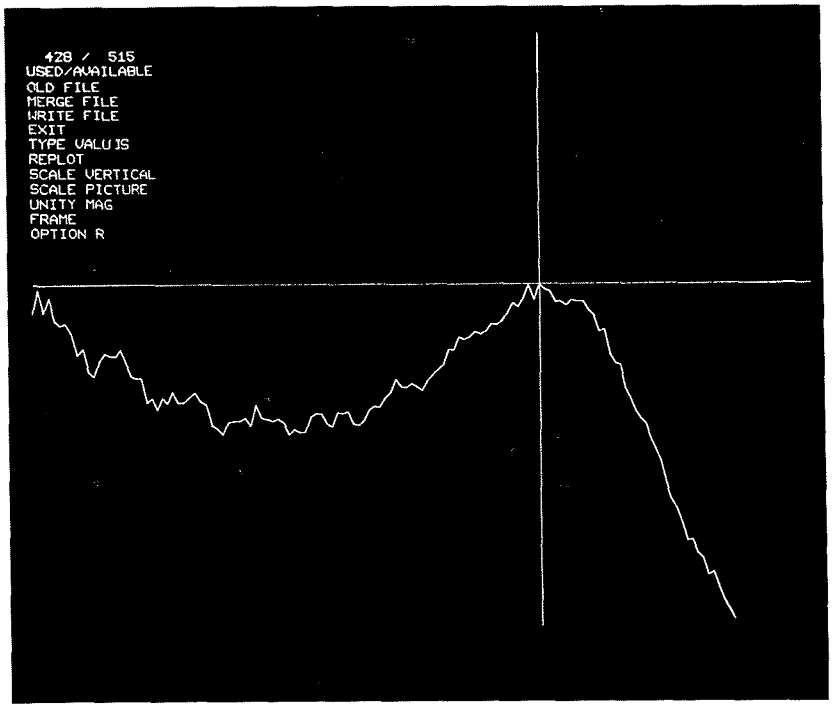
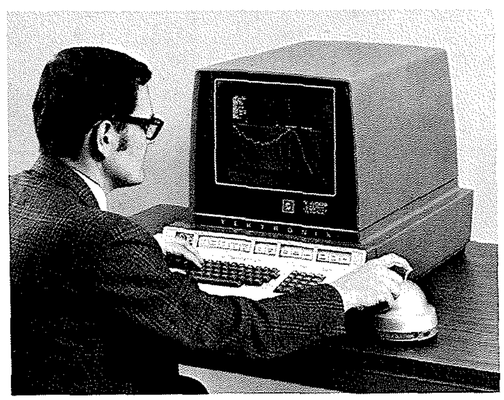




Interactive Graphics

It is easier to point to a location than to describe it. That is a fundamental concept in Tektronix Interactive Graphics. Interactive Graphics is the operation of pointing when a man talks to machine about a graphic display.

Pointing in communications between people is a mechanical action, visually interpreted. Pointing in communications between man and computer is a mechanical action by the man, electronically interpreted by the computer through a computer terminal.

The CRT in graphic terminals is a one-way device. It displays, but *it does not see.* It has no electrical characteristics that are easily used for seeing information from the man. You **cannot point** anything at the display CRT and have the CRT see the point.

There are ways to point to locations on CRT's and have the computer terminal "see" that location. On a refreshed CRT, any point on the CRT face is scanned repeatedly with a process similar to that used in television. Scanning is a precisely timed process. If a photosensitive device is pointed at a CRT, an electrical pulse is developed each time that location is scanned. This pulse has a *time* relationship in the scan sequence that can be processed and communicated to a *computer.* The *photosensitive* device is generally called a LIGHT PEN.

LIGHT PENS are commonly used with refreshed CRT's, but they cannot be precisely placed on the location pointed to. Mechanical parallax results from the separation of the display and the CRT surface. Other parallax problems are caused by electronic dissimilarity between separate *write* and *read* circuitry.

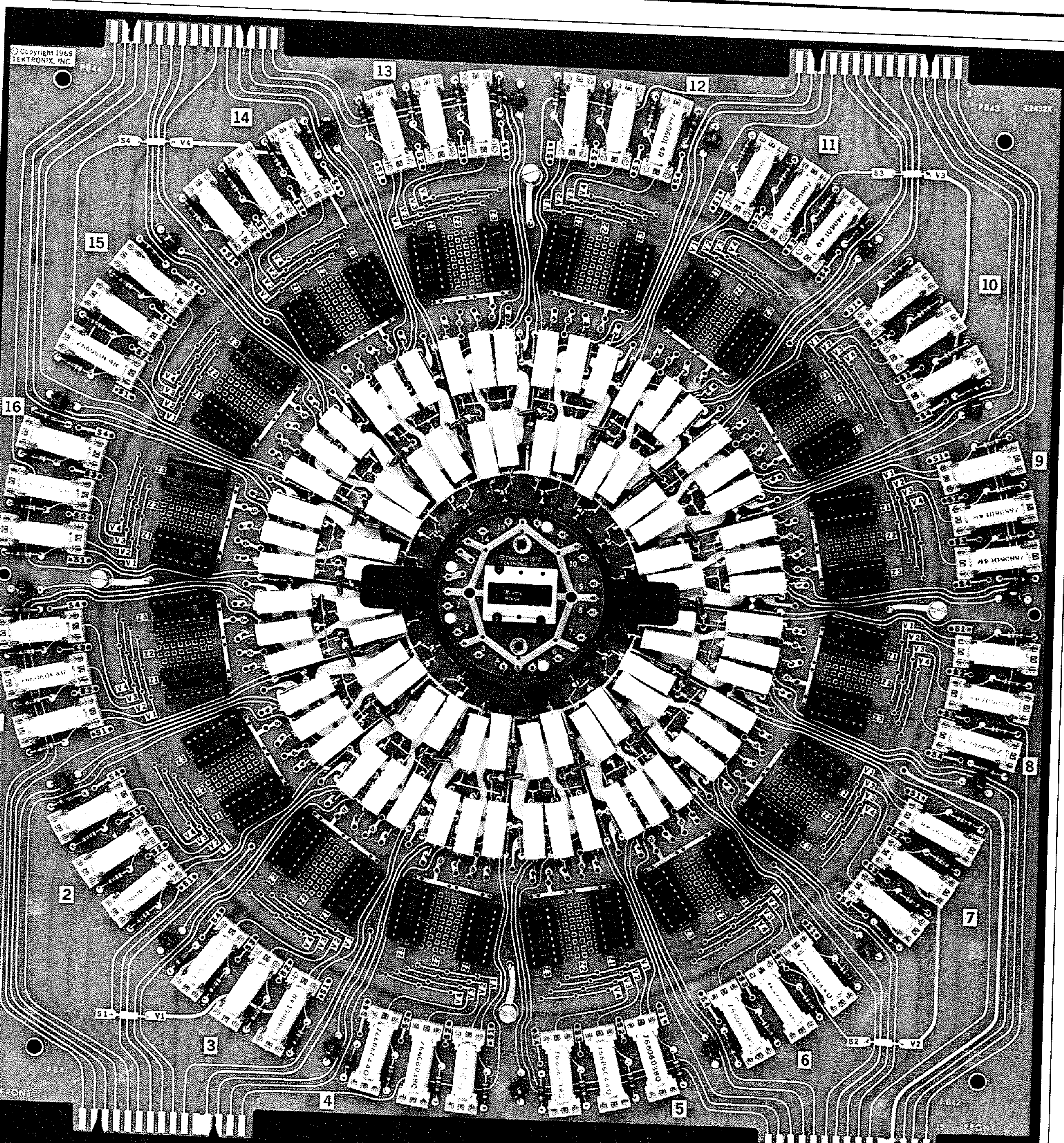
The Tektronix T4002 Graphic Computer Terminal uses a **pointer** that is unique, accurate, and simple. This pointer uses the write-through function of the Tektronix Bistable Storage Tube to eliminate mechanical parallax. A cross-hair cursor (pointer) is written through the stored graphic display. The terminal operator points by *positioning* the cross-hair cursor on the graphic display. On command, A to D conversion *precisely defines the location in digital form.* This data is sent to the computer. Now, the computer can see the *operator's point within* one least significant location bit.

The pointing device used by the operator can be a mouse, scratch pad or the Tektronix Joystick. The Joystick is an accessory to the 4901 Interactive Graphic Unit. The 4901 can communicate location precisely on the T4002 Graphic Computer Terminal because the voltages developed by the Joystick, or any similar device are **seen** by the same circuitry used to plot the *original, computer-generated* display.

The Tektronix T4002 Graphic Computer Terminal with the unique **4901 INTERACTIVE GRAPHIC UNIT** achieves no parallax, two-way graphic communications.

TEKSCOPE

AUGUST 1970

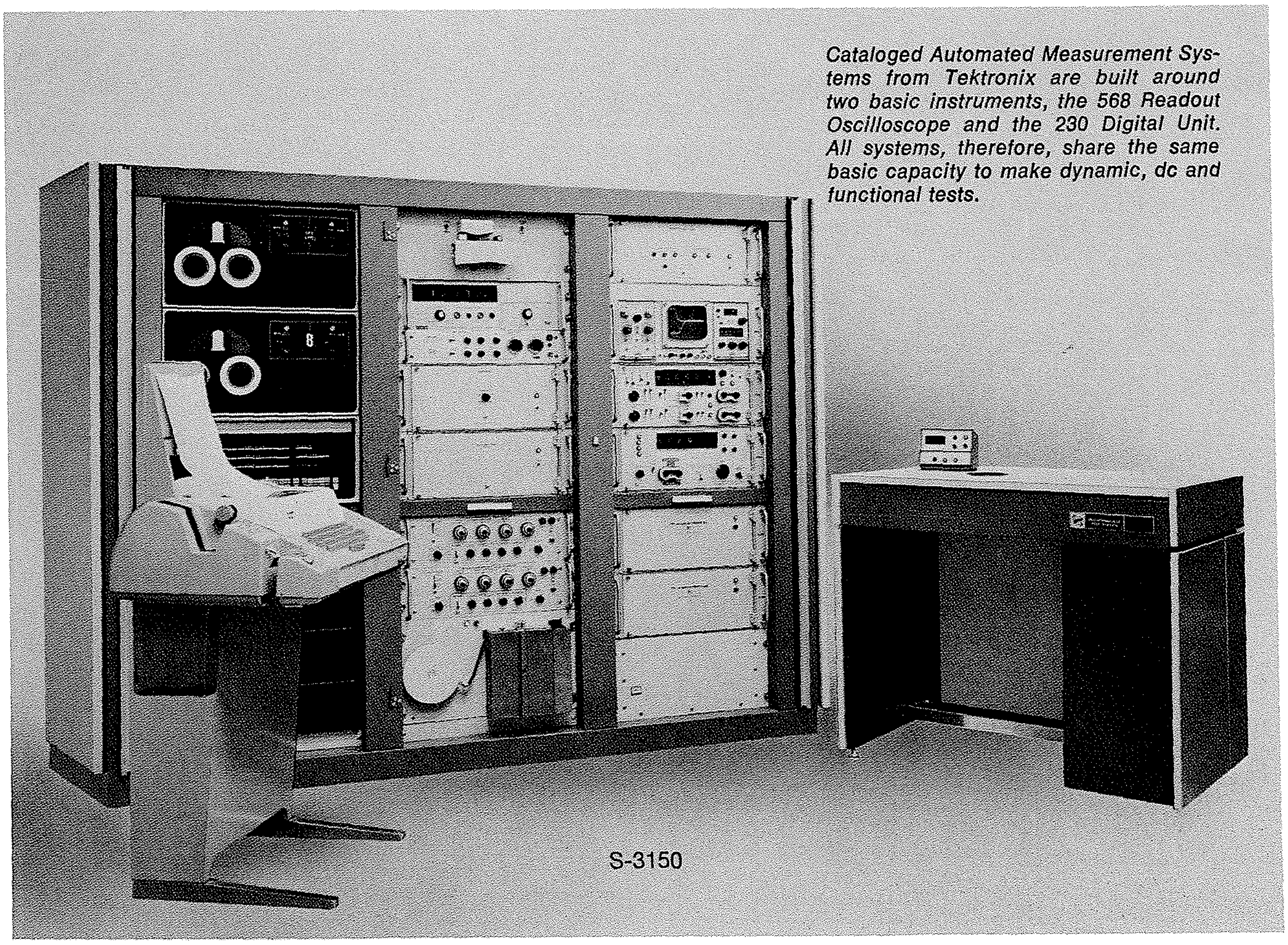


Automated Measurement Systems | Hazardous Material Identification | Service Scope | Fast Writing CRT

COVER—5 milliseconds from 10 nanoamps to 1 nanosecond — Rapid reconfiguration of test environments is imperative when large numbers of devices must be tested functionally and dynamically in addition to having dc characteristics determined. This LOAD BOARD in the S-3150 Automated IC Measurement System is part of the new test station that provides a no compromise test environment less than 5 milliseconds after program command.

automated measurement systems

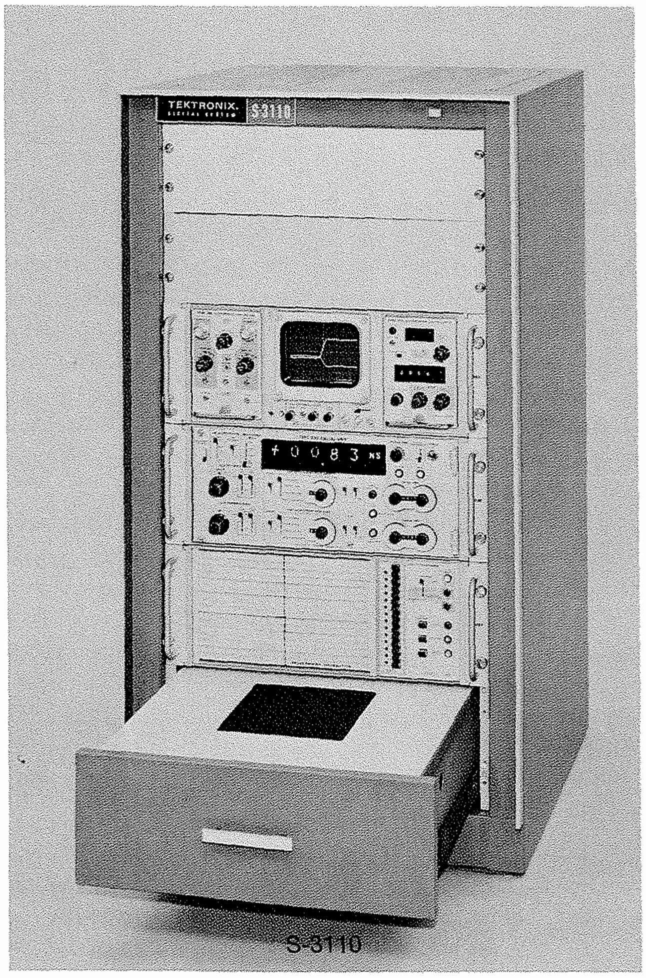
Complete testing of integrated circuits may require fifty or more measurements under varied stimulus and load situations. When thousands of devices must be tested, problems become formidable and it is obvious that sophisticated, automatic measurement systems are required. Where fewer measurements on a lesser number of devices are to be made, simpler systems can perform the same tests—and at economical per unit cost rates.



Cataloged Automated Measurement Systems from Tektronix are built around two basic instruments, the 568 Readout Oscilloscope and the 230 Digital Unit. All systems, therefore, share the same basic capacity to make dynamic, dc and functional tests.

Automatic Measurement Systems by Tektronix, Inc., simple or sophisticated, are all able to make the same measurements. Measurement repeatability between sophisticated and simple systems makes it possible to correlate results between systems. Now the development lab and manufacturing plant of the integrated circuit producer and the integrated circuit user can make the same tests, using the same basic measurement package and their results will correlate.

Tektronix manufactures a number of automatic measurement systems used in integrated circuit, semiconductor, and board testing. These systems all are built around the same basic measurement package. Differences are in fixturing, stimulus, handling and programming. Systems by Tektronix, Inc. are built using standard catalog products, supplemented with products from other manufacturers. Since both systems and their components are catalog products, many options and choices are open to the user.



Choice One—Purchase a fully operational system with catalog specified performance. Catalog systems are assembled, tested, and, in the case of the more complex packages, installed by digital systems specialists. Training for systems support personnel is available at no extra cost.

Choice Two—The Tektronix Automated Systems group can add custom measurement capacity to standard catalog systems. A significant number of delivered systems have been tailored to individual customer needs by modification or the addition of products of other manufacturers. Custom systems can include dvm's, power supplies, stimulus sources, fixturing, handlers, etc.

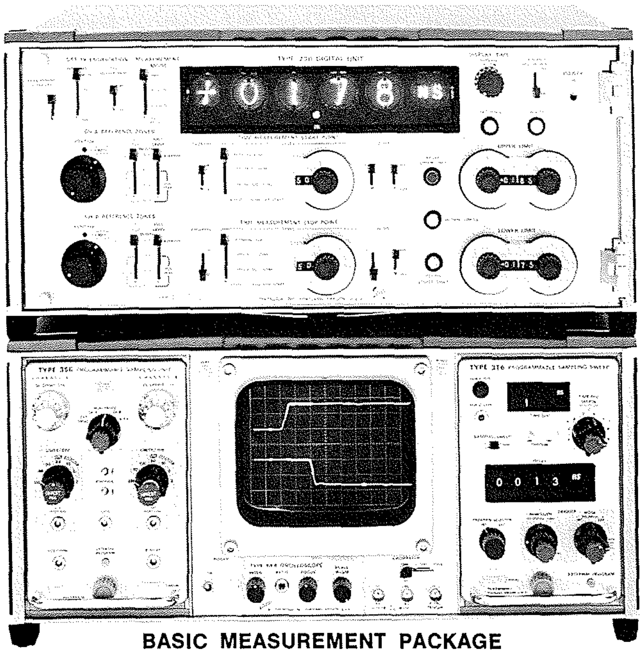
Choice Three—Systems components can be assembled by the customer. It is occasionally an advantage for a customer to use his in-house system assembly capacity. Tektronix catalog products, used in systems, are readily combined using standard accessories and hardware. It may well be that some Tektronix systems instruments are already in use in-house. Integration of these instruments in customer-assembled systems is very practical. Customers can also expand their existing Tektronix systems by adding cataloged items. A 241 Programmer, for example, is an excellent addition to a bench set up that includes a 568 Readout Scope and 230 Digital Unit.

BASIC MEASUREMENT PACKAGE

The basic measurement package in a Tektronix system consists of a 568 Readout Oscilloscope and plug-ins plus a 230 Digital Unit. The prime function of the 230 is conversion of sampled analog data to digital form. An understanding of the 230 Digital Unit and sampling is the key to understanding how Tektronix systems make measurements.

Sampling was developed to display fast information on response limited devices such as the cathode ray tube. It was found that the conversion of fast, repetitive information by sampling not only provided the technique for analog display, but formed a basis for further conversion to digital form. Digitizing of the analog display formed by the sampling process takes place in the 230 Digital Unit.

Fundamental to the 230 digitizing process is the use of a precise number of samples per CRT horizontal division. The horizontal axis of the sampling scope is scaled in equivalent time per division; therefore, each sample represents an equivalent time period. A group of equivalent time periods form an *equivalent time clock*. For



BASIC MEASUREMENT PACKAGE

example, if the number of samples per division is 100 and the time per division is 1 nanosecond, each sample represents 10 pico-seconds.

Many system measurements are of time differences between two levels or percentages of amplitudes. It is a relatively simple process for the 230 to store voltages representative of peak amplitudes on a CRT waveform. These memorized voltages are divided and used to set separate start and stop count comparators. When the 230 is programmed for a period measurement, the count starts at 50% amplitude on the plus (or minus) slope and stops at 50% amplitude on the negative (or plus) slope. The count and scaling of the counted samples (equivalent time clock) provides the digitized value of period. Most 230 time measurements are made with this technique of counting samples between two waveform points.

Voltage measurements require a different, but equally straight-forward technique. The waveform peak voltages stored in memory are used to start and stop a count of an internally generated, 10 MHz clock. The technique used compares a ramp against the memory levels, the resulting count is scaled and presented in alphanumerics.

Time and amplitude data in digital form is also used by the 230 to make decisions as to whether a test result is above, below, or within limits. The readout and limits data is also available for driving external devices such as printers and handlers. The 230's ability to make test result decisions enables less skilled individuals to complete complex tests without using analytical skills. With the 230 Digital Unit and the 568 Readout Oscilloscope, only one more unit is needed to form a basic automatic system. That unit is the 241 Programmer.

FACTORS IN PROGRAMMING A SYSTEM

Any front panel controlled function in a system by Tektronix, Inc. can be duplicated by a program control unit. This generalization applies with very few exceptions. In addition, some system functions are only available through program control units. The degree of programmability and components of the program control group varies with the measurement rate and the number of devices to be tested by the system.

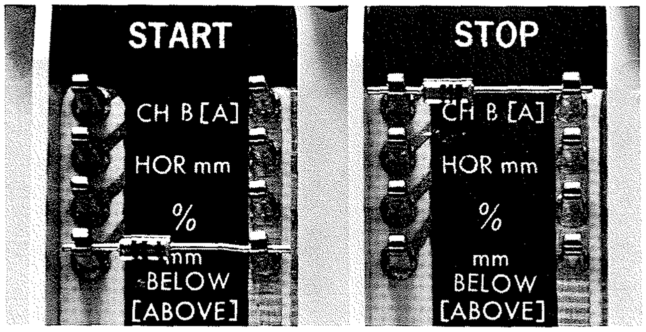
Automatic measurement systems are most used where the same measurements must be made repeatedly. This is particularly true when a large volume of units must be tested. Time required for manual operations are usually more significant than measurement rate in influencing the number of devices that may be tested per hour. The factors influencing time per measurement on a manually controlled instrument system might be arbitrarily listed in descending order of importance when just one measurement on one device must be made:

1. Getting the test system together.
2. Coupling power and stimuli to test system components.
3. Setting up the test conditions.
4. Adjusting instrument controls.
5. Interpreting indicated values.

When more tests on more units are to be made, it is the steps that are repeated often that are candidates for automation.

It is always step 5, interpreting indicated values, that is tackled first in automating measurements. This is so because it is the readout and interpretation process that is repeated in every measurement, while the other time consuming steps are often set up once for a sequence of measurements on the same device. With a simple system, consisting of a 568 Scope and a 230 Digital Unit, we must change the digital unit's instructions to make each of a sequence of tests. It is probable that scope sensitivity and equivalent time controls are only occasionally touched during the same test sequence. Test conditions, stimulus and loads, may seldom be altered. Cabling and test circuitry are often fixed, especially in simple systems. It is the functions of those controls that are most often used that are first put under program control. As more measurements on a greater number of units are required, manual operations are less and less tolerable. In a system like S3150, for example, the insertion of devices and selection or initiation of program are the only conspicuous manual operations.

With one exception, Tektronix systems instruments use parallel, negative logic. A simple ground closure or an applied voltage between 0 and +2 volts represents a logical one. Logical zero is formed by an open circuit



Programming with the 241 is simply a matter of inserting diodes.

or an applied voltage between +6 and +12 volts. A saturated transistor or a closed relay can readily form a logical one. A non-conducting transistor or open relay can form a logical zero.

A common diode to ground can also form a logical one instruction and the absence of a diode forms logical zero. The 241 Programmer works with 15 program circuit cards using diodes and controls the 568/230 basic measurement package in a simple system. In addition, the 241 can program a limited number of functions in the stimulus and/or fixturing areas, including sampling head multiplexers.

Programming the 241 is a simple process. First, set up the system front panel controls for a measurement, then insert diodes on the program card as needed to duplicate that control set up. A test with the card installed in the 241 will quickly prove if the program is correct or if it needs debugging. Any person familiar with the basic instruments can program without special instruction.

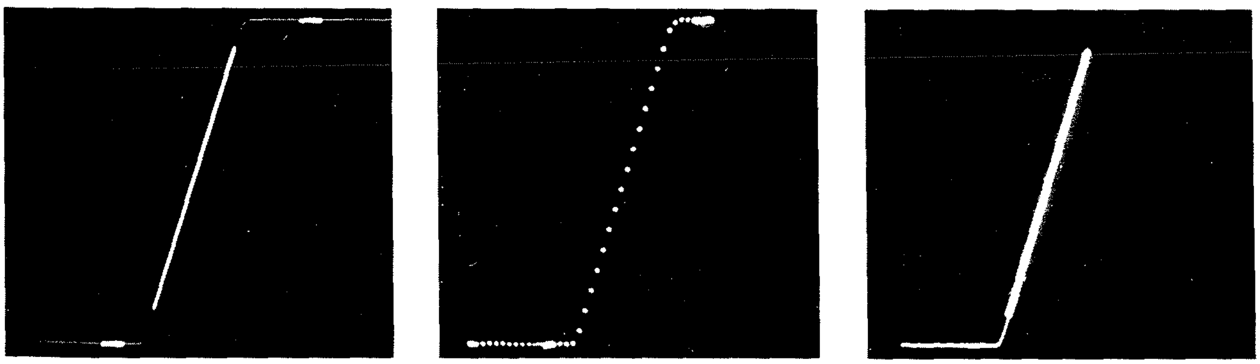
When more devices are to be tested, or more than 15 measurements per device are required, a larger number of test programs will be needed. The 240 Program Control Unit with a disc memory, holding up to 1600 measurements, fills the expanded need.

The 240 Program Control Unit converts serial by bit or serial by character program instructions to the parallel form used by systems components. The 240 is used with the 250 Auxiliary Program Unit to control stimulus sources, fixturing, and other systems components in larger systems. A measurement rate of 100 per second is feasible in a system using a 240. The actual measurement rate is dependent on many factors, and sometimes, in actual practice, it is less than 100 per second.

HOW MANY MEASUREMENTS PER SECOND

One factor controlling measurement rate, in dynamic measurement systems using sampling oscilloscopes, is the repetition rate of the stimulus, but stimulus rate limitations usually are not the most limiting factors. Load switching and settling time are more significant. When two or three of the basic tests are to be made, the number of units completely tested per hour is a better indication of system speed than a fast measurement rate emphasized over all the other time consuming operations in device testing.

There are many ways to speed the measurement rate in a system based on a sampling oscilloscope. High speed programs are used to reduce dot density (number of samples), the number of memory charging sweeps, and to end time bases just after a measurement. These techniques speed up the measurement rate by factors more than 10. Handling of devices and fixture reconfiguration usually slows measurement rate below that of the sampling rate. In a system performing all three basic tests, a measurement rate of 50 plus tests per second and a unit test rate of more than 250 per hour is common. Automatic handlers can increase the unit per hour rate (throughput) to 1000.


Left — In the absence of high speed program instructions, two sweeps of 1000 samples each are needed per measurement. Center — A single measurement sweep ending after 0% and 100% memories (intensified) are charged requires only 92 samples. Sampling density is reduced except in memory zones. The memory charge sweep is made just once for a number of measurements. Right — A measure sweep ends just after the measurement zone (intensified) requiring only 300 samples. Total time required for this high speed, risetime measurement is approximately 4 milliseconds.

THE S-3150 SYSTEM TEST STATION

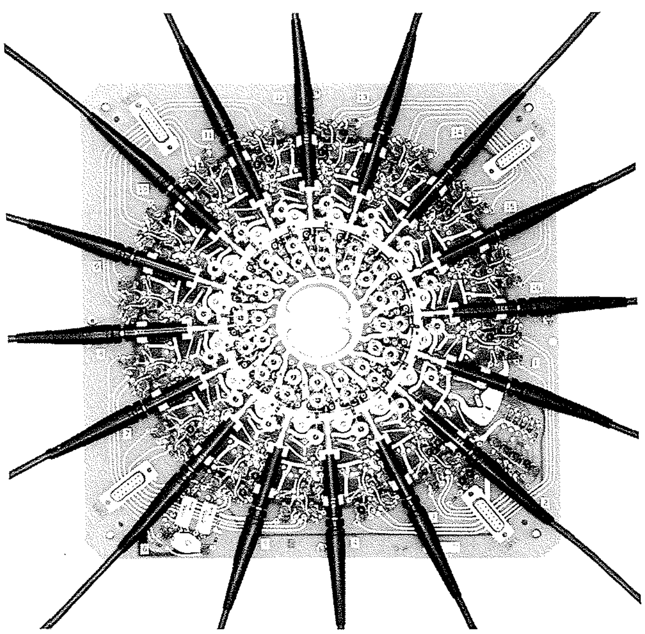
The effort required to test one integrated circuit by any of the three methods is not difficult or particularly costly. Problems multiply, however, when great numbers of IC's and tests per IC are added.

There are a wide variety of integrated circuit types available and fifty or more tests must often be made on each device. When the units to be tested reach quantities of hundreds and thousands, connections to the test socket must be automatically reconfigured for many of the tests. This reconfiguration is often by cross bar matrixing in a DC tester, but where device switching speeds are faster than 50 nanoseconds, the cross bar matrix cannot be used because of its excessive capacitance. High speed function and dynamic testing requires a more acceptable switching element.

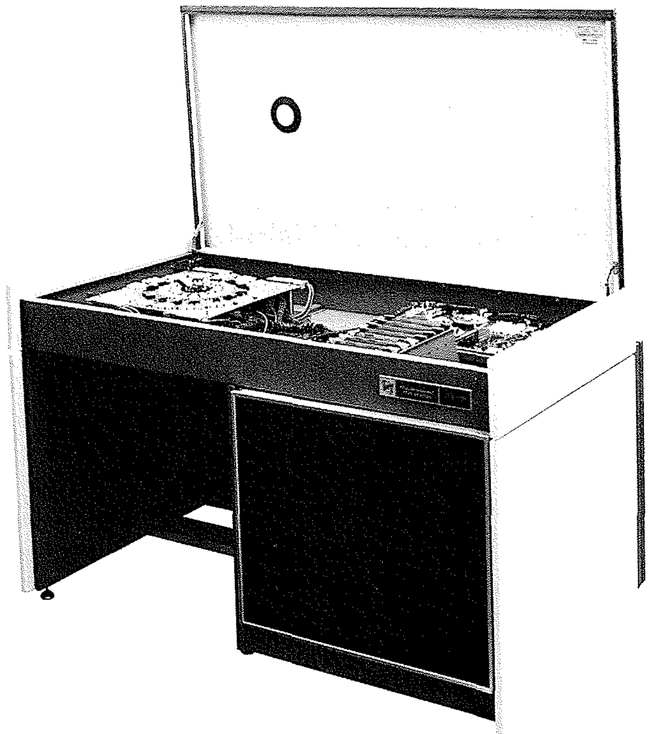
The reed relay proves to be the best switching element. Its low off-capacitance and low on-resistance make the reed relay acceptable in 50 ohm as well as in much higher impedance systems. Operating speeds in milliseconds are practical and life times in millions of operating cycles are to be expected.

The reed has exceptional performance in the nanosecond region. Advantages in capacitance, conductance, isolation and break-down voltages qualify it for the nanosecond environment of S3150 System. It also provides a complete dc matrix for dc and function testing.

A full scale testing system must have facilities for switching load networks. Testing many different integrated circuits requires different load networks and, during a



One Probe Per IC Pin—The Probe Board of the S-3150 Automated Measurement System is the heart of the IC Test Station. Each pin of the DUT has program controlled individual power and pulse sources with a variety of loads.



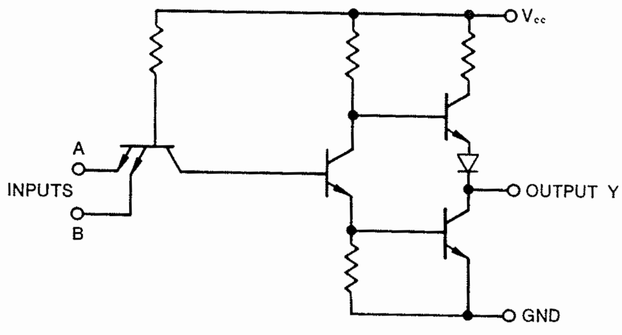
The Test Station—Here both 10 nanoamp dc as well as 1 nanosecond dynamic measurements are made with only 5 milliseconds required to change test conditions between the two measurements.

sequence of tests, loads must be reassigned to different device pins. In addition, the same pin of a device may be loaded with one network during a turn on propagation delay test and another load for turn off delay. In a TTL device, it may be necessary to switch two or three loads to any pin. In the S3150, each pin has its own set of load networks. Loads are duplicated for each pin to save space and cost while shunt capacitance is minimized.

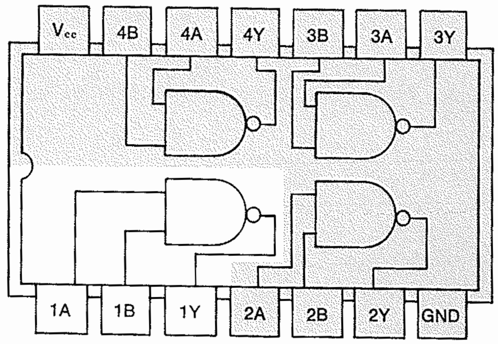
With three loads available to each of 16 pins, a total of 48 loads are included in an S3150's Test Station. The loads used are usually resistive. Values from 100 to 4000 ohms are used in many cases with 10 to 200 pf shunt capacitances to simulate fan-out loads. Loads and driving sources consisting of semiconductor and integrated circuits are often supplied in addition to passive loads. Naturally, the complexity and lead length of such a system are potentially sources of aberrations. The use of individual loads for each device pin, each with its own reed relay, insures against unacceptable responses.

The S3150's Test Station has the unique feature of a separate sampling probe, dc sub-system, three switchable loads, three switchable power sources, and a pulse source for each IC pin. Very flexible reconfiguration for all testing is achieved in a system that can measure both 10 nanoamps dc current and 1 nanosecond risetime.

COMPLETELY TESTING THE QUADRUPLE 2-INPUT POSITIVE NAND GATE
60 TESTS IN LESS THAN 1 SECOND

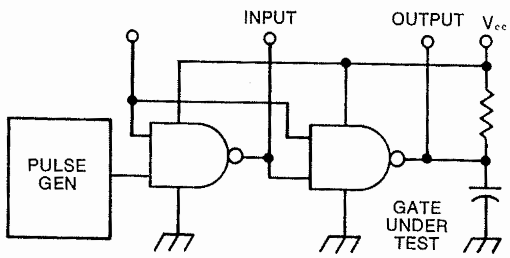


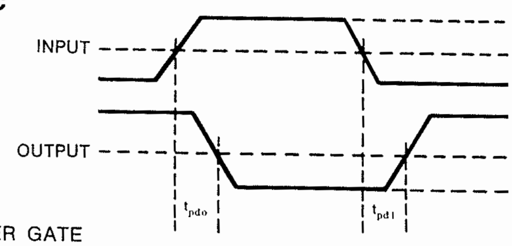
INDIVIDUAL GATE CIRCUIT



4 GATES ON 1 IC

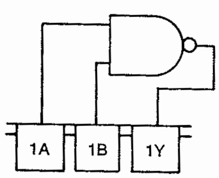
DYNAMIC





2 PROPAGATION
DELAY TESTS PER GATE
ASSURE PROPER ARRIVAL TIME OF LOGIC BITS

FUNCTIONAL

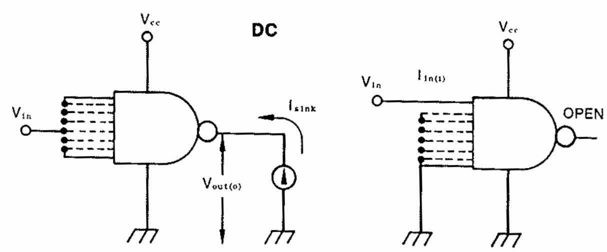


POSITIVE LOGIC
$Y = \overline{AB}$

1	2	Y
H	L	H
L	H	H
H	H	L
L	L	H

4 TESTS PER GATE VERIFY PROPER LOGIC FUNCTION

DC



9 DC TESTS PER GATE INCLUDE INPUT AND OUTPUT CURRENTS AND VOLTAGES UNDER 6 CONFIGURATIONS PER GATE

INTEGRATED CIRCUIT TESTING

There is no consensus on how an integrated circuit should be tested. The decision on how to test must be resolved by each user, considering the expected performance of the device he is manufacturing or buying, and the cost of testing or not testing. There are three tests commonly made today: dc tests, functional tests, and dynamic tests. Each type of test has merits and each test has proponents favoring it to the point of excluding the other tests as "not needed".

DC Testing applies steady state voltages and currents as stimuli to the integrated circuit. After a brief settling interval, measurements are made of the response to the dc stimuli. Both input and output parameters are measured while the device is loaded with standard test loads. DC testing, during the manufacturing process, often requires a high degree of measurement accuracy. DC testing by the user, performing acceptance tests on purchased integrated circuits, can be of 1% to 3% accuracy.

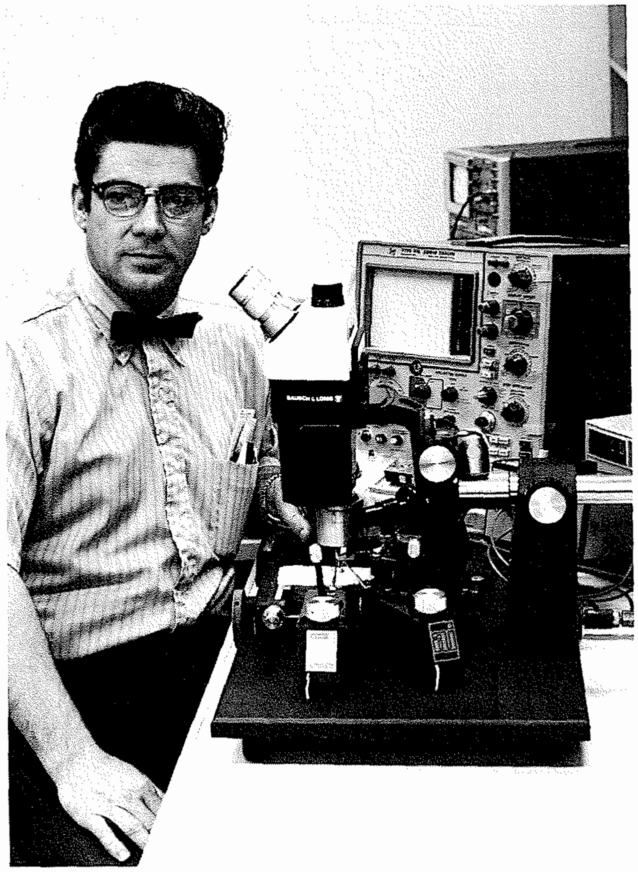
Digital integrated circuits are often tested for conformity to their truth table. This is **Functional Testing.** Thorough exercising of a device's logic functions is of value, but often is not sufficient. Functional testing will not reveal excessive leakage conditions or high saturation voltages. The loading effects of the integrated circuit on other devices are not detected by this test. Symptoms of potential early failure can also be missed completely in the process of function testing only.

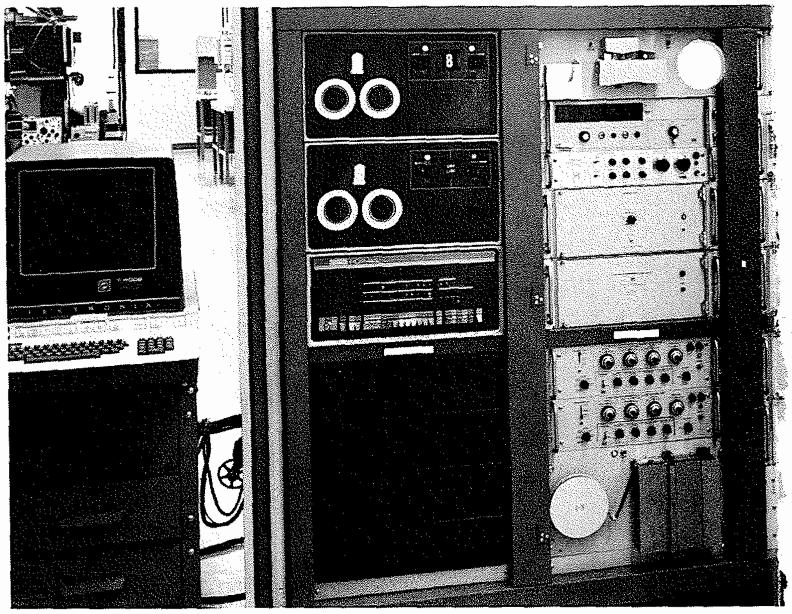
Dynamic Testing is testing in the time domain. Another term used for this process is switching time testing. Risetimes, falltimes, and propagation delays of a device are measured in a system based on a digital readout oscilloscope. Dynamic testing was said to be more costly than just dc or functional testing, but dynamic testing combined with dc and functional testing in a single system is economical. It is especially economical when related to the repair and troubleshooting costs that are incurred when defective integrated circuits are not caught before installation in a final product.

Full characterization of packaged, integrated circuits require all three basic tests. Integrated circuit performance is specified in values that can only be measured by a complete system. Specifications are formed from the results of all tests. Users of integrated circuits, therefore, require elements of all tests to assure themselves that the purchased items will perform according to expectations.

SOME EXPERIENCES IN IC TESTING

By Oris Nussbaum
Manager, Integrated Circuits Manufacturing Test





We are using integrated circuits in volume and the volume is increasing significantly. All our new instruments are heavily populated with both commercially available and Tektronix developed and manufactured integrated circuits. This commitment in integrated circuits has made it necessary for us to develop testing routines suitable for both integrated circuit manufacturing routines and acceptance inspection of purchased devices.

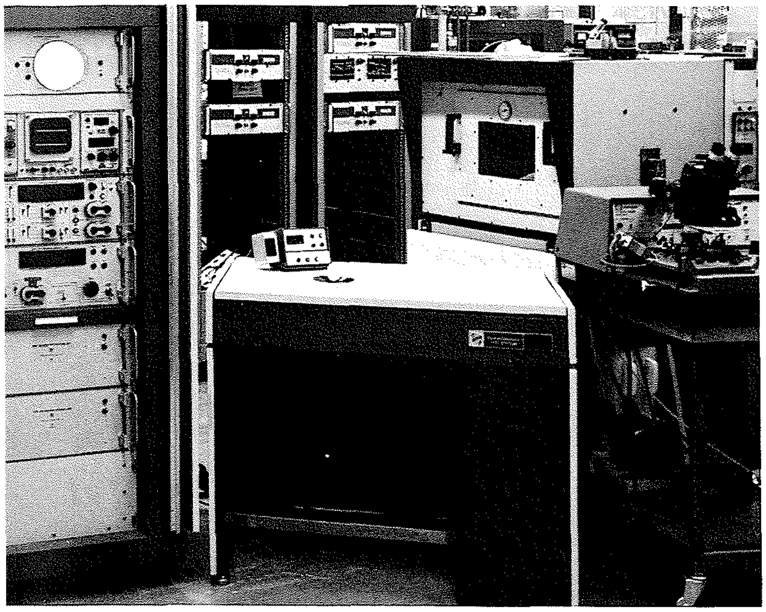
Our objectives in testing our own manufactured IC's are: 1. Assurance of conformity to design parameters. 2. Reduction or elimination of troubleshooting and repair during product manufacture. 3. Elimination of those devices most likely to fail in service. 4. Reduction of integrated circuit testing costs in manufacturing to less than 10% of the IC production expense.

Our objectives in testing integrated circuits from outside sources are essentially the same as for internally produced units, except that testing costs are related to purchase price rather than production costs. It has been our experience that extensive testing of purchased integrated circuits is a worthwhile investment in total product quality. We have been performing dc, dynamic and functional tests for more than two years with a Tektronix S3130 Automatic Measurement System. Recently we have added the new S3150 to our facility and both systems are used heavily. At this time the S3130 has accumulated 17,000+ hours of ON time. Although we have the unique advantage of "living" with the source of our systems, maintenance of these systems is the responsibility of technicians from our service group. The reliability of both systems has been excellent.

Presently we are testing 200 to 250 integrated circuits per hour, per system. A typical test sequence consists of more measurements than 50 per device, averaging less than one second from test number one until completion. We find the slowest part of the process is hand insertion of devices in test sockets. To minimize this step, we are adding automatic handlers and expect to reach a throughput rate of 1000 tested units per hour, per system.

The flexibility of the S3150 allows us to use it in wafer probing. At the present time, we are dc testing in the wafer stage. We also make automatic measurements with DUT's in environmental chambers. The S3150's capacity for reprogramming, while regular tests are being simultaneously run, increases the number of units that can be completely tested per day. The S3150 also allows us to data log, analyze data, as well as write programs without disrupting regular testing runs.

In conclusion, it is my opinion that our function of supplying high quality integrated circuits for use in Tektronix, Inc. products would be very difficult without our two automatic measurement systems.



The Automated Systems department is a part of Tektronix Marketing to keep in close contact with customers needs for special requirements. This is unique in that we function within the company as a purchaser of Tektronix products, a purchaser of other peoples' products and as a system engineering and assembly activity. We provide support for Tektronix Field Engineers and Representatives in their contacts with customers. We can supply a variety of systems composed of catalog products and supported by all our field people. This makes our position a good one.

I would suggest that individuals and organizations needing systems' information talk to their local Tektronix Field Engineer or Representative. He is equipped to answer your questions, provide systems proposals, and help you support any Tektronix System. The support services are of the same high quality of that support available on all Tektronix products. The services are tailored to meet the demand of customers production effort.

We will be at WESCON and other trade shows. If you are unable to attend a system demonstration, contact your Field Engineer or Representative. He can suggest other ways of getting the facts on systems. There is, for example, a 17 minute demonstration film available.

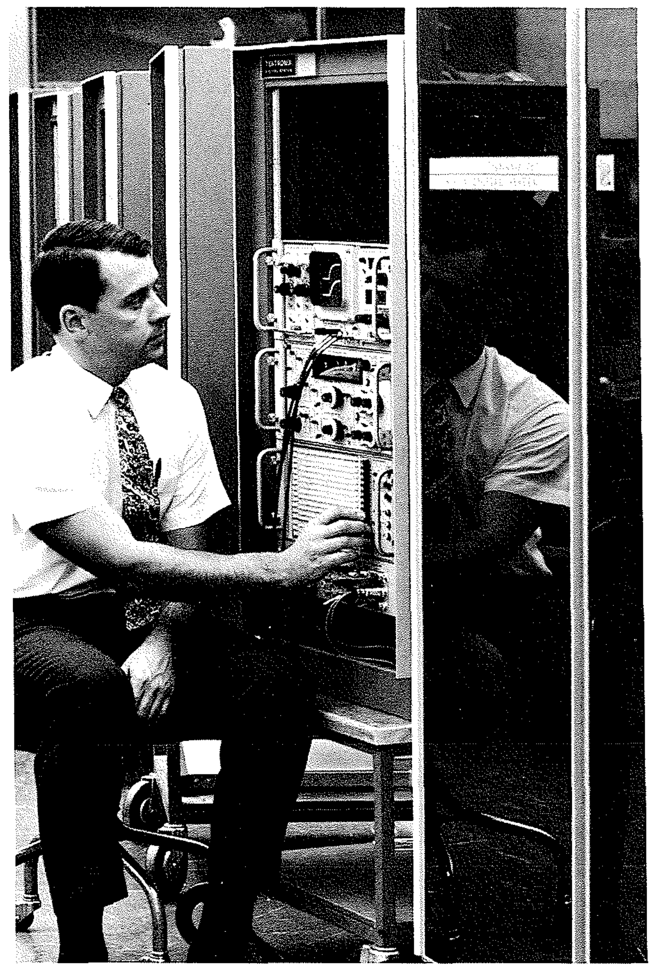
SOME THOUGHTS FROM A SYSTEM BUILDER

By Morgan Howells
Manager Tektronix Automated Systems

New activities are exciting and the activities related to automatic testing of integrated circuits are new. The competition in all aspects of automatic measurement keeps things lively. We have received no easy orders in the automatic measurement field. The customer contemplating an automated system presses hard for factual information on: What can we measure? How many units per hour will our systems process? How much will it cost? How does he keep the thing going? The customer knows the strong points offered by competitive systems and he asks excellent questions. I think I can give some pretty good answers, but more important, I believe I can raise a few questions in return.

The rough and tumble is all to the good of the industry. The better approaches will survive. Some better approaches are already Tektronix catalog products, fully spec'd and supported. These systems, the S3110, S3111, S3120, S3130, and S3150, meet recognized, consistent requirements by customers. Options to these systems adapt performance to the individual need.

Even with a group of catalog systems, we get requests for special systems—systems that don't exist complete in our catalog. We eagerly respond to these requests. Our automated system department has the capacity to design and build systems to meet many needs in many areas of automatic measurement. Multi-pin IC's, a variety of semiconductors, logic boards, we take a crack at them all.

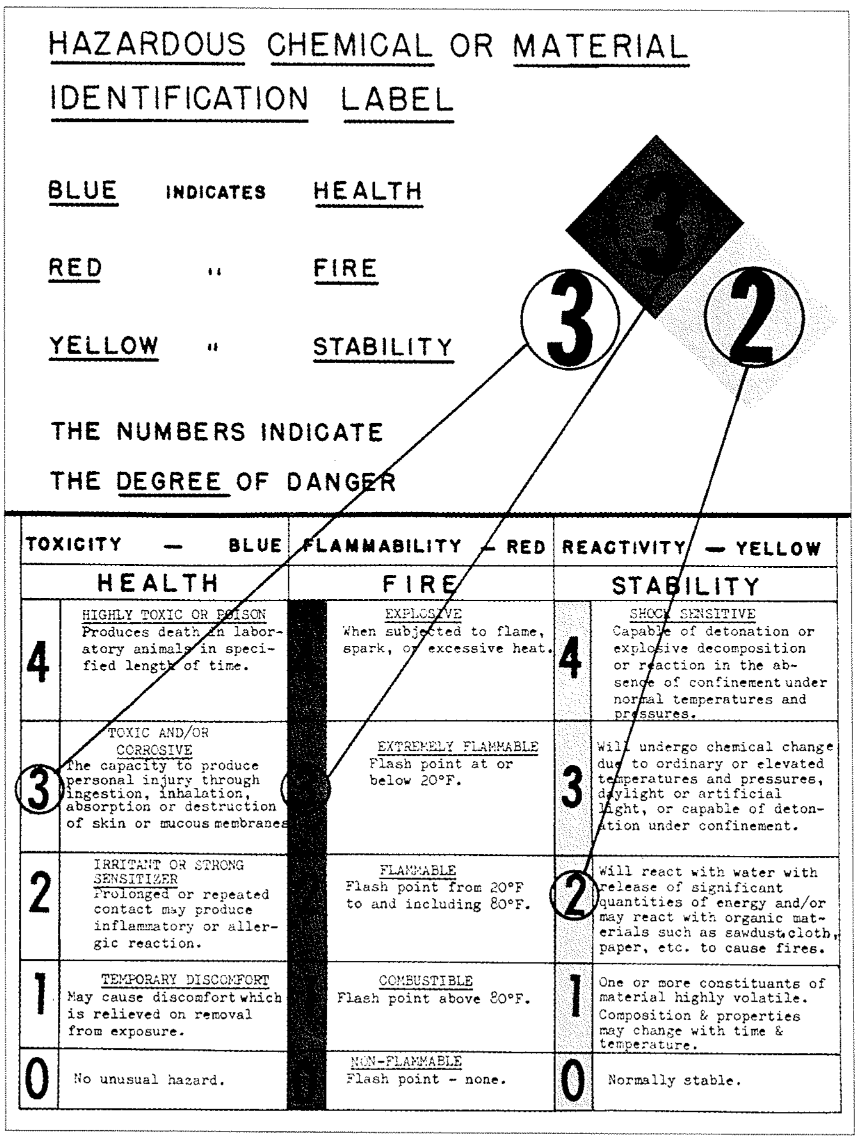


HAZARDOUS MATERIAL IDENTIFICATION

By Chet Schink, PhD
Manager, Electrochemistry Engineering

Everyday exposure to material hazards, particularly chemical hazards, are increasingly a part of everyone's job. Many materials in common use offer little danger but still are not to be lightly treated. Several years ago, we at Tektronix set up an in-plant chemical safety program that has as an objective positive identification and labeling of the specific degree and classification of chemical hazard. To this end, hazardous materials are labeled with a four color, diamond shaped tag. This tag includes the chemical or trade name in a white area near the bottom. The other three colors, blue, red, and yellow, each represent a specific area of safety concern. Blue, for example, represents toxicity—a health hazard. Red represents flammability—the potential for fire. Yellow is assigned to reactivity or stability when exposed to common materials such as water or common events such as jarring shocks. In each colored area a number from 0 through 4 has been assigned, proportional to the degree of hazard. 0 represents a relatively harmless classification. Posters explaining the tag are displayed wherever people are likely to be working with chemicals. Today, that means almost everywhere.

In addition to the Hazardous Material Tag, detailed information is made available through a loose leaf, Chemical Safety Book. One edition contains data based on reports from chemical manufacturers, recognized reference texts,


HAZARDOUS CHEMICAL OR MATERIAL IDENTIFICATION LABEL

BLUE INDICATES HEALTH

RED " FIRE

YELLOW " STABILITY

THE NUMBERS INDICATE THE DEGREE OF DANGER

TOXICITY — BLUE		FLAMMABILITY — RED		REACTIVITY — YELLOW	
HEALTH		FIRE		STABILITY	
4	HIGHLY TOXIC OR POISON Produces death in laboratory animals in specified length of time.		EXPLOSIVE When subjected to flame, spark, or excessive heat.	4	SHOCK SENSITIVE Capable of detonation or explosive decomposition or reaction in the absence of confinement under normal temperatures and pressures.
3	TOXIC AND/OR CORROSIVE The capacity to produce personal injury through ingestion, inhalation, absorption or destruction of skin or mucous membranes		EXTREMELY FLAMMABLE Flash point at or below 20°F.	3	Will undergo chemical change due to ordinary or elevated temperatures and pressures, daylight or artificial light, or capable of detonation under confinement.
2	IRRITANT OR STRONG SENSITIZER Prolonged or repeated contact may produce inflammatory or allergic reaction.		FLAMMABLE Flash point from 20°F to and including 80°F.	2	Will react with water with release of significant quantities of energy and/or may react with organic materials such as sawdust, cloth, paper, etc. to cause fires.
1	TEMPORARY DISCOMFORT May cause discomfort which is relieved on removal from exposure.		COMBUSTIBLE Flash point above 80°F.	1	One or more constituants of material highly volatile. Composition & properties may change with time & temperature.
0	No unusual hazard.		NON-FLAMMABLE Flash point - none.	0	Normally stable.

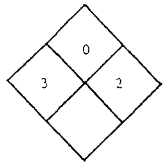
A conspicuous poster gives further information to Tektronix employees about the Hazardous Material Label.

This is a typical sheet from the Hazardous Material Safety Book. The brand name has been removed.

CHEMICAL SAFETY DATA

[redacted]

Tek Part No. [redacted]



Uses: Alkaline cleaner

Hazardous Properties:

Fire Hazard: nonflammable.

Health Hazard: Toxic and corrosive. This material is caustic and is very corrosive to the eyes and skin, if not washed off immediately. Dust and mists can cause serious damage to the upper respiratory tract and to the lungs.

Precautions:

Personal Protection: Use with adequate ventilation. Avoid breathing dust or mists. Avoid skin or eye contact. Wear safety glasses and rubber gloves.
CAUTION: Do not add to solutions that are hotter than 60°C (140°F). [redacted] generates heat when mixed with water.

Spillage:

Shovel up dry material immediately and flush area with water. Dilute acetic acid may be used to neutralize final remaining traces. If liquid is spilled, mop up with mop or rags. Wash mop or rags in water. Wear safety glasses and rubber gloves. No spillage of this material should ever be left unattended. It is very slippery and someone might slip and fail and be severely injured.

Repackaging and Storing:

Repackage and store in tightly covered containers in a dry place.

Technical Data:

Specific gravity (water-1)	1.14
pH	13

Respirator: AO 30 30 W 600A Monomask

VH:is
2/8/67

EMERGENCY PROCEDURES

Fire: Nonflammable

Inhalation: Remove from exposure. If breathing has slowed or stopped give artificial respiration. Call the company nurse.

Skin: WASH IMMEDIATELY with copious amounts of water. Remove contaminated clothing. Call the company nurse.

Eyes: IMMEDIATELY flush with copious amounts of water for 15 minutes. Call the company nurse.

Internal: Do not induce vomiting. Give two glasses of water or, if available, dilute acetic acid (1%), vinegar (1:4) or lemon juice, followed with milk. Call the company nurse immediately.

and medical advisors. (When we are uncertain as to the chemical contents of brand name items, we request details from our suppliers or make our own analysis.) This edition is used by those whose work exposes them to potential harm. An augmented edition of the Chemical Safety Book contains medical treatment information beyond first aid. This edition is available only to qualified medical personnel at our facilities.

The hazard label we use is an adaptation of a tagging system originated by the National Fire Protection Association. The label developed by this group is primarily based on hazards of materials in flame or exposed to heat. Our adaptation attempts to indicate hazards under "normal" use conditions.

We are printing this information in TEKSCOPE for its possible value to those implementing safety practices in their organization. The Chemical Safety Book mentioned is *not available* for distribution since it represents some arbitrary classifications of hazard levels based on our judgments.

INFORMATION SOURCES

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9. Sax, N. I.: **Handbook of Dangerous Materials.** Reinhold Publ. Corp., New York, 1951.
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14. Manufacturing Chemists' Assn., Inc. **Chemical Safety Data Sheets.**
15. **National Safety Council Data Sheets.**
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17. **Fire Protection Guide on Hazardous Material.** National Fire Protection Association, 2nd Ed.
18. **Chemical Data Sheets.** Manufacturing Chemists Association, Inc.

TECHNIQUE: *Time measurements to better than 1%*

Your Oscilloscope was adjusted to nearly perfect accuracy during its last calibration—but only on one postion on each time base and one range of the delay time multiplier.

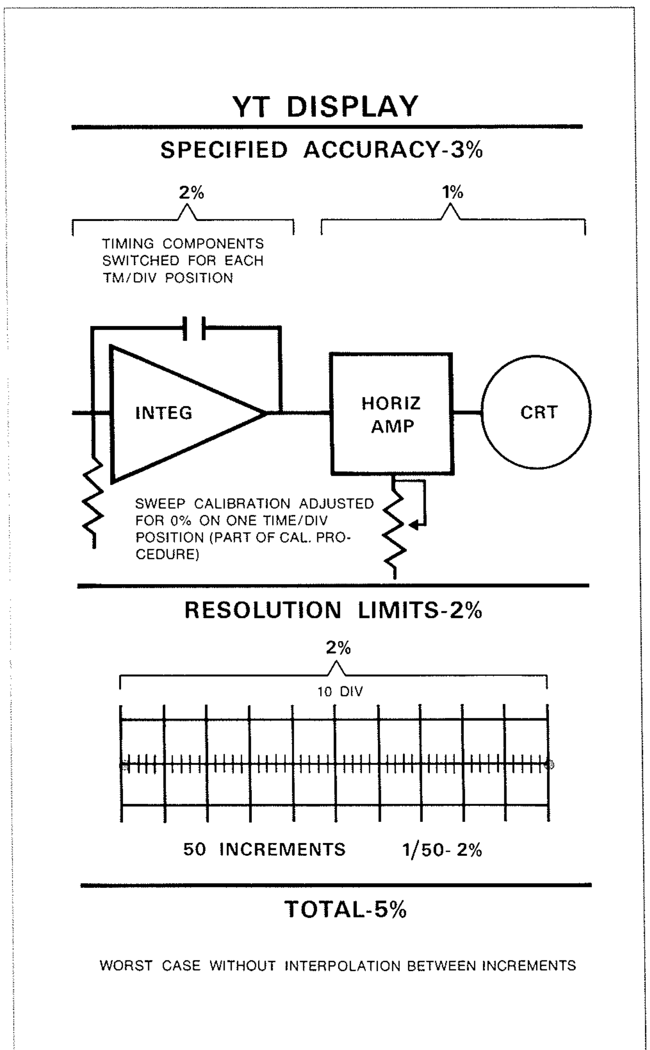
Time base accuracy is often specified as 3%, an uncertainty statement that accounts for worst case system differences over all time base ranges. It is unusual in practice to actually find an error as great as 3%. Often overlooked is that other source of measurment uncertainty: Resolution. Some aspects of specified accuracy and resolution limits are illustrated on this page.

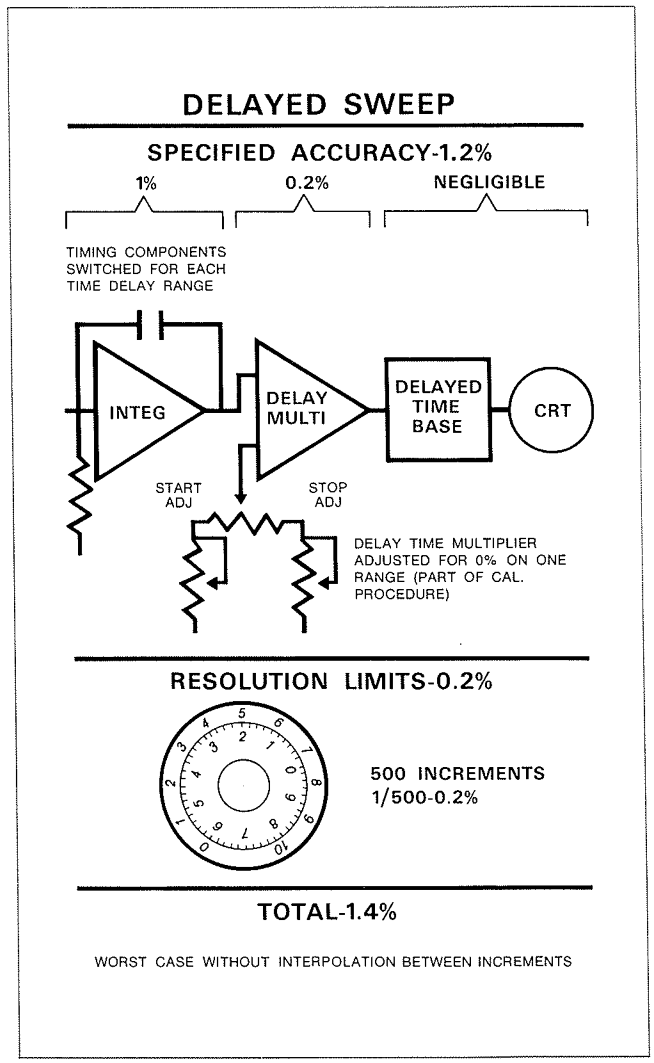
When you must make better than 5% time measurements, resolution uncertainties can be minimized by using proper delaying sweep techniques. To assure better than 1% accuracies, on a selected delay time range, a standard period source must be used for verification*. If you find that the specific delay accuracy is not as desired, that range can be adjusted by a knowledgeable calibration technician to be better than 1%.**

Specified accuracies are statements of possible worst case conditions, but in most cases, a well maintained instrument will do much better than specifications indicate.

**Tektronix 2901 Time Mark Generator*

***A cautionary note: This technique does not conform to standard calibration procedures and if used, the instrument should be tagged with appropriate information. Conformance with the standard manual procedures will assure that accuracy specifications will be met on all ranges. Deviation may result in out of specification results on some ranges.*





SERVICE SCOPE

TROUBLESHOOTING THE 453

By Charles Phillips
Product Service Technician, Factory Service Center

The 453 Oscilloscope has become the most widely used instrument in field servicing. It's also a popular lab item. This popularity makes it likely that you will work on one some day soon. When that day comes and a 453 turns up on your bench needing service, normal scope troubleshooting procedures and the manual are sufficient to locate the source of trouble. All of us develop extra problem solving techniques when we work regularly on a particular series of instruments. We come to recognize and look for troubles we have seen before. I would like to share a few experiences and ideas related to the 453, particularly those with serial numbers above 20,000.

TIME BASE

When time base troubles are suspected, the first thing to do is eliminate possible front panel problems. Remember, all four levers up in the A Sweep control area will produce a time base functioning scope. Then push the TRACE FINDER button to reveal a trace. If no trace appears, we must then positively eliminate the horizontal amplifier as the trouble area. To do this, set the Horizontal Display to EXT. HORIZ. Use the Trace Finder and Horizontal Position controls; you should have a spot that can be moved freely across the CRT.

O.K., we have established the trouble is in Time Base A (A Sweep).

Time base generators consist of a gate generator and an integrating circuit. There are a number of auxiliary circuits tied into the complete time base package. Since everything in this package is dc coupled, chasing voltages around a defective sweep circuit can be confusing. Something more is needed to reveal the component at fault and simplify your task. Here are a few techniques that I have found. They get answers quickly.

When a time base generator malfunctions, almost always we have four conditions. That is, the beam is at the left side of the CRT, on or off; or it is on the right side, on or off. If the beam or spot is hung up at the left side, try grounding Test Point 504 (collector of Q504). This should force the integration circuits into running once. You may find it helpful to use a sweep time slower than 0.1 second per division to give you time to see a sweep more readily. If you have problems getting a spot on screen, rotate focus to extreme CW position and use maximum intensity. Defocusing will eliminate any possibility of phosphor burn.

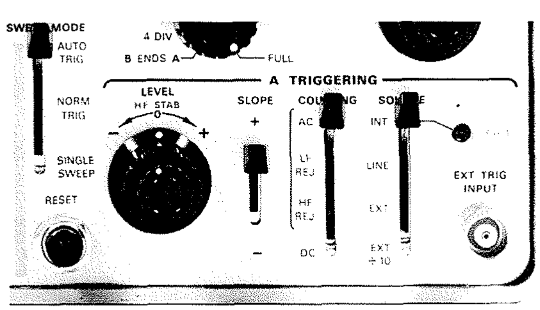
If grounding Test Point 504 starts the time base, the spot will hang up on the right after one sweep until the ground is removed. This is a positive indication that D533, Q533 and Q531 are O.K. If the trace brightened when TP 504 was grounded, Q524 and Q514 are also functioning properly.

The most suspect components are D505, Q585 or Q504. With the sweep forced over to the right, a full rundown condition exists at collector of Q531. The voltage at the collector (Pin AA is a convenient test point) should be about 0. This will be coupled through Q543 and D555 the base of Q575 (use Pin N as a handy test point).

The voltage at the base of Q575 should be about 0, and now you should test or substitute D505, Q585 and Q504. Preferably a curve tracer should be used for tests.

When the spot is hung up at the right side of the screen, the integrator circuit has run down, but has not been reset, Q514, Q543 and Q575 are suspect.

There are occasions when you will find a bright spot at the start of an otherwise normal sweep. There is no unblanking and Q544 should be checked. This is not an obvious effect from the schematic.



All levers up—A quick way to get a sweep on the 453.

If after the above checks, no active devices are found faulty, I have found that it is usually best to verify the values of precision resistors used in transistor base circuits.

B Time Base (sweep) is very similar to A Time Base. Troubleshooting procedures based on forcing the integrator into action can also be used. Just ground Test Point 704 and proceed as in Sweep A.

POWER SUPPLY

Power supply failures in the 453 can be easy to find. Here are some problems and cures.

Problem: Fuse blowing.

Check: Bridge rectifier diodes with ohmeter. Typically, forward readings will be about 2 kilohms, reverse readings should be high.

Problem: Wrong voltages.

Check: If the bridges are O.K., perhaps an overload condition exists somewhere and the protection amplifiers, built in each supply, are *saving* the supply components from destruction. If the base-emitter voltages on a protection amplifier transistor is high, you have a positive indication that an excess load exists. See the tables for typical voltages and resistance under normal conditions.

Problem: High ripple voltages on regulated supplies.

Check: Bridge output filter capacitor may be open.

Problem: Ripple voltages in excess of specifications, but still relatively low.

Check: Filter capacitor at output of each regulated supply. It may be open.

Problem: Wrong output voltage, (voltage emitter/base of protection amplifier within limits).

Check: Protection amplifier transistor for defect. If supply works properly without this transistor, the transistor is bad, replace it.

Problem: Voltages are regulated but somewhat out of tolerance.

Check: Precision resistance values.

Problem: +12 volt supply output low.

Check: Remove Q970 from CRT high voltage supply. The bridge in the +12 volt supply is the source of unregulated dc for the CRT high voltage supply.

CRT HV SUPPLY

Most scopes use a dc to dc converter to produce CRT voltages. An oscillator is used to convert a low dc level to RF. The RF is stepped up through a transformer, rectified and filtered. A sample of the resulting high dc voltage is fed back to control the oscillator voltage. This feedback is necessary to regulate the whole system.

Problem: No significant voltage at TP −1950 V.

Check: Oscillator may be overloaded, pull lead of Pin L on Z Axis Board. This kills the feedback and the oscillator may work, producing higher than normal CRT voltages.

Problem: Oscillator not working after lead to Pin L is removed.

Check: Remove CRT socket. If oscillator functions, the CRT has a problem.

Problem: Oscillator still does not work with Pin L disconnected.

Check: Lift one end of each high voltage rectifier D952, D940, V952, and V962. This "unloads" the secondary and the oscillator will probably start operating. Test semiconductor high voltage diodes D940, D952, and vacuum tube rectifiers (V952, V962) by replacing one at a time. If this does not work, the H.V. filter capacitors should be checked.

The innovative technician can often build upon the manual and other routine maintenance information. The only thing required is imagination and experience.

POWER SUPPLY

TYPICAL PROTECTION AMPLIFIER BASE-EMITTER VOLTAGES

SUPPLY	ACROSS	NORMAL VOLTAGE
−12 V	R1129	0.175 V
+12 V	R1159	0.125 V
+75 V	R1187 & R1188	0.375 V
+150 V	- -	- -

TYPICAL NORMAL RESISTANCES

SUPPLY	TEST POINT	RESISTANCE*
−12 V	H	80 Ω
+12 V	D	70 Ω
+75 V	B	1 kΩ
+150 V Unreg.	F1204	2.6 kΩ

*Negative lead of meter to ground

TEST POINTS

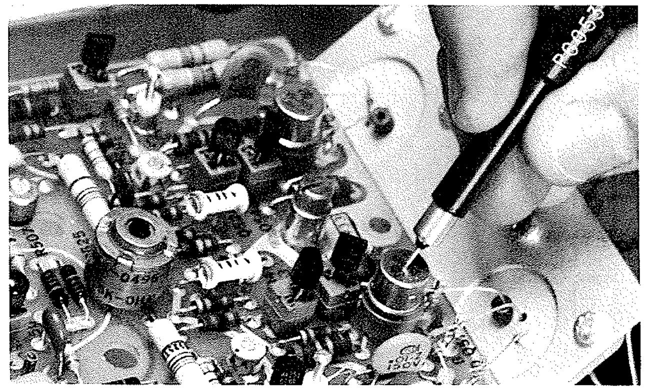
Where can you hang that scope probe or touch that meter lead? This question is a regular part of servicing. You will find very useful test points built into many recent Tektronix instruments. There are even more "test points" where you find metal case transistors.

Did you know that most metal case transistors have their case tied to collector? It makes for better thermal characteristics and it also allows secure mounting of the chip inside the can. You can use the case as a test point, you can touch a probe, but you probably won't be able to clip on to most cases. The "test point" is also labeled by Q number, making it easy to locate.

Square pin connectors on our printed circuit boards are clearly identified by letters and numbers. These connectors and attached leads make excellent test points. Individual instrument manuals contain schematics and detailed board photographs. These aid in pinpointing the connector location, electrically and physically.

Resistors and other components are purposely mounted with sufficient lead-to-board clearance to attach most probe tips.

Some caution is advised when clipping on to some of the sub-miniature resistors used today; they can break with rough handling.



Metal case transistors have easy to reach collector test points—the case itself.

INSTRUMENTS FOR SALE

LC130, 317, 503, 515, 516, several 530/540 Scopes with Plug-ins. Henry Posner, Pacific Combustion Engineering Co., 5272 E. Valley Blvd., Los Angeles, California 90032. (213) 255-6191.

524AD, $450. Larry Lawrence, Lawrence Engineering, Inc., 11965 Beach Blvd., Jacksonville, Florida 32216.

3A72, $200. Mr. Myhre, Mission Engineering, Inc., Hiawatha, Iowa 52233. (319) 393-2253.

565, 3A3, 3C66. Mr. H. Everett, c/o Dr. C. P. Bailey, St. Barnabas Hospital, 183rd Street & 3rd Avenue, Bronx, New York 10457.

127. Pat McCusker, Comsat Labs, P.O. Box 115, Clarksburg, Maryland 20734. (301) 428-4401.

531/53B, 310, 512. Fred Muessigmann, Watson Instruments, Inc., 446 Lancaster Pike, Malvern, Pa. 19335. (215) 647-3777.

547, 1A1. George Schneider, Space Electronics, Inc., 40 Cottontail Lane, Irvington, New York 10533. (914) 519-8681.

535/B, $600. Dr. J. Toole, 27 Sheldon Street, Wilkes Barre, Pennsylvania 18703.

551 with P/S. Plug-ins, D, G, Q. Scope-Mobile® Cart, 500/53A. $1800 or offer. Joe Laub, Unitek Corp., Monrovia, California. (213) 358-0123.

3T77. Les Jacobson, Allen Avionics, 255 E. 2nd Street, Mineola, New York 11501. (516) PI 7-5450.

556, 1A4, 1A5, all $4178. Howard Davis, Silton, 16222 S. Maple Avenue, Gardena, California 90247. (213) 770-0985.

514D. Robert Powers, Stellar Industries, Inc., 10 Graham Rd., W., Ithaca, New York 14850. (607) 273-9333.

181, $100. Dan Wirtz, McGraw-Edison Co., Franksville, Wisconsin. (414) 835-2921.

