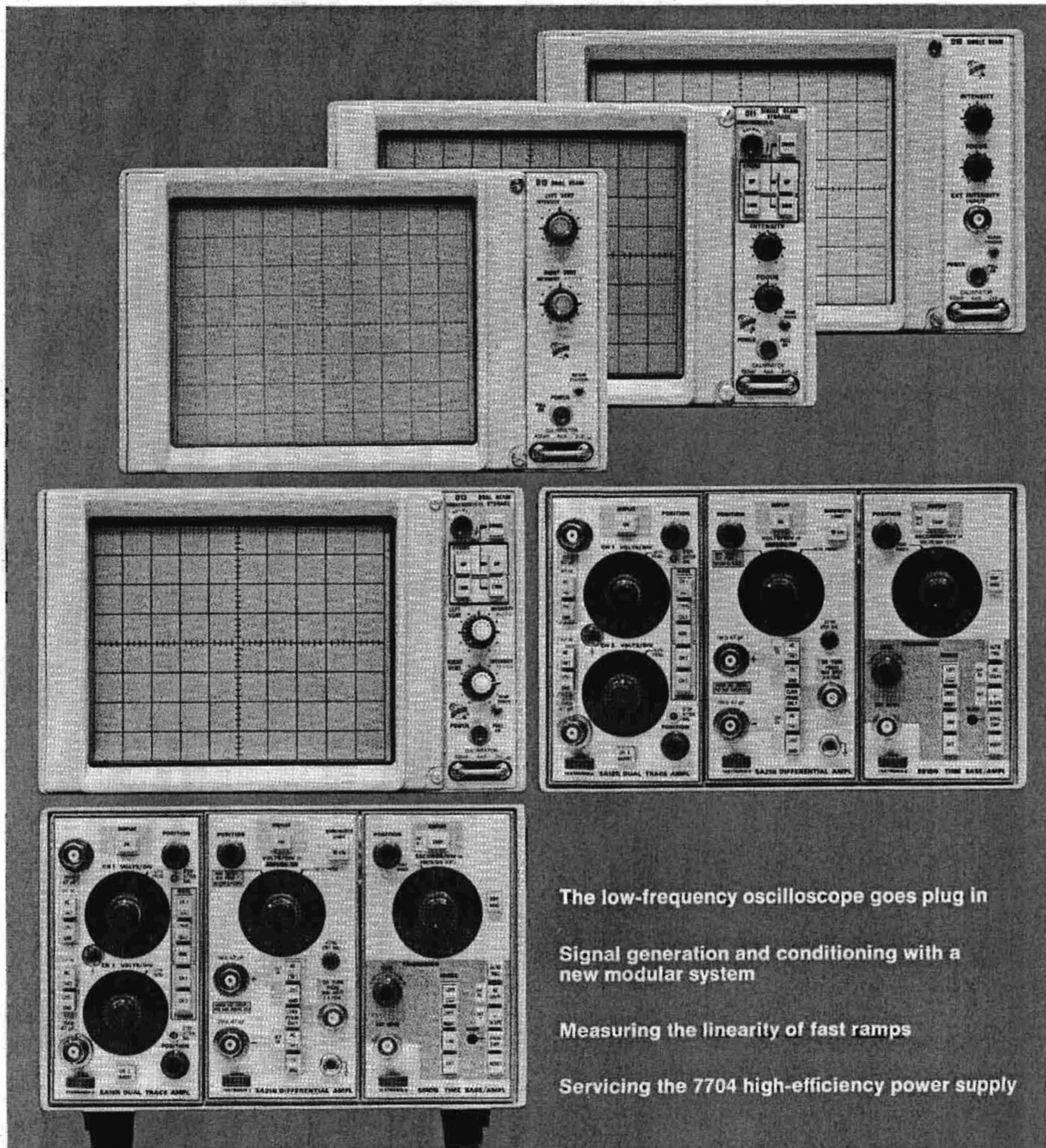
TEKSCOPE

MARCH 1971



The low-frequency oscilloscope goes plug in

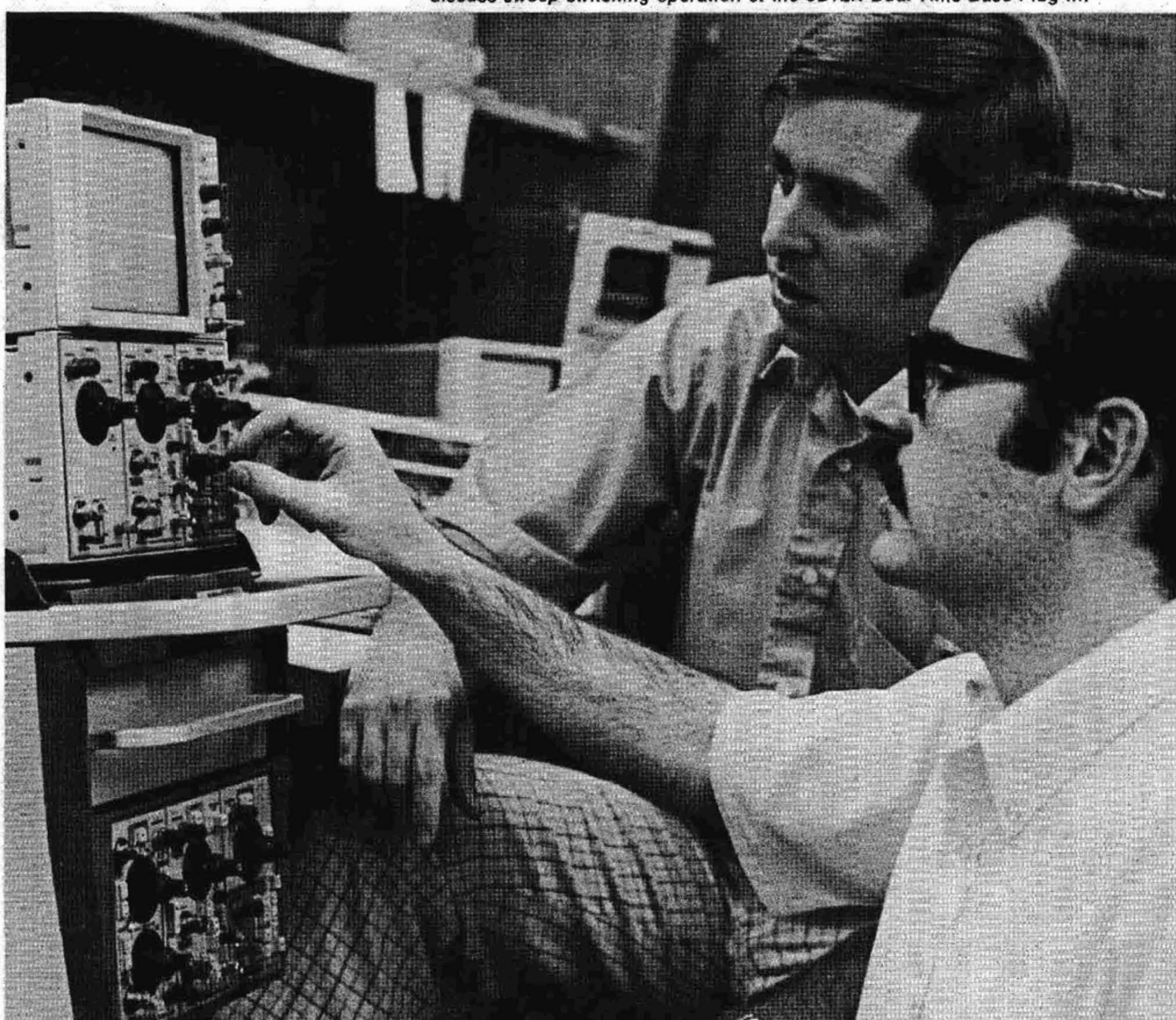
Signal generation and conditioning with a new modular system

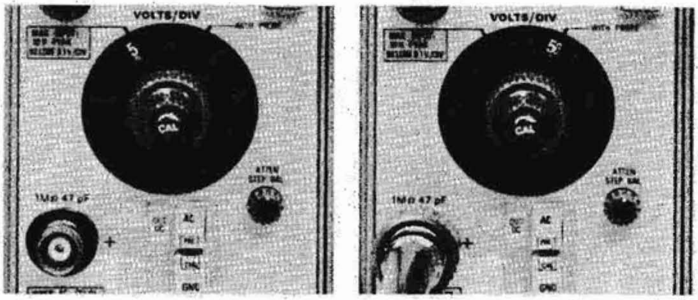
Measuring the linearity of fast ramps

Servicing the 7704 high-efficiency power supply

THE LOW-FREQUENCY OSCILLOSCOPE GOES PLUG-IN

Gary Vance, Project Engineer and George Hull, Design Engineer on the 5100 Series discuss sweep-switching operation of the 5B12N Dual Time Base Plug-In.





Scale factor readout changes automatically to indicate vertical sensitivity at probe tip when recommended 10X probe is used. Similarly, sweep-rate readout changes automatically when 10X magnifier is turned on.

By Jerry Shannon and Ahne Oosterhof

In the oscilloscope field, plug-in versatility has traditionally been limited to high-frequency instruments. Introduced by Tektronix in 1954, the plug-in concept allowed the user to easily and inexpensively change the characteristics of his oscilloscope to cover a wide range of applications.

Now, with the introduction of the 5100 Series, the users of low-frequency oscilloscopes will enjoy these same benefits.

Since the same need for versatility exists in the low-frequency as in the high-frequency oscilloscope field, we determined to do our best to meet that need. Our goal was to offer a laboratory-quality, low-frequency, plug-in oscilloscope at the lowest practical cost to the user. We also wanted to include many of the features such as scale factor readout, large screen CRT and solid state stability found only in the latest instruments.

Breakthroughs would have to be made in many areas. Simplified circuit design, new production techniques for CRT's, switches and other components, and reduced assembly and calibration time would have to be achieved if we were to reach our goal. The end result of our efforts in all of these areas is a series of products that bring you new measurement capability, plus a flexibility previously unavailable in any other oscilloscope system.

First in this series is the 5103N Oscilloscope System, a general-purpose, low-frequency (DC to 2 MHz) oscilloscope featuring cost-saving innovations such as interchangeable display modules, plug-ins, and bench to rackmount convertibility. Four display modules, each with a large 6½-inch CRT, give you a choice of single beam, dual beam, single beam storage or dual beam storage. You can readily change from one display module to another or convert from bench to 5¼-inch rackmount configuration in a matter of minutes. Nine plug-ins give you a wide choice of vertical amplifiers and time bases.

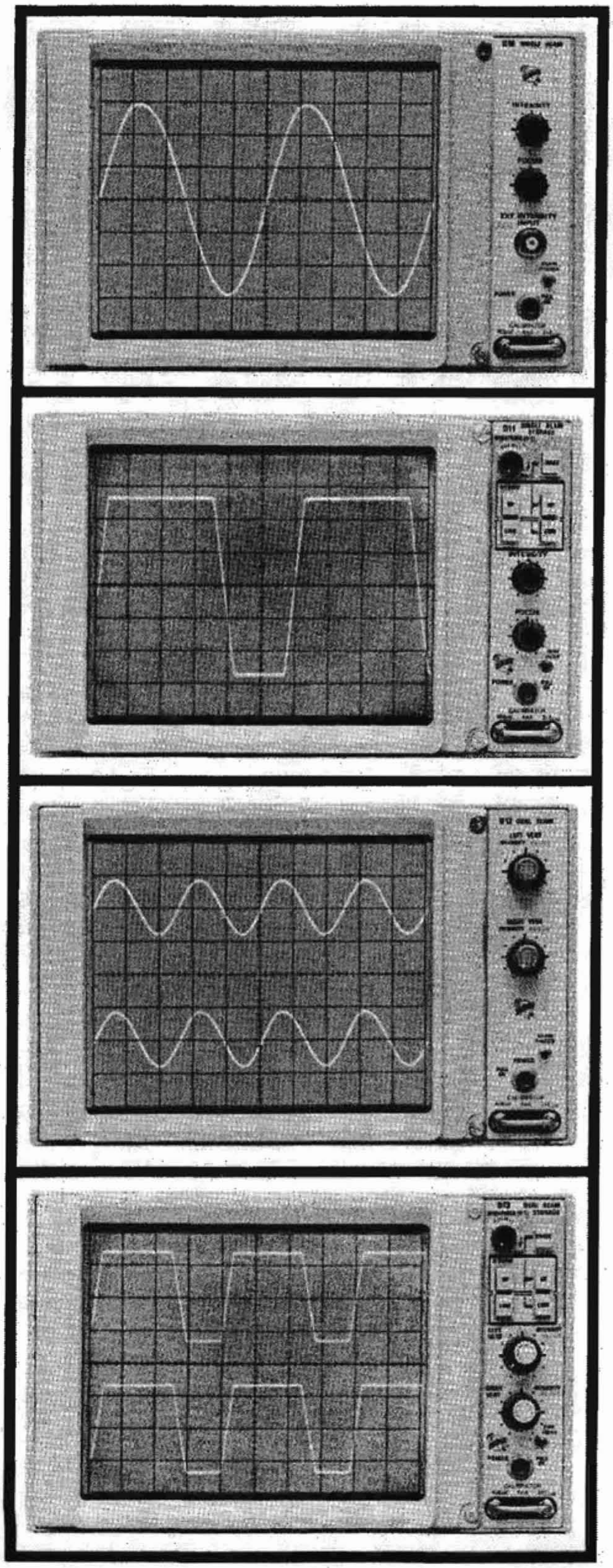
Several innovations in the amplifier and time base plug-ins enhance operating ease. For example, scale factor readout for each amplifier is provided by illuminating the knob skirt behind the area identifying the correct scale factor, even when using the recommended 10X probes. This same feature is used in the time base plug-ins to indicate correct sweep rate with the magnifier on or off. The possibility of measurement error is thus greatly reduced.

The choice between left and right vertical plug-in is made by depressing the DISPLAY button on the respective plug-in. This button also switches the light on behind the readout skirt, so a glance is all that's needed to immediately identify which channels or plug-ins are in use. With neither DISPLAY button depressed, the left hand vertical is displayed but its readout is not illuminated.

When two amplifier plug-ins are enabled, the mainframe automatically converts to the alternate or chopped mode of operation as selected by the DISPLAY button on the time base. The switching sequence allots two time-slots (in chopped) or two sweeps (in alternate) to each vertical plug-in. When dual-channel plug-ins are used, each channel takes one time slot or one sweep. In the dual-beam mainframe, switching between plug-ins is eliminated as each amplifier is permanently connected to one vertical deflection system.

THE MAINFRAME

Now let's take a closer look at each of the 5100 Series modules. The 5103N mainframe module contains the low-voltage power supplies, horizontal and vertical amplifiers, the electronic switching and logic circuitry for dual-trace operation between plug-ins, and three plug-in compartments. It will interface directly with any of the four display modules in a bench or rackmount configuration. Any plug-in can be used in any compartment to achieve X-Y, Y-T or raster displays.



Four display modules pictured from top to bottom are single beam, single beam storage, dual beam and dual beam storage. All feature a large 6¼" screen and internal graticule.

THE DISPLAY MODULES

Each of the display modules uses a new 6½-inch ceramic CRT with an 8 x 10 division (½ inch/div) internal graticule. The CRT, with 3.5 kV accelerating potential, has a bright, well-defined trace. Simplest of the display modules is the D10 single-beam display unit. In addition to the CRT, it contains the high-voltage supply, a voltage, current and time (2X line frequency) calibrator, the CRT controls and the power switch. A beam finder positions the beam on screen regardless of the setting of the vertical or horizontal position controls. The front panel Z-axis input with DC to 1-MHz bandwidth requires only 5 volts to modulate the beam.

The D12 dual-beam display module is the same as the D10 single-beam unit except the CRT has two writing guns and two pairs of vertical deflection plates. Both beams cover the full 8 x 10 division screen. Also included are separate intensity and focus controls for each beam.

Single and dual-beam storage operation are provided by the D11 and D13 display modules respectively. The bistable, split-screen storage CRT's have a unique brightness control which permits varying the stored brightness to retain the image for several hours without damage to the CRT. The brightness control, in conjunction with other storage controls, also allows integration of repetitive signals to effectively increase stored writing rate.

THE PLUG-INS

The nine plug-ins presently available include six amplifiers and three time bases. Simplest of the amplifiers is a plug-in having just an input stage with a potentiometer as an attenuator. Designated the 5A24N, the unit has a 50 mV/div sensitivity and is ideal for you who have low-cost monitor needs.

For simple measurements where signals of varying amplitude have to be measured, the 5A23N with decade attenuator steps and a 10 mV sensitivity is available. Bandwidth is DC to 1 MHz.

A companion plug-in, the 5B13N time base, provides a low cost sweep unit with sweep ranges from 5 μs/div to 0.5 sec/div in decade steps. A variable control extends the slowest sweep to 5 sec/div.

When signals of only a few millivolts are to be measured, the 5A15N provides 1 mV sensitivity and DC to 2-MHz bandwidth. The 5A18N offers the same characteristics with dual-trace capability including the convenient ADD mode. This mode is especially useful when signal differences between two points are to be measured while both points are elevated by a common signal.

Getting down into the difficult microvolt region where the applications call for low noise and high common-mode rejection, the 5A20N and 5A21N differential amplifiers with FET inputs provide stable operation to 50 μV/div. Bandwidth is DC to 1 MHz. Upper bandwidth can be limited to 10 kHz for noise reduction. Common-mode rejection at 50 μV/div, DC coupled, is 100,000:1.

To permit common-mode measurements with the use of attenuator probes, a probe having accurate attenuation has been developed. The P6060 has 10X attenuation and provides common-mode rejection of 400:1 at any deflection factor when used with the 5A20N or 5A21N.

The 5A21N plug-in, while similar to the 5A20N, has the added feature of a current-probe input. Using the P6021 current probe, bandwidth is 15 Hz to 1 MHz with sensitivities from 0.5 mA/div to 0.5 A/div. The normal 100 Hz low-frequency response of the P6021 is extended by low-frequency correction in the amplifier to permit measurements at line frequency. This makes the unit especially useful in power supply design work.

Many low-frequency applications make use of X-Y type displays. As the mainframe has identical vertical and horizontal deflection systems it is possible to make accurate phase measurements using two identical plug-ins. A control on the deflection amplifier board allows phase calibration to better than one degree at specific frequencies up to 1 MHz.

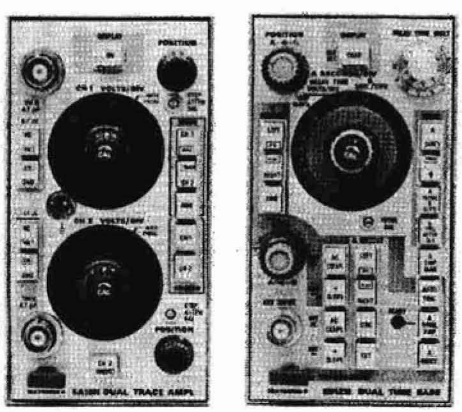
Two more time bases round out the selection of plug-ins available. The 5B10N provides sweep ranges from 1 μs/div to 5 sec/div in a 1-2-5 sequence with a 10X magnifier extending the fastest sweep to 100 ns/div. The unit offers versatile triggering from DC to 2 MHz. Both trigger source and trigger mode are selected by pushbutton. A single-sweep mode simplifies the capturing of single-shot phenomena for photographing or storing displays. Included is an external horizontal mode which provides a convenient means for making simple X-Y measurements. Sensitivity is 50 mV/div with DC to 1-MHz bandwidth.

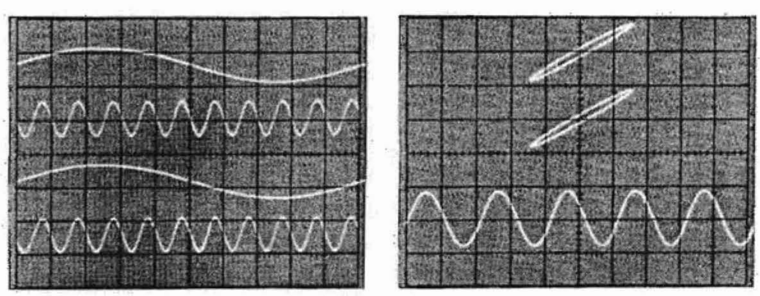
A dual time base, the 5B12N, covers a wide range of applications. Offering the maximum in versatility, it includes the popular sweep switching introduced in the 547 Oscilloscope. In the dual-sweep mode, the A sweep is slaved to the left plug-in, and the B sweep is slaved to the right plug-in. This gives you, in effect, dual-beam operation for repetitive signals. The two sweeps can also be operated in the conventional delaying-sweep modes with a 10-turn delay multiplier providing accurate delay settings. The 5B12N also includes an external horizontal mode for X-Y operation.

Some applications require a vertical sweep or raster presentation. This is easily accomplished by plugging any of the three time bases into one of the vertical compartments. The 5103N provides convenient front panel access for Z-axis modulation in these applications.

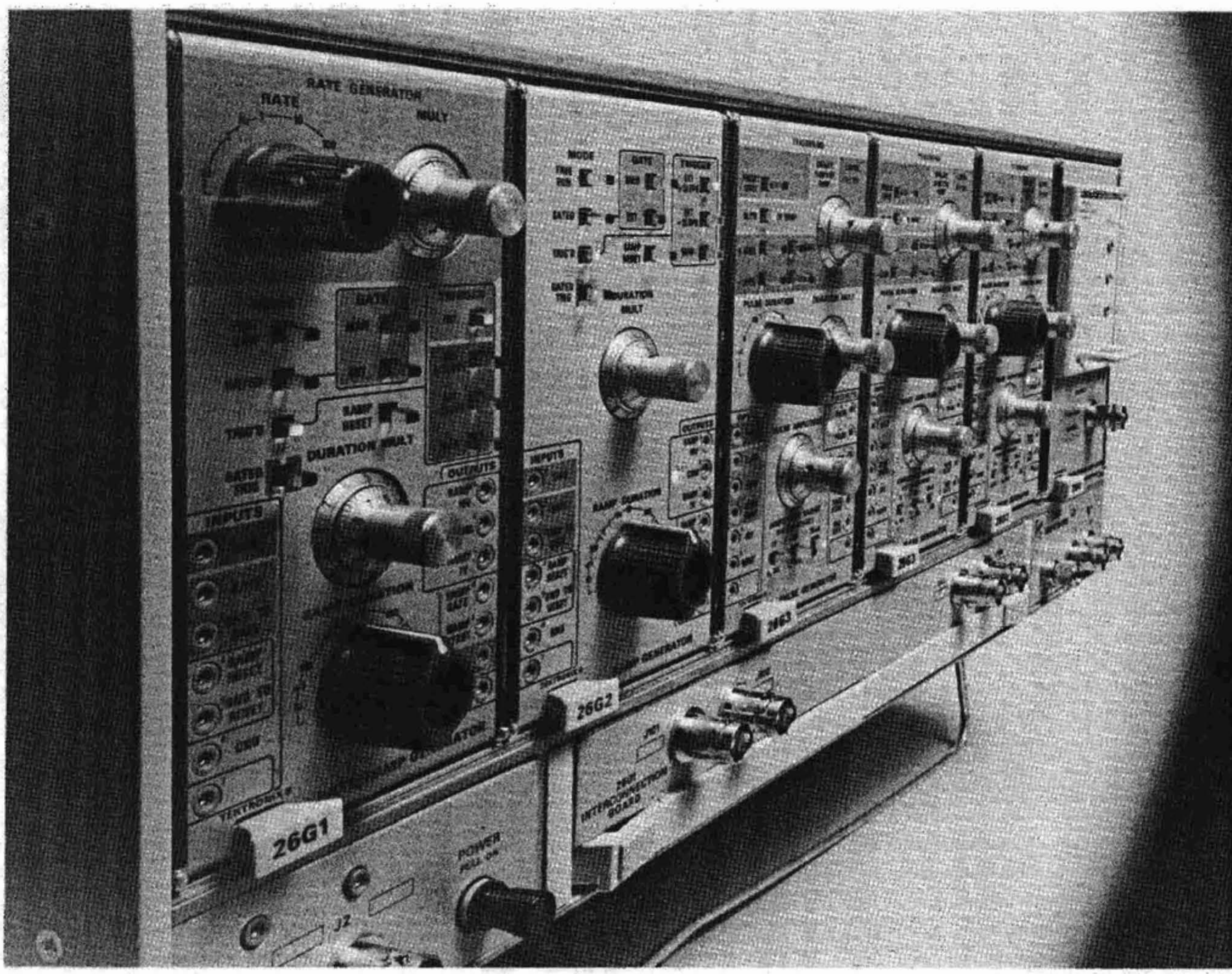
A low-cost camera, the C-5, complements the low-frequency 5100-Series instruments. Its fixed-focus, fixed-aperture design makes waveform photography simple. An access door in the top of the camera allows viewing the CRT without removing the camera.

Some of the areas expected to benefit from the versatility of the 5100 Series are medical research, educational instruction, low-frequency phase work such as servos, mechanical analysis using strain gauges and other transducers, and engine analysis.





Dual-trace vertical and dual time base plug-ins offer maximum versatility. At left above, both Ch 1 and Ch 2 are displayed by both A and B sweeps. Right above, adding a single trace plug-in, with A sweep on EXTERNAL you can have dual-trace X-Y, while right vertical and B sweep provide Y-T.



SIGNAL GENERATION & CONDITIONING

WITH A NEW MODULAR SYSTEM

Plug-in versatility has proven its worth in oscilloscopes, counters, pulse generators and myriad other products. Now this concept is extended to a new series of instruments designed to be the meeting place for many different systems. We call them the 2600-Series modular instruments. The term "modular" is used here in a broad sense and includes packaging, interconnections, input/output characteristics, power supplies and accessories.

Designed to permit relatively free interplay between analog and digital circuits, most inputs and outputs are compatible with DTL and TTL logic levels. However, they differ electrically slightly to allow proper operation with non-DTL and non-TTL circuits.

To get a feel for the versatility of the series, let's look briefly at the individual units.

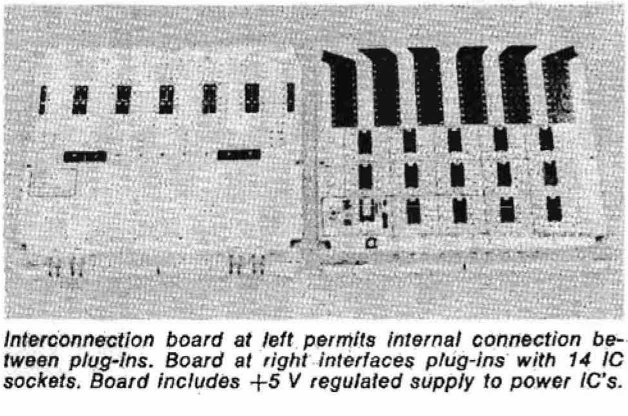
2601 MAINFRAME

The 2601 mainframe, a basic element in the series, is a power supply and interconnecting system for 2600-Series plug-in units. Providing pre-regulated voltages at up to 50 watts, the 2601 accommodates six plug-in units. The pre-regulated voltages are further regulated in the individual plug-ins and, in some instances, used to power DC to DC converters for special needs. This provides maximum decoupling between units.

A seventh plug-in section in the 2601 plays a vital role in the versatility offered by the 2600 Series. It contains the interconnection board. The primary function of this board is controlling plug-in unit operation, processing signals to or from a plug-in, or passing signals between units. Thus, having planned and set up system operation from the front panel, you can duplicate the connections between units on the interconnection board and then tuck them away out of sight. Spare boards may be used to change rapidly from one setup to another. Most plug-in front panel inputs and outputs are coupled through the interface connections at the rear of the plug-ins and are duplicated on the interconnection board.

