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 1.

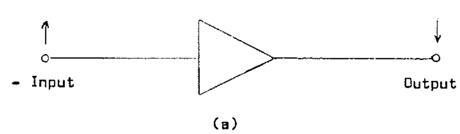
Functionally speaking, an operational amplifier is a device which, by means of negative feedback, is capable of processing a signal with a high degree of accuracy limited primarily only by the tolerances in the values of the passive elements used in the input and feedback networks.

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.



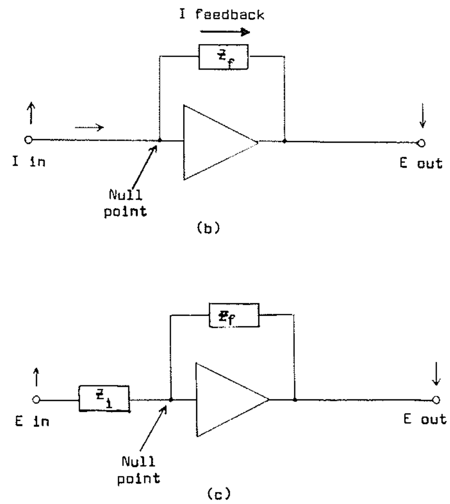


Figure 1. Conventional Operational Amplifier Symbols.

(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 $-Z_f/Z_i$.

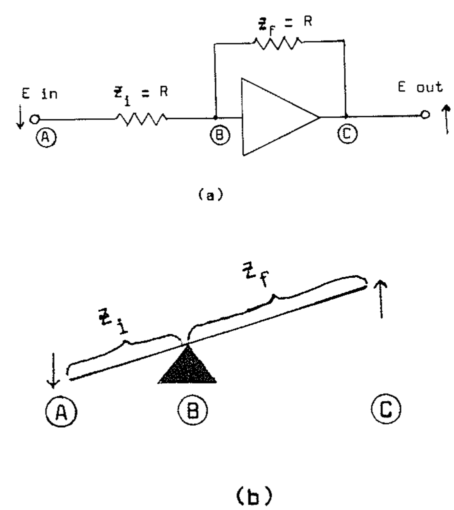


Figure 2

(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.

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.

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).

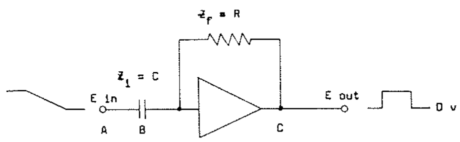


Figure 3.
Operational Amplifier as Differentiator. Output is proportional to *rate-of-change* of input voltage. $E_{out} = \frac{-dE_{in}}{dt}$ X RC.

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.

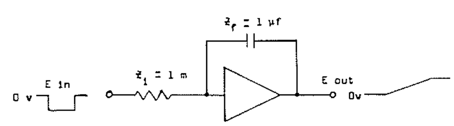


Figure 4.

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.*

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.

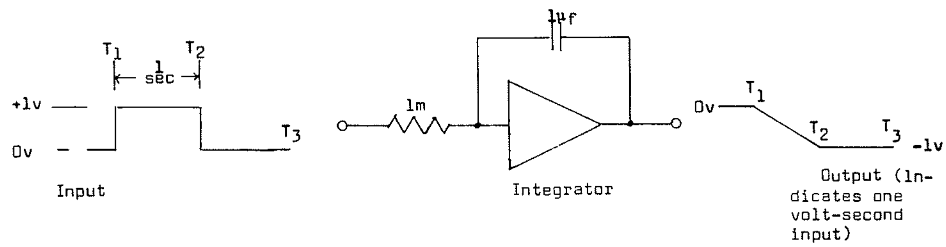


Figure 5.
Simple case of integrating 1-volt-second pulse. Integrator does not improve measurement accuracy in so simple a case.

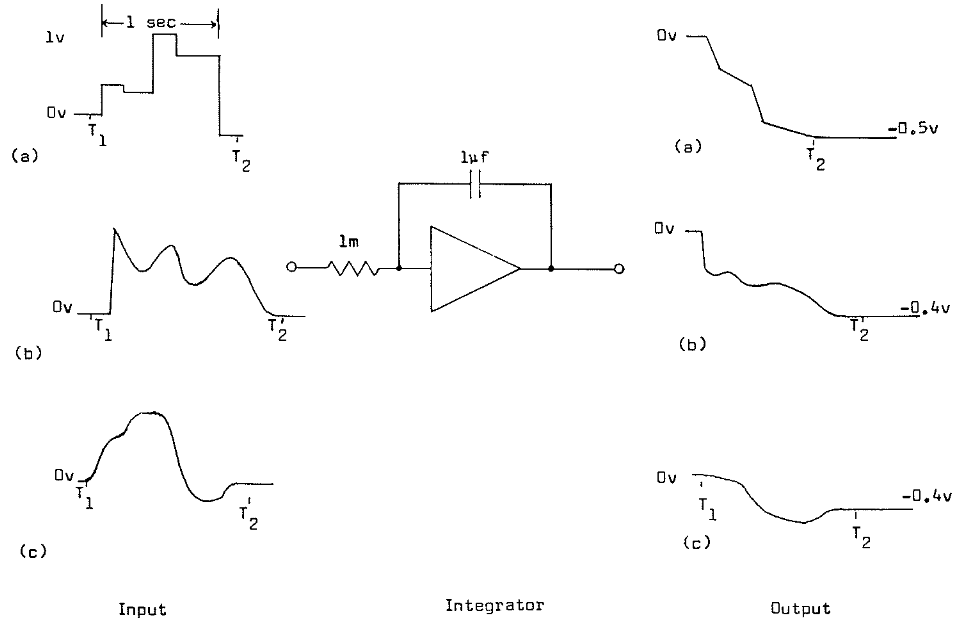


Figure 6.
Integrating more complex waveforms to determine "area under the curve" between T_1 and T_2. Note that in (c) the negative portion of the input waveform *reduces* the net integral.

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.

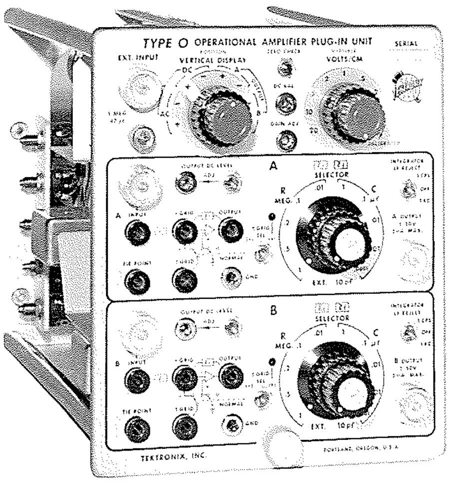
In reading this output level at T_2 we know that the input signal has amounted to 1 volt-second during the interval T_1 to T_2. Note also that a later observation, at T_3, gives the same answer, since E_{in} has been 0 between T_2 and T_3.

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:

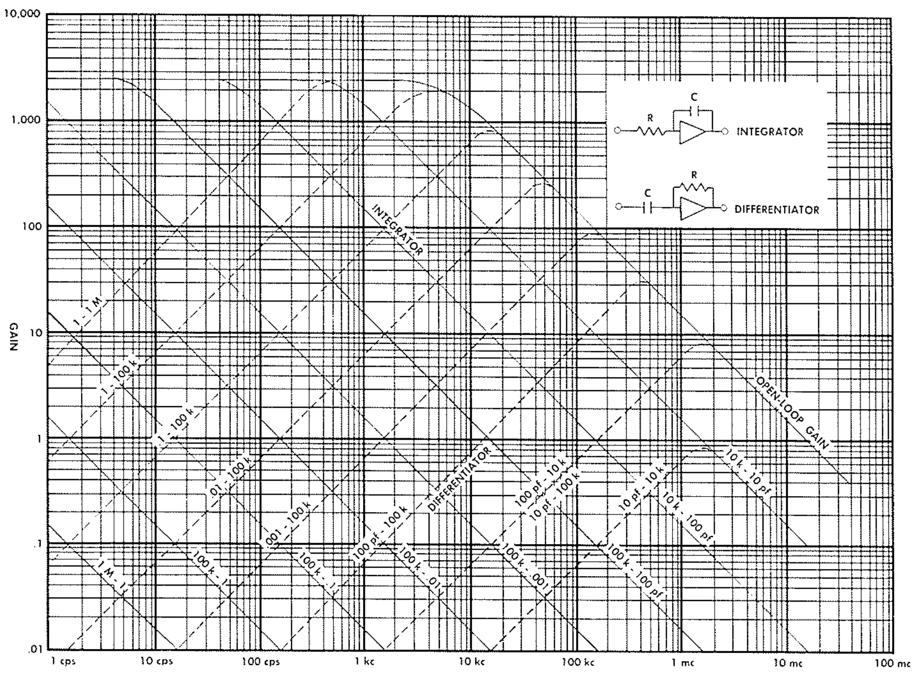
1. *Open-loop Gain*
2. *Gain-bandwidth product.*
3. *Grid current (primarily of concern during integration).*
4. *Output-current and voltage capability.*
5. *Signal-source impedance.*

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 point-



Average Gain-Frequency characteristics for integration and differentiation.