3—2A63. Make offer. Jack von der Heide, Optron, 50 Fitch Street, New Haven, Conn. (203) 389-5384.

530 Series Scope/1A7A/160 Series/360/1121. Sigmund Hoverson, Physics Department, Texas A & M University, College Station, Texas 77843. (713) 845-5455.

567 Readout Scope, $405/6R1A, $1800/3S1, $900/3T77A, $495/114 Pulse Generators, $288/P6032 Probes, $67.50. John Mattson, Laminar Corp., 222 Plato Blvd., St. Paul, Minnesota 55107. (612) 222-8411.

310A, $600. Mr. Yeomans, Mergenthaller Linotype, 300 Luckie Street, Atlanta, Georgia 30313. (404) 525-7448.

502, $300. John Breickner, Fifth Dimension, Inc., Route 206 Center, Princeton, N.J. (609) 924-5990.

517. Will swap for 15 MHz Scope. Bob Schafer, Midwest Research Institute, 425 Volker Blvd., Kansas City, Mo. 64110. (816) 561-0202, Ext. 374.

63 Plug-in Differential Amplifier, $100. 2B67 Time Base, $200. Roger Kloepfer, (517) 487-6111, Ext. 392.

410 Physiological Monitor. Rudy Kranys, Medrad, Inc., 4084 Mt. Royal Blvd., Allison Park, Pa. 15101. (412) 961-0393.

535A, $700. D Plug-in, $110, A Plug-in, $60. Summers, Simplec Mfg. Company, Inc., 8710 Empress Row, Dallas, Texas 75247. (214) 637-5470.

454, $2500. C-31 w/Pack & Roll Back and 560 Series Adapter, $400. Virgil A. Wiest or Marty Bos, Automix Keyboards, Inc., 13256 Northrup Way, Bellevue, Wash. 98004. (206) 747-6960, Ext. 21.

INSTRUMENTS WANTED

310A, 321A with probes. Mr. C. H. Wexler, Engineering Department, Phoenix Steel Corporation, Claymont, Delaware 19703 (302) 798-1411.

531 with M Plug-in. Stanley Kneppar, Technical Concepts, Inc., 580 Jefferson Rd., Rochester, N.Y. 14623 (716) 271-7953.

3A6. Jack von der Heide, Optron, 50 Fitch Street, New Haven, Conn. (203) 389-5384.

515, 516, or 524. Phil Hester, 546 Evergreen Dr., Corpus Christi, Texas 78412.

3B3 Time Base. Roger Kloepfer, (517) 487-6111, Ext. 392.

Printed in U.S.A. A-2432

TEKSCOPE

Volume 2 Number 4 August 1970

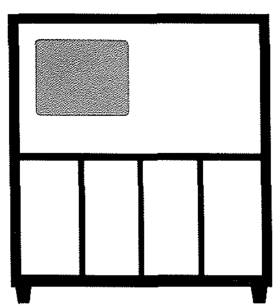
Customer Information from Tektronix, Inc., P. O. Box 500, Beaverton, Oregon 97005
Editor: Art Andersen Artist: Nancy Sageser For regular receipt of TEKSCOPE contact your local field engineer.

7 cm/ns without prefogging

Photographic writing speed is a figure of merit that describes the ability of a particular camera, film, oscilloscope, and phosphor to record a fast moving trace. This figure expresses the maximum single-event spot velocity which may be recorded on film as a trace discernible to the eye.

The results achieved are a function of the combined system performance of the oscilloscope, camera, film, recording technique, and the ability of the film reader to make a consistent interpretation of the results. Prefogging and postfogging of the recording film improve the apparent photographic writing speed of a particular system but the results are unpredictable and difficult to repeat. Because of this fact, Tektronix specifications are determined without using fogging techniques. Should the user employ fogging, then the writing speed will be increased according to his skill. Writing speed figures 50-100% higher are possible with controlled techniques on *Polaroid Type 107 and Type 410 film.

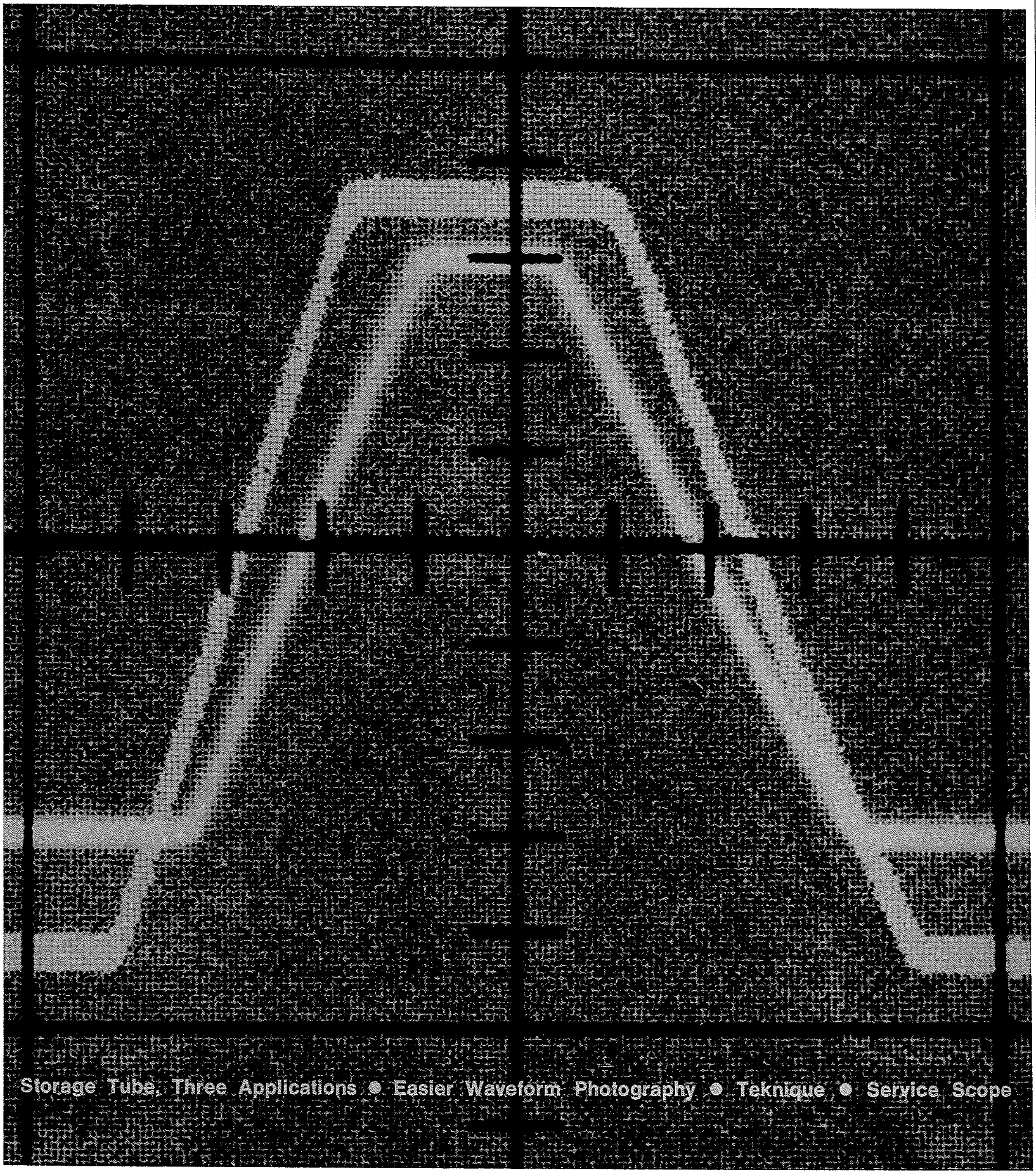
7 cm/ns is the *minimum* photographic writing speed of the Tektronix 7704 Oscilloscope with P11 phosphor. Writing speed was measured using a new P11 phosphor, a C-51 Camera and Polaroid Type 410 10,000 ASA film. The significance of the fast writing speed specification of the 7704 extends beyond an unparalleled ability to record transient events without fogging techniques—It is now possible to use the readily available, but slower 3,000 ASA film to capture extremely fast transients.



*Registered Trade Mark Polaroid Corporation

TEKSCOPE

OCTOBER 1970



Tektronix storage tubes have three major applications . . . . . . just one is the oscilloscope

The development of the Tektronix bistable-storage tube was a significant breakthrough in Cathode-Ray Tube design. This reliable and versatile CRT functioned with ease both as a conventional tube and as a tube with long term recording capacity. It was immediately apparent that this storage tube was of value in oscilloscopes, but the tube turned out to be the basis for other products.

COVER—Did you ever run your finger through a raindrop on a window screen? The resemblance of the squares pattern of the target and stored trace on a 7514 Storage Oscilloscope to lines of filled in squares on an old fashioned screen is striking. But, no window screen was ever put together with the precise care used in aligning the 5 mil target squares to an exact right angle relationship with each other. The result: A precision tube, yet rugged and able to function without special care. (The smaller, inner waveform is a write-thru plot simultaneously displayed with the stored information.)

Today, eleven Tektronix products use this remarkable device. Seven are non-oscilloscope products. The capacity to both store and display makes this CRT useful for information display in computer terminals, machine control units, and automatic-measurement systems. In addition, bistable-storage tubes make excellent scan conversion devices and there are two distinctly different Tektronix scan-conversion products based on this storage-tube function.

THE PRINCIPLES OF BISTABLE STORAGE

The Tektronix direct-view bistable storage tube (DVBST) functions by secondary emission. When the normal writing gun bombards the CRT phosphor screen with a beam of high-speed, focused electrons, the beam dislodges great numbers of secondary electrons. The phosphor surface where the beam has written loses electrons and charges positive. A conductive, transparent faceplate under the phosphor completes the circuit and allows storage of charge to take place.

In addition to the normal CRT writing gun, flood guns are used to cover the complete phosphor screen

At left are seven Tektronix Bistable Storage Tubes, the basis for a variety of Scan Conversion, Information Display, and Oscilloscope Products.

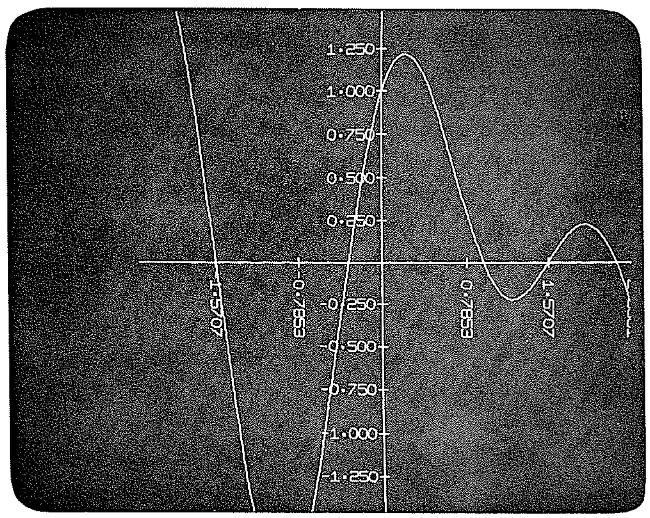
uniformly with low-velocity electrons. The electrons strike the unwritten area with too little energy to jar loose many secondaries. As a result, the unwritten areas merely collect electrons until they are driven negative and can attract no more current.

The positive target areas, where the beam has written, attract flood electrons at such a velocity that each entering electron dislodges sufficient secondaries to hold the phosphor target positive. Thus, the written area neither gains nor loses electrons but remains positively charged and continues to attract flood gun current. As a result of this equilibrium, the written trace remains stored for long periods. The same flood gun current that holds the stored trace also holds that stored trace bright, since energy of the flood gun electrons striking the stored target is sufficient to cause significant fluorescence. The unstored area in contrast remains relatively dark.

BISTABLE STORAGE TUBES IN INFORMATION DISPLAY

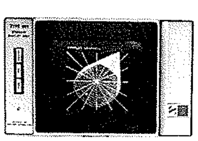
Cathode-ray oscilloscope waveform recording was the first application for the Tektronix direct-view bistable-storage tube. Very early it was recognized that the tube was, in effect, a high-capacity memory, capable of recording many equivalent bits of data. With display and memory both in the same device, information retention and display is greatly simplified. For display of computer-generated graphics and alphanumerics, the bistable-storage tube eliminates or minimizes the need for refreshed memory systems. A computer, for example, can write once and then go on to other work and the CRT display will remain, flicker-free, for continued use. The Tektronix T4005 Graphic Computer Terminal is a low-cost, but sophisticated terminal that exploits this storage tube ability. The T4005, through interface and accessory systems, not only stores and displays, but allows interactive communication at baud rates limited only, in most cases, by external data lines.

Tektronix bistable-storage tube products are used in numerous systems produced by other manufacturers. The 601 and 611 storage display monitors are available for use in various computer peripheral devices and other systems requiring the advantages of both storage and display. The 5-inch 601 and 11-inch 611 are complete storage monitors easily installed and ready to store and display X, Y, and Z information.

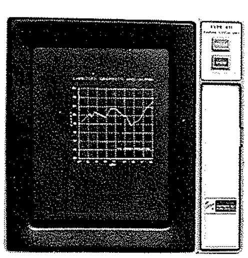


This is a display plotted on the T4005 Graphic Display Unit after repositioning and expansion by the 4201 Graphic Display Controller. When working with the IBM 1130, the Graphic Display Unit and Controller eliminates the delays caused by slow plotters.

Information Display Products Made Possible by the Tektronix Storage CRT

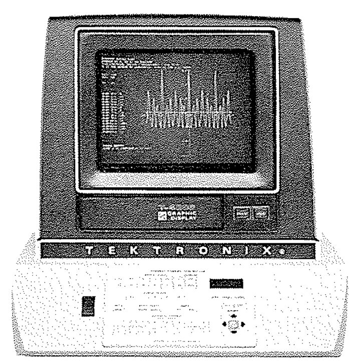


601 - STORAGE DISPLAY UNIT



611 - 11-INCH DISPLAY UNIT

T4002 - GRAPHIC COMPUTER TERMINAL



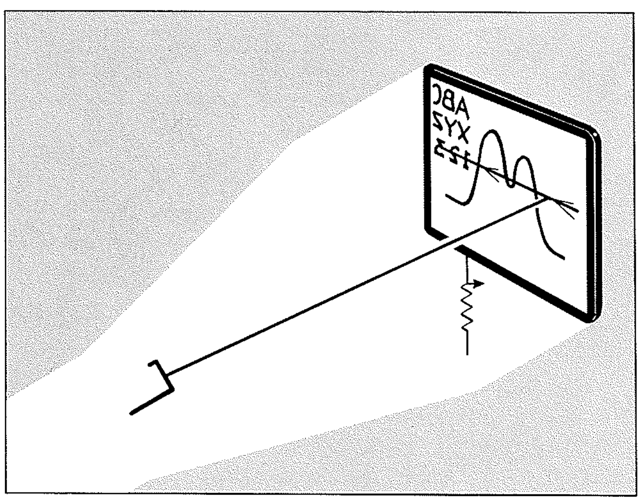
T4005/4201 - GRAPHIC DISPLAY AND GRAPHIC DISPLAY CONTROLLER

SCAN CONVERSION WITH THE BISTABLE STORAGE TUBE

Scan conversion is a process of scan reading CRT information at a different rate or in a different sequence than that in which the information was originally written. Scan converters using the bistable-storage tube write and store in an identical manner to the other storage tubes. To retrieve the information both the stored and non-stored areas of the tube are raster scanned by the beam, operating in a reading mode. The reading beam current divides into two paths after reaching the target. The ratio of the beam current in each path at any instant is determined by the charge of the target area being scanned. The difference in charge between stored and non-stored areas is reflected by a difference in current. This current develops a voltage across a sampling resistor.

At this time, scan conversion of stored displays is used in two distinctly different Tektronix products: the 4501 Scan Converter and the 4601 Hard Copy Unit. The 4501 Scan Converter uses a Tektronix storage tube which serves as a graphic memory of single events stored on the CRT or of dynamic displays of changing information. Stored information is scan converted into a format used by standard TV systems.

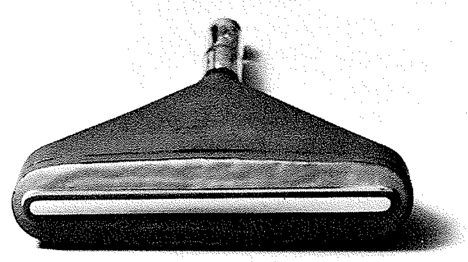
The composite TV signal is developed by processing the voltage developed by the read beam in a video amplifier, and adding sync and blanking pulses. The resulting TV signal can be to EIA or CCIR standards and may be used directly or to modulate an internally generated RF carrier. The composite TV signal can be used directly with conventional TV monitors. The modulated RF, usually Channel 3, works well with low-cost, commercial quality television sets.



The basis of scan conversion using Tektronix Storage Tubes is the ease of changing the writing beam to a reading beam. The sensing resistor detects read current differences as a scan is made of stored and unstored target areas.

The 4501 Scan Converter exists to process cathode-ray tube displays to a form that can be viewed remote from the original source or in multiple monitor displays. Generally, any information that can be displayed on a CRT can be scan converted. In most cases, it is simply a matter of providing a sample of the information that would normally drive the X, Y, and Z axes of a CRT.

The 4601 Hard Copy Unit produces permanent copies of CRT displays by scan conversion. The copy format is of standard 8½ x 11 inch size. This copy in turn can be reproduced in standard office copying machines. The 4601 can work with any direct-view bistable storage tube*. The necessary scanning voltages and control logic are generated by the 4601.



This fiber optic cathode-ray tube is the writing implement that translates scanned storage tube displays to full-sized hard copy in the 4601 Hard Copy Unit.

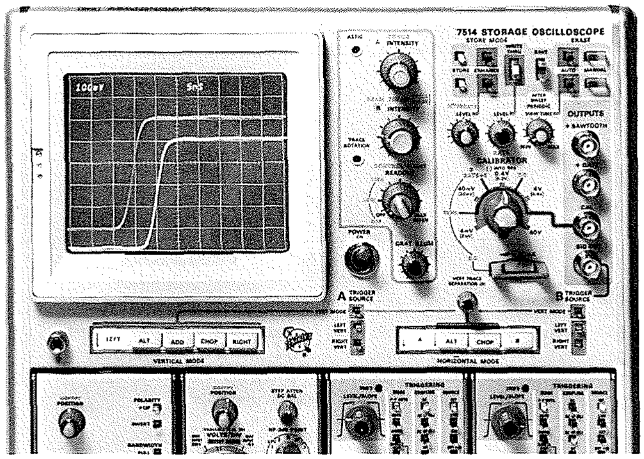
Scanning signals generated in the 4601 are used to read out stored information. The scanning signals and the voltage derived from the storage tube reading beam drive a fiber optic CRT in the 4601. Photo-sensitive paper is drawn across the faceplate of this fiber-optic tube and then is processed. A finished, permanent copy of the storage-tube display is produced. The complete sequence requires 18 seconds for the first copy, 11 seconds for each additional copy.

STORAGE OSCILLOSCOPES

The most obvious storage-tube application is to record non-repetitive events. Users soon found that the storage tube also eliminated flicker from low repetition-rate displays and in slowly plotted traces. In addition, waveforms could be stored for reference and comparison. Photography was simplified; once information was stored, the same exposure could be repeated for recording any stored plot. No matter what is recorded, the light output of the bistable tube is constant from each point of stored information, simplifying exposure. The tube could also be used for a split-screen display of both stored and non-stored traces. Four Tektronix oscilloscopes use storage tubes including the new 7514.

**Some earlier storage tube products require minor modification.*

The 7514 Storage Oscilloscope is the latest addition to the versatile 7000 Series. This instrument includes all the significant features of 7000 Series: CRT readout of scale factor and other inputs, multiple plug-in capacity, high writing-speed CRT, and 17 available plug-ins.



The latest addition to the growing 7000 Series, the 7514 shown above, introduces ***Write-Thru****. The Write-Thru feature displays real time, dynamic and stored information simultaneously—without interaction.*

450 centimeters per microsecond is the non-stored writing speed of the 7514. The stored writing speed is 1 centimeter per microsecond. In addition to the features of split screen, auto erasure, fast display integration, and long storage time, this oscilloscope introduces *write thru* and *auto focus*. In the write-thru mode a conventional, non-stored trace can be displayed simultaneously, and on the same screen area with stored displays. Bright write thru traces are displayed with no effects on previously stored information through the use of special Z-axis control circuitry. Auto focus maintains a well-defined trace or spot through a wide range of intensity settings. All that is necessary for a crisp trace is initial adjustment.

The 7514's non-stored performance is quite similar to that of the 7504. Both instruments feature four plug-in compartments. Time-shared displays in each channel adapt two vertical and two horizontal systems to a wide variety of amplifier and sweep and/or amplifier and amplifier applications. The bandpass with amplifier plug-ins is 90 MHz. In addition the 7514, like all 7000 Series instruments, provides 25-picosecond risetime and real-time sampling.

RECORDING FAST DISPLAYS ON X-Y RECORDERS

Recorders make permanent oscillograms but are much too slow for many applications. Response-limited recorders can be adapted to record repetitive fast events with the aid of a sampling oscilloscope. It is a simple matter to use your sampling oscilloscope with your X-Y plotter since sampling instruments have outputs specifically designed for that task.

The purpose of sampling is the conversion of very fast analog information for processing and display in relatively slow systems. The same technique that matches a 25-picosecond risetime to a one-megahertz scope amplifier easily matches a 25-picosecond, or a 25-microsecond risetime, to a one-kilohertz or slower recorder.

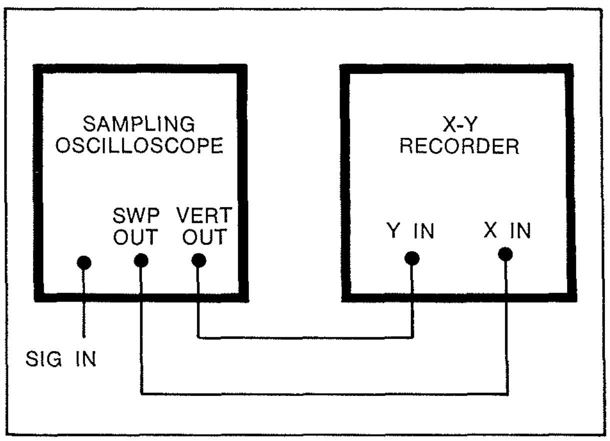
The sampling oscilloscope normally works in equivalent time. The timing of each sample in sequential systems is determined by three factors.

ONE, a ramp representing equivalent time.

TWO, a DC voltage representing T_0 in equivalent time.

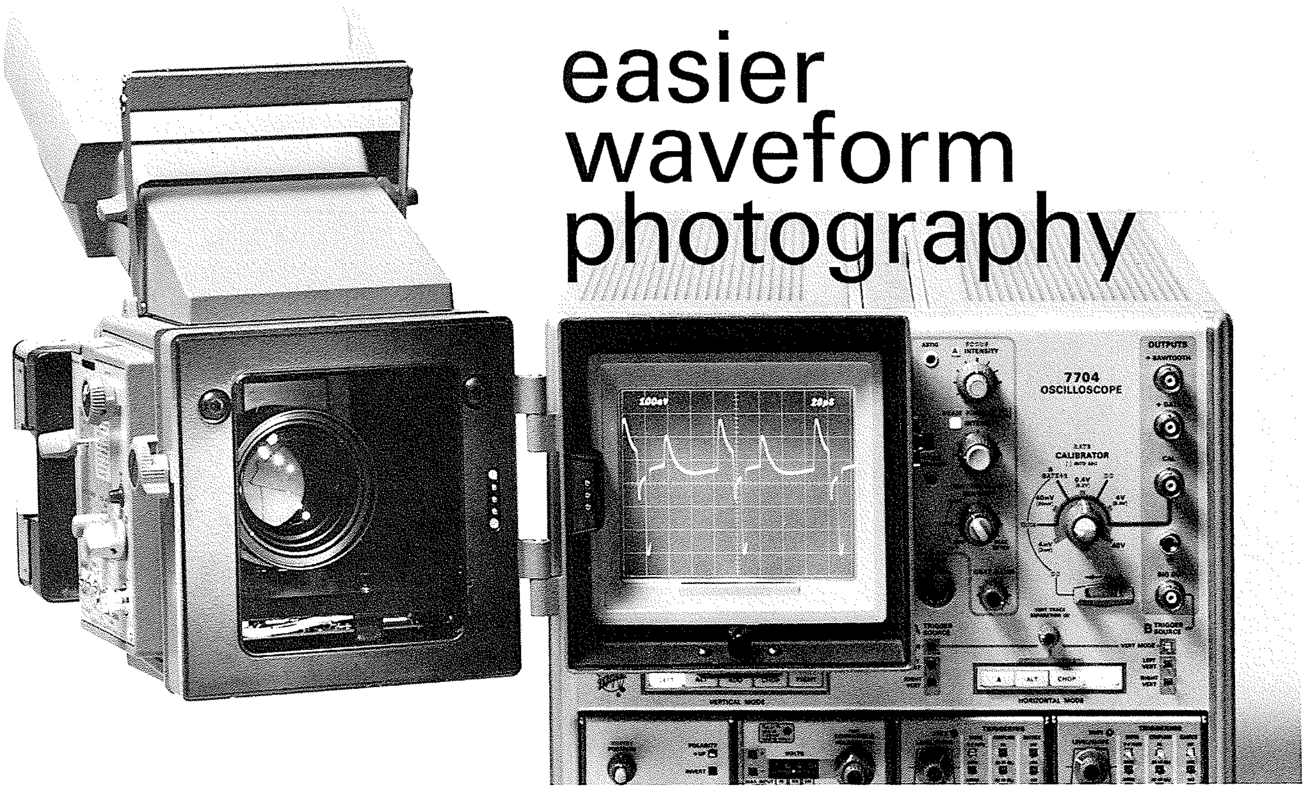
THREE, a voltage, either internally or externally generated, which plots the display in the X axis.

When using an X-Y plotter, the plotting voltage must be a slowly changing voltage. This contrasts with a CRT plot where the rate of sweep is usually fast to eliminate flicker. Substituting a slow, external X-axis signal or using the convenient manual plot control built into the sampling time base in place of the usual CRT X-axis deflection signal allows the output(s) of the sampling scope to be accurately plotted on paper. It is really quite easy.



The setup above uses the manual scan function built into samplers. If your recorder features a time base output, it can be used in place of manual scan.

easier waveform photography



Oscilloscope photography is an art involving many variables. It has probably been your experience that the first try often produces less than acceptable results. It is possible to get acceptable results on the first try if you are armed with a little extra knowledge of waveform photography. This article will discuss oscilloscope photography with the objective of clearing some of the mysteries and providing simple, workable techniques for better waveform pictures.

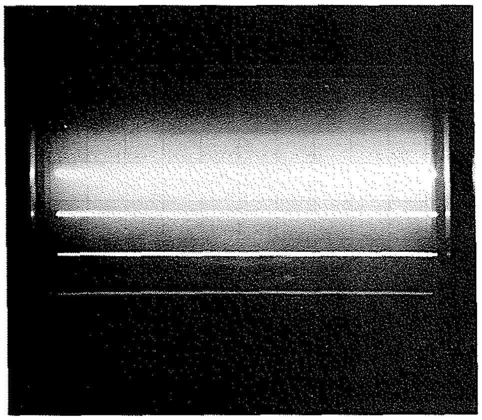
To take good waveform pictures, it is necessary to consider the difference between eye and camera. The camera obviously does not sense light as the eye does. It is also important to know the differences between ordinary scene photography and scope trace recording. You should also know that the oscilloscope is built to be used visually and therefore is usually optimized for that purpose. Now, let us look at the process of taking a waveform picture.

EXPOSURE SETTING

Exposure setting is the attempt to get just the right amount of light on the film to record the image within the photographic limits of the film. Usually exposure is determined by visual techniques although there are vast differences between the eye and the camera. The eye, for example, can sense light over a range of intensity of greater than one million to one. Film can only handle ranges of about one hundred to one. The eye's extensive range is partly because it responds to light logarithmically; film responds linearly. With the limited dynamic range of film, overexposure or underexposure is very easy. How then can acceptable trace recordings be made?

It is fortunate that the information displayed on the oscilloscope is usually graphic. It consists of lines, therefore, it does not matter if portions are overexposed. Within limits, overexposure can create a solid trace; crisp, clear, and pleasing to look at. It is the dim or indistinct portions of a waveform photograph that could be considered to be within the "normal" exposure range of the film used. It is apparent then that exposure and overexposure are terms which are more relevant to ordinary photography than to scope photography. Trace recording is ideally line photography, that is, complete exposure for the trace and graticule, no exposure for the rest. It seems that all we have to do is "overexpose" and be done with it. Unfortunately, it is not quite that simple.

Overexposure would be fine if the only source of light was from the trace and graticule. This is not the case since the fluorescence caused by the beam illuminates the area surrounding the spot. Overexposure settings,



Film cannot respond to large variations of light level. Each of the four traces shown is a single sweep, photographed with all camera and scope settings the same except vertical position and sweep time per centimeter. The lower trace sweep rate is 1 μs/div. Since each trace upward is progressively 10X slower than the preceding trace, therefore, the light available to the camera is 1000X greater for the top trace than the lowest trace. The top trace is grossly overexposed, clearly showing that film cannot handle light variations greater than 100:1 without exposure change.

if carelessly used, can result in an unattractive picture of the trace plus the reflected light of the spot. Even though this reflected light level is low and not objectionable visually, it can appear very messy on film. Another undesirable effect, as exposure is increased, is a broadening of the recorded trace. This occurs as more and more of the spot's width is recorded. The CRT beam has a Gaussian distribution of electrons through its cross section. The resulting spot has the same light distribution in cross section. As the exposure is increased, more of the skirts of the spot, plus the nearby reflected light, exposes the film and the recorded trace becomes broader. These side effects of overexposure create a practical dynamic range of beam movement that can be recorded for any one exposure setting. The best exposure setting chosen, therefore, involves an attempt to bracket the brightest and dimmest portions of the display without unattractive side effects.

It is practical to use the eye to judge exposure, even though the eye and the camera are different. Whenever the eye sees the trace as a continuous line, (no flicker or distinct spot movement), the scope user can make a good exposure estimate. If you have had problems in estimating exposure, you might try this: Adjust your scope display for "normal brightness". (That is what appears proper to you for visual use.) Set your camera for f/11 at 1/10 second and shoot. You should have an acceptable picture. At least you will be quite close. The use of f/11, a relatively small f stop, will give good depth of field. Everything will be in focus on any scope. The relatively long exposure of 1/10 second minimizes the effects of recording a fractional sweep. Now, let's look at a different photographic problem.

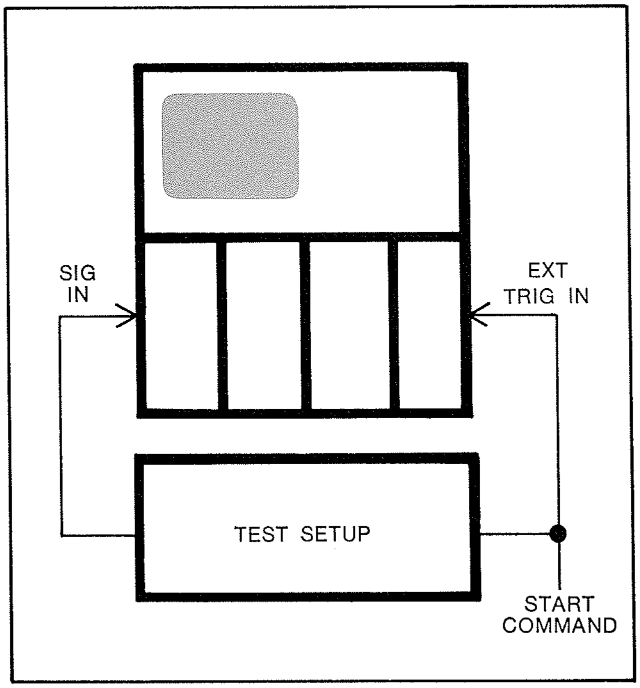
Low duty cycle, fast-sweep displays require a higher intensity control setting to bring up the brightness. If the intensity appears "normal", exposure of the display can be judged as described in the last paragraph. At some point a low duty cycle will require a very high intensity setting and a blurry, defocused trace may result. The scope's intensity control can change the light output over a very wide range. But it is the practice to have more beam current available than can be completely controlled by focus and astigmatism at the highest intensity settings.

When defocusing occurs because of high beam current, back off a bit on intensity and use a longer exposure. Control of exposure by f stop change is limited in comparison to the wide range of trace light available over the full possible ranges of sweep rate and duty-cycle combinations. Because of f stop range limitations (typically 2^7), time exposures greater than 1/10 are more useful with dim, low duty cycle displays. As an alternate to longer time exposures, you may want to try exposing to a controlled number of sweeps. Your scope's single sweep mode can be used. Press the RESET button for the number of sweeps desired for proper exposure. The shutter, meanwhile, is kept open in the Time position. This technique requires a little trial and error effort, but it can produce excellent results.

The non-repetitive event, particularly the fast transient, often strains the maximum performance of the scope/camera system and frustrates the user. Events in the microsecond or slower time domain are within the performance limits of the typical scope and camera. The problems in recording these events usually involve "posing" the waveform for trial and error runs to set correct exposure. Sometimes a lot of trial and error is involved to get just the right deflection factor and time base. Even more troublesome is the proper location of T_0 by correct triggering. What you are attempting to do by triggering is to nail down a specific, brief time interval out of infinity. It can be difficult.

TRAPPING THE ELUSIVE TRANSIENT

When setting out to trap a single transient, most users find that it is better not to use internal triggering because noise or other undesirable signals will often false-trigger. When possible, externally trigger your instrument from the same switch or circuit that initiated the transient. Another technique is to start a sweep and then use a time-related output of the scope* to initiate the transient event. Now, let us get to the problem of recording the fast, single transient.



Single Shot photography can be more trouble free if the scope is externally triggered with the same predictable and noise free command that initiates the events necessary to produce the transient. Avoid internal triggering from the transient signal source as it is often noisy and the transient itself may have a waveform unsuitable for triggering.

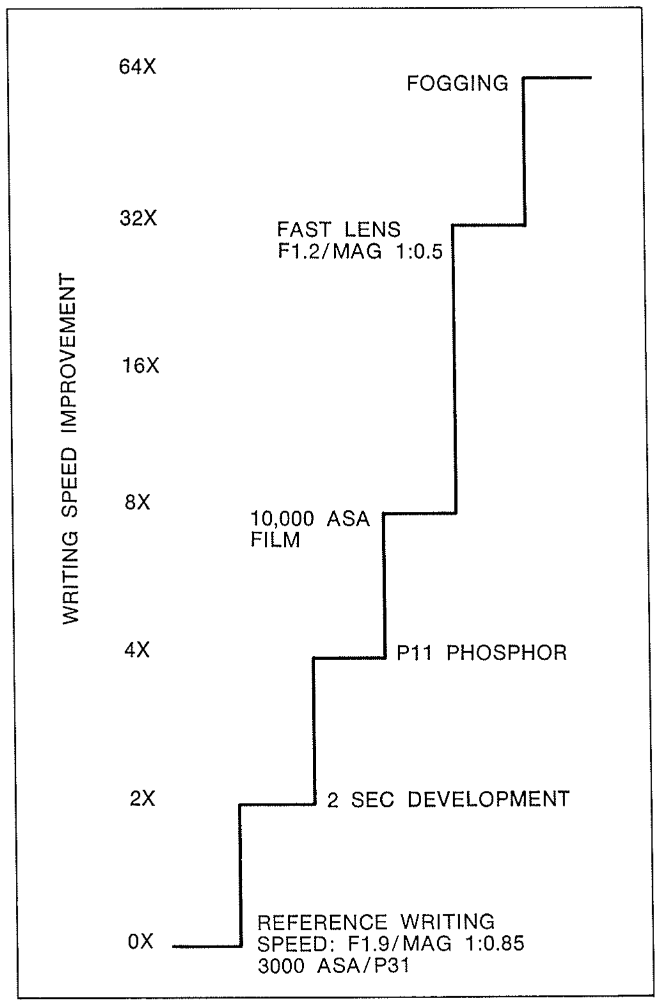
The typical scope camera has an f/1.9 lens with a magnification of 0.85. With the readily available 3000 ASA speed film, many fast transients are well within this camera's ability to record. When operating on the fringe of a camera's single transient usability, whenever maximum CRT intensity does not produce a usable trace, there are several steps that can help. Reduce the display amplitude. This reduction will decrease the rate of beam movement and often makes the necessary difference between good and unacceptable. Developing the film for 2 seconds instead of ten can also increase writing speed at the expense of contrast. This generally produces a poor looking picture. When both techniques do not work, it is time to consider a faster camera, CRT, film, or all three.

*See June 1970 Tekscope—Page 8

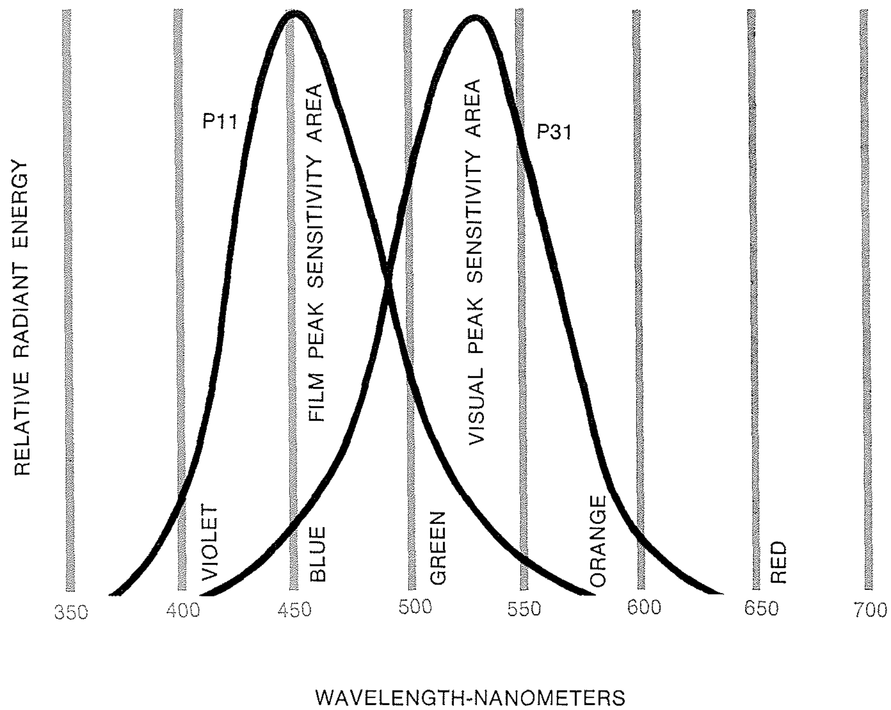
STEPS TO MORE WRITING SPEED

The oscilloscope that you are using, in all probability, has a CRT with P31 phosphor. This phosphor is a highly efficient source of light peaked at about 530 nanometers, an optimum wavelength for visual observation. For this reason, phosphor comparison charts often use P31 as a 100% reference for relative luminance.

Luminance values are light values measured through a C.I.E. Standard Eye Filter and are appropriate for visual work. Luminance charts, however, do not adequately represent the response of film. Although P31 is good for most waveform photograph applications, it is not optimum for speed. In addition, P31's persistence, or after-glow after excitation is removed, will often require a short wait to avoid recording previous traces or even the results of ambient light excitation. Colored light filters can reduce the persistence effects but filters also attenuate total light output.



How much can you improve writing speed with practical techniques? The range of improvement is ***approximated*** *above. Approximated because the many variables in CRT, film, and camera performance make writing speed prediction difficult.*



The color (wavelength) of the peak light emitted is the key to phosphor selection. Normally, P31 is selected for its excellent visibility to the eye. P11 is best only when writing speed and persistence must be optimum for oscilloscope photography.

P11 can double writing speed over P31. P11 phosphor light output peaks at 450 nanometers, very close to optimum for CRT photographic writing speed. P11 has a relative luminance of 25% compared to P31 and is far from optimum visually. In addition to its photographic writing speed, P11 has the photographic advantages of very short persistence characteristics. Most Tektronix oscilloscopes offer P11 phosphor as a no-charge option at time of purchase. Careful consideration should be given to the less-than-optimum visual-use characteristics of this P11 phosphor before making a decision to purchase.

Where an extra 2 to 2.5 faster writing speed is desired, Polaroid* Type 410 film can be used. This film is rated at 10,000 ASA. ASA ratings are not fully appropriate to scope use, but they do indicate roughly the speed in trace recording. This film is not stocked everywhere but is available through normal suppliers of Polaroid film. 410 is a roll film, not compatible with flat pack backs.

General purpose cameras are not slow cameras in the sense that they cannot capture high speed, single traces. But, at some rate of beam movement, a faster camera may be required. Faster scope cameras have a larger lens of more than an f stop better and usually a smaller magnification. Light gathering capacity is increased by the lens, by greater than two, and then concentrated on a smaller film area by the smaller magnification. An overall gain of at least four in writing speed results.

There is a less convenient step that can increase writing speed. A slight overall exposure in addition to the regular exposure can increase writing speed by a factor of two. This sensitizing process is called fogging and can be done prior to, coincidental with, or after trace exposure. Fogging techniques are not necessary when using optimum photographic techniques with the 454 and 7000 Series Oscilloscopes.

We have not covered focusing, mounting, and other factors in camera usage since this information is available in your camera manual. The subject of lens and CRT distortions and their effects has been bypassed. There are other second order writing speed improvement techniques that are doubtful in value from the point of view of results or costs. The techniques described in this article have been proven to be useful.

**Polaroid is a registered trademark of the Polaroid Corp.*

THREE IMPROVED CAMERAS

C50—General Purpose—Particularly Well Suited for the 7000 Series

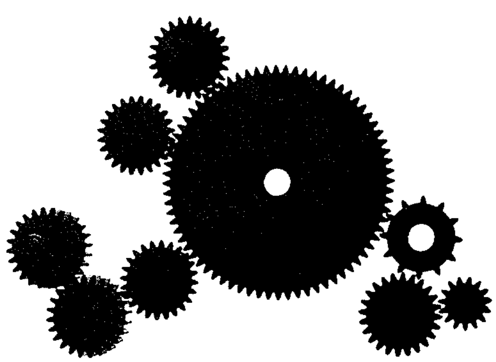
C51—Fast Scope Photography—Particularly Well Suited for the 7000 Series

C70—General Purpose—6½-Inch CRT Applications

Two important steps in waveform photography, setting focus and exposure, are greatly simplified in the newest Tektronix oscilloscope cameras. With simple adjustments, pictures will be right on the first try. Other new camera features enable the operator to control single sweep operations at the camera or at remote locations. With one step, at one location, the user can initiate the complete sequence necessary to record transient events.

FOCUS AND EXPOSURE

Setting focus on many scope cameras requires accessory focusing plates and low ambient light levels. The new cameras provide a built-in pair of focusing light bars to simplify the process. It is no long necessary to seek focusing accessories, which are often misplaced, or to turn down the lights. The bars are an aid to focusing, projected onto the CRT screen. Aligning the bars, by a simple adjustment, completes the focusing process.

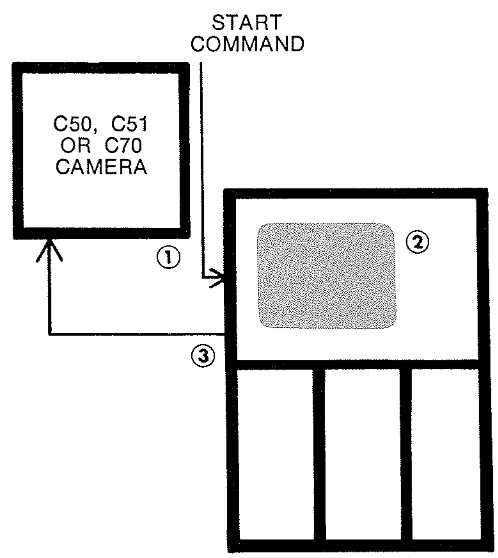


Film speed, phosphor, exposure time, and lens opening are interrelated by the computation gears of the trace brightness photometer. This feature is standard in the C50, C51, and C70 Oscilloscope Cameras.

Exposure setting is equally as easy with the aid of a new, built-in spot photometer. The operator merely matches the photometer spot intensity to the trace intensity. All factors affecting exposure such as film speed, shutter time, and CRT phosphor are related to lens aperture and trace brightness through a mechanical computer. In setting exposure the operator uses one knob to match photometer spot and trace intensity. The adjustment is quick. After setting, variation of lens aperture or exposure time will not disturb correct exposure. The computer automatically maintains correct exposure relationship through all subsequent adjustments.

SINGLE TRANSIENT PHOTOGRAPHY

Single transient photography requires careful preparation of the scope and camera to capture all information. After the initial set up, a check list is often necessary to insure that every vital step is made. In some complex experiments and tests, dozens of scope/camera systems are required to completely record the vital parameters of the transient event. This can make the process even more subject to error by multiplying the required steps. The new cameras remove at least two steps from the task of recording the single transient.



1. *The start command triggers the oscilloscope and initiates the transient event.*
2. *The trace is photographed.*
3. *Approximately 5 seconds after sweep, the shutter closes.*

One step, at the camera or remote location, initiates the complete sequence necessary to capture single events photographically.

The C50, C51, and C70 are ideal for remote operation of single or multiple camera systems. They feature electrically operated shutters. The operator, through a new single-sweep mode, can arm the scope's single sweep system at the camera, or at a remote control site. Then, after the transient event triggers the sweep, the electrically-operated shutters will be automatically closed. Just one step does it all. The new oscilloscope cameras greatly simplify the art of waveform photography, saving time, film, and frustration.

TEKNIQUE: *Amplitude measurements to better than 1%*

The first step towards making more accurate amplitude measurements is to increase resolving power. The second step is to make the measurement by comparison to an accurate voltage reference.

Certain plug-in amplifiers are built specifically to improve resolution and to provide a precision reference voltage. These units are called differential comparator amplifiers; occasionally they are described as slide-back amplifiers. These plug-ins work equally as well in either the vertical or the horizontal compartment of an oscilloscope.

In the August issue, *Teknique* discussed resolution and comparison as related to improved time base accuracy. Analogous concepts are used in differential comparison. That is magnification, employing considerable off-screen deflection, comparison to an accurate reference. The technique nulls or balances a point on the magnified waveform to the same position on the CRT screen that was occupied before comparison by the other extreme of the voltage being measured. The "readout" task is transferred from the calibrated graticule, which has limitations in resolution, to a device which is, in effect, a calibrated position control. This position control provides hundreds (sometimes thousands) of resolvable measurement increments.

Accuracy is further improved by comparison since the reference values used are more accurate than that necessary in attenuators. Attenuator tolerances are typically specified as 3% (2% in the 7000 Series). These attenuator specifications, of course, are "worst case" statements. Comparison voltage specified accuracies are always significantly better. In some units accuracies approach 0.1%.

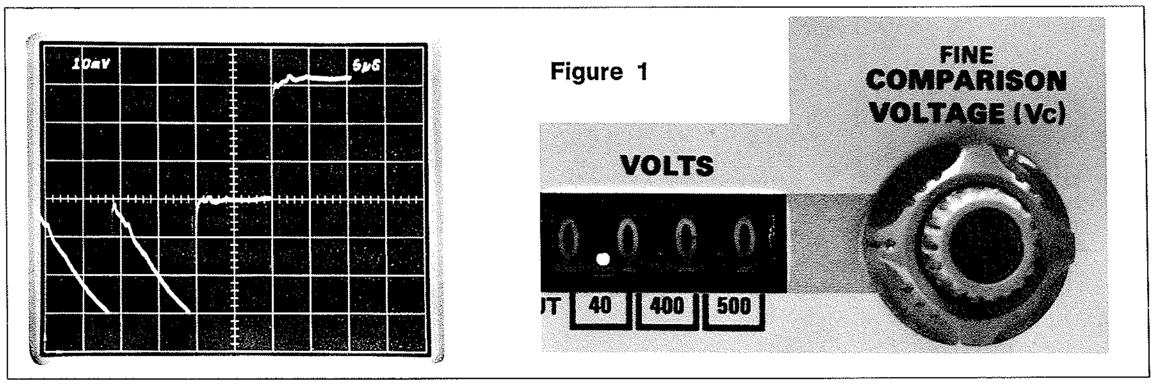


Figure 1

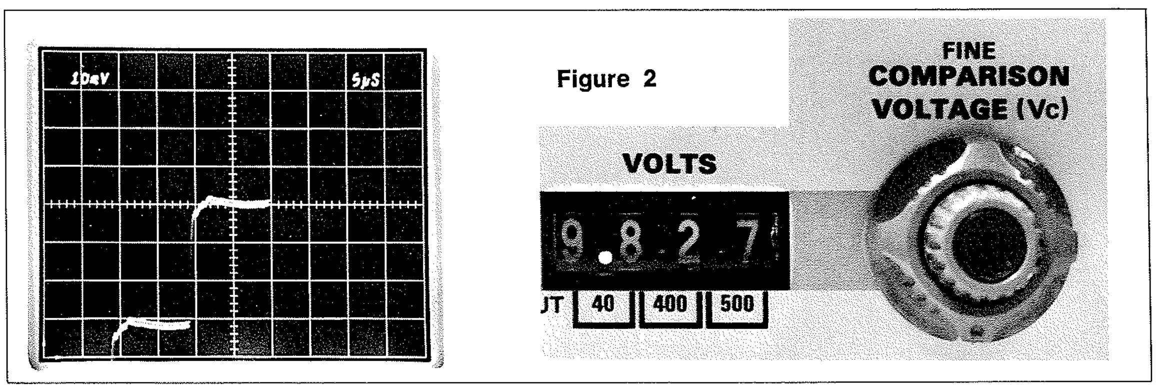


Figure 2

Figure 1 shows the bottom of a stairstep waveform of approximately 10-volts amplitude positioned to a Y-axis graticule line. The comparison voltage reads 000.0 volts. Figure 2 shows the top of the same waveform positioned to the former location of the bottom. The comparison voltage reads 9.827 volts, a precise reading of the peak-to-peak amplitude. The difference between intermediate points on the waveform can be derived just as easily.

The photographs were made displaying the equivalent time base deflection voltage of a 1S1 Sampling System. The oscilloscope is a 7503 with 7A13 Differential Comparator Amplifier. The 7A13, 1A5, W, and 3A7 are four plug-ins that feature the differential comparison measurement technique.

SERVICE SCOPE

SERVICING THE C12, C13, C19 and C27 CAMERAS

By Charles Phillips
Product Service Technician, Factory Service Center

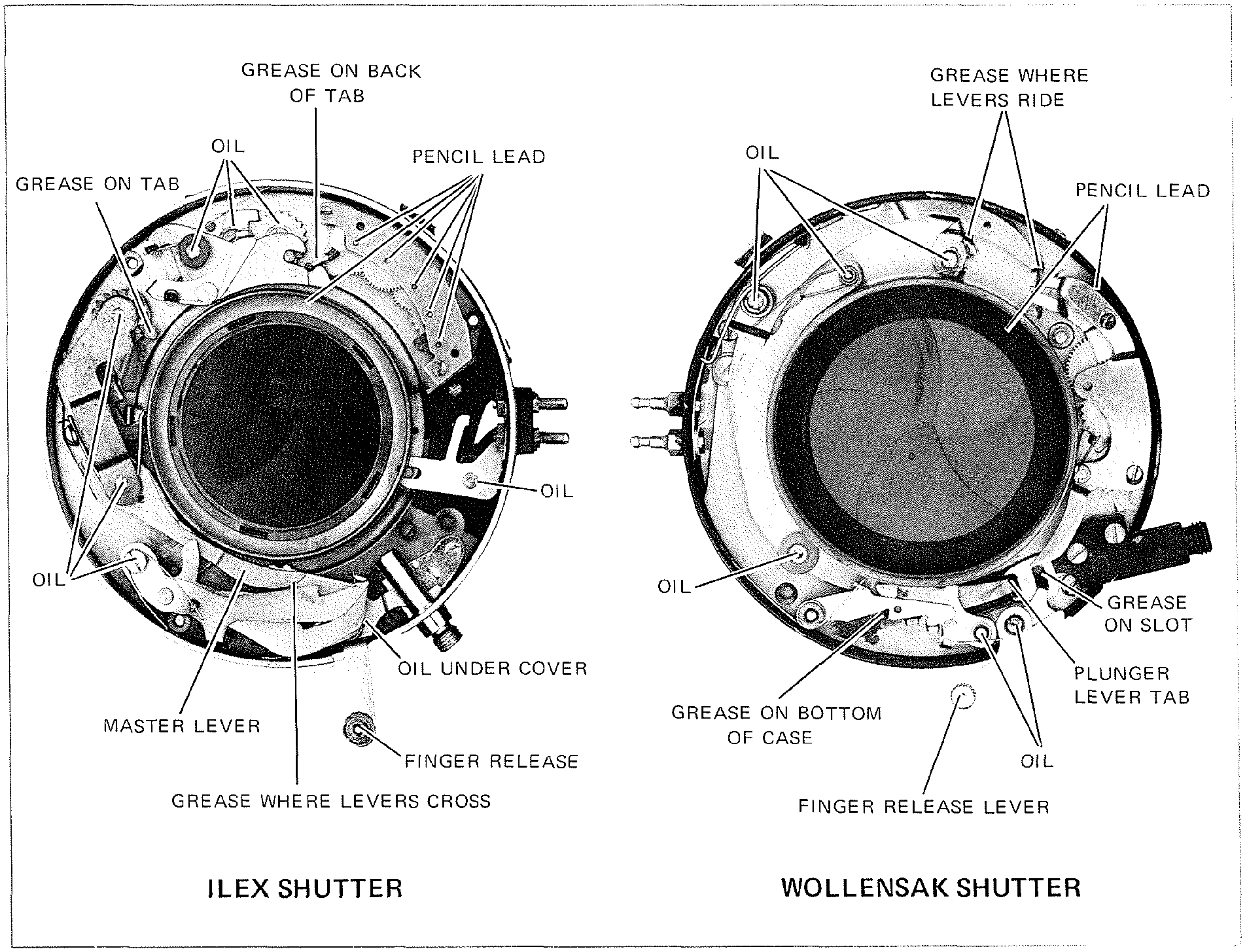
Until recently oscilloscope cameras have been assemblies of commercially available lenses, shutters, and film backs. The rest; frames, mounting hardware, and so forth; have been built by scope camera manufacturers to suit the special photographic and mounting needs of scope trace recording. Failures and malfunctions in cameras of this type are usually confined to sticking shutters and light leaks. There is some rare breakage due to accidents. Mechanical parts broken by such accidents are readily replaced. Each camera manual shows a detailed exploded view of the necessary replacement parts. These parts, except for components of the lens/shutter assembly are readily obtained through the same channels you use to get other Tektronix parts. Be sure to use the full nine digit part number and the camera type and serial number when ordering.

If you have a light leak you may find the source difficult to locate. In general, they are due to improper installation of camera hardware. It pays to carefully examine the camera back for loose or missing screws. If you have a "light leak" that occurs only with extra long exposures, you may be recording the light emitted by the CRT heater. This is not a common occurrence today. Aluminized tubes have virtually eliminated the effect. There isn't much you can do about this light source except shorten your exposure. Long exposures, on older scopes, are sometimes subject to light leakage in through the scope sides and out through the CRT.

Shutter sticking is an occasional problem. Servicing shutters requires some mechanical skills; not quite as much as clock repair, but the task is not to be undertaken casually. You may prefer to have your Tektronix Field Engineer arrange repair through a Service Center. It is practical, however, for you to cure this problem using normally available equipment.

The following servicing techniques apply to both the Elgeet/Ilex 3X and the Ilex 3X Shutter as well as the Wollensak Alphax and Pi-Alphax Shutters.* If you are not familiar with shutter mechanisms, I recommend that you tackle an Ilex before a Wollensak. The springs in a Wollensak are apt to pop out as you work the shutter without the cover. The Ilex springs are held in place by screws and won't pop out. Therefore, it's best to get a feel for the action with an Ilex.

**Ilex is a registered trademark of Ilex Optical Company, Inc. Alphax and Pi-Alphax are registered trademarks of Wollensak.*



Proper attention to the above points, during servicing, will assure smooth and reliable shutter function.

First, determine that the shutter is malfunctioning by the feel of the actuator (a spongy or rasping action is a common symptom). Then unscrew the lenses from front and rear of the shutter housing.—Be sure to remember or mark which is which; you could have an identification problem at reassembly. If the lenses are stubborn, use a towel to get a better grip. In a few cases, mostly with Wollensak lens assemblies, Glyptol cement was used to seal the assembly. Acetone will soften it. In extreme cases, a gripping device such as used to open stubborn jars may be necessary.

After the lenses are removed, set the shutter speed at 1. Put a mark on the shutter cover at the finger release lever. Then put a mark on and remove the second cover. (Ilex and Elgeet only). The marks aid in alignment at reassembly. Note the position of levers and springs. *Don't operate the Wollensak shutter with the cover off.* The springs can jump off their posts.

Next, fill a small bowl with enough Freon to cover the shutter. Caution—use tube puller or similar gripping device to dip shutter into Freon. Freon will remove oil and foreign matter from the shutter *and the hand;* it is best not to touch.

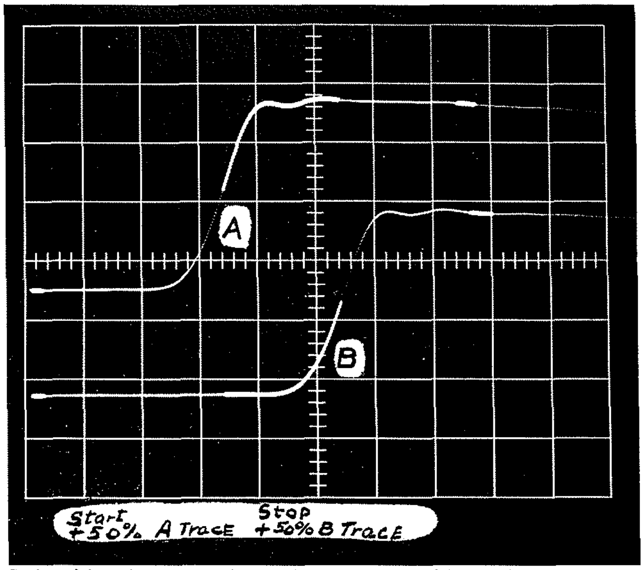
A Freon bath will remove encrusted material from the vital moving parts in a shutter assembly.

Let the shutter dry, you can use low pressure air if available. The shutter should now work freely. If not, here are some suggestions:

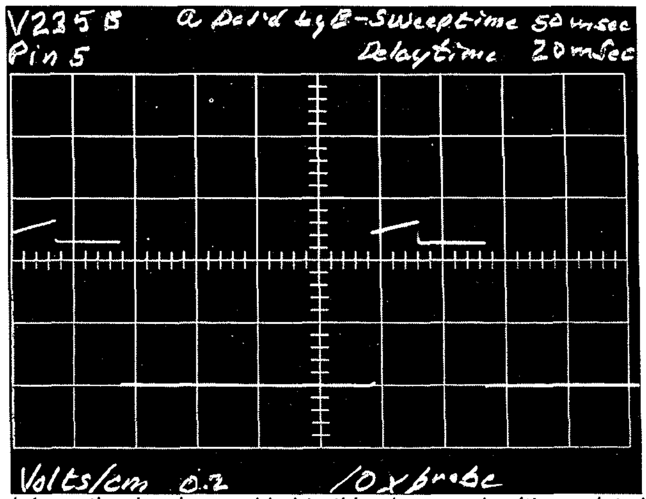
Wollensak	Problem #1	—	Plunger lever jumps out of slot.
	Solution	—	Bend tab inward slightly and reinstall in slot.
	Problem #2	—	Bent master lever or plunger lever.
	Solution	—	Carefully experiment, small bends may be necessary to make it work.
Ilex & Elgeet	Problem #1	—	Finger release lever rides over or under master lever.
	Solution	—	Raise or lower end of master lever to ride in slot on finger release lever. A small bend upward on the end of the master lever will prevent these two levers from jamming.

Next, some lubrication. On Ilex shutters, loosen screws (see photo) one at a time and add a small drop of oil on top of post. Retighten screw. On the Wollensak, just add a drop of oil. Blot excess oil; a cotton tip swab is excellent. There are four oils that we feel are satisfactory; WD40, No Noise, Clock Oil, or the oil commonly used on meter movements. Rub a dry lubricant or a "lead" pencil (graphite), on the points shown on the photograph. Install cover on Wollensak and operate shutter a few times. Blow off any excess dry lubricant. Grease at points indicated with switch detent lube. Check springs and levers again for proper function. Assemble shutter assembly. Check all ranges of speed control.

Now clean the lens with lens paper or tissue. Blow off any lint. Reassemble all lenses and the shutter. You should now have a reliable shutter, good for years of service.



Polaroid prints can be written upon with ordinary pen or pencil—see Technique 1 for details.



Information has been added to this photograph with a pointed implement—see Technique 2 below for details.

ADDING INFORMATION TO POLAROID PRINTS

Over the years customers have had the need to record data on Polaroid waveform photos. Some imaginative techniques have been reported to us and we are passing them along.

Technique 1—Use a draftsman's thin metal erasing shield and an eraser (an electric eraser is ideal if you're lucky enough to have one handy) to label or pinpoint information on Polaroid Land prints. The shield and eraser will enable you to erase through the print to the underlying white paper. You can erase away a portion of the print to form an arrow or a space to write in a number or a brief description.

This technique is most effective when used after the surface has dried a few minutes after development. Don't apply the coater until after completing the erasure and recording your data.

Technique 2—Polaroid prints are soft enough to be scratched for some time after development. This softness enables a metal point to scribe data on the print. The point should be sized somewhere between a common pin and a sharpened pencil. If the print is too hard, soften it with reapplication of the coater.

Technique 3—Apply SNOPAKE® correction fluid, manufactured by Litho-Art Products, Inc., to a select section of the print. This fast drying stuff will form a surface for writing. Ask your secretary; she probably has some stashed away. If not, your local office supply source has it.

Technique 4—Less convenient, but effective. Take a pencil type soldering iron and write. The results should be clear and distinct.

MARKING PHOTOS FOR ORIENTATION

You can avoid confusing moments for others if you will mark on your waveform photos which end is which. Some cameras reverse the waveform, some don't; some flip it upside down, some don't. Most of you indicate this information in a note attached to the photo, but woe to a person who gets the photo minus the note!

SPRAY MATTE FINISH ACCEPTS PEN OR PENCIL

The glossy surface of Polaroid opaque prints can be dulled to a matte finish by application of Marshall's Pre-Color Spray or Marshall's Pro-tek-to Spray.

The dulled surface can easily be written on with ordinary lead pencil, ball-point pen, etc., Dulling the surface also makes the prints suitable for use in opaque slide projectors (magic lantern).

The spray treatment is not a substitute for application of the regular coating chemical provided with each roll of Polaroid film for fixing and protecting the print; use Marshall Spray after the regular protective coating has been applied and allowed to dry.

Marshall's Pre-Color Spray is available through artist supply stores. Marshall's Pro-tek-to Spray is available through photo dealers.

WRITING ON GRATICULES

For writing on graticules for photographic purposes, we suggest a yellow grease pencil. Flora-Fluorescent made by the Swan Pencil Co. is one type that may be useful.

INSTRUMENTS FOR SALE

316, $450. CA Plug-In, $120. Roy B. Lang, 1003 Reseda Drive, Houston, Texas 77058. (713) 488-0149.

547, 1A2, $1900. Mr. J. Infusino, 3 Dogwood Lane, Nutley, N.J. (201) 667-4266.

601. Manny Mandell, Tonus, Inc., 45 Kenneth Street, Newton Highlands, Mass. 02161. (617) 969-0810.

RM181. Dr. D. Mellon, University of Virginia, Department of Biology, Charlottesville, Virginia. (703) 924-7119.

453, $1500. Jack Hart, New Jersey Communications, 760 Fairfield Ave., Kenilworth, New Jersey. (609) 245-8000.

532, 53C. Roger Harker, Bently Nevada Corporation, Box 157, Minden, Nevada. (702) 782-2255.

516 with P6017 Probes. Carl Frederiksen, Moline Tool Company, 102 20th Street, Moline, Illinois 61265. (309) 764-2418.

545B, 1A1, $2000. P.O. Box 1300, Winter Park, Florida. (305) 831-6222.

310A. Paul Katz, 5224 Linden, Bellaire, Texas 77401. (713) 524-3761 or (713) 667-5232.

454 Mod 163D, $2500. Palmer Agnew, 314 Front Street, Owego, New York 13827.

551, CA, 53/54C. Guy O'Balinski, Bromion, Inc., Rt. 17, Sloatsburg, New York 10974. (914) 753-2733.

535A, 545A, 531A & CA, L - 503, 515A, LC130. Henry Posner, Pacific Certified Electric Co., 5272 E. Valley Blvd., Los Angeles, California 90032 (213) 225-6191.

R422, $1000. William H. Greenbaum, Unilux, Inc., 48-20 70th Street, Woodside, New York 11377.

520, $1850. Jerry Childs, Datatron, Inc., 1562 Reynolds Avenue, Santa Ana, California. (714) 540-9330.

535A, CA Plug-In, $950. Bob Duke, 13526 Pyramid Drive, Dallas, Texas 75234. (214) 241-2888.

RM15, $600. RM45, $900. Z Plug-Ins $275 each. Stuart Ex, 14827 Cohasset Street, Van Nuys, California 91405, (213) 786-7672 or (213) 873-7672.

519, C-27, 202-1 Mod 52. All $4500. Bill Hall, KMS Technology Center, 7810 Burnet Avenue, Van Nuys, California 91405. (213) 787-7300.

514AD, $350. Dr. Robert Howson, Bell Telephone Laboratories, Room 1E-315, Holmdel, New Jersey 07733. (201) 949-5503.

80 with probes, 53/54B, T Time Base, 535. Joe McCauley, P.O. Box 118, Carmichael, California 95608. (916) 635-1773.

519, $3200. Ed Snyder, Science Accessories Corporation, 65 Station Street, Southport, Connecticut. (203) 255-1526.

122, $45. Mr. A. Wolff, Caltronic Laboratory, P.O. Box 36356, Los Angeles, California 90036.

323, $950. R. H. Ellis, Ellis Automotive Electrics Co., 7 Century St., Hamilton 21, Ontario, Canada.

555, 21A, 22A, M, CA, $2400. Ken Buddin, Optical Scanning Corp., Newtown, Pa. (215) 968-4611.

RM535A, 127 Power Supply, O, Q, E, Z, M Plug-Ins. RM567, 6R1A, 3A2, 3B2. C12 w/Graflok & Polaroid. Peter M. Guida, 525 East 68th Street, New York, N.Y. 10021.

127, 132, 123, H, L, D, G, B, 160A, P, TU-2. Ken Huff, Bryant Computer Products Division Ex-Cell-O Corp., 850 Ladd Road, Walled Lake, Michigan 48088. (313) 624-4571.

531, $400. Dennis Kraft, 7522 Tampa, Reseda, California 91335. (213) 881-1551.

130, $200. Robert H. Becker, Becker Electronics, Inc., 144 Westside Ave., Freeport, New York 11520. (516) FR 8-3005 or (516) FR 8-3092.

531A, 1A2, N, $1250. Michael Muegge, 100 Foerster St., San Francisco, California 94112. (415) 931-8000, Ext. 522 or (415) 585-1625.

INSTRUMENTS WANTED

453. Carl Frederiksen, Moline Tool Company, 102 20th Street, Moline, Illinois 61265. (309) 764-2418.

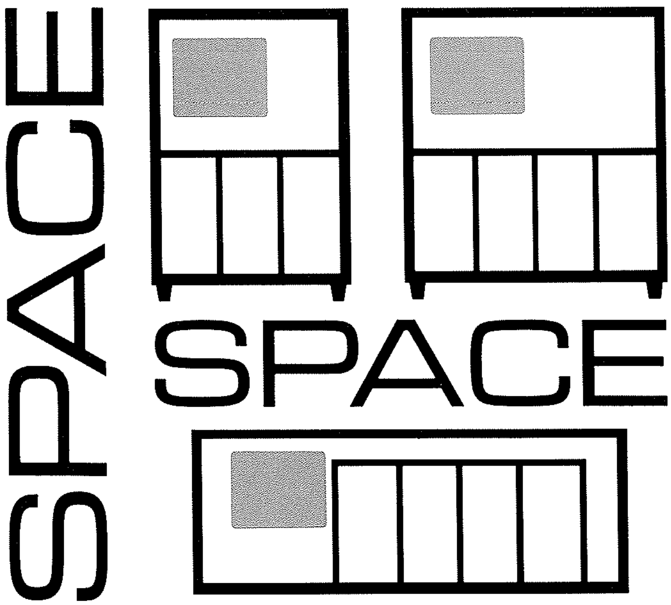
453. F. Jambor, 302 Easy St., Apt. 60, Mt. View, California 94040.

517A Power Supply. Prefer working, will consider repairable unit. J. E. Churchill, P.O. Box 4092, Santa Fe, New Mexico 87501.

TEKSCOPE

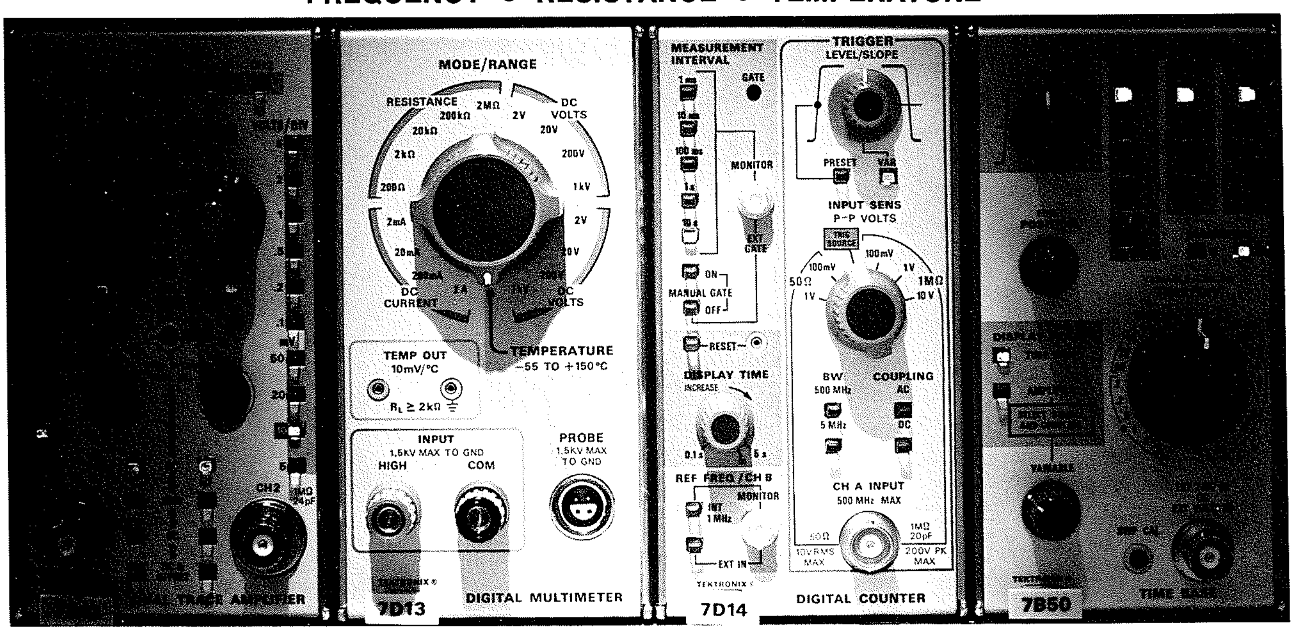
Volume 2 Number 5 October 1970

Customer Information from Tektronix, Inc., P. O. Box 500, Beaverton, Oregon 97005
Editor: Art Andersen Artist: Nancy Sageser For regular receipt of TEKSCOPE contact your local field engineer.