Pictured below are two of the interconnection boards currently available. The board on the left is used primarily to provide interconnection between plug-ins.

The board on the right also provides interconnection between plug-in units but has an exciting additional feature. Fourteen 16-pin dual in-line plastic I.C. sockets, plus a locally regulated +5 volt supply, are mounted on the board. Ready connection between I.C.'s and the plug-in units is made by standard 40-mil patch connectors. This permits you to add the relays, switches, pulse transformers, resistor networks, op amps and many other functions available in the dual in-line package, to the functions available in the 2600-Series plug-ins. Instrument versatility thus becomes virtually unlimited.



Interconnection board at left permits internal connection between plug-ins. Board at right interfaces plug-ins with 14 IC sockets. Board includes +5 V regulated supply to power IC's.

You may also elect to use the I.C. board and 2601 mainframe plug-ins completely independent of one another. Ten spare front panel jacks on the interconnection board provide convenient interface points. Front and rear panel BNC connectors on the 2601 may also be connected internally to any jack on the I.C. interconnection board. The pre-regulated +17 and −17 volt supplies are available on the board and can often be used to power linear I.C.'s where other than +5 volts is required.

RATE AND RAMP GENERATORS

Now let's take a look at the plug-ins. The 26G1 and 26G2 are basically ramp generators and produce ramp voltages ideal for analog timing applications such as delayed triggering of pulse generators, time bases for monitors, and raster generation.

Several ramp modes are available to you. Free run, gated, triggered, and gated trigger, plus manually gated or triggered operation is readily accomplished from the front panel. In addition, the 26G1 can be internally triggered by the rate generator which is an integral part of the unit. The trigger and gate levels, both input and output, are compatible with logic levels used in most DTL and TTL logic devices.

A convenient feature is the ability to terminate the ramp at any point in its excursion by applying a positive logic 1 to the Ramp Reset input or a logic 0 to the Ground to Reset input. This provides for some interesting possibilities. For example, the 26G1 or 26G2 can serve as a time-to-height converter. The amplitude of the ramp output can be made proportional to the input pulse width simply by feeding the pulse into both the Trig and Ground to Reset inputs. The ramp is then started by the leading edge of the pulse and terminated when the pulse falls to zero.

In addition to the main ramp output of 10 volts, several other signals are available at the front panel. A 1-volt ramp output serves as a convenient time base for the 601, 602 and 611 monitors which are ideal companion units to the 2600 Series. The +3-volt Ramp Gate, of the same duration as the ramp, provides unblanking for the monitor. A +3-volt, 1.5-μs pulse coincident with the start of the ramp is handy to trigger your oscilloscope or other associated circuitry used in the application.

We mentioned earlier that the 26G1 also contains a rate generator. Normally free-running at a frequency determined by the Rate and Multiplier settings, it can also be gated manually or by an external gate. All that is needed is reversal of an internal 3-pin connector. The Gate and Ground to Gate inputs then serve to gate the rate generator, with the first pulse from the rate generator coincident with the start of the gate. The rate generator may be used independent of the ramp generator portion of the 26G1.

PULSE GENERATION

The 26G3 Pulse Generator plug-in unit provides precise rectangular pulses with amplitude to ±10 volts and pulse duration from 1μs to 11 seconds. Pulse risetime and falltime is less than 200 ns. In addition, the unit has two other output modes. With the Pulse Duration control set to Bistable, the output changes state with each succeeding trigger, that is, the output goes to the high state on one trigger and to the low state on the next. A highly symmetrical waveform or pulses longer than 11 seconds can thus be easily generated.

The third mode, DC, or as it is sometimes called, "locked on", is appearing with increasing frequency on the newer pulse generators. In this mode the output is simply a DC level which can be accurately set to any value up to ±10 volts by means of the Pulse Amplitude control. Accuracy is 1% of full scale, full scale being 1 volt, 10 volts, or a value you may choose by selecting an appropriate external resistance. Output current up to 20 mA is available to drive the selected resistance, however, maximum output voltage is limited to ±10 volts.

Three other outputs are available on the front panel: the Pulse Start, a +3-volt pulse serving as an output trigger; the Pulse Gate, a +3-volt gate with the same duration as the pulse output; and the Trigger Gate, a +3-volt gate coincident with the start of the pulse output and whose width is determined by the Delay control setting.

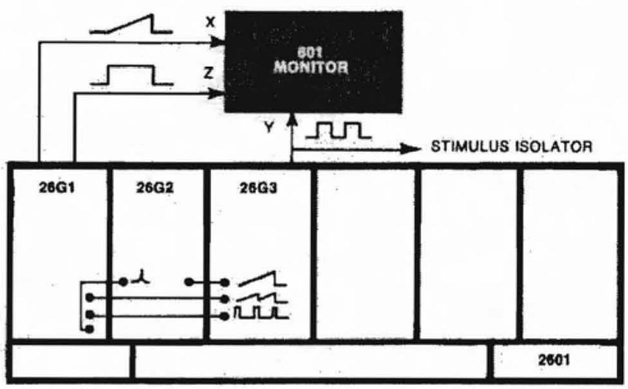
Turning to the 26G3 inputs, we see a wide range of control for starting and stopping the pulse. Selection of slope and level, much the same as on your oscilloscope, is available. A preset +1-volt level is useful when triggering from logic circuits, and a ramp input provides for triggering at any point on a +10-volt ramp giving you a choice of accurate time delay before starting the pulse. The Slew Ramp input offers some interesting capabilities: a signal fed into this input is combined algebraically with the signal fed into the Ramp input to effect triggering. This gives you a convenient means of generating two pulses whose time relationship can be made to change at a controlled, linear rate.

One of the common uses of this technique is found in the field of biophysical research, the objective being to determine the ability of a nerve to respond to separate stimuli occurring within a brief time span. A look at how we can accomplish this objective using the 2600 Series will serve to demonstrate the flexibility of the system, but first let's finish our review of the 26G3 inputs.

In addition to the Trigger, Ramp and Slew Ramp inputs, there are Set and Reset inputs. A +1-volt signal to the Set input, will set the output to its high state regardless of the state of all other inputs except the Reset input. Conversely, a +1-volt signal to the Reset input will set the output to its low state regardless of the state of all other inputs including the Set input.

SYSTEM APPLICATION

Now let's look at how we can accomplish the objective mentioned above, that of determining nerve response to closely spaced stimuli, using the 2600-Series instruments. The block diagram below shows the system we can use to generate the variable-spaced pulses, including a 601 monitor to display the pulses. The system consists of the 2601 Mainframe, the 26G1 Rate/Ramp Generator, the 26G2 Ramp Generator, the 26G3 Pulse Generator and the 601 Storage Display Unit.



Simplified block diagram of system to produce pulse pairs having gradually reduced spacing between pulses.

Interconnection of the units and the control settings for the respective units are shown on the interconnection board worksheet at right. These worksheets are replicas of the interconnection board and provide a handy reference for repeating the set-up for a particular measurement. Replicas of the front panels of the plug-in units are available with gummed backing for pasting on the worksheet as shown. The photo in the lower right-hand corner of the worksheet shows the signal generated by the set-up.

The pulse train is initiated by pressing the Manual button on the 26G2. The 26G2 performs four functions. It starts the pulse train, gates the 26G1, provides the slew ramp for the 26G3 and determines the total period over which the nerve will be exercised, in this instance, 10 seconds.

The 26G1 also performs four functions. It determines how often the 26G3 generates pulse pairs, provides the ramp input for the 26G3, determines, in conjunction with the slew ramp and the Delay control setting on the 26G3, when a stimulus pulse will be generated, and provides the sweep and unblanking signals for the 601 monitor.

The 26G3 merely stands by and generates a pulse of the appropriate duration and amplitude when its triggering level is reached.

Now let's see what happens when we push the Manual button on the 26G2. A single pulse, 1 volt in amplitude and 300 μs in duration is generated, followed by an identical pulse 10 ms later. The two pulses are then repeated at 1.5 sec intervals with the time between them reduced 1.5 ms each time they repeat. A reset pulse from the 26G1 prevents the slew ramp from triggering the 26G3 at the peak of its excursion, producing an unwanted pulse.

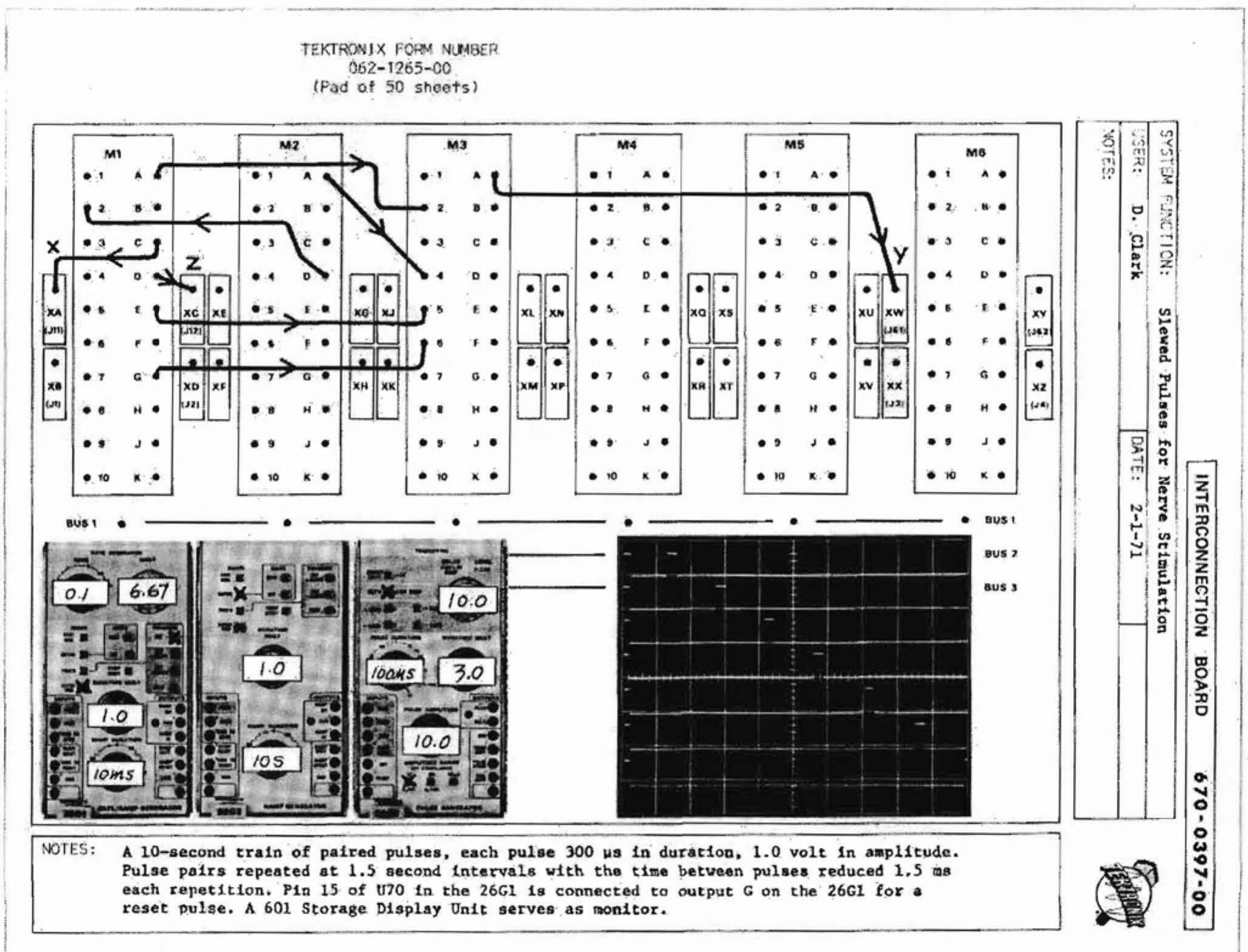
OUTPUT CONDITIONING

One other important plug-in currently available in the 2600 Series is the 26A1 Operational Amplifier. It is a high-power operational amplifier ideal for final processing of signals generated in 2600-Series system. Output capabilities are ±50 V and up to ±50 mA. Open loop gain is 10,000 into a 1 kΩ load with a unity gain bandwidth of 5 MHz.

Access to the operational amplifier inputs and outputs is via a Terminal Access Adapter which plugs into the plug-in unit. The adapter also provides access to the front panel connectors and the regulated +15 and −15 volt supplies. Clips and jacks are mounted on the adapter circuit board so you can easily change the operational amplifier function. A Terminal Access Adapter kit which includes a circuit board with a 0.1 x 0.1 inch grid of plated-through holes is available for constructing circuits to meet your specific needs.

7000-SERIES COMPATIBILITY

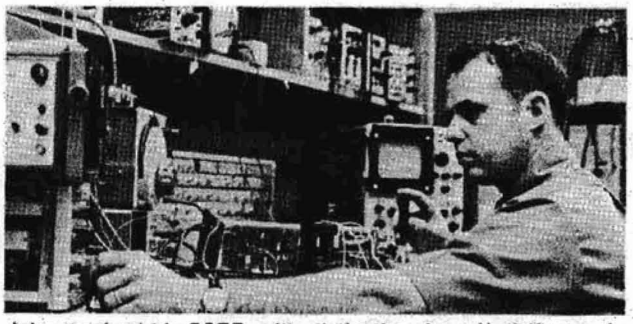
The 2600 Series also brings new capabilities to you who own 7000-Series oscilloscopes. Through the use of an adapter, you can operate any of the 2600-Series plug-ins in your 7000-Series mainframe; truly plug-in versatility at its best.



Interconnection board worksheet shows connections between units, front panel control settings and waveforms generated by set-up. Notes include signal parameters and special instructions. Worksheet provides permanent record of set-up.

TEKNIQUE: *measuring the linearity of fast ramps*

By John McCormick, Project Engineer



John received his BSEE, with distinction, from U of Kansas in 1962 and his MSE with a Materials Sciences Option from Princeton in 1965. With Tek since 1965, he has contributed much to fast-ramp technology while working on sampling sweeps.

The time measurements you make with your oscilloscope can only be as accurate as the time base displayed on the CRT screen. Improvements in components, ramp generator circuitry and CRT construction have given us time bases specified accurate within 2 or 3% and typically accurate within 1%. With the great strides being made in vertical amplifier bandwidth has come the challenge of providing the fast sweeps needed to properly display these higher-speed phenomena. Generating and measuring fast, linear ramps poses unique problems. This article discusses a solution for one of those problems, that of measuring the linearity of fast ramps.

There are two important quantities used to specify and describe a ramp. These are the mean slope of the ramp, and linearity or slope deviation from the mean. An ideal ramp has a constant slope and is perfectly linear. It is usually easy to measure the mean slope of the ramp but linearity measurements are difficult to make and are usually made in an indirect manner. This is especially true in the case of very fast ramps (tens of nanoseconds in length).

The terminology used to describe linearity varies according to the method used to measure it. A sampling oscilloscope can form the basis for a convenient and precise method of ramp slope and linearity measurements. However, before describing the method it will be necessary to define a few terms.

DEFINITIONS

Mathematically speaking, the slope of a waveform at any point in time is the derivative of the waveform with respect to time. If V (t) is a voltage waveform, then the slope at any time is given by

$$\text{slope} = m(t) = \frac{dV(t)}{dt}$$

In the case of an ideal ramp, the slope would be constant. To describe a ramp we may consider an ideal ramp with the desired constant slope which we will call the mean slope, plus some deviations of the slope from this constant value.

$$m(t) = m_o + l(t)$$

Where m (t) is the actual slope at any given time, m_o is the mean slope and l (t) is the nonlinearity of the ramp.

Percentage of nonlinearity is expressed by the equation

$$\%\ \text{Nonlinearity} = \left(\frac{m(t) - m_o}{m_o}\right) \times 100\% = \frac{l(t)}{m_o} \times 100\%$$

The nonlinearity is a function of time and can be determined if we know m (t) and m_o. It is relatively easy to measure m_o by feeding the ramp into the vertical system of a scope and measuring its amplitude and duration; m (t) is the time derivative of the ramp waveform. It is possible to measure an approximation to m (t) by several methods, only one of which we will discuss in detail here.

The derivative of a voltage that is a function of time V (t) is given by the basic definition:

$$\frac{dV(t)}{dt} = m(t) = \frac{V(t+\Delta t) - V(t)}{\Delta t}$$
$$\text{limit } \Delta t \rightarrow 0$$

What we can measure is

$$m^*(t) = \frac{V(t+\Delta t) - V(t)}{\Delta t}$$
$$\Delta t \text{ finite}$$

It is obvious that m* (t) is just the average slope of the function V (t) measured over a time Δt at each point in time as in Fig. 1. A convenient name for Δt is the time resolution or simply, the "resolution" of the measurement. The resolution is indicative of the detail that can be resolved. If the slope m (t) has components which last for a time on the order of Δt as in Fig. 1, they will be smoothed out in the measurement. If the ramp has a fast start like the ideal ramp in Fig. 2 (a), then the m* (t) Fig. 2 (c) will differ from the actual derivative in Fig. 2 (b) because of the finite resolution time. The smaller the resolution time, the closer m* (t) will be to m (t). Now let's consider methods of measuring m* (t).

MEASUREMENT OF m*(t)

One simple way to obtain m* (t) for a waveform would be to process the waveform with an analog differentiator as in Fig. 3. This works pretty well with slow ramps but is very difficult to implement for fast ramps. A better method for fast ramps makes use of sampling techniques to time-convert the ramp to a slower-speed replica. Measuring the slope is then an easy matter. The technique shown in Fig. 4 can be used to measure V (t+Δt) and V (t). The ramp waveform is fed into two identical sampling heads, A & B, each of which produces a DC voltage in its respective memory, proportional to the value of the ramp voltage at a time t_s when the strobe opens

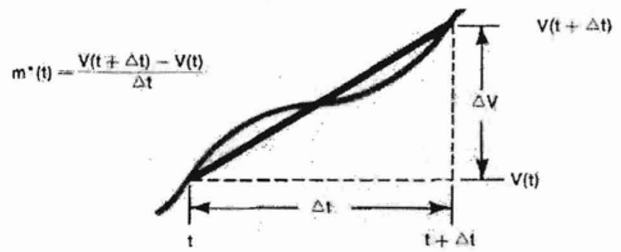


Fig. 1. Resolution limits measurement detail. Components lasting for a time on the order of Δt will be smoothed out.

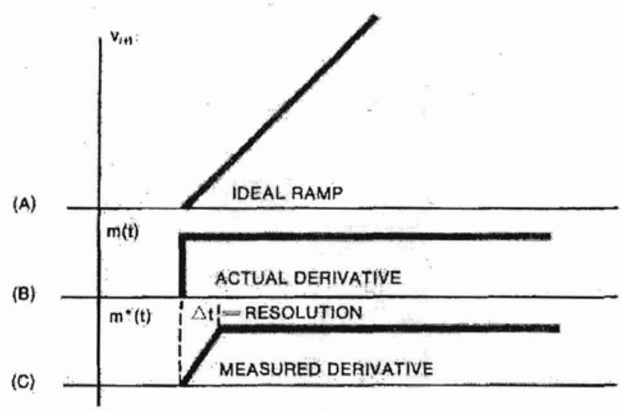


Fig. 2. Measured slope differs from the actual derivative because of the finite resolution time.

the sampling gate. If the strobe time for channel A (t_{SA}) is made different from that for channel B (t_{SB}) by some time (Δt) due to unequal delays T_A and T_B, then the voltage measured by the respective sampling heads will be

$$V_{SA} = V(t_{SA}) \qquad V_{SB} = V(t_{SA} + \Delta t)$$

We can then substract them at each time t.

$$V(t)_{B\text{-}A} = V_{SB} - V_{SA} = (V(t + \Delta t) - V(t))$$

If we divide the difference in strobe time Δt we have

$$\frac{V(t)_{B\text{-}A}}{\Delta t} = \frac{(V(t + \Delta t) - V(t))}{\Delta t} = m^*(t)$$

A convenient realization of the above technique can be obtained with a sampling system set up as in Fig. 5. The system consists of a 7000-Series four-compartment mainframe, a 7T11, two 7S11's, two S-1 sampling heads and a 7A22. If the signal cannot be loaded by 50Ω then a probe such as the P6034, P6035 or P6051 can be used to couple the signal to the power divider tee. An alternate approach would be to use S-3A or S-5 sampling heads in place of the S-1.

The gains of both sampling channels should be adjusted so that they are equal (note variable front panel control on the 7S11 does not effect the gain of the vert sig out). This can be done by inserting a variable attenuator in the leads from the vert sig out to the 7A22. Comparing the amplitudes of the two vertical signals out is easily done with the 7A22. Just feed both signals differentially into the 7A22 and adjust the gains until the base line is at the same level before and after the ramp.

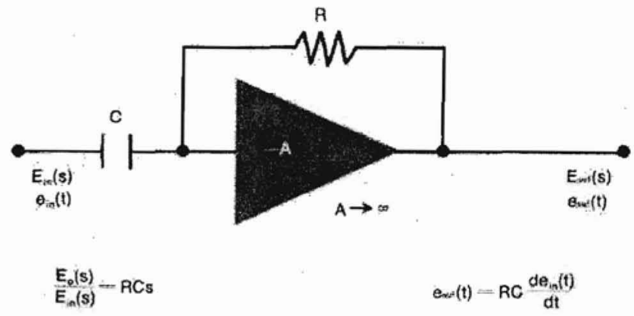


Fig. 3. Analog differentiator is a convenient means of measuring slope and linearity of slower ramps.

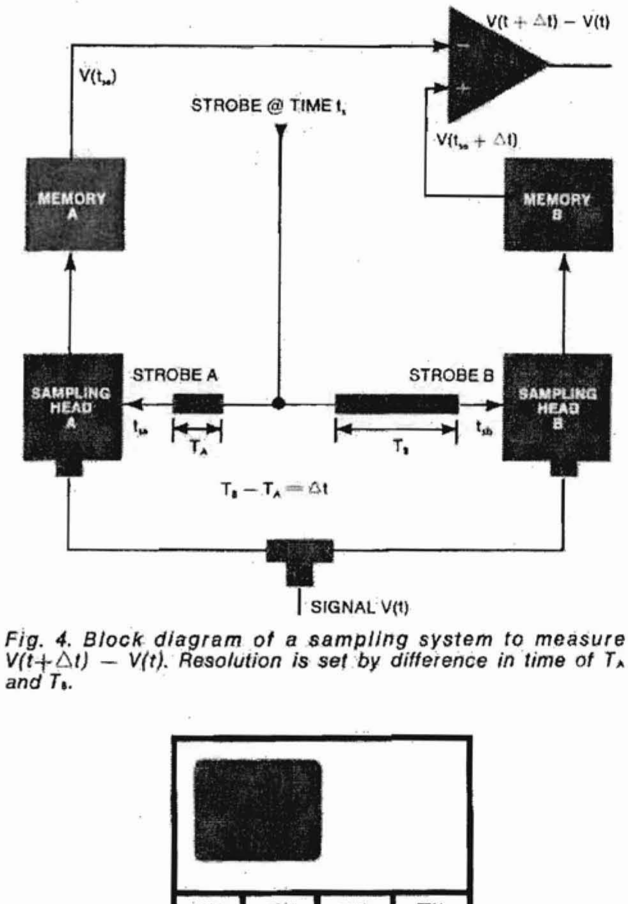


Fig. 4. Block diagram of a sampling system to measure $V(t + \Delta t) - V(t)$. Resolution is set by difference in time of T_A and T_B.

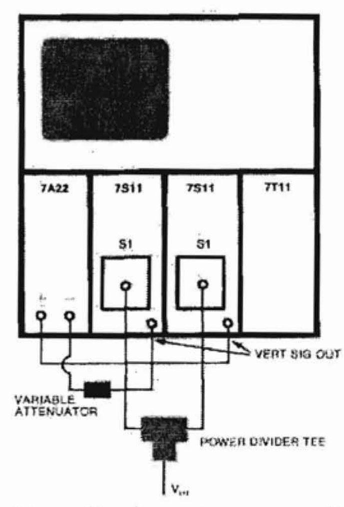
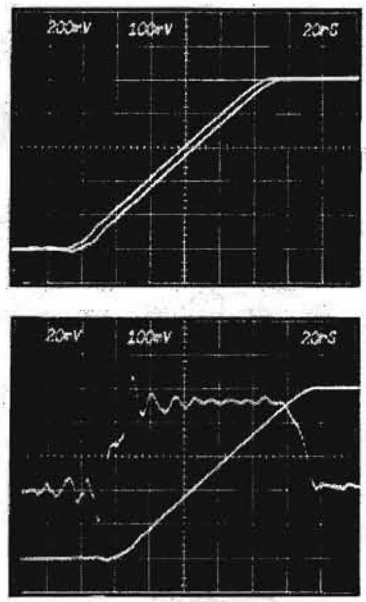


*Fig. 5. 7000-Series system to measure ramp (Vt) and slope (m*t) and display them simultaneously. Attenuator is placed in series with 7A22 input having largest signal so inputs to 7A22 may be set to same amplitude.*

The resolution should be set by turning the right hand 7S11 Delay Control full CCW, grounding the negative input of the 7A22 and setting the left hand 7S11 Delay Control for the desired Δt by observing the separation of the two traces on the screen. Be sure to adjust the gain of the 7A22 using the variable if necessary so that the two traces have the same amplitude on the screen. The top photo below is a typical display for setting resolution.



Top photo is typical display for setting resolution. Bottom photo shows ramp and its slope. Aberrations are caused by nonlinearities in the ramp. Resolution is 6 ns.

After setting the desired resolution or Δt, the negative input of the 7A22 is moved to the DC position. Now displayed on the CRT is the voltage differential between the outputs of the samplers which is proportional to Δt and the slope of the ramp. Measuring the amplitude of this voltage differential and knowing Δt we arrive at $m^*(t)$ or the slope of the ramp.

The bottom photo above shows the slope waveform and the ramp whose slope it represents. Aberrations on the slope waveform are due to nonlinearities in the ramp. The amplitude of these aberrations relative to the amplitude of the slope waveform is the measure of the nonlinearities that exist in the ramp.

ACCURACY OF THE MEASUREMENT

Although the absolute slope in volts per nanosecond can be measured with this system, the accuracy is not as good as it is when measuring linearity unless the system is calibrated with a known slope. Contributing to the accuracy of the slope measurement are the accuracy of the sampling channel gains, the accuracy of the 7A22 gain, and the accuracy with which the time Δt is known.

One method of eliminating the problem of absolute sweep calibration for accurate Δt is to adjust for both channels to sample at the same time and add a known length of delay line in the signal path of one of the sampling channels.

Two other factors effect the accuracy of the linearity measurements. These are nonlinearity in the vertical response and nonlinearity in the sampling sweep. Of the two, the sweep nonlinearity is the dominate effect. The linearity of the sweep is specified to be within 3% over most of the Time Position Range and can be checked by the usual method with accurate time marks. For sweep speeds with low magnification the linearity is typically better than 1%.

PRECISION OF THE MEASUREMENT

Precision refers to the ability to measure small differences in signal amplitude and is limited primarily by noise. With the system described we can easily measure 1% differences in slope. It must be borne in mind that the response of the 7S11's must be identical. A convenient way to assure this is to set the dot response of both 7S11's to unity. It is also important that the scan rate be slow enough for the bandpass used on the 7A22.