Figure 7.

ed 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 cut-off. 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).

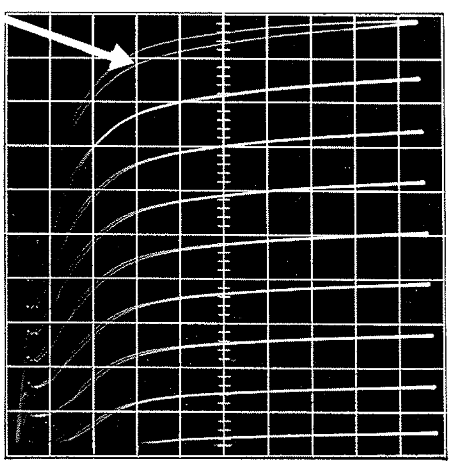


Figure 1
6AG7's with weak or inactive cathodes will show excessive retrace lines (see arrow) on the top member of a family of curves.

  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.

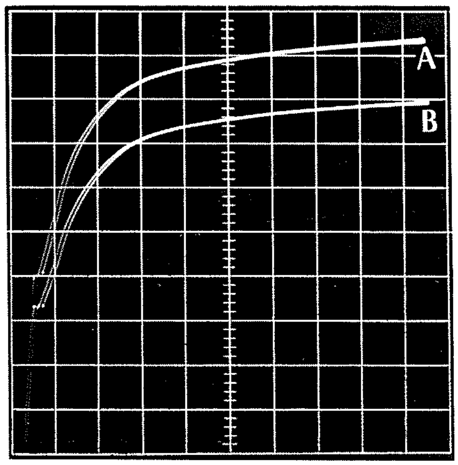


Figure 2
Waveform photo (double exposure) showing the E_p — I_g curve of a 6AG7 with a weak or inactive cathode; (A) at the instant after depressing the ZERO BIAS button and (B) at the point of maximum deflection change during depression of the button.

  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 (± ½ kc or ± 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 ±½%, 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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Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

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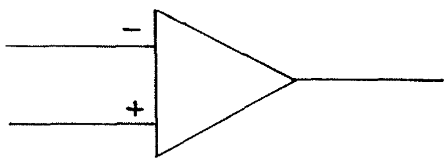
INTRODUCTION TO OPERATIONAL AMPLIFIERS

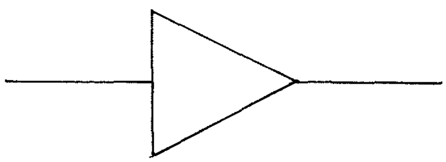
Prepared by
Tektronix Field Information Department
Part 2

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.



(a)



(b)

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 $R_i = R_f$.

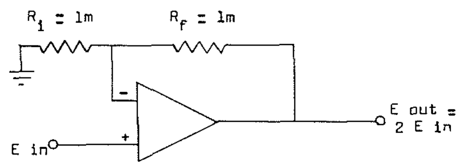


Figure 9

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 $1 - \dfrac{A}{A - 1 - \dfrac{Z_f}{Z_i}}$. So long as $\dfrac{Z_f}{Z_i}$ 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 $1 - \dfrac{2500}{2502}$, or less than 0.1%. For a gain of 100, however, the error becomes $1 - \dfrac{2500}{2601}$, 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 [illegible] it 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:

$$\varepsilon = 1 - \left[\frac{\dfrac{E_{out}}{E_{in}} - A}{1 - A}\right]$$

, or, more simply,

$$\varepsilon = \frac{1 - \dfrac{E_{out}}{E_{in}}}{1 - A}$$

, 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.

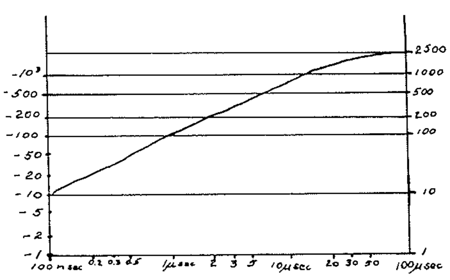


Figure 10 (a)

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).

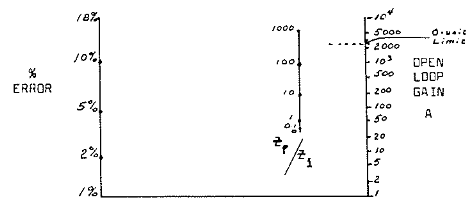


Figure 10 (b)

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 $G_v = \dfrac{-t}{RC}$, 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: $G_v = \dfrac{-RC}{t}$, 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).

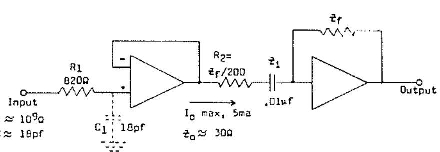


Figure 11

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.

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.

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).

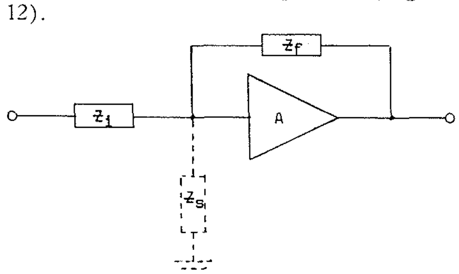


Figure 12 (a)

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.

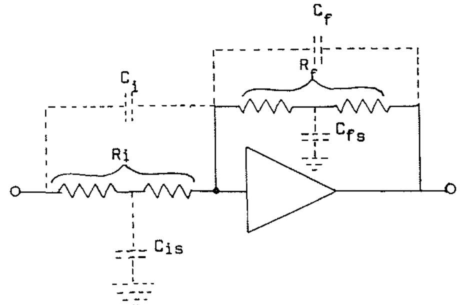


Figure 12 (b)

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:

$$\frac{E_{out}}{E_{in}} = \frac{-Z_f}{Z_i}\left[\frac{A}{A - 1 - \frac{Z_f}{Z_i}\left(\frac{Z_s + Z_i}{Z_s}\right)}\right]$$