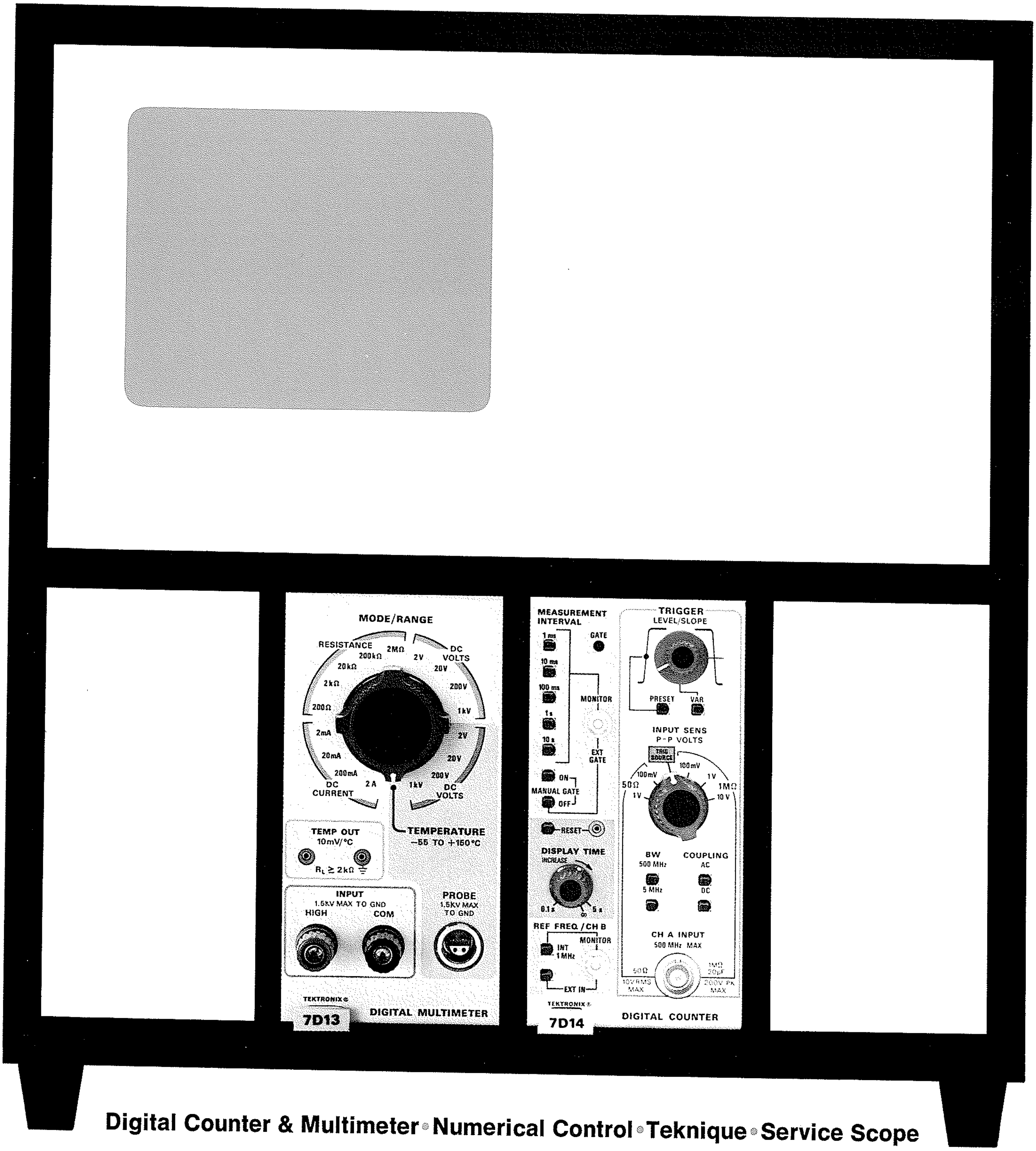
Separate instrumentation requires space, space required by separate digital multimeter, separate counter, separate oscilloscope. Now the 7000 Series combines three, basic instrument functions in one system—saving space, without sacrificing performance. The Integrated Test System, a new and unique concept from Tektronix, has been created. Created by the addition of the plug-in 7D13 Digital Multimeter and the plug-in 7D14 Digital Counter to the 15 Oscilloscope Plug-Ins already available.

MEASURES: VOLTAGE ● CURRENT ● PERIOD FREQUENCY ● RESISTANCE ● TEMPERATURE

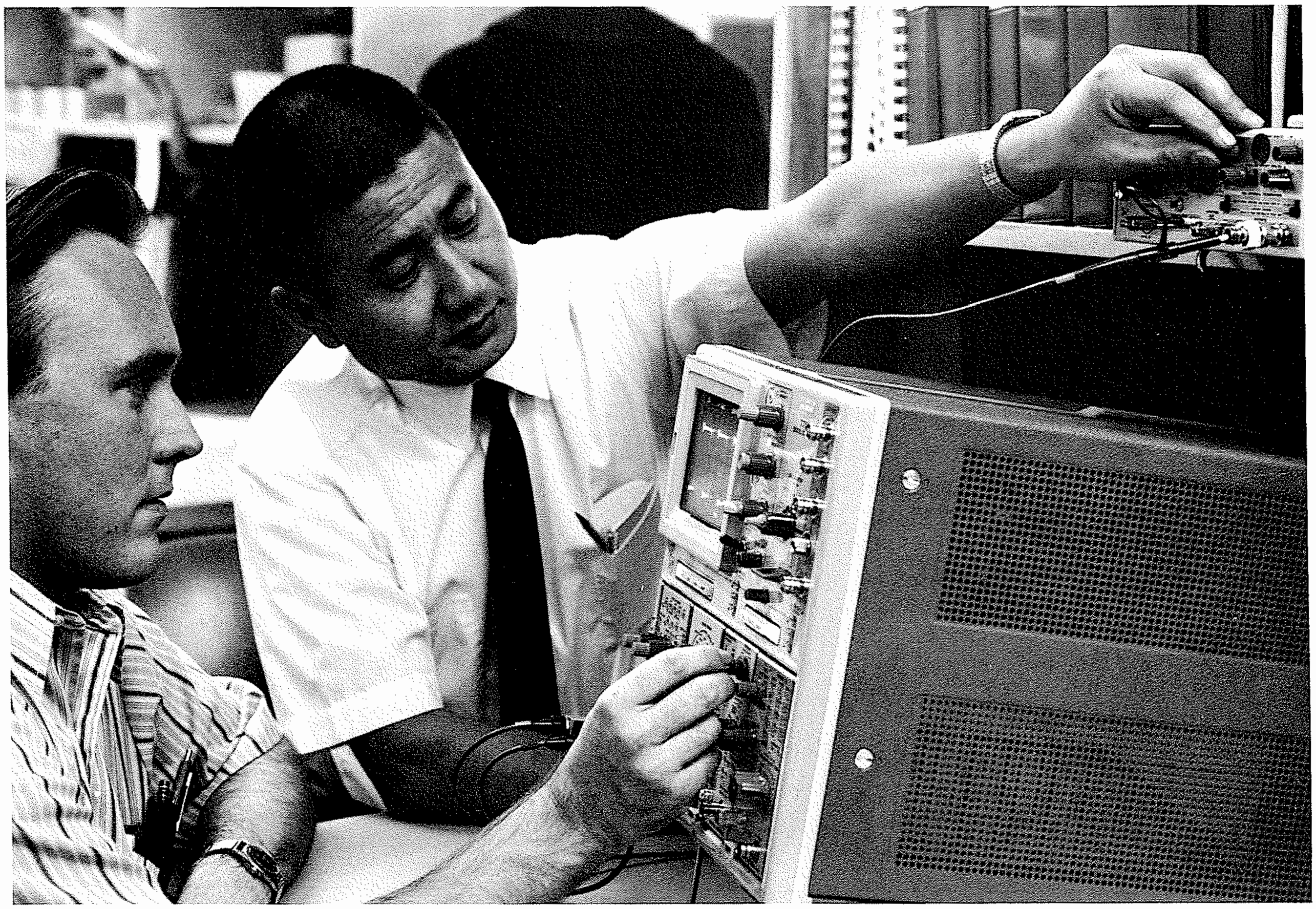


TEKSCOPE

JANUARY 1971



Digital Counter & Multimeter • Numerical Control • Teknique • Service Scope



a new world of measurements for the oscilloscope

COVER—Two new plug-ins open the door to a world of measurements formerly outside the domain of the oscilloscope. The 7D14 Digital Counter plug-in directly-gated to 500 MHz and the 7D13 Digital Multimeter with temperature readout make the oscilloscope a more versatile measurement tool than ever before.

Oscilloscopes in the last twenty-five years have advanced from relatively simple indicating devices to sophisticated measurement tools used in nearly every segment of our society. However, the basic function of displaying waveforms for time and amplitude measurement has remained relatively unchanged.

Now, for the first time, the oscilloscope can measure voltage, current, resistance, temperature, and frequency, all digitally.

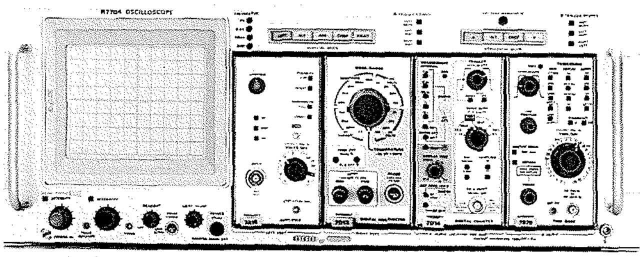
With the introduction of the 7D13 Digital Multimeter and the 7D14 Digital Counter plug-ins for the Tektronix 7000 Series, the oscilloscope assumes an entirely new role in the field of measurement.

Counters and digital multimeters are rapidly becoming necessities on the engineer's workbench. Integration of these capabilities into the oscilloscope provides an ideal answer to the space problem and, more important, offers many capabilities not available in stand-alone instruments.

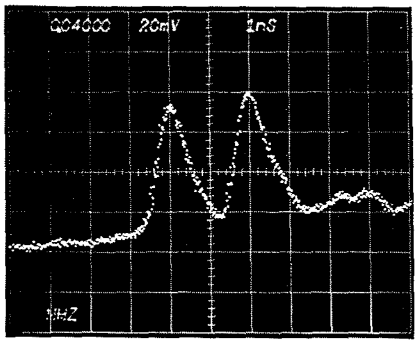
Hiro Moriyasu, Manager of Advanced Concept Development and Neil Robin, Project Engineer with primary responsibility for the 7D13 and 7D14 discuss operation of the 7D14 Digital Counter plug-in.

What are some of the advantages of marrying the digital counter, digital multimeter, and oscilloscope? Most obvious, of course, are savings in space and cost. For example, a 150 MHz oscilloscope complete with digital counter and digital multimeter use only 7" of rack height. A significant breakthrough for users where space is at a premium.

To you who record data on photos for your engineering handbook, another advantage readily apparent is the ability to display and photograph amplitude, time, frequency, temperature, and the wave shape all at the same time.



A 150 MHz oscilloscope, 500 MHz counter, and a digital multimeter, all in only 7" of rack space.



500 MHz direct-gated capability of the 7D14 is dramatically illustrated in this photo showing counting of a high-speed double pulse with a 20 kHz rep rate; a difficult, if not impossible measurement to make with most counters.

Signal conditioning is a must for many applications, and the wide range of vertical amplifier plug-ins available for the 7000 Series make excellent signal conditioners for the counter. With the 7D14 in either of the horizontal compartments, a signal connected to a vertical plug-in can be internally routed to the counter by the trigger source switches. In addition to conditioning the signal, this mode of operation lets you view the signal while counting, with minimum loading of the circuit under test.

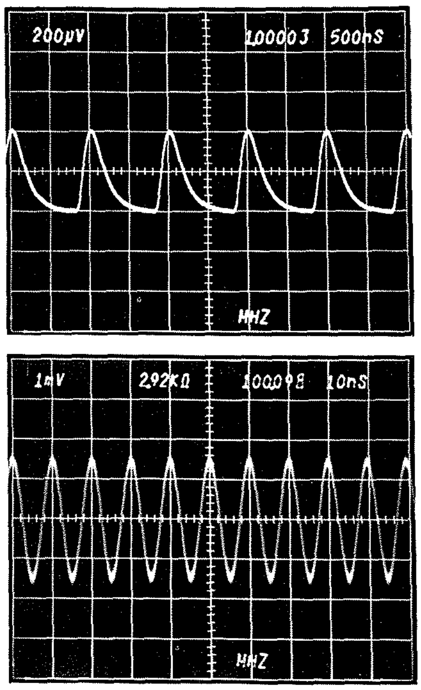
MINIMUM CIRCUIT LOADING

Circuit loading is given special attention in the 7D14. The wide frequency range of DC to 500 MHz, all directly-gated, calls for something other than just the 50-ohm input normally found on high-frequency counters. The 7D14 provides both 50-ohm and 1-megohm input impedances, and either may be AC or DC coupled. In addition, by using the vertical plug-ins as conditioners, the 7D14 Counter enjoys the same freedom from loading you've come to expect in oscilloscopes. The wide range of Tektronix probes, from FET's with high resistance and low capacitance to current probes with practically zero circuit loading, can be used to acquire the signal. Many of the probes can be used directly on the counter if attenuation of the signal can be tolerated. This leads us to another advantage of the counter/scope combination.

COUNTING LOW-LEVEL SIGNALS

Low-level signals are not among "the counted" for most counters today. The 100 mV P-P (35 mV RMS) sensitivity of the 7D14 is better than that of most counters. However, even signals in the microvolt region can readily be counted using the vertical plug-ins as conditioners. Pictured below is a 400 μV, 1 MHz signal being counted after conditioning by the 7A22 Differential Amplifier.

Low-level, high-frequency measurements beyond 150 MHz can easily be made using the 7A11 or 7A16 wideband plug-in amplifiers for conditioning. The photo showing a 3 mV, 100 MHz signal being counted, illustrates this unusual capability.

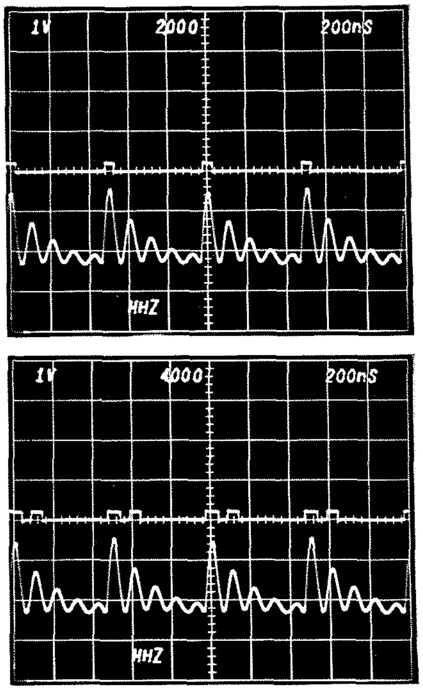


Signal conditioning using vertical amplifier plug-ins greatly expands the range of signals that can be counted. Top, a 400 μV, 1 MHz signal is counted using the 7A22 Differential Amplifier for conditioning. Bottom, 3 mV, 100 MHz signal is counted after conditioning by the 7A13 Differential Comparator Amplifier.

TRIGGER INDICATOR

One of the most difficult problems encountered when using conventional counters has been in determining just what the counter is counting. Noise peaks may trigger the counter or variations in signal level may cause an event to be missed. The 7D14 ends that uncertainty. Now we can see the same "shaped" input signal that the counter section actually sees.

The input signal passes through conditioning circuits in the 7D14. One of these is a Schmitt trigger which serves to reject noise and shape the input signal to the counter. The output of the Schmitt is a rectangular wave and drives the counter circuits. This makes it an ideal waveform to display on the CRT along with the input signal. With the 7D14 in a vertical plug-in compartment, we can view the Schmitt output. It can be displayed as a separate signal or "added" to the input signal to show precisely the portion being counted.



The value of the 7D14 trigger indicator when counting complex waveforms is apparent in these photos. The only change between the top and bottom photo was a slight adjustment of the counter's trigger level control.

EXTERNALLY-GATED MEASUREMENTS

Externally-gated measurements usually entail a lot of guesswork, especially when the signal to be counted is a burst. Using the 7D14 with delaying sweep plug-ins such as the 7B70/7B71 greatly simplifies these measurements.

The 7D14 is located in one of the vertical plug-in compartments and the sweeps are operated in the delaying time base mode. The signal to be measured is displayed with A time base while B time base intensifies the trace and provides the counter gate. We can set B gate (or delayed gate) to the desired width and position it anywhere along the displayed sweep. Thus, we can gate the counter for any portion of the display we choose.

Gating the counter with an external gate that coincides with the intensified portion of the trace offers many measurement possibilities. For example, measuring the duration of a ramp, time interval, counting events in a burst and the frequency in a burst are but a few of the measurements you can make using this technique.

COUNTING EVENTS IN BURST

To count the number of events in a burst, feed the burst signal into the counter Channel A input. Gate the counter externally with the delayed gate output from the scope and set the intensified portion of the sweep to bracket the burst to be counted. The counter readout displays the number of events occurring in the burst. Moving the intensified portion back and forth with the Delay Time Multiplier while observing that the counter readout remains steady will verify that all of the events in the burst are counted. This is particularly important when measuring bursts of 10 μs or shorter duration.

COUNTING FREQUENCY IN BURST

To count an unknown frequency in a burst, the setup is the same as above only the intensified portion is made shorter than burst width and positioned within the burst. The counter readout is noted. The width of the external gate, which corresponds to the intensified portion, is then measured by one of two methods.

The most accurate method is signal substitution. The burst signal is removed and a known reference frequency connected to the signal input. The counter readout is again noted. External gate duration is calculated by multiplying the number of reference frequency cycles counted, times the period of the reference frequency (Gate Width = N_{ref} x period). The burst frequency is then easily determined by dividing the number of burst cycles counted, by the gate width

$$(f_{burst} = \frac{N_{burst}}{\text{Gate Width}}).$$

The second method, though not as accurate, is somewhat simpler since it requires no external reference frequency. The external gate width is simply measured using the scope time base. Once the external gate width is measured, the frequency in the burst is calculated as before. The number of burst cycles counted is divided by the gate width

$$(f_{burst} = \frac{N_{burst}}{\text{Gate Width}}).$$

FREQUENCY COMPARISON

Frequency comparisons are commonly made by alternately feeding the two signals into the counter and noting the difference between the two readings. These measurements are made more quickly and accurately with the 7D14 using a dual-trace or differential plug-in to switch rapidly between the two signals. The 7A12, 7A13, and 7A22 are ideal for this application.

COUNTER READOUT

The 7D14 provides 8-digit readout on the CRT with leading zeros suppressed, that is, zeros leading the first major digit are not displayed. Accuracy of the counter is parts in 10^7. Why then 8-digit readout? There are a number of reasons: first, provision is made to drive the 7D14 with an external reference oscillator of greater accuracy and stability. This could easily yield measurement accuracy to the eighth place. Second, resolution; some measurements are best made using comparison techniques. Frequency difference is then of more importance than absolute frequency. The more resolution you have, the closer the two frequencies can be compared. Third, the 7D14 can be manually or externally gated for "totalizing" measurements. The 8-digit readout makes possible totalizing counts from 0 to 10^8.

7D13 DIGITAL MULTIMETER

Thus far we have discussed primarily the 7D14 Digital Counter. Now, let's take a look at the 7D13 plug-in Digital Multimeter.

The 7D13 brings several new measurement capabilities to the oscilloscope. We're accustomed to taking AC waveform measurements from the CRT, but seldom do we take DC measurements from it. Perhaps we forget the oscilloscope has that capability. More likely, we need better resolution than an oscilloscope trace provides, or we find a meter easier to read.

The 7D13 brings improved resolution and accuracy to oscilloscope measurements, plus the convenience of digital readout. In addition to measuring DC voltage, the 7D13 measures DC current, resistance, and temperature. The temperature mode is new to the digital multimeter field and brings a much-needed tool to the engineer's fingertips.

THE TEMPERATURE SENSOR PROBE

The heart of the temperature sensor probe is an ordinary silicon npn transistor mounted in the tip of the probe. It is a characteristic of solid-state devices that the voltage across a forward-biased p-n junction is temperature dependent. It is this voltage that we use to measure temperature. There are, however, drawbacks to measuring the junction voltage (V_{be}) directly. V_{be} is not a perfectly linear function of temperature and varies from one device to another. This presents problems in measurement accuracy and, more important, in providing replacement sensors.

There is a solution to these problems. If, instead of using a constant collector current, the current is varied between a fairly high value, I_{c1}, and a fairly low value, I_{c2}, with resultant base voltages, V_{be1} and V_{be2}, we find that the base-voltage excursion (ΔV_{be}) has much-improved linearity and is proportional to absolute temperature.

The relationship between collector current, base-emitter voltage, and temperature is shown by the equation:

$$\Delta V_{be} = V_{be1} - V_{be2} = \frac{kT}{q} \ln \frac{I_{c1}}{I_{c2}}$$

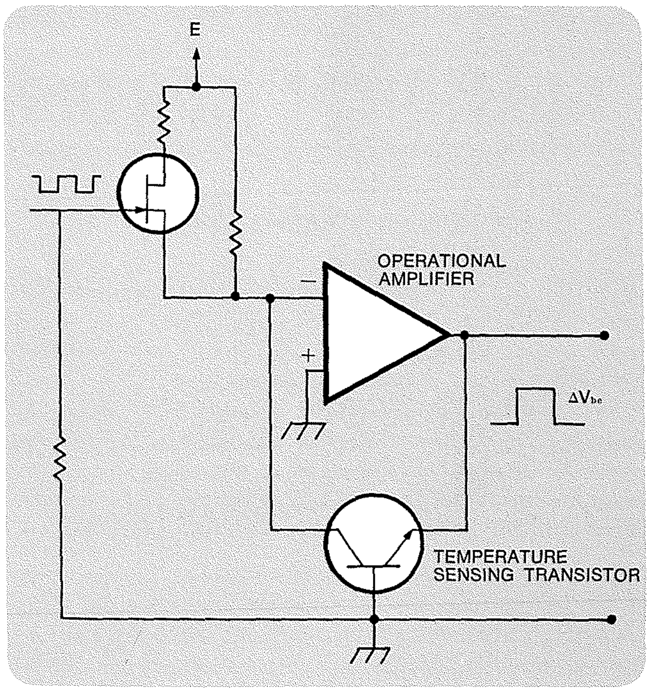
where k is Boltzmann's constant, q is the electron charge and T is temperature. Differentiation of this voltage excursion, ΔV_{be}, gives its temperature coefficient:

$$\frac{d}{dT}(\Delta V_{be}) = \frac{k}{q} \ln \frac{I_{c1}}{I_{c2}}$$

Using the switched-collector technique and measuring ΔV_{be} as the indicator of temperature change, we achieve improved linearity in temperature measurements and ease of interchangeability of the transducer transistor or probe tip.

Pictured is the basic circuit used in achieving the change in base-emitter voltage for a given change in collector current. The sensor transistor is connected in the feedback loop of an operational amplifier with the collector at the input, emitter connected to the output, and the base grounded. For a given current input, the output of the operational amplifier forward biases the emitter-base junction of the transistor to the level necessary to maintain the input collector current.

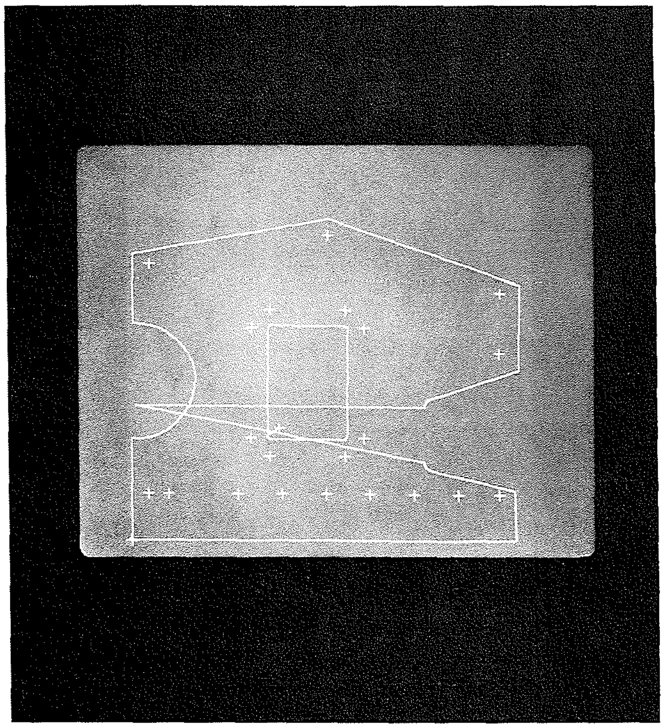
The ratio of the two levels of collector current is set at about 100:1, giving the base-emitter voltage a sensitivity to temperature of slightly less than 0.4 mV/°C.

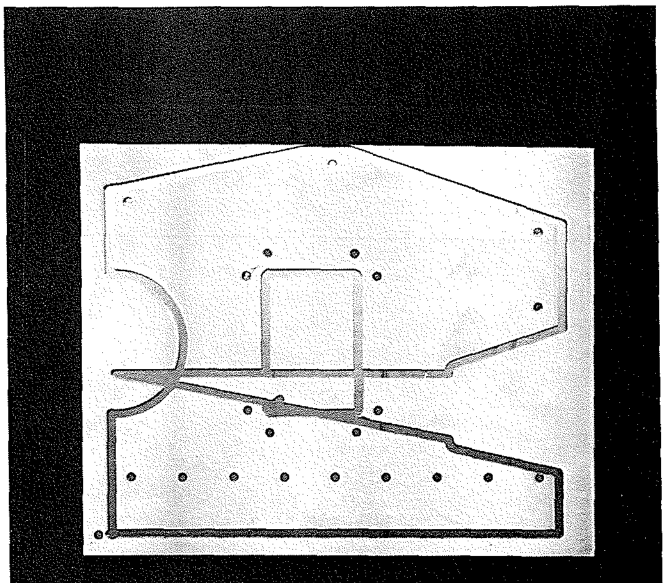


Simplified circuit for achieving improved linearity by switching collector current and measuring ΔV_{be} as indicator of temperature change.

ELEVATED INPUT CAPABILITY

Another valuable feature of the 7D13 is the ability to float the input circuit up to 1.5 kV above chassis ground. This gives us considerable flexibility in measuring parameters that have a high common-mode voltage. The temperature probe shares this capability and can take temperatures of components elevated to 1.5 kV.





Errors are inevitable in part programming. With Tektronix Machine Control errors are quickly detected by previewing tool path on a storage CRT (left) instead of cutting the machined part (right).

NUMERICAL CONTROL

a fast method of tape verification is introduced

By Gary Neher and Art Andersen

Tektronix products include numerous parts requiring high-quality machining. There are too many of each part for economical, manual operation of machine tools, yet the numbers are fewer than that required for the intensive degree of automation found in the automobile or other high volume industries. The medium volume of each part to be produced means Tektronix is a heavy user of numerical control, because it is in the medium-volume production of parts where numerical control excels.

Numerical control (NC) is simply a means of directing some or all of the functions of a machine automatically from numerical instructions. These numerical instructions are introduced to the machine by some form of stored input medium such as a punched or magnetized tape. The machine control unit (MCU) interprets these instructions and directs the machine through the required operations with a combination of speed, accuracy and consistency that cannot be equalled by human operators. Although the machine tool industry is the most conspicuous use area of NC, any mechanism requiring controlled motion is a candidate for numerical control.

In our production areas we use substantial numbers of numerically controlled machine tools. These NC units are a cross section of the high quality products of a number of well-known companies. We were pleased with these products, but, since numerical control is not a static field, it was felt that we could contribute improvements. These improvements are incorporated in the Tektronix 1701 two-axis and 1702 three-axis Machine Control Units.

CONTOURING AND POINT-TO-POINT

There are two basic types of machine tool control. The simplest is point-to-point in which the tool or part is directed to a position and a machine operation such as drilling or punching is performed. The path to that point is of consequence only in terms of time required for movement or obstacles that may exist along that path. Positioning control is another term for point-to-point control.

A more sophisticated NC concept is continuous-path or contouring control. The continuous-path MCU precisely commands tool path in multiple axes and receives confirmation of actual path through feedback. Contouring control is normally used in milling operations when cutting is simultaneous with movement. When feedback is used in an NC system, it is called a closed-loop system. Closed-loop requires a command signal from the MCU to the machine and feedback to the control from position transducers on the machine. In an open-loop system, no feedback exists. Most open-loop systems depend on precision stepping motors to maintain positioning accuracy. Open-loop systems usually sacrifice fast feedrate and accuracy.

The Tektronix 1701 two-axis and the 1702 three-axis MCU's are closed-loop, contouring units that are also useful for positioning control.

PROGRAMMING

Contouring systems generally use incremental dimensioning, a technique that references each new command to the last position on the work piece. Absolute dimensioning references all positions to one common zero-reference point. All dimensions are in one quadrant, eliminating negative commands. Absolute dimensioning is usually found on point-to-point systems. It has the following advantages:

1. Part programming is directly related to the dimensions of a part drawing.
2. Part program additions or deletions can easily be made.
3. Starting in the middle of a part program is much simpler.

The 1701 and 1702 combine the features of the positioning and contouring control. The absolute dimensioning of the positioning control is combined with some of the interpolation techniques of the contouring control, offering a control which is adaptable to either positioning or contouring applications. Full floating-zero is a standard feature in Tektronix NC that allows the zero-reference point to be established manually at any position over the full travel of the machine.

There are two types of tape coding recognized by the numerical control industry. The standard for the industry is a code with which most of us are familiar, ASCII. However, previous to the development and widespread use of ASCII, the numerical control industry had its own standard, the EIA code. The EIA code seems to be more popular in the U.S.; ASCII is generally finding acceptance in the European market. The 1701 and 1702 can accept either code by simply changing a circuit card.

AUXILIARY FUNCTIONS

The purpose of a machine control unit is not merely to control a position or move. The control must also decode from tape and indicate to the machine tool miscellaneous and preparatory functions to be performed.

Tektronix machine control units have a standard feature, the ability to command the machine tool to perform up to 80 miscellaneous functions. Some examples of miscellaneous functions are:

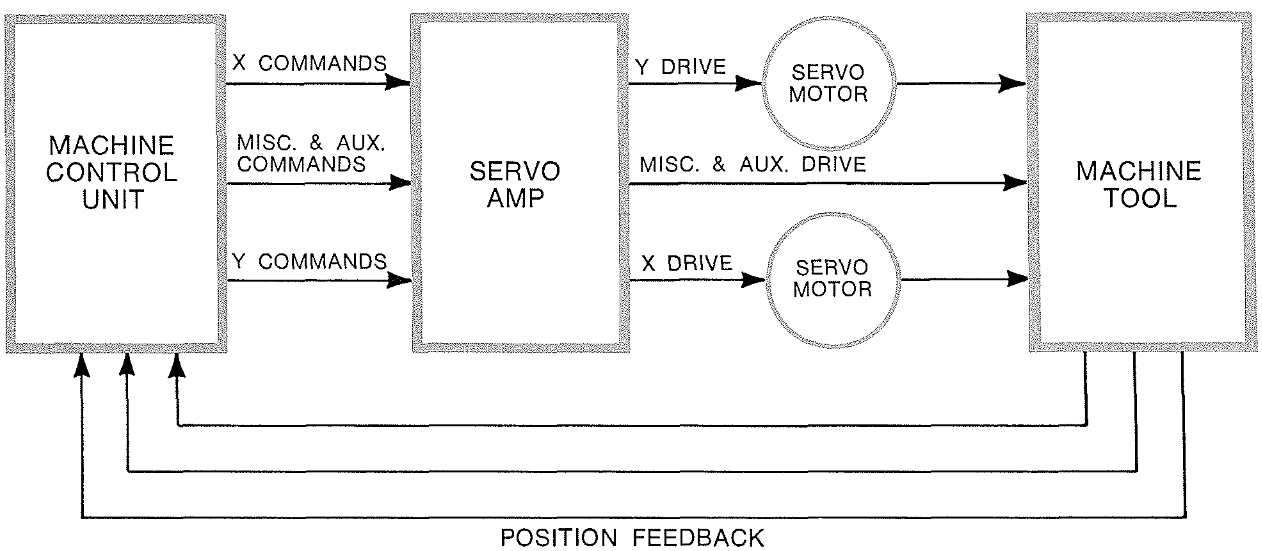
1. Control of the insertion and retraction of cutting tool, punch, or drill on a 2-axis control.
2. Turning the coolant on or off for a cutting tool or drill.
3. Positioning a turret and selecting a tool.

During a part program it may be desirable to change the mode of operation of the numerical control via preparatory functions. Some examples of preparatory functions are:

1. Selecting linear or circular interpolation on a contouring control.
2. Inhibiting the deceleration function of the control.

TEKTRONIX NC

Tektronix has entered the NC field with two and three-axis, closed-loop contouring machine control units. These machine control units (MCU) are a direct result of the influence of our own extensive machine-tool user experience (from programming to machining) combined with established product design skills. Tektronix MCU's offer the machine-tool user and the machine-tool manufacturer the new program-tape-verification option, along with easier maintenance through functional layout and many features not found in other units in its price range.



Closed-loop contouring numercal control of a machine tool requires these elements for two axis machining.

PART PROGRAMMING

As the application of numerical control has increased, there has been, naturally, a proportional increase in the need for methods to provide the necessary instruction coding for efficient operation of the machines. This instruction coding lies under the broad classification of part programming.

Part programming is defined as the technique used to provide all the data, in some coded form, to instruct the machine tool, through a numerical control unit. The MCU controls coordinate-motions, plus all of the auxiliary functions such as the spindle rotation speed and the table traverse feed necessary to produce the desired work-piece. The part programming technique may be as straightforward as manual coding each separate instruction in the MCU or as sophisticated as using a computer language, such as APT, and a large computer. A sophisticated program might define all the geometric elements of a part along with inputs to control five simultaneous axes of motion such as required to produce the complex impeller wheel for a gas turbine.

A strip of one-inch wide, eight-channel punched tape is the typical medium of part programming. This punched tape programs the machine control unit. After programming and tape punching, a very significant problem becomes apparent. How do you verify that the punched tape does, in fact, have the correct data to produce the desired part?

In other words, how do you check for programming errors? One of the least desirable, but most direct ways of checking, is to try to produce a first part on the machine from the untried tape. A second, and more tedious method, is to double check each entry on a printout of the tape against the original part program source (the part drawing). A better approach is to use some plotting device to graphically display tool paths programmed by the tape.

The plotting device that proved to be best-suited for fast tape verification was the Tektronix 611 Storage Display Unit. The 611 had been proven to be an excellent plotter of computer-generated graphics. It could follow the tape-reader speed of 300 characters per second, therefore, a part program could be plotted in seconds, rather than minutes.

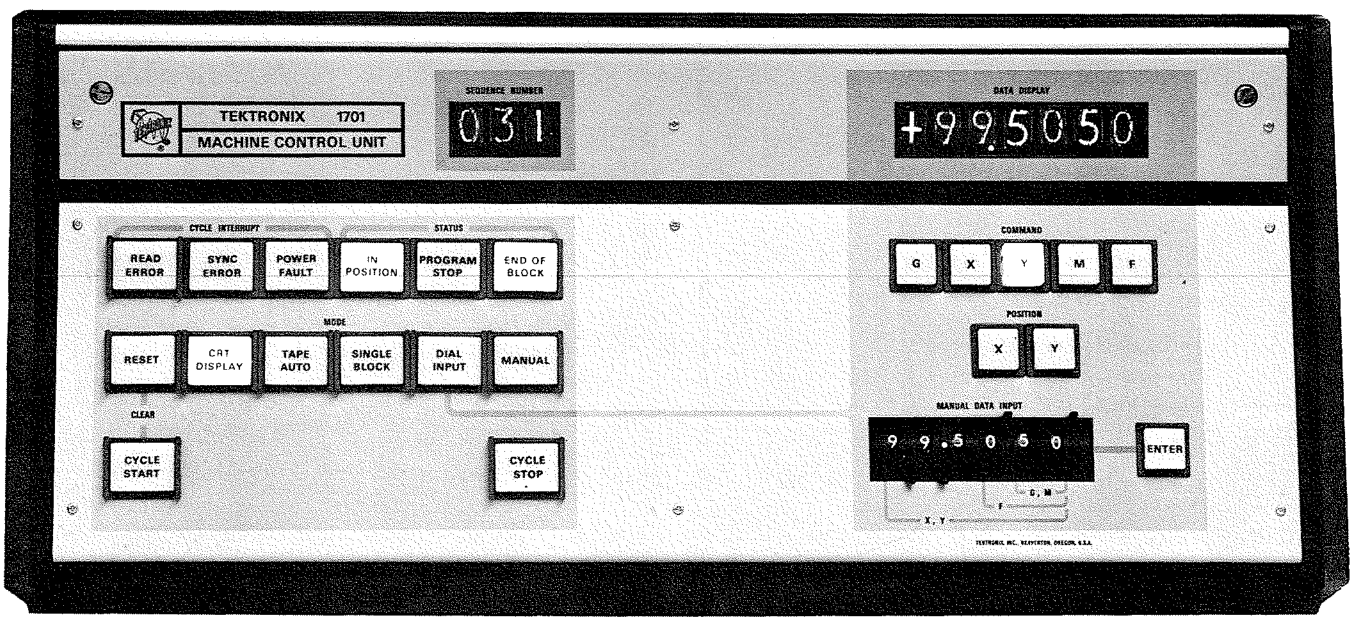
Unique to the 1701 and 1702 Machine Control Units is the built-in ability to interface with the 611 Storage Display Unit for previewing programmed tool path. The 611 reveals the programmed tool path before actual machining takes place and graphically reveals most programming errors. Most programming errors are time-wasting, gross errors, potentially destructive in terms of ruined workpieces, broken tools, or even machine damage.

In evaluating the graphic method of tape and program verification for Tektronix numerical controls and allied products, the following requirements for optional utility were reached:

1. While graphic checking during interim programming phases is valuable, it is highly desirable to be able to verify the actual tape that will be used in operation on the machine.

2. The graphic display must be produced much more rapidly than the machine cycle time to produce the part.

3. Permanent file copies of the display should be easily obtainable.



A close look at the panel of the 1701 Two-Axis Machine Control Unit shows the standard features of sequence, command and position readout and manual data input. The 1701 is a full-performance, closed-loop, contouring control competitive in price with open-loop systems.

4. The coordinate and auxilary function command values on the tape should be easily read in decimal form.

5. A scaling feature would be needed to enlarge or decrease the plotted area on the 611 Storage Display Unit.

6. For three-axis paths, the ability to view total tool path isometric display is needed, plus the ability to produce all three orthographic views.

7. There should not be a necessity to modify the tape commands to produce graphic display.

8. Display capability should be offered at a low cost and be independent of a computer system.

Using the above requirements as a guideline during the product development of the 1701 and 1702 Machine Control Units, the application of the 611 Storage Display Unit and 4601 Hard Copy Printer resulted in a system which not only meets those requirements, but also provides additional benefits for system maintenance and machine tool monitoring. This system offers:

1. On-site tape verification. The actual part-program tape is checked on the same control and same machine on which the part is to be produced.

2. Rapid display. The display is generated at the maximum read rate of the tape reader (300 characters per second).

3. Hard-copy capability. With the 4601, permanent copies can be produced in 18 seconds.

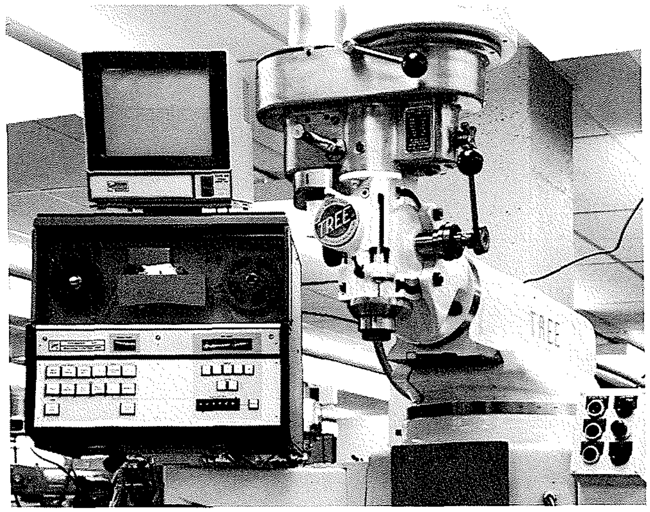
4. A plot scaling feature from twice size, full size, 1/2, 1/4, 1/8, and 1/16 part size.

5. Isometric and orthographic path display for the 1702 three-axis control.

6. Low cost. Since graphic-display interface is built into the controls, the user needs only the 611 for tape verification and the 4601 (if permanent, hard copies are desired).

Graphic tool path verification capability is a unique feature of Tektronix 1701 and 1702 Machine Control Units. The controls use standard EIA or ASCII word address tape format, absolute dimensioning, programmable feedrates, sequence number display, command and position display to six decades and manual data input capability. The controls provide command of axis movements up to 99.9999 inches in each axis with 0.0001 inch resolution. Both the 1701 and 1702 are closed-loop controls capable of driving either electric or hydraulic servo systems.

To use the Tektronix system of tool path verification, the programmer or operator connects the 611 (and 4601, if hard copies are desired) to the output connectors provided on the control. He then loads the program tape to be checked into the MCU, selects the scale size to be used, and depresses the "CRT DISPLAY" button and the "CYCLE START" button. The machine control unit will then read the tape at 300 characters per second and produce a plot of the total motion of the tool as coded on the tape. The display will show a line plot of all the milling paths, plus centerline marks for hole locations and termination points of non-cutting moves. On the 1702, for three-axis displays, the operator can select one of the three (X-Y, Y-Z, X-Z) orthographic views, or he can select the isometric mode to see the total cutting path in one view.

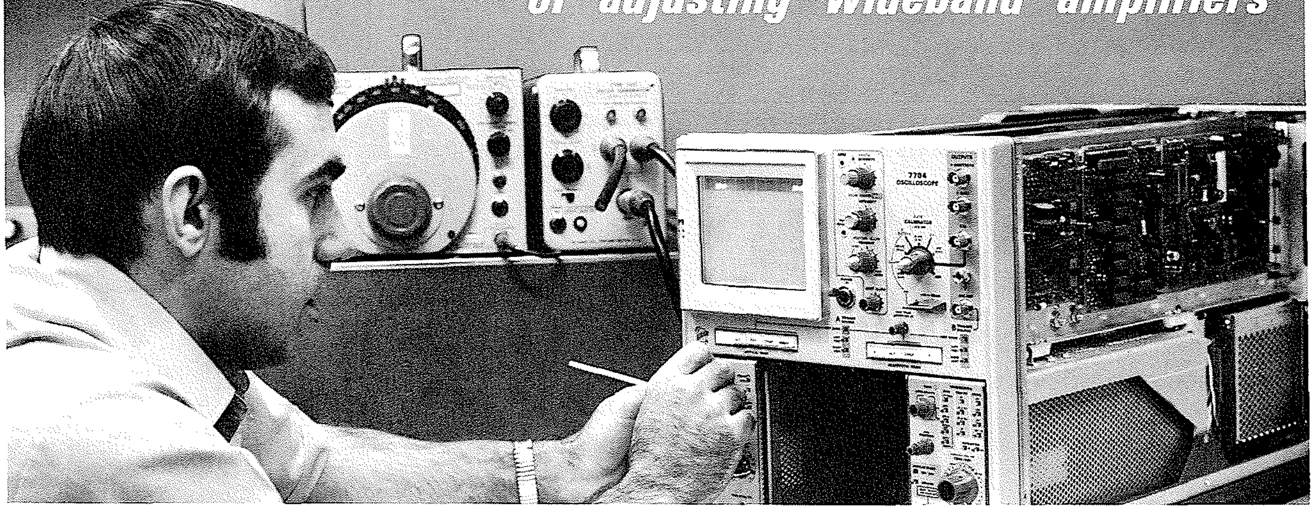


A 1701 Two-Axis Machine Control Unit mounted on a vertical milling machine.

These views, plotted on the 611, are used to check the tool path for general part configuration and for common errors, which are easily identified on such a plot. For more precise verification of certain areas of the tool path, the user may use a larger scale factor to get more detail. The user can step the display through one command at a time, and use the six-decade Data Display on the MCU front panel to show the actual dimension programmed on tape. This same Data Display can be used to verify the feedrate and auxiliary functions programmed in each block of tape. Once the tape is verified the 4601, if used, can be activated to produce permanent copies of the plot shown on the 611.

After verification is performed, the 611 can be disconnected for use at other machine tools and the MCU returned to machine control. If the 611 remains connected to the system, an additional "over-plot" is produced while the machine is in operation. With this over-plotting feature, a trace of actual tool path while machining is shown on the 611 Display Unit. This feature allows the operator to verify that the machine tool is actually traveling along the path directed by the tape commands plotted previously during tape verification. During corrective maintenance of the numerical control system, another benefit occurs from the control-to-storage tube interface. When using the "CRT DISPLAY" mode with a 611 Display Unit, if the tool path plot is correct, the maintenance technician knows the problem is probably in the machine tool. If the plot is incorrect, the trouble is probably in the MCU. Thus, troubleshooting time is greatly reduced and expensive down time is kept at a minimum by means of this graphic tool.

TEKNIQUE: *short pulse technique of adjusting wideband amplifiers*

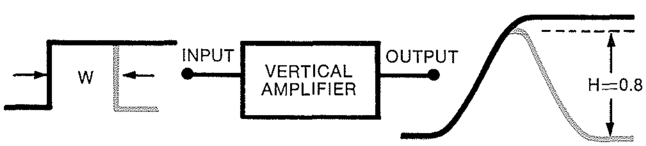


Ed Handris, Factory Service Technician, adjusts 7A16 using short pulse technique.

By Carl Battjes
Manager in Portable & Low Frequency Instruments

Adjusting wideband amplifiers for maximum bandwidth consistent with minimum aberrations can be a difficult, time-consuming task. Use of short pulse techniques makes the chore much easier.

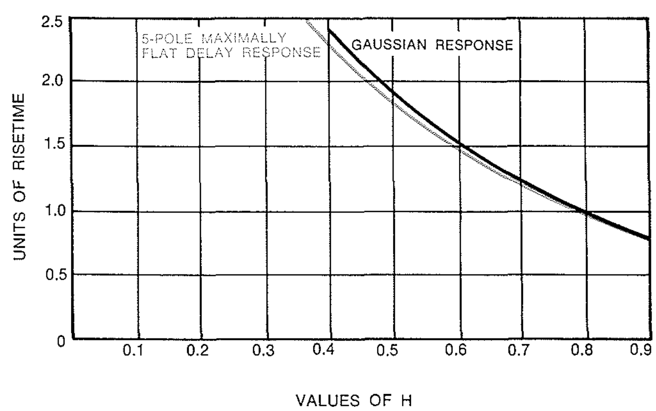
This technique uses short and long duration pulse inputs of equal amplitude to measure bandwidth and risetime. If we drive an amplifier with equal amplitude pulses, one whose pulse duration "W" equals the amplifier risetime, the other of relatively long duration, the output pulse amplitudes will bear a definite relationship. That is, the short pulse height "H" will be 0.8 that of the long duration pulse. If amplifier risetime is faster than the short pulse duration, amplitude "H" will be greater than 0.8, if slower, less than 0.8. Using these values of "H", we can determine bandwidth and risetime. The chart at the right shows the units of risetime for various values of "H".



Equal amplitude input pulses, one whose pulse width equals amplifier risetime, the other of relatively long duration, produce pulse outputs having a predictable relationship.

Once risetime has been determined, bandwidth is calculated by use of the familiar formula "bandwidth in Hz x risetime in sec = 0.35". For amplifiers exhibiting preshoot and/or overshoot, the actual bandwidth will exceed the calculated bandwidth. This is due to the variation in the bandwidth-risetime product of different responses. Tektronix vertical amplifiers typically have bandwidth-risetime products of 0.35 to 0.36.

The relationship between short and long duration pulses holds for a variety of amplifier responses, the main source of error being lack of equality in the 10% and 90% slopes. This lack of equality is not of consequence for wide-bandwidth amplifiers since such amplifiers tend to have a high degree of symmetry. The chart shows the value of "H" for several responses and the percentage of errors in risetime and bandwidth associated with each response. The first five curves show the effect of symmetry on risetime determination accuracy. If an amplifier has many stages, the response has more poles and the step response more symmetry.



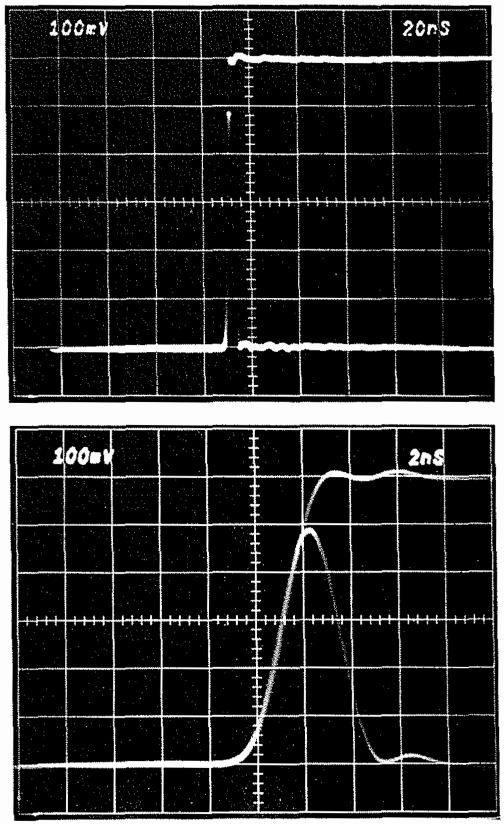
Graph showing relationship of risetime to short pulse height "H" for two different responses. Values of "H" should be 0.7 to 0.9 for best accuracy.

The photo at the left shows the setup for adjusting the 7A16 Amplifier using the short pulse technique. The signal source is a Tektronix Type 109 Pulse Generator which generates alternate pulses of independent length. A Type 113 Delay Cable provides the long duration pulse and the 2.4 ns charge line the short duration pulse. Cutting the 2.4 ns charge line to proper length is accomplished using a 568/230 Sampling System. The 5-ns, 50-Ω cables supplied as accessories for the 109 are a convenient source of charge lines since both ends have GR connectors. Output of the 109 is terminated in 50 Ω at the 7A16 input.

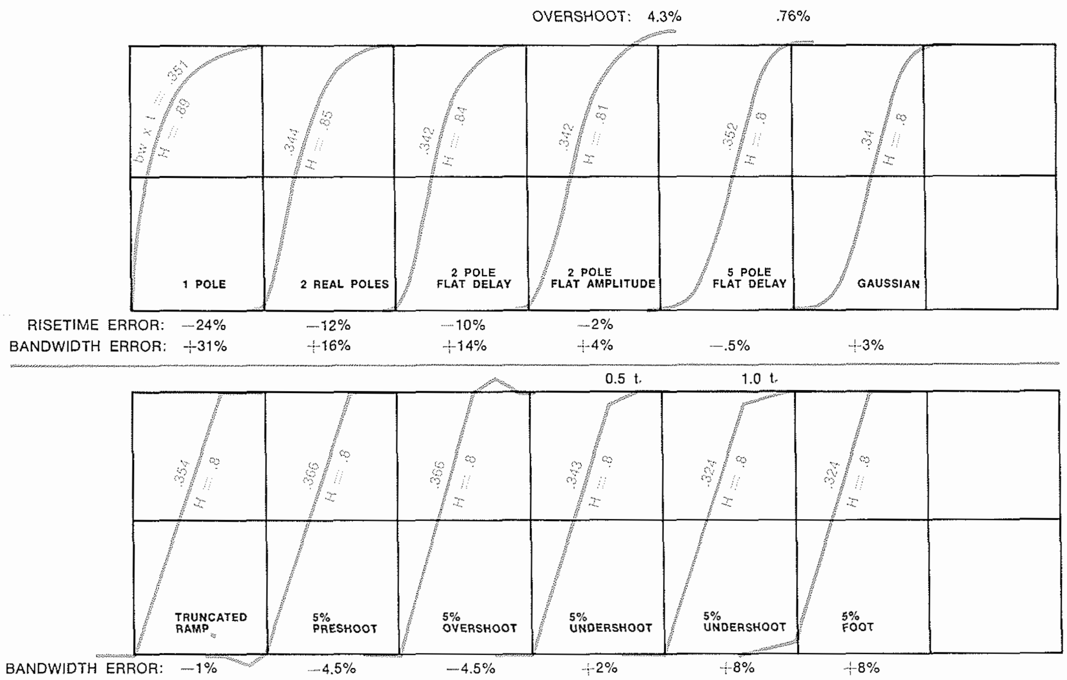
The amplifier is adjusted for minimum aberrations on the long duration pulse while observing the amplitude of the short pulse. An amplitude of 0.8 or greater assures the amplifier will meet bandwidth and risetime specs. You will notice that some adjustments have relatively little effect on the aberrations while changing the short pulse height appreciably. These adjustments should be set for maximum short pulse height consistent with minimum long pulse aberrations.

Short pulse techniques are also useful in checking the bandwidth of the amplifier system on higher attenuator settings. Constant amplitude signal generators available today lack adequate output voltage for making measurements above 1 V/div.

Using the short pulse technique not only simplifies compensation of the vertical amplifier and checking bandwidth of attenuators, but also yields better resolution for measuring the risetime of the entire vertical amplifier system.



Top photo shows dual pulse waveform displayed while adjusting amplifier for minimum aberrations using the short pulse technique. Bottom photo is the same display expanded ten times and shows correlation of risetime and short pulse height.



A "foot" has the same effect on bandwidth-risetime product as undershoot of the same magnitude and duration.

Risetime error is less than 1% where unspecified.

Effect of step response shape on short pulse height "H" and bandwidth-risetime product. Error in bandwidth caused by variation in bandwidth-risetime product and error in risetime caused by lack of equality in the 10% and 90% slopes is also shown.

SERVICE SCOPE

TROUBLESHOOTING TEKTRONIX HIGH FREQUENCY SPECTRUM ANALYZERS

By Darrell Brink
Product Service Technician, Factory Service Center

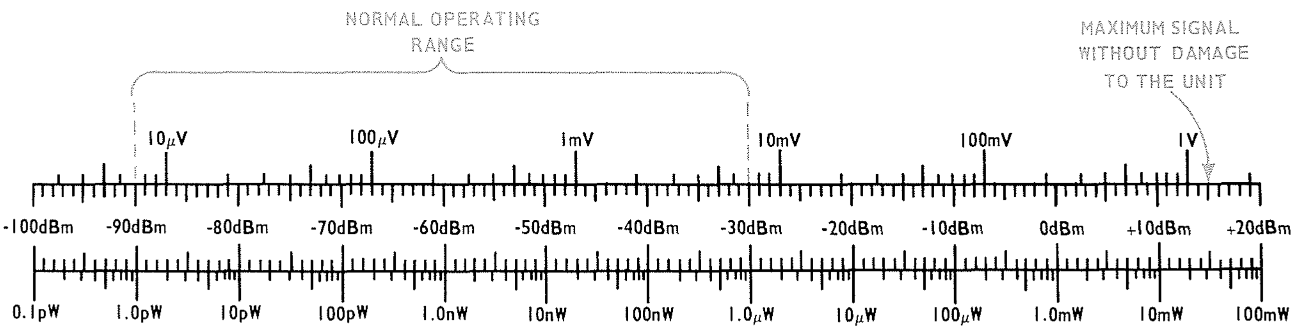
Familiarity with the function of one Tektronix Swept IF Spectrum Analyzer is familiarity with all. All use similar tunable RF oscillators and swept IF systems. The user sees an operational difference in the range covered by the RF center frequency control. The service technician will see a difference in configuration (plug-in form or a complete, self-contained unit) plus differences in RF oscillator circuitry.

The "honeycomb", containing most of the sweeper and IF circuitry, is a conspicuous feature. This method of construction provides excellent shielding between stages and simplifies troubleshooting since it can be replaced to isolate a problem.

A certain amount of troubleshooting can be done using a minimum of equipment. The noise generated internally by the analyzer and the 1 MHz markers available at the phase-lock jack on the front panel can be used as signal sources. However, a test oscilloscope, a time-mark generator such as Tek's 184 or new 2901 and a signal generator capable of 200 MHz with variable attenuation will help considerably. Higher frequency generators will be required if sensitivity or dial tracking is to be checked.

As with oscilloscopes, analyzer problems can often be isolated to a particular section by observing the pattern on the CRT. To insure seeing any signals or noise that may be present, it's usually best to start troubleshooting with the front panel controls set for wide dispersion, maximum gain, and minimum IF attenuation. With plug-in analyzers, be sure the oscilloscope SAWTOOTH OUT is connected to the analyzer SWEEP INPUT—this is often overlooked by the operator. The time base should be set to "free run" at 5 ms/div or slower. A note of caution is in order before applying a signal to the analyzer RF input. *Care should be taken not to exceed the maximum power limits of the input.* For linear operation no greater than —30 dBm should be applied. Signals greater than +15 dBm may damage the unit. See chart below.

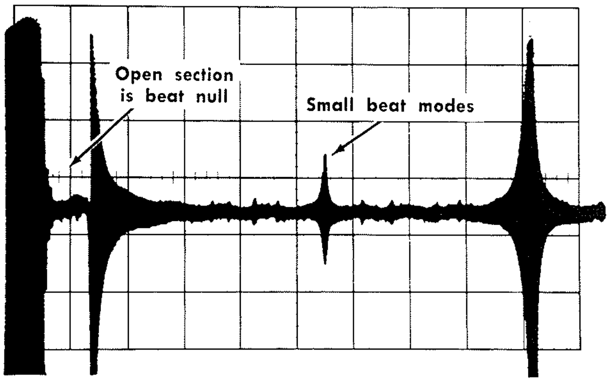
The most common problems encountered in these analyzers are defective mixers and oscillators. Let's take a look at these and other areas that may cause difficulty.



Volts-dBm-Watts conversion chart for 50 Ω impedance.

RF OSCILLATOR SECTION

RF oscillator operation can be checked by applying a known signal to the analyzer and tuning the oscillator to it, or by turning on the PHASE LOCK and checking for beat notes as the oscillator is tuned through its range. Assuming that the phase lock is working, beat notes should be seen across the entire oscillator range as shown below. An *RF oscillator failure* will usually result in the loss of beat notes and signal across all or part of the bands.



Typical display showing presence of phase lock beats, as the RF center frequency control is rotated.

The 1L20 and 491 utilize more than one RF oscillator to cover their respective range. If you suspect oscillator problems, switch to a range which uses a different oscillator. If the problem still exists, the difficulty probably is elsewhere in the analyzer.

An *open oscillator filament* in early vintage plug-in analyzers will remove the +75 volts feeding the 10 volt power supplies, causing them to be very low. In this case, a dead oscillator causes other symptoms such as complete loss of gain and possibly horizontal or vertical positioning problems. Later model 1L20's (above s/n 1150) have zener diodes across the filaments to prolong their life. These diodes also prevent the 10 volt supplies from dropping due to an open filament.

Another type of RF oscillator failure, particularly in the band C oscillator in the 491, is a phenomenon known as *"squegging"*. Squegging occurs when the oscillator breaks into another mode of oscillation and extra sidebands appear or the main signal "breaks up". A low-frequency sinewave several volts in amplitude, e.g., 30 kHz and 10 volts peak-to-peak will appear on the band C oscillator B+ lead (orange wire).

Squegging generally will not occur throughout the band, but only at one or two points. Phase lock beat notes will usually appear distorted and very noisy when squegging occurs. The only cure is to replace the oscillator. Should this be necessary, and if you are not properly equipped to do a total realignment of the RF section, we recommend the complete RF assembly or the complete unit be returned to Tektronix for repair.

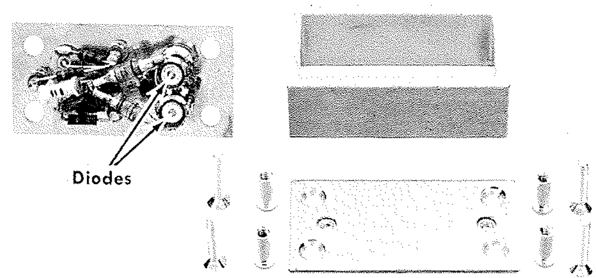
MIXER SECTION

Excessive power inadvertently applied to the analyzer input causes most mixer failures. The presentation on the screen will depend somewhat on the band being viewed. For example, *if the mixer fails in band B* of the 1L20 or 491, you may see a signal on screen (shorted or open diodes still pass signals), however, sensitivity will be down. Varying the mixer peaking knob will have little or no effect on the signal amplitude, and noise amplitude or "grass" will appear normal.

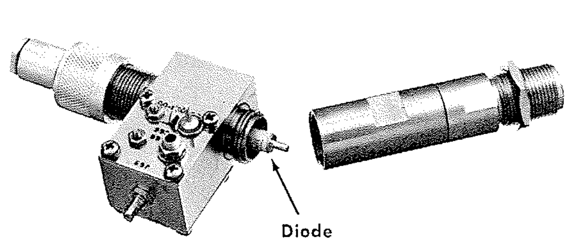
Mixer diode failure in band A of these units typically results in large, spurious signals appearing on screen at about 37.5 MHz, and they cannot be tuned out with the internal mixer adjustments. The mixer peaking control has no effect, as it is out of the circuit when band A is selected.

Mixer diode failure is best confirmed by replacement of the diode. The usual practice of checking diodes with an ohmmeter should not be used, as the current supplied by the ohmmeter may damage the device. Care should also be exercised when replacing the diodes. If soldered in, be sure to "heat sink" them with pliers to prevent damage.

To replace the mixer diode in band B of the 1L20/491 or in the 1L30, remove the mixer from the instrument and carefully unscrew the barrel from the body using a wrench and a vise. Then remove the diode with a pair of pliers. When installing the new diode, be careful not to break the fingers on the contacts in the mixer. Often it requires some force to push the diode into the contact.



(A) Band A mixer assembly. Replace diodes with a matched pair.



(B) Band B mixer assembly. Unscrew the 1 dB pad to replace diode.

Mixer assemblies for bands A and B of the 1L20.

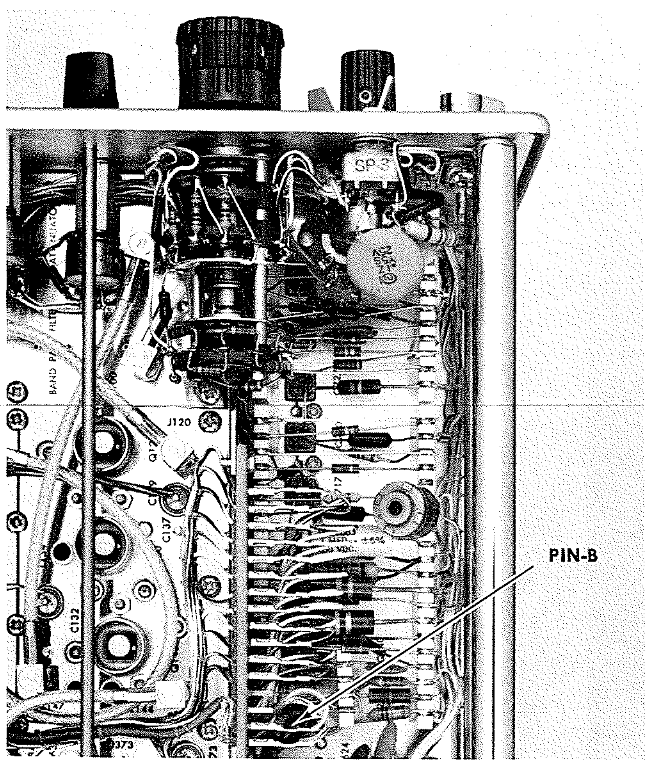
IF SECTION

Although not as common as "front end" problems, the IF section sometimes causes trouble.

Loss of gain can generally be traced to the IF system. When the gain is turned up and little or no noise is seen on screen, the trouble can be in either the honeycomb or the output stages. The output of the honeycomb can be checked with an oscilloscope for noise of about 1 volt peak-to-peak when the GAIN control is fully clockwise. *Absence of noise* could mean the 70 MHz crystal oscillator in the narrow band IF section of the honeycomb has quit. If that is the case, a slight adjustment of the oscillator coil, L444, should cause the noise to suddenly appear. A defective transistor in the wide band amplifier, narrow band amplifier, or resolution sections of the honeycomb will cause a loss of noise also.

Sufficient noise out of the honeycomb, but none on screen in a plug-in analyzer, could mean a defective recorder output transistor Q650, output amplifier V620, or detector diodes D660 and D661. In a 491, check amplifiers Q620, Q630, Q631, and the detector diodes D640 and D641. A failure of Q640 or Q641 will usually shift the trace off screen.

When *noise is present on screen but no signal*, most likely the sweeper is not running or the signal is being lost prior to the honeycomb. A quick way to check sweeper operation is to look at the waveform on pin M of the square pin connector strip of the honeycomb. The signal should appear as a large nonlinear sawtooth. Your manual shows the typical waveform. Normal sweeper operation at this point would indicate that the signal is being lost in the mixer, filters, or cables between the analyzer input and the wide band mixer transistor, Q140.



Output of "honeycomb" can be checked on pin B of the square pin connector. Other key test points are on this same connector.

When working in these circuits, you will find a BNC-to-Sealectro adapter cable very useful as you can insert a 200 MHz signal from a generator at any point up to the input of the honeycomb to help isolate the trouble. Generally, mixers will have a loss of 15 to 20 dB; filters, cables and switches, virtually no loss.

If the sweeper is defective, the analyzer display may appear as either *no signal, extreme nonlinearity of frequency markers, or a short sweep*. The waveform observed on pin M may be a badly distorted sawtooth, a squarewave, or just a DC voltage, depending upon the problem.

Since the sweeper has two feedback loops, troubleshooting can be difficult. However, there are several checks that can be made to isolate the trouble. Set the dispersion range switch to kHz and see if normal operation can be obtained. This eliminates the MHz discriminator diodes. If the symptoms are still present, return the range switch to MHz and check the DC voltage on pin P of the honeycomb. It should be adjustable to about —0.8 V DC with the IF CF (amplitude comparator) range pot (R290) if the amplitude regulating loop is operating. If it cannot be adjusted, continue on to the next check as something else may be causing the loop to lock up.

Next, check the DC voltage on pin M of the honeycomb. If it's within the range of about +14 to +55 volts, the discriminator loop is probably operating, and the trouble probably is a defective sweeper transistor, Q310, or output amplifier, Q340-Q350. However, other active components in the sweeper circuitry can also be suspect. Abnormal voltage readings on pin M usually indicate a problem in the discriminator loop. Grounding the discriminator output (pins N and O) will establish a reference for checking operation of the loop. Checking voltages at several points around the loop should disclose which stage is at fault. For example, the collector of Q260 should go to about +6 V under this condition.

PHASE LOCK SECTION

Phase lock beat notes are produced on the screen when the RF oscillator signal is beat against the internal 1 MHz reference oscillator signal. If the RF oscillator is working, loss of the beat notes can be caused by the 1 MHz crystal oscillator not running. Adjusting the oscillator coil, accessible through a hole in the phase lock chassis, may cause the oscillator to start.

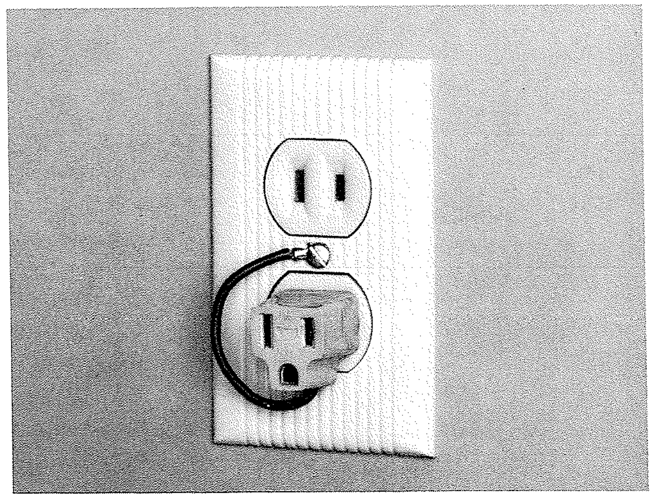
Improper avalanche adjustment can also cause loss of beat notes, low amplitude beat notes, or excessive noise. Check your manual for the proper adjustment procedure.

The trace shifting off screen when the LOCK CHECK button is depressed can be caused by a defective lock check switch, or a leaky capacitor across the switch.

UNGROUNDED INSTRUMENT HAZARD

No one knowingly grabs a bare power line. Yet, many of us are inviting this experience by using instruments that are not properly grounded. There are many ways the power line can accidentally come in contact with the instrument frame; vibration wearing through the insulation where the lead touches the chassis, an accidental touch with the soldering iron, connection to another instrument with faulty insulation. Whatever the reason, the danger is the same. To be safe, make sure the instrument is properly grounded.

One area often overlooked is the 3-to-2 wire adapter supplied with many instruments. Its purpose is to allow the three-pin plug, now used on most power cords, to plug into the older style two-pin power outlets. Unless the ground lead projecting from the adapter is properly grounded, the mainframe of your instrument is *not* grounded. The proper practice is to connect the lead from the adapter, to the ground screw of the two-wire outlet as shown in the photo. In older installations this screw may not be grounded. A quick check with a voltmeter between the ACTIVE output and the ground screw on the outlet will tell you. If the screw is not grounded, an alternate ground should be found for the adapter lead.



Proper method of installing 3-to-2 wire adapter.

Some applications call for measuring voltages across components elevated to a hazardous potential. One approach has been to "float" the scope by removing the ground to the power system. Much safer techniques are now available to make most of these measurements. Your field engineer will be glad to help you with them.

INSTRUMENTS FOR SALE

564, 3B3, 3A6 with Cart, $1450. R. Ahnemann, Redactron Corporation, 100 Parkway Drive South, Hauppauge, N. Y. 11787. (516) 543-8700.

541A, 53C, $750. 310, $250. Jim Woodworth, Broadcast Products, Inc., 12330 Wilkins Avenue, Rockville, Maryland 20852. (301) 933-3400.

113. Mr. Oberton, Ikor, Inc., N.W. Industrial Park, Burlington, Mass. 01803. (617) 272-4400.

Two S-4 Sampling Heads, $500 each. Dynetics, Inc., Box 845, Bellevue, Wash. 98009.

531A, 53/54C, $595. Dick Everson, Box 63B, Friendsville, Penn. 18818.

535, $450. 545, $1000. 545A, $1100. Liberty Electronics, Inc., 548 Broadway, New York, N.Y. 10012. (212) 925-6000.

541A, CA, $1200. Mr. Sperber. (201) 276-3944.

545, 53/54C, D, $1100. Bill Bradford, 12772 Hickory Branch Rd., Santa Ana, California 92705. (714) 838-1218.

561B, 3S2, 3T2, Two S2 Heads. $1750 complete. Wilmar Electronics Leasing, 2103 Border Avenue, Torrance, Calif. 90501. (213) 320-6565.

Two - R561A's, Five - 2A60's, Two - 2B67's. Al Kutas, Dorex, 10221 Nottingham, Westminster, California 29683. (714) 523-1566 or (714) 531-9914.

422 with AC current Probe, $1100. Earl Olson, Electro-sonic Oil Tools, Inc., 2560 Wyandotte St., Mountain View, Calif. 94040. (415) 964-0555.

547, $1595. Mr. W. A. Brown, Rt. 4, Riddles Bend, Gadsden, Alabama 35904. (205) 442-5449.

535A, CA. Gene Clark, 1722 East 7th St., Duluth, Minn. 55812. (218) 724-0307.

3B3, Two - 2A61's. Make offer. Dick Robertson, ACL, 9125 Gaither Road, Gaithersburg, Maryland 20760. (301) 948-5210.

502A with C-27 Camera. Bids must exceed $1000. Pete Momcilovich, Int'l.-United Corp., P.O. Box 88870, Seattle, Wash. 98188. (206) 248-1550.

310A, $450. Hugh Neil, Jr., Special Instruments Laboratory, Inc., P.O. Box 1950, Knoxville, Tennessee 37901. (615) 525-9538.

D54 with P6011 and P6012 Probes, $550. Robert Stout, 5546 Little Lake, Bellaire, Texas 77401. (713) 668-9803.

545A, 1A1, CA, 500/53A Scope-Mobile Mod 2, $1400 complete. Bob Cobler. (916) 273-0322.

535, $850. 545, $950. Pat Gee, Mobilscope, Inc., 17734½ Sherman Way, Reseda, Calif. 91335. (213) 342-5111.

511AD. Dean Fredericks, 1814 Johnson St., N.E., Minneapolis, Minn. 55418. (612) 781-2583.

B Plug-In, $100. D. C. Malatesta, EMCEE Electronics, Inc., P.O. Box 32, New Castle, Delaware 19720.

D53A with TD51, A, G, and two probes, $750 complete. C. E. Price, Medatron, Inc., 1724 N. Main St., Dayton, Ohio 45405. (513) 274-2053.

561A with 3A3 and 2B67. Richard F. Hahn, 630 Fountainhead Way, Naples, Fla. 33940. (813) 649-2081.

RM564, 3A72, 2A60. Jack Hattan, Meditron, 1981 S. Ritchey, Santa Ana, Calif. 92705. (714) 541-0468.

3S2, 3T2, Two - S3's, 3B3. Charles Weyble, Moore Systems Div., 1212 Bordeaux Drive, Sunnyvale, Calif. 94086. (408) 734-4020.

535A with CA Plug-In. Best offer over $900. Wayne Broyles Engineering Co., 1403 Austin, Irving, Texas 75060.

547, 1A1, $2250. 114 Pulse Generator, $300. C. French, 61 Cody Lane, Los Altos, Calif. 94022. (415) 941-2339.

INSTRUMENTS WANTED

575, 576. Liberty Electronics, Inc., 548 Broadway, New York, N.Y. 10012. (212) 925-6000.

530 Series Scope/1A7A/160 Series/360/1121. Sigmund Hoverson, Physics Department, Texas A & M University, College Station, Texas 77843. (713) 845-5455.

581A with Plug-In. Edward Withey, Laurel Drive, Lincoln, Mass. 01773. (617) 897-7647.