RANGE OF SLOPE MEASUREMENTS

The upper limit on slope, $m^*(t)$, in volts/nanosecond is determined by the risetime of the sampling system and our ability to set the resolution to be a small portion of the ramp. Ten to twenty percent of ramp duration yields good results. The system described provides resolution from 10 ns to less than 100 ps. We should keep in mind that as the resolution time decreases, so does the signal out and noise will be a problem. The 7A22 variable bandpass may be used to reduce noise but the display rate must decrease proportionally. This is easily done by varying the scan control on the 7T11.

The lower limit on $m^*(t)$ in volts/nanosecond is set by noise as the resolution time cannot be adjusted greater than 10 ns without instrument modification. A useful lower limit set by noise places the longest ramp length that can be measured with this system at about 500 ns. However, an external delay line can easily be inserted in the signal path of one sampling channel to extend the lower limit.

CONCLUSION

We have discussed how differentiation of a fast ramp leads to a convenient method of measuring ramp linearity and have shown how to construct such a measurement system. A ramp and its slope, $m^*(t)$, are shown in the bottom photo at left. The resolution is about 5% of the ramp length. The risetime of the slope can be measured as well as amplitude, overshoot, ringing and droop, just as if measuring a step response, and these quantities all relate to how linear the ramp is at any point. The advantage of having the ramp and the slope displayed simultaneously is that the effect of circuit adjustments affecting the slope are seen immediately.

The ability to differentiate fast waveforms can be useful in other applications as well, such as measuring impulse response by differentiating the step response. Differentiation of theoretical expressions has always been a useful technique in certain analysis (such as linearity of ramps), but with the ability to measure the derivative directly and display it, although limited by resolution time, the technique becomes even more useful.

SERVICE SCOPE

SERVICING THE 7704 HIGH-EFFICIENCY POWER SUPPLY

By Charles Phillips
Product Service Technician, Factory Service Center

This is the first in a series of articles on servicing the 7000-Series oscilloscopes. The 7704 serves as the basis for these articles since it contains most of the new circuitry, components and construction techniques we will be discussing. It is not our intent to discuss the general techniques used in troubleshooting oscilloscope circuitry as these were covered extensively in the February 1969 to February 1970 issues of TEKSCOPE. Copies of these articles are available through your field engineer.

Proper operation of the regulated low-voltage supplies is essential for the rest of the scope circuitry to function properly, so let's look at this section first.

The high-efficiency power supply used in the 7704 is a new concept in power supply design that results in appreciable savings in volume, weight and power consumption. It is called "high efficiency" because its efficiency is about 70% as compared to 45% for conventional supplies. The line-to-DC converter/regulator contains most of the unconventional circuitry so our discussion will deal primarily with this portion.

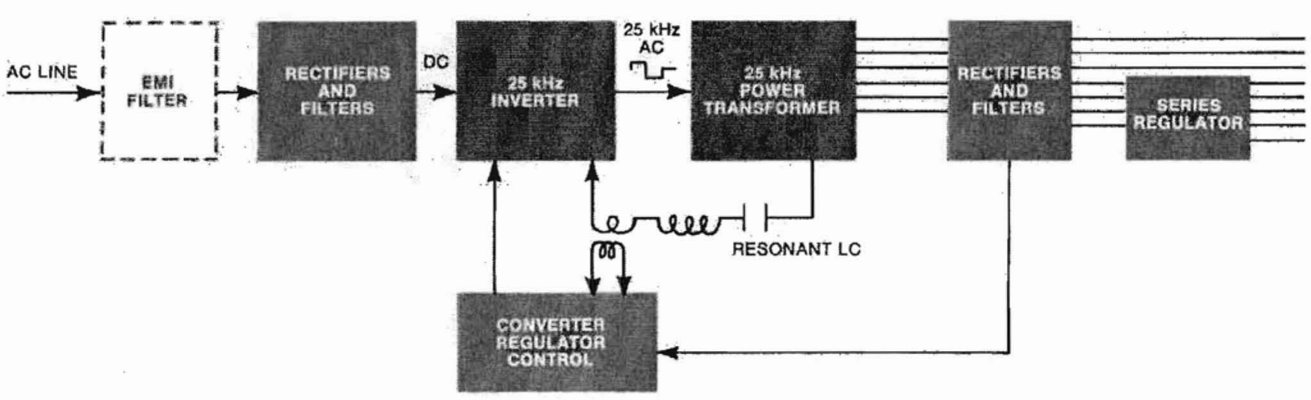
First, let's briefly review the theory of operation. The high-efficiency power supply is essentially a DC-to-DC converter. The line voltage is rectified, filtered and used to power an inverter which runs at approximately 25 kHz. The frequency at which the inverter runs is determined basically by the resonant frequency of a series-LC network placed in series with the primary of the power transformer. The inverter drives the primary of the power transformer supplying the desired secondary voltages. These are then rectified, filtered and regulated for circuit use.

Pre-regulation of the voltage applied to the power transformer is accomplished by controlling the frequency at which the inverter runs. A sample of the secondary voltage is rectified and used to control the frequency of a monostable multivibrator. This multivibrator, in turn, controls the time that either half of the inverter can be triggered, thus controlling the inverter frequency. Circuit parameters are such that the multivibrator, and hence the inverter, always runs below the resonant frequency of the LC network. Remembering that the resonant LC network is in series with the primary of the power transformer, we can see that as the inverter frequency changes, the impedance of the LC network changes. The resultant change in voltage dropped across the LC network keeps the voltage applied to the primary constant. Pre-regulation to about 1% is achieved by this means.

Now, let's turn our attention to troubleshooting the supply. Assume you have made the usual preliminary checks; you have power to the instrument, the line selector on the rear of the instrument is in the correct position for the applied line voltage and the line voltage is within specified limits. The plug-ins have been removed to eliminate the possibility of their causing the power supply to malfunction.

With the instrument power off, check the two fuses located in the line selector cover on the rear of the instrument. If the line fuse, F800, is open the problem is probably in the line input circuitry. If the inverter fuse, F810, is open the inverter circuitry is probably faulty. In either case it will be necessary to remove the supply from the mainframe to make further checks. This is easily done by removing the four screws on the rear panel that secure the power unit, then sliding the unit out the rear of the instrument.

Before removing the power-unit cover, check to see that the neon bulb on the left side of the power unit has stopped flashing. The primary storage capacitors C813 and C814



Simplified block diagram of high-efficiency low-voltage power supply.

remain charged with high voltage DC for several minutes after the power line is disconnected. When this voltage exceeds about 80 volts the neon bulb flashes. While servicing the power unit, the discharge time of the storage capacitors can be speeded up by temporarily disabling the inverter stop circuit. Pulling Q864 before turning off the scope power will allow the inverter to keep running for a short time, thus draining most of the charge from the capacitors. A voltmeter reading between test points 810 and 811 on the line input board will indicate the charge remaining on the storage capacitors. Allow at least one minute for the current-limiting thermistors to cool before turning on the power again if you use this fast-discharge technique. Do not attempt to discharge the capacitors by shorting directly across them as this will damage them.

With the power-unit cover removed, orient the supply with the rectifier board on top, the line input board on the left and the inverter board on the right. This will make it convenient to get to all the test points as we go along.

LINE INPUT BOARD

First let's check the line input board. It's fairly easy to tell if this circuit is working. The neon bulb previously mentioned will start flashing when power is applied. On some units it assumes a steady glow, on others it continues to flash. The voltage reading on test points 810 and 811 should be approximately 300 volts DC depending upon the line voltage. Be careful not to ground any point in this circuit except test-point ground or chassis.

Typical troubles in this circuit causing the line fuse to open are shorted diodes on the bridge, CR810, or a shorted capacitor C810, C811, C813 or C814.

INVERTER BOARD

Next in line is the inverter circuit. The problems most common to this circuit are open fuse F810, shorted transistors Q825 or Q835, or shorted diodes CR825, CR835, CR828 or CR838. An open inverter fuse usually indicates trouble in the inverter.

Before working in this circuit, unplug the power cord and give the storage capacitors time to discharge. Remove the line selector cover containing the line and inverter fuses. We're now ready to make some resistance checks on the inverter board.

With your ohmmeter set to the x1 kΩ scale, take a reading between test points 826 and 836. The reading should be several megohms in one direction and ≈ 1.5 kΩ with the test leads reversed. Check between test points 836 and 820. You should get a high and low reading as before. This checks the transistors and important diodes in the inverter stage. If you get a low reading in both directions on either of these tests, remove the transistor from the side having the low reading in both directions. A set of readings between the appropriate test points will show whether it is the diode or the transistor that is defective. Diodes CR826 and CR836 are not checked by the above procedure but will not prevent the inverter from running even if shorted. Once you achieve a high resistance on both sides of the inverter, it will probably operate when you apply the proper power to it. However, before applying power, a quick check should be made on rectifier board test point 860 to ground. The resistance should be ≈ 2 kΩ or 40 kΩ depending on the polarity of the meter leads.

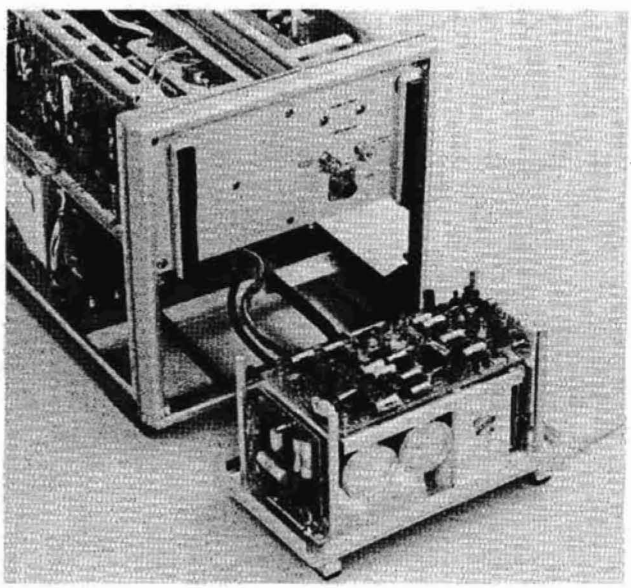
You can now prepare to apply power to the instrument. Install the line selector cover. Remove Q860 to disable the pre-regulator circuit. Connect your test scope between test point 836 and ground on the inverter board. Vertical sensitivity should be 50 V/div DC at the probe tip, the trace centered and the sweep speed set to 10 μs/div. Connect a voltmeter between the +75 V test point and ground on the rectifier board. Plug the scope into an autotransformer and with the line voltage set at zero volts, turn the instrument on. Slowly advance the line voltage while watching the test scope. If the trace moves up or down, the inverter still has problems. If the trace holds steady, the inverter should start as the line voltage approaches 80 volts. A square wave of approximately 25 kHz and 200 volts will appear on the test scope. Do not advance the line voltage any further. The +75 volt supply should not be allowed to exceed 75 volts to prevent blowing the inverter fuse.

RECTIFIER BOARD

You are now ready to check the pre-regulator circuitry. Turn off the scope and return the line voltage to zero volts. Replace Q860 in its socket. Slowly advance the line voltage while monitoring the +75 volt supply. If the +75 volts holds steady, you can advance the line voltage to a normal setting. If the voltage is not stable or if the signal being monitored on test point 836 on the inverter board is erratic in frequency, the pre-regulator is not working properly. The quickest method of troubleshooting this circuit is to check the associated transistors with a curve tracer or ohmmeter. The waveforms shown on the facing page are typical for a properly operating supply.

MECHANICAL CONSIDERATIONS

Most of the components in the power supply are readily accessible from the top of the printed circuit boards. However, when it is necessary to remove a soldered-in component, we suggest you remove the circuit board from the assembly and unsolder the component from the back side of the board. The line input board and the rectifier board are readily



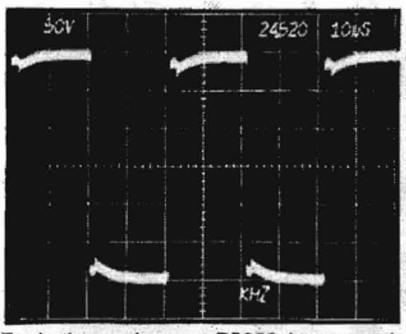
Low-voltage supply removed for easy servicing. Line input board is on the left side, rectifier board on top, and just the edge of the inverter board is visible at the right.

removed by loosening two or three screws. The inverter board is somewhat more difficult to remove; the manual gives the proper procedure.

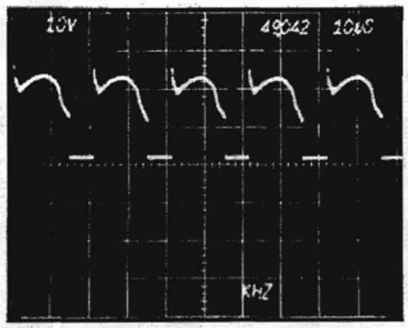
Care should be exercised when replacing Q825 or Q835 located on the ceramic heat sink on the inverter board. The mounting studs are soldered into the printed circuit board and may be broken loose by applying excessive torque.

When placing the power unit back into the mainframe take care to properly dress the power unit cables between the power unit and the logic board. Lowering the swing-down gate on the right side of the instrument will let you guide the cables into place.

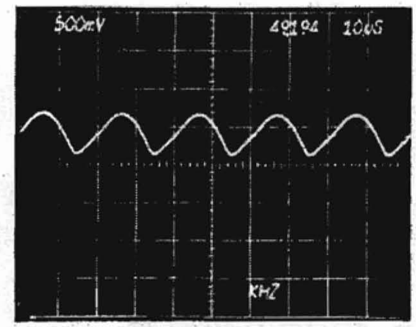
In the next issue of TEKSCOPE we will discuss the 7704 high voltage power supply.



Typical waveform at TP836 for properly operating supply. Mid-screen is 0 Volts.



Waveform at TP860. Note frequency is twice that at TP836.



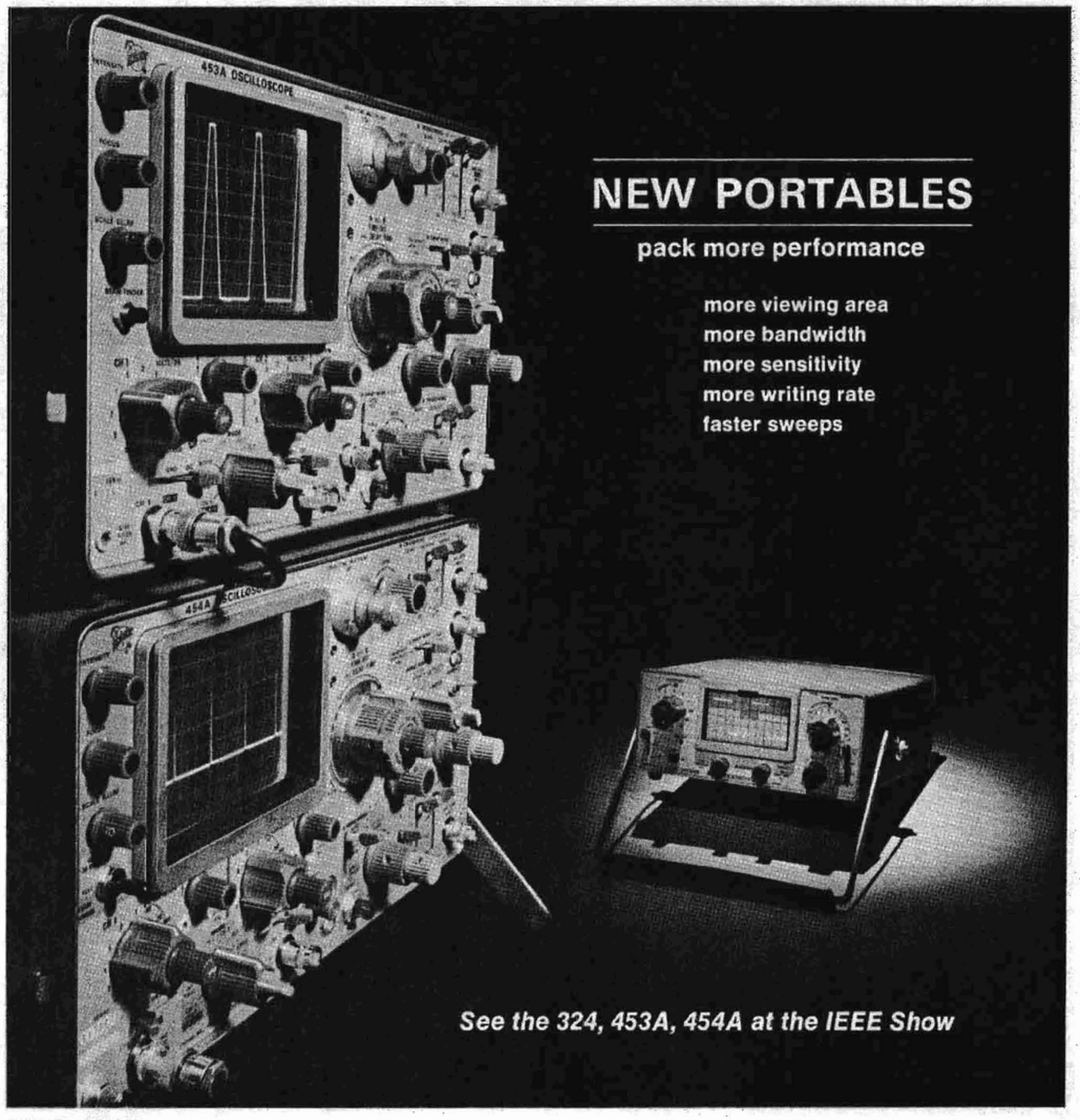
Waveform at TP859. Frequency increased slightly due to line voltage change.

TEKSCOPE

Volume 3 Number 2 March 1971

Customer Information from Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005

Editor: Gordon Allison Artist: Nancy Sageser For regular receipt of TEKSCOPE contact your local field engineer.



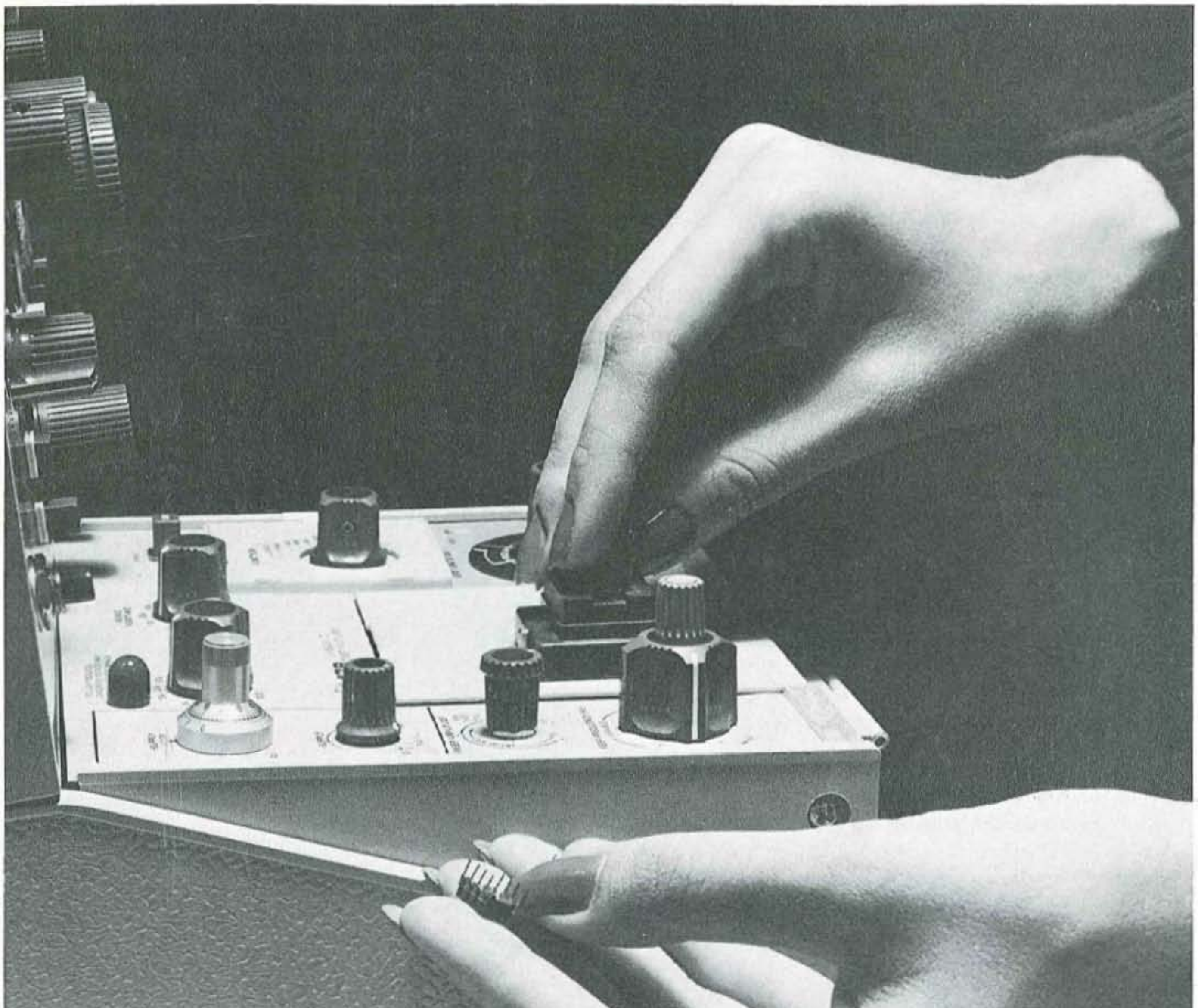
TEKTRONIX, INC.
P.O. BOX 500
BEAVERTON, OR. 97005

11/72

TEKTRONIX

TEK SCOPE

NOVEMBER 1972



PROGRESS IN SEMICONDUCTOR TESTING

LINEAR IC TESTING WITH THE CURVE TRACER

OSCILLOSCOPE TO CURVE TRACER

DELAYING SWEEP GOES DIGITAL

DIFFERENTIAL AMPLIFIER TECHNIQUES

SERVICING 5100-SERIES DISPLAY UNITS

PROGRESS IN SEMICONDUCTOR TESTING

Jack Millay — Project Manager

Providing advancements in component measurements, the new 577 Curve Tracer Measurement System combines display storage and linear IC testing capabilities in a new, inexpensive, easy to use instrument.

A curve tracer is a special purpose oscilloscope used to display the performance characteristics of many different types of electrical components. The name "curve tracer" originated from the ability of these instruments to display the characteristic curves representing the capabilities of active devices. Their use today includes not only active devices but also relays, power supplies, small induction motors, light bulbs, connectors, capacitors, and other components.

Tektronix, Inc., long the leading manufacturer of curve tracers, now introduces the 577 Curve Tracer Measurement System. This new, low-cost system makes the majority of the measurements required to test semiconductors. In addition, it is a complete system for making extensive tests on linear integrated circuits.

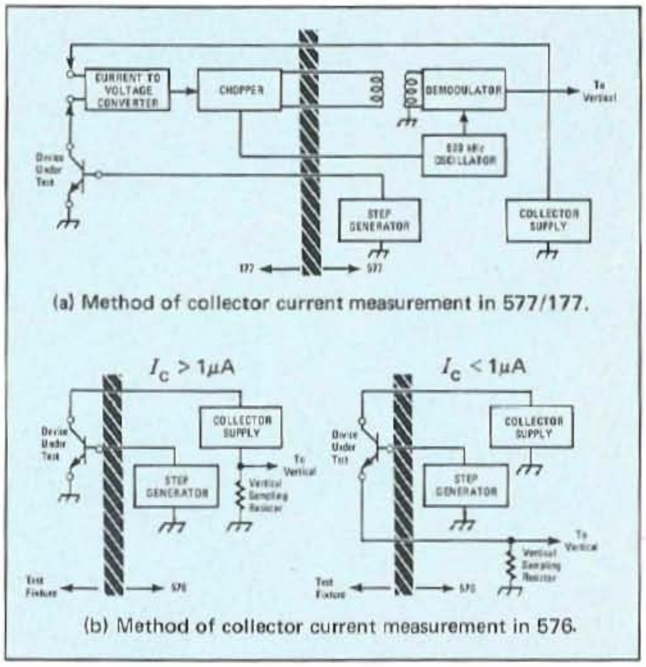
To provide the most versatile measurement system, modular construction techniques are used. The 577 Curve Tracer Measurement System consists of three major sections; display module, mainframe, and test fixture. Two display units are available; the D1 Storage, a split-screen bistable storage unit, and the D2, a large-screen non-storage display unit. These attach to the 577 Curve Tracer mainframe; the display units can be interchanged in a matter of minutes. The mainframe also accepts plug-in test fixtures. Presently available are the 177, a test fixture for displaying tests of two-, three-, and four-lead devices, and the 178, a test fixture specifically designed to display characteristics of linear integrated circuits such as operational amplifiers, differential amplifiers, and regulators. The plug-in test fixture concept also allows future expansion of the system.

***Cover**—Pictured is the 178 Linear IC Test Fixture used with the new 577 Curve Tracer which offers display storage. Most linear IC tests can be performed with this low-cost bench top system.*

The Mainframe

The 577 Curve Tracer mainframe contains the power supplies, horizontal amplifier, vertical amplifier, collector supply, and step generator. Controls for the collector supply, step generator, and horizontal volts/division are located on the 577 mainframe. Vertical deflection factor, however, is controlled from the test fixture, allowing selection of optimum ranges for the device being tested.

A new collector current measuring scheme for vertical deflection was developed for the 577. A comparison between this method and that used in previous curve tracers is shown in Fig. 1. Notice that in the 577/177 the collector current is sensed in the test fixture rather than in the mainframe as in previous instruments. This has two major advantages. First, the collector supply does not have to be isolated from ground as in previous designs, resulting in a considerable cost savings in the construction of the 577. Secondly, the test fixture can be easily designed to measure the current in any lead of the device under test as required, for example, in the 178 Linear IC Test Fixture.



(a) Method of collector current measurement in 577/177.

(b) Method of collector current measurement in 576.

Fig. 1. Block diagrams of the collector current measuring circuitry in the 576 and 577.

The Display Modules

Each of the display modules uses a 6½-inch ceramic CRT with an 8 x 10 division (½ inch/div) internal graticule. The CRT, with 3.5 kV accelerating potential, has a bright, well-defined trace. Simplest of the display modules is the D2 display unit. It contains the CRT with its controls, the high-voltage supply, a beam finder, and the power switch. In addition to the normal display functions of the D2, the D1 display module provides storage on a split-screen, bistable CRT.

The Test Fixtures

The 178 Linear IC Test Fixture allows the display and measurement of linear IC characteristics such as gain, input current, common-mode rejection ratio, and power supply rejection ratio. Its operation will be covered in a separate article immediately following this discussion.

The 177 test fixture is designed to test two-, three- and four-lead devices. This test fixture provides many of the features found in previous curve tracers such as looping compensation, Kelvin sensing, and interlocked high-voltage collector supply (100, 400, and 1600 volt positions).

The 177 can measure collector currents at sensitivities as low as 200 pA/division. This is made possible in large part by the new collector current measuring scheme. The mode switch on the 177 includes a position which allows measurement of emitter-base leakage or breakdown characteristics. Also included on this test fixture is an independent −12 to +12 V bias supply which can be used to bias the substrates of devices having more than three terminals.

A new measurement possible with the 177 is comparative capacitance measurements to as low as 1 pF. The difference in current required to charge and discharge the capacitance from the collector terminal to ground is shown by a loop in the display. By comparing the displayed looping of several devices, comparative capacitance can be determined. Unknown capacitance values can be measured by using a reference capacitor to calibrate the display in terms of capacitance/division.