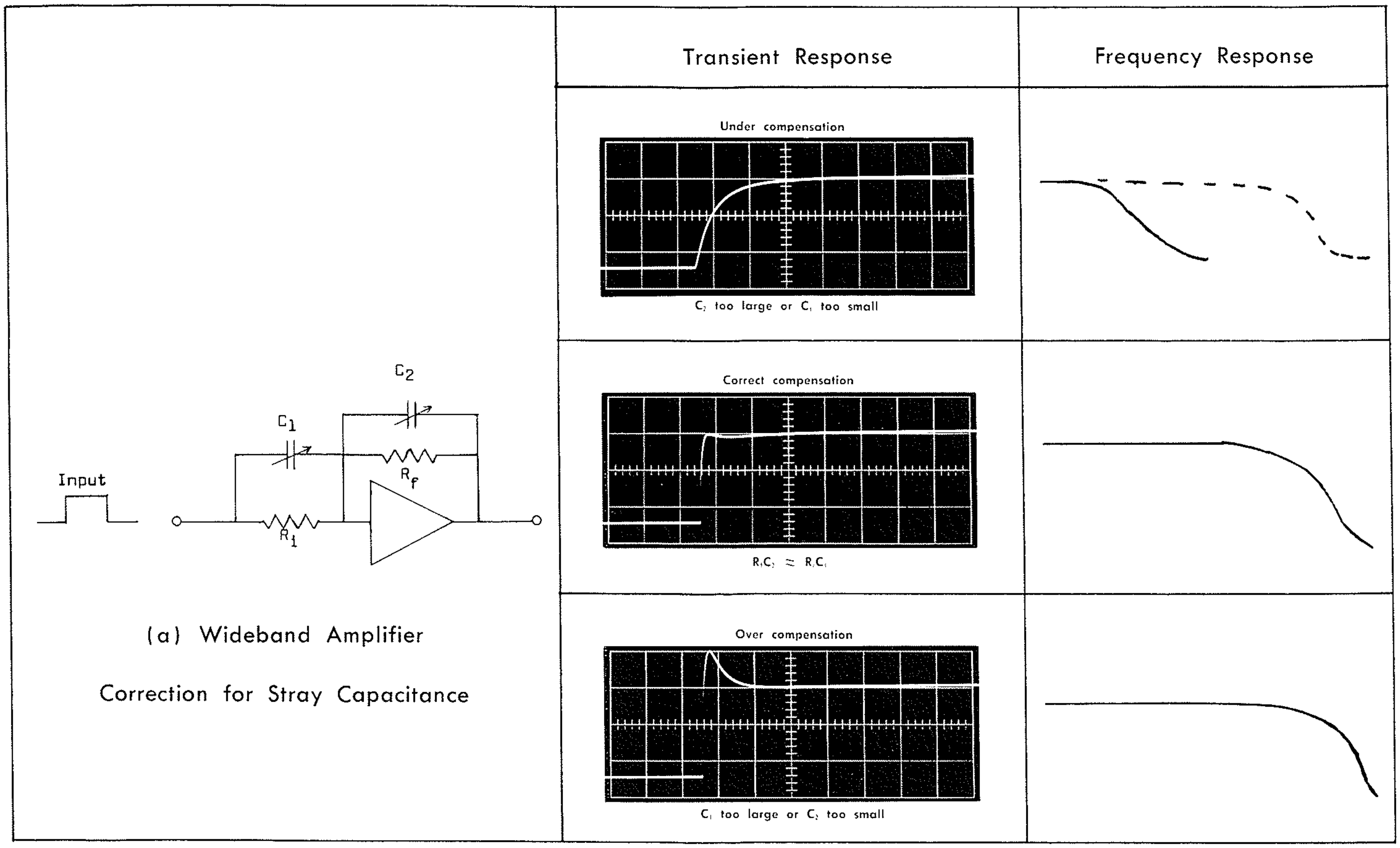
Correcting For The Effects of Stray C

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.

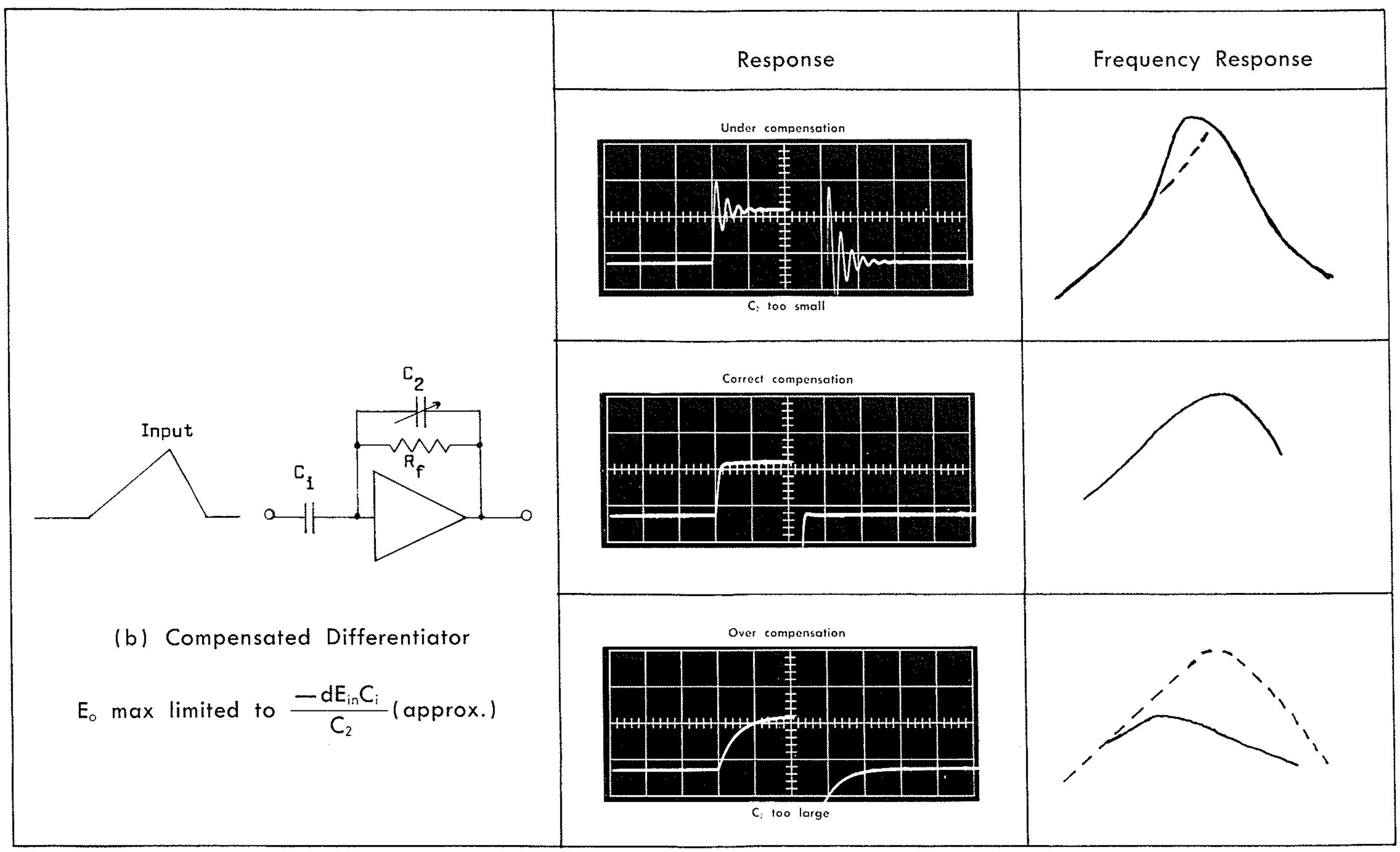
The resistors used as Z_i and Z_f, however, can be given only partial compensation internally, since the optimum value of compensation varies with the application. For this reason, it is usually necessary in dealing with short-duration or high-frequency