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BEAVERTON, OREGON 97005

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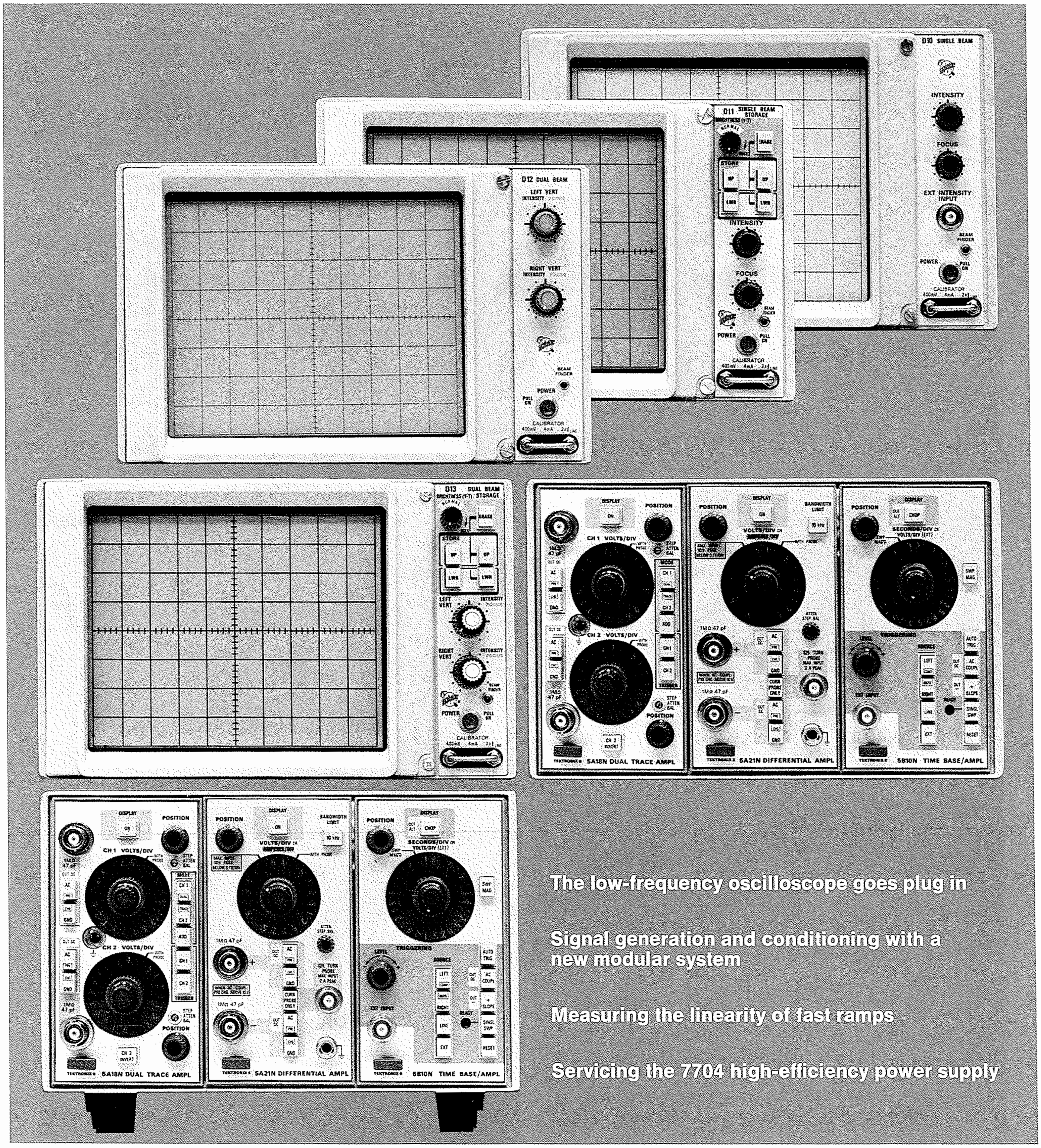
MARCH 1971



The low-frequency oscilloscope goes plug in

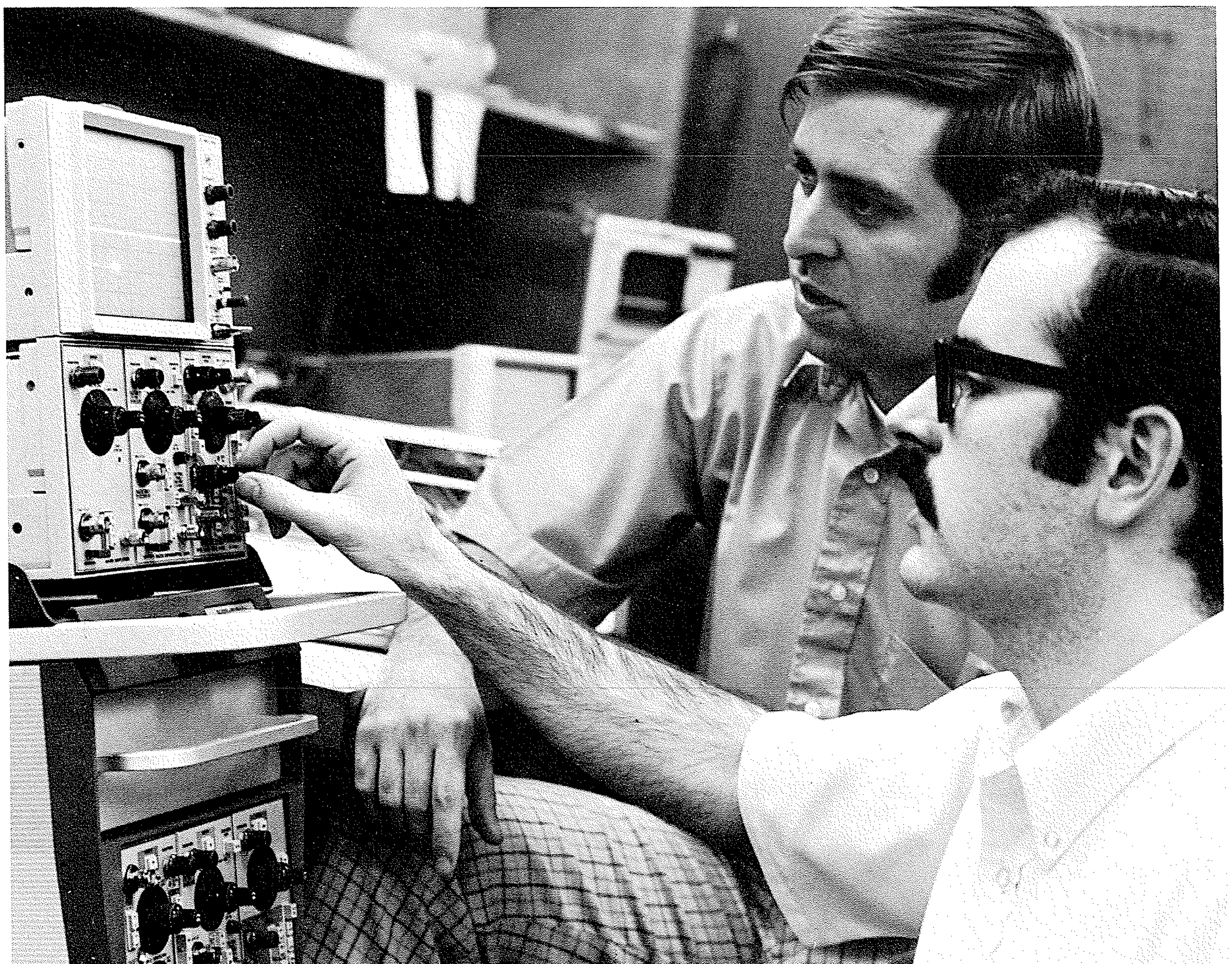
Signal generation and conditioning with a new modular system

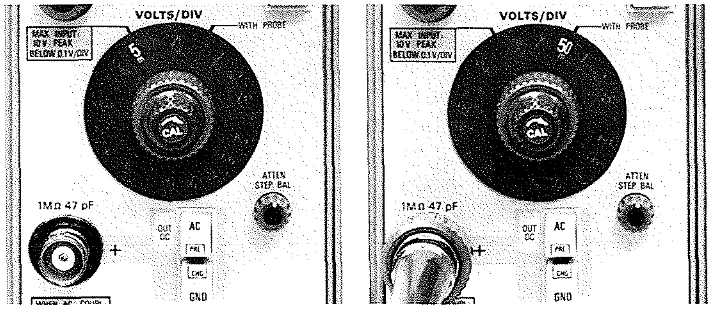
Measuring the linearity of fast ramps

Servicing the 7704 high-efficiency power supply

THE LOW-FREQUENCY OSCILLOSCOPE GOES PLUG-IN

Gary Vance, Project Engineer and George Hull, Design Engineer on the 5100 Series discuss sweep-switching operation of the 5B12N Dual Time Base Plug-In.





Scale factor readout changes automatically to indicate vertical sensitivity at probe tip when recommended 10X probe is used. Similarly, sweep-rate readout changes automatically when 10X magnifier is turned on.

By Jerry Shannon and Ahne Oosterhof

In the oscilloscope field, plug-in versatility has traditionally been limited to high-frequency instruments. Introduced by Tektronix in 1954, the plug-in concept allowed the user to easily and inexpensively change the characteristics of his oscilloscope to cover a wide range of applications.

Now, with the introduction of the 5100 Series, the users of low-frequency oscilloscopes will enjoy these same benefits.

Since the same need for versatility exists in the low-frequency as in the high-frequency oscilloscope field, we determined to do our best to meet that need. Our goal was to offer a laboratory-quality, low-frequency, plug-in oscilloscope at the lowest practical cost to the user. We also wanted to include many of the features such as scale factor readout, large screen CRT and solid state stability found only in the latest instruments.

Breakthroughs would have to be made in many areas. Simplified circuit design, new production techniques for CRT's, switches and other components, and reduced assembly and calibration time would have to be achieved if we were to reach our goal. The end result of our efforts in all of these areas is a series of products that bring you new measurement capability, plus a flexibility previously unavailable in any other oscilloscope system.

First in this series is the 5103N Oscilloscope System, a general-purpose, low-frequency (DC to 2 MHz) oscilloscope featuring cost-saving innovations such as interchangeable display modules, plug-ins, and bench to rackmount convertibility. Four display modules, each with a large 6½-inch CRT, give you a choice of single beam, dual beam, single beam storage or dual beam storage. You can readily change from one display module to another or convert from bench to 5¼-inch rackmount configuration in a matter of minutes. Nine plug-ins give you a wide choice of vertical amplifiers and time bases.

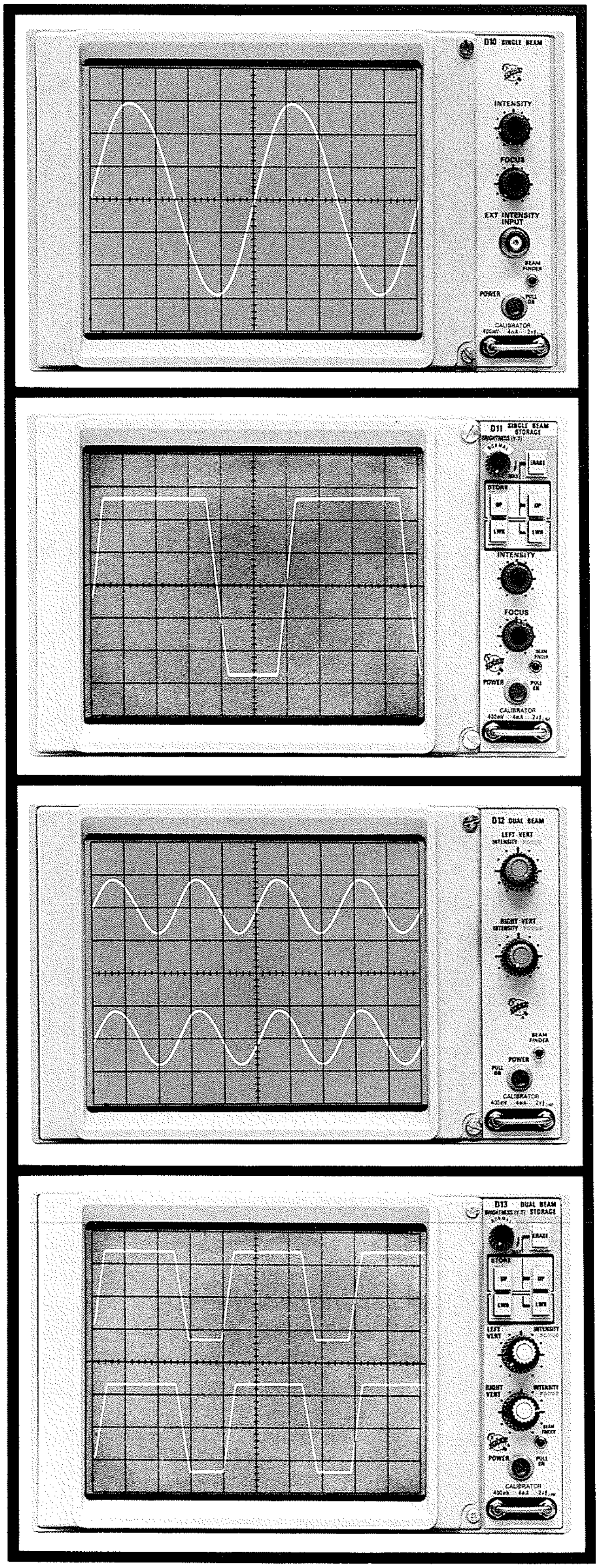
Several innovations in the amplifier and time base plug-ins enhance operating ease. For example, scale factor readout for each amplifier is provided by illuminating the knob skirt behind the area identifying the correct scale factor, even when using the recommended 10X probes. This same feature is used in the time base plug-ins to indicate correct sweep rate with the magnifier on or off. The possibility of measurement error is thus greatly reduced.

The choice between left and right vertical plug-in is made by depressing the DISPLAY button on the respective plug-in. This button also switches the light on behind the readout skirt, so a glance is all that's needed to immediately identify which channels or plug-ins are in use. With neither DISPLAY button depressed, the left hand vertical is displayed but its readout is not illuminated.

When two amplifier plug-ins are enabled, the mainframe automatically converts to the alternate or chopped mode of operation as selected by the DISPLAY button on the time base. The switching sequence allots two time-slots (in chopped) or two sweeps (in alternate) to each vertical plug-in. When dual-channel plug-ins are used, each channel takes one time slot or one sweep. In the dual-beam mainframe, switching between plug-ins is eliminated as each amplifier is permanently connected to one vertical deflection system.

THE MAINFRAME

Now let's take a closer look at each of the 5100 Series modules. The 5103N mainframe module contains the low-voltage power supplies, horizontal and vertical amplifiers, the electronic switching and logic circuitry for dual-trace operation between plug-ins, and three plug-in compartments. It will interface directly with any of the four display modules in a bench or rackmount configuration. Any plug-in can be used in any compartment to achieve X-Y, Y-T or raster displays.



Four display modules pictured from top to bottom are single beam, single beam storage, dual beam and dual beam storage. All feature a large 6¼" screen and internal graticule.

THE DISPLAY MODULES

Each of the display modules uses a new 6½-inch ceramic CRT with an 8 x 10 division (½ inch/div) internal graticule. The CRT, with 3.5 kV accelerating potential, has a bright, well-defined trace. Simplest of the display modules is the D10 single-beam display unit. In addition to the CRT, it contains the high-voltage supply, a voltage, current and time (2X line frequency) calibrator, the CRT controls and the power switch. A beam finder positions the beam on screen regardless of the setting of the vertical or horizontal position controls. The front panel Z-axis input with DC to 1-MHz bandwidth requires only 5 volts to modulate the beam.

The D12 dual-beam display module is the same as the D10 single-beam unit except the CRT has two writing guns and two pairs of vertical deflection plates. Both beams cover the full 8 x 10 division screen. Also included are separate intensity and focus controls for each beam.

Single and dual-beam storage operation are provided by the D11 and D13 display modules respectively. The bistable, split-screen storage CRT's have a unique brightness control which permits varying the stored brightness to retain the image for several hours without damage to the CRT. The brightness control, in conjunction with other storage controls, also allows integration of repetitive signals to effectively increase stored writing rate.

THE PLUG-INS

The nine plug-ins presently available include six amplifiers and three time bases. Simplest of the amplifiers is a plug-in having just an input stage with a potentiometer as an attenuator. Designated the 5A24N, the unit has a 50 mV/div sensitivity and is ideal for you who have low-cost monitor needs.

For simple measurements where signals of varying amplitude have to be measured, the 5A23N with decade attenuator steps and a 10 mV sensitivity is available. Bandwidth is DC to 1 MHz.

A companion plug-in, the 5B13N time base, provides a low cost sweep unit with sweep ranges from 5 μs/div to 0.5 sec/div in decade steps. A variable control extends the slowest sweep to 5 sec/div.

When signals of only a few millivolts are to be measured, the 5A15N provides 1 mV sensitivity and DC to 2-MHz bandwidth. The 5A18N offers the same characteristics with dual-trace capability including the convenient ADD mode. This mode is especially useful when signal differences between two points are to be measured while both points are elevated by a common signal.

Getting down into the difficult microvolt region where the applications call for low noise and high common-mode rejection, the 5A20N and 5A21N differential amplifiers with FET inputs provide stable operation to 50 μV/div. Bandwidth is DC to 1 MHz. Upper bandwidth can be limited to 10 kHz for noise reduction. Common-mode rejection at 50 μV/div, DC coupled, is 100,000:1.

To permit common-mode measurements with the use of attenuator probes, a probe having accurate attenuation has been developed. The P6060 has 10X attenuation and provides common-mode rejection of 400:1 at any deflection factor when used with the 5A20N or 5A21N.

The 5A21N plug-in, while similar to the 5A20N, has the added feature of a current-probe input. Using the P6021 current probe, bandwidth is 15 Hz to 1 MHz with sensitivities from 0.5 mA/div to 0.5 A/div. The normal 100 Hz low-frequency response of the P6021 is extended by low-frequency correction in the amplifier to permit measurements at line frequency. This makes the unit especially useful in power supply design work.

Many low-frequency applications make use of X-Y type displays. As the mainframe has identical vertical and horizontal deflection systems it is possible to make accurate phase measurements using two identical plug-ins. A control on the deflection amplifier board allows phase calibration to better than one degree at specific frequencies up to 1 MHz.

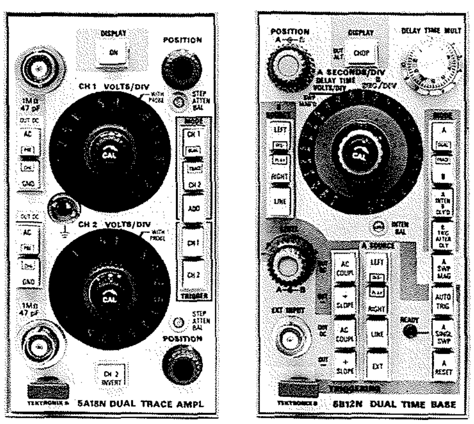
Two more time bases round out the selection of plug-ins available. The 5B10N provides sweep ranges from 1 μs/div to 5 sec/div in a 1-2-5 sequence with a 10X magnifier extending the fastest sweep to 100 ns/div. The unit offers versatile triggering from DC to 2 MHz. Both trigger source and trigger mode are selected by pushbutton. A single-sweep mode simplifies the capturing of single-shot phenomena for photographing or storing displays. Included is an external horizontal mode which provides a convenient means for making simple X-Y measurements. Sensitivity is 50 mV/div with DC to 1-MHz bandwidth.

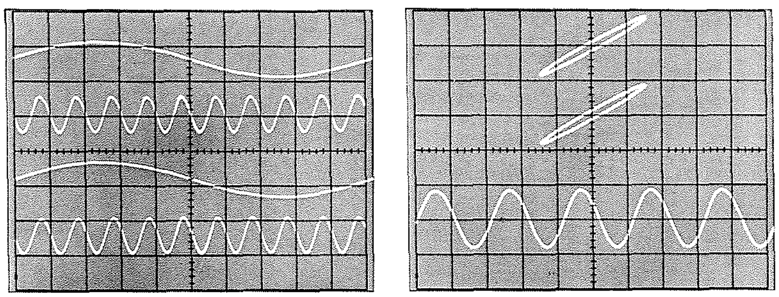
A dual time base, the 5B12N, covers a wide range of applications. Offering the maximum in versatility, it includes the popular sweep switching introduced in the 547 Oscilloscope. In the dual-sweep mode, the A sweep is slaved to the left plug-in, and the B sweep is slaved to the right plug-in. This gives you, in effect, dual-beam operation for repetitive signals. The two sweeps can also be operated in the conventional delaying-sweep modes with a 10-turn delay multiplier providing accurate delay settings. The 5B12N also includes an external horizontal mode for X-Y operation.

Some applications require a vertical sweep or raster presentation. This is easily accomplished by plugging any of the three time bases into one of the vertical compartments. The 5103N provides convenient front panel access for Z-axis modulation in these applications.

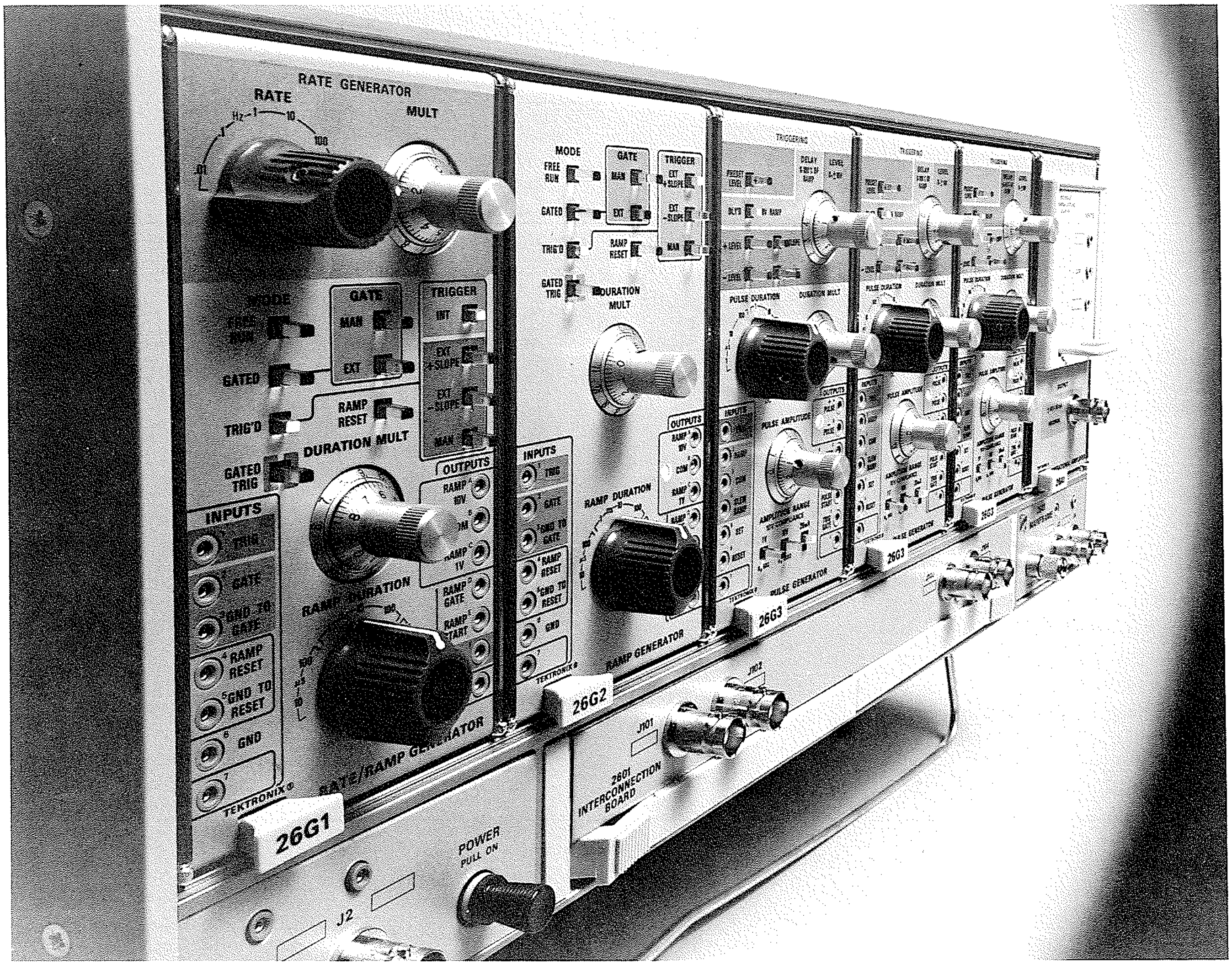
A low-cost camera, the C-5, complements the low-frequency 5100-Series instruments. Its fixed-focus, fixed-aperture design makes waveform photography simple. An access door in the top of the camera allows viewing the CRT without removing the camera.

Some of the areas expected to benefit from the versatility of the 5100 Series are medical research, educational instruction, low-frequency phase work such as servos, mechanical analysis using strain gauges and other transducers, and engine analysis.





Dual-trace vertical and dual time base plug-ins offer maximum versatility. At left above, both Ch 1 and Ch 2 are displayed by both A and B sweeps. Right above, adding a single trace plug-in, with A sweep on EXTERNAL you can have dual-trace X-Y, while right vertical and B sweep provide Y-T.



SIGNAL GENERATION & CONDITIONING

WITH A NEW MODULAR SYSTEM

Plug-in versatility has proven its worth in oscilloscopes, counters, pulse generators and myriad other products. Now this concept is extended to a new series of instruments designed to be the meeting place for many different systems. We call them the 2600-Series modular instruments. The term "modular" is used here in a broad sense and includes packaging, interconnections, input/output characteristics, power supplies and accessories.

Designed to permit relatively free interplay between analog and digital circuits, most inputs and outputs are compatible with DTL and TTL logic levels. However, they differ electrically slightly to allow proper operation with non-DTL and non-TTL circuits.

To get a feel for the versatility of the series, let's look briefly at the individual units.

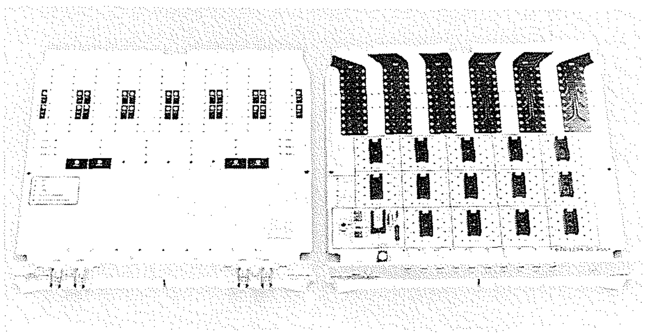
2601 MAINFRAME

The 2601 mainframe, a basic element in the series, is a power supply and interconnecting system for 2600-Series plug-in units. Providing pre-regulated voltages at up to 50 watts, the 2601 accommodates six plug-in units. The pre-regulated voltages are further regulated in the individual plug-ins and, in some instances, used to power DC to DC converters for special needs. This provides maximum decoupling between units.

A seventh plug-in section in the 2601 plays a vital role in the versatility offered by the 2600 Series. It contains the interconnection board. The primary function of this board is controlling plug-in unit operation, processing signals to or from a plug-in, or passing signals between units. Thus, having planned and set up system operation from the front panel, you can duplicate the connections between units on the interconnection board and then tuck them away out of sight. Spare boards may be used to change rapidly from one setup to another. Most plug-in front panel inputs and outputs are coupled through the interface connections at the rear of the plug-ins and are duplicated on the interconnection board.

Pictured below are two of the interconnection boards currently available. The board on the left is used primarily to provide interconnection between plug-ins.

The board on the right also provides interconnection between plug-in units but has an exciting additional feature. Fourteen 16-pin dual in-line plastic I.C. sockets, plus a locally regulated +5 volt supply, are mounted on the board. Ready connection between I.C.'s and the plug-in units is made by standard 40-mil patch connectors. This permits you to add the relays, switches, pulse transformers, resistor networks, op amps and many other functions available in the dual in-line package, to the functions available in the 2600-Series plug-ins. Instrument versatility thus becomes virtually unlimited.



Interconnection board at left permits internal connection between plug-ins. Board at right interfaces plug-ins with 14 IC sockets. Board includes +5 V regulated supply to power IC's.

You may also elect to use the I.C. board and 2601 mainframe plug-ins completely independent of one another. Ten spare front panel jacks on the interconnection board provide convenient interface points. Front and rear panel BNC connectors on the 2601 may also be connected internally to any jack on the I.C. interconnection board. The pre-regulated +17 and −17 volt supplies are available on the board and can often be used to power linear I.C.'s where other than +5 volts is required.

RATE AND RAMP GENERATORS

Now let's take a look at the plug-ins. The 26G1 and 26G2 are basically ramp generators and produce ramp voltages ideal for analog timing applications such as delayed triggering of pulse generators, time bases for monitors, and raster generation.

Several ramp modes are available to you. Free run, gated, triggered, and gated trigger, plus manually gated or triggered operation is readily accomplished from the front panel. In addition, the 26G1 can be internally triggered by the rate generator which is an integral part of the unit. The trigger and gate levels, both input and output, are compatible with logic levels used in most DTL and TTL logic devices.

A convenient feature is the ability to terminate the ramp at any point in its excursion by applying a positive logic 1 to the Ramp Reset input or a logic 0 to the Ground to Reset input. This provides for some interesting possibilities. For example, the 26G1 or 26G2 can serve as a time-to-height converter. The amplitude of the ramp output can be made proportional to the input pulse width simply by feeding the pulse into both the Trig and Ground to Reset inputs. The ramp is then started by the leading edge of the pulse and terminated when the pulse falls to zero.

In addition to the main ramp output of 10 volts, several other signals are available at the front panel. A 1-volt ramp output serves as a convenient time base for the 601, 602 and 611 monitors which are ideal companion units to the 2600 Series. The +3-volt Ramp Gate, of the same duration as the ramp, provides unblanking for the monitor. A +3-volt, 1.5-μs pulse coincident with the start of the ramp is handy to trigger your oscilloscope or other associated circuitry used in the application.

We mentioned earlier that the 26G1 also contains a rate generator. Normally free-running at a frequency determined by the Rate and Multiplier settings, it can also be gated manually or by an external gate. All that is needed is reversal of an internal 3-pin connector. The Gate and Ground to Gate inputs then serve to gate the rate generator, with the first pulse from the rate generator coincident with the start of the gate. The rate generator may be used independent of the ramp generator portion of the 26G1.

PULSE GENERATION

The 26G3 Pulse Generator plug-in unit provides precise rectangular pulses with amplitude to ±10 volts and pulse duration from 1μs to 11 seconds. Pulse risetime and falltime is less than 200 ns. In addition, the unit has two other output modes. With the Pulse Duration control set to Bistable, the output changes state with each succeeding trigger, that is, the output goes to the high state on one trigger and to the low state on the next. A highly symmetrical waveform or pulses longer than 11 seconds can thus be easily generated.

The third mode, DC, or as it is sometimes called, "locked on", is appearing with increasing frequency on the newer pulse generators. In this mode the output is simply a DC level which can be accurately set to any value up to ±10 volts by means of the Pulse Amplitude control. Accuracy is 1% of full scale, full scale being 1 volt, 10 volts, or a value you may choose by selecting an appropriate external resistance. Output current up to 20 mA is available to drive the selected resistance, however, maximum output voltage is limited to ±10 volts.

Three other outputs are available on the front panel: the Pulse Start, a +3-volt pulse serving as an output trigger; the Pulse Gate, a +3-volt gate with the same duration as the pulse output; and the Trigger Gate, a +3-volt gate coincident with the start of the pulse output and whose width is determined by the Delay control setting.

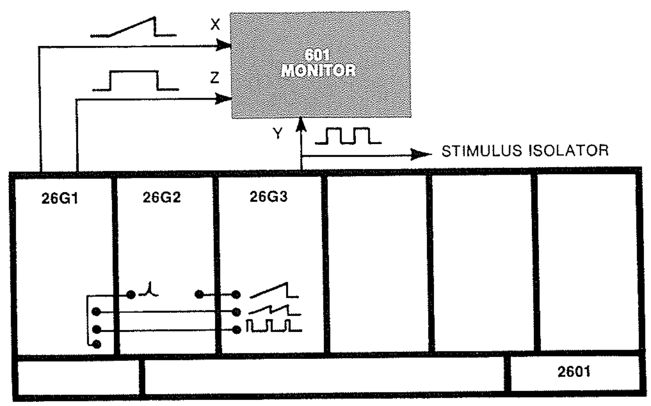
Turning to the 26G3 inputs, we see a wide range of control for starting and stopping the pulse. Selection of slope and level, much the same as on your oscilloscope, is available. A preset +1-volt level is useful when triggering from logic circuits, and a ramp input provides for triggering at any point on a +10-volt ramp giving you a choice of accurate time delay before starting the pulse. The Slew Ramp input offers some interesting capabilities; a signal fed into this input is combined algebraically with the signal fed into the Ramp input to effect triggering. This gives you a convenient means of generating two pulses whose time relationship can be made to change at a controlled, linear rate.

One of the common uses of this technique is found in the field of biophysical research, the objective being to determine the ability of a nerve to respond to separate stimuli occurring within a brief time span. A look at how we can accomplish this objective using the 2600 Series will serve to demonstrate the flexibility of the system, but first let's finish our review of the 26G3 inputs.

In addition to the Trigger, Ramp and Slew Ramp inputs, there are Set and Reset inputs. A +1-volt signal to the Set input, will set the output to its high state regardless of the state of all other inputs except the Reset input. Conversely, a +1-volt signal to the Reset input will set the output to its low state regardless of the state of all other inputs including the Set input.

SYSTEM APPLICATION

Now let's look at how we can accomplish the objective mentioned above, that of determining nerve response to closely spaced stimuli, using the 2600-Series instruments. The block diagram below shows the system we can use to generate the variable-spaced pulses, including a 601 monitor to display the pulses. The system consists of the 2601 Mainframe, the 26G1 Rate/Ramp Generator, the 26G2 Ramp Generator, the 26G3 Pulse Generator and the 601 Storage Display Unit.



Simplified block diagram of system to produce pulse pairs having gradually reduced spacing between pulses.

Interconnection of the units and the control settings for the respective units are shown on the interconnection board worksheet at right. These worksheets are replicas of the interconnection board and provide a handy reference for repeating the set-up for a particular measurement. Replicas of the front panels of the plug-in units are available with gummed backing for pasting on the worksheet as shown. The photo in the lower right-hand corner of the worksheet shows the signal generated by the set-up.

The pulse train is initiated by pressing the Manual button on the 26G2. The 26G2 performs four functions. It starts the pulse train, gates the 26G1, provides the slew ramp for the 26G3 and determines the total period over which the nerve will be exercised, in this instance, 10 seconds.

The 26G1 also performs four functions. It determines how often the 26G3 generates pulse pairs, provides the ramp input for the 26G3, determines, in conjunction with the slew ramp and the Delay control setting on the 26G3, when a stimulus pulse will be generated, and provides the sweep and unblanking signals for the 601 monitor.

The 26G3 merely stands by and generates a pulse of the appropriate duration and amplitude when its triggering level is reached.

Now let's see what happens when we push the Manual button on the 26G2. A single pulse, 1 volt in amplitude and 300 μs in duration is generated, followed by an identical pulse 10 ms later. The two pulses are then repeated at 1.5 sec intervals with the time between them reduced 1.5 ms each time they repeat. A reset pulse from the 26G1 prevents the slew ramp from triggering the 26G3 at the peak of its excursion, producing an unwanted pulse.

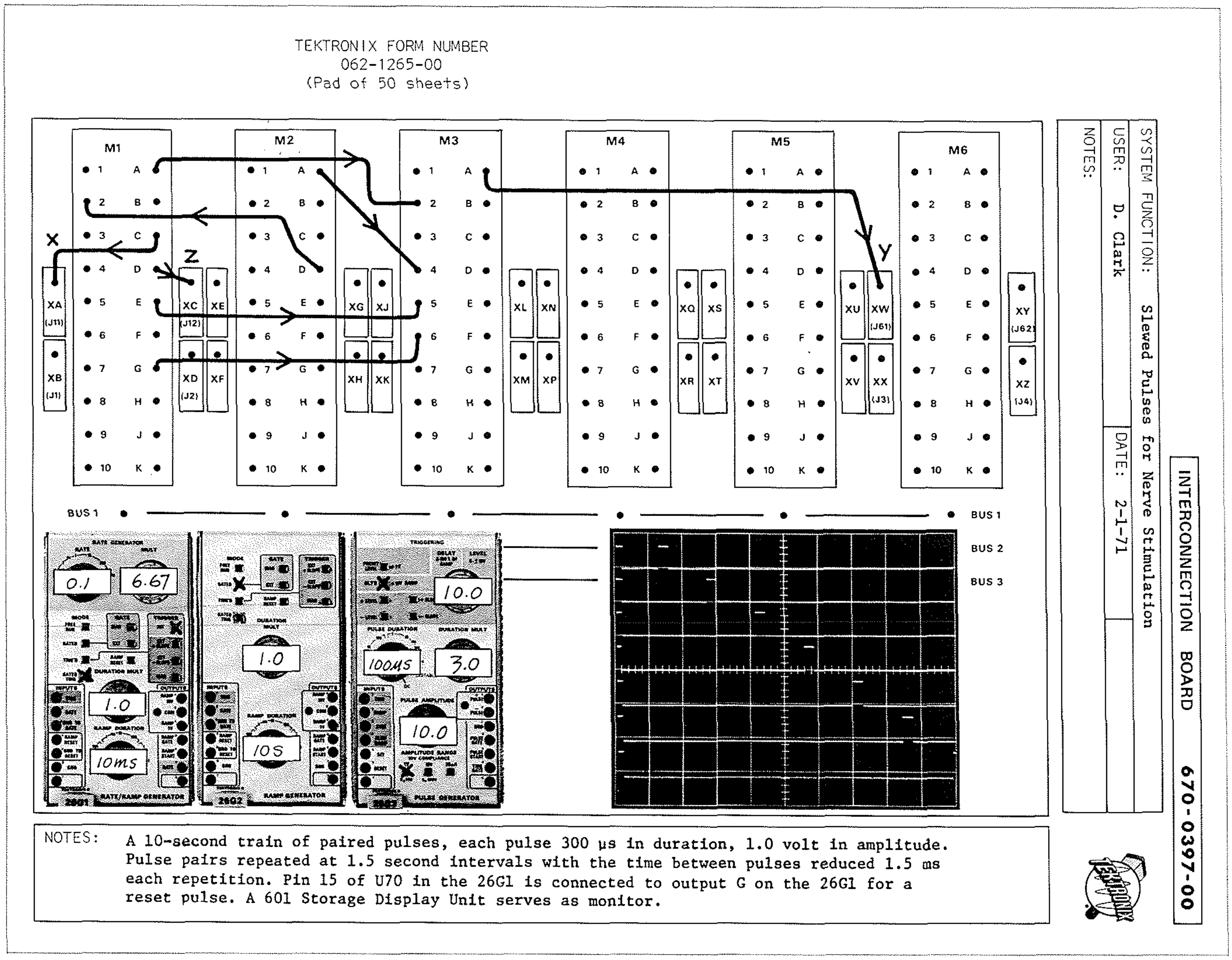
OUTPUT CONDITIONING

One other important plug-in currently available in the 2600 Series is the 26A1 Operational Amplifier. It is a high-power operational amplifier ideal for final processing of signals generated in 2600-Series system. Output capabilities are ±50 V and up to ±50 mA. Open loop gain is 10,000 into a 1 kΩ load with a unity gain bandwidth of 5 MHz.

Access to the operational amplifier inputs and outputs is via a Terminal Access Adapter which plugs into the plug-in unit. The adapter also provides access to the front panel connectors and the regulated +15 and −15 volt supplies. Clips and jacks are mounted on the adapter circuit board so you can easily change the operational amplifier function. A Terminal Access Adapter kit which includes a circuit board with a 0.1 x 0.1 inch grid of plated-through holes is available for constructing circuits to meet your specific needs.

7000-SERIES COMPATIBILITY

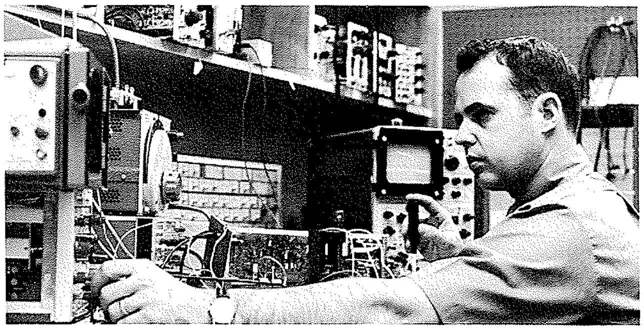
The 2600 Series also brings new capabilities to you who own 7000-Series oscilloscopes. Through the use of an adapter, you can operate any of the 2600-Series plug-ins in your 7000-Series mainframe; truly plug-in versatility at its best.



Interconnection board worksheet shows connections between units, front panel control settings and waveforms generated by set-up. Notes include signal parameters and special instructions. Worksheet provides permanent record of set-up.

TEKNIQUE: *measuring the linearity of fast ramps*

By John McCormick, Project Engineer



John received his BSEE, with distinction, from U of Kansas in 1962 and his MSE with a Materials Sciences Option from Princeton in 1965. With Tek since 1965, he has contributed much to fast-ramp technology while working on sampling sweeps.

The time measurements you make with your oscilloscope can only be as accurate as the time base displayed on the CRT screen. Improvements in components, ramp generator circuitry and CRT construction have given us time bases specified accurate within 2 or 3% and typically accurate within 1%. With the great strides being made in vertical amplifier bandwidth has come the challenge of providing the fast sweeps needed to properly display these higher-speed phenomena. Generating and measuring fast, linear ramps poses unique problems. This article discusses a solution for one of those problems, that of measuring the linearity of fast ramps.

There are two important quantities used to specify and describe a ramp. These are the mean slope of the ramp, and linearity or slope deviation from the mean. An ideal ramp has a constant slope and is perfectly linear. It is usually easy to measure the mean-slope of the ramp but linearity measurements are difficult to make and are usually made in an indirect manner. This is especially true in the case of very fast ramps (tens of nanoseconds in length).

The terminology used to describe linearity varies according to the method used to measure it. A sampling oscilloscope can form the basis for a convenient and precise method of ramp slope and linearity measurements. However, before describing the method it will be necessary to define a few terms.

DEFINITIONS

Mathematically speaking, the slope of a waveform at any point in time is the derivative of the waveform with respect to time. If V (t) is a voltage waveform, then the slope at any time is given by

$$\text{slope} = m(t) = \frac{dV(t)}{dt}$$

In the case of an ideal ramp, the slope would be constant. To describe a ramp we may consider an ideal ramp with the desired constant slope which we will call the mean slope, plus some deviations of the slope from this constant value.

$$m(t) = m_o + l(t)$$

Where m (t) is the actual slope at any given time, m_o is the mean slope and l (t) is the nonlinearity of the ramp.

Percentage of nonlinearity is expressed by the equation

$$\%\ \text{Nonlinearity} = \left(\frac{m(t) - m_o}{m_o}\right) \times 100\% = \frac{l(t)}{m_o} \times 100\%$$

The nonlinearity is a function of time and can be determined if we know m (t) and m_o. It is relatively easy to measure m_o by feeding the ramp into the vertical system of a scope and measuring its amplitude and duration; m (t) is the time derivative of the ramp waveform. It is possible to measure an approximation to m (t) by several methods, only one of which we will discuss in detail here.

The derivative of a voltage that is a function of time V (t) is given by the basic definition:

$$\frac{dV(t)}{dt} = m(t) = \frac{V(t+\Delta t) - V(t)}{\Delta t} \quad \text{limit } \Delta t \rightarrow 0$$

What we can measure is

$$m^*(t) = \frac{V(t+\Delta t) - V(t)}{\Delta t} \quad \Delta t \text{ finite}$$

It is obvious that m* (t) is just the average slope of the function V (t) measured over a time Δt at each point in time as in Fig. 1. A convenient name for Δt is the time resolution or simply, the "resolution" of the measurement. The resolution is indicative of the detail that can be resolved. If the slope m (t) has components which last for a time on the order of Δt as in Fig. 1, they will be smoothed out in the measurement. If the ramp has a fast start like the ideal ramp in Fig. 2 (a), then the m* (t) Fig. 2 (c) will differ from the actual derivative in Fig. 2 (b) because of the finite resolution time. The smaller the resolution time, the closer m* (t) will be to m (t). Now let's consider methods of measuring m* (t).

MEASUREMENT OF m*(t)

One simple way to obtain m* (t) for a waveform would be to process the waveform with an analog differentiator as in Fig. 3. This works pretty well with slow ramps but is very difficult to implement for fast ramps. A better method for fast ramps makes use of sampling techniques to time-convert the ramp to a slower-speed replica. Measuring the slope is then an easy matter. The technique shown in Fig. 4 can be used to measure V $(t+\Delta t)$ and V (t). The ramp waveform is fed into two identical sampling heads, A & B, each of which produces a DC voltage in its respective memory, proportional to the value of the ramp voltage at a time t_s when the strobe opens

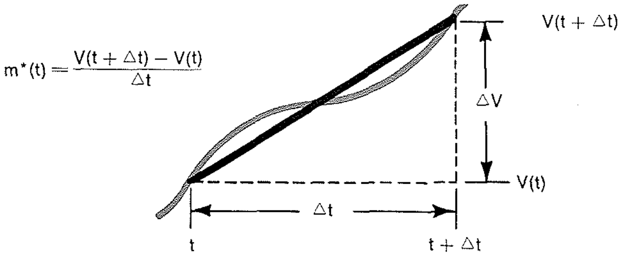


Fig. 1. Resolution limits measurement detail. Components lasting for a time on the order of Δt will be smoothed out.

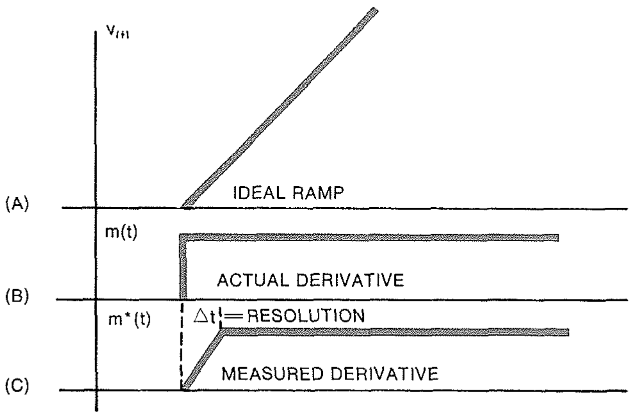


Fig. 2. Measured slope differs from the actual derivative because of the finite resolution time.

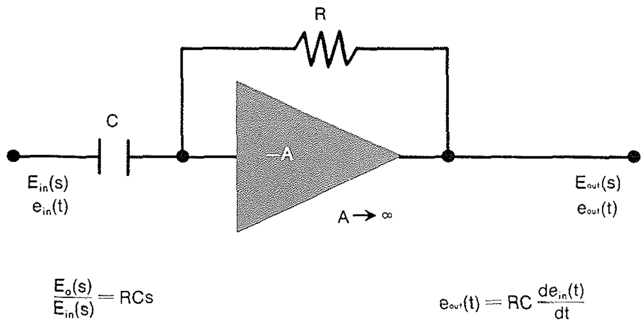


Fig. 3. Analog differentiator is a convenient means of measuring slope and linearity of slower ramps.

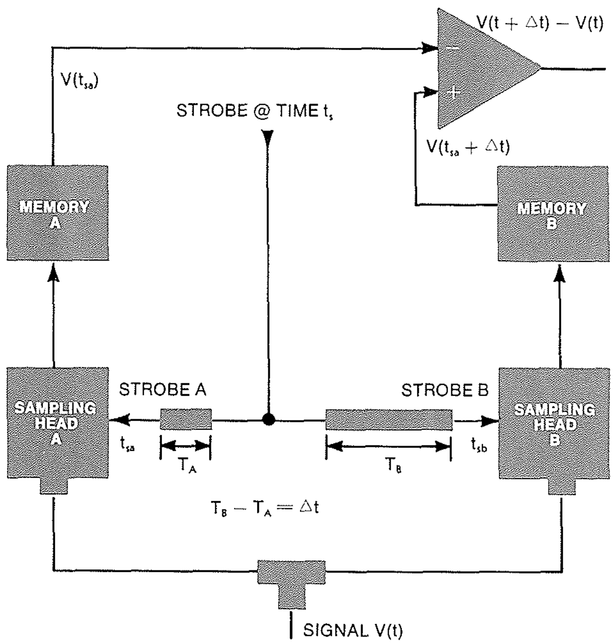


Fig. 4. Block diagram of a sampling system to measure V(t+Δt) − V(t). Resolution is set by difference in time of T_A and T_B.

the sampling gate. If the strobe time for channel A (t_{SA}) is made different from that for channel B (t_{SB}) by some time (Δt) due to unequal delays T_A and T_B, then the voltage measured by the respective sampling heads will be

$$V_{SA} = V(t_{SA}) \qquad V_{SB} = V(t_{SA} + \Delta t)$$

We can then substract them at each time t.

$$V(t)_{B\text{-}A} = V_{SB} - V_{SA} = (V(t+\Delta t) - V(t))$$

If we divide the difference in strobe time Δt we have

$$\frac{V(t)_{B\text{-}A}}{\Delta t} = \frac{(V(t+\Delta t) - V(t))}{\Delta t} = m^*(t)$$

A convenient realization of the above technique can be obtained with a sampling system set up as in Fig. 5. The system consists of a 7000-Series four-compartment mainframe, a 7T11, two 7S11's, two S-1 sampling heads and a 7A22. If the signal cannot be loaded by 50Ω then a probe such as the P6034, P6035 or P6051 can be used to couple the signal to the power divider tee. An alternate approach would be to use S-3A or S-5 sampling heads in place of the S-1.

The gains of both sampling channels should be adjusted so that they are equal (note variable front panel control on the 7S11 does not effect the gain of the vert sig out). This can be done by inserting a variable attenuator in the leads from the vert sig out to the 7A22. Comparing the amplitudes of the two vertical signals out is easily done with the 7A22. Just feed both signals differentially into the 7A22 and adjust the gains until the base line is at the same level before and after the ramp.

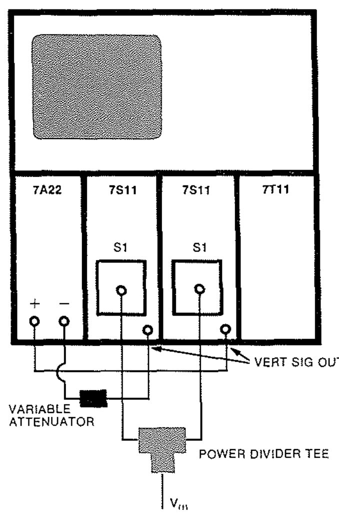
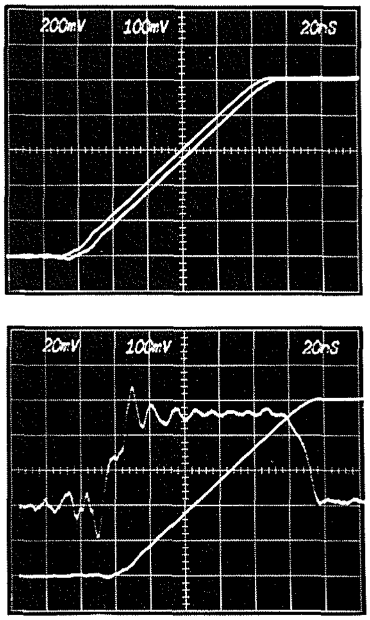


*Fig. 5. 7000-Series system to measure ramp (Vt) and slope (m*t) and display them simultaneously. Attenuator is placed in series with 7A22 input having largest signal so inputs to 7A22 may be set to same amplitude.*

The resolution should be set by turning the right hand 7S11 Delay Control full CCW, grounding the negative input of the 7A22 and setting the left hand 7S11 Delay Control for the desired Δt by observing the separation of the two traces on the screen. Be sure to adjust the gain of the 7A22 using the variable if necessary so that the two traces have the same amplitude on the screen. The top photo below is a typical display for setting resolution.



Top photo is typical display for setting resolution. Bottom photo shows ramp and its slope. Aberrations are caused by nonlinearities in the ramp. Resolution is 6 ns.

After setting the desired resolution or Δt, the negative input of the 7A22 is moved to the DC position. Now displayed on the CRT is the voltage differential between the outputs of the samplers which is proportional to Δt and the slope of the ramp. Measuring the amplitude of this voltage differential and knowing Δt we arrive at $m^*(t)$ or the slope of the ramp.

The bottom photo above shows the slope waveform and the ramp whose slope it represents. Aberrations on the slope waveform are due to nonlinearities in the ramp. The amplitude of these aberrations relative to the amplitude of the slope waveform is the measure of the nonlinearities that exist in the ramp.

ACCURACY OF THE MEASUREMENT

Although the absolute slope in volts per nanosecond can be measured with this system, the accuracy is not as good as it is when measuring linearity unless the system is calibrated with a known slope. Contributing to the accuracy of the slope measurement are the accuracy of the sampling channel gains, the accuracy of the 7A22 gain, and the accuracy with which the time Δt is known.

One method of eliminating the problem of absolute sweep calibration for accurate Δt is to adjust for both channels to sample at the same time and add a known length of delay line in the signal path of one of the sampling channels.

Two other factors effect the accuracy of the linearity measurements. These are nonlinearity in the vertical response and nonlinearity in the sampling sweep. Of the two, the sweep nonlinearity is the dominate effect. The linearity of the sweep is specified to be within 3% over most of the Time Position Range and can be checked by the usual method with accurate time marks. For sweep speeds with low magnification the linearity is typically better than 1%.

PRECISION OF THE MEASUREMENT

Precision refers to the ability to measure small differences in signal amplitude and is limited primarily by noise. With the system described we can easily measure 1% differences in slope. It must be borne in mind that the response of the 7S11's must be identical. A convenient way to assure this is to set the dot response of both 7S11's to unity. It is also important that the scan rate be slow enough for the bandpass used on the 7A22.

RANGE OF SLOPE MEASUREMENTS

The upper limit on slope, $m^*(t)$, in volts/nanosecond is determined by the risetime of the sampling system and our ability to set the resolution to be a small portion of the ramp. Ten to twenty percent of ramp duration yields good results. The system described provides resolution from 10 ns to less than 100 ps. We should keep in mind that as the resolution time decreases, so does the signal out and noise will be a problem. The 7A22 variable bandpass may be used to reduce noise but the display rate must decrease proportionally. This is easily done by varying the scan control on the 7T11.

The lower limit on $m^*(t)$ in volts/nanosecond is set by noise as the resolution time cannot be adjusted greater than 10 ns without instrument modification. A useful lower limit set by noise places the longest ramp length that can be measured with this system at about 500 ns. However, an external delay line can easily be inserted in the signal path of one sampling channel to extend the lower limit.

CONCLUSION

We have discussed how differentiation of a fast ramp leads to a convenient method of measuring ramp linearity and have shown how to construct such a measurement system. A ramp and its slope, $m^*(t)$, are shown in the bottom photo at left. The resolution is about 5% of the ramp length. The risetime of the slope can be measured as well as amplitude, overshoot, ringing and droop, just as if measuring a step response, and these quantities all relate to how linear the ramp is at any point. The advantage of having the ramp and the slope displayed simultaneously is that the effect of circuit adjustments affecting the slope are seen immediately.

The ability to differentiate fast waveforms can be useful in other applications as well, such as measuring impulse response by differentiating the step response. Differentiation of theoretical expressions has always been a useful technique in certain analysis (such as linearity of ramps), but with the ability to measure the derivative directly and display it, although limited by resolution time, the technique becomes even more useful.

SERVICE SCOPE

SERVICING THE 7704 HIGH-EFFICIENCY POWER SUPPLY

By Charles Phillips
Product Service Technician, Factory Service Center

This is the first in a series of articles on servicing the 7000-Series oscilloscopes. The 7704 serves as the basis for these articles since it contains most of the new circuitry, components and construction techniques we will be discussing. It is not our intent to discuss the general techniques used in troubleshooting oscilloscope circuitry as these were covered extensively in the February 1969 to February 1970 issues of TEKSCOPE. Copies of these articles are available through your field engineer.

Proper operation of the regulated low-voltage supplies is essential for the rest of the scope circuitry to function properly, so let's look at this section first.

The high-efficiency power supply used in the 7704 is a new concept in power supply design that results in appreciable savings in volume, weight and power consumption. It is called "high efficiency" because its efficiency is about 70% as compared to 45% for conventional supplies. The line-to-DC converter/regulator contains most of the unconventional circuitry so our discussion will deal primarily with this portion.

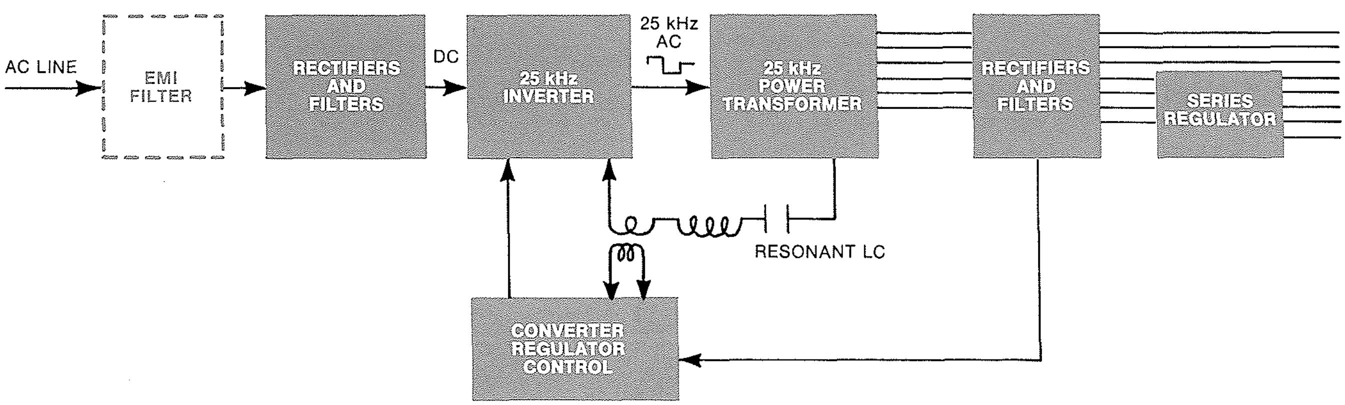
First, let's briefly review the theory of operation. The high-efficiency power supply is essentially a DC-to-DC converter. The line voltage is rectified, filtered and used to power an inverter which runs at approximately 25 kHz. The frequency at which the inverter runs is determined basically by the resonant frequency of a series-LC network placed in series with the primary of the power transformer. The inverter drives the primary of the power transformer supplying the desired secondary voltages. These are then rectified, filtered and regulated for circuit use.

Pre-regulation of the voltage applied to the power transformer is accomplished by controlling the frequency at which the inverter runs. A sample of the secondary voltage is rectified and used to control the frequency of a monostable multivibrator. This multivibrator, in turn, controls the time that either half of the inverter can be triggered, thus controlling the inverter frequency. Circuit parameters are such that the multivibrator, and hence the inverter, always runs below the resonant frequency of the LC network. Remembering that the resonant LC network is in series with the primary of the power transformer, we can see that as the inverter frequency changes, the impedance of the LC network changes. The resultant change in voltage dropped across the LC network keeps the voltage applied to the primary constant. Pre-regulation to about 1% is achieved by this means.

Now, let's turn our attention to troubleshooting the supply. Assume you have made the usual preliminary checks; you have power to the instrument, the line selector on the rear of the instrument is in the correct position for the applied line voltage and the line voltage is within specified limits. The plug-ins have been removed to eliminate the possibility of their causing the power supply to malfunction.

With the instrument power off, check the two fuses located in the line selector cover on the rear of the instrument. If the line fuse, F800, is open the problem is probably in the line input circuitry. If the inverter fuse, F810, is open the inverter circuitry is probably faulty. In either case it will be necessary to remove the supply from the mainframe to make further checks. This is easily done by removing the four screws on the rear panel that secure the power unit, then sliding the unit out the rear of the instrument.

Before removing the power-unit cover, check to see that the neon bulb on the left side of the power unit has stopped flashing. The primary storage capacitors C813 and C814



Simplified block diagram of high-efficiency low-voltage power supply.

remain charged with high voltage DC for several minutes after the power line is disconnected. When this voltage exceeds about 80 volts the neon bulb flashes. While servicing the power unit, the discharge time of the storage capacitors can be speeded up by temporarily disabling the inverter stop circuit. Pulling Q864 before turning off the scope power will allow the inverter to keep running for a short time, thus draining most of the charge from the capacitors. A voltmeter reading between test points 810 and 811 on the line input board will indicate the charge remaining on the storage capacitors. Allow at least one minute for the current-limiting thermistors to cool before turning on the power again if you use this fast-discharge technique. Do not attempt to discharge the capacitors by shorting directly across them as this will damage them.

With the power-unit cover removed, orient the supply with the rectifier board on top, the line input board on the left and the inverter board on the right. This will make it convenient to get to all the test points as we go along.

LINE INPUT BOARD

First let's check the line input board. It's fairly easy to tell if this circuit is working. The neon bulb previously mentioned will start flashing when power is applied. On some units it assumes a steady glow, on others it continues to flash. The voltage reading on test points 810 and 811 should be approximately 300 volts DC depending upon the line voltage. Be careful not to ground any point in this circuit except test-point ground or chassis.

Typical troubles in this circuit causing the line fuse to open are shorted diodes on the bridge, CR810, or a shorted capacitor C810, C811, C813 or C814.

INVERTER BOARD

Next in line is the inverter circuit. The problems most common to this circuit are open fuse F810, shorted transistors Q825 or Q835, or shorted diodes CR825, CR835, CR828 or CR838. An open inverter fuse usually indicates trouble in the inverter.

Before working in this circuit, unplug the power cord and give the storage capacitors time to discharge. Remove the line selector cover containing the line and inverter fuses. We're now ready to make some resistance checks on the inverter board.

With your ohmmeter set to the x1 kΩ scale, take a reading between test points 826 and 836. The reading should be several megohms in one direction and $\approx$ 1.5 kΩ with the test leads reversed. Check between test points 836 and 820. You should get a high and low reading as before. This checks the transistors and important diodes in the inverter stage. If you get a low reading in both directions on either of these tests, remove the transistor from the side having the low reading in both directions. A set of readings between the appropriate test points will show whether it is the diode or the transistor that is defective. Diodes CR826 and CR836 are not checked by the above procedure but will not prevent the inverter from running even if shorted. Once you achieve a high resistance on both sides of the inverter, it will probably operate when you apply the proper power to it. However, before applying power, a quick check should be made on rectifier board test point 860 to ground. The resistance should be $\approx$ 2 kΩ or 40 kΩ depending on the polarity of the meter leads.

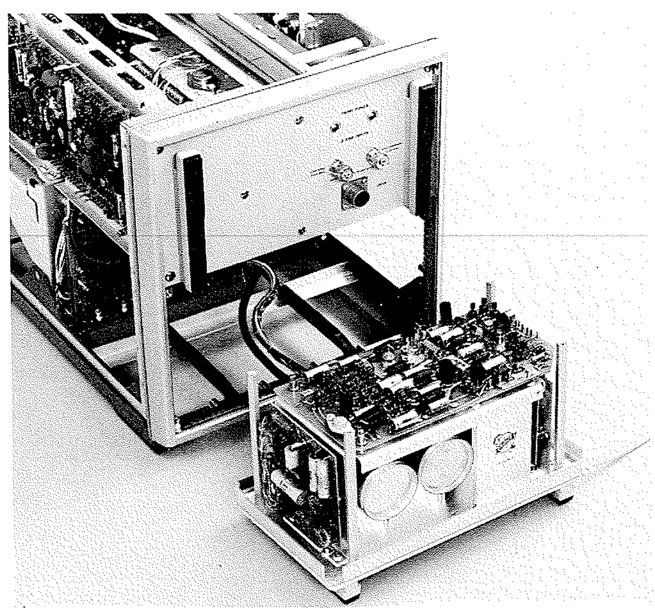
You can now prepare to apply power to the instrument. Install the line selector cover. Remove Q860 to disable the pre-regulator circuit. Connect your test scope between test point 836 and ground on the inverter board. Vertical sensitivity should be 50 V/div DC at the probe tip, the trace centered and the sweep speed set to 10 μs/div. Connect a voltmeter between the +75 V test point and ground on the rectifier board. Plug the scope into an autotransformer and with the line voltage set at zero volts, turn the instrument on. Slowly advance the line voltage while watching the test scope. If the trace moves up or down, the inverter still has problems. If the trace holds steady, the inverter should start as the line voltage approaches 80 volts. A square wave of approximately 25 kHz and 200 volts will appear on the test scope. Do not advance the line voltage any further. The +75 volt supply should not be allowed to exceed 75 volts to prevent blowing the inverter fuse.

RECTIFIER BOARD

You are now ready to check the pre-regulator circuitry. Turn off the scope and return the line voltage to zero volts. Replace Q860 in its socket. Slowly advance the line voltage while monitoring the +75 volt supply. If the +75 volts holds steady, you can advance the line voltage to a normal setting. If the voltage is not stable or if the signal being monitored on test point 836 on the inverter board is erratic in frequency, the pre-regulator is not working properly. The quickest method of troubleshooting this circuit is to check the associated transistors with a curve tracer or ohmmeter. The waveforms shown on the facing page are typical for a properly operating supply.

MECHANICAL CONSIDERATIONS

Most of the components in the power supply are readily accessible from the top of the printed circuit boards. However, when it is necessary to remove a soldered-in component, we suggest you remove the circuit board from the assembly and unsolder the component from the back side of the board. The line input board and the rectifier board are readily



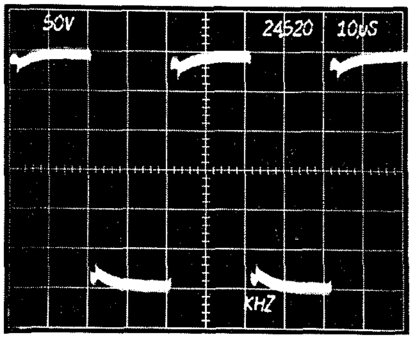
Low-voltage supply removed for easy servicing. Line input board is on the left side, rectifier board on top, and just the edge of the inverter board is visible at the right.

removed by loosening two or three screws. The inverter board is somewhat more difficult to remove; the manual gives the proper procedure.

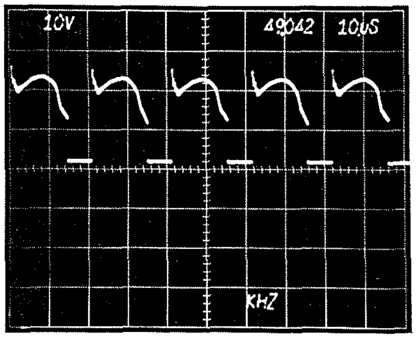
Care should be exercised when replacing Q825 or Q835 located on the ceramic heat sink on the inverter board. The mounting studs are soldered into the printed circuit board and may be broken loose by applying excessive torque.

When placing the power unit back into the mainframe take care to properly dress the power unit cables between the power unit and the logic board. Lowering the swing-down gate on the right side of the instrument will let you guide the cables into place.

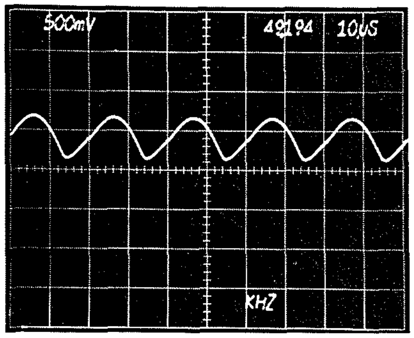
In the next issue of TEKSCOPE we will discuss the 7704 high voltage power supply.



Typical waveform at TP836 for properly operating supply. Mid-screen is 0 Volts.



Waveform at TP860. Note frequency is twice that at TP836.



Waveform at TP859. Frequency increased slightly due to line voltage change.

INSTRUMENTS FOR SALE

561A, $500. 3T77, $500. 3S76, $850. Harold Dove, 837 Uvalda St., Aurora, Colo. 80010. (303) 343-2906.

3-514D, 514AD, 524AD, 502, 541, 543A, 180A. 2 ea. 160A, 161, 163, 162. Jim Kennedy, Technitrol, Inc., 3825 Whitaker Ave., Phila., Pa. 19124. (215) 426-9105.

575, $900. Hans Frank, Dynaco, Phila., Pa. (215) CE 2-8000.

502A, 202-1. Ron Calvanio or Dr. Denton, Mass. Gen'l. Hospital, Dept. of Anesthesia, Fruit St., White Bldg., Boston, Mass. 02114. (617) 726-3851, 726-2034.

2 ea. 513D, 517. Dr. Frederic Davidson, E.E. Dept., Johns Hopkins Univ., Baltimore, Md. 21218. (301) 366-3300, Ext. 249.

515A. G. Katzen, 243 W. Main St., Cary, Ill. 60013. (312) 639-4768.

601, $925. Dr. William Spickler, Cox Heart Institute, 3525 Southern Blvd., Kettering, Ohio 45429.

514D, $250 or trade for 3 in. model. Arthur Pfalzer, Hoover Electric, Hangar 2, Port Columbus Airport, Columbus, Ohio 43219. (614) 235-9634.

561A, 3A6, 3B4. Package price, $1250. Pierre Cathou, MIT Branch, P.O. Box 104, Cambridge, Mass. 02139. (617) 868-5782.

53G, $100. 53/54B, $85. Dan McKenna. (517) 725-7211.

2-453. Dave Ballstadt, Optical Digital Systems, 1175 E. Highway 36, St. Paul, Minn. 55109. (612) 484-8589.

513D. Lou Chall, 2834 Serange Place, Costa Mesa, Calif. 92626. (714) 545-6536.

549, 1A1, 202-2, $2800 complete. J. C. Davis, Republic Nat'l Bank, Sunset Plaza, Pueblo, Colo. 81004.

611. Dr. Les Wanninger, General Mills, Inc., 9000 Plymouth Ave., N., Golden Valley, Minn. 55427. (612) 540-3444.

561A, 3A6, 3B3. Excellent condition. $1000. Might accept 321 or 321A as part payment. (213) 792-4962.

323, $850. C30AP, New, $450. Harold Moss. (213) 398-1205.

536, 53/54K, 53/54T, $800. S54, $300. Geo. Schneider, Profexray Div., Litton Medical Products, 1601 Beverly Blvd., Los Angeles, Calif. 90026. (213) 626-6861.

511AD, $300. Carl Powell, 3906 Jackson Hwy. Sheffield, Ala. 35660. (205) 383-3330.

13-RM561A/2A60/2B67 never used. Attractive discount. J. Wieland, 16950 Encino Hills Dr., Encino, Calif. 91316.

316, $600. I. R. Compton, Comptronics, 3220 – 16th West, Seattle, Wash. 98119. (206) 284-4842.

2B67, $175. 63 Plug-In, $100. Roger Kloepfer. (517) 487-6111, Ext. 392.

514A. Geo. Butcher, Electronics Marine, P.O. Box 1194, Newport Beach, Calif. 92663. (714) 673-1470.

1L20. George Bates, Dynair Elect., 6360 Federal Blvd., San Diego, Calif. 92114. (714) 582-9211.

611, $2000. Dr. A. Sanderson, Harvard Univ., Electronics Design Center, 40 Oxford St., Cambridge, Mass. 02138. (617) 495-4472.

P6046 Probe, Amplifier, P.S., $600. Bob Waters, Jr., ARCT, Inc., P.O. Box 11381, Greensboro, N.C. (919) 292-7450.

503 w/Grid. Wm. Gelb, Gelb Printing & Lithographing Co., 6609 Walton St., Detroit, Mich. 48210. (313) 361-4848.

555 complete. Scope Cart. Fred Samuel, Ch. Engr., WXTV, Ch. 41, 641 Main St., Paterson, N.J. 07503. (201) 345-0041.

547, 422, 453, 502, Plug-Ins, Cal. Fixtures. Manzano Laboratories, Inc., 146 Quincy Ave., N.E., Albuquerque, N.M. 87108. (505) 265-7511.

514AD, $260. J. Barsoomian, 31 Porter St., Watertown, Mass. 02172. (617) 924-6475.

2-531A/CA, $895. 2-531/CA, $695. 53/54C, $150. 2A63, $125. J. Boyd, Tally Corp., 8301 180th South, Kent, Wash. 98031. (206) 251-5500, Ext. 6787.

545B, 1A1, 1A7. Scientific Industries, 150 Hericks Rd., Mineola, N.Y. (516) 746-5200.

547, 1A4, 1A2, 202-2, as package or individually. Phil DiVita, Data Display Systems, Inc., 139 Terwood Rd., Willow Grove, Pa. 19090. (215) 659-6900.

105, $100. Charles Yelverton, Jones County Jr. College, Ellisville, Miss. 39437. (601) 764-3667.

516, $1020. 564B/121N, $876. 3A6, $440, 3B3, $544. 545B, $1360. 1A1, $520, 1A6, $236. 201-1, $116. 201-2, $124. 202-2, $124. Larry Glassman, 5584 Benton Woods Dr., N.E., Atlanta, Ga. 30342. (404) 255-5432.

531A, CA, 202 Mod. A, $500 package. Tom Eckols, Dow Jones Co., Dallas, Texas. (214) ME 1-7250.

INSTRUMENTS WANTED

453. W. Pfeiffer, 1332 E. Portland, Springfield, Mo. 65804. (417) 869-0249.

519. John Barth, Barth Corp., 7777 Wall St., Cleveland, Ohio 44125. (216) 524-5136.

503. A. Ruben, Medical Sales & Service, 270 E. Hamilton St., Allentown, Pa. 18103. (215) 437-2526.

R561A or B, with or without Plug-Ins. Dr. Paul Coleman, Univ. of Rochester Medical Cntr., Anatomy Dept., Rochester, N.Y. 14620. (716) 275-2581.