Operating the 577 with the 177

Operator convenience has been designed into the 577/177 system to provide faster measurements and simpler operation. The front panel has been simplified by eliminating several unimportant controls, while at the same time retaining the operator conveniences pioneered by the TEKTRONIX 576 Curve Tracer.

A new feature in the 577 system is automatic shutdown of the collector sweep if more than 2½ screen diameters of vertical deflection result (on higher current ranges only). This will often prevent the device under test from being destroyed if it is subjected to more current than is expected.

To provide easier setup, the front-panel pushbuttons have been color-coded. When all of the dark grey buttons are pressed in, the system is ready for most normal measurements. Lights are used behind the skirts of the STEP OFFSET AMPL, HORIZ VOLTS/DIV, and VERTICAL SENSITIVITY knobs. This makes the selected measurement value readily visible. Another feature of the back-lit knobs is that the lights automatically change position when the magnifiers or X.1 controls are used so they always indicate the correct measurement value.

For More Convenience, Add Storage

The D1 Storage display adds new operator convenience to semiconductor testing and makes possible measurements which previously were either very difficult or impossible to make. Comparison measurements where you want to directly compare the characteristics of one device with those of another are made easier with storage. An application of storage which uses the split-screen feature is storing the limits of device performance on one half of the screen and comparing it against the performance of another device displayed on the other half.

The changing characteristics of a device at different operating levels can be readily compared using storage. Fig. 2 shows the collector current of a transistor plotted against the base to emitter voltage. The curve at the left was plotted at a vertical sensitivity of 0.2 nA/div. Each successive curve is one order of magnitude greater and the last curve is at 20 mA/div. In this way, the performance of the transistor may be viewed and compared over nine orders of magnitude of collector current.

Storage can also be very useful to display the changes in characteristics of the device under test due to some external influence such as when heated or cooled. This is an easy way to find the zero temperature coefficient point of FET's and Zener diodes.

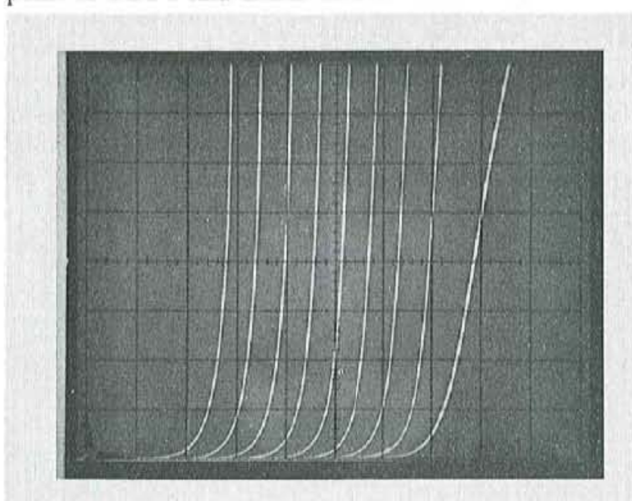


Fig. 2. Storage display of a series of single curves plotted at different vertical sensitivities.

Checking the characteristics of a device which is operated near or even beyond its specified dissipation limits can be facilitated by storage. With the stored display, the device under test needs to be subjected to the potentially destructive conditions for only long enough to store the trace. For tests where it is desired to intentionally cause the device to fail, the stored display allows close examination of the conditions present at the time of failure.

Storage also allows more convenient plotting of the characteristics of devices when using the pulsed or DC collector sweep modes. These characteristics are normally displayed as dots on the screen. Storage allows the dots to be stored as the collector voltage is varied, thus tracing out the complete curves.

Some very unusual tests can be made using storage. One example is checking relays for pull-in and drop-out voltage and current. With the collector supply operated in the DC mode, the relay coil is connected between the collector and emitter terminals. Then the collector supply voltage is varied manually. When the relay armature moves, it induces a voltage change into the coil which can be seen on the display.

Taking photographs of the display is greatly simplified with storage also, particularly when using the pulsed or DC sweep modes. Storage allows the complete display to be presented at a uniform intensity and unwanted displays can be erased as many times as necessary before the correct display is obtained, thereby saving film.

LINEAR IC TESTING COMES TO THE CURVE TRACER

Om Agrawal - Project Engineer

Until now, testing of linear ICs has been an expensive, complex job. Most of the IC testers previously available either required special test cards which could test only one specific type of IC, were computer controlled, or needed external equipment to make the measurement. This limited the use of IC testers to only the most critical or important test areas such as manufacturing or incoming inspection. As a result, linear IC testing was not available in many locations where it could be very beneficial.

With the introduction of the new 577/177/178/D1/D2 Curve Tracer Measurement System, Tektronix, Inc. now makes testing linear ICs as easy and convenient as testing transistors. The 178 was designed as part of the 577 Curve Tracer Measurement System to make it more versatile and less expensive. In addition, since many of the same areas that require discrete component testing also require IC testing, this arrangement provides extended test capabilities in a convenient, easy to use system which requires a minimum of bench space.

System Design

The 178 plugs into the 577 Curve Tracer Measurement System. The D1 Storage display is recommended for use with the 178 since it provides the best display of the very low sweep rate which must be used to display many linear IC characteristics. In combination with these units, the 178 provides the complete capabilities to measure and display the various parameters of linear ICs. The 178 includes a sweep generator, positive and negative supplies, vertical measurement system, feedback loop for the device under test, and switching capabilities to facilitate testing of the many varying parameters under diverse conditions.

Plug-in test cards define the type of IC that can be tested. Presently, two test cards are available; a card for testing IC amplifiers, and a card for testing IC regulators. These test cards can be easily interchanged to test either type of device. The pin configuration for specific devices is determined by jumper leads on the test card. The card can be quickly set up to test most of the linear ICs presently available.

Testing IC Amplifiers

The basic circuit configuration of the 178 with the Amplifier test card installed is shown in Fig. 3. This configuration makes it possible to test operational amplifiers under open loop conditions and allows the test conditions to be set up as specified by the manufacturer. The Feedback Amplifier permits measurement of AC differential input voltage without loading the inputs. The Sample and Hold Amplifier nullifies the effect of DC offset voltage while allowing this voltage to be measured without loading the inputs. The source resistors and load resistors can be easily selected by front-panel switches. The FUNCTION switch provides the necessary switching of the generators and amplifiers for the different tests. Test conditions can also be changed by varying the amplitude and frequency of the + and − voltages to the Device Under Test.

Specifications given by the IC manufacturer are at typical operating levels. However, if you are designing a circuit which requires the IC to operate at different levels than those specified (e.g., different output voltage levels, load, frequency, etc) performance could be completely different. The 178 allows you to check operation of the amplifier IC under the specific conditions at which it will be operating. Typical characteristics which can be checked on a linear IC amplifier are open-loop DC gain, common-mode rejection ratio, power supply rejection ratio, input and supply current, phase shift, effect of thermal feedback, and check of popcorn and random noise. Some of these tests on a typical linear IC are shown in Figs. 4 through 10.

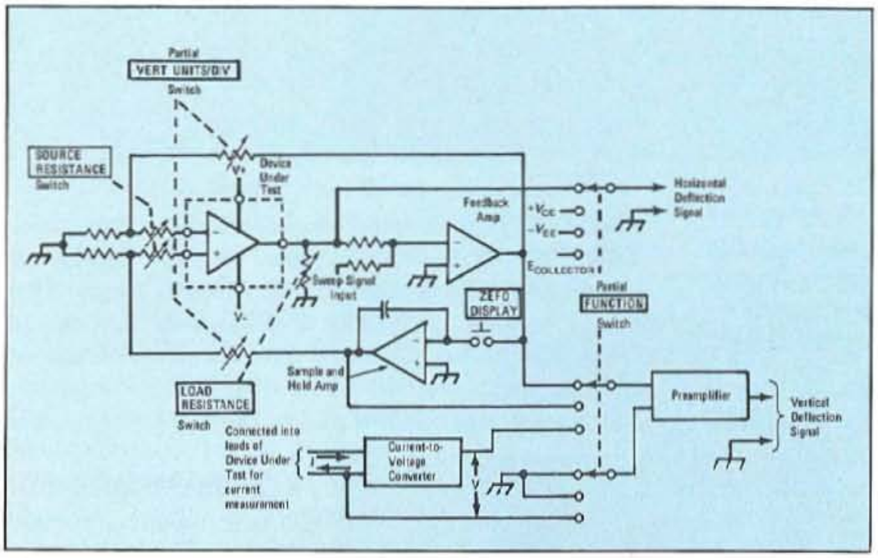


***Fig. 3.** Block diagram of the 178 configured for testing operational amplifiers.*

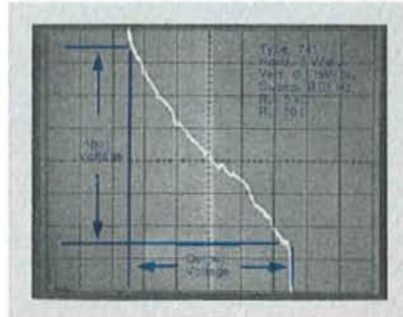


***Fig. 4.** Plot of open loop gain with bandwidth limited to eliminate noise. Small aberrations in trace indicate popcorn noise. Calculating overall gain:*

$$GAIN = \frac{\text{output voltage swing}}{\text{input voltage swing}} =$$

$$\frac{5 \text{ div} \times 5 \text{ V/div}}{6 \text{ div} \times 0.1 \text{ mV/div}} = 41{,}700$$

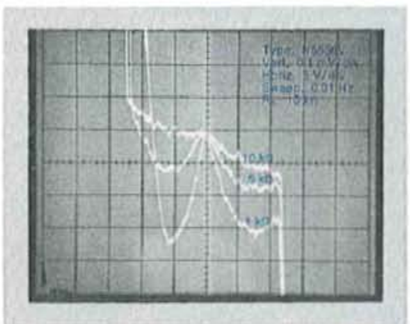


***Fig. 5.** Open loop gain changes resulting from change in load. When the output is loaded, the power dissipation in the output stage raises the temperature of the whole chip. This change in temperature causes a change in input offset voltage that changes low-frequency gain.*

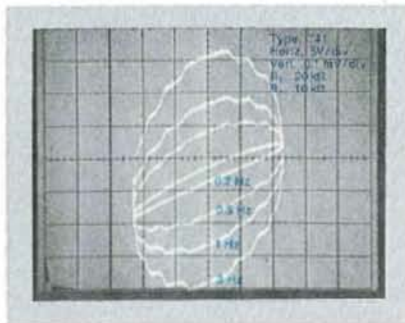


***Fig. 6.** Shows the phase shift associated with gain at several different sweep frequencies.*

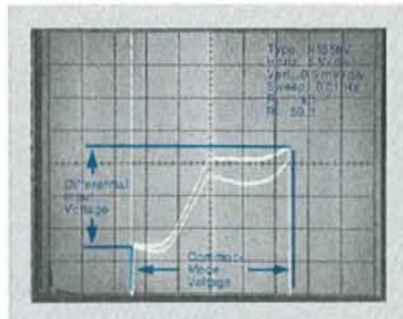


***Fig. 7.** Plot of common-mode rejection ratio (CMRR). Notice that the CMRR is changing from point to point. Overall CMRR can be calculated as follows:*

$$CMRR = \frac{\text{common-mode voltage}}{\text{differential input voltage}} =$$

$$\frac{5 \text{ div} \times 5 \text{ V/div}}{3 \text{ div} \times 0.5 \text{ mV/div}} =$$

$$16{,}700 = 20 \log_{10} (16{,}700) = 84 \text{ dB}$$

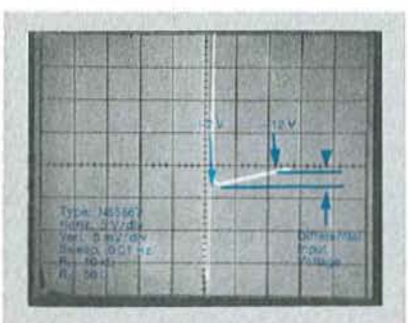


***Fig. 8.** Power-supply rejection ratio (PSRR) with both + and − supplies varied out of phase. Horizontal axis shows change in supply voltage while vertical axis shows differential input voltage. Calculating PSRR from +2 volts to +12 volts:*

$$PSRR = \frac{\text{supply voltage variation}}{\text{differential input voltage}} =$$

$$\frac{2.0 \text{ div} \times 5 \text{ V/div}}{0.5 \text{ div} \times 5 \text{ mV/div}} =$$

$$4{,}000 = 20 \log_{10} (4000) = 72 \text{ dB}$$

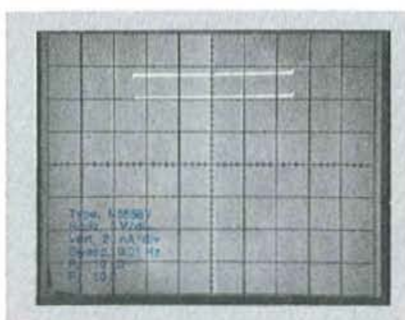


***Fig. 9.** Checking input bias current and input offset current. Top line shows positive input bias current of about 56 nA. Bottom line shows negative input bias current of about 42 nA. Difference between positive and negative input bias current is the offset current of about 14 nA.*

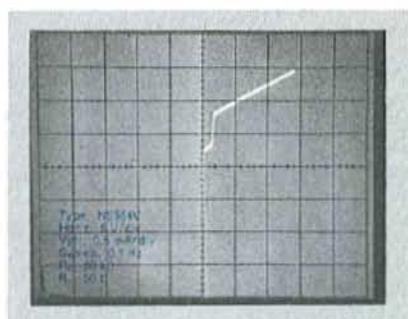


***Fig. 10.** Positive supply current plotted against positive supply voltage.*

Testing IC Voltage Regulators

IC regulators have come into common usage in low-voltage power supplies. The 178 can display the parameters of these devices when the Regulator test card is installed.

Fig. 11 shows the basic circuit configuration when this card is installed. The Sample and Hold Amplifier nullifies effects of DC output voltage on the Device Under Test. The output of the Feedback Amplifier is proportional to the AC changes at the output of the Device Under Test.

Just as for amplifier ICs, the 178 allows IC regulators to be tested under conditions approximating those of the actual circuit. Some of the tests which can be made are measurement of output voltage, line regulation, load regulation, and measurement of input current.

Summary

The 577/177/178 Curve Tracer system joins many other TEKTRONIX instruments which help the engineer to better understand the discipline in which he works. This system expands component measurements and makes them easier for better product specification by the manufacturer, more effective circuit design by the engineer, and quicker instrument repair by the service technician.

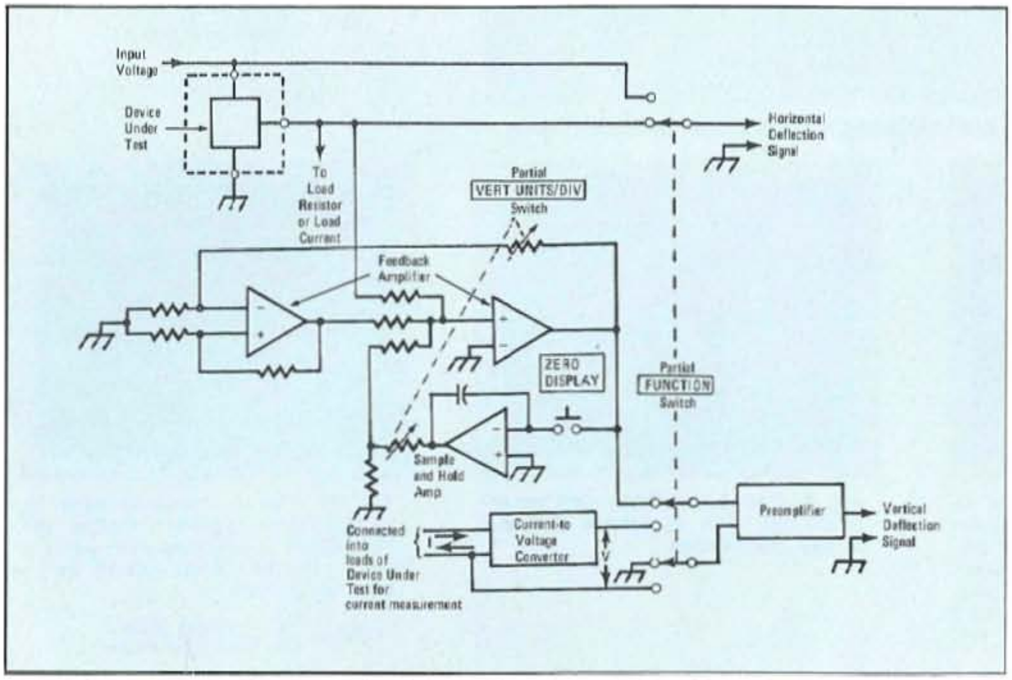


Fig. 11. Block diagram of the 178 configured for testing IC regulators.

ACKNOWLEDGMENTS

Jack Millay headed up the very able team which designed the 577 Curve Tracer Measurement System. Working on the electrical design were Jim Knapton, Bob Herb, Bob Verrinder, Om Agrawal, Dave Rule, and Gary Davis. Tom Saucy did the mechanical design while Darrell Barrett and Gil Stephens provided evaluation support. Lena McIntosh and Iona MacKay built the prototype instruments. And there were many others who helped in both large and small ways to make this project a success.

OUR AUTHORS

Jack Millay

Jack attended Multnomah College before joining TEK in 1958. As manager of the Curve Tracer Engineering Group, he has been involved in most of the recent advancements in this area and has authored several previous articles for TEKSCOPE.

Jack is married and has two children. When not working with curve tracers, he enjoys flying, bee keeping, and antique cars.

Om Agrawal

Om is a native of India and received his Bachelors of Technology in Electrical Engineering at the Indian Institute of Technology, Kanpur, India. After coming to the U.S., he attended the Case Institute of Technology, receiving an M.S.E.E. He is presently attending the University of Portland where he plans to receive an M.B.A. degree in December.

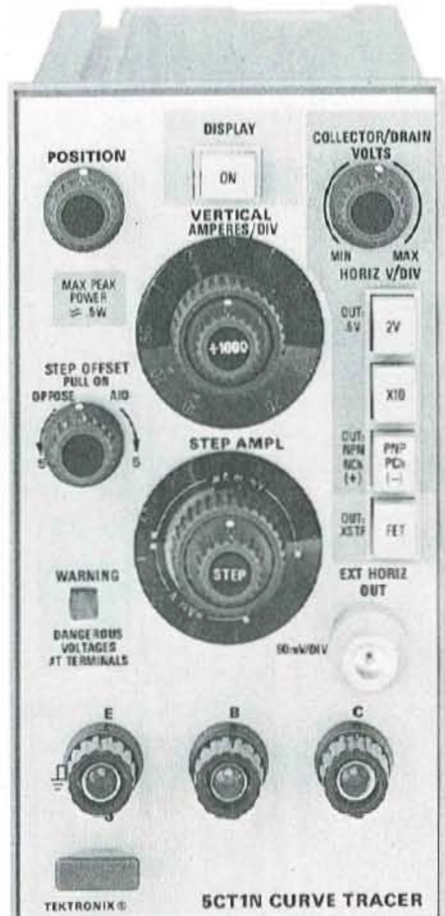
Since starting at TEK in 1970, Om has worked on the 172 as well as the current 577/177/178 project. When not working or studying, he enjoys swimming and roller skating.

OSCILLOSCOPE TO CURVE TRACER WITH ONE PLUG-IN

Matt Zimmerman - Instrument Engineering

The need for some form of tester becomes obvious to anyone who works with semiconductor devices. By measuring parameters of interest, a tester provides operating information about a device. A simple go no-go (static) tester provides a limited amount of data, and usually only about a specific operating point. Such things as breakdown, leakage, or non-linearity may go undetected, and device matching is very difficult. Dynamic testers in general, and curve tracers in particular, quickly provide information which is difficult if not impossible to obtain with a static tester.

Tektronix makes a variety of curve tracers, and each has its particular advantages. Two recent entries into the TEKTRONIX Curve Tracer line are plug-in curve tracers—the 5CT1N and 7CT1N. The 5CT1N is designed for use with the TEKTRONIX 5000-Series and the 7CT1N for the 7000-Series Oscilloscopes. The primary advantage of the plug-in curve tracer is that it is now possible to have both a laboratory oscilloscope and a moderate range curve tracer in one package. As handy as this is for bench use, it is even more useful for on-site repairs. Other advantages are low cost and ease of operation.



These units have been designed to make the usual tests quickly, but even extensive tests can be done with a minimum of difficulty. Power available at the test terminals is limited to 0.5 watt. While this may seem insufficient at first, most small signal devices can be adequately tested with this power level. Also, because of this limited power, it is unlikely that a device will be accidentally destroyed and errors caused by device heating are almost eliminated. Now let's look at some of the tests that can be made with this curve tracer.

Testing Signal and Power Diodes

Set up controls and connect diode as shown in part A of the Basic Measurement Reference Chart. For a functional check, turn COLLECTOR/DRAIN VOLTS clockwise. A trace similar to the one shown should appear if the diode is good. Horizontal displacement is forward voltage (V_F), and vertical displacement is forward current (I_F).

Forward current up to 160 milliamps can be measured. By pressing the NPN-PNP switch, reverse polarity voltage is applied to the diode and reverse current or leakage (I_R) as low as 10 microamps can be measured. By changing the .5 V - 2 V and X10 buttons, reverse voltages (V_R) up to 200 volts may be applied to the device.

If it is desired to look at an I_R of less than 10 microamps, return COLLECTOR/DRAIN VOLTS to zero and release the ÷1000 button. This increases the sensitivity of the VERTICAL AMPERES/DIV by a factor of 1000 and puts the plug-in into a DC sweep mode. The normal display becomes a dot. Position the dot to the upper right hand corner of the CRT and increase COLLECTOR/DRAIN VOLTS. I_R as low as 10 nanoamps can now be measured.

Testing Zener Diodes

When testing Zeners, usually only the reverse or breakdown characteristics are important. Make initial set up and connections as shown in part B with the .5 V - 2 V and X10 buttons set to the appropriate range for the Zener being used. Advance COLLECTOR/DRAIN VOLTS until diode breakdown occurs. Zener voltage (V_Z) is measured horizontally, and Zener current (I_Z) is measured vertically. Zeners up to 200 volts can be tested in this manner, but the available power is limited to 0.5 watts peak. Pressing the NPN-PNP switch displays the Zener's forward characteristics.

Testing Tunnel Diodes

The important characteristics of a tunnel diode—peak current (I_P), peak voltage (V_P), valley current (I_V), and valley voltage (V_V)—ocur in the forward direction, normally with less than one volt across the device. Set up as noted in part C with diode connections as shown. Advance COLLECTOR/DRAIN VOLTS until tunnel action occurs. Any diode having an I_P less than 160 milliamps can be checked. The display will be adequate for functional checks. If a more detailed analysis is required, the horizontal scan can be expanded by connecting the external output to an Amplifier plug-in. By setting the amplifier deflection factor below 50 mV/div (100 mV/div for the 7CT1N), the horizontal voltage can be expanded as desired.

Testing Silicon-Controlled Rectifiers & Silicon-Controlled Switches

These devices may be functionally tested only if their gate firing current is less than 15 mA. Set up and connections are shown in part D. Adjust COLLECTOR/DRAIN VOLTS for full scale deflection and advance STEP control until SCR or SCS conducts. If this does not supply enough current to switch the device, pull out the STEP OFFSET control and adjust aiding offset for about 5 more milliamps. Forward voltage at any current up to 160 milliamps can now be measured. The reverse characteristics of an SCS can be tested by pressing the NPN-PNP switch.

To measure forward blocking voltage up to 200 volts, connect the gate terminal to the cathode terminal directly or through a fixed resistor. Advance COLLECTOR/DRAIN VOLTS until the device starts to conduct as in diode breakdown. When a current level above the holding current is reached, the device will switch to the ON state, and forward voltage will drop to a low level. Pressing the NPN-PNP switch allows measurement of reverse blocking voltage.

Testing NPN-PNP Transistors

The 5CT1N/7CT1N are designed to give functional, β or h_{fe}, and $V_{CE}(sat)$ measurements easily. Other tests that can be made are BV_{CEO} and I_{CEO}, BV_{CER} and I_{CER}, BV_{CBO} and BV_{EBO}. Since the maximum peak power delivered to the device is only 0.5 watt, most transistors are safe from accidental damage due to excess power.

For a functional test, set up as in part E. Set COLLECTOR/DRAIN VOLTS for full screen display (less if transistor exhibits breakdown). Turn STEP control clockwise to increase number of steps until a family of curves is displayed. Small signal β or h_{fe} is $\Delta I_C/\Delta I_B$ and can be calculated from the display as follows: set collector current (I_C) to desired level using STEP AMPL, STEP, and VERTICAL AMPERES/DIV controls. Divide VERTICAL AMPERES/DIV setting by STEP AMPL setting to obtain β/div. Measure the vertical distance between two curves near the desired I_C level and multiply by β/div to obtain β for the device under test. Positioning or offset may be used to set the desired curve at a convenient reference point.

$V_{CE}(sat)$ is the collector to emitter voltage at a point near or below the knee of the displayed curve. $V_{CE}(sat)$ is dependent upon base drive and collector current, so these factors must be considered if $V_{CE}(sat)$ is being measured to verify a specification.

To measure BV_{CEO} and I_{CEO}, open the transistor base-lead by removing it from the test adapter or B/D jack. Adjust COLLECTOR/DRAIN VOLTS and change .5 V - 2 V and X10 buttons until specified I_{CEO} is obtained vertically. Read BV_{CEO} horizontally. I_{CEO} less than 10 microamps may be tested by using the ÷1000 button. BV_{CES} and I_{CES} are measured the same way, except that the base lead is shorted to the emitter lead. To measure BV_{CER} and I_{CER}, the base lead is connected to the emitter lead through an external resistor.

BV_{EBO} is the reverse voltage necessary to break down the emitter base junction. The easiest way to measure it is to connect the base lead to the emitter terminal and the emitter lead to the collector terminal, leaving the collector lead open. Adjust COLLECTOR/DRAIN VOLTS until breakdown occurs, which is usually at less than 20 volts.

Testing Field-Effect Transistors

Most FET's can be checked with the 5CT1N and 7CT1N. Functional, I_{DSS}, g_m, and V_P are the most common operational checks. Placing the XSTR-FET button in the FET position sets the plug-in to measure FET's in the depletion region. The same test adapter can be used, since the XSTR-FET button changes the internal lead connections, and changes the transistor base current drive to opposite polarity FET voltage drive. However, proper device basing configurations as specified by the FET manufacturer must be observed.

For a functional check, set up as in part F. Turn COLLECTOR/DRAIN VOLTS to obtain full screen deflection and adjust the STEP AMPL and STEPS controls to display a family of curves. I_{DSS} is measured by turning the STEP control fully counterclockwise. This applies zero bias to the FET, and the single curve that remains is the I_{DSS} curve.