Figure 13



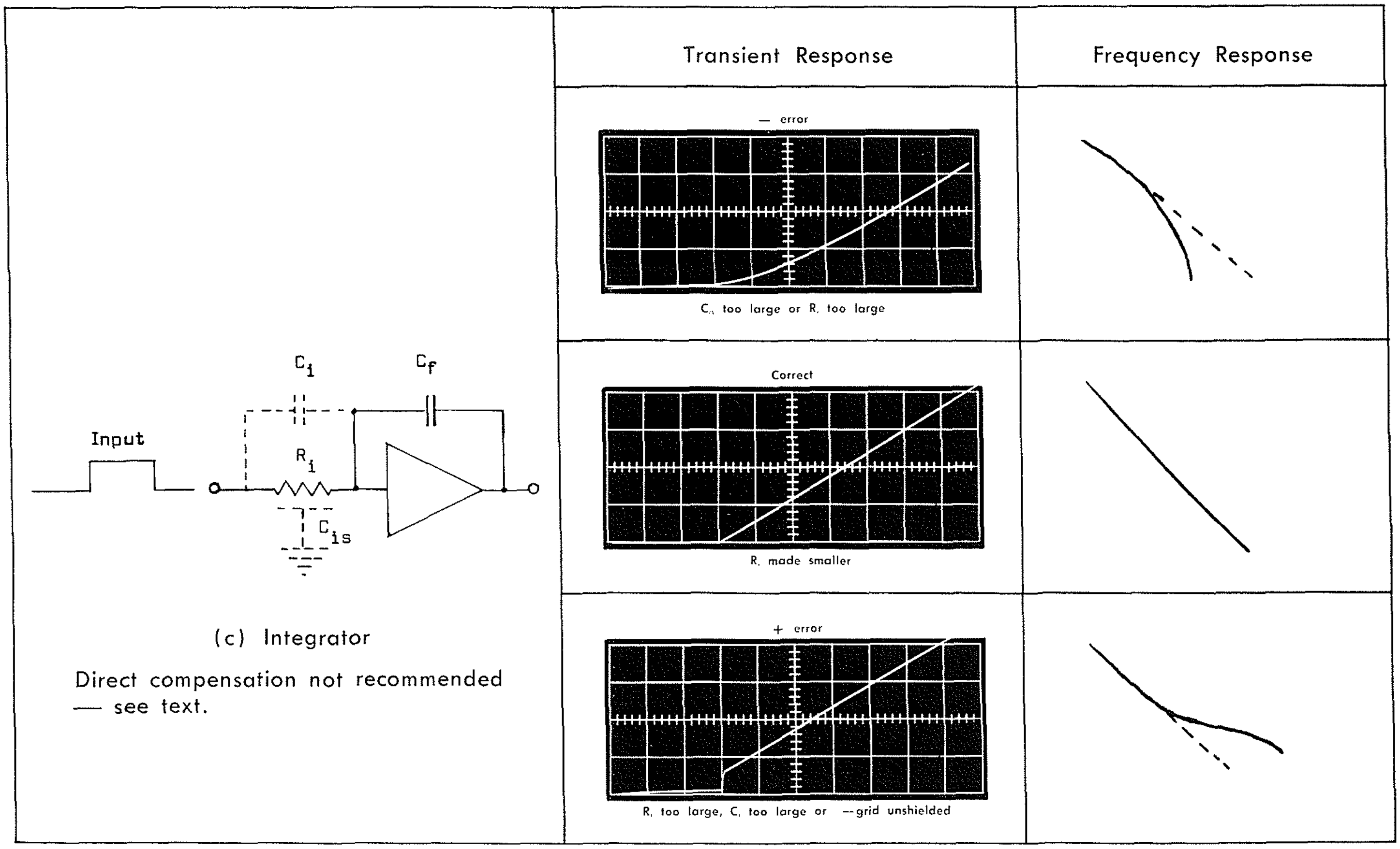
(a) Wideband Amplifier

Correction for Stray Capacitance



(b) Compensated Differentiator

E_o max limited to $\frac{-dE_{in}C_i}{C_2}$ (approx.)



(c) Integrator

Direct compensation not recommended — see text.

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.

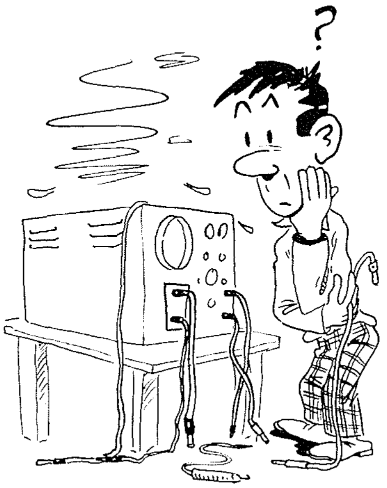
Subsequent investigation by the police revealed other stolen electronic equipment on the premises of the would-be owner of the stolen oscilloscope.

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

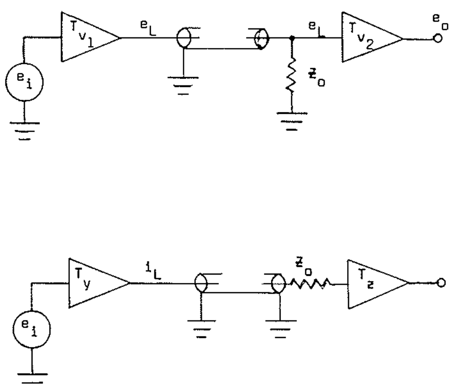


FIGURE 1

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.

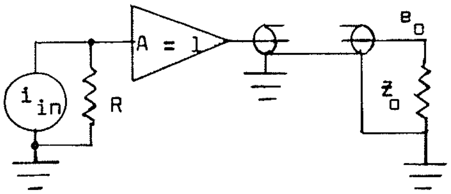
Input		Output		Name
Signal	Impedance	Signal	Impedance	And Symbol
Voltage	High	Voltage	Low	Voltage Gain $e_o/e_{in} = T_V$
Current	Low	Current	High	Current Gain $i_o/i_{in} = T_I$
Voltage	High	Current	High	Transadmittance $i_o/i_{n} = T_Y$
Current	Low	Voltage	Low	Transimpedance $e_o/i_n = T_Z$

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.



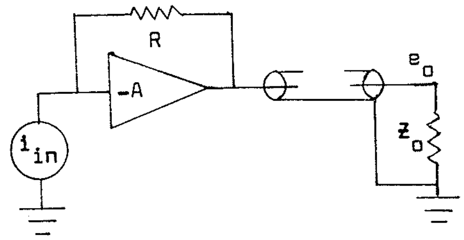
Z_o is less than R, A is greater than R_o/Z_o except in (a)

$e_o = i_{in} R$ $P_o = i_{in}^2 R \times \frac{R}{Z_o}$

$P_i = i_{in}^2 R$ $T_p = \frac{R}{Z_o}$

Output power requirement large, good signal/noise

(a)

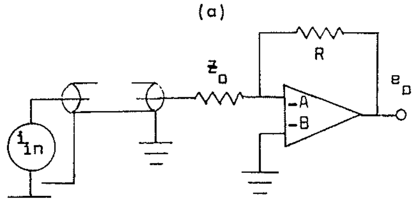


$e_o = -i_{in}^2 R$ $P_o = i_{in} R \frac{R}{Z_o} + 1$

$P_{in} \approx 0$ $T_p \approx \infty$

Output power requirement largest, good signal/noise

(b)

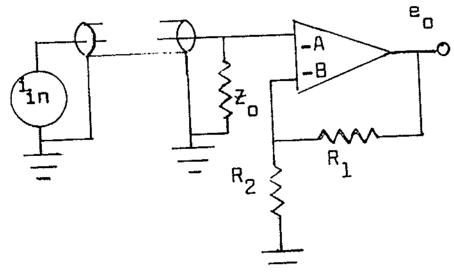


$e_o = -i_{in}^2 R$ $P_o = i_{in}^2 R$

$P_o = i_{in}^2 R$ $T_p = \frac{R}{Z_o}$

Lower power output required, reasonable signal/noise with currents to 10^{-6} amps and negacycle bandwidth.

(c)



$R_1 + R_2 = R$, $R_2 = Z_o$, $R_1 = R + Z_o$,
$e_o = i_{in} R$ $P_o = i_{in}^2 R$

$P_{in} = i_{in}^2 Z_o$ $T_p = \frac{R}{Z_o}$

Same power as (c), but signal/noise difficult with small current.

(d)

FIGURE 2

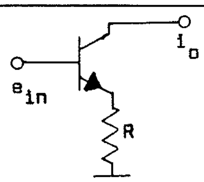
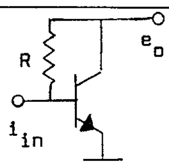
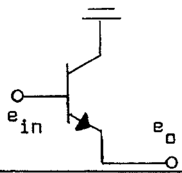
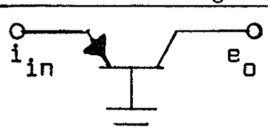
Circuit Example	Transfer	Good	Bad
	Transadmittance (1) $T_Y = \frac{-1}{R}$ High input Z Low output Z	High output Z High input Z	Transfer $\propto$ dependent
	Transimpedance (2) $T_Z = -R$ Low input Z Low output Z	Low input Z	Loop gain strongly load dependent with $R_L < R$.
	Voltage gain (3) $T_V \approx 1$ 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