TEKSCOPE

Volume 3 Number 2 March 1971

Customer Information from Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005

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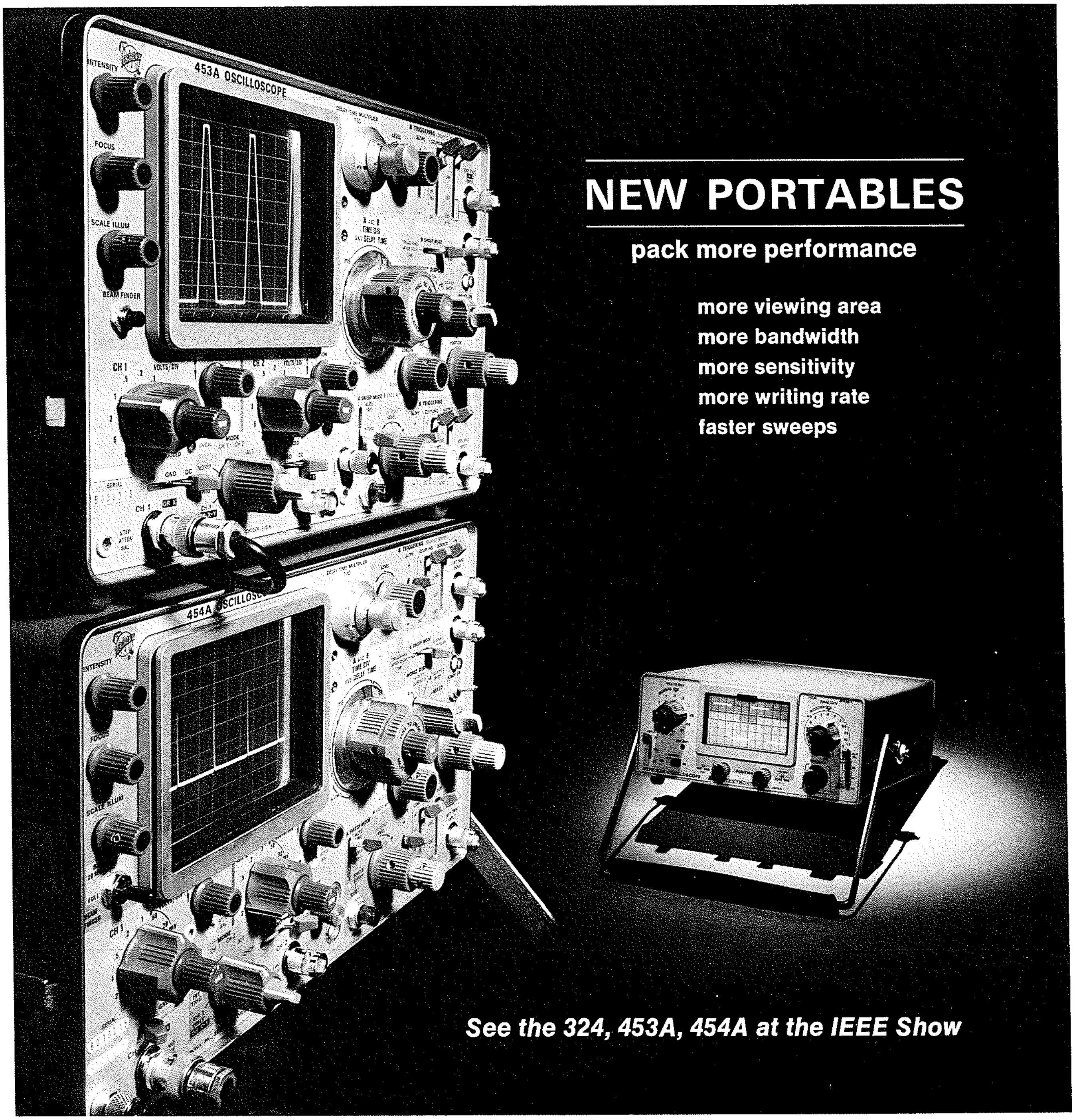

TEKTRONIX, INC.
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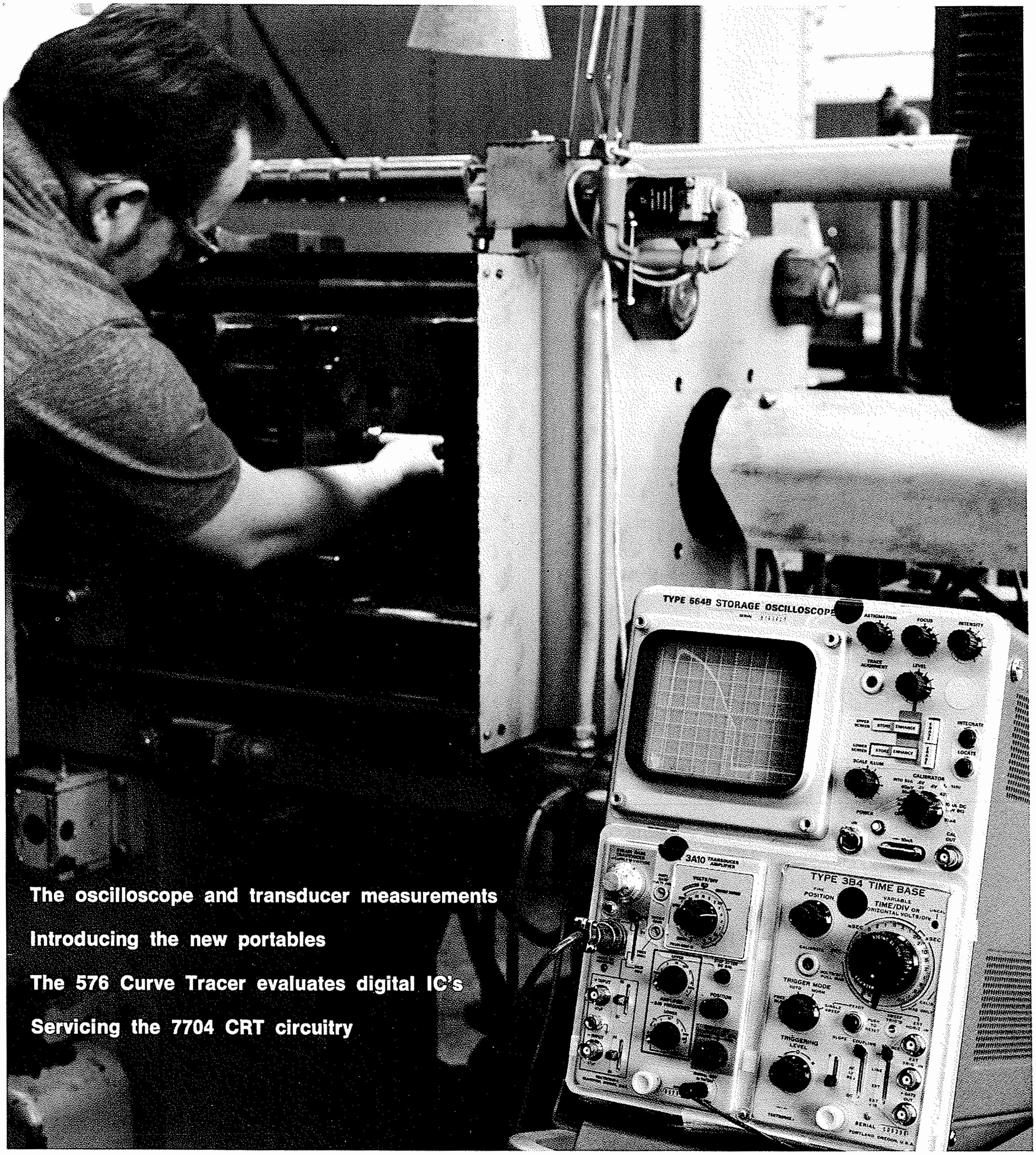
BEAVERTON, OR. 97005

TEKSCOPE

May 1971



The oscilloscope and transducer measurements

Introducing the new portables

The 576 Curve Tracer evaluates digital IC's

Servicing the 7704 CRT circuitry

COVER—Photo of the Beloit Injection Molding Machine in action with the process being monitored by the 3A10 transducer system.

the oscilloscope and transducer measurements

Denny Magden of Plastics adjusts the 3A10 transducer system used in monitoring injection molding of cam switch blanks.

By Ken Arthur, Staff Engineer

The fields of mechanical measurement and electrical waveform measurement have long been linked by a device called a transducer. In the context of mechanical measurements, a transducer is a device which converts some physical quantity, force, property or condition into an electrical signal. When this signal is measured, and the relationship between its parameters and those of the quantity being measured are known, the magnitude of the quantity can be calculated. Since many physical phenomena occur at frequencies beyond the range of galvanometers and chart recorders, the oscilloscope logically becomes the recognized readout device for high-frequency physical measurements. In mechanical measurements, the term "high-frequency" can be applied to any effect having a frequency component higher than one kilohertz.

Tektronix oscilloscopes having high gain differential amplifiers have been used in transducer measurements for many years. However a significant step was taken when the Type Q and 3C66 Carrier Amplifier plug-ins were introduced. With these units the transducer power supply, signal conditioner, and oscilloscope readout device were packaged in a single unit; an innovation made possible by Tektronix' revolutionary "plug-in" concept of oscilloscope design. Then came the Engine Analyzer System and the 410 Physiological Monitor. Although highly specialized in application, these instruments were designed with a "systems" approach; that is, the minimum basic components required in any transducer measurement, (the transducer itself, a signal conditioner and a readout device) were combined in an integrated system. Thus the customer was relieved of the burden of designing his own measurement system from separately purchased components—an irksome task at best, and one which many customers were ill-equipped to perform.

Now, with the introduction of the Type 3A10 Transducer Amplifier, Tektronix makes another substantial contribution to the mechanical measurement field. Along with its family of especially selected and tailored transducers, the 3A10, mounted in a 560-Series Oscilloscope, constitutes the first integrated, general-purpose transducer measurement system to appear on the mechanical measurement scene.

Design of the 3A10 was based on a survey of existing transducer instrumentation. This survey revealed a pronounced need for a transducer measurement system with the following primary characteristics:

- Ease of operation
- Functional flexibility
- Predictable system accuracy (when used with one of the system's transducers)
- Optimum sensitivity and bandwidth

The degree to which these design objectives have been met is evidenced by the number of "firsts" incorporated in the 3A10 system. Among these are:

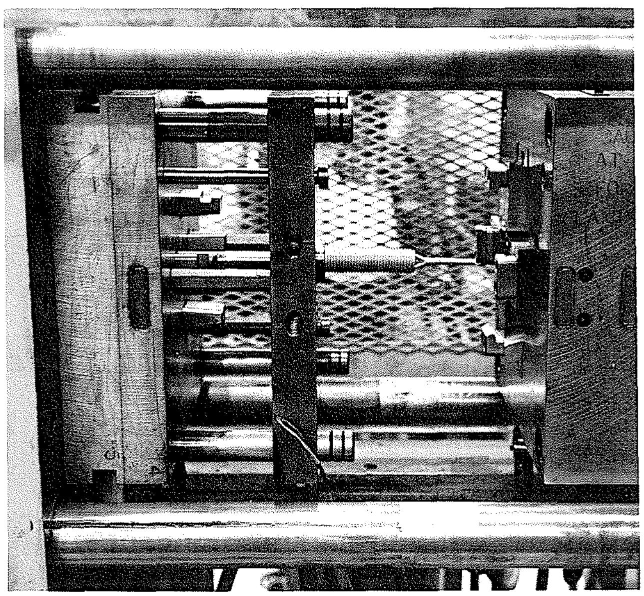
1. Snap-in attenuator scales, permitting the quantity to be read out directly in appropriate metric or U.S. system units.
2. A variable, calibrated (1 to 11 V DC) transducer power supply for strain gages, strain-gage type transducers, and other voltage-excited types.
3. Factory installed, ½ full scale calibration resistors in strain-gage type transducers, permitting transducer calibration at the push of a button and eliminating lead impedance errors.
4. Differential inputs with switchable 1 and 10 megohm input impedances, permitting the use of both piezoelectric transducers and standard oscilloscope voltage probes.
5. Separate amplifier gain control circuit for calibrating active transducers without disturbing main amplifier gain.
6. No attenuation imposed on signals below 20 mV, thereby achieving a CMRR of 100,000:1 for low amplitude signals.
7. A strain-gage adapter with a variable, precision calibration resistor, allowing compensation for variations in gage factor between different lots of gages.
8. Tektronix designed low-hum interconnecting cables to eliminate noise interference with low-amplitude transducer signals.
9. Bandwidth selection to eliminate or reduce unwanted signals, and to permit differentiation and integration of transducer signals.

The versatility of the 3A10 system stems from the fact that each of the ten transducers provided as accessories has been carefully selected, tailored or manufactured by Tektronix to take full advantage of the 3A10 Transducer Amplifier's characteristics. With these transducers, magnitudes of acceleration, force, displacement, pressure, temperature, strain, vibration velocity and vibration displacement can be measured under either static or dynamic conditions. Furthermore, the system lends itself for use with practically any transducer the customer may possess or acquire. These transducers can be incorporated in the system by following simple instructions included in the operating manual and/or the TRANSDUCER MEASUREMENTS concepts book provided as standard accessories.

The range of measurements to which the 3A10 system may be applied is virtually unlimited. Optimum utilization of the system's capabilities, of course, depends to some extent on the imagination and ingenuity of the user. At Tektronix, many of the manufacturing processes have been improved and are maintained on a day-to-day basis through the use of 3A10 systems.

PRODUCTION APPLICATION

A good example is provided by a problem recently encountered in manufacturing the cam switches which contribute substantially to the superior performance of the new 7000-Series Oscilloscopes. One of the components of these switches is a plastic '"drum" having as many as 40 individual operating cams. This drum is machined from an injection-molded "blank". Because the molecular structure of this part is crystalline rather than amorphous, it must be annealed to assure permanency of dimensions. The annealing process, however, results in some shrinkage, which varies with the degree of "mold packing" or density of the molded part. Unfortunately these variations in density are not evident until the annealing process is completed. As a result, we experienced an unacceptably high reject ratio of the finished blanks.



Uniform dimensions of injection molded cam switch blank are achieved using the 3A10 Transducer Amplifier and a force transducer to control degree of mold packing.

The problem was solved through the use of the 3A10 Transducer Amplifier and a force transducer. Since the degree of mold packing varies directly with the pressure on the molten plastic during injection, the force transducer is applied to the ejector sleeve of the molding die. As the pressure of the molten plastic rises, it exerts a corresponding force against the sleeve which is in turn detected by the force transducer. Shortly after the peak pressure is attained, the cooling plastic begins to shrink, reducing the pressure on the walls of the sleeve. Once the plastic has solidified, the die is opened and the pressure drops to zero. The resulting waveform is shown in Fig. 1. Experiments soon established the desired parameters and allowable tolerances for this waveform which would result in the most economical and productive use of the molding machine and, at the same time, yield parts of consistent quality. The reject ratio fell dramatically—virtually to zero.

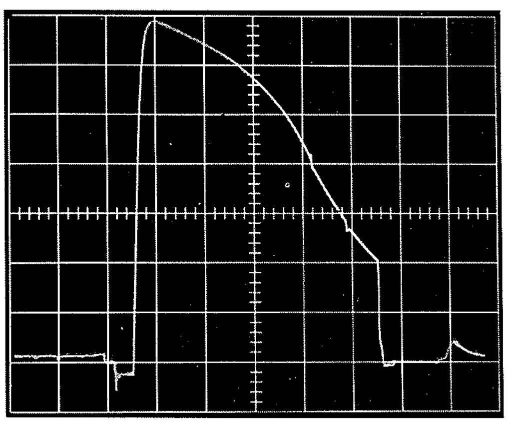


Fig. 1.
Waveform produced by force transducer during the injection molding process. Problems in the process are immediately detected by monitoring this waveform.

Other advantages were gained as bonuses. First, the operator is now able to monitor each injection by observing the oscilloscope waveform. Problems are immediately detected. Second, by connecting an X-Y chart recorder to the SIGNAL OUT jack of the 3A10, a permanent record is made available to supervisory personnel. Fig. 2 shows the record of two extended periods of operation. (The "pulses" shown on the chart are actually time-compressed versions of the waveform shown in Fig. 1.) Process problems are clearly revealed and readily identified by an examination of these records, permitting corrective measures to be taken.

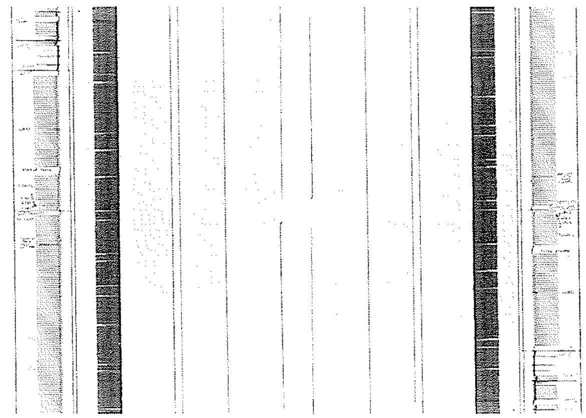
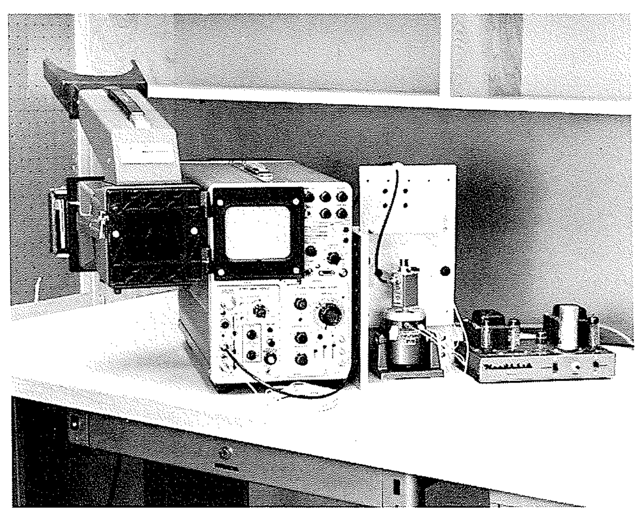


Fig. 2. Permanent chart recordings are useful in analyzing repetitive problems and for production control.

TEACHING APPLICATION

The 3A10 system has also proven its worth as a versatile training aid in the teaching of physics and even mathematics. For example, in the study of the laws of motion, it can be established through the application of mathematical procedures that velocity is the first derivative of displacement with respect to time, and acceleration the first derivative of velocity. These relationships can be demonstrated graphically by using the 3A10 system and the simple apparatus shown below. It consists of a small shake table driven by a 60-Hz squarewave voltage. The 3A10 system's vertical vibration transducer is mounted on the shake table and the accelerometer mounted on top of the vibration transducer.



Apparatus used in demonstrating the mathematical principles relating to the laws of motion.

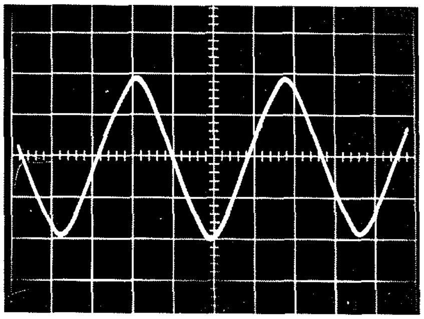


Fig. 3.
Displacement waveform from displacement output of vertical vibration transducer. Bandwidth is DC to 1 MHz.

The first step of the demonstration is to measure the vibration displacement of the table. The damping effect of the mass of the table and transducers results in a displacement which has the form of a distorted sinewave (Fig. 3). This measurement is taken with the amplifier's bandpass filter wide open (DC - 1 MHz).

Next, the lower bandpass switch is set to 10 kHz, so that the displacement signal is differentiated on the lower slope of the bandpass curve. Although this procedure attenuates the signal, the gain of the amplifier may be increased to give a clear impression of the waveform (Fig. 4). According to theory, this differential displacement signal should represent the velocity of the shake table's vibration. To test the theory, it is only necessary to transfer the connecting cable to the VELOCITY output of the vibration transducer and restore the amplifier to full bandwidth. As shown in Fig. 5, this direct measurement yields a waveform practically identical to that of the differentiated displacement waveform.

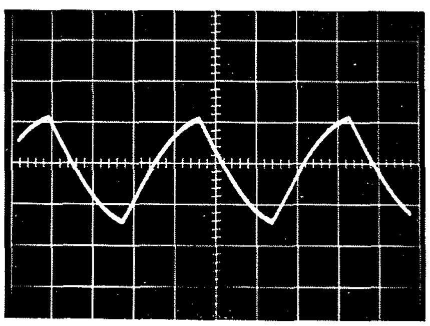


Fig. 4.
Differentiated displacement waveform. Note similarity to the velocity waveform in Fig. 5. Bandwidth is 10 kHz to 1 MHz.

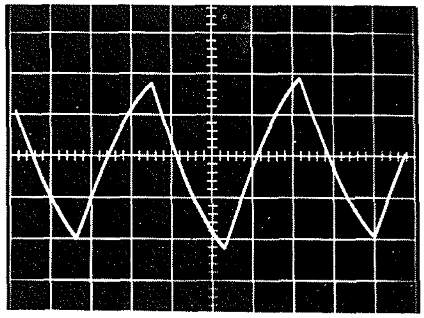


Fig. 5.
Velocity waveform from velocity output of vertical vibration transducer. Bandwidth is DC to 1 MHz.

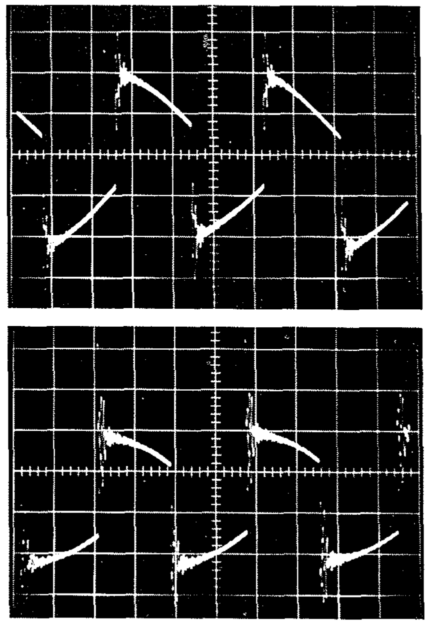
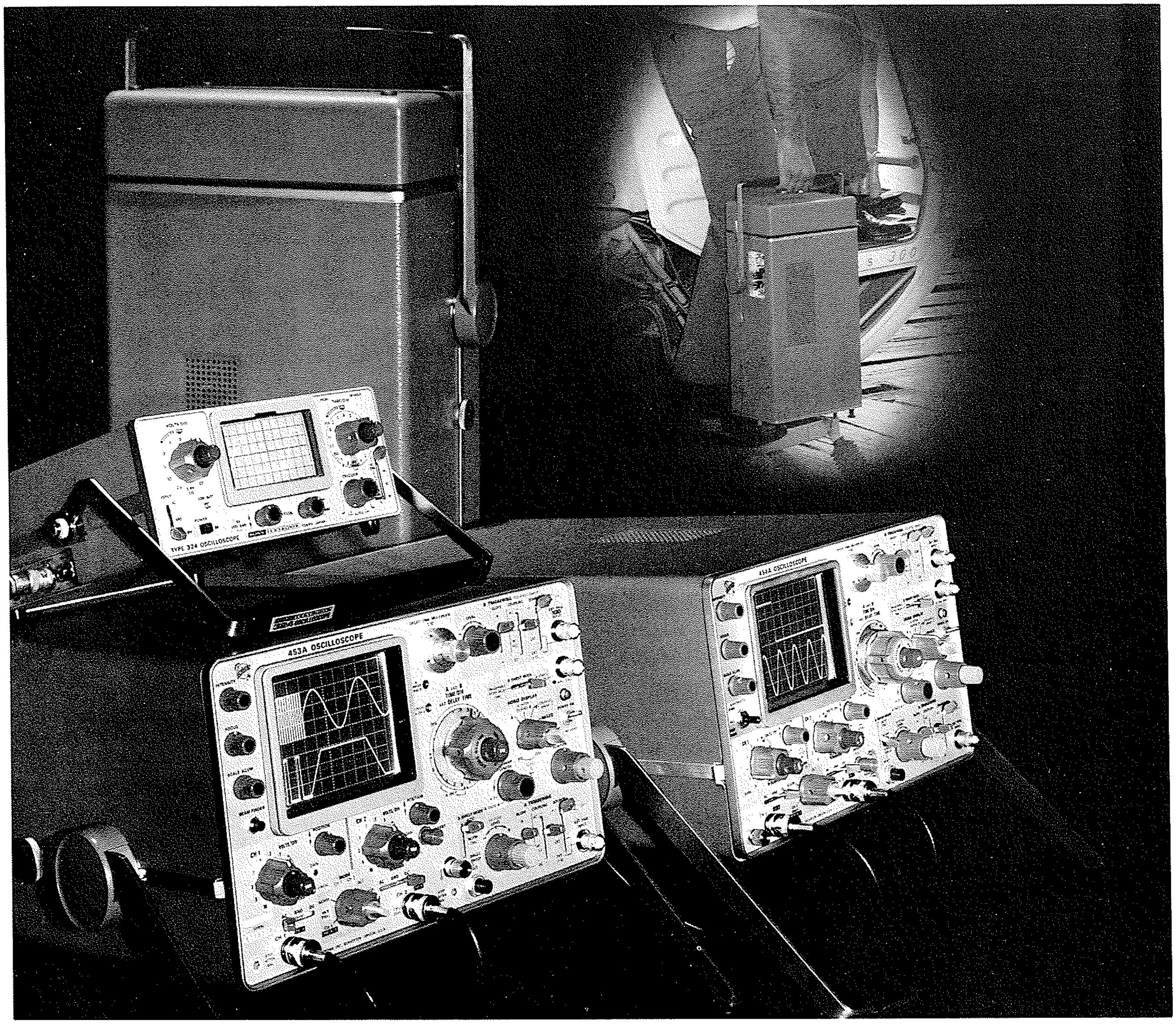


Fig. 6 & 7.
Top: Differentiated velocity waveform. Mathematically differentiating velocity should yield acceleration. Bandwidth is 10 kHz to 1 MHz.

Bottom: Acceleration waveform from accelerometer is similar to differentiated velocity waveform above, validating mathematical thesis. Bandwidth is DC to 1 MHz.

When the vibration velocity signal is differentiated and compared with the directly measured accelerometer output the resultant waveforms once again are practically identical (Fig. 6 & 7).

These two widely-divergent applications are but a small sample of the many measurements possible with the 3A10. We expect the system will find extensive application not only in the mechanical-measurement field, but also in medical research, environmental studies and other fields of endeavor.



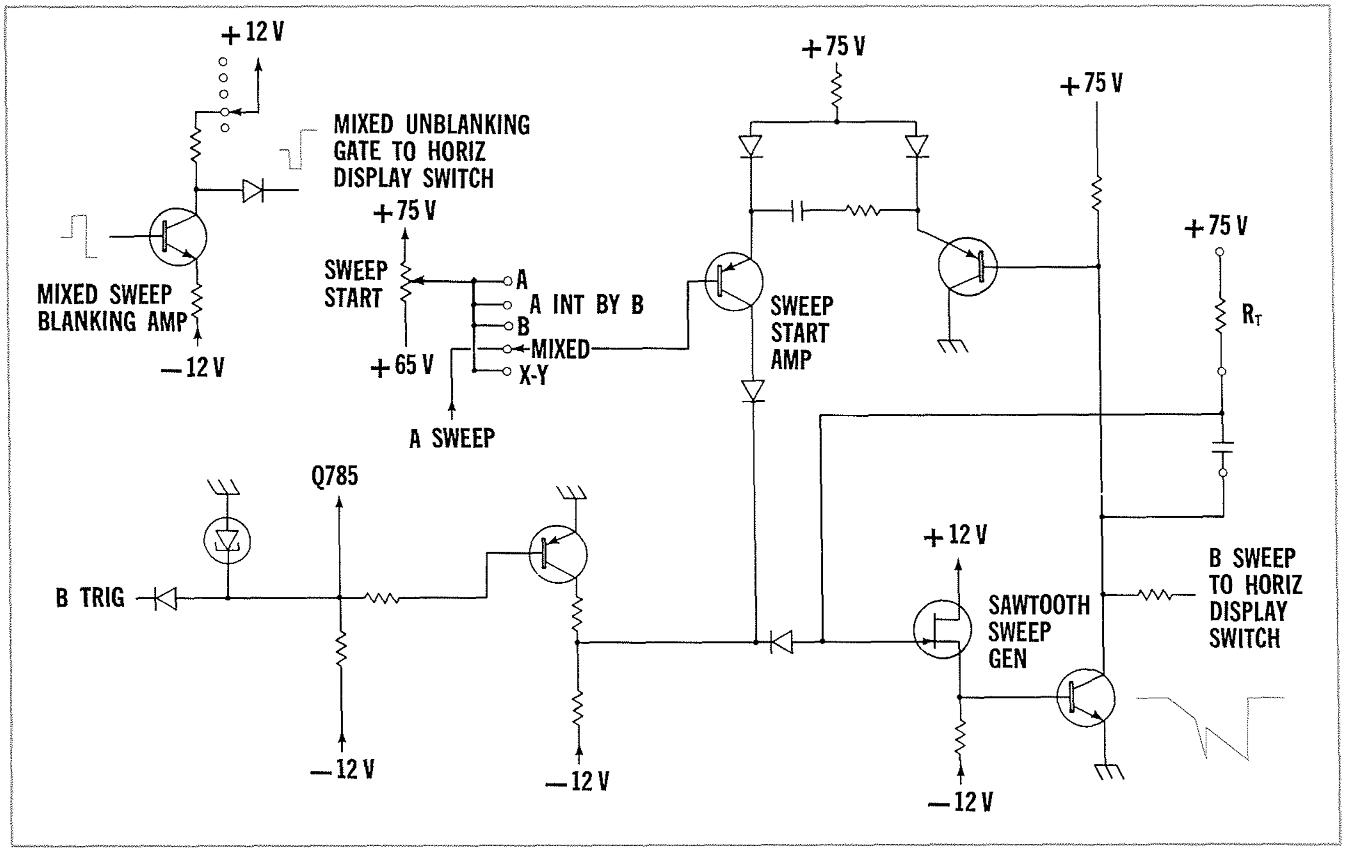
the new portables

Change for the better has always been a way of life at TEKTRONIX. New components, new techniques, new applications and sometimes problem areas, are all factors that continually bring change to our products. Often the changes are small and go unnoticed by the average user. Sometimes, however, the changes are substantial resulting, in essence, in a new product.

Two standards in the portable oscilloscope field, the 453 and 454, have recently undergone such a transformation. We now call them the 453A and 454A. A glance at the front panel reveals both instruments have big new CRTs. Screen size has been increased to 8 x 10 div providing 33% more viewing area. Accelerating potential on the 453A is raised to 14 kV giving the same bright trace as the 454A.

One thing you notice is, that in spite of the larger CRT, there seems to be more front panel space. New knob design and layout and the new color-coordinated front panels provide improved appearance and operating ease. The knobs are where you're accustomed to finding them, but there's more room to operate them.

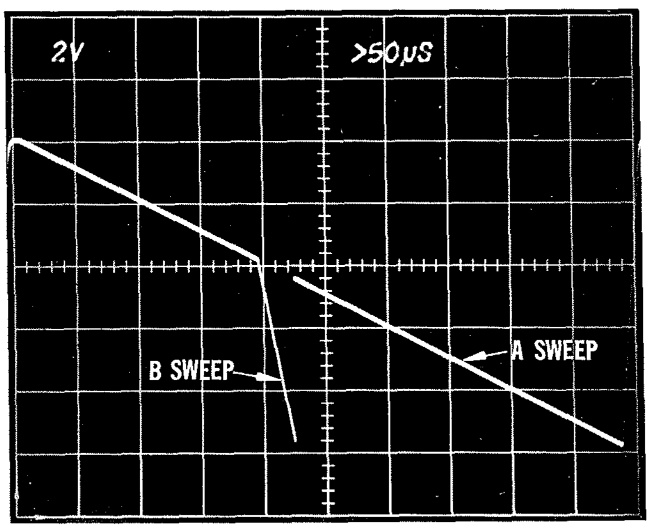
In addition to the larger CRT, improved appearance and operating ease, both instruments pack considerably more performance than their earlier counterparts. A new "mixed" sweep mode lets you view the main sweep out to the point selected by the delay time multiplier, then the delayed sweep for the remainder of the display.



Simplified partial B sweep schematic for the 453A.

The delay time is calibrated, and display repetition rate is independent of delay time. The manner in which the mixed sweep is achieved is somewhat unique. A simplified schematic of the B sweep generator is shown above. In the mixed-sweep mode, the sawtooth from A sweep generator is coupled to the start amplifier for the B sweep generator. Thus, the DC starting point of the B sweep is a direct function of the level of the A sweep. When the B sweep generator is enabled by a signal from the delay multivibrator, the B sweep starts at the point on screen reached by the A sweep. In this mode the output of the B sweep generator drives the horizontal amplifier. The output of the B sweep generator takes the form of a composite sawtooth waveform with the first and last parts occurring at a rate determined by the A sweep generator and the middle occurring at a rate determined by the B sweep generator. The A sweep unblanking turns on the beam during mixed sweep. Additional unblanking during the B sweep portion of the display is provided by the mixed sweep blanking multivibrator through the mixed sweep blanking amplifier. A signal generated by the end of B sweep drives the mixed sweep blanking amplifier to a level which blanks the remainder of A sweep.

Delay accuracy of 1.5% now extends from 50 ms/div to 0.1 μs/div, and the fastest sweep rate on the 454A is increased to 2 ns/div for better resolution of fast risetimes.

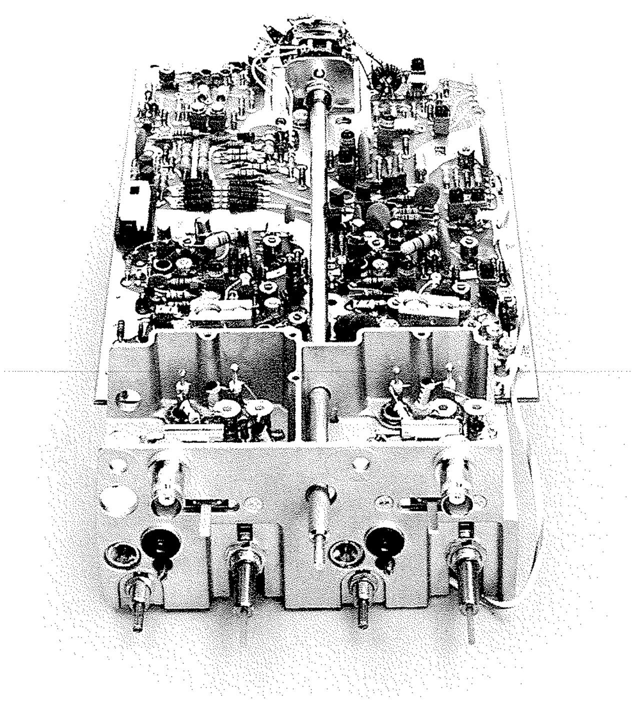


Output of the B sweep generator with Horizontal Display switch in the MIXED mode. Position of the B sweep is determined by the Delay Time Multiplier setting.

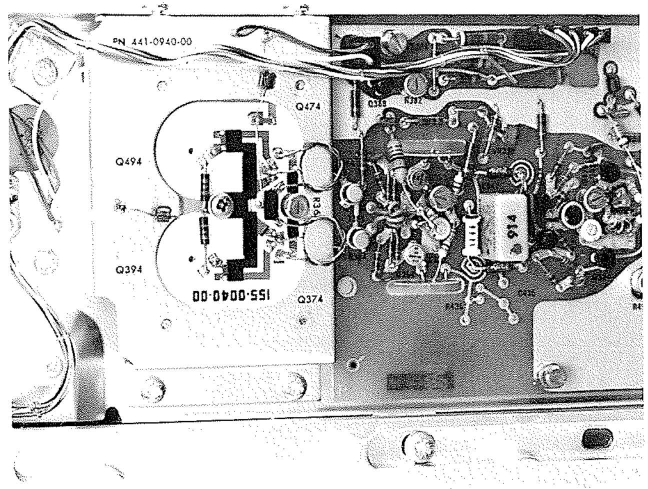
The Vertical Amplifier

The vertical amplifier in the 454A is a completely new design. FET inputs give rock-solid operation down to 2 mV/div and full 150-MHz bandwidth is available at 10 mV/div. A new delay line eliminates preshoot and a cleaner response is obtained. You will notice less effect of vertical position on amplifier response and negligible baseline shift as you switch through the attenuator positions. Crosstalk between trigger, vertical, horizontal and Z-axis signals is substantially reduced.

Complementing the new vertical amplifier system is a new, compact 10X passive probe, the P6054. The offset design of the small compensation box keeps the front panel controls clear for easy operation.



New one-piece casting provides improved shielding and rigid mounting for attenuator switches and vertical preamplifier board in the 454A.



In the 454A Vertical Output Amplifier, many of the components are an integral part of the circuit board or are a part of the thick-film etched circuitry pictured above.

Several mechanical improvements increase the ruggedness and serviceability of the 454A. The vertical attenuator switches are mounted on a one-piece casting to which the vertical amplifier printed board is attached, resulting in better shielding and stability in switch alignment. Harmonica connectors speed disconnecting and removal of etched circuit boards, and access to other areas for servicing has been improved.

A seemingly minor change will be appreciated by those of you who have to carry your instruments around. The feet on the rear form a new power cord wrap that holds the cord securely in place. No more danger of stumbling over the power cord while running for your airplane.

The 453A

Long recognized for its record of dependable maintenance-free operation, the 453 underwent somewhat fewer changes. Most noticeable is the big CRT with the bright trace.

The 14-kV accelerating potential lets you view low rep rate pulses even in adverse ambient light conditions. It, too, has a new, color-coordinated front panel, new knobs and improved layout for easier operation. The bandwidth of the vertical amplifier is increased to 60 MHz at 20 mV/div sensitivity, with 50 MHz at 10 mV/div and 40 MHz at 5 mV/div. In the horizontal section we have added the calibrated mixed sweep function and a more convenient X-Y mode. New, smaller probes and a new power cord wrap complete the major changes found in the 453A.

THE 453A-1, 453A-2, 453A-3, 453A-4

Of major importance to many customers is the addition of four new models to the 453A line. Many applications, especially in field service, require an oscilloscope which will be used exclusively to solve defined measurement problems. Once the measurement problems are defined, the oscilloscope performance characteristics needed to solve these problems are easily defined. These four new models are designed to meet these special requirements.

Since these instruments are intended for use in those applications where versatility and convenience are of secondary importance, certain 453A features have been removed to offer the user performance at a cost compatible with his needs. Features which have been removed include gate output sources, some power options, warning lights indicating uncalibrated modes, X-Y operation, scale illumination and current calibrator loops. Major differences in the models occur in the horizontal section. For example, the 453A-1 has uncalibrated delay of the delayed sweep, while the 453A-2 offers calibrated delay time. The 453A-3 has both calibrated sweep delay and mixed sweep and the 453A-4 has only a single time base. All of the instruments have vertical deflection systems identical to the 453A, except the warning lights indicating uncalibrated vertical modes have been deleted.

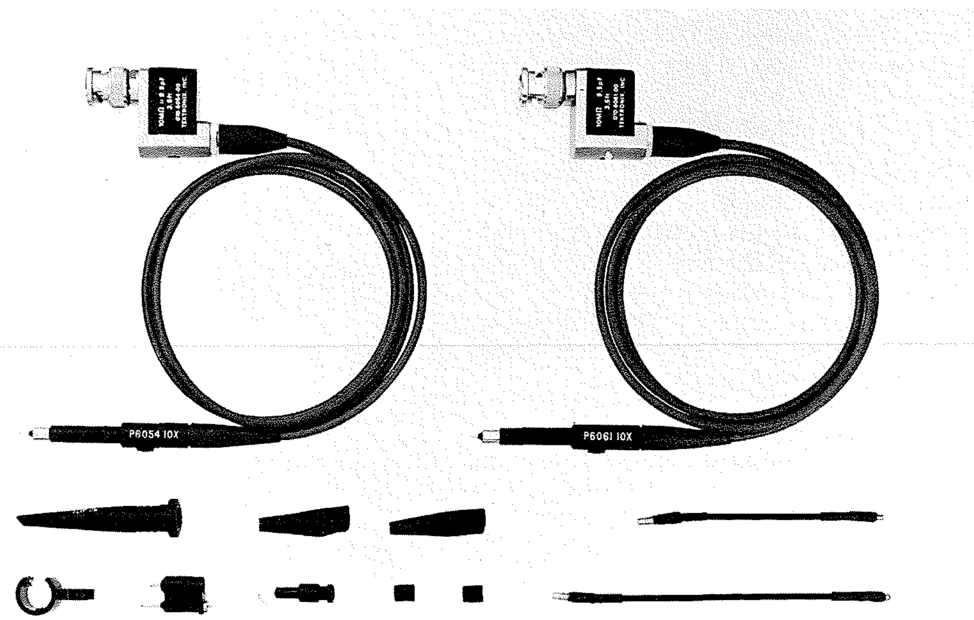
THE 324

No discussion of the new portables available from Tektronix would be complete without mentioning the 324.

Offering 10 MHz, single-channel operation in a package weighing only 8 pounds including batteries, the 324 is ideal for "on-site" maintenance applications. Up to 3 hours continuous operation is provided by an internal rechargeable power pack. The unit also operates from an external DC supply of 6.5 to 16 volts or from the AC line. Power consumption is only 8.5 watts on DC operation. An extra power pack is available to allow one power pack to charge while the other is powering the oscilloscope.

The vertical deflection factor is 10 mV/div at the full 10-MHz bandwidth and 2 mV/div at 8 MHz. Calibrated sweep rates are 1 μs/div to 0.2 s/div with a X5 magnifier extending the top of the range to 0.2 μs/div.

All of the portables are designed to withstand severe environments and include front panel covers and complete accessories.



Pictured above are two new probes developed for use with the 453A and 454A. The P6061 is designed for use with the 453A and the P6054 for use with the 454A. The probes are similar in appearance and feature small, lightweight design ideal for working with today's compact circuitry and miniature components. The offset design of the small compensation box keeps oscilloscope front panel controls clear for convenient operation. Both probes are available in 3.5-foot, 6-foot and 9-foot lengths.

TEKNIQUE: evaluating digital IC performance using the 576 curve tracer

By Jack Millay

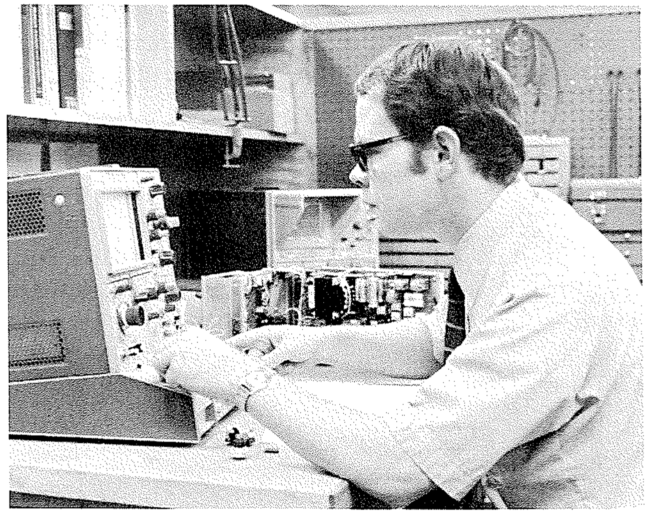
The curve tracer can be a valuable tool to circuit designers, device designers and device evaluation engineers working with integrated circuits. Most of the DC parameters of digital IC's can be displayed as a "curve" such that the point specified by the manufacturer can be verified. Because the display is a curve, much more about the device's performance can be quickly determined than with a single-point measurement. Integrated circuit input and output characteristics as well as voltage supply (V_{cc}) current can be evaluated.

Connecting the integrated circuit to the curve tracer terminals has been a problem. Now an integrated circuit adapter available from Tektronix greatly simplifies the task. The adapter plugs into the Type 576 standard test fixture. Barnes Corporation Series RD-86 sockets and contactors plug into this adapter. Sockets are available for dual-in-line, 6 through 14-lead round-pin-pattern TO packages, and flat pack. Connection to the Type 576 is performed by patch cords from the pin terminal to the 576 terminal on the adapter. The pins on the Barnes Corporation socket are so arranged that the integrated circuit pin numbers agree with the pin terminal numbering around the adapter. Some of the earlier Barnes Corporation Series RD-86 sockets and contactors were not pin compatible. Dual-in-line 14 pin and flat pack are all compatible, as are other sockets and contactors having a yellow base. The units that are now purchased from either Tektronix or Barnes Corporation are all pin compatible.

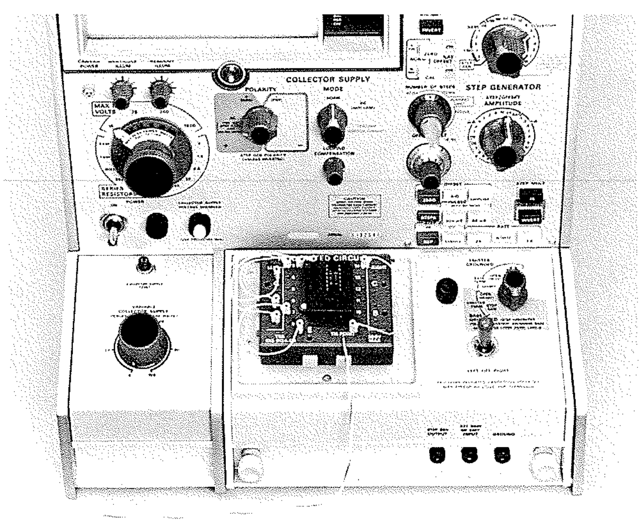
The 576 COLLECTOR SUPPLY may be used to drive the input, load the output, or drive the V_{cc} terminal. When driving the inputs or loading the outputs of an IC, the AC polarity position of the collector supply allows viewing of both current sourcing and current sinking on the same display. When displaying supply current as a function of supply voltage, usually the + polarity is used instead of AC.

The 576 STEP GENERATOR may be used as a signal source, a power supply, or a combination of both. As a signal source it will output a voltage (or current) stairstep or a squarewave by turning the NUMBER OF STEPS control to 1. To use it as a power supply, the SINGLE STEP FAMILY button is pushed and the OFFSET MULT control is adjusted to obtain the desired voltage (or current). The CURRENT LIMIT control adjusts the limit from 20 mA to 2 A when in the voltage mode.

For many IC tests such as $I_{in}(0)$, $I_{in}(1)$, I_{os}, $I_{cc}(0)$ and $I_{cc}(1)$, the 576 COLLECTOR SUPPLY, the STEP GENERATOR and the E terminal for ground are the only connections needed. For some tests, such as $V_{out}(0)$, $V_{in}(1)$, $V_{out}(1)$ and $V_{in}(0)$, another voltage supply is needed. It may be connected between the GROUND connection on the front of the test fixture and the TIE POINT on the integrated circuits adapter. From the TIE POINT it can be connected with the patch cords to any pin(s) desired.



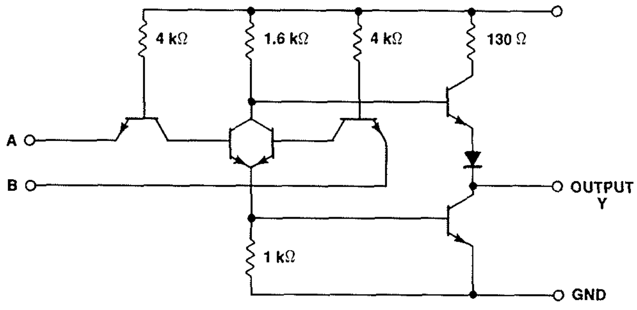
Jack has been with Tek since 1958. For most of his career he has been involved with evaluation of active devices. He was manager of component evaluation for five years and is currently project manager for curve tracers.



The Integrated Circuits Adapter plugs directly into the standard test fixture for the 576.

EVALUATING TTL

Following are some examples of measurements on a Texas Instruments SN7402N IC. The SN7402N is a typical example of a digital integrated circuit. Shown below is the schematic of this circuit. The measurement techniques used here can be applied to other families of circuits as well.



One of four identical sections of the SN7402N IC.

INPUT CHARACTERISTICS OF THE SN7402N

Input current of this circuit can be displayed over the full range of input voltages of interest. The STEP GENERATOR OFFSET of the 576 is used as the V_{cc} supply. The COLLECTOR SUPPLY is used to drive the input that is being evaluated. Because we want to observe both current sourcing and sinking of the input, AC collector sweep is used. Fig. 1 shows the $I_{in}(0)$ condition. The specified value of $I_{in}(0)$ may be measured on this display. It measures about -1 mA at the specified measurement point of 0.4 volts, well within the specification of -1.6 mA max. The input voltage "point" where the input voltage changes from a logical zero to a logical one can be determined by observing the sharp transition in input current. This occurs at about $+1.4$ volts. $I_{in}(1)$ may also be measured by increasing the vertical sensitivity until a reading can be obtained as shown in Fig. 2. In order to perform this measurement as the manufacturer specifies, it is also necessary to move the input not being tested, from ground to the V_{cc} supply. However, this will usually not change the measurement.

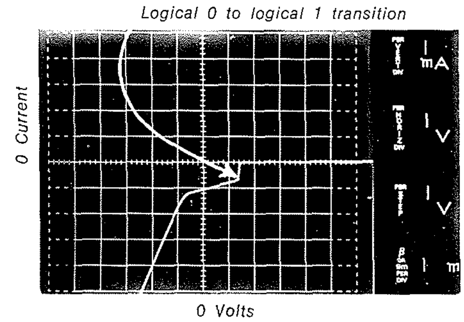


Fig. 1.
$I_{in}(0)$ condition. Step generator offset is used as V_{cc} supply. AC collector sweep drives the input being evaluated so we can observe both current sourcing and sinking.

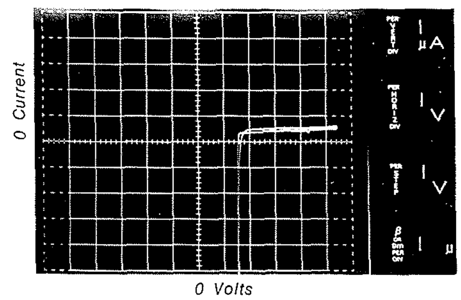
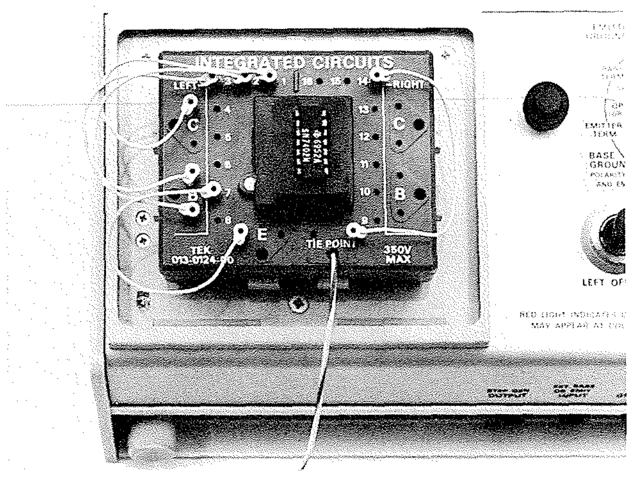


Fig. 2.
$I_{in}(1)$ condition. Same set up as in Fig. 1 with vertical sensitivity increased to permit reading of input current.



Close-up of Integrated Circuits Adapter showing pin numbering details and adapter for 14-lead dual-in-line package.

OUTPUT CHARACTERISTICS OF THE SN7402N

The ability of the output to source or sink current can also be evaluated. The STEP GENERATOR OFFSET is used to bias the input for the $V_{out}(0)$ condition. The COLLECTOR SUPPLY is used to load the output. Because we want to observe both current sourcing and sinking of the output, AC collector sweep is used. An external voltage supply is used for V_{cc}.

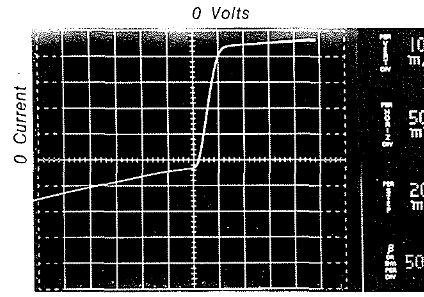


Fig. 3. $V_{out}(0)$ condition. Step generator offset is used to bias input for the $V_{out}(0)$ condition. AC collector sweep is used to load the output being evaluated. External voltage supply is used for V_{cc}.

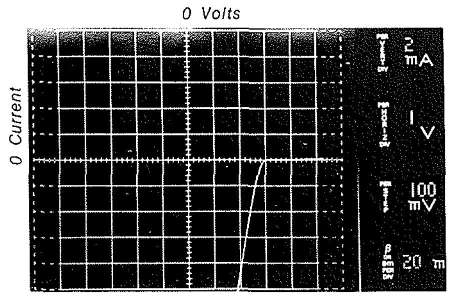


Fig. 4. $V_{out}(1)$ condition. Same set up as in Fig. 3 except the step generator offset is set to bias the input for $V_{out}(1)$ condition and the deflection factors are set accordingly.

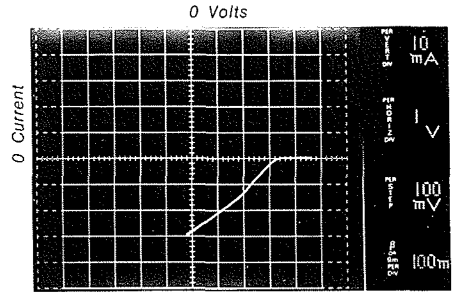


Fig. 5. Short-circuit output current, I_{os}, measured using same test set up as for $V_{out}(1)$. Vertical deflection factor is decreased to observe point at which the curve crosses the zero-voltage line.

Fig. 3 shows the $V_{out}(0)$ condition. The manufacturer's specification can be verified and actual performance measured. The device is specified able to sink 16 mA at no more than 0.4 V. From this display it is apparent that it will actually sink 35 mA at 0.4 V and will have a voltage drop of 0.25 V at the 16 mA specified. The normal fan out is specified at 10, but this particular gate could drive over 20 gates, at least as far as DC characteristics are concerned.

It can also readily be determined from the display how much current is available to drive shunt capacitance, and by knowing the amount of the capacitance, calculate the time for this current to discharge this C to the logical zero state.

Fig. 4 shows $V_{out}(1)$ of one of the SN7402N outputs along the horizontal axis as a function of output current along the vertical axis. This device is specified able to source at least 400 μA at 2.4 volts. From the curve it is apparent that it will actually source 4 mA at 2.4 volts and has a logical 1 voltage of 2.7 volts at 400 μA. Because the maximum input current $I_{in}(1)$ is specified at 40 μA, this output could drive almost 100 other worst-case inputs for a fan out of almost 100 instead of the 10 specified. However, this measurement was performed at 25°C, and when the device is operated at lower ambient temperatures, the performance for this characteristic decreases.

Short-circuit output current (I_{os}) may be measured using the same test set up as for $V_{out}(1)$ by decreasing the vertical deflection factor. The deflection factor is decreased until we can observe the point at which the curve crosses the zero-voltage line. Fig. 5 shows this characteristic. The manufacturer specifies the current to be at least —18 mA, and no more than —55 mA. This device measures —29 mA, well within specifications.

V_{cc} CHARACTERISTICS

The current required from the V_{cc} supply as a function of supply voltage and input levels can also be displayed. The COLLECTOR SUPPLY is used to drive the V_{cc} terminal. The + polarity of the supply is used as we only have to supply current (not sink). The STEP GENERATOR can be used to voltage drive the inputs from 0 volts to +5 volts by setting the AMPLITUDE control to 1 volt/step and using 5 steps. No offset is used. Fig. 6 shows this characteristic.

Only 2 curves are displayed because the zero and one-volt steps are below the level where the transition from the logical zero to the logical one takes place. The other four steps are above the transition point. $I_{cc}(0)$ measures 15.5 mA, and $I_{cc}(1)$ measures 13.6 mA, well within the manufacturer's specifications.

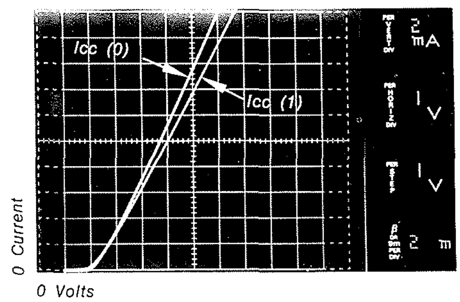


Fig. 6.

$I_{cc}(0)$ and $I_{cc}(1)$. The V_{cc} terminal is driven by the collector supply, using + polarity. The step generator drives the inputs from 0 volts to +5 volts using 1 volt/step. The outputs are open.

From the same display we can also determine the effect on V_{cc} current when V_{cc} or the input voltage is changed. Changing the input voltage has very little effect except in the logical zero to the logical one transition zone. However, a small change in V_{cc} voltage produces a relatively large change in V_{cc} current.

These examples are typical of the IC measurements that can be made using the 576. Many of these measurements can also be made on the 575 but with somewhat greater difficulty. The integrated circuits adapter will fit on the 575. However, you will need to use patch cords to connect the collector and base terminals on the right hand side of the adapter to the 575. AC collector sweep is not available on the 575 so that two displays will be needed to display both current sourcing and sinking. Also the base step supply is much more limited and cannot do some of the functions we required of the 576. This difficulty can usually be overcome by using an additional external power supply.

SERVICE SCOPE

SERVICING THE 7704 CRT CIRCUIT

By Charles Phillips, Product Service Technician
Factory Service Center

This is the second in a series of articles on servicing the 7000-Series Oscilloscopes. The March TEKSCOPE discussed servicing of the high-efficiency low-voltage power supply in the 7704.

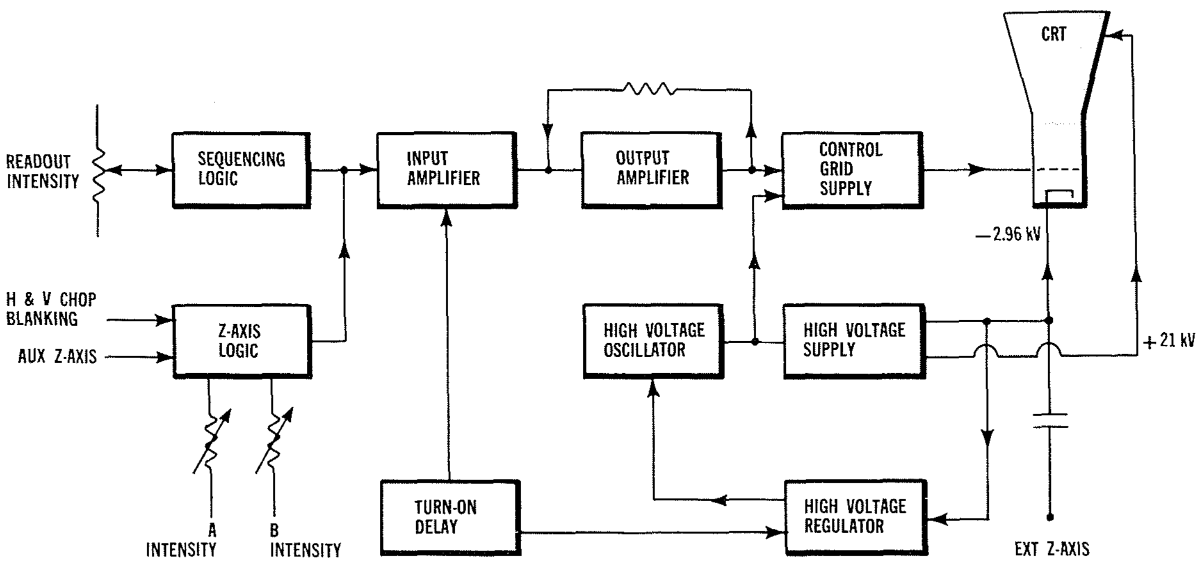
The CRT circuit in today's advanced oscilloscopes performs the same basic functions as in early day instruments. It produces the high-voltage potentials to accelerate the electron beam and provides control circuits to turn the beam on and off and to set the intensity level.

While the basic functions have not changed, the complexity of the functions has. As bandwidth and sweep rates have increased, so have accelerating potentials and the speed with which the beam must be turned on or unblanked. Multiple signals now often control the beam. Main and delayed-sweep unblanking, horizontal and vertical chopped blanking, CRT readout, and external Z-axis modulation must all be accommodated. Logic circuitry and a Z-axis amplifier provide a convenient means of processing these varied signals for control of the beam in the 7000 Series.

With the increase in complexity of the CRT circuitry arises the need for a systematic approach to servicing this portion of the circuitry. Several clues as to the probable location of a problem are available to us from the front panel. For example, there are three intensity controls on the 7704 front panel, A Intensity, B Intensity and Readout. The A and B Intensity controls are activated when plug-ins are inserted into the respective horizontal compartments. The readout is activated when a plug-in is inserted in any of the four plug-in compartments. Intensity levels set by the A and B Intensity controls pass through the Z-axis logic circuitry to the Z-axis amplifier, while the intensity level set by the Readout control goes through the sequencing logic to the Z-axis amplifier. This gives us a quick check to determine whether the problem exists in the Z-axis logic or elsewhere in the CRT circuitry.

Let's assume you have a plug-in in the A Horizontal compartment, the A Horizontal mode button depressed and the A Intensity and the Readout controls set to mid-range. You are experiencing intensity problems. Here are some symptoms and the probable causes:

1. No trace and no readout—
   a) Trace and readout off-screen—Pulling the beam finder control should bring the readout and trace on-screen.
   b) Readout locked up—Pull the readout board. If this clears the problem, U1210 on the readout board is a likely suspect.
   c) Defective Z-axis amplifier—If you have a spare Z-axis board, try replacing the entire board. If not, try replacing Q704, Q706 or Q718.



Block diagram of the 7704 CRT circuit. Note separate logic paths for readout intensity and A and B intensity.

d) Blown fuse F921—Replace the fuse located on the low-voltage regulator board. Corona discharge may cause the fuse to blow. Defective components in the high-voltage oscillator and rectifier assembly can also blow the fuse.

e) Defective CRT—See discussion on troubleshooting the —2960-volt supply. An open CRT heater or defective CRT socket can also be at fault.

2. A spot only, whose intensity is controlled by the Readout intensity control—Defective readout. Pull the readout board or replace U1210 on the readout board.

3. Readout only—

a) Trace off-screen—Pulling the beam-finder control should bring the trace on-screen.

b) Defective plug-in—Replace the plug-in. If plug-in is a time base, check to see that the controls are set to generate a trace.

c) Defective Z-axis logic—Replace U170 Z-axis logic IC.

4. Bright trace and readout but no intensity control.

a) Defective CRT.

b) Defective Z-axis logic or Z-axis amplifier.

c) Defective high-voltage circuitry.

5. Normal trace but no readout—

a) Defective readout board.

b) Defective plug-in unit.

TROUBLESHOOTING THE —2960-VOLT SUPPLY

Now let's take a closer look at some of the problems noted. First, that of no trace and no readout. We have determined that the trace is not off-screen and have pulled the readout board to eliminate it as a contributing factor. The next step is to check the —2960-volt cathode supply. This is available at a test point located in the high voltage assembly on the top right side near the rear of the instrument. A note of caution. Turn off the scope before applying or removing the meter lead to or from this test point. Corona discharge may damage some of the solid state components. If you have no voltage on this point, turn off the scope and disconnect the cable running from the CRT anode to the left side of the high voltage assembly. Lowering the swingdown chassis on the right side of the instrument gives you ready access to the anode cable connector. Touch the CRT anode lead to ground to remove the electrostatic charge on the CRT. After you have discharged the anode lead, turn the scope on. If the —2960-volt supply comes up, you have a bad CRT. If the supply still fails to come up, turn off the scope and remove the CRT base socket. This will remove any loading on the supply due to shorted elements in the CRT.

If you still do not have —2960 volts, check Q712, Q752, Q756 and Q758 on the Z-axis board. The oscillator transistors Q764 and Q766 can also be defective. If none of these units are at fault, you will need to get into the high-voltage assembly to troubleshoot further.

The simplest method to accomplish this is to lower the swing-down chassis on the right side of the instrument. Place a piece of cardboard or a tablet on the chassis as an insulator on which to lay the high-voltage assembly.

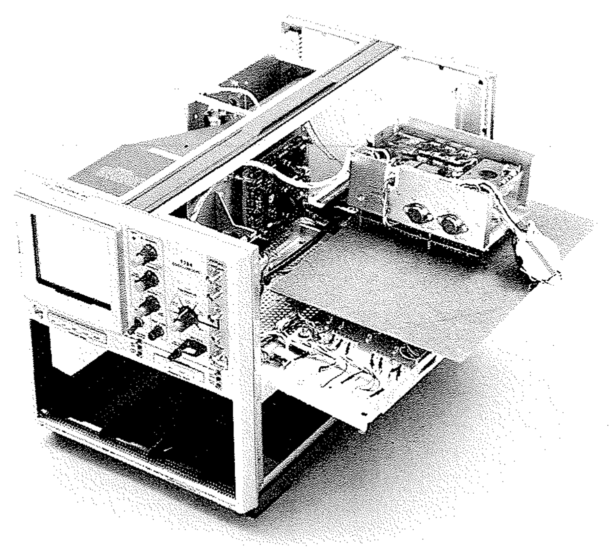
The assembly is removed by removing the seven screws holding the upper half of the back panel and the two screws holding the front of the assembly. Work the assembly around so you can lay it on the insulating material on the swing-down chassis. The brown and red leads from the trace rotation coil on some early instruments are too short to permit laying the assembly down. Just remove the Z-axis board, unplug the leads and dress them out of the way. They need not be connected to troubleshoot the supply. Reinstall the Z-axis board. Next, remove the plastic cover from the supply and locate the white-green wire running from the encapsulated assembly to the high-voltage transformer. Unsolder this lead and again check the —2960-volt supply. If it comes up, you have trouble in the encapsulated assembly and you will have to replace the entire assembly. If it is not at fault, leave the white-green wire unsoldered. This allows you to pick up the rest of the circuitry involved with the high-voltage transformer and the components around that area.

Another condition that would prevent the high-voltage oscillator from running is a shorted or leaky diode in the high-voltage secondary. We can check CR771 and CR772 by lifting their anode lead and taking a voltage reading. The anode of CR771 should read about —30 V and the anode of CR772 about —3 kV. We cannot lift CR781 to check it as this would remove the feedback to the regulator circuit. The best procedure is to replace it or substitute CR772 temporarily to determine if CR781 is defective.

Other possible causes of high voltage failure are the high-voltage transformer and filter capacitor in the secondary circuitry.

INTERMITTENT OR NOISY HIGH VOLTAGE

Another problem you may experience is an intermittent —2960-volt supply, flashes on the screen, or noisy Z-axis modulation. Principal source of this problem is the thick-film assembly containing resistors R740 through R744. On later schematics these are numbered R740A through E. The assembly is located in the high-voltage plastic housing and can be reached by lifting the circuitry from the housing.



High voltage supply removed for servicing. Insulating board between supply and swing-down gate allows unit to be operated while open for troubleshooting.

The elastic bands holding the thick-film card to the assembly are usually the culprit. The tails of the bands protruding through the circuit board sometimes come in contact with the high-voltage diodes causing a corona discharge. Clipping off these tails may cure the condition. Corona discharge also sometimes occurs between the elastic bands and the thick-film resistors. If removing the bands clears the problem, you can leave them off. If the problem is still present, replace the thick-film card. The leads to the thick film should be unsoldered at the circuit point rather than at the thick film as the card is coated with an insulating material.

NO INTENSITY CONTROL

When you have a bright trace and no control of the intensity, the first thought is to suspect the CRT. Shorted elements in the CRT will cause this. However, problems in the Z-axis amplifier can also give the same symptom. If Q724 or Q734 is defective, you will have no intensity control. A defective Q708 will cause the trace to be bright when the scope is first turned on then dim after several seconds to normal intensity.

Q732, the remaining transistor in the Z-axis amplifier, has no effect at slow or medium sweep rates. However, if you have modulation on the trace at faster sweep rates, suspect Q732. Incidentally, it's not readily apparent how to remove the heat sink from this transistor. The heat sink is in two sections; just unscrew the top from the bottom.

This covers most of the problems you may experience with the high-voltage section of the 7704. High-voltage circuitry in other 7000-Series instruments with readout is similar and can be serviced using the same techniques.

INSTRUMENTS FOR SALE

130LC Meter, $190. 115, $695. 514D, $350. S. King, 725 Little Silver Point Rd., Silvermere, Little Silver, N.J. (201) 741-3891.

3T2, 3S2, S3, 3 ft. cable ext., All $2250. R. Wagner, Wesleyan Univ., Physics Dept., Middletown, Conn. 06457. (203) 347-9411, Ext. 865.

535A with CA Plug-In. d b Electronic Enterprises, 13526 Pyramid Dr., Dallas, Texas 75234. (214) 241-2888.

535A with H Plug-In, $1000. 545A, $1250. G Plug-In, $125. Geo. Maxwell, Rescuair Corp., 9030 Owensmouth Ave., Canoga Park, Calif. 91304. (213) 882-6161.

556. Ron Seldon, Digital Development Corp., 7514 Clairemont Mesa Blvd., San Diego, Calif. 92111 (714) 278-1630.

454, Mod 163D. New condition. Palmer Agnew, 314 Front St., Owego, N.Y. 13827. (607) 687-2406.

Three new Mod 130 LC Meters. Bob Rust, (213) 889-1010, Ext. 1081.

545, CA, $550. J. R. Shapiro, 5 Lynn Dr., Englewood Cliffs, N.J. 07632 (201) 568-9287.

454, RM15, 130, 134, P6022. Three months old. Mr. Puzzuti, Aries Technology, 3475 Victor St., Santa Clara, Calif. (408) 248-9685.

Two 3A3's. B. Murray, Picker Electronics, 601 S. Bowen St., Longmont, Col. (303) 776-6190.

453, $1600. 555 w/2 D's, $1600. 585 w/81 Adapter, D Plug-In, $1500. Ed Franchuk, 1203 Opal Ave., Anaheim, Calif. 92805. (714) 546-0431.

Q Unit, $350. Never used. Vern Iverson, Possis Machine Corp., 825 Rhode Island Ave., S., Minneapolis, Mn. 55426. (612) 545-1471.

310. Norman Orr, Radio Specialists Co., 2450 W. 2nd Ave., Denver, Col. 80223. (303) 744-3461.

Two 422's. $1000 each. David Young, Interdata, Inc., 2 Crescent Pl., Oceanport, N.J. 07757. (201) 229-4040, Ext. 396.

531A, 1A2, N, L, $950. Michael Muegge, 100 Foerster St., San Francisco, Calif. 94112. (415) 931-8000, Ext. 522 or (415) 585-1625.

504, $400. 551, $1000. CA, $125. H, $125. Vince Murray, Audio Devices, 100 Research Dr., Glenbrook, Conn. (203) 324-6761.

561A/3A6/3B3 w/Probes, $1525. James Gamble, 21917 Grant Avenue, Torrance, Calif. 90503. (213) 542-2680.

453 Mod 127C, $1850. 191, $350. E. Paulaitis, 19 W. 380 Lake St., Addison, Ill. 60101. (312) 543-9260 or E. Lauer, (312) 259-6300.

453. Mike Logue, Heidelex Corp., Stuart Rd., Alpha Ind'l Park, Chemsford, Mass. 01824. (617) 256-3921.

545, $700. D, $60. K, $50. B, $45. L, $90. Time Mark Gen, 180-S2, $95. Frank Aamodt, Golden West Airlines, 4200 Campus Dr., Newport Beach, Calif. (714) 546-6570.

531, 53B, $400. Gene Mirro, P.O. Box 274, Hightstown, N.J. 08520 (609) 799-1495 after 6:00.

Two K's, $80 each. 80 w/Prb. & Atten., $80. Mr. Jordan, 1125 Greengate Rd., Fredericksburg, Va. (202) 337-7600, Ext. 711.

Will trade RM17 for 503. T. W. Moore, Mt. Holyoke College, South Hadley, Mass. 01075. (413) 536-4000.

661 w/5T3, 4S1, 51A and two P6032's. Will trade for 454. John Riccitelli or N. Bicknell, The Foxboro Co., Foxboro, Mass. (617) 543-8750.

Six 2A60's, unused. 25% discount. Harold Childers. (713) 771-5821.

512. J. C. Leifer, 328 Cree Dr., Forest Heights, Md. (301) 839-1548 or (703) 560-5000, Ext. 2773.

Sale or trade 1A1, 53/54 K, 110 Pulse Generator. Lawrence Kahn, Gamma Electronic Research Co., 6042 Rockrose Dr., Newark, Calif. 94560. Call evenings & weekends. (415) 797-2595.

317, $665. John Nicholas, Buckeye Cablevision, Inc., 1122 N. Byrne Rd., Toledo, Ohio 43607. (419) 531-5121.

575 Mod 122C, $1000. Jerry Setliff, Nuclearay, Inc., P.O. Box 9320, N.W. Station, Austin, Texas 78757. (512) 836-1120.

503, C-27. Dr. Farhang Soroosh, 1126 E. 2nd St., Casper, Wyoming 82601. (307) 234-2613.

541A, CA, $1000. Frank Cosenza, Trid-air Industries, Fastener Div., 3000 W. Lomita Blvd., Torrance, Calif. 90505. (213) 530-2220.

661/4S1/5T3 and Access. Mr. Mawson, Scientific Measurement Systems, 351 New Albany Road, Moorestown, N.J. 08057. (609) 234-0200.

Will trade N for M Plug-In, Four P6010 Probes. Lloyd Hanson, Tri-State College, Engineering-Business Adm., Angola, Ind. 46703.

INSTRUMENTS WANTED

561A, 564, 201-2. 565, 205-1. 1L20. Lawrence Kahn, Gamma Electronic Research Co., 6042 Rockrose Dr., Newark, Calif. 94560. Call evenings & weekends. (415) 797-2595.