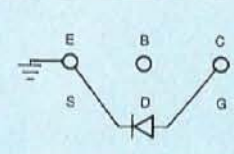
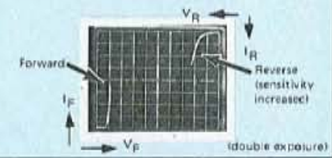
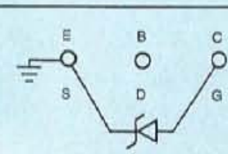
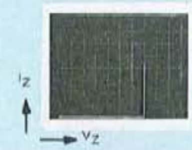
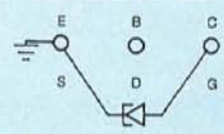
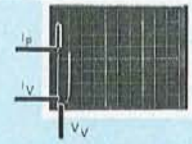
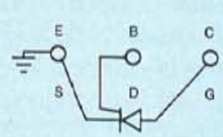
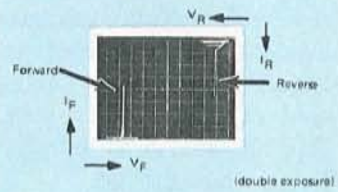
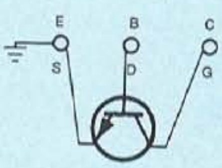
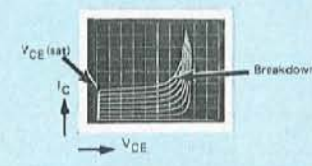
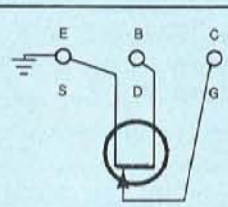
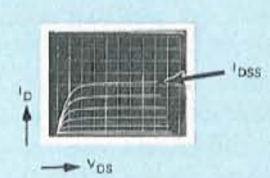
Small signal transconductance (g_m) is $\Delta I_D/\Delta V_{GS}$. To measure g_m, obtain a display of I_D as described for a functional check. Use STEP AMPL, STEPS, and VERTICAL AMPERES/DIV to obtain desired I_D. Calculate g_m/div by dividing the VERTICAL AMPERES/DIV setting by the STEP AMPL setting. Measure vertical distance between two curves and multiply by calculated g_m/div. If it is desired to look at an FET in the enhancement region, pull out the STEP OFFSET knob and adjust up to 5 steps of opposing offset. Since the offset is uncalibrated, the zero bias (I_{DSS}) point must be marked in some manner.

Pinch off voltage V_P is measured by increasing the STEP AMPL and STEP controls until a specified pinch off current is reached. V_P is the step amplitude multiplied by the number of steps required to reach pinch off.

Summary

The 5CT1N and 7CT1N are designed to give a rapid check of device characteristics. Only a few of the checks which can be made have been discussed here. For more detailed information or for further tests, see either the Tektronix Measurement Concepts Book "Semiconductor Device Measurements" (P/N 062-1009-00) or the instruction manual for the particular plug-in.

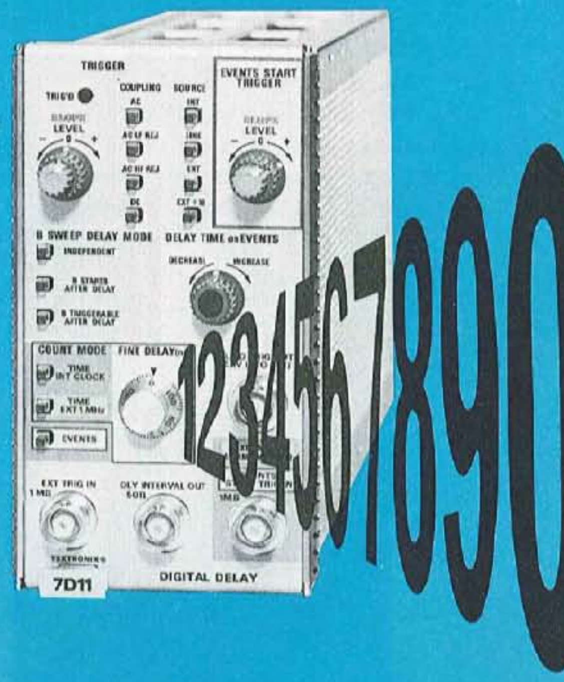
5CT1N/7CT1N
BASIC MEASUREMENT REFERENCE CHART

DEVICE	CONTROL SETTINGS		CONNECTIONS	TYPICAL WAVEFORM
A. Signal & Power Diodes	COLLECTOR/DRAIN VOLTS .5 V - 2 V X10 VERTICAL ÷1000 NPN-PNP XSTR-FET	MIN Out (.5 V) Out (X1) 1 mA/DIV In (÷1) Out (NPN) Out (XSTR)		
B. Zener Diodes	COLLECTOR/DRAIN VOLTS .5 V - 2 V X10 VERTICAL ÷1000 NPN-PNP XSTR-FET	MIN As needed As needed 1 mA/DIV In (÷1) Out (NPN) Out (XSTR)		
C. Tunnel Diodes	COLLECTOR/DRAIN VOLTS .5 V - 2 V X10 VERTICAL ÷1000 NPN-PNP XSTR-FET	MIN Out (.5 V) Out (X1) 1 mA/DIV In (÷1) Out (NPN) Out (XSTR)		
D. SCR & SCS	COLLECTOR/DRAIN VOLTS .5 V - 2 V X10 VERTICAL ÷1000 STEP OFFSET STEP AMPL STEP NPN-PNP XSTR-FET	MIN Out (.5 V) Out (X1) 10 mA/DIV In (÷1) In (off) 1 mA/step ccw Out (NPN) Out (XSTR)		
E. NPN - PNP Transistors	COLLECTOR/DRAIN VOLTS .5 V - 2 V X10 VERTICAL ÷1000 STEP OFFSET STEP AMPL STEP NPN-NPN XSTR-FET	MIN In (2 V) Out (X1) 1 mA/DIV In (÷1) In (off) 5 μA/step ccw Match Transistor Out (XSTR)		
F. Field Effect Transistors	COLLECTOR/DRAIN VOL⁻S .5 V - 2 V X10 VERTICAL ÷1000 STEP OFFSET STEP AMPL STEP NCh(+)-PCh(—) XSTR-FET	MIN In (2 V) Out (X1) .5 mA/DIV In (÷1) In (off) .2 V/step ccw Match FET In (FET)		

Matt Zimmerman—Matt began his electronics training while in the U.S. Navy and continued his studies to receive an Associate Degree in Electronics from Long Beach City College. In his six years at TEK, Matt has worked in the Standards Lab, CRT Support, and now as Design Technician in the 5100-Series group. Among the products he has worked on here are the 5CT1N/7CT1N, 5100 Series, and TM 500 Series.

Matt is married and has two children. In his spare time, he is building a new house for his family.

DELAYING SWEEP GOES DIGITAL



Bob Beville – Design Leader

Delayed sweep in the oscilloscope takes on a new face with the introduction of the 7D11 Digital Delay Unit. As a new complement to the Tektronix 7000 Series of products, the 7D11 can assist the oscilloscope user in need of accurate, low-jitter sweep delays, or having delay-by-count applications.

Before Digital Delay

Until now, sweep delays and differential time interval measurements have been made with the analog ramp—pickoff method. The function of the delaying sweep is to: accept the desired trigger, initiate its sweep—a calibrated ramp, run out to the desired delay time as determined by the pickoff comparator circuit and generate the delay gate that notifies the delayed sweep to start or arm for triggering. The delayed sweep usually is set to run a decade or more faster than the delaying ramp. The delayed ramp is then applied to the horizontal amplifier and displays the waveforms of interest with added resolution.[1-2] Intensification on the CRT by the delayed sweep gate helps in setting the start of the delayed sweep to the point desired.

The analog ramp type delay has been, and still is, doing an effective job. Some users, however, have applications that now exceed its capabilities in the areas of jitter, accuracy and linearity. Out of need to overcome some of these limitations, the 7D11 evolved.

Digital Delay By Time

The 7D11 has two basic modes of operation. The first is the Delay by Time mode—where a highly accurate internal clock is the time base from which delays are derived. Its function is still to notify the delayed sweep when to run. Its uses, such as measuring the width of a given pulse or determining the stability of an astable multi, are similar to analog ramp delay methods in that both deal in calibrated absolute time.

The selected delay time is set by the number that is placed into a digital counter. Each count is related to one period of the crystal controlled clock. The ambiguity of one full clock period in starting the count is ever present in methods using gated clocks. This is overcome by actually using a high frequency oscillator which is phase locked to the clock crystal. The HF oscillator is switched into a frequency divider at the time that delay counting is to begin. This method yields a trigger-coherent clock that has a gate ambiguity of only one cycle of the HF frequency. Once this trigger-coherent clock gets started, the accuracy of the count is maintained by the stability of the crystal oscillator. The temperature-controlled crystal oscillator in the 7D11 has 0.5 ppm stability, suitable for most measurements. If more is desired, the front panel external 1 MHz input may be driven from an in-house timing standard.

CRT Readout of Delay

The selected delay, by time or events, is displayed on the CRT READOUT of the 7000-Series mainframes. Seven and one-half digits are displayed. For example, in the time mode, for a delay time of 1 second, the CRT reads 1000.0000+ in the upper readout channel; the legend "ms" is displayed in the lower channel. The least significant digit, then, is 100 ns, as the 7D11's internal clock is 10 MHz. The "+" symbol reminds the operator to include the setting of the Fine Delay (ns) control on the 7D11 front panel. This control is a 0 ns to at least 100 ns analog delay in series with the digital time delay. It is provided to allow delay time adjustment through a complete digital increment and obtain all possible values of delay between. Where the helidial of the analog sweep delay was in control of the three most significant digits, the Fine Delay (ns) is only concerned with the two least significant digits of the measurement. Readings of the digital delay significant digits displayed on the CRT are unambiguous and with the Fine Delay (ns) control, resolution to one nanosecond is possible.

Forward-Reverse and Throttle

A novel control is used to set the time delay or number of events desired. A spring-loaded potentiometer is suspended in mechanical as well as electrical center. The absolute value of wiper voltage is applied to a voltage-to-frequency converter to increment (or decrement) the display counter. The wiper is also compared to ground to steer the direction rail of the display counter. In one control the decision to count forwards or backwards is made, and the rate of change of the count is set by the magnitude of the rotation of the knob. For example, a large count can be quickly set by rotating the control completely clockwise and backing off as the desired count is approached.

SOME APPLICATIONS

Measuring Propagation Time

The application of a 7D11 measuring the propagation time through a cable, network, or device under test is depicted in Fig. 1. A pulse generator is driving the device under test (d.u.t.) as well as initiating the digital time delay. The front panel delayed trigger output and the d.u.t. output are observed using a dual-trace vertical in the Alternate mode. The reference trigger for the Alternate mode is the d.u.t. output. The 7D11 output and d.u.t. output are then alternately viewed while the 7D11 digital delay is incremented, and lastly, the Fine Delay (ns) is varied until the two waveforms coincide on screen. When they coincide, as in Fig. 1, the two delay times are equal. The digital reading plus the Fine Delay reading is the delay through the device under test.

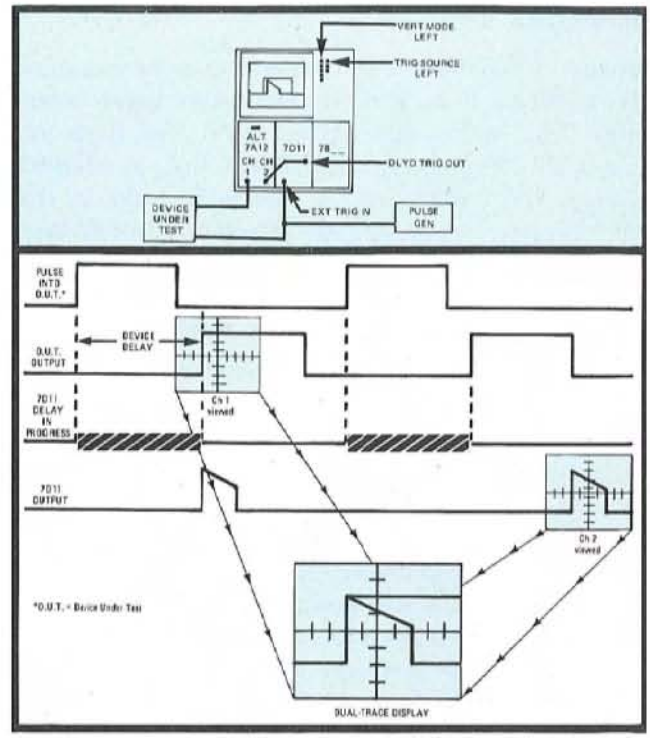


Fig. 1. The 7D11 measuring device propagation delay.

Measuring Delays <100 ns

The fact that the 7D11 minimum time delay is 100 ns, doesn't prevent measurement of delays less than 100 ns. The setup for that is depicted in Fig. 2. The waveforms below show that the second pulse in and out of the d.u.t. are measured and the difference reading $T_2 - T_1$ is the device delay.

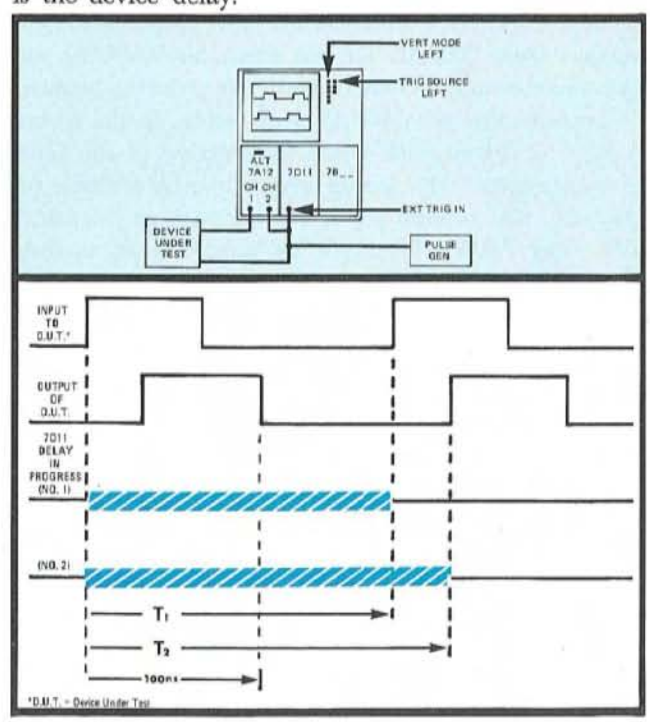


Fig. 2. Measuring device delays of less than 100 ns.

Pulse Width Variations

Suppose the width of a multivibrator is to be measured over extremes of temperature and power supply tolerances. The leading edge of the multi pulse starts the time delay. Digital, plus Fine Delay (ns), is adjusted to place the trailing edge of the multi pulse in the delayed sweep display at some reference graticule line. The circuit under test is subjected to the voltage and temperature extremes and the 7D11 delay is adjusted to bring the trailing edge back to the reference graticule line.

Measuring Jitter

The stability of an oscillator or other astable circuit can be measured (up to 0.5 ppm) with the 7D11 triggering the delayed sweep. The 7D11 accepts one of the oscillator cycles to trigger on and starts a relatively long time delay. A delayed sweep speed is used that displays approximately one whole oscillator cycle across the CRT screen. The time delay is found which exhibits a distribution of jumbled waveforms but doesn't exceed a full cycle. The time excursion of the jumbled waveforms is measured and the contribution to jitter of the 7D11 (2.2 ns or delay time x 10^{-7}, whichever is greater) is subtracted. Then the adjusted time excursion over the 7D11 delay time is computed.

Delay by Count or Events

The Delay by Events mode of operation counts arbitrary trigger events, and delivers an output (notifies the delayed sweep) when the preselected number of events is reached. The CRT READOUT now displays integer numbers from 0000001 for one event, to 10000000 for ten million events. Where formerly the delaying counter was incremented with 100 ns clock pulses, in the Event mode it is driven with pulses irrespective of the time between events. The trigger events can be periodic or aperiodic, and contain any instability such as jitter and drift. The 7D11 will trigger on these events, as they occur, up to a 50 MHz rate.

To determine when to start counting the selected number of events, the Events Start Trigger input must be provided with a related synchronization pulse of some kind. In TV line selector applications, the start trigger would be furnished by the vertical sync pulse, and the horizontal sync pulses become the events counted. In a like manner, the origin pulse of a disc memory becomes the start trigger, while the disc clock will be counted until the storage location to be observed is reached.

Delay by Event provides a significant improvement over using absolute time for sweep delay when observing events whose repetition rate is an arbitrary or irrational value, and contains cycle to cycle variations like flutter, wow, line surges, or underdamped servo response.

A Synchronization Frame Generator

If a rotational or cyclic piece of equipment is being observed, the 7D11 can become a synchronized frame generator in step with it if the equipment clock is the event start trigger as well as the trigger events to be counted. This is accomplished by setting the events delay equal to the number of clock periods in the cycle. For example, suppose a 127-bit pseudo-random-bit sequence generator is built, and a sequence-frame pulse to establish the "beginning" of the sequence is needed. The clock is counted with $n = 127$ events. A scope, triggered every 127th clock, keeps the sequence in step and stationary for viewing. The frame can be advanced or retarded by changing "n" to 128, or 126, for a moment and then back to 127. The whole sequence may be made to "pass in review" a bit at a time if large multiples of the sequence length, like $n = 12700$ are used and "n" is shifted to 12701 or 12699.

Range Calibration of Radars

An example where delay by time or delay by events are about equally desirable is the range calibration of a radar set. Time delay using 6.167 μs per nautical mile could be used. However, handling multiples of this number may soon become tedious. Consider then a gated delay line oscillator built to run at 16.215 MHz.[3] When turned on by the range gate (also turning on the Events Start Trigger) the events triggered are counted at the rate of 100 per nautical mile, a much easier number to interpret.

For radar and TDR type applications the one-way propagation time is often the more useful piece of information. A mode switch called NORM-ECHO is contained inside the 7D11. ECHO divides the time clock by two. The readout isn't altered, so the one-way-trip time is displayed directly while the time clock is doing the "out and back" computation for you.

Front Panel & Interface Outputs

As another customer benefit, the delaying interval—that time from the start of triggered counting until the time of the output delayed pulse—is applied to several places. This waveform is available at a front panel connector. With the exception of approximately 30 ns, the interval output is equal to the digital time delay read on the CRT. With the aid of the Fine Delay (ns) control, the $\approx$30 ns may be added to its width making the delaying interval useful as a precision width generator.

As long as the 30 ns delay is reckoned with by using the Fine Delay, any arbitrary width interval from 100 ns on, can be found. In the Events mode, the delay interval has the same turn-off lag as it did when it turned on. When "n" periodic events are counted, the delaying interval generates a width of n-1 periods.

Delaying Interval Viewing

The delaying interval is also made available to the mainframe. In the case where the 7D11 is used in a vertical compartment, a 'delaying pedestal" is generated on its vertical analog channel.[4-5] When the vertical mode button for this channel is pressed on, and the time base and 7D11 are triggered in parallel, the pedestal display will show the start of delay at start of sweep—out to the selected delay time.

As is customary with vertical plug-ins, provision is made in the mainframe to supply the time bases with an internal trigger. When a 7D11 is used in a vertical compartment, it too provides a trigger to the interface path for time base triggers. Some of the examples in this article depict the 7D11 in 3-hole mainframes using this path.

Used in the "A" horizontal compartment of a 4-hole, 7000 Mainframe, the 7D11 functions as a replacement for the delaying time base. The pedestal-like interval now is applied to the Z-axis by internal switch, to blank the B sweep. This is to create the useful "A intensified by B" display for locating the point in a waveform where delayed sweep is desired. As in sweep delaying plug-ins and monolithic scopes, a front panel switch permits you to select "B starts after delay" (BSAD), "B triggerable after delay" (BTAD), or INDEPENDENT operation.

INDEPENDENT or stand alone uses of the 7D11, when suitably triggered from an external generator, include precision pulse width generator, synchronous divide by N generator, TDR fault locator, and long term electronic timer. Using Line trigger as the source of events, and the Events mode maximum capacity of 10 million, nearly 46.3 hours of delay can be obtained.

Summary

Digital Delay can be used in the casual delayed sweep applications obtaining an accuracy, linearity, and low jitter never before achieved. Delay by Events gives jitterless displays that track with the clock jitter, drift and instabilities of the apparatus being observed. These and many other measurements are now available to oscilloscope users through the new capabilities and flexibility of the 7D11 Digital Delay Unit.

Acknowledgments

Credits for the 7D11 effort go to Carlo Infante, project manager; Bob Beville, design leader; Bruce Hofer, design engineer; Dick Trost, technical aide; Phil Lloyd, mechanical design; Jim Gerakos, industrial design; Lois Davis, prototype support; Donna Fricker, Mike Hughbank and Norma Peterson, EC board design. Many others were in supportng roles, and to them too— a hearty thank you.

1. Understanding Delaying Sweep, TEKTRONIX SERVICE SCOPE, June, 1968.
2. Operation Instructions: Delay Sweep Time Measurement, Delayed Sweep Magnification, Section 2 of any TEKTRONIX Manual on Delaying Sweep plug-in or portable oscilloscopes.
3. Gated Delay Line Oscillator, P. E. Dingwell, EEE, Sept., 1968.
4. 7D14 Trigger View. TEKSCOPE, Jan., 1971.
5. 7D15 Counter Signals Displayed, TEKSCOPE, Sept., 1972.

TRIGGERING

EXTERNAL TRIGGER				
SOURCE	Int, Line, Ext, Ext ÷ 10			
COUPLING	DC, AC, AC LF Rej, AC HF Rej			
MAX INPUT VOLTAGE	150 V DC + Peak AC			
LEVEL RANGE	±3.5 V in Ext ±35 V in Ext ÷ 10			
INPUT R and C	1 MΩ ±5%, 20 pF ±2 pF			
SENSITIVITY	COUPLING	FREQUENCY RANGE	MIN SIGNAL REQUIRED	
			INT	EXT
	AC	30 kHz - 10 MHz 10 MHz - 50 MHz	0.3 div 1.0 div	150 mV 750 mV
	AC LF REJ*	30 kHz - 10 MHz 150 kHz - 10 MHz 10 MHz - 50 MHz	0.3 div — 1.0 div	— 150 mV 750 mV
	AC HF REJ	30 Hz - 50 kHz	0.3 div	150 mV
	DC	DC - 10 MHz 10 MHz - 50 MHz	0.3 div 1.0 div	150 mV 750 mV

EVENTS START TRIGGER	
SOURCE	External Only
COUPLING	DC Only
MAX INPUT VOLTAGE	150 V DC + Peak AC
LEVEL RANGE	±3 V
INPUT R and C	1 MΩ within 5%, 20 pF ± 2 pF
SENSITIVITY	40 mV minimum, 30 Hz to 4 MHz; increasing to 100 mV, 4 MHz to 20 MHz; increasing to 250 mV, 20 MHz to 50 MHz.

7D11 SPECIFICATIONS

EVENTS DELAY

Events Delay Range—One to 10^7 events.

Delay Increments—One event.

Insertion Delay— 35 ns ±5 ns.

Recycle Time—Less than 500 ns.

Maximum Event Frequency—At least 50 MHz.

TIME DELAY

Digital Delay Range—Normal Mode: 100 ns to 1 s in 100 ns increments. Echo Mode: 200 ns to 2 s in 200 ns increments.

Analog Delay—Continuously variable from 0 to at least 100 ns, accuracy within 2 ns of indicated delay.

Jitter With Internal Clock— 2.2 ns or (delay time X 10^{-7}) whichever is greater.

Insertion Delay—Zero within 2 ns.

Recycle Time—Less than 575 ns.

Time Base— 500 MHz oscillator phase locked to internal or external clock.

Internal Clock— 5 MHz Crystal oscillator. Accuracy is 0.5 ppm.

External Clock— 1 MHz within 2%, AC coupled, 50 Ω.

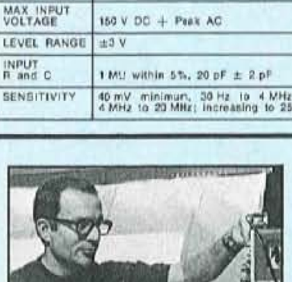
OUTPUTS

Delayed Trigger Out—Amplitude: 2 V or greater into open circuit, 1 V or greater into 50 Ω. Risetime into 50 Ω Load: 2 ns or less. Falltime into 50 Ω Load: 5 ns or less. Pulse width 200 to 250 ns.

Delay Interval Out—Amplitude: 2 V or greater into open circuit, 1 V or greater into 50 Ω. Risetime and Falltime: 5 ns or less. Accuracy: Equal to Delay Interval less 20 to 30 ns.

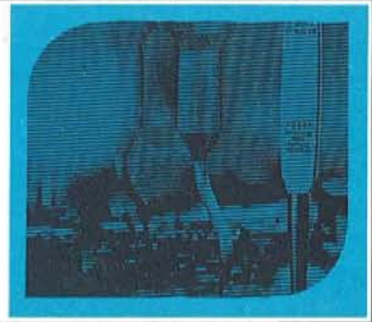
READOUT

Display— 7½ digit with leading zero suppression. ms legend in Time Delay Mode. Plus (+) symbol reminds the operator to add on the FINE DELAY (ns) setting.



Bob Beville—Bob received his B.S.E.E. in 1961 and M.S. in 1963 from the Univ. of Florida. Before joining Tek in 1964 he worked as a mission conductor of refractometer experiments at Patrick AFB. After serving as a Field Engineer in our Syracuse and Poughkeepsie Field Offices, he transferred to Electrical Evaluation. Here his varied duties included design work on the trigger circuitry for the 11B2A Delayed Sweep Time Base, responsibility for design of calibration fixtures and CRT READOUT test and evaluation. After joining the Laboratory Oscilloscope Group, he was assigned the 7D11 project. Bob also teaches logic design in the Tek Education Program, and with his family enjoys camping, metal detecting and treasure hunting.

TEKNIQUE



Fred Beckett - Engineer

A PRACTICAL APPROACH TO
DIFFERENTIAL AMPLIFIERS AND MEASUREMENTS

In Part I of this series we examined the basic concepts of the differential amplifier and the common-mode rejection ratio (CMRR). We noted that the main benefit attributed to the differential amplifier was its ability to reject the common-mode signal thereby allowing us to measure the desired signal in its true form. We also discussed sources of measurement error such as probes and source impedance differences. We will now address ourselves to the correct methods of making a differential measurement.

MAKING THE DIFFERENTIAL MEASUREMENT
PART II

There are two basic forms of differential measurements possible with an oscilloscope. The first is the conventional form of differential measurement between two electrical sources. The second is a differential comparator measurement. This latter technique is a difference measurement which compares an electrical potential against a reference voltage thereby deliberately introducing a "common-mode" condition. It is normally referred to as the "slide back" form of measurement and is a form of the null balance technique commonly found in some types of electronic measuring equipment.

The Conventional Differential Measurement

Oscilloscope manufacturers provide two means of making differential measurements by conventional methods:

(1) a differential amplifier, either as a plug-in or non plug-in with a dual beam or dual-trace display.

(2) a dual-trace instrument, either plug-in or non plug-in with the differential measurement capability when the instrument is used in the ADDED display mode.

Fig. 1 shows these two forms. The table in Fig. 2 shows the features of these two types of differential measuring instruments. The table also shows the limitations of the ADDED mode technique. The ADDED mode technique should not be disregarded as an acceptable method for a differential measurement. Clearly its limitations lie in relatively poor CMR. It should be pointed out that many differential measurements do not require the exacting capabilities offered by a differential amplifier. For example, the cancellation of the ripple component from an unregulated power supply can quite adequately be performed by the ADDED display mode. However, when measuring a small signal such as you might expect from some types of thermocouples or bridge configurations, large common-mode signals can be a problem due to the limited CMR capability of the ADDED mode.