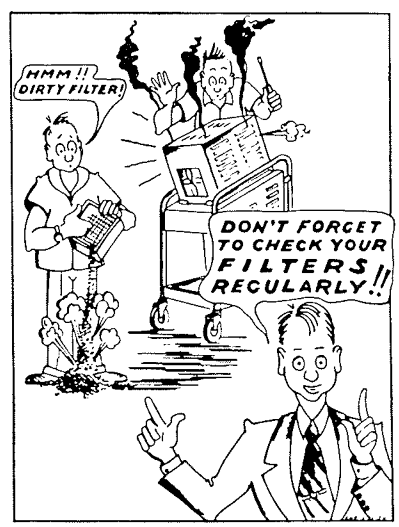


TABLE III

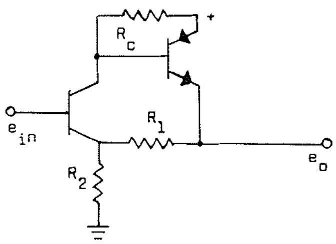
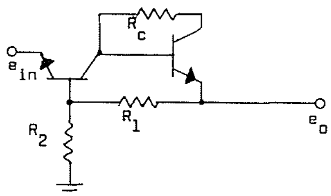
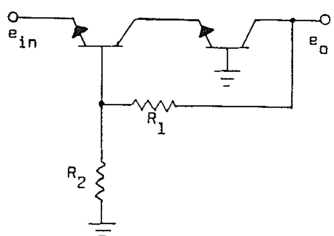
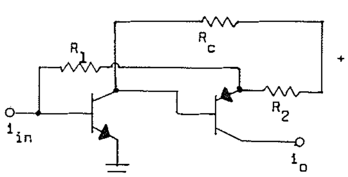
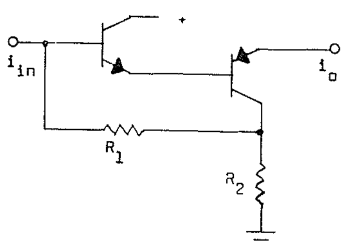
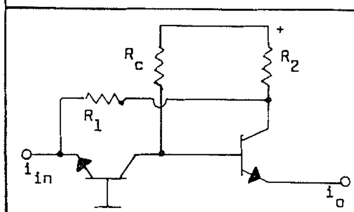
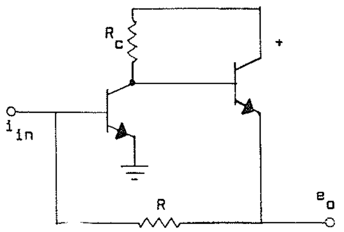
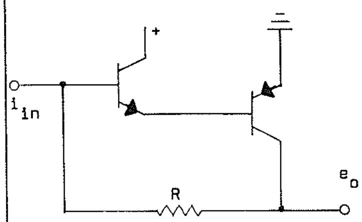
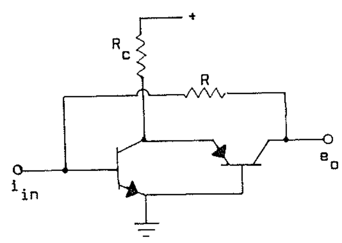
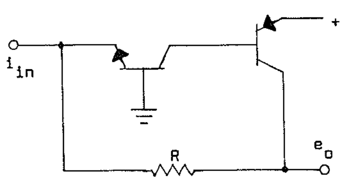
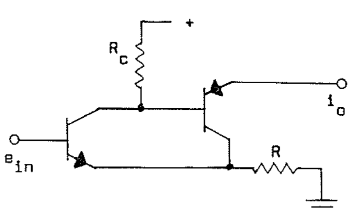
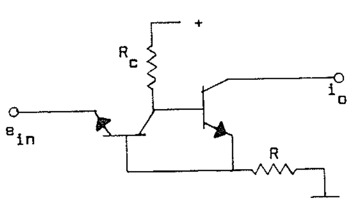
TRANSFER	CIRCUIT EXAMPLE	GOOD POINTS	BAD POINTS	USUALLY USEFUL
Voltage Gain $T_L = \dfrac{R_1 + R_2}{R_2}$ High input Z Low output Z		(1) High input Z. Open circuit gain predictability.	Output Z could be lower. Loop gain strongly load dependent when $R_L < R_1 + R^2$.	Yes
		(2) Output Z low.	Input Z 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 $T_i = \dfrac{R_1 + R_2}{R_2}$ 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

Transimpedance $T_Z = -R$ Low input Z Low output Z		(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
		(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 α dependent. Loop gain dependent — likes low Z load.	Input
		(12) High output Z	Input Z bit low, transfer α dependent.	Output

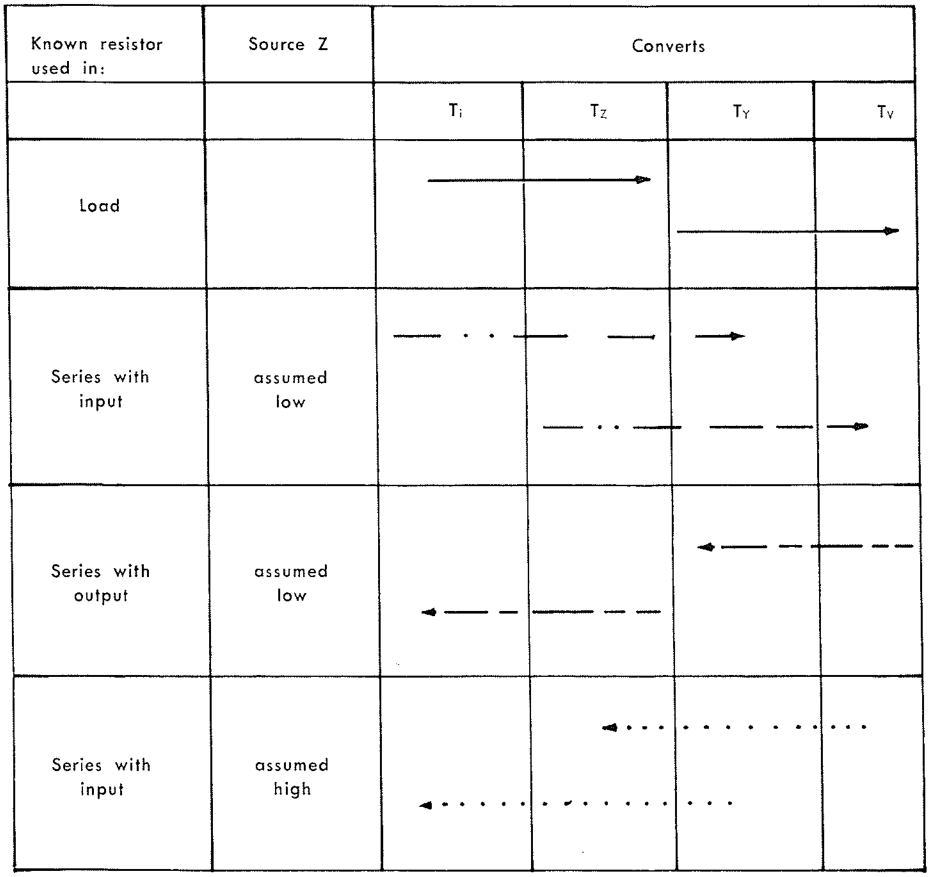


TABLE IV

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.

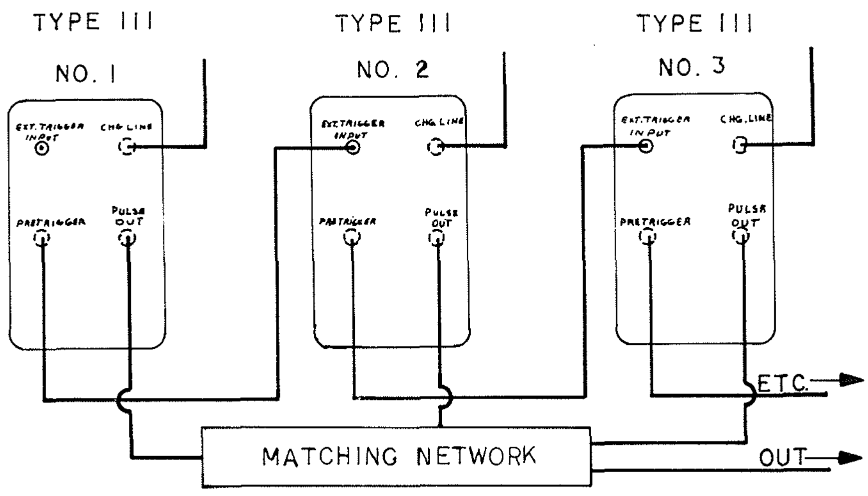


FIGURE 1

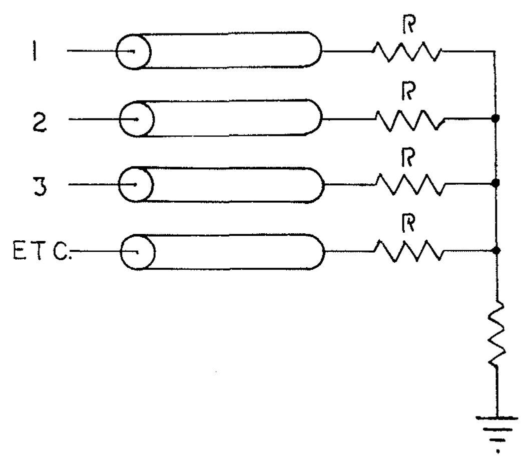


FIGURE 2

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

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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.