564B and Engine Analyzer Accessories, including 2B67, 3A74, all accessory components. As package or separately. Henry Kovar, 11823 Porter Dr., R.R. #4, Osseo, Mn. 55369.

TEKSCOPE
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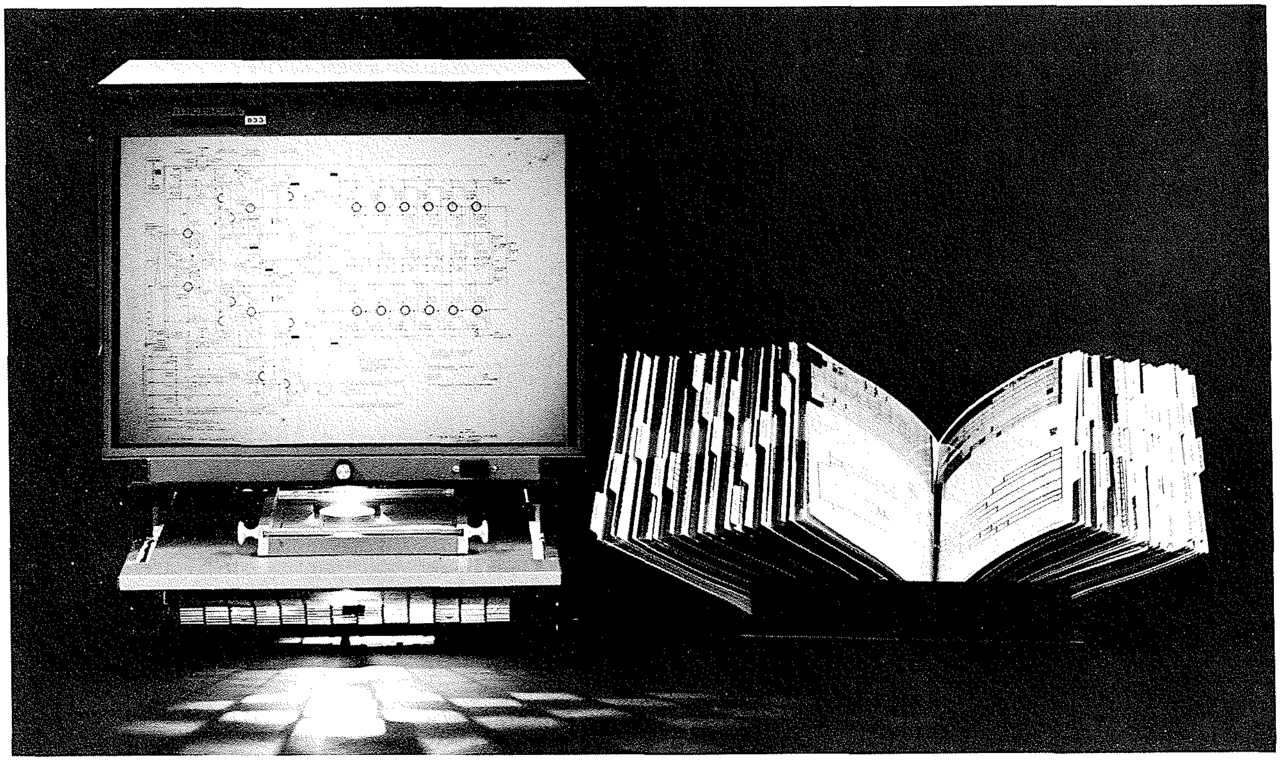


TEKTRONIX MAINTENANCE AND CALIBRATION LIBRARY

If you do in-house maintenance of Tektronix equipment, the system pictured above will help you to more effectively repair and recalibrate your Tektronix instruments. It is a micro-library of up-to-date information on the entire Tektronix product line. The information includes complete instruction manuals with latest revisions and change notices, and complete production modification history, including reasons for the modification and the effect it has. Effective serial numbers of each factory modification are noted. If a modification can be customer installed and improves performance or reliability, full instructions and parts lists are given.

The information is presented on microfilm—more precisely, map-indexed microfiche. This unique form of data presentation was developed at Tektronix for use in our own Service Centers where our Product Service Technicians are using the same information now available to you. Map-indexed microfiche combines sheet microfilm (microfiche) with an eye-readable index (map) on the same sheet of film. This concept allows direct access to the information of interest when the microfilm is placed in the reader.

The microfilm reader required for the system is The National Cash Register Company's Model 456-833T. This desk-top unit features a nonglare 13¼" high, 19½" wide screen for viewing double-page diagrams at larger than printed size. A two-position switch adjusts light intensity to any room.

Your field engineer can give you further details on the system.

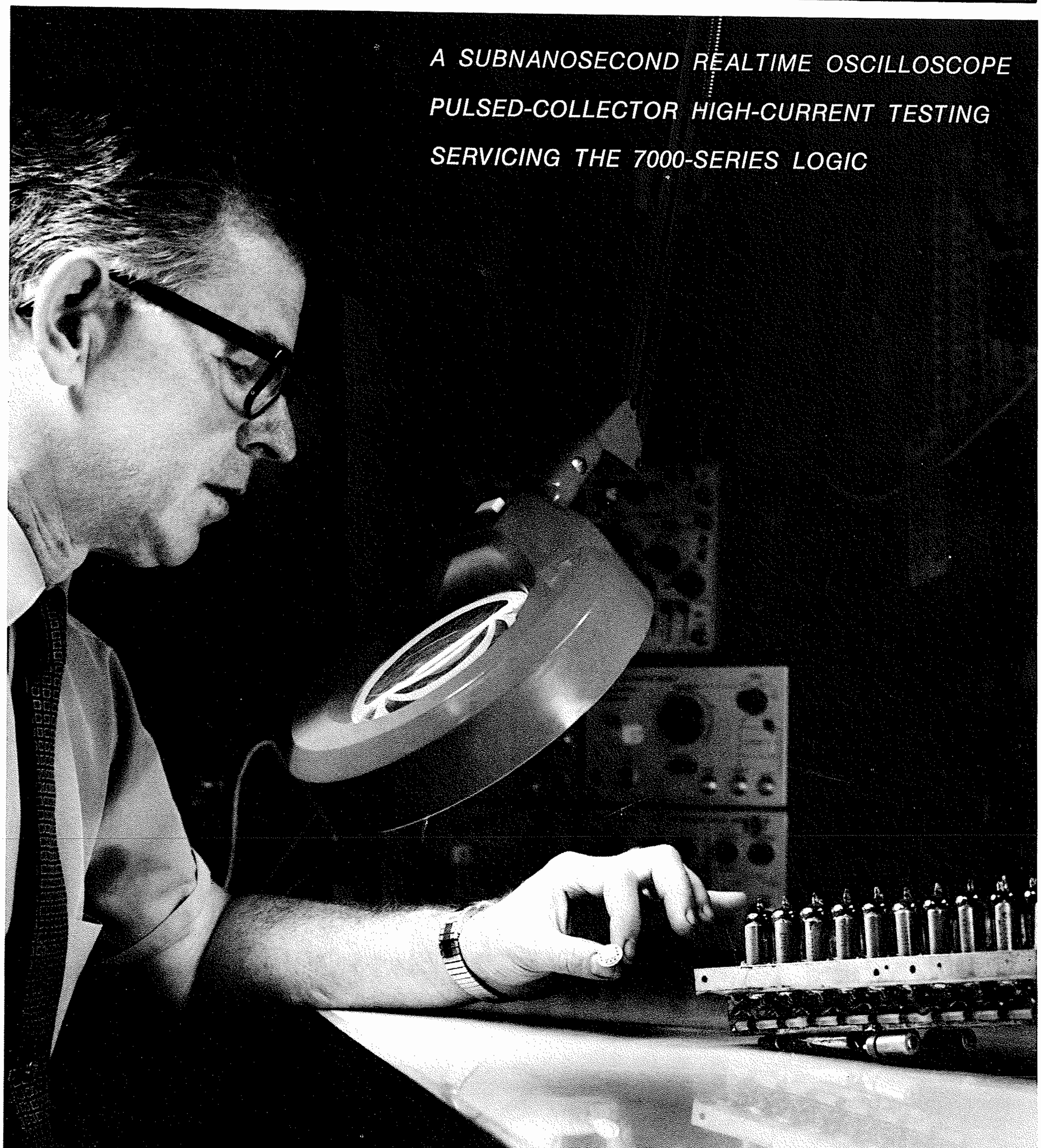
TEKSCOPE

JULY 1971

A SUBNANOSECOND REALTIME OSCILLOSCOPE

PULSED-COLLECTOR HIGH-CURRENT TESTING

SERVICING THE 7000-SERIES LOGIC



Jack Murdock

On May 16, Jack Murdock, Chairman of the Board and co-founder (with Howard Vollum) of Tektronix, Inc., suffered a seaplane mishap on the Columbia River. He has been missing since and is presumed drowned.

Many of you as Tektronix customers and friends have, through the years, expressed your appreciation for the quality of products and services provided by Tektronix. Jack was a major influence in instilling the pride of workmanship and concern for the customers' needs reflected in these products and services. That influence is best expressed in the following letter to Tektronix employees from Howard Vollum, President.

Newspaper stories since Jack Murdock's death have merely sketched, rather than elaborated on, his many achievements. This is fitting; Jack was a modest and unassuming man with no taste for the limelight.

Yet he was warm and outgoing. To many of you, as to me, he was a good friend, a person you could bring your problems to. Jack deserved his reputation as a great listener – always genuinely willing to tune into "the other guy's" point of view.

I met him in the spring of 1937. He had opened a store on 67th and Foster, after high school graduation. His father had offered to send him to college, or give him an equal amount of money to start a store. He chose the latter, and began Murdock Radio and Appliance Company.

While Jack was a very competent technician, it was more important that he spend full time managing the store. So I took on the radio service job. Jack was an excellent salesman, largely because he was such an exceptional listener. No high pressure at all, just genuineness; but many times I saw a person who had come in only to complain stay to make another purchase, once he had his troubles all talked out.

Jack was always oriented toward the customer's viewpoint, and toward the ideal of service. Both these characteristics were transmitted to Tektronix, when it was founded in 1946. He is responsible for our first-name salutations, for our disregard of status symbols and for many other ways we have come to behave toward one another, and toward our customers.

He led by setting an example. Despite his achievements, he was a humble man, without pretense. For many years our general manager, Jack was responsible for Tek's then-innovative "personnel policies" (although we didn't call them anything so formal then), most of which continue today.

But his biggest contribution was as the key Tektronix organizer. He was the person with enough business experience and contacts that the rest of us felt the thing would "go". Without his leadership, I think none of us – even though we knew by then we could build a superior product – would have felt comfortable starting such an enterprise.

Jack was deeply involved with the mental-health and human-relations aspects of industry, also with the study of semantics. He always felt that knowledge was the key to solving any problem, and that if you knew enough about it you could arrive at the appropriate solution. He played down his own academic achievements – largely because he had chosen not to go to college – but in terms of broad education, he had far more than many college graduates do.

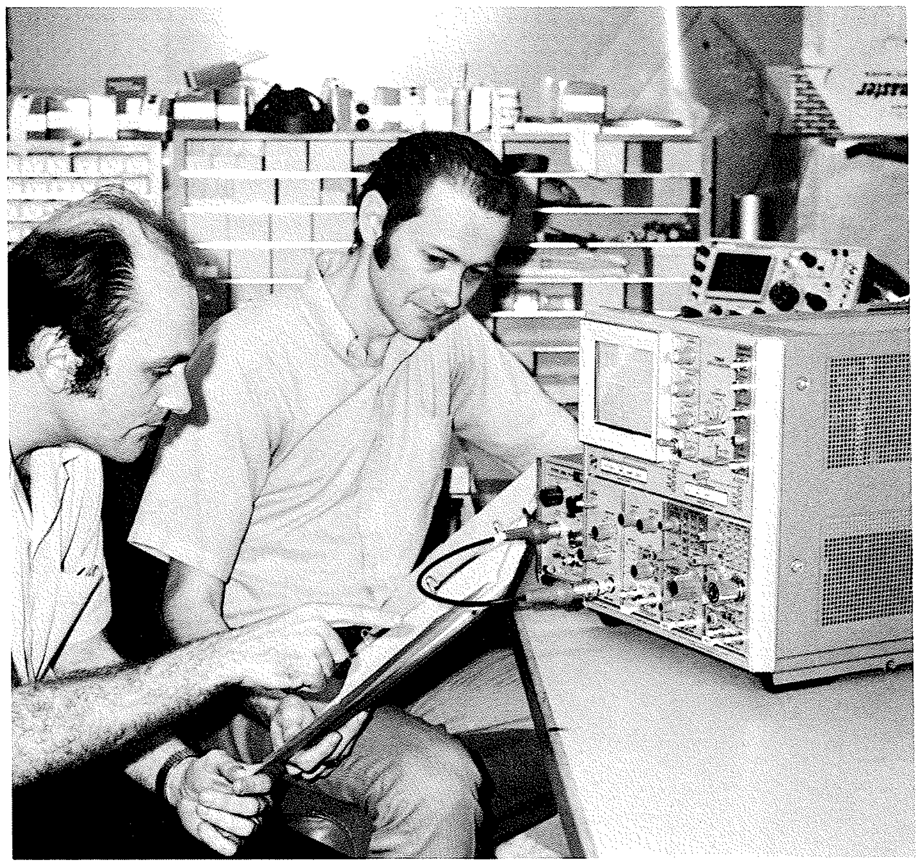
Although both eager and able to be outgoing, he intensely disliked personal publicity, particularly in the news media. (It was always my feeling, however, that he could have charmed any of the press corps off their feet.)

Many of his beliefs will live on as part of our company. But Tektronix, like the rest of the business world and the community at large, has suffered a loss now that his service to it has ended. The world is always the poorer when a positive influence is lost. So it will miss Jack Murdock, a good man and a close friend to so many of us.

Howard Vollum

COVER—Advances in state-of-the-art amplifier circuitry is dramatically illustrated in photo showing the output amplifiers for the 7904 and the 517. The 517, for many years, was the high-speed scope standard.

Val Garuts and Thor Hallen discuss operation of the 7904.



a subnanosecond realtime oscilloscope

"The window to electronics" – you have probably heard this phrase used to describe the oscilloscope. Today, we can see more through this window than ever before. The new Tektronix 7904 now expands the real-time horizon from DC to 500 MHz. We have viewed signals of this bandwidth before but with limitations. The signals needed to be several volts in amplitude to drive the CRT directly, or repetitive in nature to permit the use of sampling techniques. With the 7904, fast signals only a few millivolts in amplitude and of single occurrence can be measured.

With the introduction of the 7000-Series instruments in the fall of 1969, Tektronix brought unparalleled versatility and performance to oscilloscope users. The 7904, latest in this series, brings exciting new performance with no sacrifice in versatility. For example, any of the twenty-two 7000-Series plug-ins currently available can be used in the 7904.

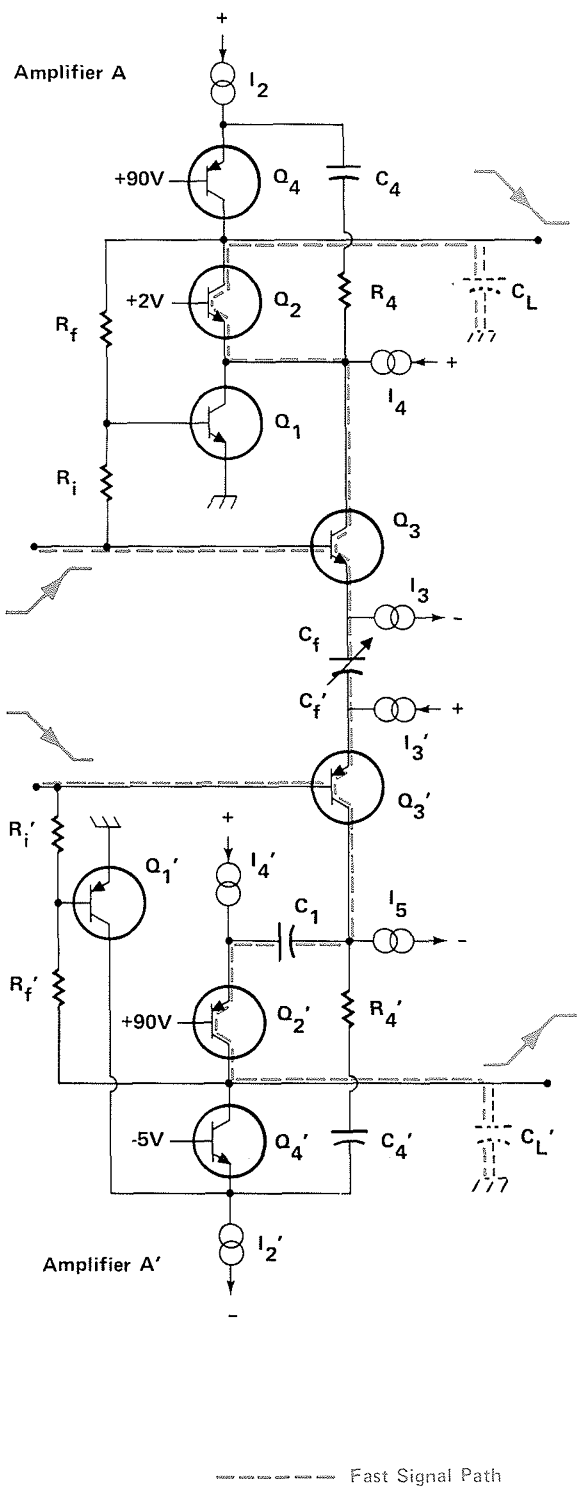
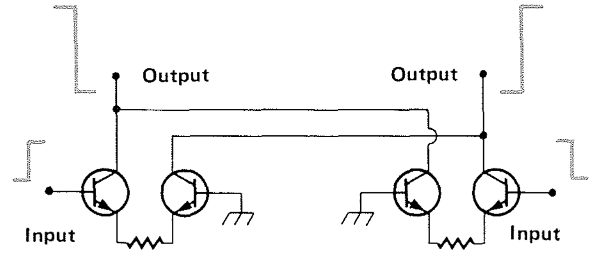


Fig. 1 Simplified schematic of the horizontal output amplifier.



The fT Doubler Circuit.

The CRT

Design work on the 7904 commenced with development of the cathode ray tube. The goal: a tube with sensitivity and spot size similar to the CRT in the 7704, but having 3 to 4 times the bandwidth and increased writing speed.

The 7704 CRT uses a segmented vertical deflection-plate structure with a top bandwidth of about 500 MHz. To achieve the additional bandwidth needed in the 7904, we selected a helical traveling-wave structure. Similar structures have been used in CRT's for high-speed scopes for several years. Their major drawbacks have been limited scan, low sensitivity, and cost.

The problems of sensitivity and limited scan are overcome by using a dome-shaped mesh electrode between the deflection-plate structure and the post-accelerator field. The mesh effectively shields the beam in the deflection area from the post-accelerator field and shapes the field to achieve a deflection magnification of 2 times in both the vertical and horizontal axis.

The optimum shape for the mesh to achieve good geometry was determined using a computer to plot the fields developed by the mesh, and the path of the electron beam through these fields. The equation producing the desired shape of mesh was then fed into a numerical control machine which made the tool for producing the mesh.

A unique method of fabricating the helical deflection structure yields a vertical scan of 8 cm and bandwidth in excess of 1 GHz. It is also relatively inexpensive to produce.

The CRT uses a ceramic funnel, now standard for most Tektronix CRT's, which permits edge lighting the internal graticule.

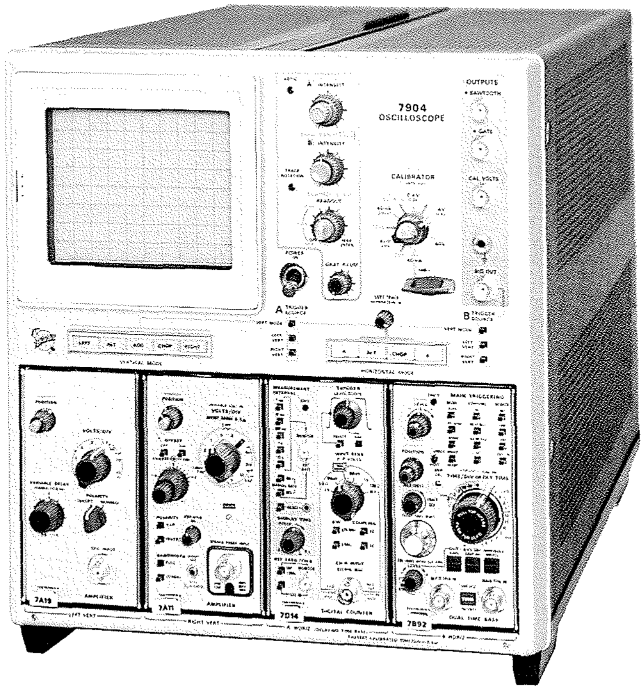
The 24 kV accelerating potential applied to the CRT yields excellent visual brightness and photographic writing speeds. Using a C-51-R Camera, P11 phosphor and 10,000 ASA film, the writing speed is 10 cm/ns. Fogging techniques extend this to 20 cm/ns.

THE VERTICAL SYSTEM

Coupled to the advances in CRT design is a vertical amplifier system containing many advances in state-of-the-art amplifier design.

Acquisition and processing of 500-MHz signals requires techniques considerably different from those used to handle signals in the 100-MHz region. In the early planning stages of the 7000 Series, the designers anticipated that bandwidth limits would be continually pushed upwards, and designed the interface between the mainframe and plug-ins to accommodate these greater bandwidths. The characteristic impedance at the interface is 50 ohms, an ideal environment for piping around UHF signals. In the 7904, the signal paths between circuit elements are all transmission lines terminated in their characteristic impedance. The result is a very clean transient response with aberrations typically less than 5%.

A new delay line design avoids preshoot and contributes much to the clean response. Optimized for maximum delay in a minimum volume, and short risetime, the line consists of two parallel solid conductors in a polyethylene dielectric with a foil wrap and extruded polyethylene protective jacket.



The 7904 DC to 500 MHz Oscilloscope System.

The input impedance of the 7A19 Amplifier Plug-in is 50 ohms. A Tek-made high-frequency cam switch permits input coupling of AC, DC or ground. The signal then passes through a 50-ohm turret attenuator providing deflection factors of 10 mV/div to 1 V/div. Attenuator switching is done ahead of the preamp except for the 10 mV/div position. The basic sensitivity of the plug-in amplifier is 20 mV/div. Since the 50-ohm line carrying the signal from the plug-in to the mainframe is double terminated, switching out the source termination increases the gain by a factor of 2 for a sensitivity of 10 mV/div.

An optional variable delay control permits matching the transit time of two preamps and probes to within 50 picoseconds. The delay is varied by mechanically moving a trombone section of transmission line. Range of delay is ±500 picoseconds.

From the variable delay the signal passes to the first amplifier stage. This is a unique wideband circuit which we call an f_T doubler. The simplified schematic opposite shows the basic circuit. The circuit was originally conceived several years ago by Carl Battjes. Considerable work by Thor Hallen coupled with the development of sophisticated IC fabrication techniques put the concept to practical use.

The f_T Doubler Circuit

f_T is the frequency at which the common-emitter current gain is one. If normal cascading of stages is used, no more than unity current gain can be achieved. The f_T doubler overcomes this limitation by effectively arranging for the base-emitter inputs of four transistors to be in series. The push-pull configuration allows the collectors to be effectively paralleled. At f_T the current gain of this arrangement is approximately two.

The f_T doubler can be thought of as an amplifier building block with twice the f_T of a single device. Using several of these building blocks, an amplifier with significant current gain at f_T can be built.

Once the basic design for the vertical amplifier had been chosen, the next step was to develop state-of-the-art high-frequency IC fabrication techniques to produce the transistors and couple them together. The emitter degeneration resistors were to be processed on the same chip with the transistors. This called for depositing precise amounts of nichrome on the substrate, a state-of-the-art process in itself. Since many critical processes were involved in producing a single f_T doubler stage, we decided to use a separate IC for each stage rather than integrate the entire vertical amplifier on one chip. The mainframe vertical amplifier uses three f_T doubler stages with coupling between stages via 50-ohm transmission lines.

The Output Amplifier

The output amplifier is a hybrid IC with a substrate carrier for mounting five silicon chips. Included on the IC is an f_T doubler, two small chip capacitors and two discrete output transistors.

Considerable design effort was expended in eliminating circuit elements that did not contribute to improving the signal gain. For example, there are no DC level shifting stages in the amplifier. The inductance of bond wires in the IC's, usually a problem in high-frequency design, is used as peaking inductance. There are no high-frequency adjustments in the vertical amplifier in the conventional sense. Transistor leads forming half-turn inductors are adjusted for optimum transient response.

THE TIME BASE PLUG-IN

The 7B92 Dual Time Base Plug-in used in the 7904 system features a fast 500 picosecond/cm sweep which complements the ultra-high bandwidth of the 7904 mainframe.

Delaying sweep measurements are made more convenient by a single front panel control which selects sweep rates for both normal and delayed sweeps, and selects either for display.

A new system of triggering the delayed sweep permits setting the time delay control to zero to view the triggering event on the delayed sweep.

An ALTERNATE sweep mode, available for the first time in a single plug-in, provides essentially dual beam operation for many applications.

Viewing of signals to 600 MHz and beyond is possible using the HF Sync triggering mode. When using an external trigger, either 50-ohm or 1-megohm input impedance can be selected to minimize loading of the trigger source.

THE HORIZONTAL AMPLIFIER

The top sweep rate of 500 picoseconds/cm places some pretty stringent demands on the horizontal amplifier. The CRT horizontal deflection plate sensitivity is 7 volts/cm which means the output amplifier must swing 70 volts in five nanoseconds. Fig. 1 is a simplified schematic of the circuit developed by Val Garuts to provide the fast, large-signal amplification needed in the output amplifier.

The horizontal output amplifier actually incorporates two amplifiers: A and A′. Amplifier A provides drive to the negative-going deflection plate and so is designed to have good performance in the negative direction of output. Amplifier A′ drives the positive-going deflection plate and has good performance for positive-going output signals.

Each amplifier provides two signal paths to its horizontal deflection plate, a high-frequency path using series feedback and a low-frequency path using shunt feedback. The bandwidth of the high-frequency path is 1 MHz to about 200 MHz and that of the low-frequency path is DC to about 30 MHz.

The high-frequency path for Amplifier A is through Q3 and Q2 to C_L, the load capacitance, consisting of the deflection plate, output amplifier and distributed capacitance. The gain of the fast (series-feedback) path is the ratio of the feedback capacitance to the load capacitance (C_f/C_L). C_f is made variable and set for a gain of ten for the high-frequency path.

The low-frequency path is through Q1 and Q2 to C_L. The values of the input resistance and feedback resistance are chosen to give the low-frequency amplifier a gain of ten also.

Amplifier A′ driving the positive-going deflection plate is arranged slightly differently, but the dual-path principle is maintained. The fast path is through Q3′ and Q2′ as before but a coupling capacitor C_I is inserted between them for DC blocking.

The low-frequency path is through Q1′ and Q4′ (rather than Q2′) because of the DC level at the emitter of Q2′. A gain of ten for both low- and high-frequency paths is selected as in Amplifier A.

An additional fast path is provided in each amplifier by C4, R4 and C4′, R4′ to speed up the positive transition of C_L and the negative transition of C_L'.

The Z-Axis Amplifier

The Z-axis amplifier in the 7904 uses a dual-path amplifier similar to the positive-going horizontal amplifier. The main difference is that the high-frequency path consists of PNP devices and the low-frequency path uses only NPN devices. This provides large output current for a negative-going output, and while the risetime in the negative direction is not as fast as in the positive direction, it is considerably faster than in the configuration used in the horizontal amplifier.

THE POWER SUPPLY

Both the low-voltage and high-voltage supplies in the 7904 are contained in a compact unit weighing just 7½ pounds. The high-efficiency supply provides 150 watts of regulated DC at an efficiency of about 80%.

A considerable savings in cost, weight and space is realized by winding both low-voltage and high-voltage transformers on a common core. The inverter, operating at about 23 kHz, drives both supplies.

Pre-regulation to better than 0.5% is achieved by controlling the inverter conduction time. The control circuitry is designed to switch the inverter transistors off at the zero-voltage point on the sinewave. This eliminates the large amount of EMI normally generated by high-efficiency supplies, and reduces the likelihood of damaging the inverter transistors.

Secondary regulation of the high-voltage supply is achieved using an amplifier to control only the −3 kV section of the supply.

Acknowledgments

Design of the 7904 system was a team effort. Val Garuts was project manager and developed the large signal amplifier circuit used in the horizontal and Z-axis amplifiers. Thor Hallen did the vertical amplifier and John McCormick the horizontal. The trigger and time base were done by Les Larson and Bill DeVey. Bill Peek worked on the Z-axis amplifier and auto-focus, with Hans Springer doing the mainframe interface and channel switching. Joe Burger's work on the power supply, coupled with Joel Swanno's efforts in mechanical design, reduced the weight to only 30 pounds. Ken Hawken did the fine job on the CRT. Certainly much credit is due the IC development team who built the devices that make possible the 7904's 500-MHz bandwidth.

TEKNIQUE: PULSED-COLLECTOR HIGH-CURRENT TESTING WITH THE 176

by Jim Knapton, Senior Engineer

The 176 Pulsed High-Current Fixture brings a new dimension of operating convenience to semi-conductor high current and high power testing. Used with the 576 Curve Tracer, it provides currents up to 200 amps peak and power levels up to 1000 watts.

With the pulsed collector supply, new tests are possible in the area of breakdown voltage where the device normally would latch up. Other tests are possible at current levels available in the 576, but which could not be made on low power devices because of the duty cycle. Probably the two most neglected tests now made possible are rectifier forward drop at normal peak operating current, and transistor secondary breakdown.

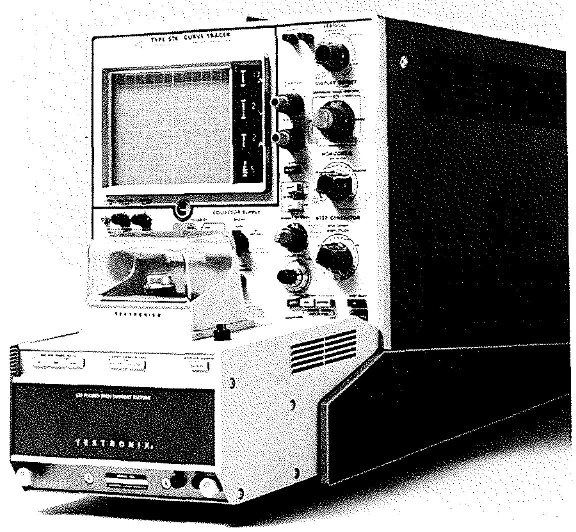
The pulsed nature of the 176 collector output with its low (1.8%) duty cycle makes heat sinks unnecessary in most cases — even at the highest power levels. The same Kelvin contact device adapters used for low power tests may be used even at the highest current levels, and device adapters to cover the more common high power device packages are now available.

Soon to be announced is a TO-5 device adapter with Kelvin contacts. This will make possible accurate high current measurements on devices in TO-5 and other small signal packages. The internal wiring of the adapter can be readily rearranged for different lead configurations.

Now, let's look at some of the measurements that can be made with the 176.

Power Transistor High Current Beta and Saturation Tests

The 176 may be used to perform high current beta, saturation and breakdown tests on power transistors. Saturation and beta tests may be performed at collector currents up to 200 amps and, as previously noted, usually without using heat sinks. Because of the Kelvin connection method of measurement, devices may be connected using relatively small wires without measurement error. However, the voltage drop that occurs in the collector and emitter leads will limit the peak currents obtainable. The maximum peak power watts position that should be used will depend on the device being tested. In general, the 10 and 100 positions are safe for forward biased transistor characteristics without heat sinks, if the peak collector voltage is limited to a value below device breakdown. The 1000 position should be used with some caution as average power dissipation can be about 20 watts (1.8% duty cycle).



The 176 Pulsed High-Current Fixture slides into the 576 in place of the Standard Test Fixture. It provides a pulsed collector supply of 200 amps peak and pulsed step generator output of 20 amps peak.

Because Kelvin connections are not used on the *base* connection, some measurement error could be present when making $V_{BE\,(SAT)}$ measurements.

Figure 1 shows DC beta (h_{FE}) of a Westinghouse 1743-0620, TO-3 power transistor. The point of interest is a collector current of 90 amps at a collector voltage of 10 volts. This particular device required eight steps of 500 mA each to get 90 amps of collector current. Since $h_{FE} = I_C/I_B$ we have $90 \div (8 \times 0.5)$ for an hFE of 22.5. If the base steps selected do not give us a curve that crosses the desired reference point, we can use the step generator offset to achieve the desired collector current. This offset must be added to or subtracted from the base current drive when calculating beta.

Keep in mind that when the X10 step button on the 176 is illuminated, the steps and offset are both pulsed. When it is extinguished, only the steps are pulsed. A note of caution — it is possible to put excessive average power into a transistor base when making high current collector measurements using offset base drive.

Small signal beta (h_{fe}) can easily be measured by noting the distance between two characteristic curves for different base drive levels. The β per division readout does the calculating for you. All that is necessary is to multiply the vertical separation of two adjacent curves by the β per div readout. For example, the h_{fe} of this device is about 9 at 90 amps. The display offset can be used with the vertical magnifier to improve resolution for this type of measurement.

$V_{CE\ (SAT)}$ can be readily read from the same photograph. For example, $V_{CE\ (SAT)}$ at 50 amps is 3.0 volts and for 90 amps it is 6.9 volts.

Transistor Breakdown Tests

The pulsed collector feature of the 176 makes it possible to make many breakdown tests that would otherwise destroy the device. This applies to secondary breakdown or any other situation where the device will "latch up" so that a pulsed base test cannot be used. For this reason, the 176, is quite useful for measuring breakdown voltages of small signal transistors as well as high power devices.

There is a less convenient way to test BV_{CEO} where latch up may occur, using only the 576. It involves using one step of offset to saturate the transistor at all times except during the 300 or 80 microsecond base pulse interval. During this interval, the offset is canceled by a one step base pulse, effectively opening the base momentarily while the measurement is made. This method can be used only at relatively low currents.

When measuring reverse breakdown characteristics with the 176, the maximum peak power watts 10 position should usually be used. Caution must be exercised whenever looking at reverse characteristics as small amounts of power in the breakdown mode destroy some very high power devices.

There is no provision on the 176 to open the base connection. However, BV_{CEO} can be measured by setting the base step generator to a very low current position so that for all practical purposes the base can be considered as open.

BV_{CES} is measured by connecting a patch cord between the BASE and GND connectors on the front of the 176. Care must be taken to avoid dangerous shock when connecting the jumper if the collector supply is energized on the 75 V or 350 V range. The device under test might be shorted collector to base and open base to emitter. An insulated jumper should be used and it should be connected to GND terminal first. Quite often the breakdown characteristic will be such that oscillations will occur because of the negative resistance region of this characteristic.

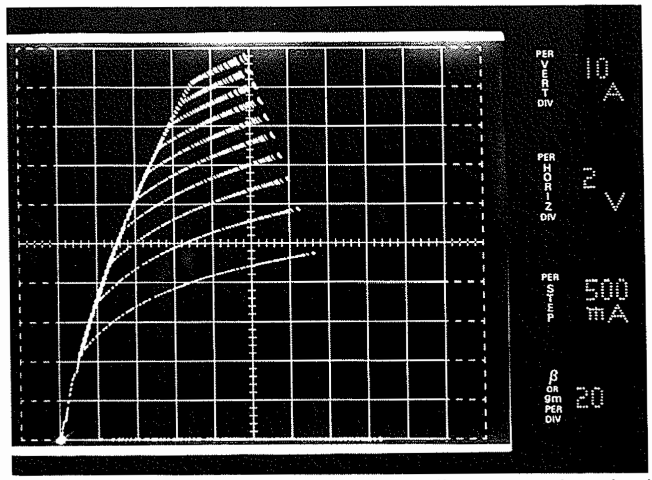


Fig. 1 Family of I_C vs V_C curves with collector supply pulsed on for 300 μs at power line frequency. Photos of waveforms are time exposures with the collector supply control manually advanced.

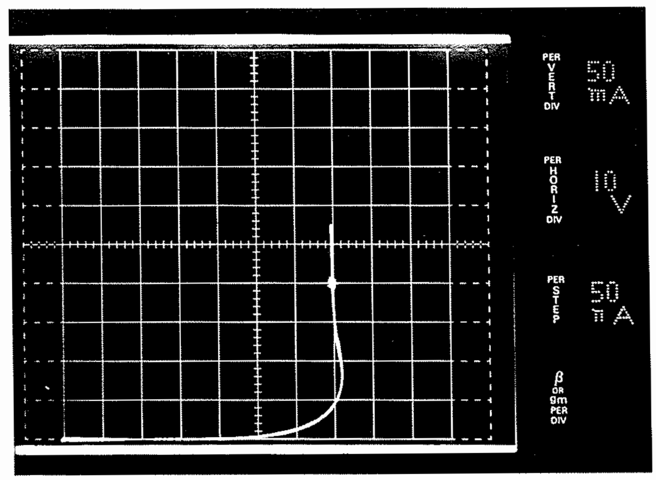


Fig. 2 Open base breakdown ($BV_{CEO(SUS)}$) of a 2N3771 measured at 200 mA. Bright spot at 200 mA is caused by momentary pause in manual advance of collector supply at point of interest.

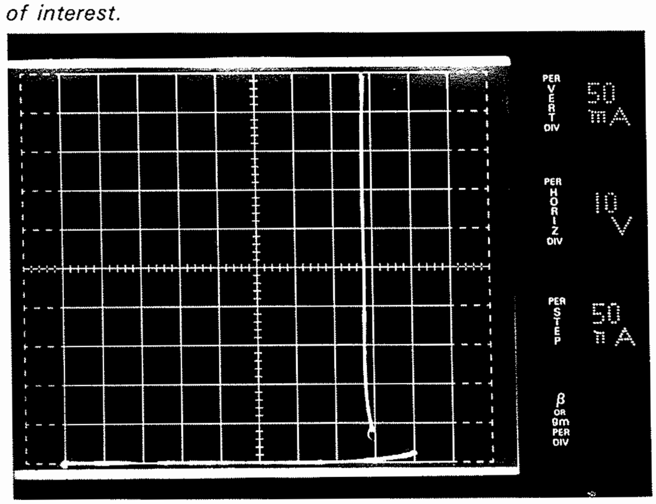


Fig. 3 Collector breakdown with the base shorted to emitter $BV_{(CES)}$ for the same 2N3771 pictured in Fig. 2.

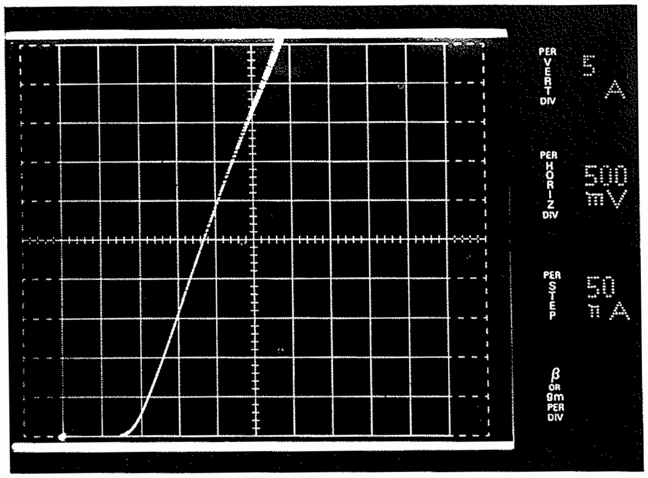


Fig. 4 Curve showing forward drop of 1N3194 rectifier. Note dot slashing above 35 amps caused by junction heating.

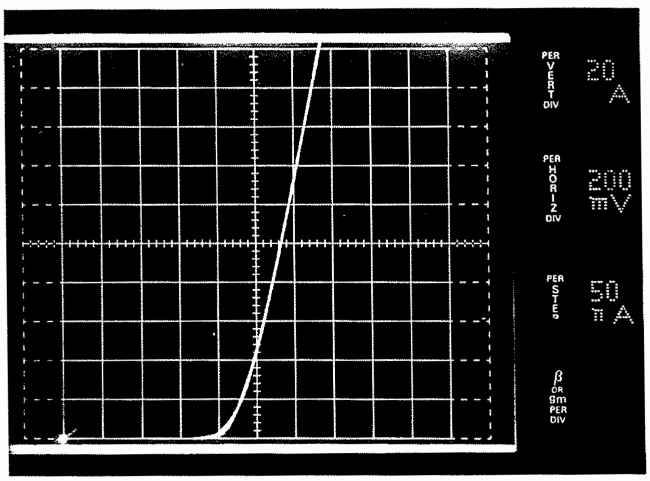


Fig. 5 Curve showing forward drop of 1N4721 3-amp rectifier at 200 amps illustrates high current capability of the 176.

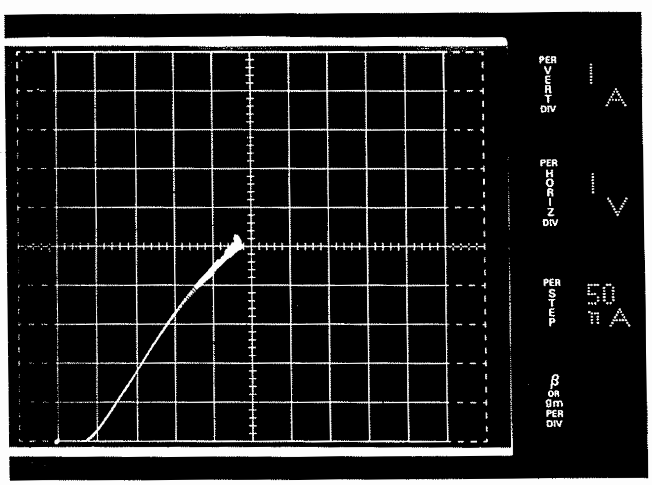


Fig. 6 Voltage vs current curve of a 1N3605 small signal diode graphically illustrates dot slashing caused by junction heating with excessive drive.

Figure 2 shows a 2N3771 silicon NPN power transistor tested for open base breakdown ($BV_{CEO(SUS)}$) at 200 mA.

The base terminal is opened by adjusting the step generator amplitude to .05 μA, as previously discussed. The variable collector supply is adjusted to obtain the desired current. Some enlarging of the spot will occur, especially before breakdown occurs. This is caused by the collector waveform turning on the base through the capacitance between collector and base. It can be ignored by measuring only the lowest current point on the enlarged waveform.

Figure 3 shows the same 2N3771 transistor as in Figure 2 tested for collector breakdown at 200 mA with the base shorted to the emitter (BV_{CES}).

To perform the test, the BASE and GND terminals at the front of the instrument are shorted with a patch cord. Then the variable collector supply is increased until the 200 mA level can be observed.

Rectifiers

With the 176 it is possible to test rectifier forward drops at currents up to 200 amps. Because the tests are done with pulses at a low duty cycle, far higher currents can be used than would otherwise be possible. For example, the Type 1N3194 rectifier is rated at 750 mA I_F average, 7.5 amps repetitive peak current and 40 amps non-recurrent peak current. Forward drop can easily be measured at 750 mA using the full wave rectified pulsating DC collector sweep of the 576. However, this does not represent actual operating conditions in a capacitor input filter. The forward drop at 7.5 amps is more meaningful as this rating allows for the actual operating current which might be encountered in a capacitor input filter. However, forward drop at this current level cannot be safely tested except at a low duty cycle such as provided by the 176.

The photo in Figure 4 shows the forward drop of a 1N3194 rectifier. The test shows the forward drops at these specified ratings to be 800 mV, 1.2 volts and 2.4 volts respectively; well within the specification. The tests at 750 mA and 7.5 amps were conducted casually with no heat sink and with plenty of time to take readings or photographs. Above the 40 amp level the device was heating rapidly but there was adequate time to take the photo without damaging the device.

Care should be taken to select the proper maximum peak power watts setting on the 176. In general, most rectifiers of the 500 mA to 1 amp variety cannot be destroyed on the 100 position if not tested for long periods of time.

Reverse breakdown of rectifiers can be investigated at higher current levels than possible before if the device has a breakdown of 350 volts or less. It is recommended that the maximum peak power watts 10 position be selected.

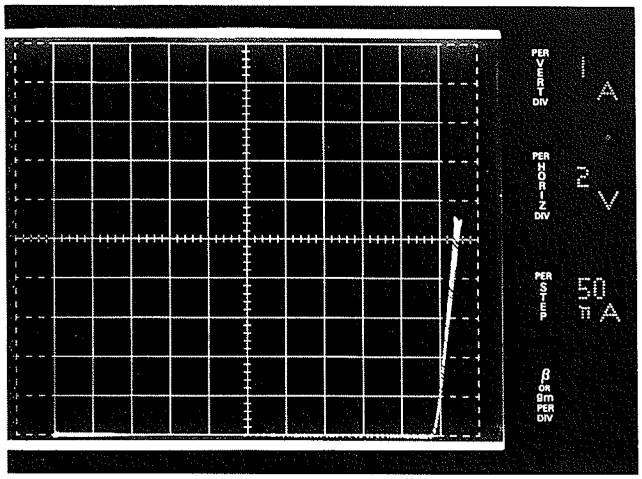


Fig. 7 Forward drop of zener diodes at high current levels can be readily checked with the 176. Curve shows characteristic of 1N3027B zener at 5 amps.

Small Signal Diodes

Just as with power rectifiers, it is possible with the 176 to test small signal diodes at high current levels not possible with the 576. However, care must be taken not to destroy the device. If the maximum peak power watts position of 10 is selected, the maximum obtainable average power will be about 200 mW in the 300 μs pulsed steps mode. The maximum peak power may be as high as 10 watts which will cause some junction heating during the pulse, depending on the thermal time constants.

When observing forward voltage current characteristics this will show up as a slash in the dot that is along the load line rather than along the characteristic curve. It increases in amplitude as the variable collector supply is advanced. When slash like this starts to occur, further advancement of the variable collector supply control may destroy the device.

Breakdown characteristics of the diode may also be displayed. However, it is very easy to destroy the unit as no warning is displayed prior to failure.

Figure 6 shows the voltage vs current characteristic of a 1N3605 small signal diode. This diode has an average current rating of 150 mA. Note the dot slashing caused by junction heating that is occurring above about 3.5 amps. The 80 μs pulse width may prove useful at these higher current levels. If some devices of a given type exhibit more change during the pulse than others, it may indicate poor die attachment.

Zener Diodes

With the 176 it is possible to measure zener breakdown voltages at high current levels. The maximum peak power watts 10 position should be used on 400 mW and lower zeners to avoid overheating. On higher power devices, the higher power levels may be used. Stud mounted devices can be tested on the 100 or 1000 positions if care is taken to avoid overheating.

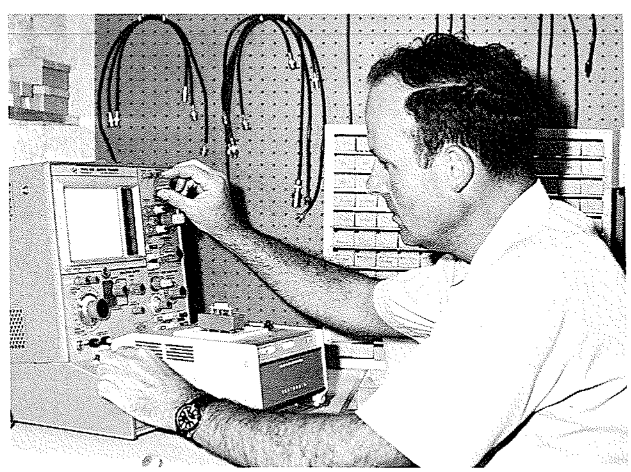
Figure 7 shows the voltage drop at 5 amps of a 1N3027B, 20 V, 4 watt zener diode. This particular device has a V_2 of 20.9 V at 5 amp. If a reading of greater accuracy is needed, first obtain the desired current without using the display offset, being careful not to over dissipate the device. Then use the display offset to magnify and reposition the display for a more accurate measurement.

Silicon Controlled Rectifiers

The 176 may be used to test the forward drop of SCR's at currents up to 200 amps. Testing methods would be the same as for ordinary power diode rectifiers except that the step generator must be used to turn the gate on. Gate firing levels may be determined readily using the offset feature of the step generator.

JAMES H. KNAPTON—Jim started his career with Tektronix in November, 1961 with design of the horizontal amplifier and calibrator in the 647, Tek's first solid state lab scope. After a period of working with pulse generators and time mark generators, he tackled the chore of developing a replacement for the 575 Curve Tracer. Jim contributed many of the fine features found in the 576, and recently added the 176 Pulsed High-Current Fixture.

Jim received his BSEE in June of '48 from the University of California at Berkeley. He spends his leisure time sailing with his wife and two children, skin diving and dabbling in photography.



SERVICE SCOPE

SERVICING THE 7000-SERIES LOGIC AND READOUT

by Charles Phillips,
Factory Service Technician

This is the concluding article on servicing the 7000-Series oscilloscopes. Other articles in this series appeared in the March and May issues of TEKSCOPE.

The one word that best describes the 7000-Series oscilloscopes is versatility. The key to this versatility is the logic circuitry which develops control signals for circuits in the plug-ins and the mainframe. The CRT readout also plays a key role in extending this versatility to encompass measurement areas formerly outside the scope domain. Digital multimeter and counter applications are now conveniently handled by Tektronix oscilloscopes using the CRT readout.

This article discusses servicing the logic and readout circuitry. Since the instrument instruction manuals include detailed operation of these circuits, we will limit this discussion to a brief summary of their operation and then discuss troubleshooting techniques and typical problems.

The Logic Circuit

The logic circuit is comprised of seven integrated circuits, seven transistors and a handful of components all located on one circuit board. The logic board is mounted on the rear of the main interface circuit board.

The basic functions of the logic circuits are to:

1. Provide command signals to the Vertical Channel Switch, Horizontal Channel Switch and Trigger Selection Circuit.
2. Provide CHOP and ALTERNATE drive signals to dual trace amplifiers.
3. Provide sweep inhibit signals for either the A or B Time-Base Plug-ins.
4. Provide logic for steering of Z-axis signals from:
   a. Time-base plug-in blanking circuits.
   b. A and B intensity controls.
   c. External Z-axis inputs.
   d. Vertical and horizontal chopped blanking circuits.
   e. Z-axis commands from the readout circuit.

All of the logic inputs and outputs are binary signals except for the Z-axis logic. The external Z-axis input, the intensity control inputs and the Z-axis logic output are analog signals. Inputs to the logic circuits come from the Vertical and Horizontal Mode Switches and the plug-in units. In addition, the Z-axis logic receives inputs from the sequencing logic in the readout, the intensity controls and the external Z-axis input.

The logic circuit outputs go to the Vertical Channel Switch, the Horizontal Channel Switch, the Trigger Selection Switch, the plug-ins and the Z-axis amplifier.

Mainframe Interface Switches

We should briefly discuss the function of the vertical, horizontal and trigger selector switches. Each is a separate etched circuit board mounted on the main interface board.

The Vertical Channel Switch determines which input signal drives the delay-line driver. The Horizontal Channel Switch determines which input signal drives the horizontal amplifier, and the Trigger Selector Switch determines which trigger signal is connected to the A and B Time-Base units. It also provides the drive signal for the Vertical Signal Amplifier whose output is the Vertical Signal Out.

A block diagram of the switches with their respective inputs and outputs is shown in Fig. 1.

Pictured on pages 13 and 14 are the switching sequences of the horizontal and vertical channels for several modes of operation.

The Vertical Mode Switch selects one of two different binary signals to be the Vertical Mode Command. In CHOP operation the Vertical Chop signal (1 MHz) is the command signal. When the Vertical Mode Switch is in ALT, the output of the Vertical Binary is the command signal. In this mode the command signal changes state at the end of each sweep (with Horizontal ALT) or at the same time the Display B Command switches (with Horizontal CHOP).

Notice that with the Vertical Mode Switch in ALT (Fig. 2 a and b) that the left vertical is slaved to B sweep and the right vertical to A sweep. This is with the time bases operated in INDEPENDENT mode. If the delayed sweep is used, the switching sequences are changed to that shown in Fig. 3 a and b.

The switching sequences for dual trace plug-in operation are shown in Fig. 4 and 5. The plug-in CHOP command (500 KHz) is always present regardless of the mainframe operating mode selected. It is directed only to the vertical plug-in compartments.

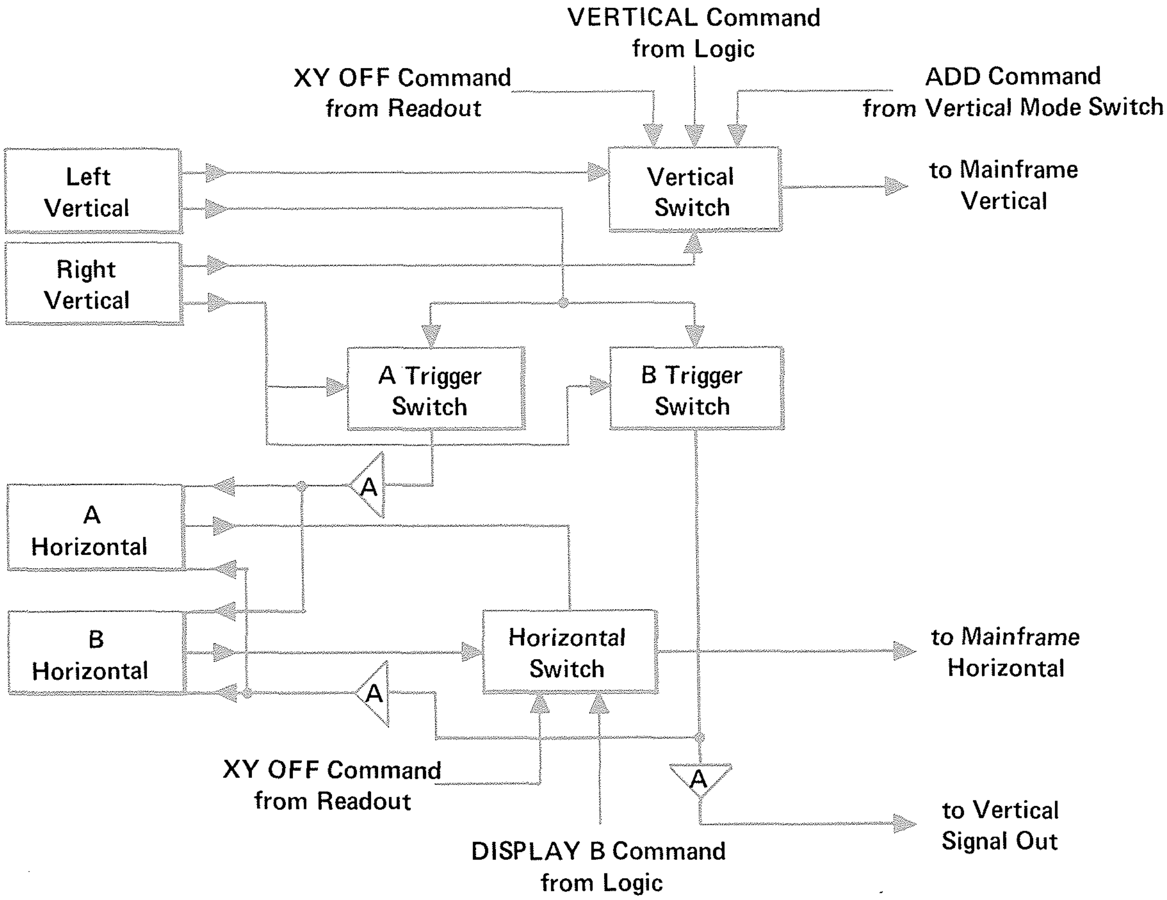


Fig. 1 Vertical, Horizontal and Trigger switching block diagram.

The plug-in ALT command is connected to all four plug-in compartments. It switches states at the end of each sweep for LEFT or RIGHT Vertical operation in the mainframe. In Vertical Mode ALT the plug-in binary counts down by 2 so that the plug-in ALT is operating at half the rate of the mainframe Vertical ALT. Notice that in Fig. 4a and Fig. 5a and b that left vertical is slaved to B sweep and right vertical to A sweep. When the Horizontal Mode is ALT or CHOP, the Vertical Mode is LEFT or RIGHT, and a dual trace plug-in is operated in ALT, Channel 1 is slaved to B sweep and Channel 2 to A sweep.

Troubleshooting the Logic Circuit

There are twenty display modes possible using the Vertical Mode and Horizontal Mode switches on the front panel. In addition, there are several other modes available using the mode switches on the vertical and horizontal plug-ins. Since it is beyond the scope of this article to present the logic signals for each of these modes, we have elected to list the logic output levels available at the test points on the logic board and describe what these levels accomplish. Also listed are the operating malfunctions that would occur should a given active component fail in the logic circuit.

Most of the problems experienced in the logic circuitry are caused by temperature-sensitive components. A can of spray coolant can be very helpful in locating this type of problem.

Following is a list of the logic outputs showing the output level and the function performed. The command signals from the logic circuit are typically small. In most cases the high level is about +1.0 volt and the low level about -0.5 volt. You will need to remove the low-voltage power supply from the scope mainframe to reach the test points on the logic board.

TP 196 Vertical Mode Command – A high level displays the right vertical channel.

TP 137 Plug-in Chop Command – A high level displays channel 2 in dual trace plug-ins.

TP 190 Plug-in Alternate Command – A high level displays channel 2 in dual trace plug-ins and is locked (slaved) to the A horizontal time base when the horizontal mode is in ALT or CHOP.

TP 164 Display B Command – A high level displays the B horizontal time base.

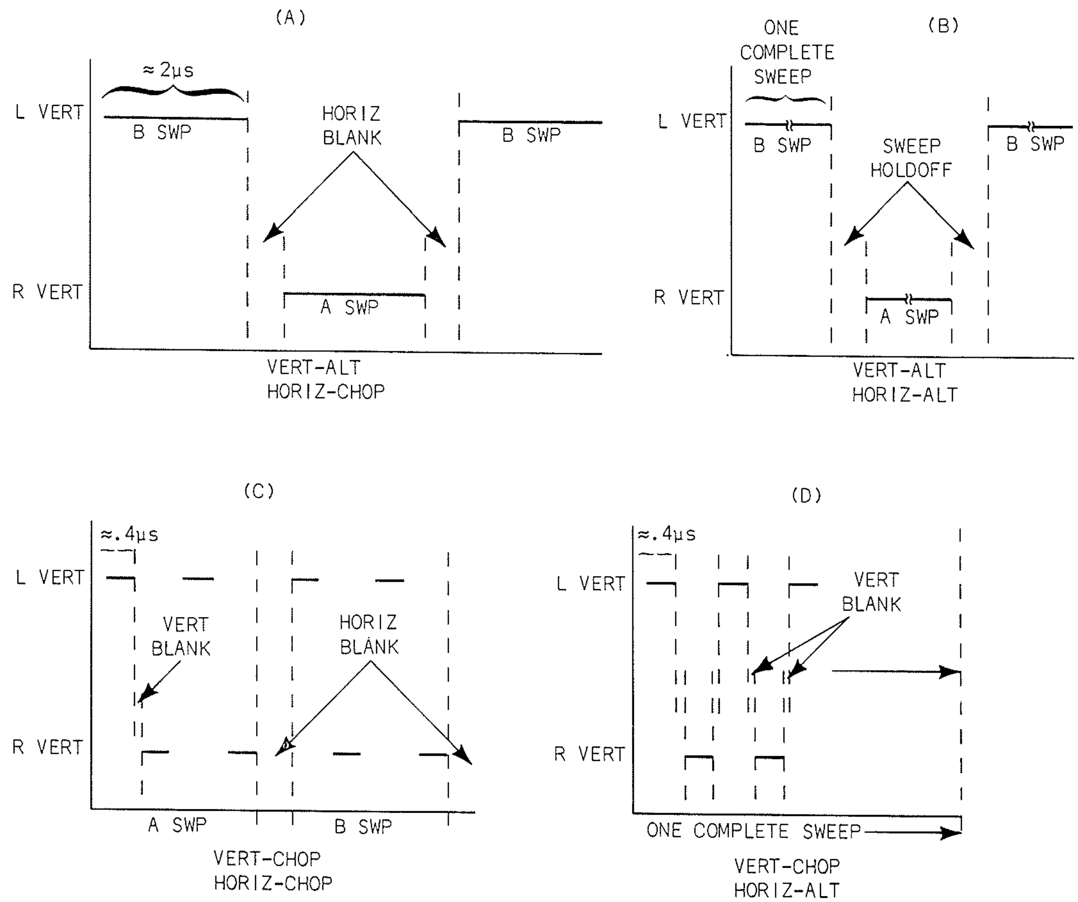


Fig. 2 Switching sequence of two single trace amplifiers with two time base units operated in the INDEPENDENT mode.

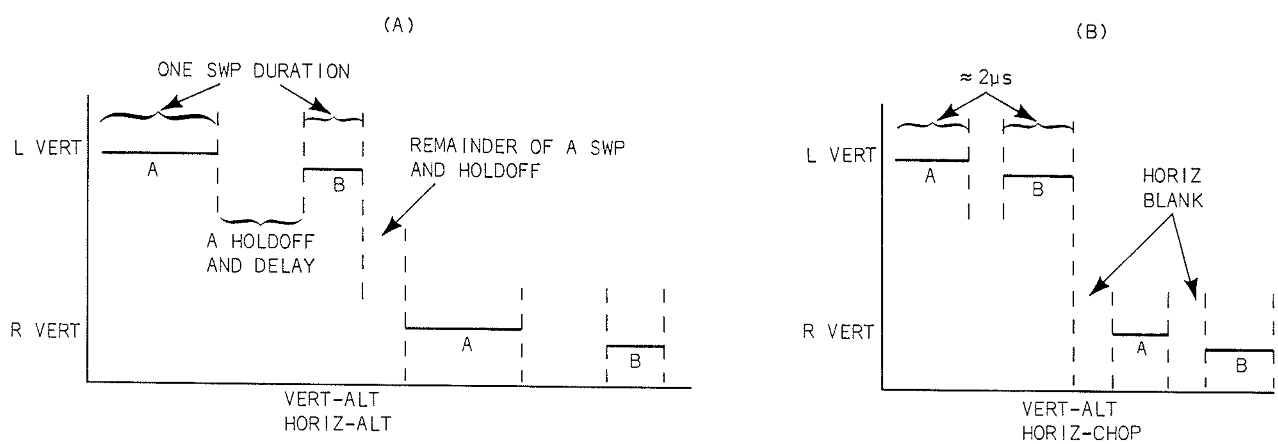


Fig. 3 Switching sequence of two single trace amplifiers with two time base units operated in the DELAYED SWEEP mode.

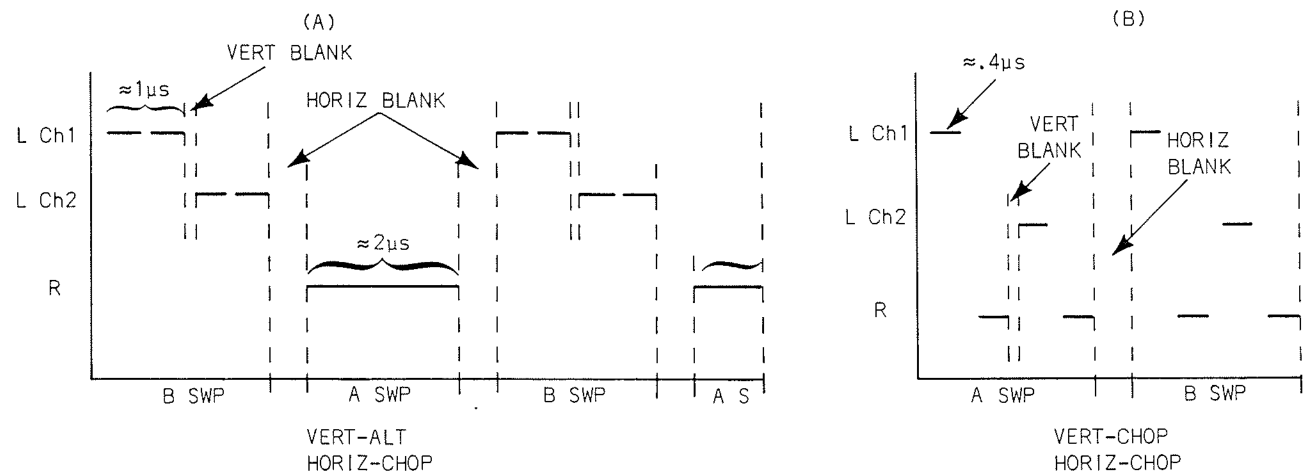


Fig. 4 Switching sequence of one dual trace amplifier operated in CHOP mode with one single trace amplifier and two time base units.

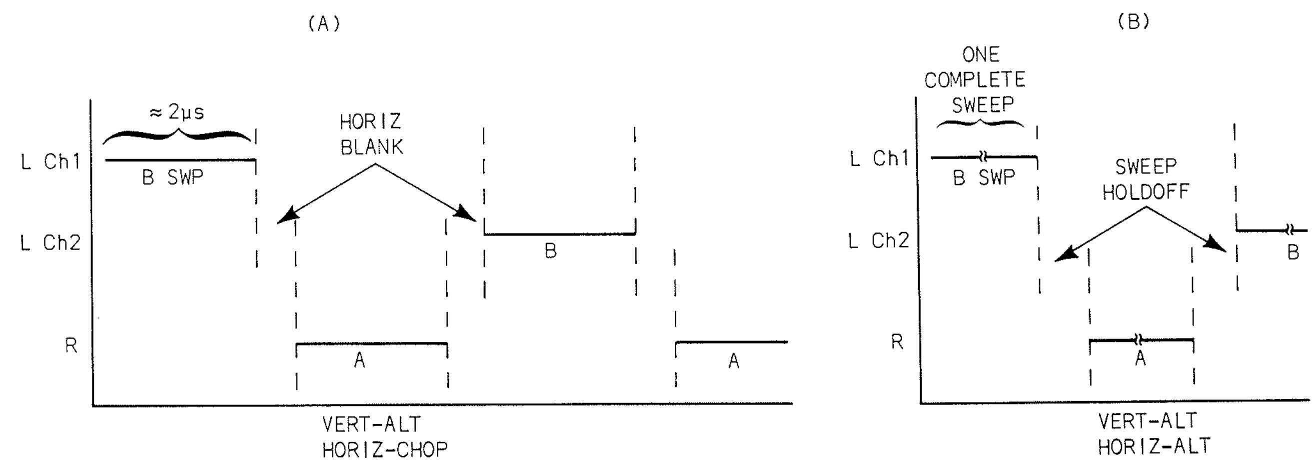


Fig. 5 Switching sequence of one dual trace amplifier operated in ALT mode with one single trace amplifier and two time base units.

TP 167 A Sweep Inhibit – A high level prevents A sweep from running during the time B sweep is displayed.

TP 168 B Sweep Inhibit – A high level prevents B sweep from running during the time A sweep is displayed.

Z Axis Signal – Provides the drive to the Z axis amplifier for the A and B intensity controls. Blanking signals for the vertical, horizontal and readout, and intensity limit control for the 6 slower sweep rates. The output will be about +6 volts with A & B intensity counter-clockwise and the readout turned off.

Following is a list of operating malfunctions and the logic component failure most likely to cause the malfunction.

1. No vertical chopped mode
   No horizontal chopped mode
   No plug-in chopped mode
   Check U120
2. No trace intensity
   Check U130, U170, Q146.
3. No vertical alternate mode
   No horizontal alternate mode
   No plug-in alternate mode
   Check U160, Q168.
4. No horizontal alternate mode
   No horizontal chopped mode
   No horizontal "B" mode
   Check U150
5. No slaving when operating vertical mode in alternate and horizontal in chopped or alternate.
   Check Q182

6. No delayed mode control when operating vertical and horizontal in alternate. The right vertical is displayed with A sweep and the left vertical with B sweep. B sweep is delayed.
   Check Q162

7. No vertical alternate mode
   No plug-in alternate mode
   Check U180

8. No plug-in alternate mode
   Check U190

9. No slaving when vertical mode is in LEFT or RIGHT and plug-in is in alternate.
   Check Q192

10. No vertical alternate, chopped or right mode.
    Check Q194

11. Right vertical mode only. Other vertical modes don't work or foul up readout display.
    Check Q196

THE READOUT SYSTEM

The readout system in the 7000 Series employs an electronic character generating circuit which time shares the CRT with the normal scope function. The characters are formed by a series of X and Y analog currents developed by character generating integrated circuits. Analog data generated in the plug-in determines which characters will be displayed. You must have a plug-in installed in the mainframe for a readout to be displayed.

The character generating circuitry is located on the readout etched circuit board mounted on the right side of the instrument. This board is easily removed and, since it is interchangeable from instrument to instrument, you can speedily confirm that the board is defective by substituting a known good one. A defective readout board can cause the normal scope functions to malfunction. This is true even though the readout is turned off by the front panel intensity control. Removing the readout board will confirm whether the problem is in the readout or elsewhere in the scope circuitry.

A defective plug-in can, in turn, cause the readout to function improperly. This can be quickly checked by substituting another plug-in. The time bases will readout properly in the vertical plug-in compartments and the amplifier plug-ins in the horizontal compartments in a properly operating instrument.

Now let's look at some typical problems that may occur in the readout circuitry. As in the logic circuit, the cause of the problem is often a temperature-sensitive device and a can of spray coolant is of help in troubleshooting.

The readout can be divided into three main sections: the sequencing logic, data collection, and the character generators and output processors. Here are the typical problems relating to these sections, and their probable causes:

The Sequencing Logic

1. No readout
2. No trace
3. No readout and the readout intensity control varies trace intensity.
   Check U1210
4. No readout, trace intensity normal
   Check U1226

NOTE: Troubles in the sequencing logic usually affect the complete display.

Data Collection

1. Mixed up information or no information on one channel of the readout display.
2. Typically the IDENTIFY function will be misspelled when displayed.
3. Interchanging the two suspected IC's will generally cause the problem to go to a different channel (usually a vertical channel).
   Check U1130 and U1170.
4. Symptoms similar to those above but there will be more missing letters or wrong spelling of words.
   Check U1166 and U1186.
5. Improper number of zeros in the displayed word. Typically there is a ten times error such as 1 ms instead of 10 ms.
   Check U1190.

Character Generators and Output

1. One or more characters missing from a word.
   Check U1251 through U1255.

NOTE: Each of five IC's makes ten different characters. If one is suspected, you can trade with another to verify the problem. However, each IC should be put back in its correct location to permit selection of the proper characters.

2. All of the characters smeared or positioned incorrectly on the CRT.
3. Trace displayed vertically or horizontally and no readout.
   Check U1270.
4. Characters overlapping or not spaced properly on the CRT.
   Check U1260.

These are the readout problems encountered most frequently by the factory service center. The instrument instruction manual contains a more detailed troubleshooting procedure should you experience problems not covered here.

TEKSCOPE

Volume 3 Number 4 July 1971

Customer Information from Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005
Editor: Gordon Allison Graphic Designer: Jim McGill For regular receipt of TEKSCOPE contact your local field engineer.

INSTRUMENTS FOR SALE

526. Frank Maser, WBEN, 2077 Elmwood Ave., Buffalo, N.Y. 14207. (716) 876-0930.

585, Viewing Hood, 86, 10X Probe, Scope-Mobile Cart, Mod. 500A. All $1200. SSR Instrument Co., 1001 Colorado Ave., Santa Monica, Calif. 90404. (213) 451-8701.

511A. Best offer. Ira Goldstone, Emerson College, 148 Beacon St., Boston, Mass. 02116. (617) 262-2010, Ext. 230.

504. Bernie Cohen, P.O. Box 862, Stamford, Conn. 06904. (203) 327-6967.

647A, 10A2, 11B2, All $1500. Stevens Engineering, P.O. Box 25070, Portland, Ore. 97225. (503) 292-9201.

RM565 with two 2A63's. Total $650. Jack von der Heide, Optron Corp., 30 Hazel Terrace, Woodbridge, Conn. (203) 389-5384.

545A, 1A1, CA, 500/53A Scope-Mobile Mod 2, $1400 complete. Bob Cobler. (916) 273-0322.

519 w/misc. attenuators, 201-1 Scope-Mobile Cart. All $3500. George Sakai, P.O. Box 2999, Torrance, Calif. 90509. (213) 534-2121, Ext. 145.

162, Four 161's. Mobilscope, Inc., 17734½ Sherman Way, Reseda, Calif. 91335. (213) 342-5111.

Two 611's, Mod 162C. M. Giallango, P.O. Box 1999, Hudson, Ma. 01749. (617) 562-3424.

422, 6 mo. old, $1425. Frank Leenecht, Telemation. (714) 278-9680.

564B/3A74/3B3 complete, including Scope-Mobile Cart. Jerry Huber, Diversified Products, 7625 E. 46th Pl., Tulsa, Okla. 74145. (918) 622-5809.

561A, 3A6, 3B4. All $1100. Pierre-Yves Cathou, MIT Branch, P.O. Box 104, Cambridge, Mass. 02139. (617) 492-2526.

502A, 24 hr. use. Best offer over $900. Dr. M. Siegman, Dept. of Physiology, Jefferson Medical College, 1020 Locust St., Phila., Pa. 19107.

1A1, $520. Brian Wachner, 1600 E. 25th, Los Angeles, Calif. 90011. (213) 934-9991.

3L5. Never used. Dave Hohlfeld, Security Systems, Inc., P.O. Box 595, Siloam Springs, Arkansas 72761. (501) 524-6441.