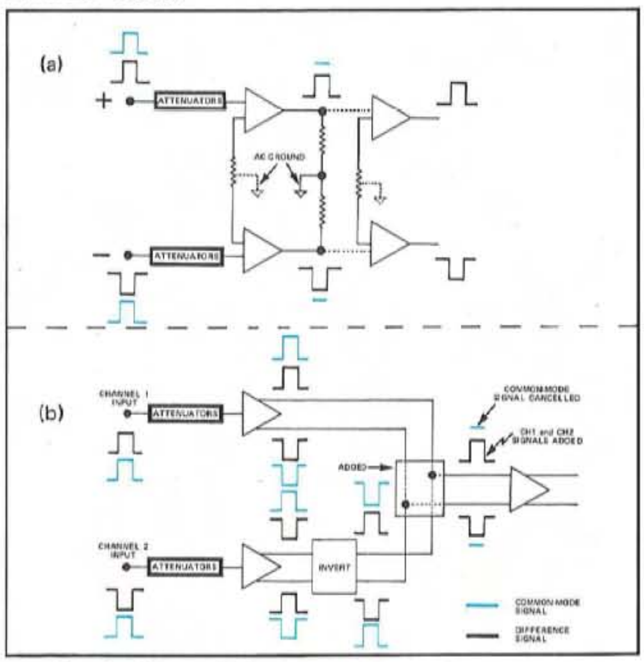


***Fig. 1.** Figure 1(a) shows a block diagram of the conventional differential amplifier. Figure 1(b) is a block diagram of the "ADDED" mode technique in which the outputs of CH 1 and CH 2 are added algebraically.*

FEATURES	DIFFERENTIAL	ADDED MODE	COMMENTS
Typical CMRR	Typically between 10,000:1 to 100,000:1 from DC to 100 kHz	100:1 or greater at 50 kHz (422 Spec)	Using the "ADDED" mode, CMR can be optimized by connecting Channels 1 & 2 inputs to a common source (calibrator) and adjusting Channel 1 or 2 GAIN for minimum CM display.
Probes CMRR Compensatable or matched for CMRR	YES	NO	
Balanced Input Circuits	YES	NO	With the "ADDED" mode, input RC input TC may vary within ±2% between channels.
Input Amplifiers Phase Corrected	YES	NO	
High Sensitivity	YES	NO	Typical for "ADDED" 5 mV/div (453A) Typical for differential 10 μV/div (7A22)
High Input Impedance	YES See Comments	NO Nominal 1 megohm input impedance	This feature is either switchable (W unit) or by strap removal, (7A22, 5A22N)

Fig. 2. Table showing the relative merits of a true differential amplifier and one using the "ADDED" mode technique.

The Differential Comparator

You will recall in Part 1 of this series we stated that the differential amplifier appears in two basic forms: namely, the paraphase type and the push-pull. The only difference between the two is that the paraphase has one input referenced to a fixed potential—this is the basic form of the differential comparator. To make it useful, the fixed potential is replaced by a calibrated variable DC supply which is called the comparison voltage (V_c).

Fig. 3 shows a functional block diagram of a typical differential comparator system. Notice that we can operate this unit as a conventional differential amplifier by simply switching to the A—B mode with the DISPLAY switch.

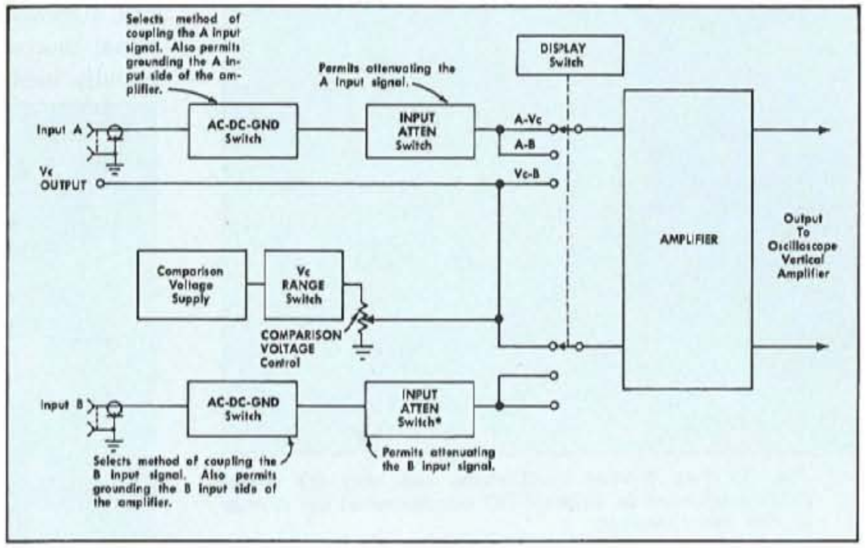


Fig. 3. A block diagram of a typical differential comparator. Notice when the DISPLAY mode switch is in the A—B position the unit becomes a conventional amplifier.

Let's see how we go about making a differential comparator measurement. First, we establish a reference position on our display by grounding both inputs. Then, selecting the appropriate input (positive voltage source to the + INPUT, negative voltage source to the − INPUT), we switch the other input to the comparison voltage (V_c). Next, the comparison voltage is adjusted until the trace "slides back" to the reference position. What have we accomplished? Using the "difference" principle we have introduced a "common-mode" condition in the form of the comparison voltage; that is, the comparison input voltage now equals the signal input. We see that we now have the ability to measure any potential whether it be DC, complex in nature, or a combination of both—such as a complex wave superimposed on a DC potential. Thus, we have an extremely versatile measuring tool. Notice, however, it does not have the mechanism to reject any interfering signal.

From the practical point of view, we must recognize some limitation when making comparator measurements. In order to measure a large potential or a waveform which is superimposed on a large potential, it may be necessary to attenuate the input signal to within acceptable limits to prevent damage to the input circuits. The first thing we must recognize is that the probes and/or attenuators, plus the comparison voltage circuits, will introduce an error by the amount they deviate from their true value. Simply stated, a resistance divider with a tolerance of ±0.1% will introduce that same error to our final reading. You must be aware of these limitations when making an absolute measurement with a differential comparator. These errors may differ from instrument to instrument so it is advisable to check your instrument manual for these details.

DC OFFSET

When making a differential measurement with a conventional differential amplifier, we are often confronted with a situation whereby we have different DC conditions at the source of the measurement. Fig. 4 shows two typical cases, one involving a biomedical measurement, the other an electronic circuit measurement. In these cases we must "offset" one DC potential against the other and at the same time provide symmetrical input conditions to the differential amplifier. This is the purpose of the offset feature. Offset may be described as another form of "slide back" whereby we "cancel out" the effect of DC unbalance, allowing true differential measurement with the benefits of common-mode rejection.

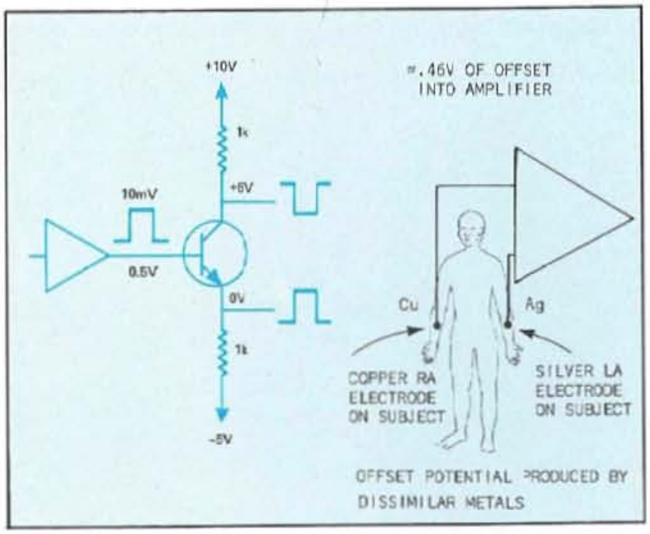


Fig. 4. Two typical applications requiring the offset feature because of different DC conditions at the source of the measurement.

Making the Differential Measurement

Now let's look at some basic procedures to observe when making differential measurements.

1) Check the gain of the amplifier using a known calibration source. When using a dual-trace amplifier in the "ADDED" mode you will need to check the gain of both vertical channels. Make sure both step attenuators are set to the same deflection factor and the VARIABLE controls are in the calibrated position.

2) If the measurement requires the use of probes, the following points should be observed:
   a) Use only the probes recommended for the instrument.
   b) Make sure the probes are properly compensated.
   c) If the probes are CMR compensatable such as the TEKTRONIX P6055, connect both probes to a common source (scope CALIBRATOR) and adjust them for minimum common-mode deflection.

3) If the measurement requires the use of interconnecting cables between the signal source and the amplifier, the following rules should be observed:
   a) Make the cables as short as practical.
   b) Make both cables the same length and strive for symmetry in all respects.
   c) Connect the cable shields as shown in Fig. 5(a).
   d) Avoid running the cables past known sources of interference such as electrical switchboards and the like.

In a severe common-mode environment, the method you use to connect the signal source to the measuring instrument may be the limiting factor between an accurate measurement and one you have to compromise. Improper use of ground leads may introduce common-mode loops or EMI into your measuring system. Figure 5 shows the correct method of connecting to the signal source and some incorrect methods that are frequently used.

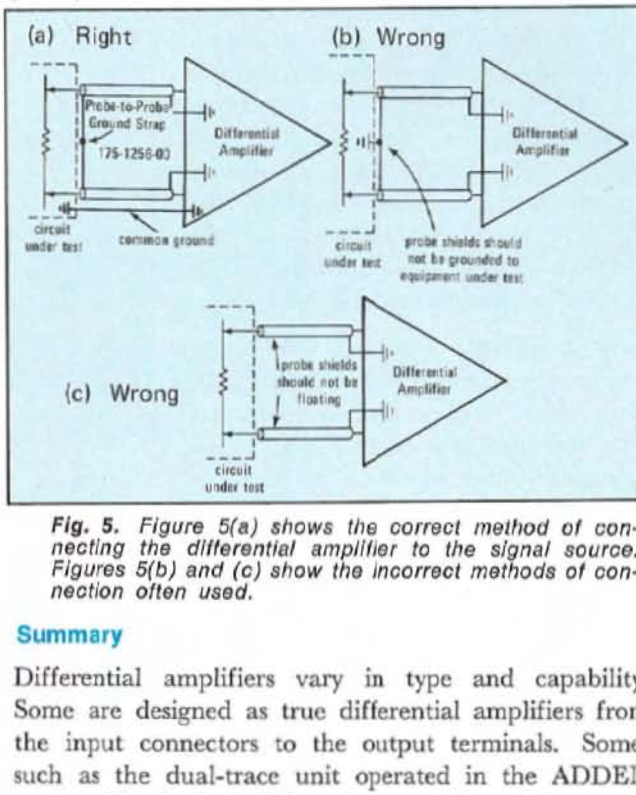


Fig. 5. Figure 5(a) shows the correct method of connecting the differential amplifier to the signal source. Figures 5(b) and (c) show the incorrect methods of connection often used.

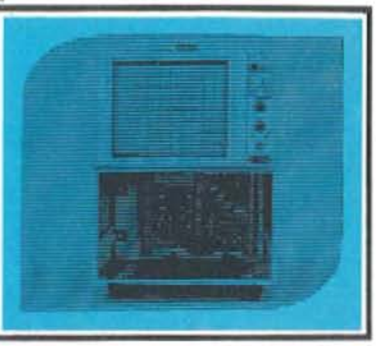
Summary

Differential amplifiers vary in type and capability. Some are designed as true differential amplifiers from the input connectors to the output terminals. Some, such as the dual-trace unit operated in the ADDED mode, offer limited differential capability. Others provide a calibrated DC voltage source for highly accurate comparison measurements. All are designed to let you make measurements that are difficult, if not impossible, with single-input instruments. Selecting the appropriate differential amplifier and using proper techniques to connect the signal source are of equal importance in achieving accurate differential measurements.

In the concluding article in this series we will discuss "guarded" measurements and other techniques that further enhance our measurement capability.

SERVICE SCOPE

SERVICING 5100-SERIES DISPLAY UNITS



Ken Kinman—Service Support Coordinator

There are five display units currently available for the 5100-Series Oscilloscopes. These include single and dual beam units with conventional CRT's and their counterparts with storage CRT's. Much of the circuitry is common to all of the units so we will limit our discussion to the D11 Single Beam Storage Display unit in the interest of brevity.

The display units contain the CRT and its associated controls, the high voltage and Z-axis circuitry, calibrator, horizontal and vertical amplifiers, and in storage units, the storage circuitry and controls.

The modular type construction used in the 5100-Series Oscilloscope system is a boon to the service technician as it provides a quick means of isolating problems to major components. For example, if you suspect trouble in the indicator unit, it can be quickly checked by operating the oscilloscope without the plug-in units installed. Under these conditions a defocused spot at or near the center of the CRT should be obtainable if the unit is working properly. The intensity of the spot should be adjustable with the INTENSITY control.

If, upon turning up the INTENSITY control, no spot is visible, press the BEAM FINDER button. If the problem is in the deflection amplifiers, the spot should appear somewhere on screen. Its position should point you directly to the vertical amplifier, horizontal amplifier or both.

Let's consider a situation in which the spot appears to the left of center screen when the BEAM FINDER is pressed. It would be helpful at this point to install an amplifier plug-in in both the vertical and horizontal compartments of the scope. If an amplifier is not available for the horizontal compartment, a time base will do. Now press the BEAM FINDER button and note that the position of the spot is still to the left of center screen. Place a shorting lead between the bottom leads of R123 and R133 (refer to the Deflection Amplifier/High Voltage Board Parts Location Grid in the manual). If this produces no change in the spot position, interchange Q124 and Q134. If the spot position reverses, Q134 should be suspected of being open. If there is no change, interchange Q126 and Q136. This should reverse the spot position. If so, Q136 is probably open.

Should these procedures fail to locate the problem, it will be necessary to investigate the passive components associated with the active devices just discussed.

Problems in the vertical amplifier can be located using the same technique.

The High Voltage Supply

The circuitry for the high voltage supply is shown in the CRT circuit diagram in the manual. The high voltage oscillator consists of Q252 and the primary windings of T240. The lower primary winding provides the necessary feedback for the oscillator. The drive to the oscillator is regulated by Q262, Q264, Q278 and their associated components.

You will notice that the CRT grid supply is referenced to the Z-axis amplifier consisting of Q222, Q226 and Q234. Therefore, the Z-axis amplifier must be working properly if we expect to control beam current properly.

High voltage malfunctions are readily apparent at the CRT faceplate and usually result in one of two conditions:

1) No intensity.
2) Maximum intensity, unaffected by the INTENSITY control or Intensity Range control.

Let's troubleshoot the high voltage circuit assuming we have the first condition, no intensity. Caution should be observed when troubleshooting this area as dangerously high potentials may exist in the CRT circuitry.

Measure the CRT cathode supply (−3400 V) at the H.V. Test Point. If it is not present, the gate of Q278 will rise, pulling the source with it until CR264 conducts. The source of Q278 should measure about 0.6 V. This condition will cut off Q264, which in turn cuts off Q262. CR262 will be reverse biased. This condition should provide maximum drive to the base of the high voltage oscillator Q252. If you can verify these conditions within the regulator circuit, you can assume it is functioning normally.

The next step is to check the voltages supplying the high voltage oscillator. You may find the collector voltage of Q252 is at −38 V. This would indicate a blown fuse in the +40 V supply. The fuse is located in the 5103N mainframe.

The Z-Axis Amplifier

If the CRT cathode supply is normal and you have no intensity or intensity control, check the voltage at the CRT control grid. That voltage should be about −3450 V. Watch the CRT faceplate while measuring the control grid voltage. If the beam appears but the intensity is not adjustable, the reference for the control grid supply is incorrect and you are providing a source through your voltmeter.

Next, check the voltage at the collector of Q226. It should be about +65 V with the INTENSITY control clockwise. If the voltage at that point is negligible, check the current source transistor, Q234. If the voltage at the collector of Q226 is high (+65 V or more), the beam current will be at maximum and not adjustable. You should suspect Q226 or Q222 or their associated circuitry as being defective.

The Storage Circuitry

Now let's take a look at the storage circuitry. Storage tube characteristics have a tendency to change with age. What appears to be a defective unit may only require calibration to restore it to normal operation. Here is a quick and easy procedure for setting up the storage controls.

With the power off, insert an amplifier plug-in and time base plug-in in their respective compartments in the mainframe. Remove the right side cover and locate the storage circuit board near the front of the instrument. Now perform the following steps:

1. Pull the POWER switch to on.

2. Obtain a trace using a 1-ms/div sweep speed. The trace should be sharply focused.

3. Rotate INTENSITY full ccw. If the writing beam cannot be fully extinguished, push the BEAM FINDER switch and adjust the Int Range control (R245) until the trace is just visible. Releasing the switch should result in no visible trace.

4. Push the STORE buttons to the in position. Push both ERASE buttons at the same time to the in position.

5. Measure the voltage at TP2. (See Fig. 4-1 in the D11/D15 manual.) You should read +370 V. R387 should swing that voltage about ±5 V. If this cannot be accomplished, turn the instrument off. Now check the insulated heat sink jackets (black) on Q362, Q364, Q372, Q392 and Q396. Access to these is accomplished by removing the large heat sink plate at the rear of the instrument. Apply power to the instrument and check to see if any voltage is present on the top portion of the black heat sink jackets. Those showing any voltage reading should be replaced as they will improperly load the +370-V supply. Reinstall the large heat sink plate.

   If the +370-V supply is still abnormal, measure the drop across CR387. This is a protection diode and should not be conducting during normal operation. If the diode is in its zener mode (about 34 V), Q386 is probably defective.

6. With the +370-V supply operating properly, slowly increase the trace intensity and write the entire screen positive by slewing the trace vertically several times. If the trace cannot be stored, rotate the Store Level control cw until storage is possible. If storage still cannot be accomplished, check the voltage at TP1. It should be about +125 V. If it is abnormally high, check Q356 and Q358. If that point is unusually low, check Q362 and Q364. The STORE LEVEL control R350 should swing the voltage at TP1 from about +20 V to +290 V DC.

   Now turn the BRIGHTNESS control clockwise. Once the CRT screen is fully written, adjust R390 (CE1) fully ccw. The display should resemble that in Fig. 1. Note that at the point where the screen fills completely, the corners will begin to darken. The final setting of R390 should be at a point between full screen and the appearance of dark corners. See Fig. 2.

   If a display similar to Fig. 2 cannot be achieved, check the voltage at TP3. It should swing from 0 to +200 V when R390 is rotated through its range. Ideally the voltage should read +50 V, ±5 V.

   Another point to check is the waveform present at pin 1 (►) of P389. This should be a 120-Hz sawtooth about 15 V in amplitude. Any irregularity in the waveshape would indicate a defective bridge, CR329.

7. Adjust Non-Store Level (R395). Write the entire screen positive. Release UPPER STORE switch and note that the upper screen background glow disappears quickly (less than 1 sec). Adjust Non-Store (R395) to insure proper upper screen background fade rate. Half-screen storage should resemble Fig. 3.

   If proper storage fade rate cannot be accomplished, measure pin #6 of the harmonica connector at the upper right hand corner of storage board. This should be 140 V ±1.4 V. If Q396 is defective (i.e., open) the display will appear as in Fig. 4.

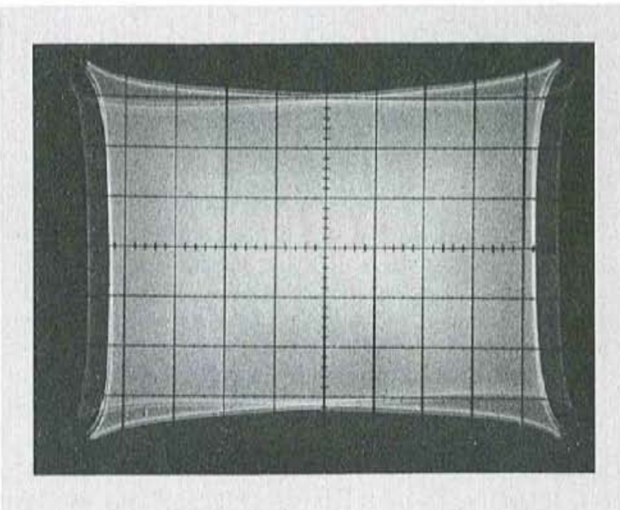


Fig. 1. Typical stored display with R390, CE1 set full counterclockwise.

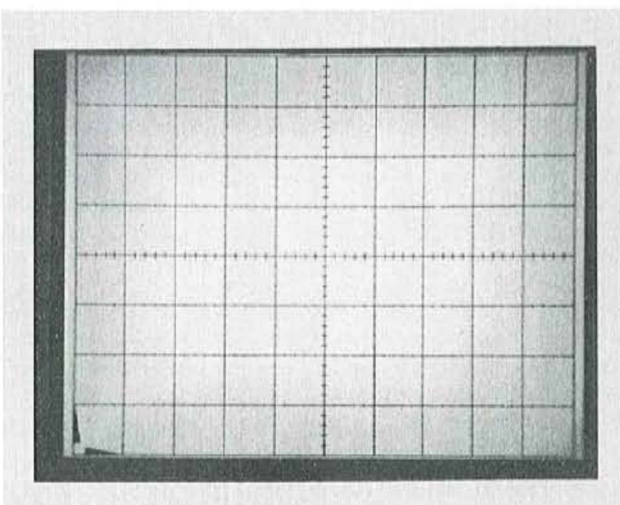


Fig. 2. Typical stored display with R390, collimation electrode control properly adjusted.

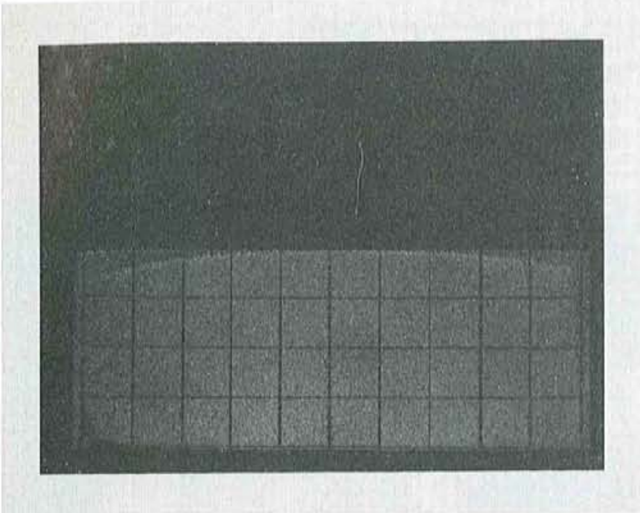


Fig. 3. Typical half-screen stored display.

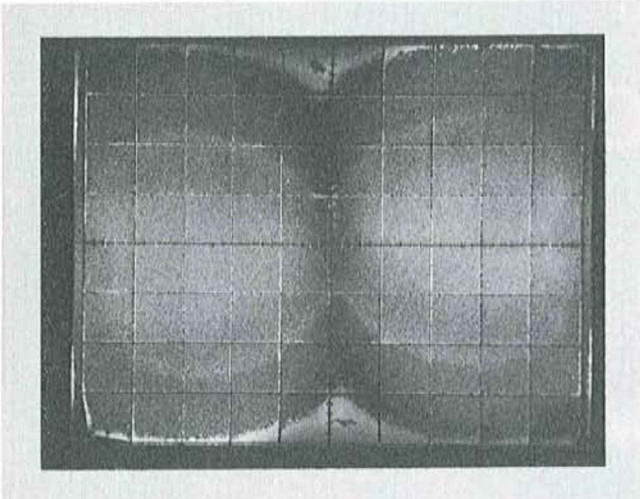


Fig. 4. Stored display resulting from improper flood gun anode voltage due to open Q396.

8. Adjust Store Level R350. Push store switches to "out" (non-store). Set TIME/DIV to 0.2 msec. Feed a 1.5-kHz sine wave signal into the vertical input and set the amplitude for 3.2 div of deflection. Trigger the sweep and adjust INTENSITY to a point where the trace just starts to defocus. Readjust the focus for a sharp trace.

   Set the time base Sweep Mode to Single Sweep and erase the stored display. Alternately store and erase single sweeps while increasing the sine-wave generator frequency in small increments. Allow about five seconds after each erasure before writing another display. Adjust the frequency to the highest rate that will permit the vertical transitions of the sine wave display to store anywhere on the center 6 x 8-division area of the screens, with no more than a 50% loss in luminance, or with the breaks in the trace not exceeding 0.025 inch. This is the maximum writing speed of the CRT.

   Maximum writing speed is calculated as follows:

   Writing speed (in divisions/second $= \frac{2\pi \text{ F } V_{PP}}{2}$)

   substituting the display amplitude of 3.2 divisions for V_{PP}, the expression is reduced to
   Writing Speed $\approx$ 10 X F.
   Thus, for example, if the sine wave generator frequency is two kilohertz or greater, the maximum writing speed of the CRT is 20 divisions/millisecond (20,000 divisions/second) or greater.

   The writing speed should be $\geq$20 divisions/millisecond for the D11, $\geq$200 divisions/millisecond for the D15.
   Note: It may be necessary to repeat this step with a slightly higher trace intensity or store level.

   As the storage tube ages, its ability to store diminishes. This effect is first apparent in the center screen area.

9. Store Balance (R370). Measure the DC voltage at TP1. Probe TP4 and adjust Store Balance (R370) to a voltage identical to that at TP1.

   Inability to adjust R370 properly could be caused by Q372 being defective or possibly the 110-V zener diode VR370 failing. A quick check of store balance would be to check background level differences between erase "in" and "out" positions.

10. Sensitivity Correction (R385). Obtain a display of exactly 6 div of sine wave at 1 kHz (non-store). Switch to Single Sweep and push in both STORE buttons. Store a trace and check for exactly six divisions of signal. If the amplitude of the stored display differs from the non-stored display, adjust R385 while displaying the sine wave alternately in store and non-store.

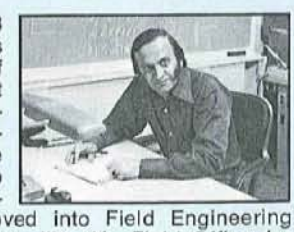
Summary

This information pretty well covers the majority of possible trouble spots related to the 5100-Series display units.

Even though the situations were hypothetical, an attempt was made to familiarize the technician with the circuitry, and offer quick uncomplicated checks which in the long run reduce down time.

Most technicians will agree that the best troubleshooting aid is a good circuit description.

ABOUT OUR AUTHOR



Ken Kinman—During his 13 years at Tek, Ken has served in many areas of Marketing. Following a stint as Product Service Technician he moved to a technical writing group where he authored the "Sweep Generator Circuits" concept book. Ken then moved into Field Engineering and worked out of the Huntsville, AL. Field Office for a year and a half. Returning to Beaverton he joined the Product Service Support Staff.