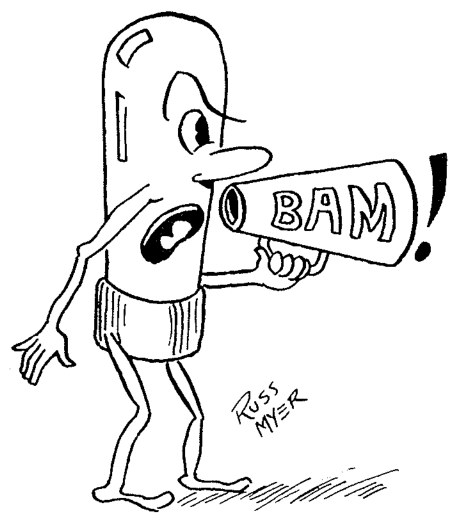
The noise discussed here is more or less inherent in electronic components—not that due to manufacturing defects or to deterioration or damage (as, gas in tubes or moisture in transistors), or that due to external interference (e.g., atmospheric noise or RFI).

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 $10 \log \dfrac{R_{opt} + R_{equiv}}{R_{opt}}$ 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.

$$\begin{aligned} R_{equiv} &= 720\ (\text{antilog}\ 0.194 - 1) \\ &= 720\ (1.56 - 1) \\ &= 420\ \Omega \end{aligned}$$

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.

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.

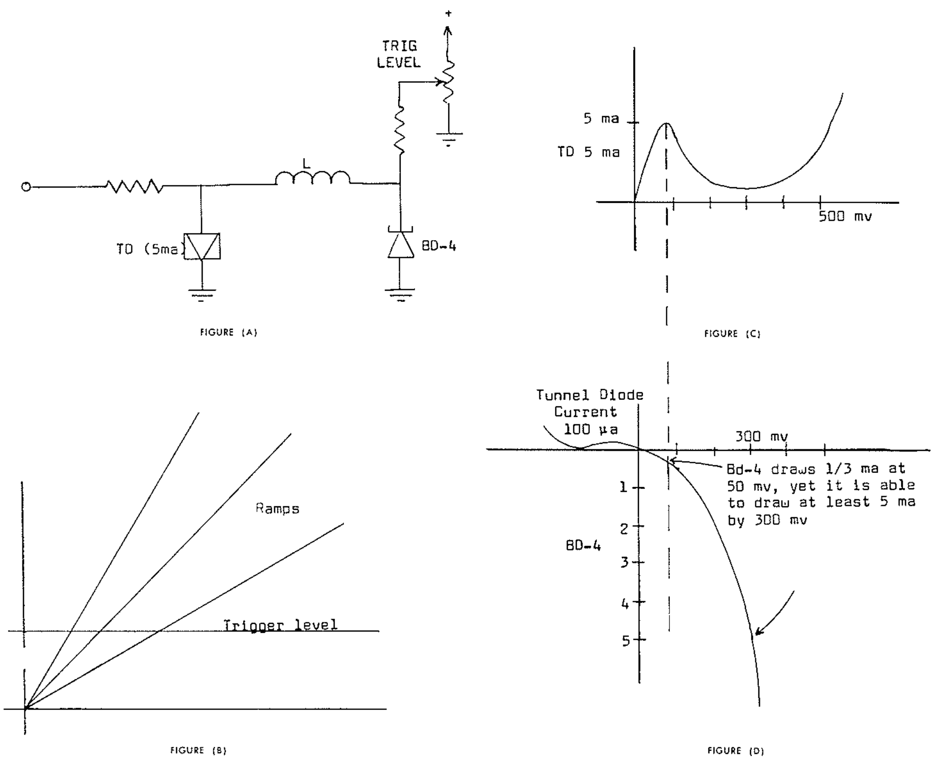


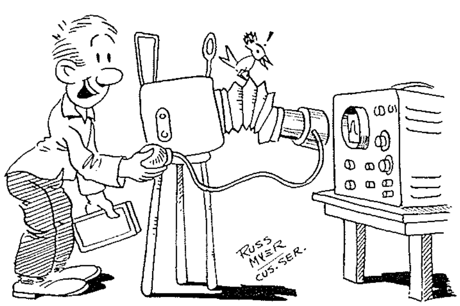
FIGURE 1

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.

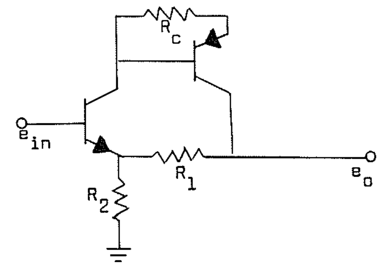
	0.022 μf		0.1 μf	
Measurement Error due to Capacitor	From Signal Source < 1 k	With 10X Probe	From Signal Source < 1 k	With 10X Probe
1%	50 cps	5 cps	11 cps	1.1 cps
2%	35 cps	3.5 cps	7.8 cps	.78 cps
3%	30 cps	3 cps	6.4 cps	.64 cps
5%	22 cps	2.2 cps	4.8 cps	.48 cps
10%	15 cps	1.5 cps	3.3 cps	.33 cps
20%	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

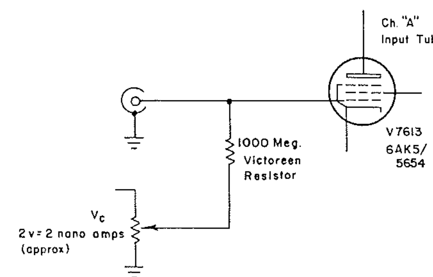
Charlie Rhodes, Tektronix project Engineer, contributes a technique for making measurements not ordinarily possible with an oscilloscope because of circuit loading by the usual 1 or 10 meg input resistor. This technique requires the use of a modified Type Z Plug-In Unit in a Type 530, Type 530A, Type 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.

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USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

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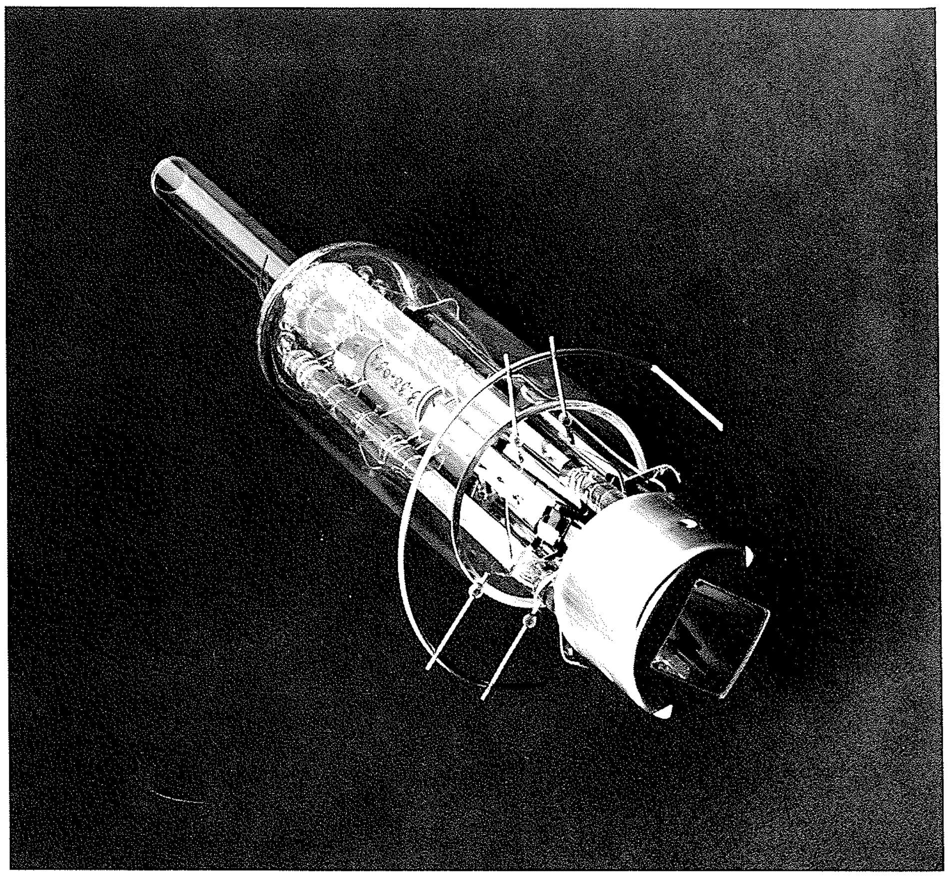
CRT-Design Review
Mesh and Frame-Grid Characteristics

By Geoff Gass
Tektronix Staff Field Engineer

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.



FRAME-GRID GUN ASSEMBLY READY FOR SEALING INTO THE CRT ENVELOPE

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).