517A w/Cart, $250 or w/trade for 531. Mr. Sargeant, Chelmsford, Ma. (617) 256-9344.

535A, $600. 1A1, never used, $500. Q, $80. Cover & two 10X probes included w/Oscilloscope & Plug-In. Hugh Adams, 1008 Beachview Dr., Fort Walton Beach, Fla. 32548.

502, $450. 532, M, $500. Dr. Joseph Tupper, Syracuse Univ., Biology Dept., Syracuse, N.Y. 13210. (315) 476-5541, Ext. 2584.

535, 53/54C. David Singh, Nothelfer Winding Labs, 220 Ewingville Rd., Trenton, N.J. (609) 882-2500.

520A. Roger H. Baum, Bennett Respiration Products, 1639 11th St., Santa Monica, Calif. 90406. (213) 451-1671.

543B w/CA and Scope-Mobile Cart, $1620 or best offer. Robert Moss, WBNB-TV, P.O. Box 1947, St. Thomas, U.S. Virgin Islands 00820.

422 Mod 125B w/scope cart 200-2. Ken Chant, Standard Power, 1140 W. Collins Ave., Orange, Calif. 92667. (714) 633-1092.

132, 160A, 162, Plug-in TU-2. Jack Wilkinson, Ex-Cell-O Corp., 850 Ladd Rd., Walled Lake, Mi. 48088. (313) 624-4571.

536, 53/54D, H, L, R Plug-Ins, 80 with probe, 81. 581, 551, 541, 541A. Best offer. John Ivimey, 391 Kings Hwy., Valley Cottage, N.Y. 10989. (914) 358-1773.

502A S/N 027572. Mr. Vavoudis, 4 Naples Ave., E. Norwalk, Conn. 06855. (203) 846-0232.

502A. Gd. Cond. Dr. W.R. Klemm, Biology Dept., Texas A&M, College Station, Texas 77843. (713) 845-6131.

422. S/N 008736, 3 yr. old, Best offer. Gary Carlson or Denny Krieger, Osseo Jr. High School, 10223 93rd Ave. N., Osseo, Minnesota 55369.

453-127C Scope, S/N 38600, P6028 BNC 1X Probe. Frederick Bock, Bock Video Systems, Inc., 11 Kercheval Ave., Grosse Pointe, Mi. 48236. (313) 886-4050.

515A, #8748. $600 or best offer. F. Robert Werner, Professional Electronics, 7054 South 2300 East, Salt Lake City, Utah. (801) 277-0200.

547. 6 mos. old. $1600. Dick Peugeot, Ridge Instrument Co., 4176 First Ave., Tucker, Ga. 30084. (404) 939-1554.

549 Scope, 1A1 Amplifier & probes. $2700 or best offer. Mr. R. Olsen, Hospital for Sick Children, 555 University Ave., Toronto, Ont. (416) 366-7242, X1648.

581A, 82; 585A, 82, 661, 4S1, 5T1A; 531, 53/54C. All w/scope carts. Fred Besnoff, Computer Test Corp., 3 Computer Dr. Cherry Hill, N.J. 08034. (609) 424-2400.

535A, 565, 555, 551, 515A, 531A, 545A, 661, 647A, Plug-ins CA, R,S,G,H. Mr. R. Inabinette, Anaheim, Ca. (714) 956-2300.

262, S/N 299, $650; 3S76, S/N 1114, $450; 3T77, S/N 951, $450. Will trade for 2 or 3 Series Plug-ins. Mr. John Forster, MIT Branch PO, Box 48, Cambridge, Ma. 02139. (617) 864-6900.

(2) 541A, (2) CA Plug-ins, (2) 500/53A Scope-mobiles; (1) 545A, (1) CA Plug-in, (1) 500A Scopemobile. Gene Horn, Offshore Systems, Inc. (713) 464-8301, X59.

INSTRUMENTS WANTED

453, any condition. John Lum, 825 Erie St., Apt. 3, Oakland, Calif. 94610. (415) 893-7033.

576. Dick Landis, Cal State Electronics, 5222 Venice Blvd., Los Angeles, Calif. 90019.

422 or 453, Gene Bilich, 2525 S. 44th St., Milwaukee, Wi. 53218. (414) 545-0958.

453. Bernard L. Terrill, Computer Maintenance, Iowa Tech. Ottumwa, Iowa, 52501. (515) 682-8081 or (515) 684-8707.

531A w/o plug-in. D.K. Hiskey, 4662 Lakeview St., Yorba Linda, California, 92686. 528-7379.

MISSING INSTRUMENTS

453's, Ser. Nos. 44002, 45595, 45652, 45657, 45658, 45559. Contact IBM, World Trade Dist. Ctr., East Fishkill, New York.

Telequipment Scope, Ser. No. 412844, in San Francisco 4/16/71. Contact S. N. Bragg, Novar Corp., 2370 Charleston Rd., Mt. View, Calif. 94040.

TEKSCOPE

VOLUME 3 NUMBER 5

CLEAR

simple operation

$|x|^y$

$\sqrt{x^2+y^2}$

+

one key programming

=

no need for complex computer language

CLEAR

REMOTE

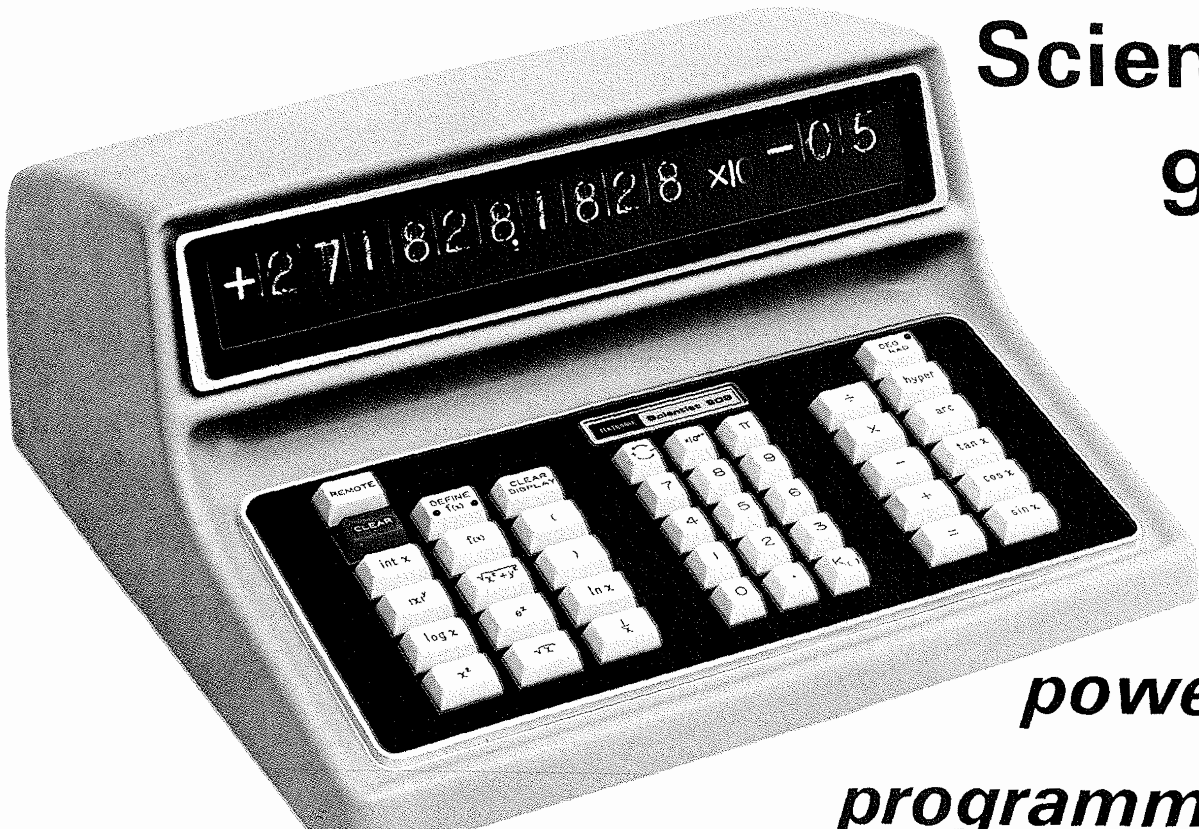
DEFINE

● $f(x)$ ●

- a programmable desktop calculator
- the R1340 data coupler
- the 7D14 counts current to minimize circuit loading
- regulated power supplies as operational amplifiers

Cover: The front cover bears a message —did you see it? It says, "Simple operation plus one key programming equals no need for complex computer language." It means it doesn't take an expert to use the Scientist 909.

the TEKTRONIX® Scientist 909: a *powerful, programmable desktop calculator*



By Dave Takagishi, Electronics Engineer
Calculator Products Division

For the first time, it is unnecessary to learn a complicated machine language in order to operate a powerful desktop calculator. The TEKTRONIX Scientist 909 (and its companion, the Statistician 911) speaks the universal language of mathematics, substituting a simple keyboard language for complicated machine languages in scientific calculators.

This new calculator incorporates a powerful keyboard that is unmatched for simplicity of operation.

OPERATION BY MATHEMATICAL EXPRESSION

Mathematical expressions are entered directly as they would be written in equation form, using parenthesis if desired. For example, to solve the equation

$$(a - b)^{(c \times d)} \times \frac{(e + f)}{(g - h)} =$$

where a,b,c. . . .h are variables of the user's choosing.
Press:

[CLEAR] [(] a [−] b [)] [|x|^y] [(] c [×] d [)] [×] [(] e [+] f [)] [÷] [(] g [−] h [)] [=] **answer**

ONE-VARIABLE FUNCTION KEYS

Trig, Log, x^2, $\frac{1}{x}$, $\sqrt{x}$, and other one-variable function keys operate directly on the number in the display. For example, to find:

$$\sin h \frac{1}{(\ln \cos a)^2} \qquad \text{for } a = 36.5°$$

Press:

[CLEAR] [DEG ● ● RAD] **36.5** [cos x] [ln x] [x^2] [$\frac{1}{x}$] [hyper] [sin x]

Read the answer, **+644839326.7**

TWO-VARIABLE FUNCTION KEYS

Two-variable function keys such as [$|x|^y$] and [$\sqrt{x^2+y^2}$] operate on the display as the first variable x, and on the next entry or expression as the variable y. For example, to find:

$$a^b + \sqrt{c^2 + d^2 + f^2}$$

Press:

[CLEAR] a [$|x|^y$] b+c [$\sqrt{x^2+y^2}$] d [$\sqrt{x^2+y^2}$] f [=] **ans.**

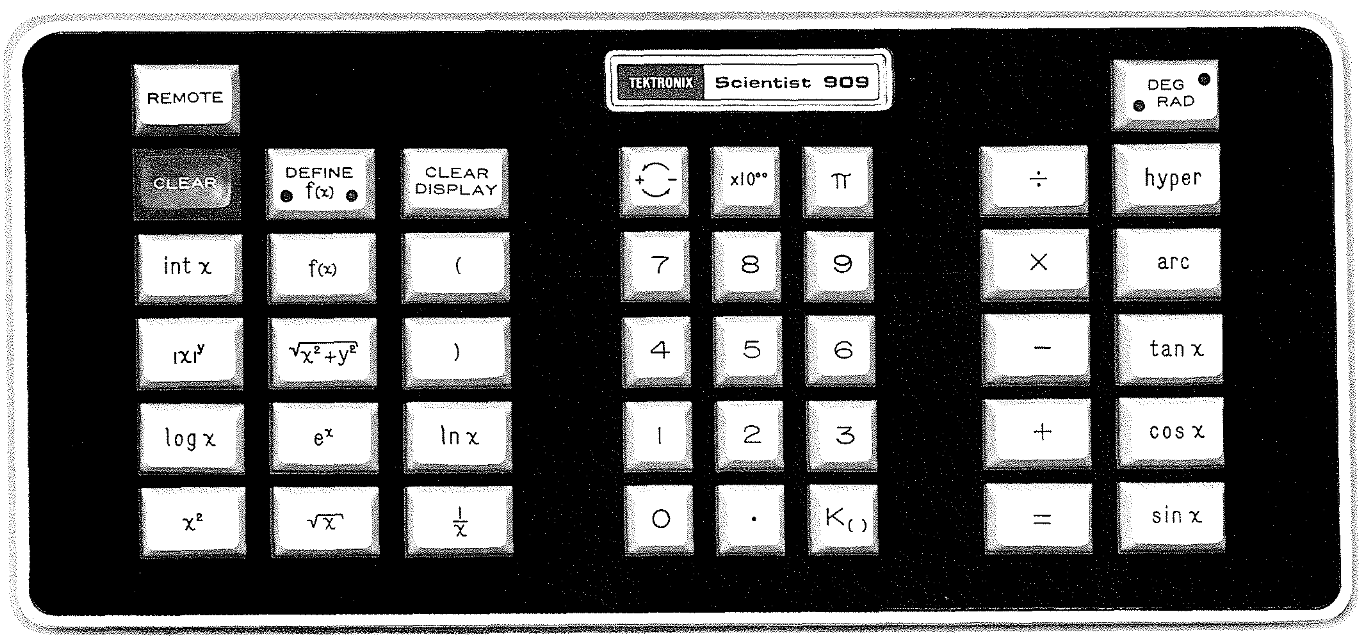
MEMORY STORAGE

The TEKTRONIX Scientist 909 has memory storage and recall that is extremely easy to operate. Any number in the display can be stored and identified with a two digit constant by pressing [=] [K( )] followed by the two subscript digits, 00 through 25.

For example, to display 17 and store it in register number 21

Press:

[CLEAR] **17** [=] [K( )] **21**



The powerful Scientist 909 keyboard provides access to more mathematical functions than any other machine with fewer total keys.

The stored number (17 in the above case) can be recalled to the display again and again at any later time by pressing [K( )] and the two subscript digits (21 in the above case). These recalled numbers can be used in all keyboard operations just as new digit entries are used.

Example:

$$\left[(3 \times K_{00} + K_{01}{}^2) \times 7 + \sin K_{00}\right] \times K_{02} = K_{03}$$

Indirect subscript addressing allows the Scientist to automatically sequence and operate on all stored constants. The number in the display is stored and identified with indirectly addressed subscripts by pressing [=] [K( )] [K( )] followed by two digits.

Example: Let π = constant indirectly addressed as K_{17}. Pressing [π] [=] [K( )] [K( )] 21 will label K_{17} = 3.141592654 if K_{21} = 17 (from previous example). Subsequently whenever pressing [K( )] [K( )] 21, π will appear in the display.

PROGRAMMING

A "learn program" key is included on the Scientist 909 keyboard. While this key, [DEFINE •f(x)•], is activated, the calculator is in a learn mode in which every key stroke (up to 256 steps) is memorized. These memorized key depressions may be automatically repeated at any time by pressing the key called [f(x)] (thereby eliminating repetitive keying sequences). This feature may be used to define your own special function key. For example, to define your own special inverse Gudermannian function key where

$$f(x) = \ln \tan\left(\frac{x}{2} + \frac{\pi}{4}\right)$$

Press:

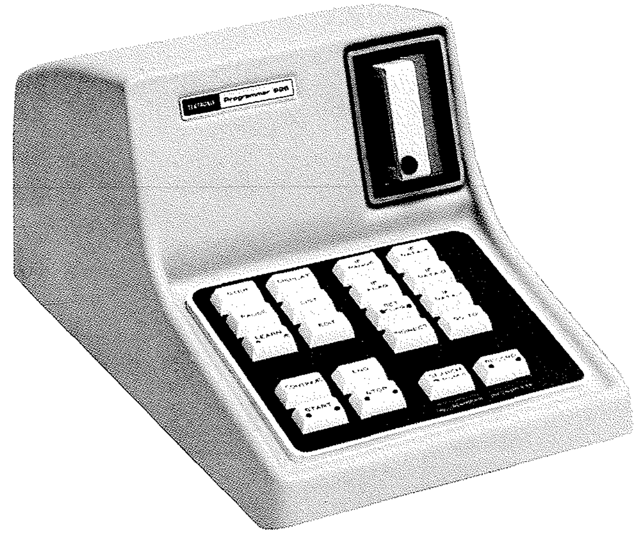
[DEFINE •f(x)•] [÷] 2 [+] [π] [÷] 4 [=]

[tan x] [ln x] [DEFINE •f(x)•]

Now use the [f(x)] key like any other function key operating on one variable.

In addition to the above type of programming, which is essentially linear (no branching or looping) the TEKTRONIX calculator family includes an "add on" programmer, the 926.

This programmer unit provides the branching and looping features of a small computer and will store 512 program steps in its internal MOS storage. The contents of this storage can be transferred to a tape cartridge which installs in the Programmer. Each cartridge holds up to 10 blocks of these 512 step programs. The Programmer 926 combined with a TEKTRONIX Scientist 909 or Statistician 911 Calculator can accomplish most tasks a scientific computer can, with the exception of those tasks requiring very large data storage.



APPLICATIONS OF THE SCIENTIST 909

Applications for the TEKTRONIX Scientist 909 span virtually every discipline and profession where mathematics is used. Scientists, engineers, educators, statisticians, surveyors, metallurgists, astronomers, bankers, merchants, designers — all can be freed from the confusion of machine language and the tedium of paper and pencil arithmetic to spend their valuable time on more creative processes.

ANALYTICAL INSTRUMENTATION SYSTEMS

Application requiring control and readout of analytical instruments may frequently be handled by a modern programmable calculator instead of a high cost mini-computer. The laboratory may already own (or plan to buy) a scientific calculator for individual desk use, and would like to avoid the purchase of a larger, faster machine unless the application really requires it.

A good example of an application that can be handled by a programmable calculator is the Gas Chromatograph/Mass Spectrometer (GC/MS). This type of instrumentation system has been successfully controlled and monitored by a mini-computer, is relatively low speed, and therefore well suited to calculator control.

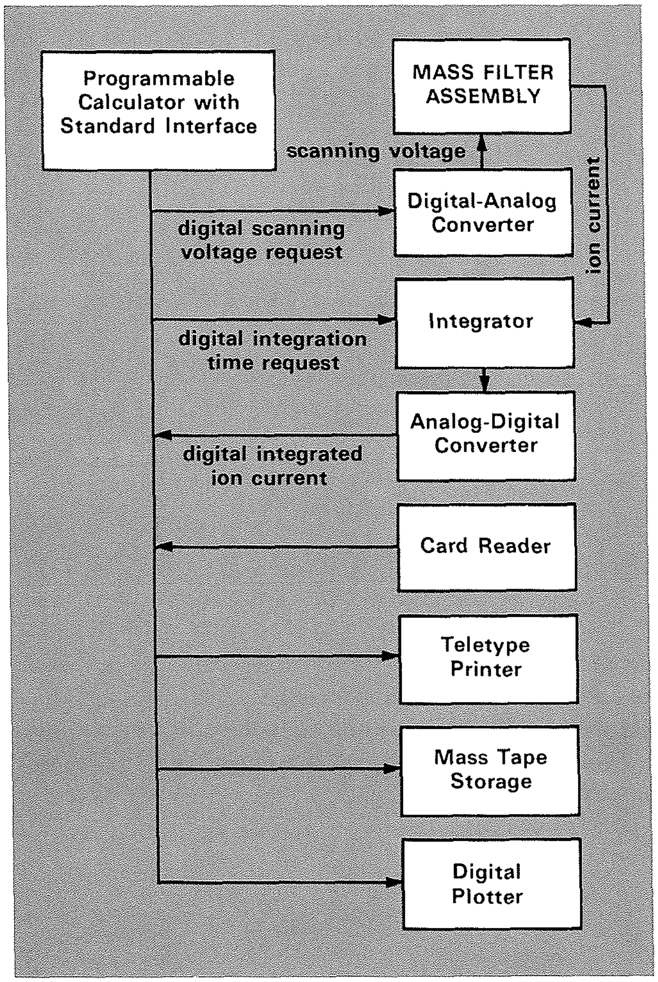
The heart of the GC/MS is a mass filter assembly. Gas samples for mass analysis are inserted into the ionizing chamber and forced through the filter by accelerating electrodes.

The mass of any ions that successfully pass through the filter is directly proportional to the applied scanning voltage. Ions passing through are detected by a photo-multiplier whose output current is fed to an integrator.

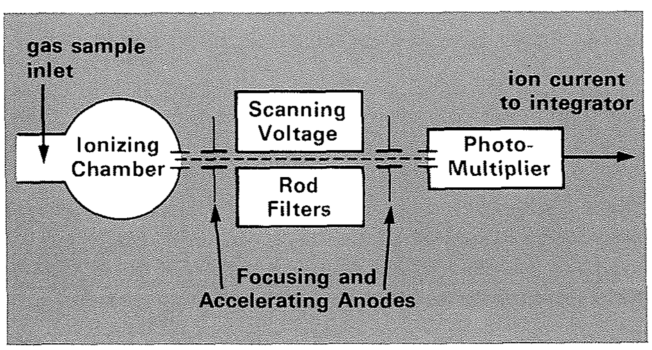
GC/MS operation begins with a calibration cycle program. A reference compound with a few known mass spectrum lines is placed in the inlet. The mass of these known lines can be entered from the keyboard or by punched card. The scanning voltage is then incremented, and at each step the ion current is determined. Signal to noise can be optimized by programming the integration time as a function of signal strength, since the integrated current is divided by the integration time to obtain the actual current.

The scanning voltage of each ion current peak is combined with the known mass of each peak and interpolated to produce a calibration curve which is stored for later use.

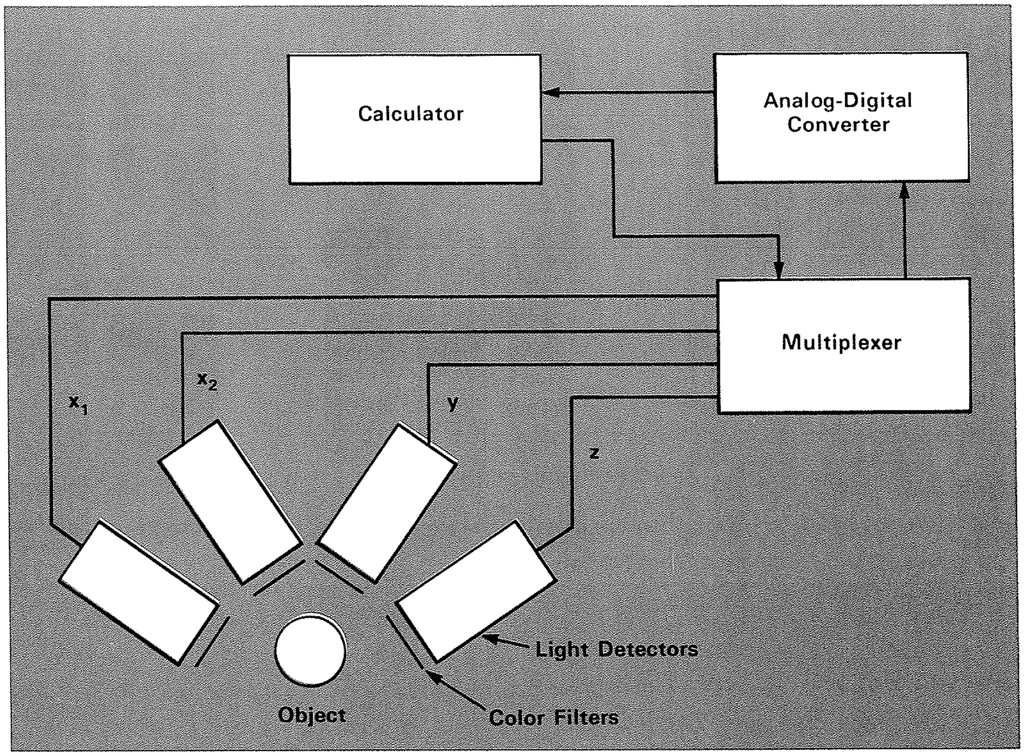
After calibration, the unknown sample is placed in the inlet. The scanning voltage is stepped from the lowest to the highest value required, stopping at each step while the calculator adjusts the integration time for best signal to noise. The resolution (separation of voltage steps) can be constant, or variable, within a scan. Each voltage step is corrected by the calibration curve referred to earlier. The integrated current divided by the integration time gives the amplitude of the mass corresponding to each voltage step. A plotter records the resulting spectrum as it is produced and stored on tape for future use. The voltage and amplitude of each peak can be found mathematically and printed out on a teletype or printer.



Simplified block diagram of a Gas Chromatograph/Mass Spectrometer.



Block diagram of the mass filter assembly of a GC/MS.



Simplified block diagram of a colorimetry system.

COLORIMETRY

Programmable calculators have been successfully applied to the measurement of color. A typical system is illustrated at right. Light from the object being measured passes through color filters which divide it into basic colors. These are measured with photo detectors whose outputs are scanned by a multiplexed analog-to-digital converter and sent to the calculator. The calculator performs the following calculations:

$$x = (x_1 + x_2) \qquad \frac{y}{x + y + z} = K_{00}$$

$$\frac{x}{x + y + z} = K_{01} \qquad \frac{z}{x + y + z} = K_{02}$$

This computes and stores three numbers that uniquely identify the color.

The system referred to has been used to color match mink fur for repair of coats, replacing an experienced "mink matcher" with a calculator and a less experienced technician.

This system could be applied to color matching in process control. More multiplexer stations could be added to monitor the color of material and dyes going into a process, the color of material coming out, and a desired color sample. Using the information and a programmed knowledge of color mixing, the calculator could interface with valves controlling the dye inputs to match the output with the sample.

OTHER CALCULATOR PERIPHERALS

The utility of TEKTRONIX Calculators is enhanced with a family of peripherals including a digital strip printer, X-Y plotter, punched card reader and magnetic tape storage devices.

Dave Takagishi is one of the original 10 people responsible for development of the Scientist 909. He has been involved with design and implementation of the calculator from pre-breadboard through its production phase.

Dave is a graduate of San Jose City College and worked four years with Fairchild Semiconductor before joining Cintra in 1968. He became a Tek man in May, 1971, when Tektronix bought the Cintra assets.

Dave is 31 years old and married. His interests outside of calculators include golf and photography.

the R1340 Data Coupler

Complete testing of today's complex integrated circuits, printed circuit boards and other such products is a formidable task. To accomplish it, an equally formidable array of signal sources, power supplies, test fixtures and measuring devices are brought together to form automatic measurement systems. Some of the more sophisticated systems also include a computer.

How well we accomplish the testing task depends, to a large extent, on the ease with which the various elements of the system "communicate" with each other and with the computer.

The new TEKTRONIX R1340 Data Coupler could be called a "systems communication expert". The coupler is designed to multiplex data inputs and outputs of various system components to a common TTL data bus. This data bus can, in turn, be interfaced to a computer, data receiver, or data source. Using optional interface circuit cards, nearly any form and format of data can be applied to, or acquired from, the R1340. The unit can perform such functions as input/output level conversion, serial-to-parallel and parallel-to-serial format conversion and temporary storage of data in latching registers.

The unit is designed primarily for use with TEKTRONIX Automated Measurement Systems. However, it can serve just as well as an important building block in your system. Here are some of the chores it can perform:

- Provide the interface to bring your system under computer control.
- Couple the system to data-logging equipment.
- Interface the computer to registers, DVMs, test fixtures and other programmable instruments in the system.
- Digitize high-speed waveforms for computer analysis.

The R1340 consists of a rackmount cabinet with power supply, space for twelve plug-in cards and eighteen wired connectors providing a total of 648 input/output lines. Combinations of from one to twelve plug-in cards within the R1340 perform the various functions desired.

The block diagram in Fig. 1 shows four major application areas using the R1340. (Type numbers of TEKTRONIX instruments used in our automated measurement systems are shown in the appropriate blocks.) Although not apparent from the diagram, data logging from a system using the 230 and 240 can be performed through the R1340 without using the computer. Data is logged on computer-compatible magnetic or punched paper tape.

INTERFACE OPTIONS

Since different applications or functions require different interfaces, we should discuss the various interface options available for the R1340 before getting into specific applications. An option consists of a package which includes one or more plug-in circuit cards, interconnecting cables and an instruction manual. Several options (up to a total of 12 cards) can be accommodated in the unit at one time. There are ten options presently available with several more in the design stage. Briefly they are:

1. R1340 to PDP-8/L Computer Interface
2. R1340 to IBM 1800 Computer Interface
3. R1340 to R230/R240 Interface
4. R1340 to Paper Tape Punch/Reader Interface
5. R1340 Data Logging Interface
6. 16-bit Input/16-bit Output Interface
7. 32-bit Input Interface
8. 32-bit Output Interface
9. R568 to R1340 Waveform Digitizing Interface
10. Vertical and Horizontal Signal References Interface.

The waveform digitizing and the signal reference interfaces merit special consideration since they bring new capability to automated testing.

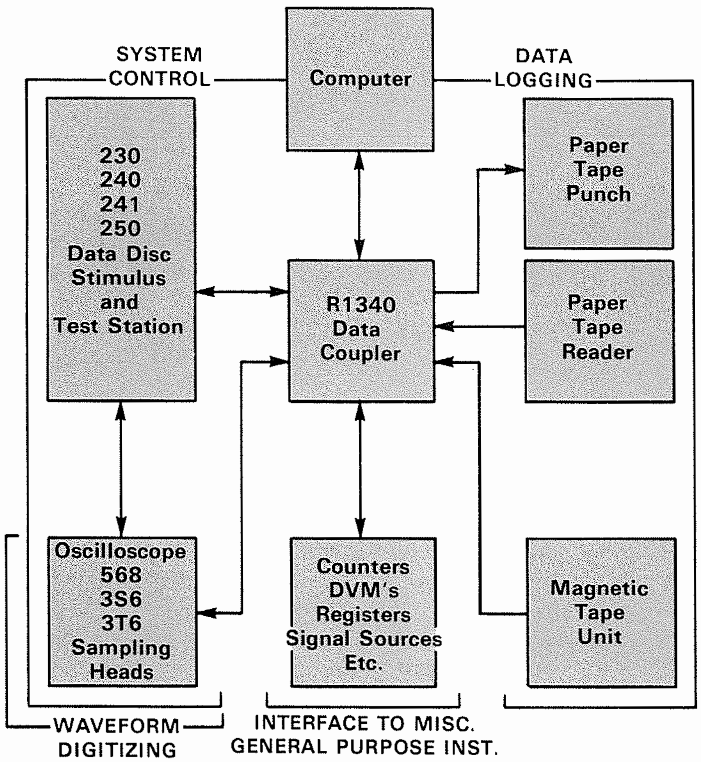


Fig. 1 Four major application areas of the R1340 include system control, data logging, waveform digitizing and interfacing to many general purpose instruments.

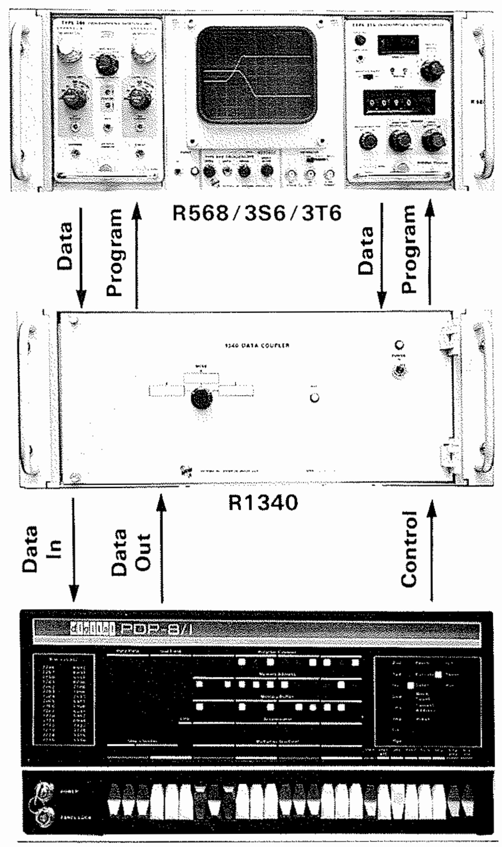


Fig. 2 A basic waveform digitizing system consisting of the R1340 Data Coupler, an R568/3S6/3T6 Oscilloscope and a DEC PDP-8 minicomputer.

WAVEFORM DIGITIZING

Waveform digitizing, as the name implies, is a means of converting an analog waveform into its digital equivalent. A computer can then be used to measure whatever parameters are desired such as risetime, pulse width, period, or delay between two pulses. Smoothing or noise reduction can be performed to improve measurement accuracy or to extract a low-level signal from noise.

A block diagram of the basic waveform digitizing system is shown above. It consists of the R568/3S6/3T6 programmable oscilloscope, the R1340 and a PDP-8 minicomputer. A total of seven interface cards reside in the R1340. Three cards are required to interface the computer to the R1340, two cards program the R568 and plug-ins, and the remaining two cards are the digitizer interfaces.

One of the digitizer interface cards has two, 10-bit A-D converters, buffers and control logic to convert the 3S6 channel A and B analog information to binary numbers. These numbers are then made available to be read by the computer under software control.

The other card consists of a buffered 10-bit D-A converter which outputs an analog voltage to the 3T6 to determine the time position of a particular sample. It, in essence, generates the analog ramp for the sampling sweep unit. Both cards rely on computer-generated operating instructions.

WAVEFORM DIGITIZER LOGIC

Three operating modes are available for the waveform digitizer. One is called the SCAN, SAMPLE and HOLD mode, wherein the horizontal sweep is stepped across the screen in 1023 increments. This is like the normal sampling scope operation with one important difference. The sweep is prevented from going to the next time position until the data in one or both of the A-D buffers has been read by the computer. This enables the memory location itself to be used as a time position pointer for that data word.

The second operating mode is called PARK, SAMPLE and HOLD. In this mode, the self-incrementing operation of the register driving the D-A converter is disabled and now becomes a simple 10-bit latch which will accept a data

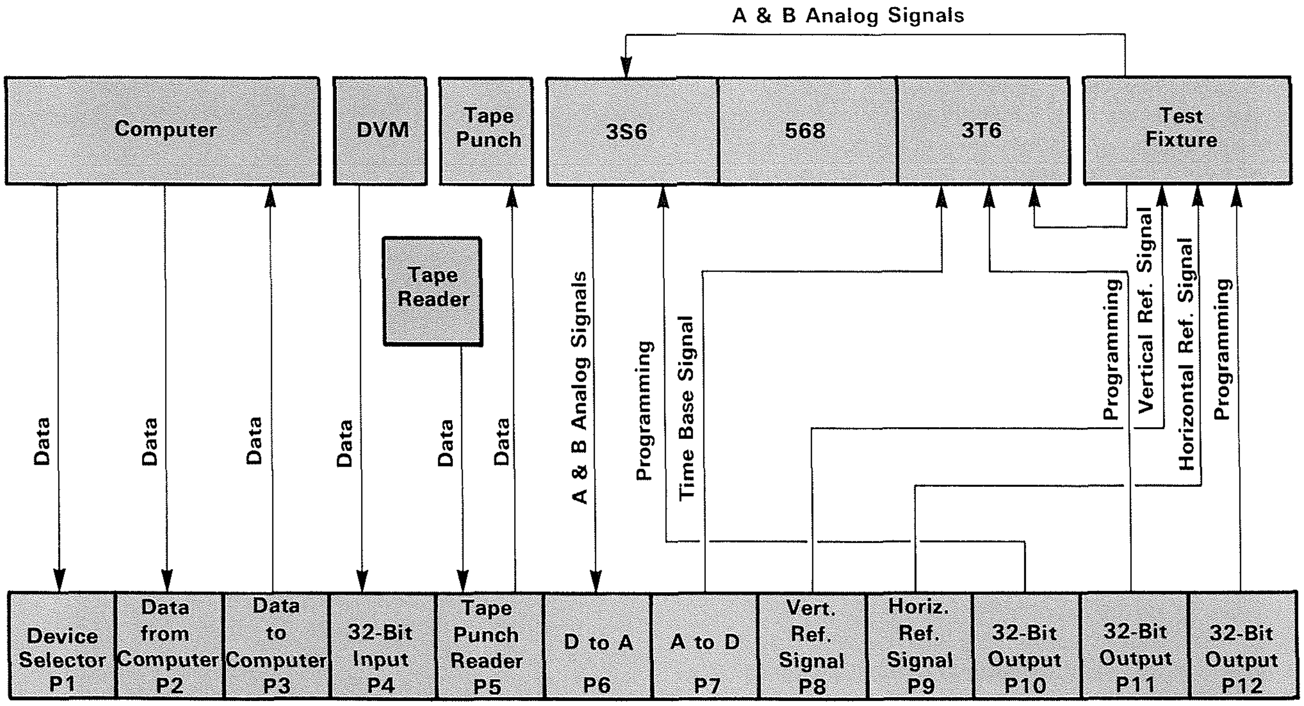


Fig. 3 Block diagram of a computer-controlled system which includes waveform digitizing and vertical and horizontal reference signals.

word from the computer. The sampler now makes samples at any one of 1023 time positions on the waveform being measured. Any number of samples desired may be read at that single time location by the computer. A new word may be loaded into the D-A register at any time to select a new time position or the mode may be changed back to SCAN, SAMPLE and HOLD. Thus, any segment or segments of a waveform may be stored in core, or multiple measurements at single-time locations may be stored for use in noise reduction.

The third operating mode is called SCAN, FREE RUN. Here the sweep D-A operates in the self-increment mode and the logic loop requiring the computer to read the A-D converter before allowing the D-A to move to the next time position, is disabled. This mode is most useful for initial setup of the package since in the SCAN, SAMPLE and HOLD mode, only one sweep can be seen, and in the PARK, SAMPLE and HOLD mode, only a single dot can be seen on screen.

Any of those three modes can be entered via computer, while the SCAN, FREE RUN mode may also be entered by a front panel control on the R1340.

APPLICATION CONSIDERATIONS

Of the two data acquisition modes discussed, the SCAN, SAMPLE and HOLD mode offers the greatest flexibility in the range of measurements that can be made. However, it requires up to 2048 words of computer memory to store a complete sweep of data from channels A and B. Since most standard minicomputers have only 4K of memory, the user would almost certainly have to add storage capacity to accommodate a comprehensive program package.

It should be apparent that a great deal of redundant information is contained in a typical oscilloscope display. This leads to a second type of acquisition routine which uses the PARK, SAMPLE and HOLD mode. It requires somewhat more sophisticated software but has several important advantages over the first method.

Prior to the data acquisition stage, the user specifies the type of measurement and what points must be measured on the waveform. For example, suppose we want to measure risetime, amplitude and channel A to channel B delay. These measurements require 0%, 10%, 50%, 90% and 100% points of the pulses on both channels to be stored.

A 0% zone is established by parking the sweep at the left edge of the screen and then reading the channel A and B samples. Next, the sweep is parked a few tens of increments to the right, samples read and compared with the first ones. A zero slope area is quickly found by stepping the time position around as necessary. Once a suitable time-position is established, several readings of the A-D converters at that one time position are averaged and then stored as the 0% locations for channels A and B. Similarly, to locate the 100% time and amplitude, the time position (sample) is programmed to the right edge of the screen then moved to the left or backward in time. Now the 50% voltage value is calculated and the sampling time position moved around until this value, or something near it, is found. Multiple A-D readings are then made at adjacent time positions with each time location given some average value of these readings. These noise-reduced values are then used to calculate the time position of the "smoothed" 50% crossing. The 10% and 90% points are found in a similar way.

The required parameters of the two vertical channels are stored in only 20 memory locations (10 amplitude and 10 time) compared to 2048 memory locations for storing the complete waveform. Furthermore, the noise level and, hence, repeatability of the measurement have been greatly enhanced, and the whole process carried out with fewer than 100 samples, depending upon the number of samples used for noise reduction purposes.

VERTICAL AND HORIZONTAL SIGNAL REFERENCE INTERFACE

Designed to be used with the Waveform Digitizing Interface, a programmable time standard and programmable voltage standard are available as plug-in cards for the R1340. These standard signals are made available at the system measurement fixture so that all combinations of sampling heads, channel A or B, and 3S6 sensitivity will have a calibration coefficient tabulated in the computer memory. Similarly, a calibration table can be stored for all sweep rates of the 3T6 between 500 ms/div and 1 ns/div. Time and amplitude measurements can thus be made to better than 1% with traceability to NBS.

COMPUTER-CONTROLLED WAVEFORM DIGITIZING SYSTEM

Pictured on the preceding page is a block diagram of a computer-controlled system using the Waveform Digitizer and the Vertical and Horizontal Reference interfaces. The computer has master control over all of the cards in the coupler via Pl, the Device Selector.

The Device Selector takes data from the computer, converts it from a binary number to a selection code and uses it to select one or more cards in the data coupler. The selected card immediately transfers data to or from the interface bus in the R1340. The computer generates a strobe pulse when it sends or receives data.

The Device Selector also receives a signal from each card which indicates the status of that card. When the computer is ready for data from the coupler, it looks for a signal from the Device Selector and then handles the data as the computer program requires.

SOFTWARE

No software is presently available as part of the R1340 except as part of an operating S3150 system, and that software is in a language closely related to the particular hardware in the system.

Existing hardware interfaces used in the R1340 for the DEC PDP-8/L and IBM 1800 computer are well documented and allow machine-language drivers to be easily written. Hardware interfaces for other computers (including the DEC PDP-11) are under development. Special software, a high-level language written in DEC PDP-11, FORTRAN IV, will be available in 1972. The TEKTRONIX programming language being developed for the PDP-11 will allow interactive English-language control of computer peripherals and test instruments interfaced through the R1340. Digitized waveform data acquired by the Waveform Digitizing Interface can be computer processed through measurement routines for determining such parametric data as risetime, pulsewidth, etc. Measurement routines may be interactively altered or extended for unusual applications by writing FORTRAN routines to perform special functions. Arithmetic, data-logging, instrument programming and display operations are to be included.

CONCLUSION

The R1340 Data Coupler greatly expands system flexibility with or without the use of a computer. Through waveform digitizing and accurate voltage and timing references it brings new measurement capability to dynamic testing. Your TEKTRONIX field engineer can help you apply the R1340 to solving your measurement problems.

TEKNIQUE:

THE 7D14 COUNTS CURRENT TO MINIMIZE CIRCUIT LOADING

by Emory Harry, Field Engineer

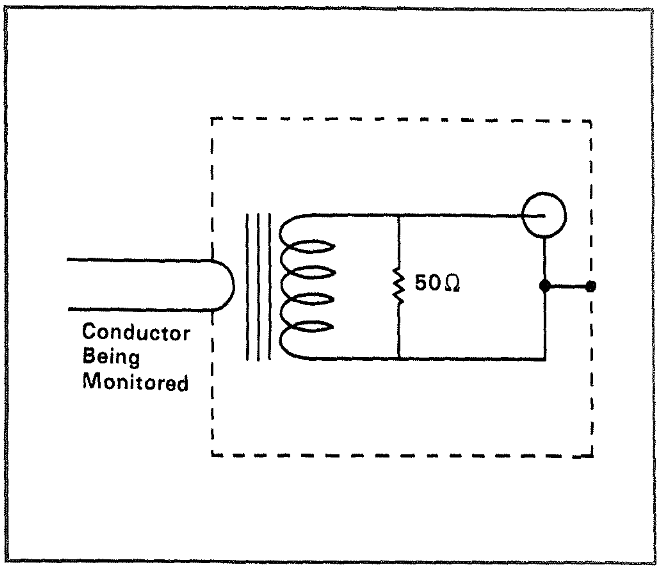


Fig. 1 Simplified circuit of the CT-1 probe.

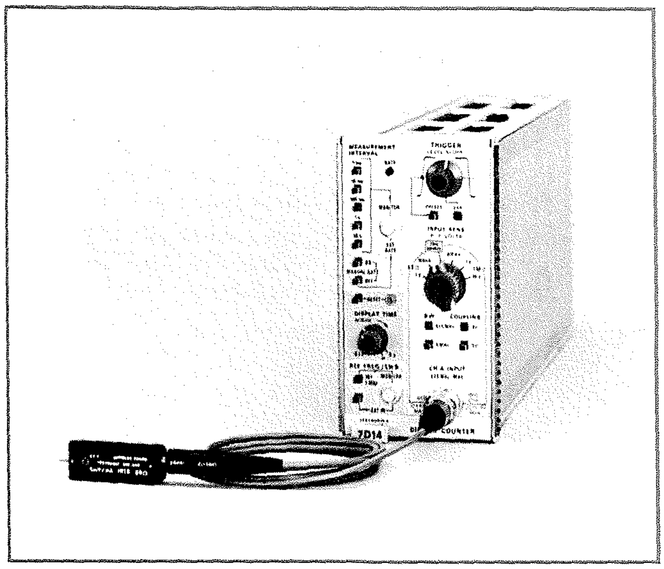


Fig. 2 The 7D14 Counter plug-in with P6041/CT-1 Probe

The 7D14 is a 525 MHz direct-reading counter. Circuit loading is often a problem when coupling to circuits operating in this frequency range. Often it is possible to use a current probe to couple the signal to be counted to the 7D14 and realize much less loading. No electrical connection is made and the current probe heads are not grounded, therefore, the possibility of accidental grounding is also avoided.

The current probe which offers the most performance coupled to the 7D14 is the P6041/CT-1. This combination makes available the full 525 MHz bandwidth of the 7D14.

Pictured at left above is a simplified circuit of the CT-1 Current Transformer. It has a frequency response of 35 kHz to 1 GHz with a sensitivity of 5 mV/mA when operated into 50Ω. It can be used with either the 50Ω or 1MΩ input impedances of the 7D14; however, the insertion impedance is lower when the 50Ω input is used (1Ω shunted by 5 uH vs 2Ω shunted by 5 uH).

The capacitance added to the conductor when passed through the CT-1 is determined primarily by the wire size. It will be 0.6 pf for No. 20 bare wire and 1.5 pf for No. 14 bare wire. This capacitance and the inductance of the conductor form a transmission line with Zo of approximately 50Ω for No. 14 wire and approximately 100Ω for No. 20.

The maximum voltage on the circuit under test is limited to 1000 V DC and the RMS current to 100 A peak with an amp-second product of 1A-us. When the amp-second product is exceeded, the core saturates and the output of the CT-1 falls to zero.

Since the input sensitivity of the 7D14 is 100 mV and the sensitivity of the CT-1 is 5 mV/mA it can be seen that approximately 20 mA must be flowing through the circuit under test to drive the counter.

The 1MΩ rather than the 50Ω input of the 7D14 can be used to effectively double the sensitivity of the CT-1, however, the insertion impedance also doubles. When operating the probe into the 1MΩ input of the 7D14 it is only necessary for 10 mA to be flowing in the circuit under test.

If the signal current is less than 10 mA, the wire can be looped through the CT-1 more than once if the conductor is small enough. The insertion impedance will go up approximately as the square of the number of times the wire is looped through the CT-1. For example, five loops will result in an insertion impedance of about 50Ω when operating into the 1 MΩ input.

SERVICE SCOPE

A PRACTICAL APPROACH TO REGULATED POWER SUPPLIES AS OPERATIONAL AMPLIFIERS

By F.J. Beckett, Engineer

From time to time, Service Scope articles are written with the intent of broadening the technician's understanding of basic circuits used in TEKTRONIX oscilloscopes rather than discussing troubleshooting techniques. Such is the intent of this article on regulated power supplies.

Most sophisticated electronic equipment uses some form of regulated power supply. Generally speaking, these supplies fall into two categories: constant voltage or the constant current form or, in some cases, a combination of both types.

By far the most common is the constant voltage type. A constant voltage generator is defined as "a two-terminal circuit element with a terminal voltage independent of the current through the element" (extract from the I.R.E. Dictionary of electronic terms and symbols). This definition implies that a constant voltage generator has a zero source impedance.

Source impedance is that impedance we see looking back into the output terminals. In the strict sense of the definition, we cannot build a power supply whose output impedance is zero.

At this point, we must ask the question, why does it matter if the output impedance is not close to zero? To answer this question, let us look at an amplifier and its power supply (Fig. 1). We see that the power supply output impedance (Z_o) appears in series with the load resistance (R_L) of the amplifier. If Z_o is not low, the result will be that the power supply will not deliver a constant voltage but will vary with I_s.

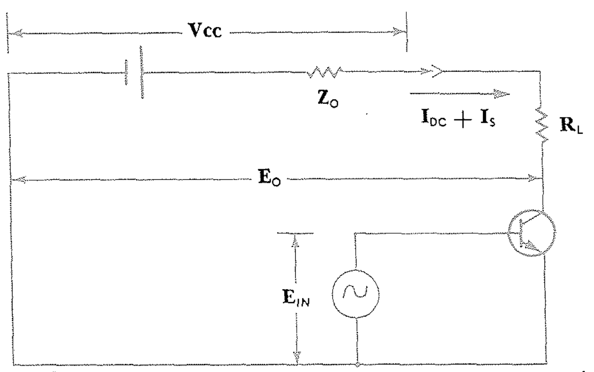


Fig. 1 Equivalent circuit showing that the output impedance of the power supply appears as part of the load.

We should keep in mind that in oscilloscopes, the varying load presented by the sweep, trigger, unblanking and other circuits could generate an I_s of several hundreds of milliamps on a peak-to-peak basis. This calls for a supply having not only a low output impedance, but it should be capable of handling wide variations in load as well.

A power supply employing feedback principles provides an ideal solution. It can accommodate varying loads and the output impedance can be made very low.

Let's take a look at the low voltage power supplies in the 453A (Fig. 3). A careful examination of the feedback networks in the amplifier portions of the circuitry shows that these are, indeed, operational amplifiers. A simplified equivalent circuit is shown at the right of each supply.

Before analyzing these supplies in detail, we need to consider operational amplifiers in general and examine some of their limitations. Shown at right is a DC analysis of the inverting and non-inverting type of operational amplifier. The analysis suggests that the most important parameter to be considered is the open-loop gain (A_{OL}). If A_{OL} is high, then the feedback resistors (R_F and R_i) are the sole factors determining the amplifier closed-loop gain. Further, we see from equation (2) that with A_{OL} very large, E_s will be very small (in the order of a few millivolts) and so E_{out} will be essentially proportional to E_{IN}.

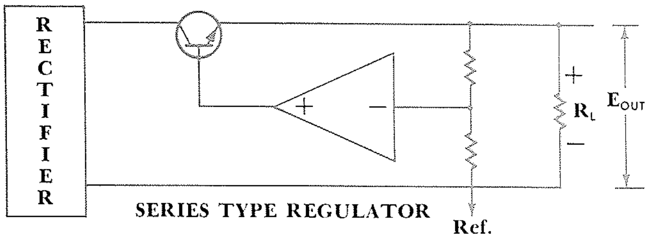
OPERATIONAL AMPLIFIER LIMITATIONS

At lower right are typical plots of A_{OL} in terms of frequency and output impedance (Z_o). We see that if we are to achieve a true constant voltage power supply, A_{OL} must be infinite. This is not possible, of course, but we can approach the ideal situtation at frequencies approaching DC. However, note that as the signal frequency increases two things happen: open-loop gain decreases and output impedance increases. The result is that we do not have a constant-voltage supply at all frequencies. Since the power supply is a common meeting point for many circuits, the variations in supply voltage caused by high-frequency circuit loads are coupled into other circuits and cause problems. This coupling can be minimized by filters and decoupling networks but is still a persistent problem to circuit designers.

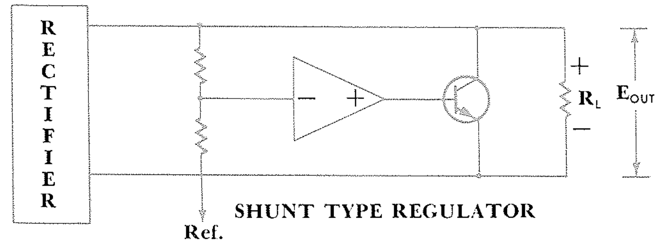
TYPICAL CONSTANT VOLTAGE SUPPLIES

Let us now turn our attention to the more practical aspects of the constant voltage power supply. In analyzing a power supply circuit, we must first recognize the type of regulator and its control amplifier. At upper right are the two types of regulator circuits commonly used, the series type and the shunt type. The most common is the series regulator for the reason of the power dissipated across the regulating element.

Once the type of regulator is determined, it then becomes an exercise to recognize the type of feedback amplifier involved and the feedback networks.



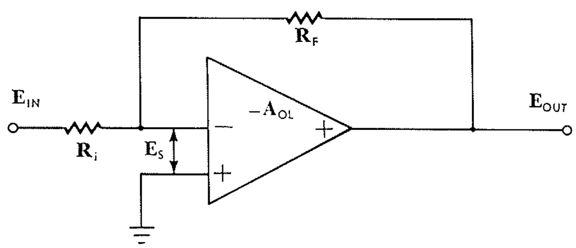
SERIES TYPE REGULATOR



SHUNT TYPE REGULATOR

DC GAIN ANALYSIS OF OPERATIONAL AMPLIFIERS

INVERTING



Now, using the superposition theorem:

$$E_S = \frac{R_F\,E_{IN}}{R_i + R_F} + \frac{R_i\,E_{OUT}}{R_i + R_F} \qquad (1)$$

and $E_{OUT} = -\,A_{OL}\,E_S$ where A_{OL} is the open-loop gain (2)

so
$$-\frac{E_{OUT}}{A_{OL}} = \frac{R_F\,E_{IN}}{R_i + R_F} + \frac{R_i\,E_{OUT}}{R_i + R_F} \qquad (3)$$

rearranging Eq(3) in terms of closed-loop gain, $\frac{E_{OUT}}{E_{IN}}$ or $A_{(V)}$

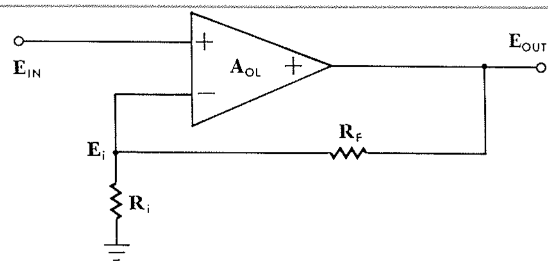
$$\frac{E_{OUT}}{E_{IN}} = A_{(V)} = -\left[\frac{\dfrac{A_{OL}\,R_F}{R_i + R_F}}{1 + \dfrac{A_{OL}\,R_i}{R_i + R_F}}\right] \qquad (4)$$

$$A_{(V)} = -\frac{A_{OL}\,R_F}{R_F + R_i\,(A_{OL} + 1)} = -\left[\frac{R_F - \dfrac{R_F}{A_{OL} + 1}}{R_i + \dfrac{R_F}{A_{OL} + 1}}\right] \qquad (5)$$

Now if $A_{OL} \longrightarrow \infty$

then $A_{(V)} = -\dfrac{R_F}{R_i}$ (6)

NON-INVERTING



Using the superposition theorem:

$$E_i = \frac{R_i\,E_{OUT}}{R_i + R_F} + \frac{E_{OUT}}{A_{OL}} = E_{OUT}\left(\frac{R_i}{R_i + R_F} + \frac{1}{A_{OL}}\right) \qquad (1)$$

$$\frac{E_i}{E_{OUT}} = \frac{R_i A_{OL} + R_i + R_F}{(R_i + R_F)(A_{OL})} = \frac{R_i(A_{OL} + 1) + R_F}{(R_i + R_F)(A_{OL})} \qquad (2)$$

Now $E_{IN} = E_i$ because of the null situation between the inputs. So subst. E_{IN} for E_i and inverting Eq(2) we have:

$$\frac{E_{OUT}}{E_{IN}} = A_{(V)} = \frac{A_{OL}\,(R_i + R_F)}{R_i\,(A_{OL} + 1) + R_F} \qquad (3)$$

where $A_{(V)}$ = closed-loop gain

$$= \frac{A_{OL}\,(R_i + R_F)}{(A_{OL} + 1)\left(R_i + \dfrac{R_F}{A_{OL} + 1}\right)}$$

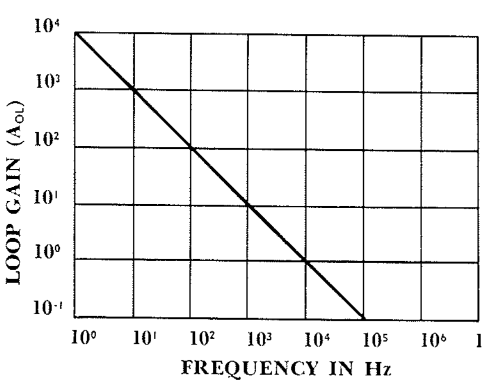
and for values of $A_{OL} \gg 1$

$$A_{(V)} = \frac{R_i + R_F}{R_i + \left(\dfrac{R_F}{A_{OL} + 1}\right)} \qquad (4)$$

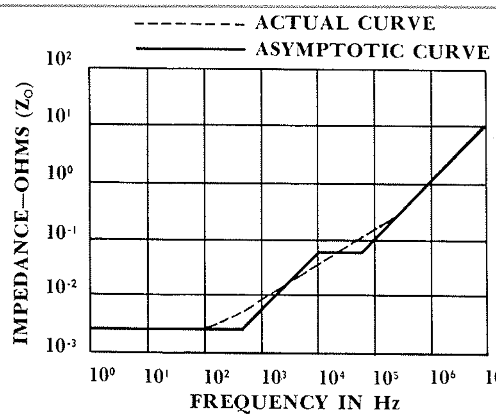
and if $A_{OL} \longrightarrow \infty$ then $A_{(V)} = \dfrac{R_i + R_F}{R_i}$ (5)

OUTPUT IMPEDANCE $= Z_O = \dfrac{Z}{1 + \beta A_{OL}}$

where Z_O is the output impedance with feedback
Z = output impedance without feedback
$$\beta = \frac{R_i}{R_i + R_F}$$



CONSTANT VOLTAGE FEEDBACK AMPLIFIER OPEN-LOOP GAIN CHARACTERISTIC



OUTPUT IMPEDANCE OF CONSTANT VOLTAGE REGULATED SUPPLY

Fig. 2

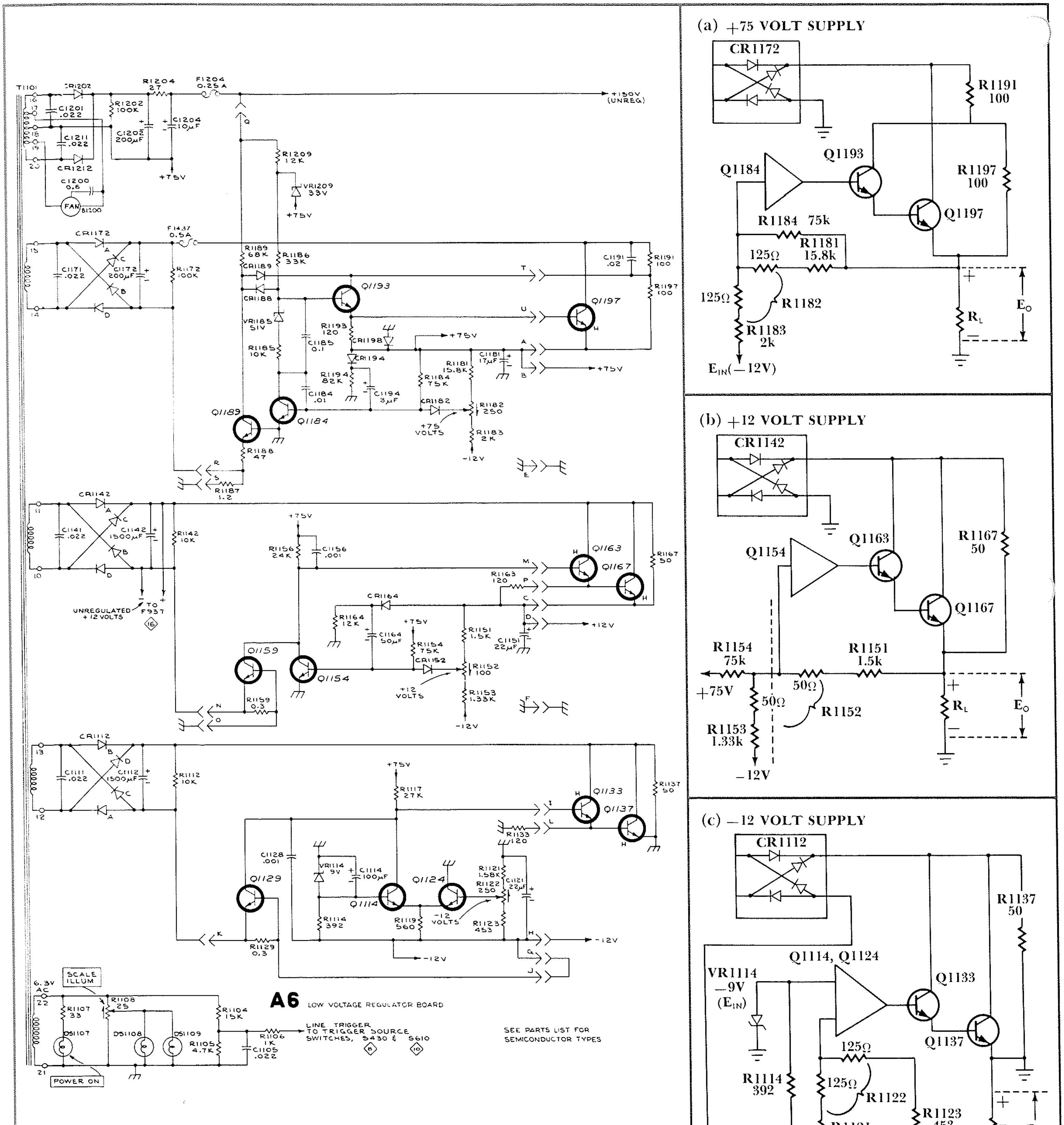


Fig. 3 Low voltage power supplies for the 453A with their simplified equivalent circuits at right.

Let's look again at the low voltage power supplies for the 453A (Fig. 3) and analyze them as operational amplifiers.

+75 VOLTS SUPPLY ANALYSIS

Fig. 3(a) shows the +75 volt supply in its simplified form. Recognize that this supply is a series regulator, Q1197 and Q1193 being the series element, with Q1184 the regulating amplifier (operating as an inverting amplifier). Notice we consider R1182, 250Ω potentiometer at mid range, half of R1182 is with R_F and the other half with R_i. R1182 is adjusted for the final value of +75 volts.

E_{IN} is the DC reference voltage for the supply.

So

$$R_F = 15800\Omega + 125\Omega \text{ in parallel with } 75000\Omega$$
$$= 13130\,\Omega\text{s}$$

$$\text{and } R_i = 2000\Omega + 125\Omega$$
$$= 2125\Omega$$

$$\therefore \frac{E_O}{E_{IN}} = -\frac{R_F}{R_i}$$

$$\frac{E_O}{-12} = -\frac{13130}{2125}$$

$$\therefore E_O = \frac{12 \times 13130}{2125}$$

$$= 74.2 \text{ volts}$$

A slight adjustment of R1182 will bring E_o to exactly +75 volts.

+12 VOLTS SUPPLY ANALYSIS

Fig. 3(b) shows the +12 volt supply in its simplified form. We proceed along the same lines as we did in the +75 volt analysis. Q1167 and Q1163 are the series regulator elements while Q1154 is the regulating amplifier, once again the inverting type. R1152, 100Ω pot, is the adjustment for setting the supply to +12 volts. Consider R1152 set at mid range, half of which is associated with R_F while the other half we find associated with R_i. However, the values of R_i and E_{IN} are not so apparent here. We must first calculate these values. R_i is Thevenin's equivalent resistance, while E_{IN} is the Thevenin equivalent voltage to the left of the dashed line.

So

$$R_i = \frac{(1330 + 50) \times 75000}{(1330 + 50) + 75000}\,\Omega\text{'s}$$
$$= 1355\,\Omega\text{s}$$

$$\text{and } E_{IN} = -12 + \frac{87 \times (1335 + 50)}{(1335 + 50) + 75000} \text{ volts}$$
$$= -12 + 1.57$$
$$= -10.43 \text{ volts}$$

now

$$R_F = 1500\Omega + 50\Omega$$
$$= 1550\Omega$$

so finally

$$\frac{E_O}{E_{IN}} = -\frac{R_F}{R_i}$$

$$\frac{E_O}{-10.43} = \frac{1550}{1355}$$
$$= \frac{+10.43 \times 1550}{1355} \text{ volts}$$
$$= +11.93 \text{ volts}$$

A slight adjustment of R1152 will bring E_o to exactly +12 volts.

-12 VOLTS SUPPLY ANALYSIS

Fig. 3(c) shows the -12 volt supply in its simplified form. Q1137 and Q1133 are the series regulating elements. Q1124 and Q1114 are the regulating amplifiers. Notice that the simplified form is of the *non-inverting* type of operational amplifier. This is not so apparent at first glance and is determined by the fact that the reference voltage (E_{IN}) is a negative voltage and results in a negative output voltage. However, the feedback loop is connected to the opposite input of the amplifier and any change in output voltage is amplified and inverted to move the output back to its original level. E_{IN} in this case is the reference voltage provided by the zener diode VR1114. R1122, the 250Ω pot is the -12 volt adjustment, so as before, we identify R_F and R_i.

So

$$R_F = 453\Omega + 125\Omega$$
$$= 578\Omega$$

$$R_i = 1580\Omega + 125\Omega$$
$$= 1705\Omega$$

$$\therefore \frac{E_O}{E_{IN}} = 1 + \frac{R_F}{R_i}$$

$$\frac{E_O}{-9} = 1 + \frac{578}{1705}$$
$$= \frac{2283}{1705}$$

hence

$$E_O = \frac{-9 \times 2283}{1705}$$
$$= -12.05 \text{ volts}$$

A slight adjustment of R1122 will bring E_o to exactly -12 volts.

CONCLUSION

In summary, we find that the typically high open-loop gain and low output impedance of operational amplifiers make them ideal for use in achieving a constant voltage power supply. They do, however, have limitations as to the range of frequencies over which they can maintain a constant output voltage.

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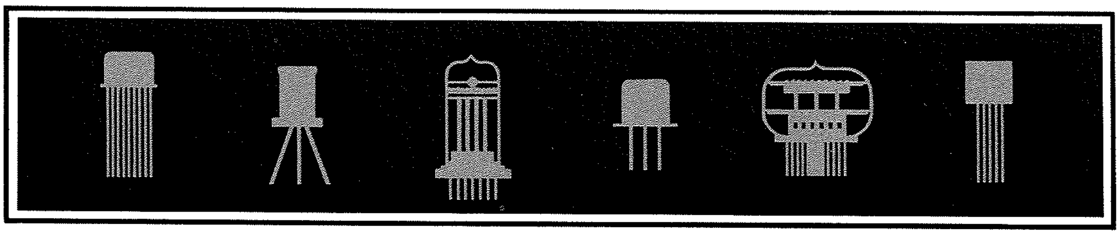
Service Scope

A PRACTICAL APPROACH TO TRANSISTOR AND VACUUM TUBE AMPLIFIERS

BY F. J. BECKETT
TEKTRONIX, INC.
ELECTRONIC INSTRUMENTATION GROUP
DISPLAY DEVICES DEVELOPMENT



Two articles published in past issues of Service Scope contained information that, in our experience, is of particular benefit in analyzing circuits. The first article was "Simplifying Transistor Linear-Amplifier Analysis" (issue #29, December, 1964). It describes a method for doing an adequate circuit analysis for trouble-shooting or evaluation purposes on transistor circuits. It employs "Transresistance" concept rather than the complicated characteristic-family parameters. The second article was "Understanding and Using Thévenin's Theorem" (issue #40, October, 1966). It offers a step-by-step explanation on how to apply the principles of Thévenin's Theorem to analyze and understand how a circuit operates.

Now we present three articles that will offer a practical approach to transistor and vacuum-tube amplifiers based on a simple DC analysis. These articles will, by virtue of additional information and tying together of some loose ends, combine and bring into better focus the concepts of "Transresistance."

Part I

THE TRANSISTOR AMPLIFIER

INTRODUCTION

Tubes and transistors are often used together to achieve a particular result. Vacuum tubes still serve an important role in electronics and will do so for many years to come despite a determined move towards solid state circuits.

Whether a circuit is designed around vacuum tubes or transistors or both, it is important to recognize the fact that the two are in many ways complementary. It is wrong to divorce vacuum tubes and transistors as separate identities each peculiar to their own mode of operation. Indeed, as this series of articles will show there is an analogy between the two. It is true of course, that the two are entirely different in concept; but, so often we come across a situation where one can be explained in terms of the other that it is very desirable to recognize this fact.

Transistor and vacuum tube data give us very little help in the practical sense. Parameter Curves and electrical data show the behavior of these devices under very defined conditions. In short, they are more useful to the designer than the technician. We are often reduced to explaining most circuits in terms of an ohms law approach; so, it seems pointless not to pursue this approach to its logical conclusion.

In this first article we will look at a transistor amplifier as a simple DC model; and then, in the second article, look at a vacuum-tube amplifier in a similar light. We will assume that both devices are operated as linear amplifiers and then use the results in a practical way.

One must bear in mind that this approach cannot be assumed in all cases. It is, as it is meant to be, a simple analysis but the results will prove to be a valuable tool in trouble-shooting and understanding circuits.

OBJECTIVE

The objective of this paper is to present a practical approach to Transistor and Vacuum-tube amplifiers based on a simple DC analysis.

The articles will be published in the following sequence.

1. The Transistor Amplifier.
2. The Vacuum-tube Amplifier.
3. An analysis of a typical Tektronix hybrid circuit (Type 545B vertical) based on conclusions reached in (1) and (2).

As a corollary they will bring forward some important relationships between vacuum tubes and transistors.

Let us consider the general equation for current through a P.N. diode junction.

$$I = I_o \left[\exp \frac{V}{\rho V_e} - 1\right] \quad (1)$$

where V = applied volts

I_o = reverse bias current

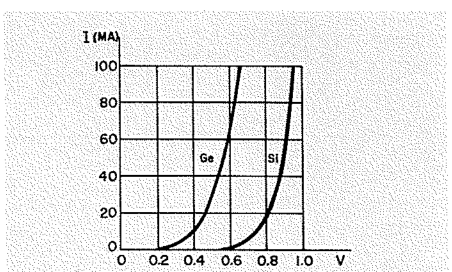
ρ = constant between 1 & 2

and $V_e = \frac{kT}{q}$ where k = Boltzmans Const., 1.38×10^{-23} Joule/°Kelvin

T = absolute temperature in degree Kelvin at room temperature, i.e., T = 300°K

q = electronic charge 1.602×10^{-19} Coulomb.

$$V_e = \frac{300}{11600} = 0.026 \text{ volts}$$



THE FORWARD VOLT-AMPERE CHARACTERISTICS OF A GERMANIUM AND SILICON DIODE

Figure 1.

Figure 1 shows a typical forward volt/amp characteristic for germanium and silicon diodes. Figure 2 is a plot of the collector current or the base current versus the base-to-emitter voltage of a transistor; point A on this curve is a typical operating point.

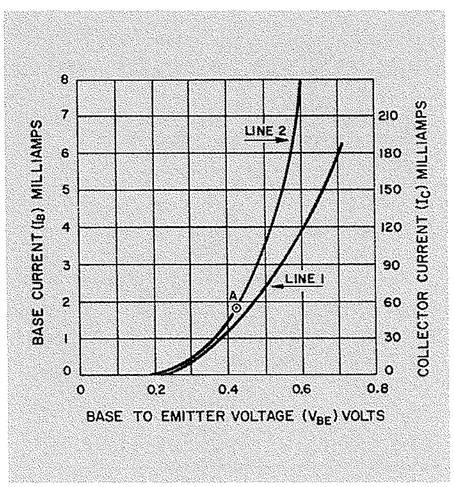


Figure 2. Line (1) is a plot of the base current versus the base-to-emitter voltage (V_{BE}). Line (2) is a plot of the collector current versus the base-to-emitter voltage (V_{BE}). Point "A" is a typical operating point.

One is quite justified in looking at a transistor in terms of the two-diode concept, refer to Figure 3. Therefore, assuming diode A to be forward biased and diode B to be reverse biased, as would be the case if we were to operate the transistor as a linear amplifier, the current through diode A will conform to equation (1). Let us take a closer look at Figure 2.

We define conductance in the general case as

$$g = \frac{I}{V}$$

and therefore at our operating point "A" the dynamic conductance

$$g' = \frac{\Delta I}{\Delta V} \quad (2)$$

hence

$$g' = \frac{I_o \exp \frac{V}{\rho V_e}}{\rho V_e} = \frac{I + I_o}{\rho V_e} \quad (3)$$

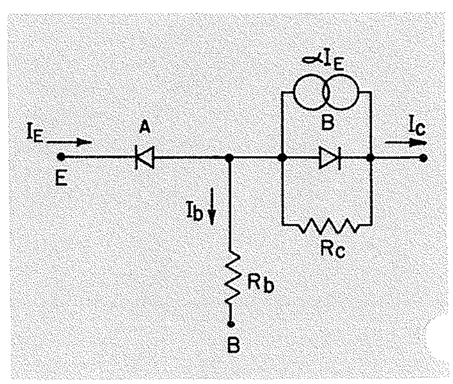


Figure 3. Illustration of the two-diode concept of a transistor.

but $I >> I_0$ then $g' = \frac{I}{\rho V_e}$

or $g' = \frac{I}{0.026\rho}$ mhos (4)

The term "ρ" takes into account the recombination of carriers in the junction region. It is approximately unity for germanium and approximately 2 for silicon. At a typical operating point this term can usually be neglected. Therefore, we may say that

$g' = \frac{I}{26}$ if I is in milliamps. (5)

Now resistance is the reciprocal of conductance and therefore the value of conductance at point "A" can be given in terms of resistance

$r_e = \frac{26}{I}$ Ω's (6)

This resistance (r_e) is commonly known as the dynamic emitter resistance.