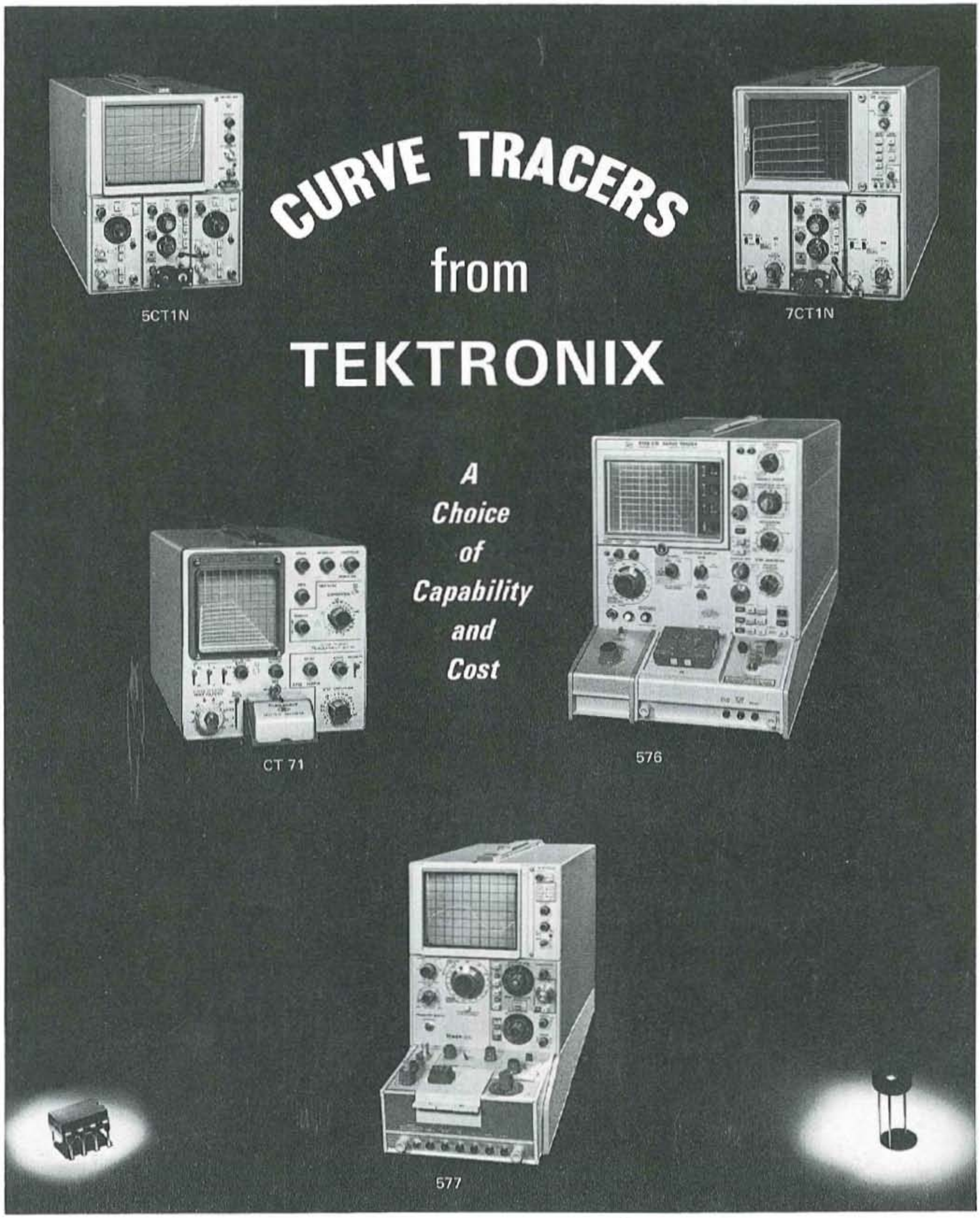
Ken is a graduate of DeVry Technical Institute of Chicago. His hobbies include photography, motocross cycle competition and music a la Neil Diamond.

TEKSCOPE

Volume 4 Number 6 November 1972

Customer Information from Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005

Editor: Gordon Allison, Ass't Editor: Dale Aufrecht, Graphic Designer: Tom Jones, Assistant: Diane Dillon.



A-2577

TEKSCOPE Classified Ad Supplement

INSTRUMENTS FOR SALE

555/E/(2) L, cart & probes, $3000. Lawrance F. Buckland, Inforonics, Inc., Maynard, Mass. (617) 897-8815.

RM564/3A6/3B3. C. T. Nottingham, 6024 Pulaski Pike, Huntsville, Ala. 35810.

5103N/D10, 8 mos. old. Henry Liu, Quantum Dynamics, Inc., 19458 Ventura Blvd., Tarzana, Ca. 91356. (213) 345-6828.

453A (6), 545B/1A2/C-27, all w/ carts. Howard Player/Jim Jacks, Computer Micro-Image Systems, 7825 Deering Ave., Canoga Park, Ca. 91304. (213) 340-0300.

S4 (2), $650 each. Ken Olive, 415 Rainier Ave. North, Renton, Wash. 98055. (206) 228-2000 or 772-1800.

R520, $1950; R140, $1550; RM529, $1175; 015-0062-00 TV Sync separator, $75. All like new. D. G. Butz, N. J. Communications Corp., Kenilworth, N. J. 07033. (201) 245-8000.

5A18N. Bruce Giessel, Box 14168, Houston, Tex. 77021.

Telequipment D54, Exc. cond., Ben's TV, 1105 Cedar, P.O. Box 116, Bandera, Tex. 78003. (512) 796-4567.

545-S1, 53/54K, 53/54D, & a new 202-1. Entire pkg. for $625. Jim Eytalis, Rockford Electrical Engineering Co., 2408 Paradise Blvd., Rockford, Ill. (815) 962-1169.

515A, $450. Robb Warner, Professional Electronics, (801) 277-0200.

Telequipment S51 (5), $500 for whole batch. Dr. F. McGuigan, Hollins College, Hollins College, Va. 24019. (703) 362-6531.

Q, $150; 127 power supply, $300; D, $100. Dr. L. Jerome Krovetz, CMSC 504, The Johns Hopkins Hospital, Baltimore, Md. 21205.

453A mod 127C, $1850. Carl Amato, 39 Wyckham Rd., New Shrewsbury, N. J. 07724. (201) 542-2962.

516, $700. Stanley Kawalerski, Suntronics, 6832 W. Archer Ave., Chicago, Ill. 60638. (312) 586-9300.

P6046 Diff. Probe w/Amp., $600. Bob Waters, (919) 292-7450, Ext. 62.

INSTRUMENTS FOR SALE

310A, Probes (3), best offer. Tom Wiehl, Maron Bronze Corp., 2500 Plainfield Ave., Scotch Plains, N.J. 07076. (201) 232-0495.

453, 7403N/7A18N/7B53. Bob Stevens, Vector General Corp., 8399 Topanga Canyon Blvd., Canoga Park, Ca. 91304. (213) 346-3410.

545/L/M and 500/53A Cart, $900. Walt Harbers, Western Co., P.O. Box 186, Ft. Worth, Tx. (817) 737-4041, Ext. 279.

Telequipment S54. Jack Gamon, Riverside Press, 4901 Woodall, Dallas, Tx. (214) 631-1150.

516 w/Polaroid viewer & cover, $650. William D. Kraengel, Jr. 65 Sunset Rd., Valley Stream, N.Y. 11580.

Telequipment TLD67, (2) 10X probes. Lorne D. or Hazel J. Kruse, E. 17611 Appleway #2, Greenacres, WA 99016. (509) WA4-7374.

453, Exc. cond. Bernard Terrill, 8 E. Rochester Rd., Ottumwa, Ia. 52501. (515) 684-8707.

491. Carl Prufer, California Microwave, 455 W. Maude Ave., Sunnyvale, Ca. 94086. (408) 732-4000.

R116, 317, 453, 545A, 547, 549, 555, 567, 575, 581A, 585A w/plug-ins. T. J. Bruckner, Infotrac, P.O. Box 151, Livingston, N. J. 07039. (201) 267-6560.

561A, 3A75, 2B67. Gil Weinstein, 32 Van Vleet Court, Clifton, N. J. (201) 471-3878.

515A, $345. Exc. cond. Richard Demers, 10355 Wells Ave., Riverside, Ca. 92505. (714) 689-8652.

RM45A/CA/D, $650. Scott Stever, 44 Camden Place, Corpus Christi, TX 78412. (512) 991-4688.

524D, $325. Exc. cond. Ken Woolf, Photo-Sonics, Inc., 820 S. Mariposa, Burbank, Ca. 91504. (213) 849-6251.

535A, 545A, 53/54G, D. Peter Karvellas, Valparaiso Univ., Dept. of Psychology, Valparaiso, Ind. (219) 462-3059.

107 Sq. Wave Gen., $150. Exc. cond. Alton P. Witt, Jr., Quality Medical Electronics, 2291 Austell Rd., Suite 104, Marietta, Ga. 30060. (404) 432-3308.

P6015 HV Probe, $150. Exc. cond. John Zielinski, Spitz Laboratories, Chadds Ford, Pa. 19317. (215) 459-5200.

INSTRUMENTS FOR SALE

532/53B, $600, best offer, or trade. David W. Loder, 19511 N.E. Halsey #2, Portland, Ore. 97230.

RM35A/CA, $650. T. E. Prescott, 1798 Rocky Creek Rd., Macon, Ga. 31206.

661/4S1/5T1A, $1350. Exc. cond. Rapido, 412 S. Anaheim Blvd., Anaheim, Ca. (714) 956-3555.

561A/3B5/3A5, $1800 or make offer. Al's TV Clinic, 1696 San Leandro Blvd., San Leandro, Ca. 94577. (415) 483-4330.

RM515. Ed Wong, Clinical Laboratory, S. F. General Hospital, (415) 648-8200, X405.

1S1, $600; P6045 (2), $190 ea., R. Perelman, Datac, Inc., 1773 S. Taylor Rd., Cleveland, OH 44118. (216) 371-5577.

INSTRUMENTS WANTED

5A14N. Bruce Giessel, Box 14168, Houston, Tx. 77021.

3A6, 3L5 plug-ins, any cond. Don Campbell, James Development Co., 2971 Deckebach Ave., Cincinnati, OH 45220. (513) 751-6197 or 872-4721.

422 & scope camera in good cond. Carl W. Reed, Dakota Medical Systems, Inc., 503 1/2 N. 7th St., Fargo, N.D.

503. Steve Kaplan, Dept. of E.E., Computer Science, Rm 367 Cory Hall, Univ. of Calif., Berkeley, Ca. 94720.

1L5 & 132 w/sweep freq. converter. Bruce Hatch, Sound Genesis, 445 Bryant St., San Francisco, CA 94107. (415) 391-8776.

Type T Plug-In. Mr. Sawyer, Electronics Dept. Winona Area Vocational-Technical School, 1250 Homer Rd., Winona, Mn. 55987.

Type 82 Plug-In, any cond., T. E. Prescott, 1798 Rocky Creek Rd., Macon, Ga. 31206.

321A, want (4) in operable cond. Tim Medric, Goodyear Aerospace, 1210 Massillon Rd., Akron, O. 44315. (216) 794-3035.

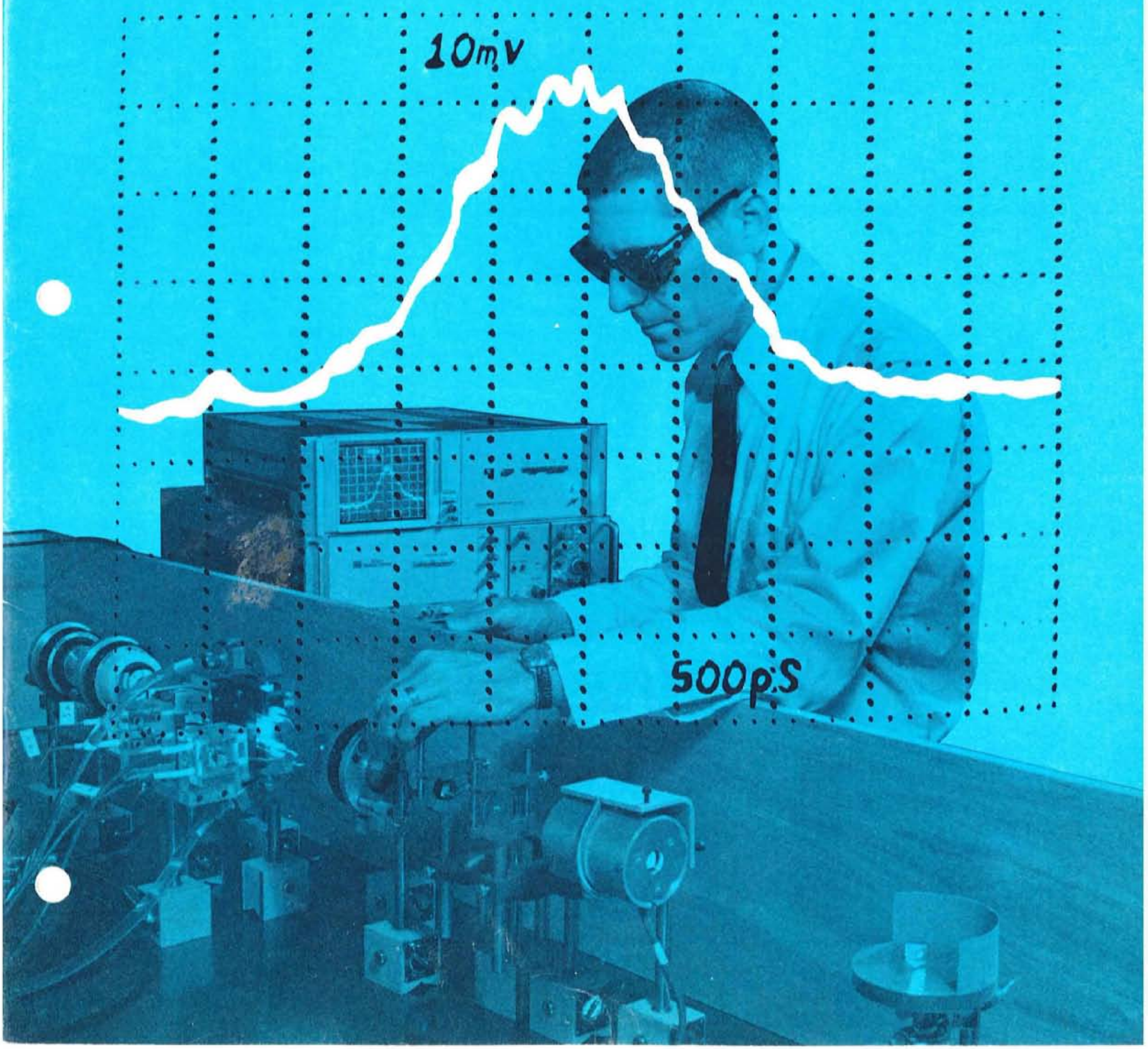
TEKTRONIX®

committed to technical excellence

TEKSCOPE

Volume 5 Number 6

Nov/Dec 1973



TEKTRONIX®
committed to technical excellence

TEKSCOPE

Customer Information from Tektronix, Inc.
P.O. Box 500, Beaverton, Oregon 97005

Editor: Gordon Allison,
Ass't Editor: Dale Aufrecht,
Graphic Designer: Tom Jones

Contents

3 **A new way to look at transients**

Fast, single-shot pulses are digitized for computer analysis or display on large-screen X-Y monitors.

10 **A fast A/D plug-in for the oscilloscope**

A plug-in that accepts plug-ins expands 7000-Series Oscilloscope measurements to include true RMS and peak-to-peak voltages displayed digitally and with typical digital accuracies.

16 **Digitizing and displaying fast pulses**

Q-switched lasers generate very short pulses of light. The R7912 is an ideal instrument for measuring the fast pulses from this type of laser.

18 **Getting around in Tektronix instruments**

Color-coded wires, well-marked printed circuit boards and unique connectors are a big help in servicing today's compact oscilloscopes.

20 **Tekscope 1972-73 Index**

A chronological listing of articles that appeared in Tekscope during 1972-73.

Cover: Dr. Gail Massey of the Oregon Graduate Center makes adjustments to a Q-switched neodymium YAG laser using the R7912. The dot pattern is the electronically-generated graticule and the waveform is typical of a detector output from a pulsed laser.

A new way to look at transients

Carlo Infante

The display and analysis of fast, single-shot pulses has long been one of the most challenging problems in oscillography. These pulses result from measurements in a wide variety of fields such as laser research, nuclear research, computer design and service, stress analysis of components, and others. In the past, the only way to view fast transients, which may be a nanosecond or less in duration, has been to use an oscilloscope with a viewing hood or the very best scope/camera combination. These methods have been quite successful as proven by the many thousands of TEKTRONIX oscilloscopes in installations of this kind, but there are some obvious disadvantages. One is the need to dark-adapt one's eyes before attempting to view a fast transient. Another is the time required to develop and analyze the photograph containing the waveform. Still another is the expense and inconvenience of using film, particularly when the waveforms need to be digitized for computer processing. Many of the present methods for digitizing waveforms from film involve hand processing with resultant time-consuming delays and possibility for errors.

The TEKTRONIX R7912 Transient Digitizer solves these problems in a unique and novel way, and in addition, provides features not available on earlier instruments. The functions of writing and reading, which in a normal oscilloscope are carried out by the same CRT beam, are accomplished by two separate electron beams in the R7912; waveform display is handled by a third beam in an associated monitor. This allows optimizing the design of each function to achieve the overall goal of large, bright, high-resolution waveform displays. The waveform can be displayed on a TV monitor such as the TEKTRONIX 632 to provide a bright, large-screen display easily viewable in room-ambient light; equivalent photographic writing rate in this mode is 30,000 div/μs. In addition, the waveform can be automatically digitized; i.e., the waveforms are processed into a computer-compatible format so they can be analyzed by a computer. Or, if desired, the waveforms can be stored in a self-contained memory (optional) and displayed on an X-Y monitor; an equivalent stored writing rate of 8,000 div/μs can be achieved with no limitation on storage time. (If display area is 8 by 10 centimeters stored writing rate is equivalent to 8,000 cm/μs.)

Instrument Description

Fig. 1 shows a block diagram of the instrument. The writing section of the R7912 is similar to a conventional oscilloscope. The input signal is acquired, conditioned, and amplified by vertical plug-ins from the TEKTRONIX 7000-Series family. Any of the 7A-Series plug-ins can be used, allowing a wide choice of vertical capabilities from high gain (as low as 10 μV/div with the 7A22 Differential Amplifier) to maximum bandwidth (1 GHz with the 7A21N Direct Access Unit). Horizontal sweep and sweep gate are generated by a 7B-Series time base plug-in.

The input signal is applied to the CRT writing gun. Design and operation of the CRT is described in a special feature section of this article. The waveform written on the target by the writing gun is read out by the reading gun. With the instrument operating in the NON STORE mode, the reading beam scans the target linearly in a TV format and operation is quite similar to that of a conventional TV camera. Each time the reading beam crosses a written point, a small current pulse is generated in the target lead. This pulse is amplified and processed to provide the video output signal.

Synchronizing signals for the Read System and the associated video monitor are generated by the Sync Generator. The X and Y Ramp Generator and Scan Amplifier produce the waveforms required to drive the X and Y deflection plates of the Read System.

In the DIGITAL mode, the read sequence is changed while the write sequence remains as already described In this mode, the target is scanned in steps in a 512 by 512 matrix rather than linearly. Also, fast scanning occurs vertically in the DIGITAL mode which is opposite to the NON STORE mode where fast scanning is done in the horizontal direction as in conventional TV. Fig. 2 illustrates these two scan modes using simplified waveforms and scan lines. The NON STORE mode, being similar to conventional TV, will not be explained further here.

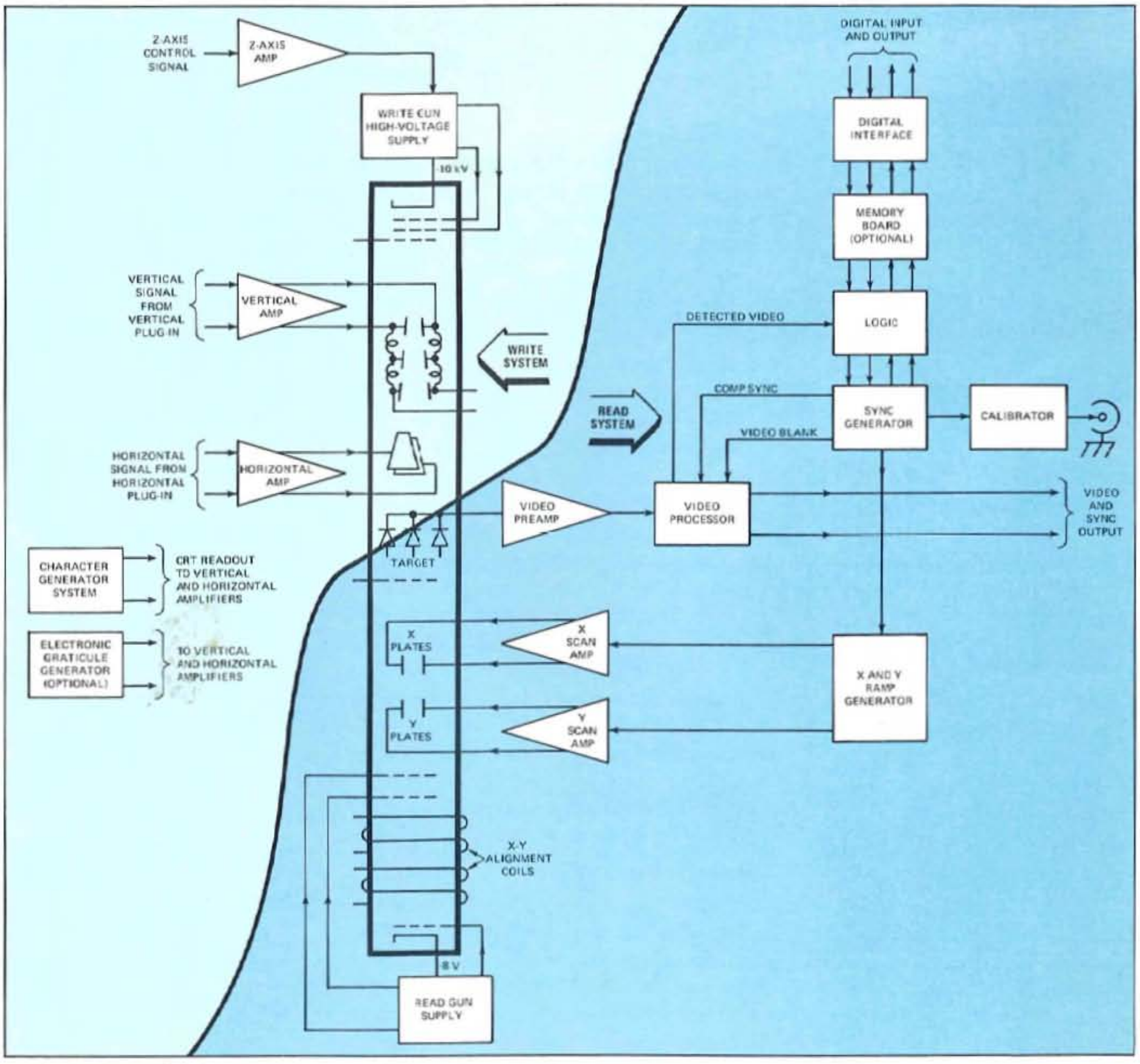


Fig. 1. R7912 Block Diagram.

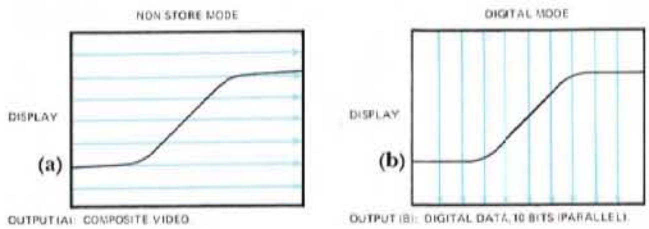


Fig. 2. Target scanning modes.

Vertical scanning is used in the DIGITAL mode due to the nature of the waveforms normally digitized. Notice that for the simplified scan shown in Fig. 2B, each vertical scan line intersects the waveform only once. In this mode, addresses of points on the target are transferred and stored in memory only when a trace has been written at that point on the target. This results in the fastest readout of information needed to define a waveform, and requires less storage space in memory for the waveform. In actual operation, the trace is several samples wide and circuitry is incorporated in the instrument to reduce the amount of information which must be communicated to define a trace. The counters and logic circuits required for digital operation are contained in the Logic circuit. The optional Memory allows waveforms to be stored in the DIGITAL mode for later transfer to a computer, or for display on a storage display unit through a display interface.

The R7912 uses the CRT READOUT SYSTEM pioneered in the TEKTRONIX 7000 Series to display measurement parameters along with the waveform. These characters are written on the diode target by the writing beam on a time-shared basis and become part of the output signal in the NON STORE mode. An optional converter is available for use in the DIGITAL mode to take the readout information directly from the plug-ins and convert it into an ASCII coded format which becomes part of the data communicated to the computer.

The optional Electronic Graticule Generator produces a dot array similar to the graticule on a conventional oscilloscope CRT. The electronic graticule is written on a time-share basis with the input signal and, like the CRT READOUT signal, becomes part of the output signal from the Read System. This electronic graticule eliminates parallax associated with overlay graticules and minimizes errors due to non-linearities or drift in the amplifiers or CRT deflection system.

Novel Circuitry—The Key to Performance

As you would expect in a state-of-the-art instrument, many novel circuits make up the R7912. These include a highly stable −10 kV power supply, an electronic graticule generator, low-noise amplifiers, and unique logic circuits. Let's look at several of these circuits in more detail.

Ramp Generator. A block diagram of the Ramp Generator is shown in Fig. 3. Two of these circuits are used in the R7912; one for the vertical and one for the horizontal. In the NON STORE mode, the Integrator generates a highly linear ramp (waveform A) whose amplitude is precisely set by two stable discriminators which define the upper and lower end points of the ramp. This waveform is synchronized by the action of the Phase Detector which compares the end of the ramp with the sync pulses. If there is an error, it changes the timing, or charge current, of the integrator to insure proper timing.

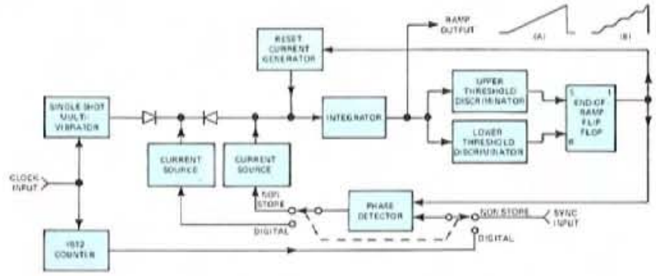


Fig. 3. Ramp Generator.

In the DIGITAL mode, 5-MHz clock pulses are connected to a Single-Shot Multivibrator and to a ÷ 512 Counter. Each time the Multivibrator fires, a small amount of current is injected into the Integrator, resulting in a step at its output. The voltage of the output step remains stationary during the Multivibrator's quiescent period. After a number of ramp and hold steps have been accomplished, the Upper Threshold Discriminator resets the End-Of-Ramp Flip Flop causing the Integrator to reset. The circuit is then ready to produce a new staircase waveform. The output of the End-Of-Ramp Flip Flop and the ÷ 512 Counter are compared by the Phase Detector. If these pulses do not occur simultaneously, a correction signal is generated by the Phase Detector and the charging current of the Integrator is suitably adjusted. In this fashion, the Phase Detector insures that precisely 512 steps are generated for each vertical or horizontal scan, resulting in a stable digitized waveform.