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

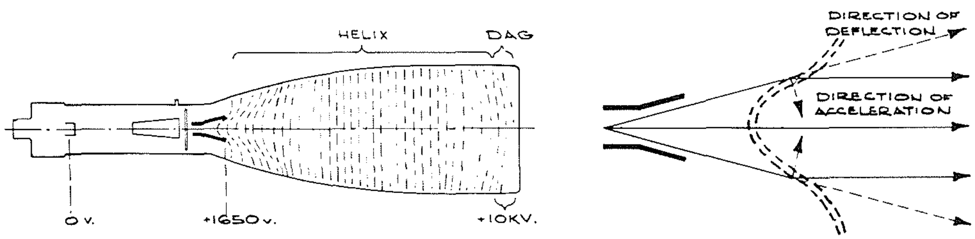


FIGURE 1. CONVENTIONAL PDA CRT.

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.

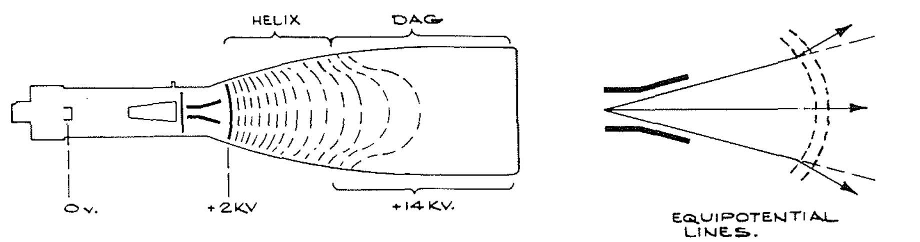


FIGURE 2. MESH-TYPE CRT.

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.

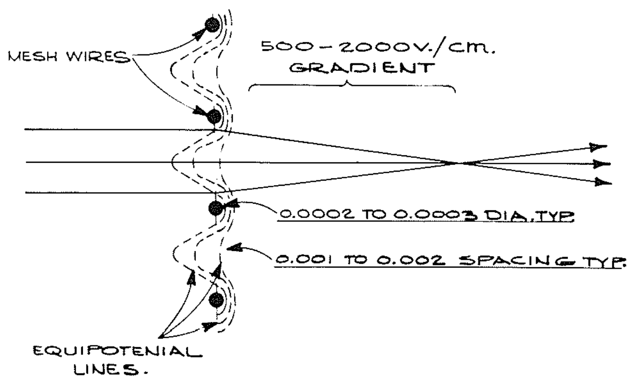


FIGURE 3. ACCELERATION FIELD OF THE MESH STRUCTURE.

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.

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.

* 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.

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.

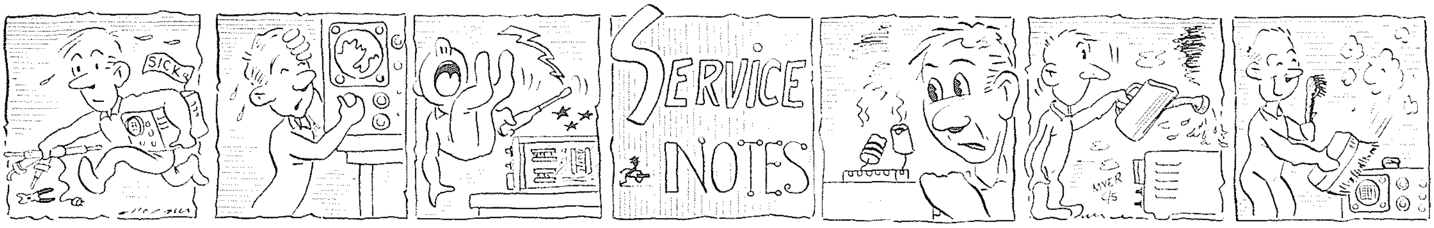
The commercial availability of transducers for conversion of mechanical, thermal, optical and chemical phenomena into electrical signals has extended the utility of the oscilloscope well beyond the electrical industry. This article analyzes the relationship between an incident and a system response in 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.

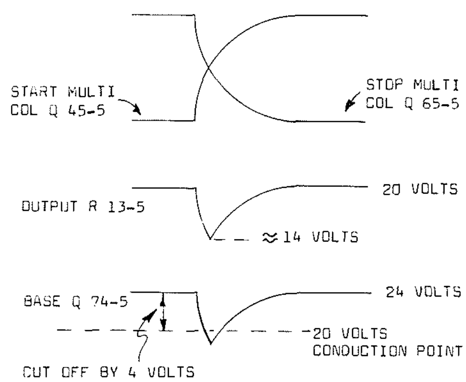
The problem is this: There are *two* capacitors in the circuit — the input coupling capacitor and the preamplifier coupling capacitor. The LF Comp. or LF Adj. controls are intended to compensate only for the second (preamplifier) time constant so the response will be substantially the same as in the 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.

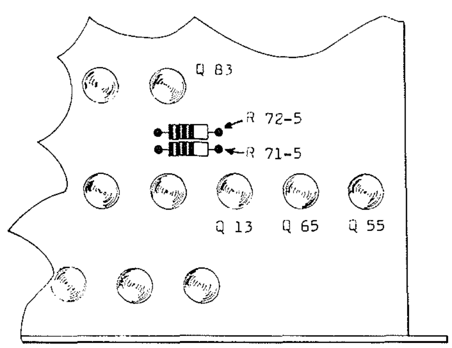
The square-wave adjustment as outlined is probably the best approach; however, we still experience a rise at approximately 5 cps when doing it this way. Those interested in low-frequency sine-wave response, may want to adjust accordingly.

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

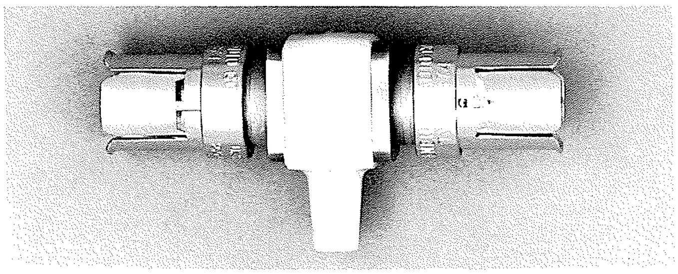
Type 6R1's employing a Model 2A, Series 5, Master Gate circuit board will produce a spurious (one extra) count during the reset phase of the Start and Stop multivibrators. This shows up when making voltage measurements with either a Type 3S76 Dual-Trace Sampling Unit or a Type 3S3 Sampling-Probe Dual-Trace 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
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	Westchester County, Western Conn., Hudson River Valley...144 Morgan Street, Stamford, Connecticut Telex 096-5917 ...... Telephone: (203)DAvis 5-3817
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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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Area Code Numbers are in parenthesis preceding telephone number.

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• 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

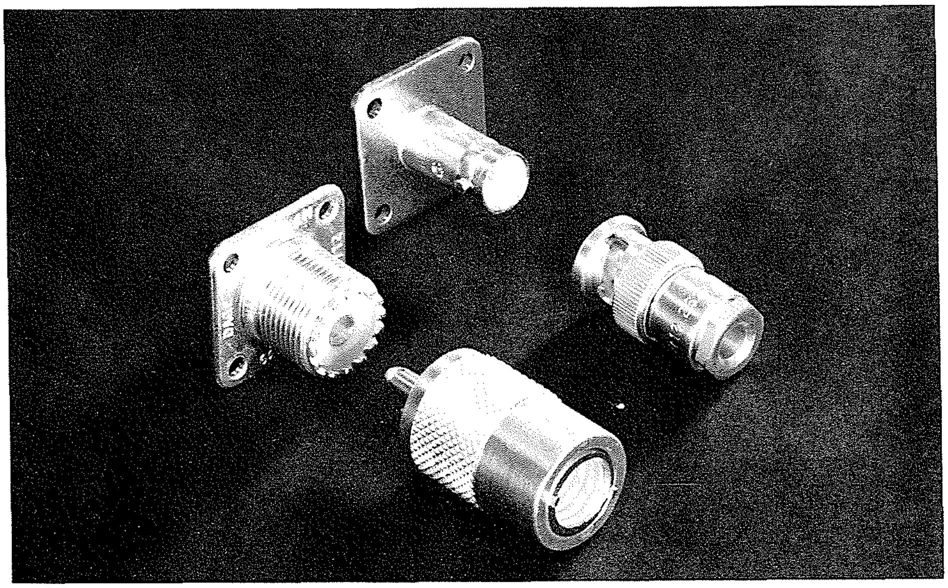
Service Scope

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

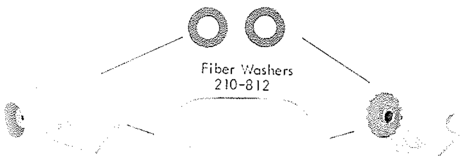
BNC | UHF

131-277

131-051

131-278

131-038



Fiber Washers
210-812

131-279

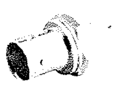
Nylon Insulator
406-244

131-064

131-274

Insulated connectors. Includes mounting hardware.