At this point we will depart from our simple model and look at the transistor in another form; but, bear in mind our first thoughts. Transistor parameters are derived from various equivalent circuits depending upon the configuration i.e., common emitter, common base, or common collector. We will not consider any detailed analysis in this approach; but, to understand the approach it is necessary to know how these parameters are derived. It will be simple enough to derive another set of parameters once we have our basic model constructed.

The simplest and easiest equivalent circuit of a transistor is the "Tee" equivalent. It is a very good approximation about the behavior of a transistor, especially at DC and low frequencies. We can also represent either the common emitter or the common base simply by interchanging R_b and R_e. Figure 4 is a "Tee" equivalent circuit of the common emitter and the common base configurations.

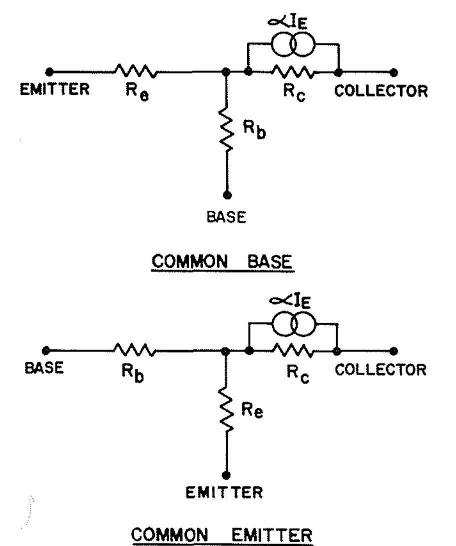


Figure 4. "Tee" equivalent circuits for the common-base and common-emitter configurations of transistors.

Firstly, let us define the term β (the small-signal current gain) as

$$\beta = \frac{\Delta I_c}{\Delta I_b} \quad (7)$$

and since $I_E = I_c + I_b$

$$\text{then } I_E = I_c \left(1 + \frac{1}{\beta}\right) \quad (8)$$

usually $\beta >> 1$ then $I_E \approx I_c$

Equation (8) shows us that only $\frac{1}{\beta}$ of the emitter current flows into the base. Hence, it is reasonable to suppose that any impedance in the emitter, when viewed from the base, will be β times as great; and, any impedance in the base, when viewed from the emitter, will be β times as small. That is to say, the dynamic resistance multiplied by β must equal R_e in our equivalent "Tee" circuit.

Hence $R_e = \beta r_e$

Our equivalent circuit shows a resistance R_b. This resistance is known as the base-spreading resistance. It is a physical quantity and can be expressed in terms of resistivity associated with the base-emitter junction. It can vary between a few ohms to hundreds of ohms, depending upon the type of transistor; and therefore, must be taken into consideration. Looking into the emitter we see it as an impedance whose value is divided by β and appears in series with the dynamic emitter resistance (r_e). Hence the emitter current encounters an impedance in the base/emitter junction which is equal to the sum of the dynamic resistance plus $\frac{R_b}{\beta}$, the latter term we will designate R_r and the sum of these two resistances we will designate R_t.

$$\text{Hence } R_t = r_e + R_r \quad (9)$$

The value of R_r can vary anywhere between 2 Ω to 24 Ω depending on the value of R_b. R_b is difficult to measure and rarely given in electrical data on transistors. A figure of 250 Ω's is a typical value at low frequencies. Therefore, if β were 50 then R_r would be 5 Ω's.

Now if we look into the base in the common emitter or the common collector configuration it is reasonable to suppose we will see the resistance (R_t)—plus any other impedance which may be wired to the emitter terminal—multiplied by β, then

$$R_{in} = \beta(R_t + R_E) \quad (10)$$

where R_E = the external emitter resistance.

If $R_E >> R_t$ then $R_{in} = \beta R_E$

So far we have had very little to say about R_c shunted by the current generator $\propto I_E$. If our equivalent "Tee" circuit consisted of resistances alone, it would be passive; i.e., it could supply no energy of its own. But a transistor can amplify energy to the signal. To represent this we have shown a current generator shunting R_c. The value of R_c will depend on the circuit configuration; i.e., tens of kilohms for a common emitter configuration, to many megohms for a common base configuration. In our approach it is not necessary to pursue this matter any further since we will not be considering a transistor in any extreme condition.

Now in a more practical sense, let us look at Figure 5, a typical common-emitter configuration.

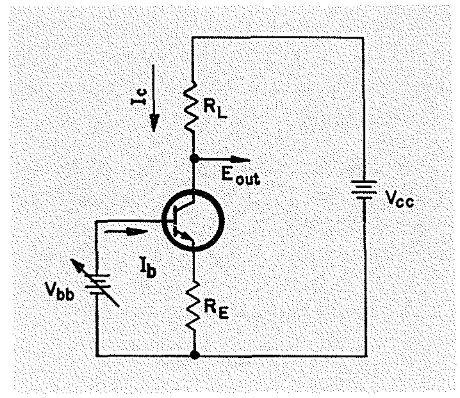


Figure 5. A typical common-emitter circuit.

Now we will assume $R_c >> R_L$.

Now by inspection

$$E_{out} = V_{cc} - I_c R_L \quad (11)$$

$$\text{hence } \Delta E_{out} = -\Delta I_c R_L \quad (12)$$

The input impedance we see looking into the base of a transistor in the common emitter configuration is

$$R_{in} = \beta(R_E + R_t) \quad (10)$$

$$\text{also } \Delta I_b = \frac{\Delta V_{bb}}{R_{in}}$$

$$= \frac{\Delta V_{bb}}{\beta(R_E + R_t)} \quad (13)$$

we also recall that

$$\beta = \frac{\Delta I_c}{\Delta I_b} \quad (7)$$

$$\text{hence } \Delta I_c = \beta \Delta I_b \quad (14)$$

Therefore substituting equation (13) in equation (14)

$$\Delta I_c = \beta \frac{\Delta V_{bb}}{\beta(R_E + R_t)} \quad (15)$$

and from equation (15)

$$\Delta V_{bb} = \Delta I_c (R_E + R_t) \quad (16)$$

we define the voltage gain as

$$A_{(v)} = \frac{\Delta E_{out}}{\Delta V_{bb}}$$

Then from equation (12) and equation (16)

$$A_{(v)} = -\frac{\Delta I_c R_L}{\Delta I_c (R_E + R_t)}$$

$$= -\frac{R_L}{R_E + R_t} \quad (17)$$

and if $R_E >> R_t$ then

$$A_{(v)} = -\frac{R_L}{R_E} \quad (18)$$

If we analyze the common-base configuration in a similar manner we arrive at the same result with the one exception that the sign is positive.

The conclusion we can draw from this analysis is that the gain of a transistor stage is set by external conditions provided that the emitter resistance is sufficiently great enough to "swamp" our internal resistance (R_t). In the absence of an emitter resistance

$$A_{(v)} = \frac{R_L}{R_t}$$

There is one very important fact we must remember about R_E. R_E will be that impedance in which the signal current will flow to the AC ground. We define an AC ground point as that point in a circuit at which the power level of the signal has been reduced to zero.

We normally encounter three types of an AC ground:

1. An Actual AC Ground.

This is the chassis point or the DC ground point. It is as well to remember the

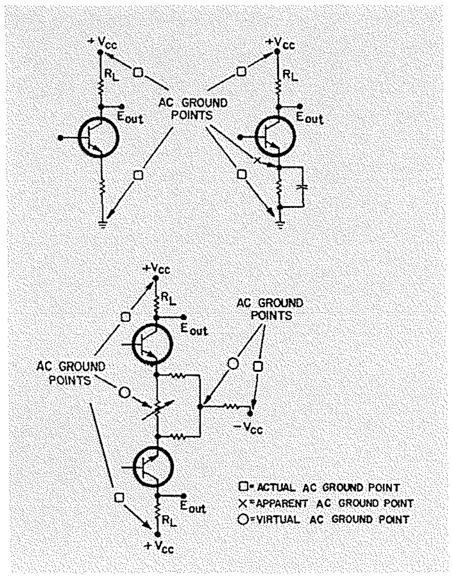


Figure 6. Illustrating the three types of AC ground normally encountered in electronic circuits.

power supply can be placed in this category so far as the signal is concerned.

2. An Apparent AC Ground.

The apparent AC ground may be represented by any point in a circuit which acts as to represent a low impedance between that point and the actual AC ground thereby bypassing the signal to an actual AC ground. A large value capacitor is a typical example should one side be returned to an actual AC ground.

3. The Virtual AC Ground.

The virtual AC ground point is perhaps the most difficult to recognize. It may best be explained as that point in a circuit where we have two signals of equal amplitude and frequency but exactly opposite in phase. Figure 6 will help clarify these points.

Figure 8 summarizes the results of our DC analysis of the common emitter, common base and common collector.

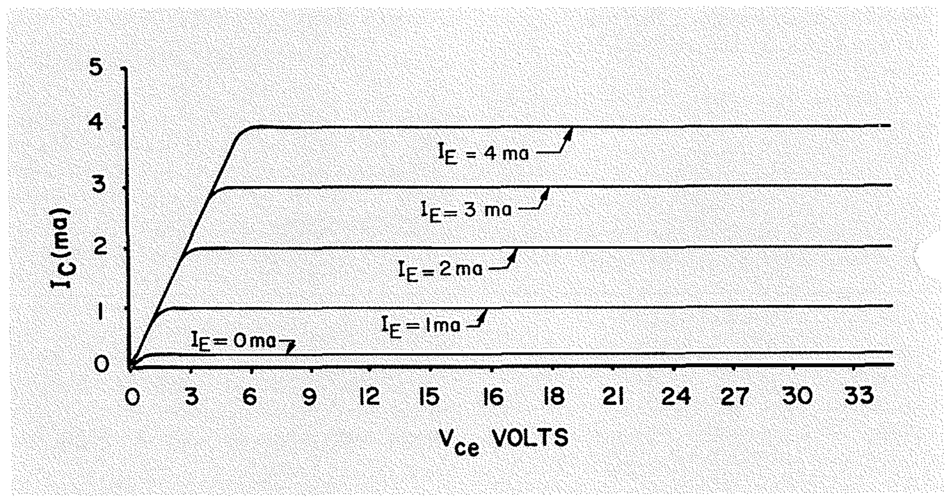


Figure 7. We define the parameter R_c in the common-base "Tee" configuration as;

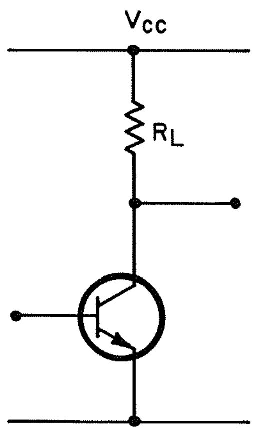
$$R_c = \frac{\Delta V_{ce}}{\Delta I_c}\Bigg|_{I_E} \text{ ohms}$$

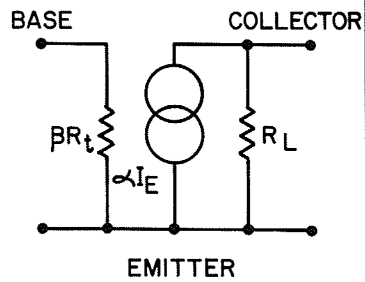
Where ΔV_{ce} is the change in the collector voltage because of the change in collector current ΔI_c, when we hold the emitter current I_E constant.

Once the collector becomes saturated, the change in I_c is very small for a large change in V_{ce}. Hence, R_c is a very large resistance and does not modify the DC equivalent circuit to any extent. For this reason it was omitted from Figure 8. Therefore; $R_{out} = R_L$ (Common Base).

BASIC CIRCUIT	EQUIVALENT CIRCUIT	EQUATIONS	REMARKS

COMMON EMITTER





GAIN = $A(v) = -\frac{R_L}{R_t}$

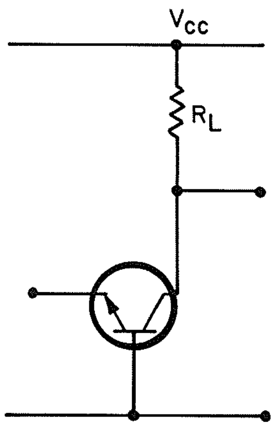
$R_{IN} = \beta R_t$

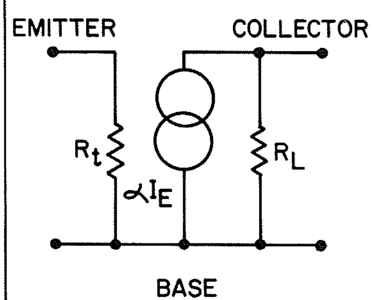
A resistance (R_E) between the emitter terminal of the transistor to the AC ground will modify the gain equation and the input impedance; then,

$A_{(v)} = -\frac{R_L}{R_t + R_E}$ and

$R_{in} = \beta\ (R_E + R_t)$.

COMMON BASE





GAIN = $A(v) = +\frac{R_L}{R_t}$

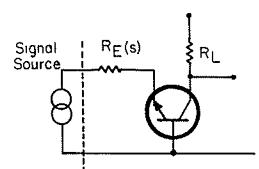
$R_{IN} = R_t$

$R_{OUT} = R_L$

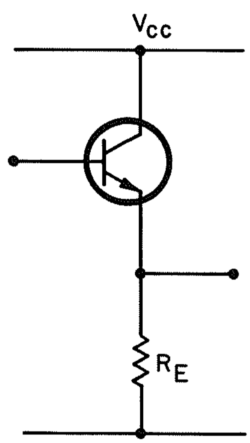
The equivalent resistance $R_{E(s)}$ between the input signal source and the emitter terminal of the transistor will modify the gain equation and the input impedance as seen from the signal source; then,

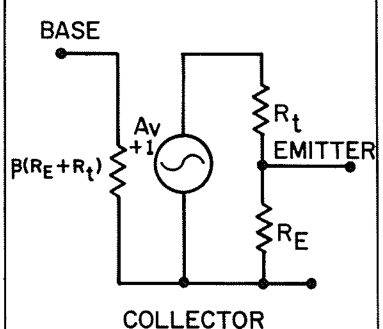
$A_{(v)} = +\frac{R_L}{R_t + R_{E(s)}}$ and

$R_{in} = R_t + R_{E(s)}$.



COMMON COLLECTOR





GAIN = $A(v) = \frac{R_E}{R_E + R_t}$

$R_{IN} = \beta\ (R_E + R_t)$

$R_{OUT} = (R_t + \frac{1}{\beta})$ in parallel with R_E

The actual value of R_{out} will depend on what resistance is connected to the base. Let us assume the base is directly coupled to the preceding stage. The equivalent output impedance of the preceding stage becomes the numerator over beta in the second term in the parenthesis and the output impedance of the stage under consideration R_{out} is modified accordingly; e.g., if the output impedance of the previous stage is 1000 Ω, then

$R_{out} = (R_t + \frac{1000}{\beta})$ in parallel with R_E.

Figure 8.

PART 2
THE VACUUM TUBE AMPLIFIER

In the previous article (Part I, "The Transistor Amplifier) of this series, it was shown that the gain of a linear transistor amplifier is set by external conditions. The same reasoning can also be applied to vacuum tubes. The equivalent circuit of a vacuum-tube amplifier is shown in Figure 9. The current that is produced in the plate circuit by the signal (E_g) acting on the grid is taken into account by postulating that the plate circuit can be replaced by a generator, $-\mu E_g$ having an internal resistance (rp). We may also consider a vacuum-tube amplifier in terms of the constant-current form by replacing the voltage generator in the constant-voltage form with a current generator (gm E_g) shunting the internal resistance (rp).

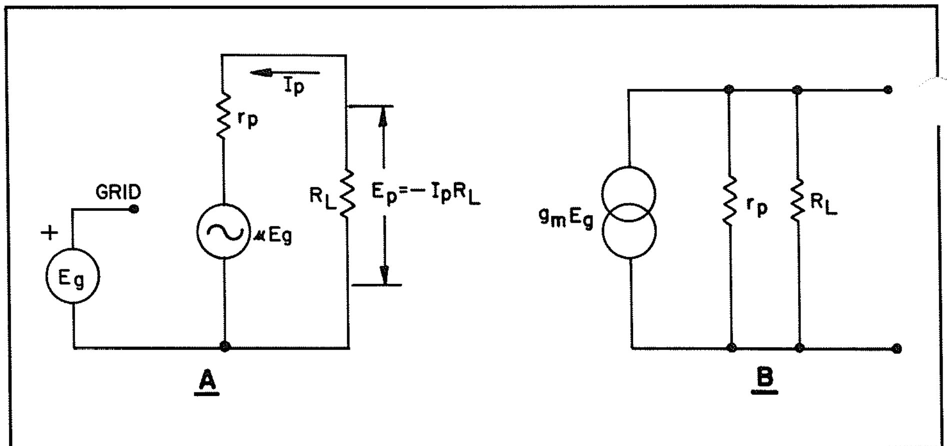


Figure 9. Illustrating the more familiar equivalent circuit of a vacuum tube amplifier.
(a) The constant voltage generator form or the Thévenin equivalent.
(b) The constant current generator form or the Norton equivalent.

These two approaches are valid in every respect but they do not convey much to us in the practical sense. Let us now consider a vacuum-tube amplifier from another approach.

In an amplifier which has its grid referenced to ground all plate-circuit impedances, R_L and rp, when viewed from the cathode are multiplied by the term $\frac{1}{\mu + 1}$. Also, by the same reasoning, the cathode impedances when viewed from the plate circuit are multiplied by the term ($\mu + 1$). Therefore, the impedance we see looking into the cathode must be

$\frac{rp + R_L}{\mu + 1}$, where μ equals the amplification factor of the tube.

Hence it is reasonable to suppose that the voltage E_c, reference Figure 10, appears across this impedance we see looking into the cathode.

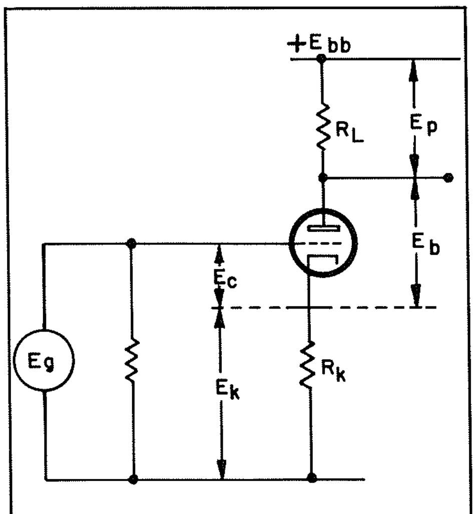


Figure 10. A vacuum tube amplifier in the grounded cathode configuration showing the various voltage measurements around the circuit.

The Triode Amplifier (Grounded Cathode)

We will now look at a triode amplifier in terms related to our equivalent circuit. The common component is of course, the plate current. The change in this current due to the action of a control grid will determine the output voltage across the load impedance (R_L).

Now $E_g = E_c + E_k$ (19)

That is to say

$$E_g = I_p\left[\frac{rp + R_L}{\mu + 1}\right] + I_pR_k$$

$$\text{Or, } E_g = I_p\left[\left(\frac{rp + R_L}{\mu + 1}\right) + R_k\right] \quad (20)$$

Also, $E_{bb} = E_b + E_p + E_k$ (21)

or $E_b = E_{bb} - E_p - E_k$ (22)

and $E_p = -I_pR_L$ (23)

We define the voltage gain $A_{(v)}$ as

$$A_{(v)} = \frac{E_p}{E_g} \quad (24)$$

$$\text{Then } A_{(v)} = -\frac{I_pR_L}{I_p\left[\left(\frac{rp + R_L}{\mu + 1}\right) + R_k\right]}$$

$$= -\frac{R_L}{\left(\frac{rp + R_L}{\mu + 1}\right) + R_k} \quad (25)$$

We now have arrived at an equation for gain which is a ratio of impedances. The same approach may be applied to the grounded-grid configuration and we arrive at a similar result, except the sign is positive.

The Pentode Amplifier

In the triode amplifier all the cathode current will flow through the output load impedance (R_L). However, in the case of the pentode and other multigrid tubes, some of this current is diverted into the screen. Equation (23) defines the output voltage in terms of the plate current. Therefore, to derive the actual gain figure we must determine the actual amount of cathode current which will finally reach the plate and become signal current. This figure can be arrived at from a graphical analysis of the mutual-conductance curves. In most cases, about 72% of the cathode current reaches the plate to become signal current. A typical example is a type 12BY7 pentode. However, this figure can be as high as 90% for some types—for example a 7788 pentode. The ratio of the plate c[illegible] rent (I_p) to the cathode current (I_k) is [illegible] plate efficiency factor, i.e., $\eta = \frac{I_p}{I_k}$.

Now let is reexamine what effect this fact must have on the gain of a pentode amplifier as compared to a triode amplifier. The impedance we see looking into the cathode of a pentode is the same as for a triode.

That is $\frac{rp + R_L}{\mu + 1}$

however rp >> R_L and therefore R_L can usually be neglected in this equation.

That is to say $\frac{rp}{\mu + 1} \approx \frac{1}{gm}$

and since conductance is the reciprocal of resistance we will call this impedance r_k.

$$\text{i.e. } r_k = \frac{1}{gm} \quad (26)$$

We have seen that the gain equation of the triode amplifier is defined in terms of the parameters μ and rp. We should not lose sight of the fact that μ and rp are related to the plate current and therefore when these parameters are transferred to cathode dimensions these terms must [illegible] multiplied by the plate efficiency factor ([illegible] That is to say the impedance we see looking into the cathode r_k must be multiplied by (η). With these facts in mind let us now derive the gain equation for a pentode amplifier.

We recall that:

$$= E_{bb} - E_p - E_k \quad (22)$$

and $E_p = -I_pR_L$ (23)

also $E_g = E_c + E_k$ (19)

$$= \eta r_k I_k + I_k R_k \quad (27)$$

but $I_k = \dfrac{I_p}{\eta}$ (28)

Therefore substituting equation (28) in equation (27)

$$E_g = \frac{\eta r_k I_p}{\eta} + \frac{I_p R_k}{\eta}$$

$$= I_p \left(r_k + \frac{R_k}{\eta}\right) \quad (29)$$

and since the voltage gain

$$A_{(v)} = \frac{E_p}{E_g} \quad (24)$$

$$= -\frac{I_p R_L}{I_p \left(r_k + \dfrac{R_k}{\eta}\right)}$$

$$= -\frac{R_L}{r_k + \dfrac{R_k}{\eta}} \quad (30)$$

The same remarks we made about the external emitter resistor R_E (refer to Part No. 1, The Transistor Amplifier) apply equally as well to the cathode resistor, R_k; *namely, R_k will be that impedance in which the signal current will flow to the AC ground.*

In the case of the grounded plate (the cathode follower) we do not need to consider the plate efficiency factor if the amplifier is triode connected, therefore, the "gain" can be considered in terms of a simple divider network which can never be greater than unity.

$$A_{(v)} = \frac{R_k}{R_k + r_k} \quad (31)$$

The Push-Pull Amplifier

We can view a push-pull amplifier in a similar light by recognizing the existence of a virtual AC ground point between the cathodes of $V_{(1)}$ and $V_{(2)}$ as shown in Figure 11. Therefore, the gain of a push-pull triode amplifier will be:

$$A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{r_{k(1)} + r_{k(2)} + R_{k(1)} + R_{k(2)}} \quad (32)$$

where subscripts (1) and (2) are associated with $V_{(1)}$ and $V_{(2)}$.

And if:

$$R_{k(1)} = R_{k(2)}$$

and $r_{k(1)} = r_{k(2)}$

which is usually the case; then,

$$A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{2r_k + 2R_k} \quad (33)$$

Where $r_k = \dfrac{r_p + R_L}{\mu + 1}$ (either $V_{(1)}$ or $V_{(2)}$)

and $R_k = R_{k(1)}$ or $R_{k(2)}$

With a push-pull pentode amplifier we must consider the plate-efficiency factor (η). Therefore,

$$A_{(v)}\text{ pentode} = \frac{R_{L(1)} + R_{L(2)}}{2r_k + \dfrac{2R_k}{\eta}} \quad (34)$$

where $r_k = \dfrac{1}{gm}$ either $V_{(1)}$ or $V_{(2)}$

$R_k = R_{k(1)}$ or $R_{k(2)}$

η = plate-efficiency factor of either $V_{(1)}$ or $V_{(2)}$.

The Cascode Amplifier

The cascode amplifier fundamentally consists of two tubes connected in series, see Figure 12. Normally we usually fix the grid of $V_{(1)}$ at some positive voltage.

The key to understanding this type of circuit is to consider $V_{(2)}$ as a voltage-activated current generator. All the current delivered by $V_{(2)}$ passes through the output load impedance R_L. Any change in voltage appearing at the grid of $V_{(2)}$ appears as a change in current across R_L. We can derive the gain equation in the same way as we did for a pentode amplifier. There is no need to consider (η) if both tubes are triodes.

$$A_{(v)}\text{ (stage)} = \frac{R_{L(1)}}{R_{k(2)} + r_{k(2)}} \quad (35)$$

$$\text{where } r_{k(2)} = \frac{r_{p(2)}}{\mu_{(2)} + 1}$$

$$= \frac{1}{gm_{(2)}}$$

where the subscripts (1) and (2) are associated with $V_{(1)}$ and $V_{(2)}$.

One of the advantages of this type of circuit is that the internal impedance which shunts R_L is extremely high.

In this respect the triode cascode amplifier closely approximates a pentode amplifier. If we compare the plate-current versus plate-voltage curves of both devices we see a close resemblance.

The Hybrid Cascode Amplifier

Figure 13 is a typical configuration consisting of a vacuum tube V_1 and a transistor, Q_1, connected in series. We can apply much the same approach as we did for the cascode vacuum-tube amplifier. Let us assume the base to emitter junction of Q_1 to be forward biased. The collector current of Q_1 becomes the plate current of V_1. Therefore, any change occurring at the base of Q_1 is reflected as a change in plate current in V_1.

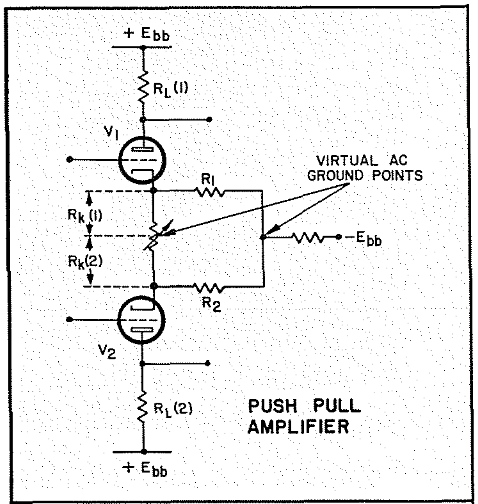


Figure 11. A typical push-pull triode amplifier. We normally encounter two virtual AC ground points between the cathodes V_1 and V_2. It may be necessary to consider the effect of the virtual AC ground point at the junction of R_1 and R_2. If R_1 or R_2 is large in value compared respectively to $R_{k(1)}$ or $R_{k(2)}$ then we can neglect this virtual AC ground and consider R_k in terms of $R_{k(1)}$ or $R_{k(2)}$. However, if this is not so, R_k will be the parallel combination of $R_{k(1)}$ and R_1 or $R_{k(2)}$ and R_2.

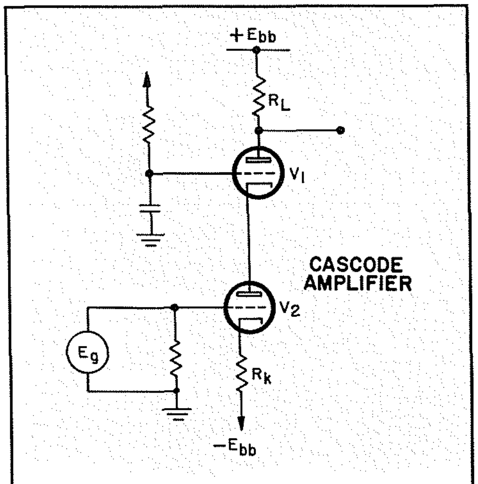


Figure 12. Illustrating a cascode amplifier using two triodes.

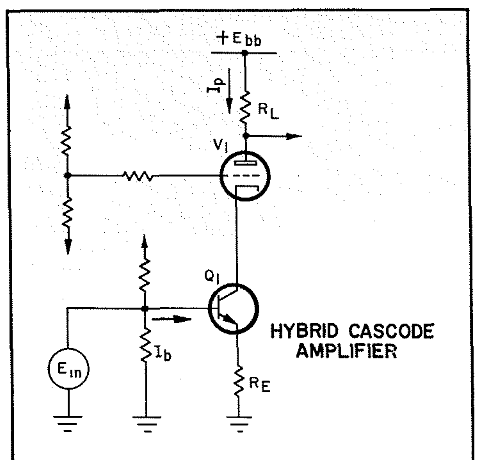
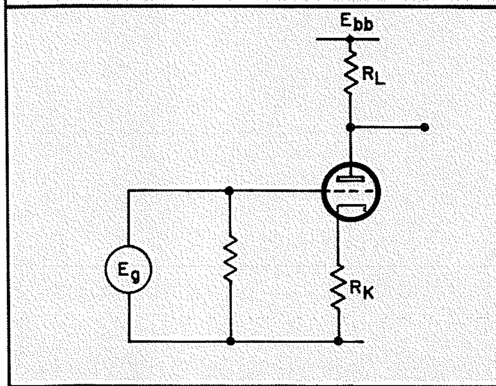
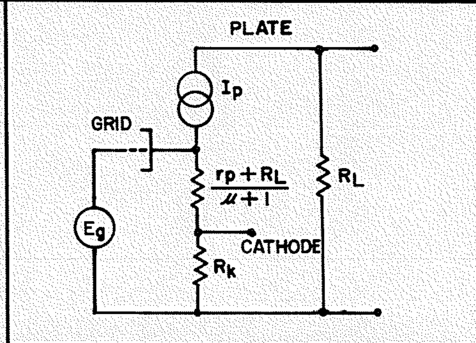


Figure 13. A typical hybrid cascode amplifier using a transistor and a vacuum tube.

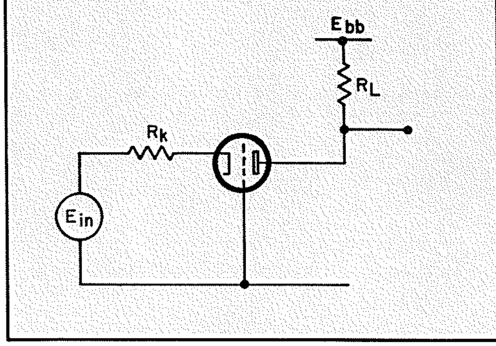
BASIC CIRCUIT (TRIODE)	EQUIVALENT CIRCUIT	EQUATIONS

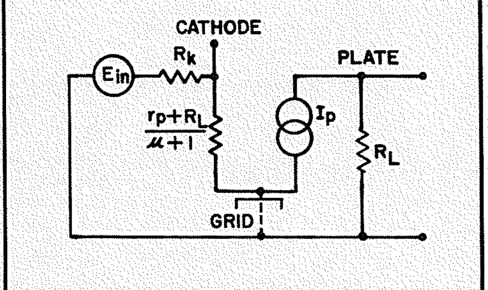




GROUNDED CATHODE

$$\text{GAIN} = A_{(v)} = -\frac{R_L}{\frac{r_p + R_L}{\mu + 1} + R_k}$$

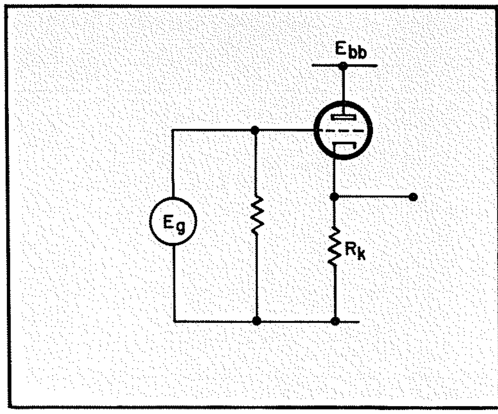


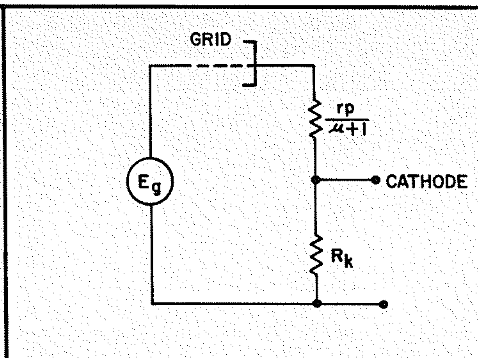


GROUNDED GRID

$$\text{GAIN} = A_{(v)} = +\frac{R_L}{\frac{r_p + R_L}{\mu + 1} + R_k}$$

$$R_{IN} = R_k + \frac{r_p + R_L}{\mu + 1}$$





GROUNDED PLATE

$$\text{GAIN} = A_{(v)} = +\frac{R_k}{R_k + r_k}$$

ROUT = r_k in parallel with R_k

WHERE: $r_k = \frac{r_p}{\mu + 1}$

PENTODE AMPLIFIER

$$\text{GAIN} = A_{(v)} = \frac{R_L}{r_k + \frac{R_k}{\eta}}$$

WHERE:

R_L = LOAD RESISTANCE

$r_k = \frac{1}{gm}$

R_k = CATHODE RESISTOR (Refer Text)

η = PLATE EFFICIENCY FACTOR

PUSH PULL AMPLIFIER

TRIODE PAIR

$$\text{GAIN} = A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{2r_k + 2R_k}$$

WHERE:

$$r_k = \frac{r_p + R_L}{\mu + 1}$$

PENTODE PAIR

$$\text{GAIN} = A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{2r_k + \frac{2R_k}{\eta}}$$

WHERE: $r_k = \frac{1}{gm}$

SUBSCRIPTS (1) AND (2) ARE ASSOCIATED WITH V_1 AND V_2

CASCODE AMPLIFIER

$$\text{GAIN} = A_{(v)} = \frac{R_{L(1)}}{r_{k(2)} + R_{k(2)}}$$

WHERE:

$$r_k = \frac{1}{gm_{(2)}}$$

HYBRID CASCODE AMPLIFIER

$$\text{GAIN} = A_{(v)} = \frac{R_L}{R_E + R_t}$$

WHERE:

R_L = LOAD RESISTANCE

* $R_t = r_e + R_r$

* R_E = EXTERNAL EMITTER RESISTANCE

* REFER PART I "THE TRANSISTOR AMPLIFIER"

Figure 16

We recall (Part 1, The Transistor Amplifier, Eq. 10) that the input impedance we see looking into the base of a transistor in the common-emitter configuration is:

$$R_{in} = \beta\,(R_E + R_t) \qquad (10)$$

Now $E_{in} = I_b R_{in}$

$$= I_b\, \beta (R_E + R_t) \qquad (36)$$

also $\beta = \dfrac{I_c}{I_b}$

or $I_c = \beta\, I_b \qquad (37)$

therefore substituting equation (37) in equation (36)

$$E_{in} = I_c\,(R_E + R_t) \qquad (38)$$

now the collector current Q_1 becomes the plate current of V_1. Then,

$$E_{in} = I_p\,(R_E + R_t) \text{ since } I_p = I_c \qquad (39)$$

also $E_p = -I_p R_L \qquad (23)$

and since

$$A_{(v)}\ (\text{stage}) = \frac{E_p}{E_{in}}$$

then from equations (23) and (39)

$$A_{(v)}\ (\text{stage}) = -\frac{I_p R_L}{I_p\,(R_E + R_t)}$$

$$= -\frac{R_L}{R_E + R_t} \qquad (40)$$

If the vacuum tube is not a triode but some other multigrid tube such as a pentode, the gain equation will have to be multiplied by the plate efficiency factor (η).

The same remarks concerning the output impedance of the vacuum-tube cascode amplifier can be applied to the hybrid counterpart.

Summary

We have shown that the gain of a linear amplifier, transistor or vacuum tube, is a ratio of impedances. We can, of course, derive the gain equations for both devices in terms of mutual conductance. In fact, if we compare the transfer curves of both devices, Figure 14, we see a striking similarity. V_{BE} and E_g can be thought of in the same terms and in like manner I_p and I_c perform identical functions. Our analysis of both devices has shown that this fact is not coincidence.

It is not unreasonable to say that when we compare the cathode-follower (grounded-plate) against the common-collector configuration, Figure 15, we can think of both devices as being identical in operation—differing only in concept. The same argument can be put forward about the common-base amplifier and the grounded-grid amplifier. So too, the common-emitter amplifier and the grounded-cathode amplifier if we chose to ignore the input impedances of both devices.

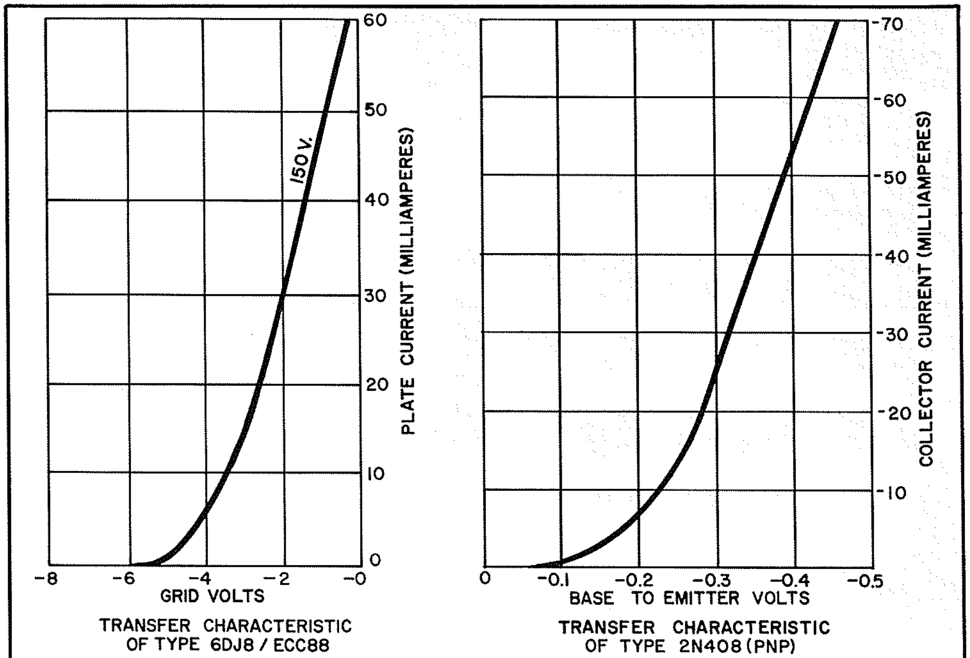


Figure 14. The transfer characteristic curves of a vacuum tube (6DJ8) and a PNP transistor (2N408), illustrating the basic similarity between vacuum tubes and transistors.

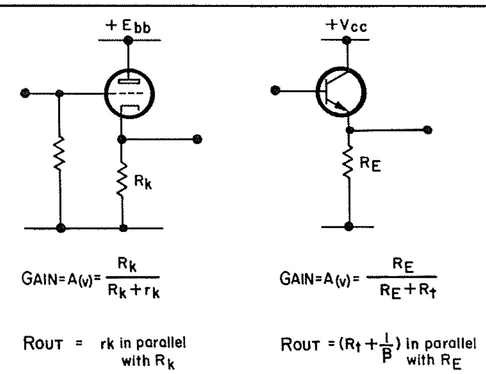


Figure 15. The analogy between the cathode follower (grounded plate) and the emitter follower (the common collector) in terms of "gain" and output impedances of both devices.

Figure 16 summarizes the results of our analysis of the grounded cathode, grounded grid, and grounded plate amplifiers.

It is not surprising we sometimes find ourselves explaining one device in terms of another. Nature has a charming way of making most things interdependent upon one another. Recognize this fact and most tasks become a little easier.

PART 3
A DC ANALYSIS OF A TYPICAL TEKTRONIX HYBRID CIRCUIT

As a typical example of a Tektronix, Inc. hybrid circuit on which to demonstrate our DC analysis, we have chosen the vertical amplifier of a Type 545B Oscilloscope. This circuit is representative of the hybrid circuit one encounters so often in electronic instrumentation today.

The Type 545B vertical amplifier is a hybrid push-pull amplifier operating in a class A mode. It incorporates a few extra circuits such as trigger pick-off amplifiers necessary to accomplish its function, but, basically it is a hybrid push-pull amplifier.

To begin our analysis of the amplifier, the first thing we must do is select a portion of the amplifier circuit which will give us the information necessary for us to make our first calculation. We are going to analyze the whole circuit so we can choose our point of entry. The input circuit is as good a point as any. Bear in mind that, for our purpose, this is not the only point of entry. Any point on the circuit which will give us useful information would do.

A quiescent DC voltage of +67 volts is the nominal voltage at the output of the plug-in amplifiers used in the Type 545B oscilloscope. This voltage appears at terminals 1 and 3 of J11 in Figure 17, and thus, at the grids of V494A and V494B, a 6DJ8 dual triode. The input cathode follower (V494 A & B) has a bias of about 4 volts; therefore, both cathodes will be at +71 volts. The base voltage of Q514 and Q524 is then fixed at 71 volts. This sets the emitter voltages of Q514 and Q524 at one junction drop more negative (they are both NPN transistors) than the base. Therefore, the voltage at the emitter of Q514 and Q524 is 70.5 volts. T500 is a small toroidal transformer used for high-frequency common-mode rejection. The DC BALANCE Control, R495, sets the quiescent condition. We mean by this that the trace is centered.

We have made certain assumptions about the bias of a vacuum tube and the base-to-emitter voltage drop of a transistor. This is quite justifiable since we know what function the device performs. One helpful hint about transistors is that you can expect a base-to-emitter voltage drop of about 0.5 to 0.6 volts for a silicon transistor and about 0.2 volts for a germanium transistor.

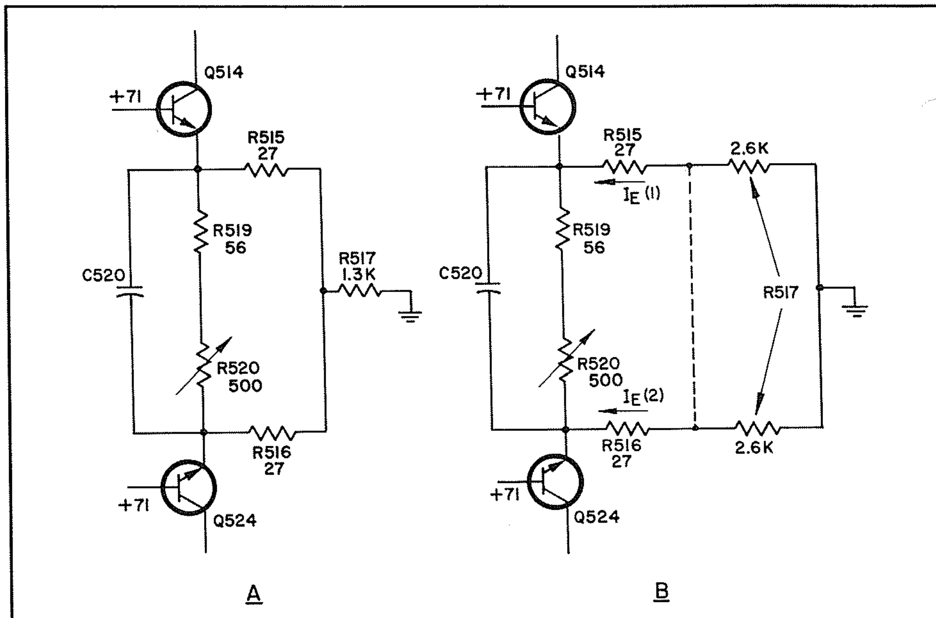


Figure 18. The circuit which will determine the DC emitter currents for either Q514 or Q524. (A)—The actual circuit as shown in Figure 17. (B)—The equivalent DC circuit considering R517 as two resistors through which the individual emitter currents will flow.

We are now able to calculate the emitter current of either Q514 or Q524. The DC-emitter current will flow through R515 or R516 and into R517 to ground. Since the emitter currents of Q514 and Q524 both pass through R517, we may think of R517 being made up of two resistors, each of 2.6 kΩ in value, in which the individual emitter currents will flow, refer to Figure 18: Therefore,

$$I_E\ (1)\ \text{or}\ (2) = \frac{70.5 \times 10^3}{2.627 \times 10^3}\ \text{mA}$$

$$= 27\ \text{mA}$$

We can now calculate the value of r_e, the dynamic-emitter resistance,

$$r_e = \frac{26}{I_E} = \frac{26}{27}$$

$$= 0.96\ \Omega$$

to this we can add our constant, R_r, of say, 4 Ω. We recall that:

$$R_t = r_e + R_r \qquad (9)$$

therefore:

$$R_t = 0.96 + 4 = 4.96\ \Omega$$

or approximately 5 Ω. We have now established the value of the emitter current and the value of R_t for Q514 and Q524.

Our next step is to find the value of R_E. We must know this value in order to calculate gain. You will recall that R_E will be that impedance through which the signal current will flow to the AC ground. Let us take another look at the resistive network between the emitters of Q514 and Q524. The signal currents flowing in this circuit will be equal and opposite at two points, refer to Figure 19. These points are virtual AC-ground points; therefore, the impedance seen by the signal current from the emitters of Q514 or Q524 will be the parallel combination of 153 Ω and 27 Ω or approximately 23 Ω to the AC ground points. Hence, R_E for Q514 or Q524 will be 23 Ω.

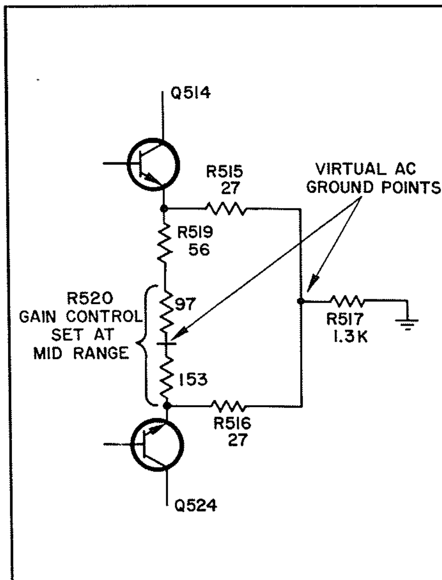


Figure 19. The location of the virtual AC ground points between the emitters of Q514 and Q524.

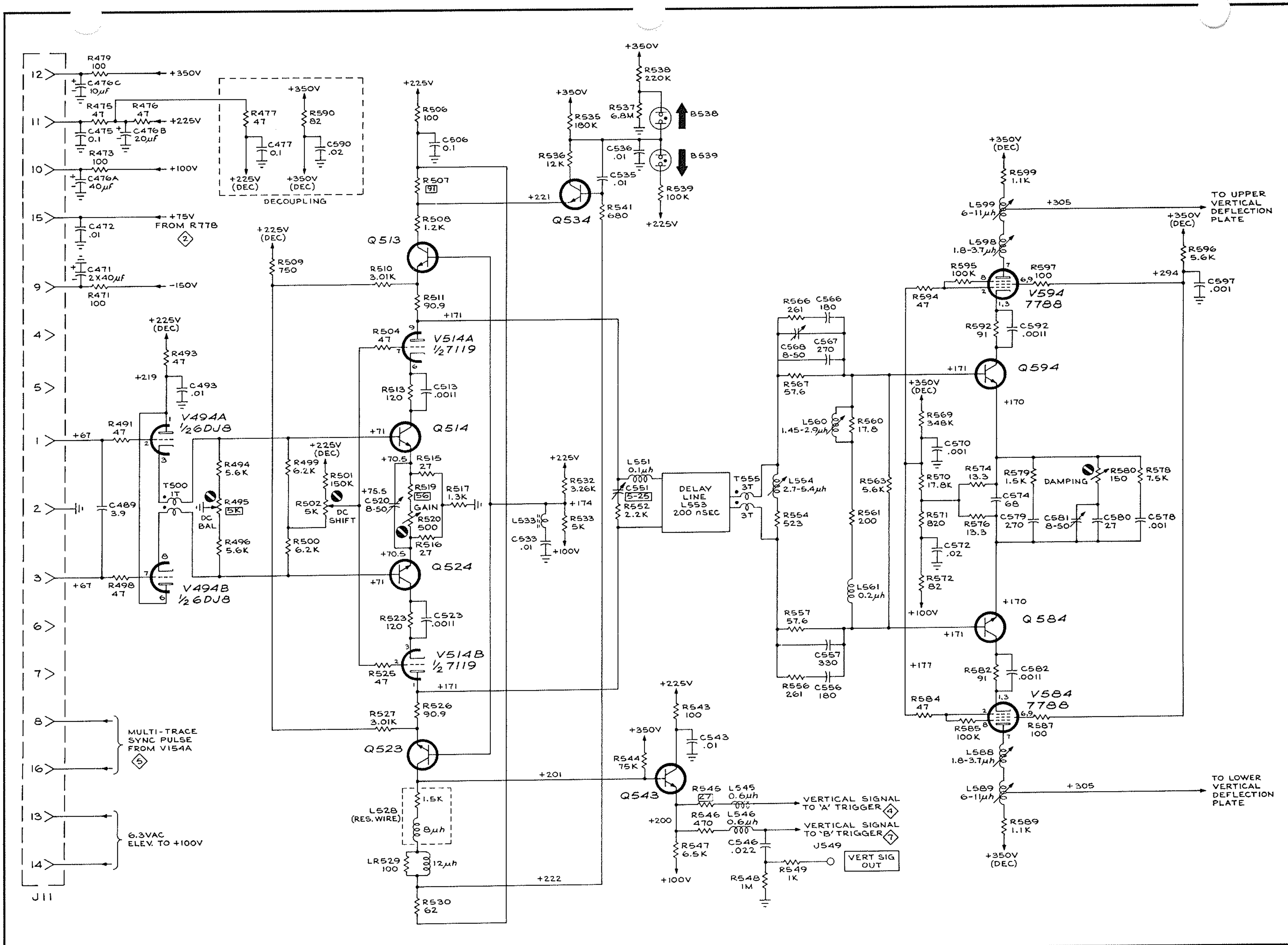


Figure 17.

TYPE 545B OSCILLOSCOPE

VERTICAL AMPLIFIER

We have now calculated from this part of the circuit all of the information we need to progress further into the circuit. Let us turn our attention to the circuit around Q513 and Q523. The first thing we notice is that the base of Q513 and Q523 are tied together at an AC-ground point. You will recall that the impedance we see looking into the emitter of the common-base configuration is R_t. In order to calculate R_t we must, of course, calculate r_e and add our constant for R_r of 4 Ω; r_e will be a function of the actual value of current flowing into the emitter. 27 milliamps has been set in the emitter circuit of Q514 and Q524; but not all of this current will flow into the emitter of Q513 and Q523. 11.5 milliamps will flow through R510 and R527, refer to Figure 20. The actual value of current into Q513 or Q523 will be 15.5 milliamps. Therefore, the impedance (R_t) we see looking into the emitter of Q513 and Q523 will be

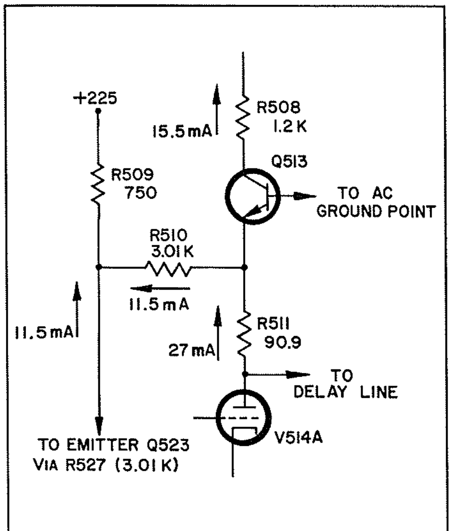


Figure 20. The DC current paths in the emitter circuit of Q513 or Q523.

$$R_t = r_e + R_r \qquad (9)$$

$$= \frac{26}{15.5} + 4\,\Omega$$

$$= 5.68\,\Omega$$

This impedance of 5.68 Ω plus R511 or R526 (90.9 Ω) constitutes part of the load impedance of the hybrid cascode amplifier Q514, V514A or Q524, V514B and the necessary matching impedance for the delay line.

There is one point we should make clear here. We have assumed a value of 4 Ω for R_r which you will recall is equal to $\frac{R_b}{\beta}$. R_r can vary from between 2 Ω to 24 Ω depending upon the type of transistor (refer to Part 1, "The Transistor Amplifier" SERVICE SCOPE #42, February 1967). This is one of those few times we should be really a bit more specific about assuming a value of R_r. The sum of the impedances 5.68 Ω and 90.9 Ω should be equal to 93 Ω since our delay line is a 186 Ω balanced line. Therefore, we have a difference of 3.58 Ω between the theoretical value and the calculated value, or an error of approximately 3.7%. This error has been due in part to our presupposed value of R_r to be 4 Ω. Such an error could not be tolerated in design work but it is acceptable here for our purpose of DC analysis. Bear this limitation in mind when you apply this analysis.

There is another point we must clear up. What is the load impedance of the hybrid cascode amplifier Q514, V514A or Q524, V514B? Clearly it will be that impedance or impedances connected from the plate of V514A or V514B to the AC ground. We are using a balanced delay line of 186 Ω, (93 Ω to a side), referenced to the AC ground. Therefore, the delay line impedance (93 Ω) must shunt R511 in series with R_t (or R526 in series with R_t) making an effective load impedance of approximately 47 Ω in the plate circuit of V514A or V514B. We now have all the necessary information to calculate the gain to this point.

$$A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{R_{E(1)} + R_{E(2)} + R_{t(1)} + R_{t(2)}}$$

$$= \frac{47 + 47}{23 + 23 + 5 + 5}$$

$$= \frac{94}{56}$$

$$A_{(v)} = 1.68$$

Q523 is the trigger pick-off amplifier and Q543 is an emitter follower providing isolation between the vertical amplifier and the trigger circuits.

The trigger pick-off amplifier Q523 is one part of a transistor cascode amplifier. The input stage is Q514 and Q524. Normally, the gain of a transistor cascode amplifier is the ratio of R_L to $R_E + R_t$. The gain in this case must be multiplied by 0.5 for the following reason. The signal current is equally divided at the plate of V514B, half of the signal current will flow through the delay line impedance (93 Ω) and the other half through R526 and finally through the load impedance of Q523. The load impedance will be that impedance which is connected to the AC ground. The collector of Q523 is connected to the base of Q543. The impedance we see looking into the base of Q543 is

$$R_{in} = \beta\,(R_E + R_t) \qquad (10)$$

If we choose to neglect the input circuit of the trigger amplifier we see that R_E in this case is R547 6.5 kΩ. A beta of 50 is a close figure to use for Q543, and since $R_E >> R_t$ then,

$$R_{in} = \beta\, R_E$$

$$= 50 \times 6500\,\Omega$$

$$= 325\,k\Omega$$

This impedance shunts R544 (75 kΩ) and L528 a 1.5 kΩ wire-wound resistor. We may then, for all practical purposes, consider L528 the collector load resistance (R_L); therefore,

$$A_{(v)} = 0.5\left[\frac{R_L}{R_{E(1)} + R_{E(2)} + R_{t(1)} + R_{t(2)}}\right]$$

$$= 0.5\left[\frac{1500}{23 + 23 + 5 + 5}\right]$$

$$= 13.3$$

Q534 is the beam-indicator amplifier. Its function is to drive two neon lamps situated above the CRT on the front panel of the oscilloscope. These neons indicate the position of the trace in a vertical direction. In the quiescent condition the voltage at the junction of R535 and R536 is 287 volts. Both indicator neons, B538 and B539, have [illegible] volts across them, not enough voltage to strike either neon. (This type of neon has a striking voltage in excess of 68 volts.)

When we apply a negative signal to the vertical input of the oscilloscope, the base of Q524 is driven negative and the base of Q514 moves in a positive direction by a similar amount. Therefore, the current through R530 decreases and the current through R507 increases. The voltage at the emitter of Q534 increases and the voltage at the base of Q534 decreases. As a result, the base-to-emitter junction of Q534 becomes reverse biased and Q534 ceases to conduct. Therefore, the voltage at the junction of R535 and R536 rises towards 350 volts striking neon B539 which indicates trace has shifted down.

R513 and R523 and the DC SHIFT control R502 are thermal-compensation networks associated with Q514 and Q524. The thermal time constants are long and the visible result appears on the CRT display as a DC shift in trace position after a step function. The DC SHIFT control is adjusted for the best dynamic thermal compensation, typically about 1% tilt.

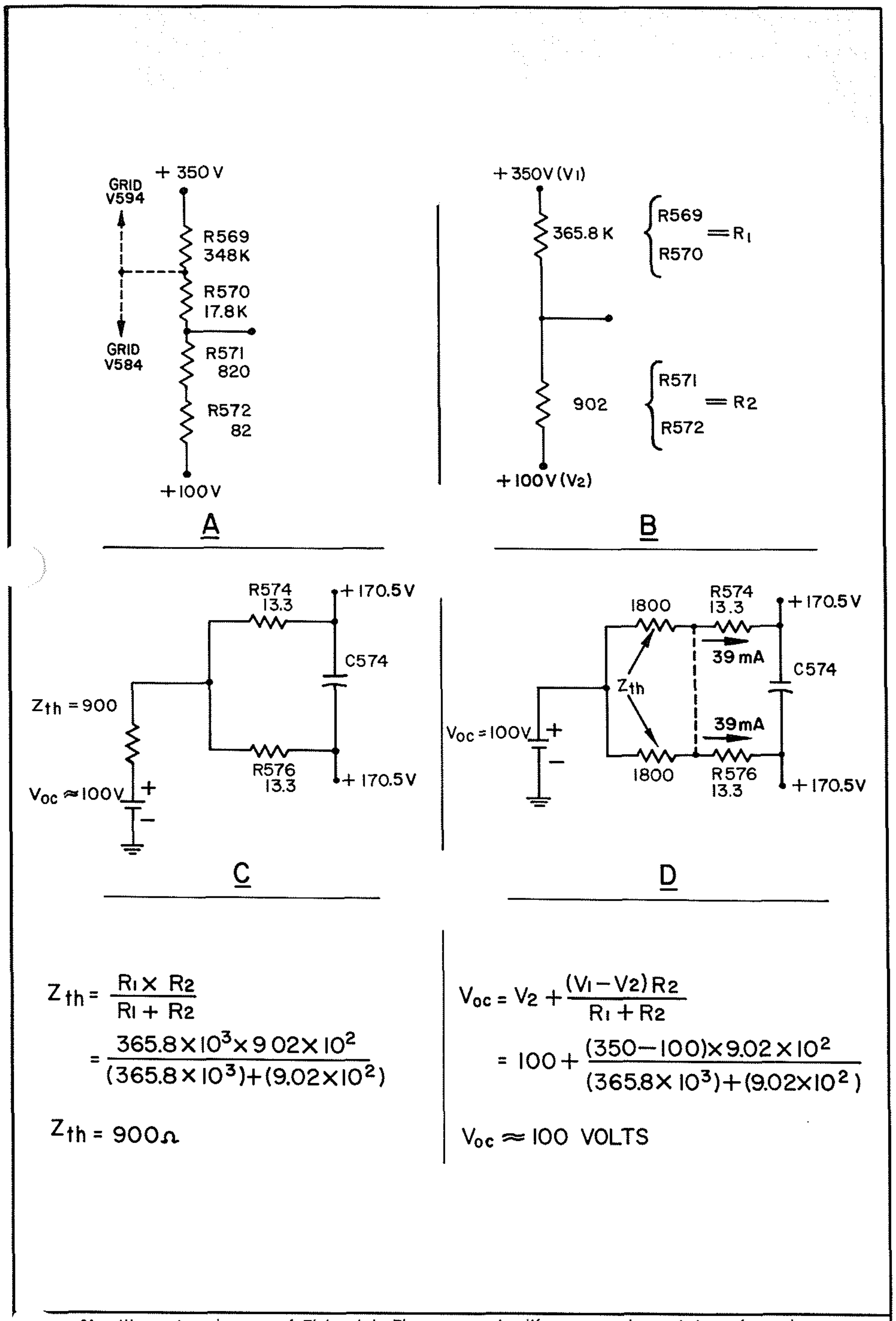


Figure 21. Illustrating the use of Thévenin's Theorem to simplify a network consisting of a voltage source and a resistive network. (A)—The network whose Thévenin equivalent is to be determined. (B)—Determining the equivalent source impedance (Z_{th}) and the equivalent voltage source (V_{oc}). (C)—The Thévenin equivalent network of (A) connected to the junction of R574 and R576. (D)—The equivalent circuit considering Z_{th} as two resistors through which the individual emitter currents will flow.

We will now analyze the output circuits to the right of the delay line, refer to Figure 17. The first thing we must do is to calculate the voltage at the base of Q594 or Q584. The voltage at the junction of R532 and R533 (174 volts) will set the base voltage of Q513 and Q523. Assuming a junction drop of 0.5 volt the voltage at the emitter of Q513 and Q523 will be 173.5 volts. The current through R511 and R526 is 27 milliamps, hence the voltage drop across these resistors will be

$$\frac{90.9 \times 27}{1000}$$

$$\approx 2.5 \text{ volts}$$

therefore, the voltage at the plate of V514A and V514B is

$$173.5 - 2.5 = 171 \text{ volts.}$$

This 171 volts is directly coupled to the base of Q594 and Q584 via the delay line. The voltage at the emitter of both Q594 and Q584 is then 170.5 volts. We will now calculate the current flowing into the emitter of Q594 or Q584. Figure 21 shows a step-by-step approach in solving this problem. The simplest approach is to use Thévenin's Theorem to simplify the resistive network R569, R570, R571 and R572. The result is we have a V_{oc} of +100 volts and a Z_{th} of 900 Ω to the junction of R574 and R576. Therefore, looking from the emitter of either Q594 or Q584 we see an impedance of 13.3 Ω in series with 1800 Ω to +100 volts.

$$I_E = \frac{(170.5 - 100)10^3}{1.8 \times 10^3} \text{ mA}$$

$$= \frac{70.5}{1.8}$$

$$= 39 \text{ mA}$$

we now calculate r_e

$$r_e = \frac{26}{I_E} = \frac{26}{39}$$

$$\approx 0.7\,\Omega$$

and to this we add our constant R_r of 4 Ω; therefore,

$$R_t = r_e + R_r \qquad (9)$$

$$= 0.7 + 4.0$$

$$= 4.7\ \Omega\text{'s}$$

We have only one point in this circuit (a virtual AC ground point) at which the signal currents will be equal and opposite. That point is the junction of R574 and R576 (13.3 Ω resistors). This fact sets R_E at 13.3 Ω. The purpose of the RC network to the right of R574, R576 is to compensate the high frequencies.

The input impedance we see looking into the base of Q594 or Q584 is

$$R_{in} = \beta\ (R_E + R_t) \qquad (10)$$

A beta of 75 for this type of transistor is a close figure to use for practical purposes. Therefore,

$$R_{in} = 75\ (13.3 + 4.7)\ \Omega\text{'s}$$

$$= 1350\ \Omega$$

The value of R_{in} is part of a resistive network which will terminate the delay line in its correct impedance. Therefore, before we leave this section we must check to see if our value of R_{in} is within practical limits. Figure 22 shows a progressive breakdown of this network.

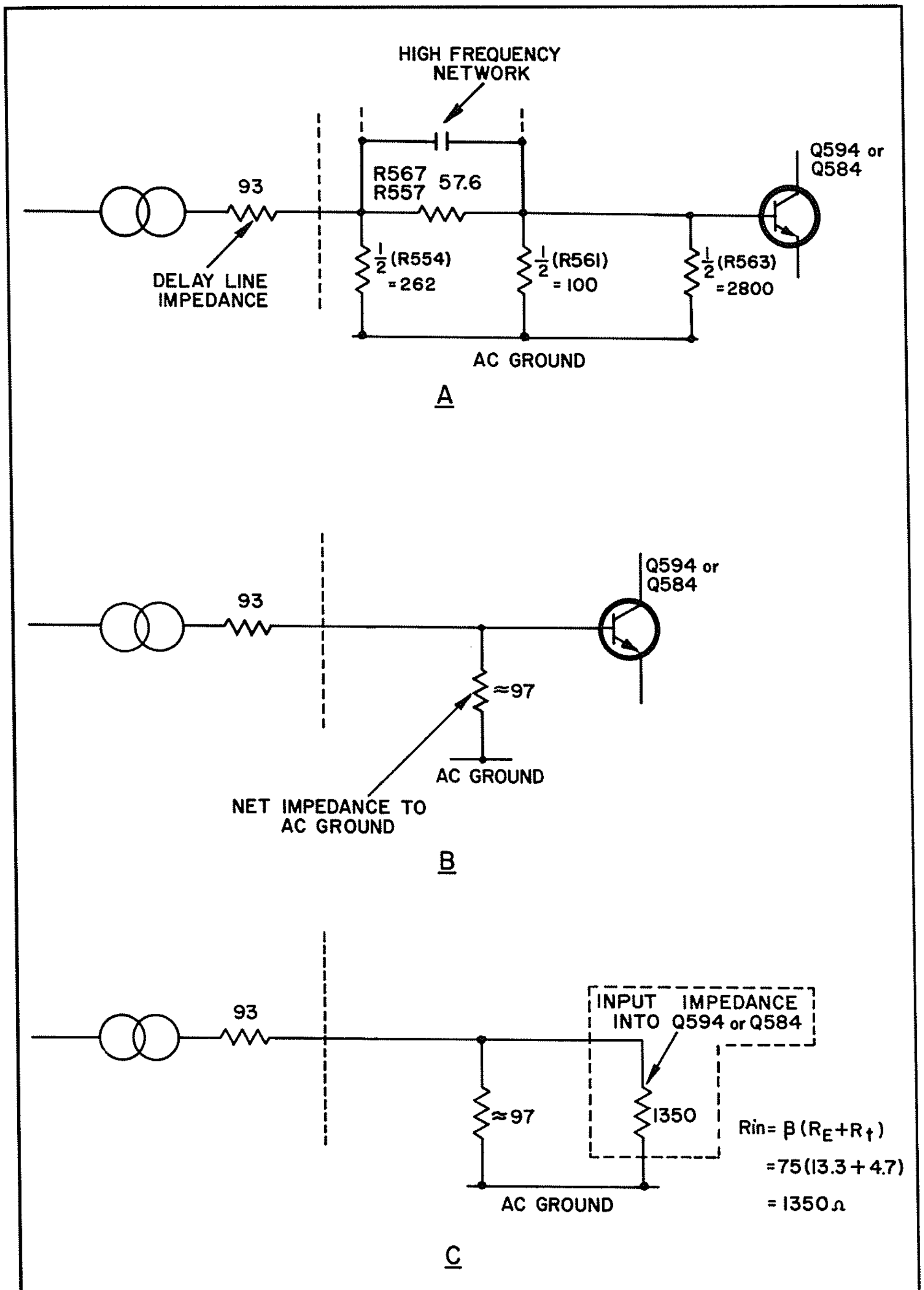


Figure 22. Illustrating a step-by-step approach for analyzing the circuit between the output of the delay line and the base of Q594 or Q584. (A)—The circuit between the output of the delay line and the base of Q594 or Q584. (B)—The net impedance of the circuit in (A) to the AC ground between the output of the delay line and the base of Q594 or Q584. (C)—The input impedance into Q594 or Q584 and the net impedance, as shown in (B), providing the terminating impedance for the delay line.

This network will induce a loss between the two stages. The signal is reduced in amplitude by a factor of 0.64 because of the voltage divider network consisting of 57.6 Ω and the parallel combination of 100 Ω, 2800 Ω, and the input impedance into Q594 or Q584.

The gain of the output stage is

$$A_{(v)} = \left[\frac{R_{L(1)} + R_{L(2)}}{R_{E(1)} + R_{E(2)} + R_{t(1)} + R_{t(2)}}\right]\eta$$

$$= \left[\frac{1100 + 1100}{13.3 + 13.3 + 4.7 + 4.7}\right]\eta$$

$$= \left[\frac{2200}{36}\right]\eta$$

$$= 61\ \eta$$

You recall that the gain equation of a hydrid cascode amplifier (refer part 2, "The Vacuum Tube Amplifier," Service Sc #43, April 1967) must be multiplied by the plate efficiency factor (η) if the vacuum tube is not a triode. The plate efficiency factor (η) normally varies from between 0.7 to 0.9. In this case (η) is approximately 0.9 - 0.88 to be exact. So finally,

$$A_{(v)} = 61 \times \frac{9}{10}$$

$$= 54.9$$

The gain of the complete Type 545B vertical amplifier is

$$A_{(v)}\ (\text{total}) = 54.9 \times 1.68 \times 0.64$$

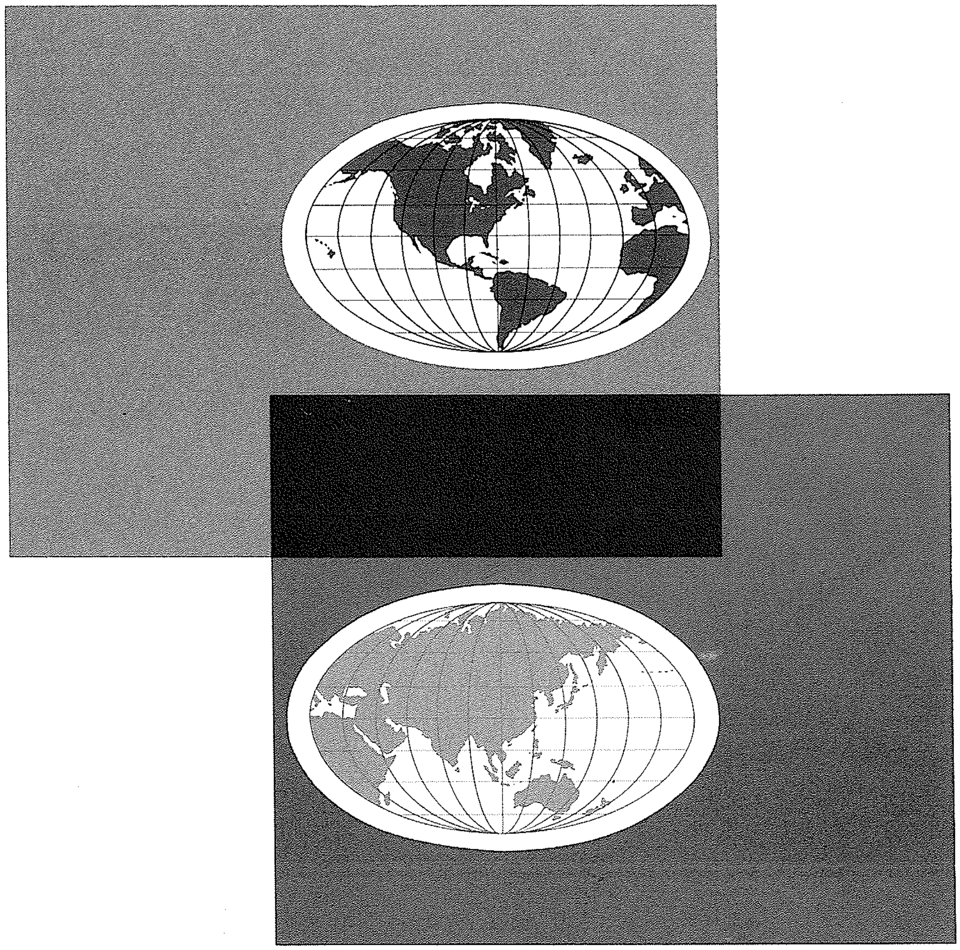
$$= 59$$

Summary

This brings to a close this series of three articles dealing with a practical approach to transistor and vacuum-tube amplifiers. This approach has been offered as a direct method of trouble shooting and understanding circuits. There are limitations as to application as we have seen. However, these limitations do not impair the practical approach we must apply to our everyday maintenance and trouble shooting problems.

LIST OF SYMBOLS

[illegible]	Voltage gain defined as $\frac{\Delta E_{out}}{\Delta E_{in}}$
E_b	Average or quiescent value of plate voltage
E_{bb}	Plate supply D-C voltage
E_c	Average or quiescent value of grid voltage
E_g	Effective or maximum value of varying component of grid voltage
E_k	Average or quiescent value of cathode voltage
E_p	Effective or maximum value of varying component of plate voltage
gm	Mutual conductance
I_b	Base current
I_c	Collector current
I_E	Emitter current
I_k	Cathode current
I_p	Plate current
R_b	Base spreading resistance (Tee Equivalent)
R_c	Collector resistance (Tee Equivalent)
R_e	Emitter resistance (Tee Equivalent)
R_E	External Emitter resistance (refer to text)
$R_{E(s)}$	The equivalent resistance between the signal source and the emitter terminal of the transistor in the common base configuration
r_e	Dynamic emitter resistance
R_k	Cathode resistance (refer to text)
r_k	The impedance seen looking into the cathode of a vacuum tube and defined as $\frac{rp + R_L}{\mu + 1} \approx \frac{1}{gm}$ (if $rp >> R_L$)
R_L	Load resistance
rp	Dynamic plate resistance
R_r	$\frac{R_b}{\beta}$
R_t	The "Transresistance" resistance ($r_e + R_r$)
V_{bb}	Base voltage
V_{cc}	Supply voltage
V_{ce}	Collector to emitter voltage
α	(alpha) The total forward current gain of the transistor as viewed from an external circuit. Normally defined as the ratio of I_c/I_E
β	(beta) The small signal current gain
Δ	(delta) The change in the variable with which it is associated
η	(eta) Plate efficiency factor (refer to text)
μ	(mu) Amplification factor



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