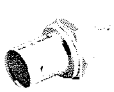
131-320



131-126

Single-hole, 1/2 inch mount. Includes mounting hardware.

131-081

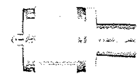


131-106
Single-hole 3/8 inch mount. Includes hardware.

No UHF Counterpart

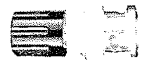
ADAPTERS

BNC | UHF



103-015
BNC Female to UHF Male

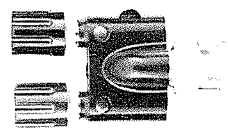
103-032
UHF Female to BNC Male



103-033

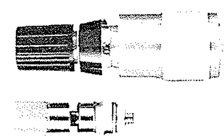
Binding Post Adapter
Single

013-004



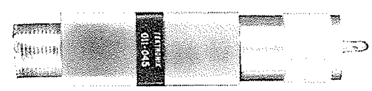
103-035

Binding Post Adapter
Double



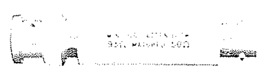
013-009

ATTENUATORS



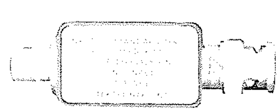
BNC		UHF
011-059	50 Ω, 10X	011-031
011-060	50 Ω, 5X	011-032
011-061	75 Ω, 10X	011-033
011-062	93 Ω, 10X	011-035

MINIMUM LOSS NETWORKS



011-057	50 Ω-75 Ω	011-041
011-058	50 Ω-93 Ω	011-042

INPUT RC STANDARDIZERS



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.

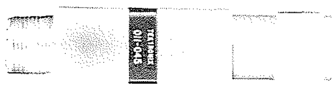
TERMINATIONS

BNC

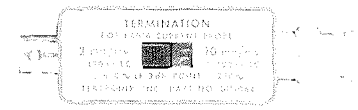
011-049
011-055
011-056

50Ω
75Ω
93Ω

UHF

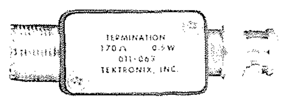


011-045
011-046
011-047



P6016 Current Probe
Termination
011-064

Same shape as BNC termination at left, but with UHF connectors.
011-028



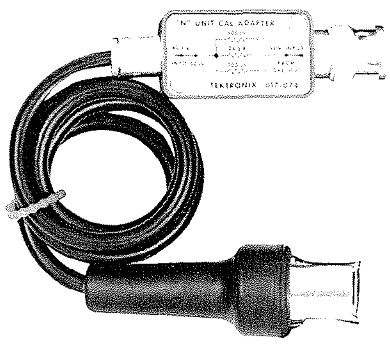
170-Ω Termination
011-063
Use with P170CF Probe on scopes other than 517A

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

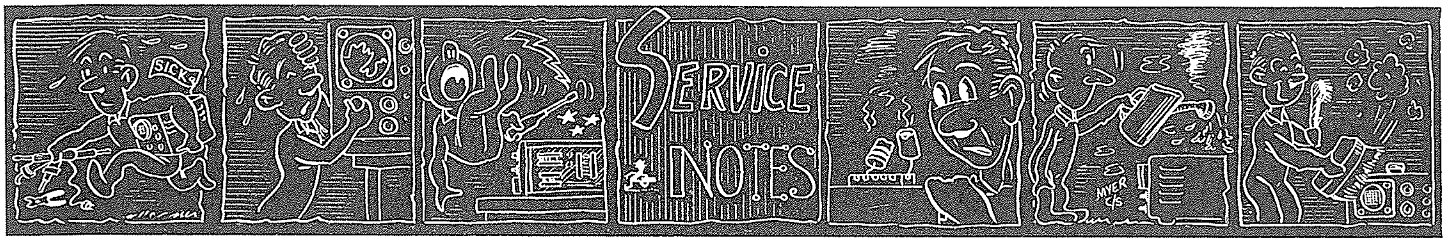
We wish to thank Mr. J. K. Grierson of the Research and Development Laboratories of the Northern Electric Company, Ltd. in Ottawa, Ontario for calling our attention to an error in the article "Noise — Some Basic Data" in the August, 1963, issue of Service Scope.

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.

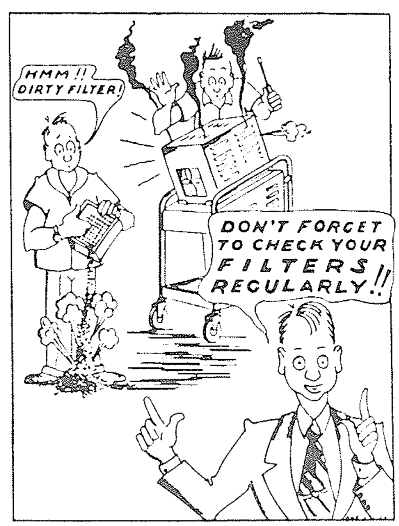
Though it lacks the non-glare feature of the polarized *viewer,* the light filter can do a good job of increasing trace contrast with minimum light loss wherever space or other considerations preclude the use of the polarized viewer.

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 rise-time 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.

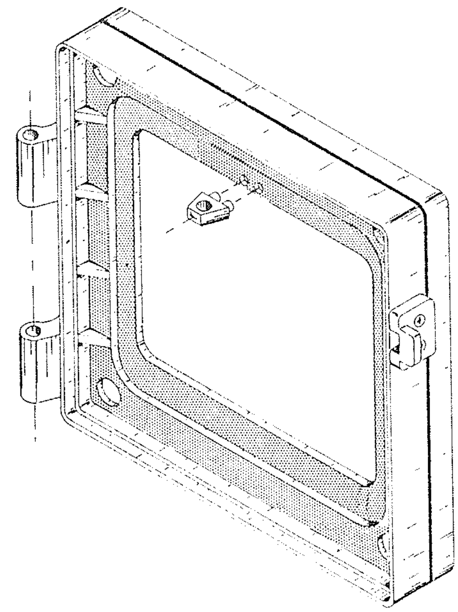
The High Voltage circuit is replaced by a new assembly which has separate secondary windings for the crt grid and cathode. This permits insertion of intensifying pulses on the crt grid and/or chopped blanking (or external) pulses on the cathode.

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.

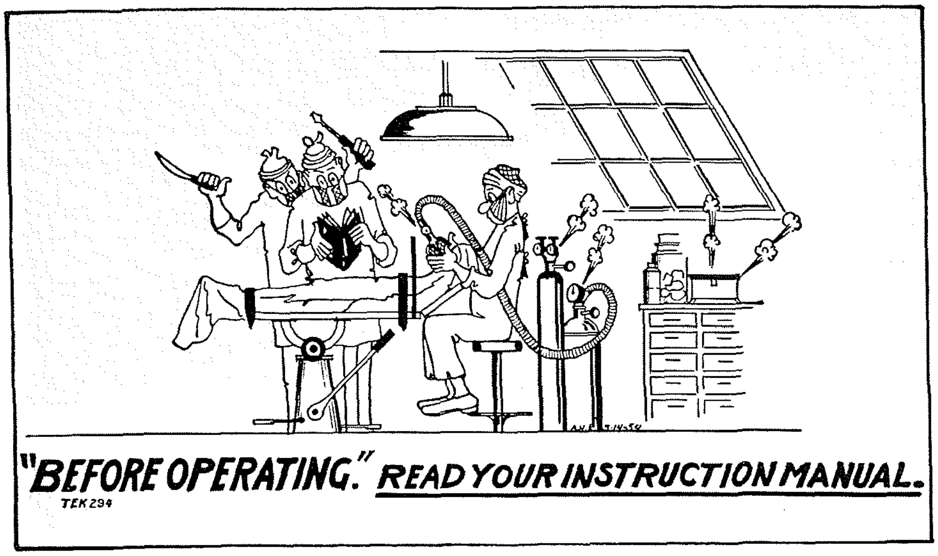
Special Note: As a further improvement in the performance of the Type 561 Oscilloscope with the Type 3B1 or Type 3B3 Plug-In Units, we suggest the installation of two previously-announced field modification kits. They are: Field Modification Kit 040-267 for Type 561 Oscilloscopes, serial numbers 102 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 DeLuc, 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