One of the features of this circuit is that the period of the staircase can be changed without affecting the accuracy of the staircase. This occurs in the operation of the R7912 when a point is addressed on the target where a waveform has been written. Normally, the staircase holds at each step for about 100 nanoseconds while the signal on the target lead is checked for a change in state since the previous sample. If there is no change, the staircase is advanced to the next step. How-

A close-up look at the crt

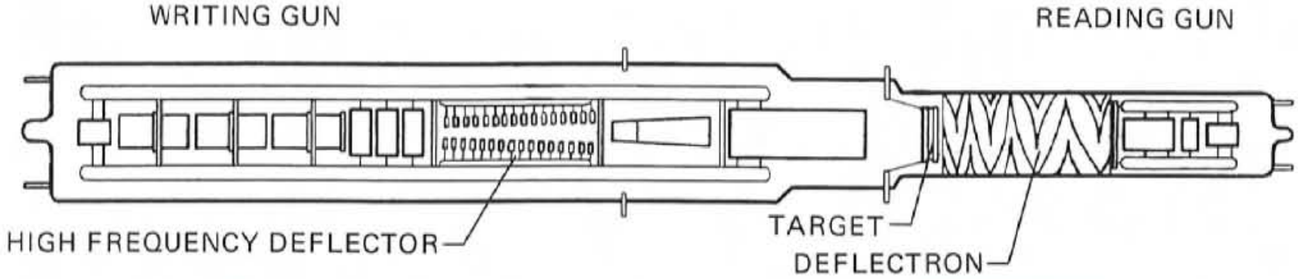


Fig. A. R7912 CRT.

The outstanding performance of the R7912 is due, in large part, to the TEKTRONIX-developed scan-converter tube forming the heart of the system. Fig. A shows a drawing of the tube along with a photograph of the final product. The tube is double-ended with the write gun and read gun facing each other axially. These guns and their associated deflection structures are separated by the target, where scan conversion occurs. The design parameters of the tube were optimized by means of a computer program to provide the best trade offs in gun structure and accelerating potential for the required resolution and scan area at the target.[1]

The input signal from the vertical amplifier is applied to the high-frequency deflector which consists of two helical delay lines assembled into a balanced deflection system. The entire writing-gun structure is operated at −10 kV to provide small spot size and fast writing rate.

The target consists of an array of diode junctions formed on a silicon wafer using integrated-circuit techniques. Fig. B shows a detailed view of the silicon target. A density of 2000 diodes per inch yields the desired resolution for the ½-by-⅜-inch scanned area. The center 0.75-inch diameter of the target is thinned to about 10 microns to facilitate operation in the double-ended mode (by comparison, the thickness of this page is about 100 microns).

The read gun produces a low-velocity electron beam with minimum shading and good resolution. Shading is caused by off-normal landing of the beam on the target and results in errors in the readout signal. This is particularly objectionable in a precision measurement instrument such as the R7912 and becomes even more of a problem when the output signal is converted into digital form (see Fig. C).

To accommodate the variable scan rates required of this instrument, electrostatic deflection was chosen for the read gun rather than the electromagnetic methods normally used for vidicons. However, if electrostatic focusing is used along with electrostatic deflection, poor shading

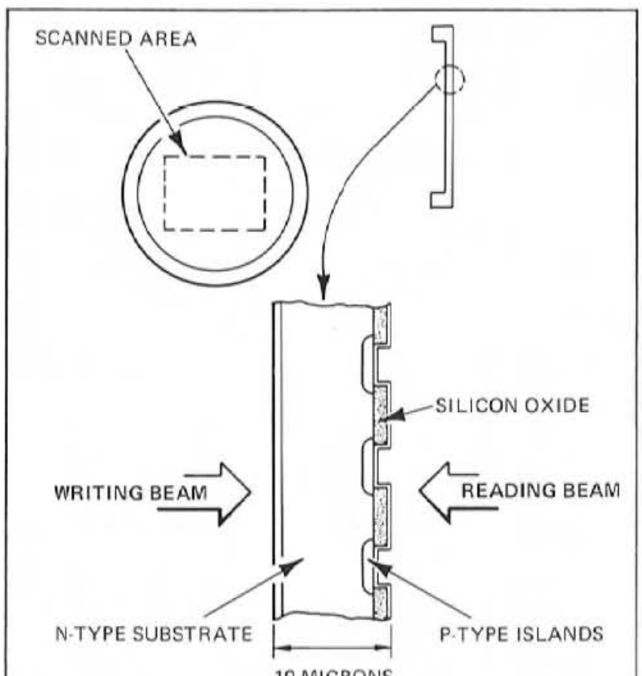


Fig. B. Target detail.

[1]For a complete discussion of the design considerations that went into the CRT for the R7912, refer to "Storage Tube With Silicon Target Captures Very Fast Transients" by Raymond Hayes, Robert G. Cutler, and Kenneth W. Hawken, *Electronics*, pp. 97-102, August 30, 1973.

characteristics result. To solve these problems, a hybrid design was developed consisting of an electrostatic deflection system surrounded by an axial magnetic focusing field. The deflection plates actually consist of a cylindrical electrode pattern photo-etched on the interior wall of the tube (see Fig. A). The axial magnetic field is provided by an external solenoid. This configuration is called a deflectron deflection system.[2]

As the reading beam is scanned across the target, it charges the target negatively towards the read-gun cathode potential and the target diodes are reverse biased. High-velocity electrons from the write gun bombard the back of the target, creating electron-hole pairs which diffuse through the target. This causes the diodes to conduct and discharge in the written area. When the reading beam next scans the written area, it recharges the diodes, producing a signal current in the target lead. Amplification and processing of this signal provides the video or digital output signal.

[2]For a complete discussion of the deflectron system, see "Electron Trojectories in Twisted Electrostatic Deflection Yokes" by E. F. Ritz, *IEEE Transactions on Electronic Devices*, November 1973.

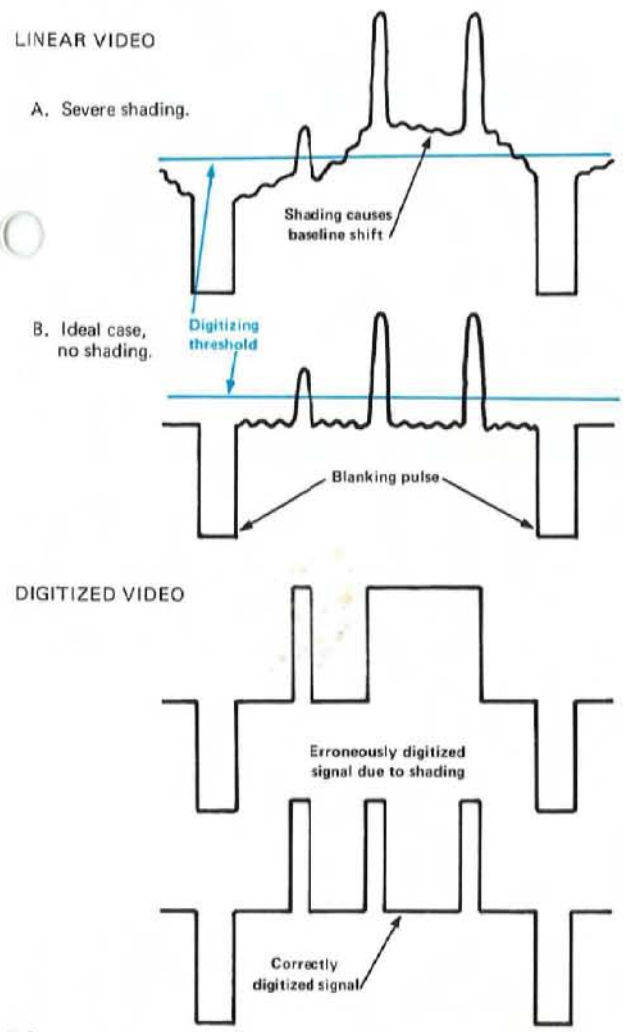


Fig. C. Effects of shading on digitized video.

ever, when a change is detected, the staircase holds at this step for about 1.6 microseconds to allow time for the address of this data point to be transferred to the computer or stored in memory. As a result, each staircase may have a different duration since the number of these pauses for address transfer will vary depending on the nature of the waveform written on the target. In a conventional feedback-stabilized circuit, this would result in timing variation and an inaccurately digitized waveform. To prevent this, the clock input pulses are interrupted during the address communication time. Both the Single-Shot Multivibrator and the ÷ 512 Counter remain inactive until the clock resumes. Highly stable circuitry in the Integrator holds the step level very constant during the pause. The overall result is that when normal operation resumes, the outputs of the End-Of-Ramp Flip-Flop and the ÷ 512 Counter have been delayed by the same amount of time. Therefore, no error signal is generated at the input of the Phase Detector and the ramp generator remains stable and phase locked even though the period of the staircase has changed.

Each of the vertical and horizontal steps has a BCD-coded address associated with it which is stored in the optional memory or transferred to a computer when valid waveform data is detected on the target. Both a vertical and a horizontal address is required to define a point on the target. Since the dot raster is a 512 by 512 matrix, there are over 250,000 addressable points on the target. The average waveform normally requires about 1500 points for complete definition. However, under some conditions such as dual-trace operation, two waveforms may be stored in memory simultaneously. To provide adequate storage, a 4000-word memory has been provided as an option for the R7912.

Electronic Graticule. Another interesting circuit is the Electronic Graticule Generator as shown by the block diagram in Fig. 4. This circuit generates all of the information needed to write the graticule on the target, along with the waveforms and readout. At the end of each sweep, this circuit is activated to begin producing the graticule. The master clock signal provides a precise reference for accuracy; all output signals are derived from the clock.

The electronic graticule is defined on the screen by a series of dots 0.2 division apart for the minor divisions and 1 division apart for the major divisions. When the electronic graticule is activated, fast ramps are produced in the vertical direction. Since the first ramp at the left side of the graticule must define both the major and minor divisions, 41 dots must be displayed to produce eight major divisions. During this ramp the master clock input is connected directly to the Dot Multiplexer which produces one Z-Axis intensifying pulse for each clock input.

The Vertical Dot Counter (÷ 45) produces an output after 45 clock pulses, which serves as a reference to the phase-locked Vertical Integrator. Operation of this ramp generator is similar to the Ramp Generator described previously. As the vertical ramp is reset, it triggers the Horizontal Staircase Generator which moves the next trace one step or 0.2 division to the right. At the same time, the output of the Major Division Counter (÷ 5) changes state, causing the Dot Multiplexer to switch from the direct vertical dots input to the Vertical-Dots-Divided-by-5 Input. During this vertical ramp, a dot is displayed every fifth clock pulse to define a major division.

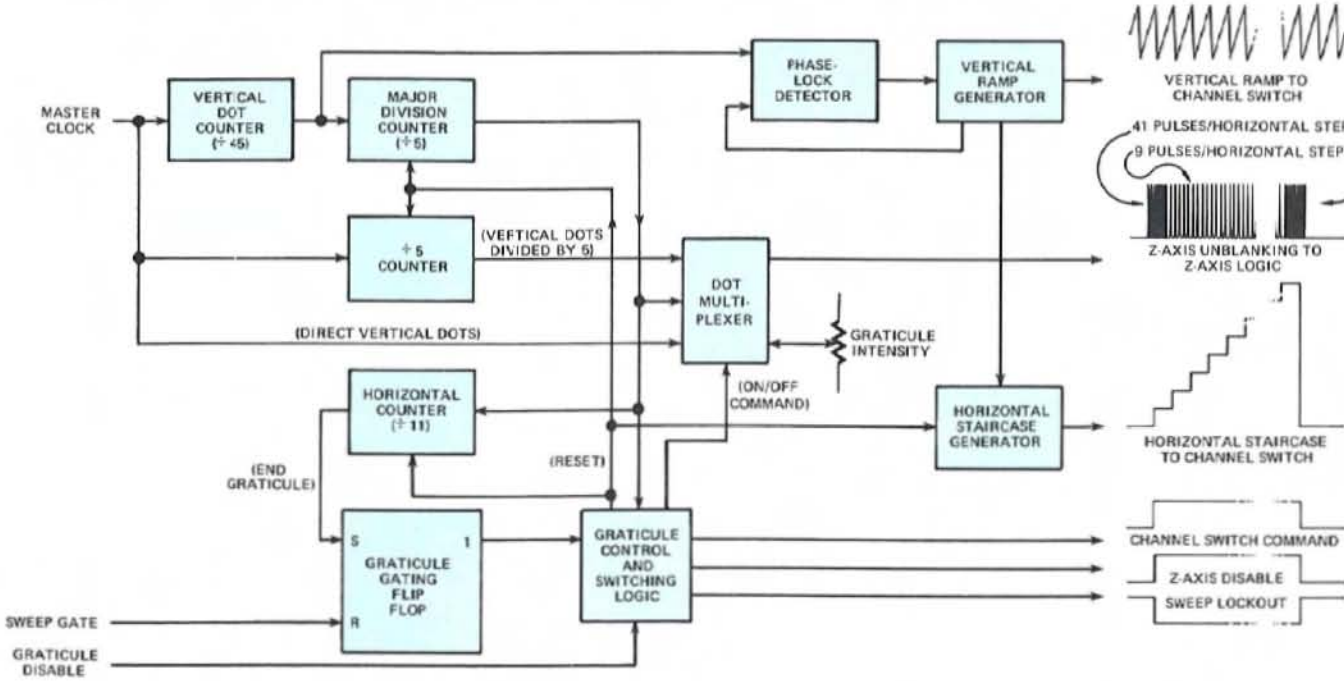


Fig. 4. Block diagram of Electronic Graticule Generator.

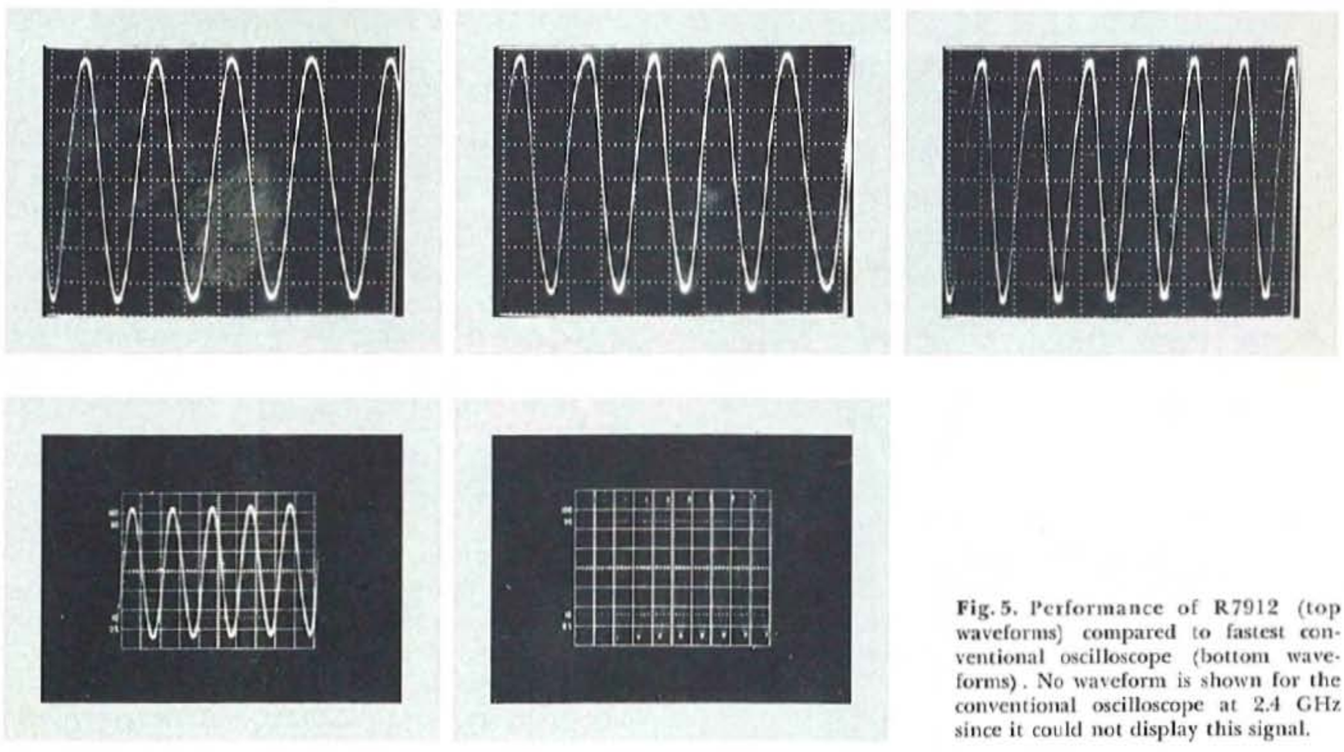


Fig. 5. Performance of R7912 (top waveforms) compared to fastest conventional oscilloscope (bottom waveforms). No waveform is shown for the conventional oscilloscope at 2.4 GHz since it could not display this signal.

Three more vertical ramps are generated in this manner. Then, the output of the Major Division Counter switches so that dots are again displayed every 0.2 division. Action continues until the graticule is complete. When the Horizontal Counter (÷ 11) has received 11 inputs from the Major Division Counter (÷ 5) the graticule is complete and it resets the Graticule Gating Flip Flop. This action turns off the Graticule Control block and halts operation of this circuit. About four milliseconds are required to write the complete graticule.

The Proof Is In The Performance

Performance of the instrument is best shown by the accompanying photographs. Fig. 5 shows continuous sinewave signals as displayed by both an R7912 Transient Digitizer/TV monitor (NON STORE mode) and a TEKTRONIX 7904 Oscilloscope. Identical plug-ins were used for both measurement systems. Fig. 6 shows the reconstructed display of a single pulse that was digitized by the R7912. The digital information was fed to a computer through the instrument's optional memory and interface circuits. It was then reconstructed and displayed on a TEKTRONIX storage display monitor.

Acknowledgments

This instrument, as many state-of-the-art projects, is the result of the dedicated effort of many people. These include: Carlo Infante, Program Manager; Jim Cavoretto, Project Engineer who also provided valuable assistance in compiling this article; Al Allworth, Don Roberts, and Stu McNaughton, Electrical Engineers; Walt Lowy, Engineering Technician; Ray Hayes, Ken Hawken, Bob Culter, Hal Cobb, Ed Ritz, and Bo Janko, CRT Engineering; Loyal Strom, Helene Albright and Ken Nesvold, Prototype Support; Doug Giesbers, Larry Pearson and Phil Lloyd, Mechanical Engineering; Nick Hughes and Ray Blohm, Instrument Manufacturing. The list would not be complete if special recognition were not given to these marketing people whose inputs and support were always very valuable: Bob Hightower, Bob Johnson, and Bill West.

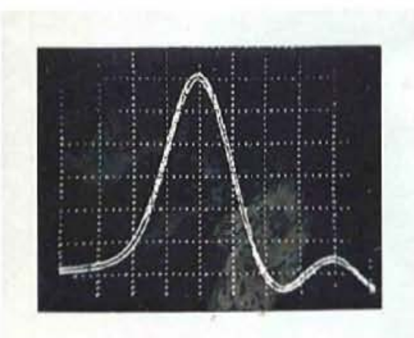
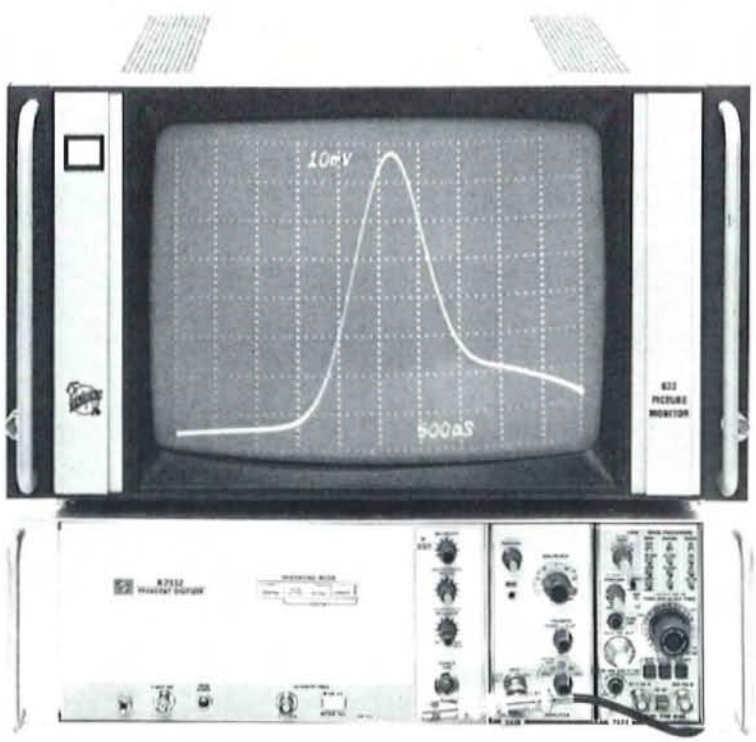
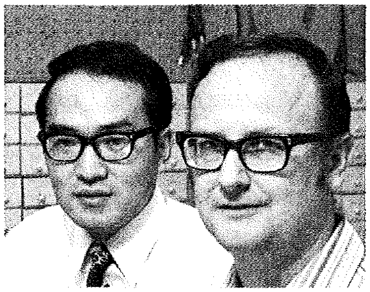


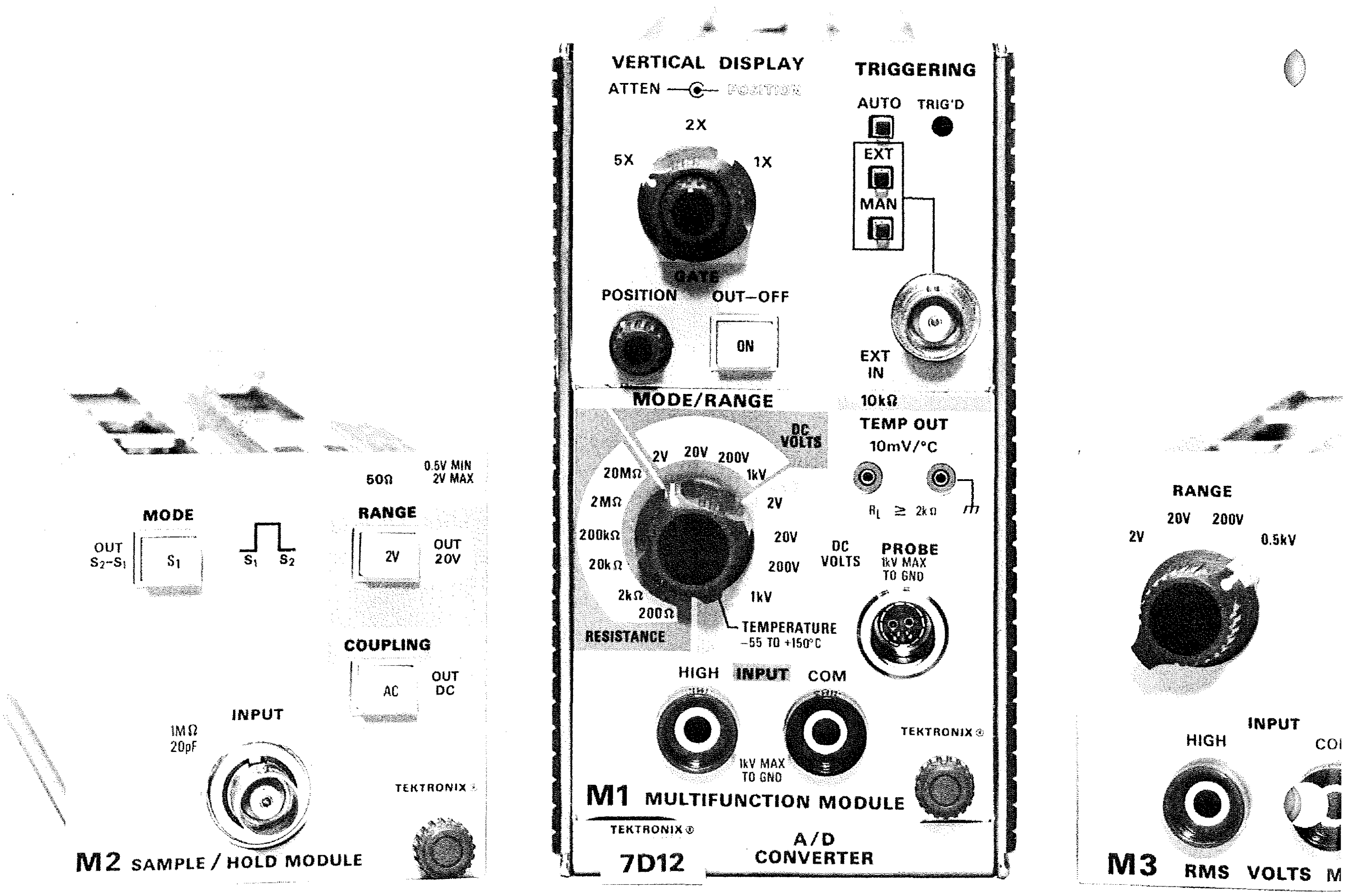
Fig. 6. Digitized waveform, reconstructed and displayed on a TEKTRONIX 603 Storage Monitor.





Hideki Iwata Ken Sternes

A fast A/D plug-in for the oscilloscope



One picture is worth a thousand words. And sometimes even a thousand words can't adequately convey the information. We might paraphrase this to say, "One waveform displayed is worth a thousand voltmeter readings." And sometimes even a thousand voltmeter readings can't adequately portray the waveform. It's true, however, that often a picture, or waveform, doesn't tell the complete story. The addition of a few words, or figures, can impart a lot of valuable information.

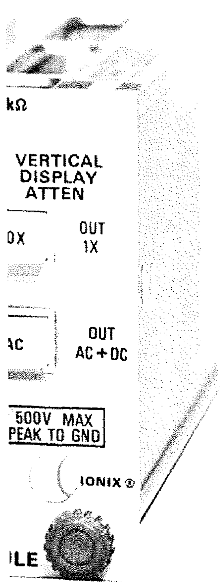
The introduction of the TEKTRONIX 7000-Series Oscilloscope with CRT READOUT brought us the powerful measuring capability afforded by displaying both waveforms and alphanumerics on the CRT at the same time. To many, this seemed to be merely a convenience for recording deflection factors along with the trace when photographing the screen. It *has* proven to be a convenience—and much more, for it has broadened the role of the oscilloscope to include counters, DVM's, computer-aided measurements and the like. Now a new analog-to-digital converter plug-in for the 7000-Series adds several highly useful measurements to your oscilloscope's repertoire.

The 7D12 Plug-in

The 7D12 A/D Converter plug-in is designed for use with any 7000-Series Oscilloscope containing CRT READOUT. The unit consists of two basic sections: the plug-in mainframe, which contains a fast, 4½-digit, A/D converter, inverter power supply, dual-trace 100-MHz vertical amplifier, readout control section and trigger circuit; and a smaller module which plugs into the front of the 7D12. Three modules are currently available—the M1 Multifunction Module for measuring DC volts, resistance and temperature; the M2 Sample/Hold Module for measuring voltage from ground to a selected point, or the difference voltage between any two selected points; and the M3 RMS Volts Module for making true RMS voltage measurements. We will discuss each of these in some detail; but first, let's take a closer look at the 7D12 mainframe.

The block diagram in Fig. 1 shows the major sections of the 7D12 and the modules. The modules process various analog signals—peak voltage, RMS voltage, resistance, temperature, etc., and produce a DC voltage which the 7D12 converts to digital readout information for the 7000-Series Oscilloscope. The M2 and M3 also provide an analog signal for display.

The function of each block in the 7D12 is readily apparent except, perhaps, for the inverter power supply. This supply permits floating the A/D converter, enabling us to make measurements with the input elevated as high as 1 kV. Triggering of the 7D12 can be accomplished internally from a unijunction transistor oscillator, externally thru a BNC connector, or manually by a front-panel push button.



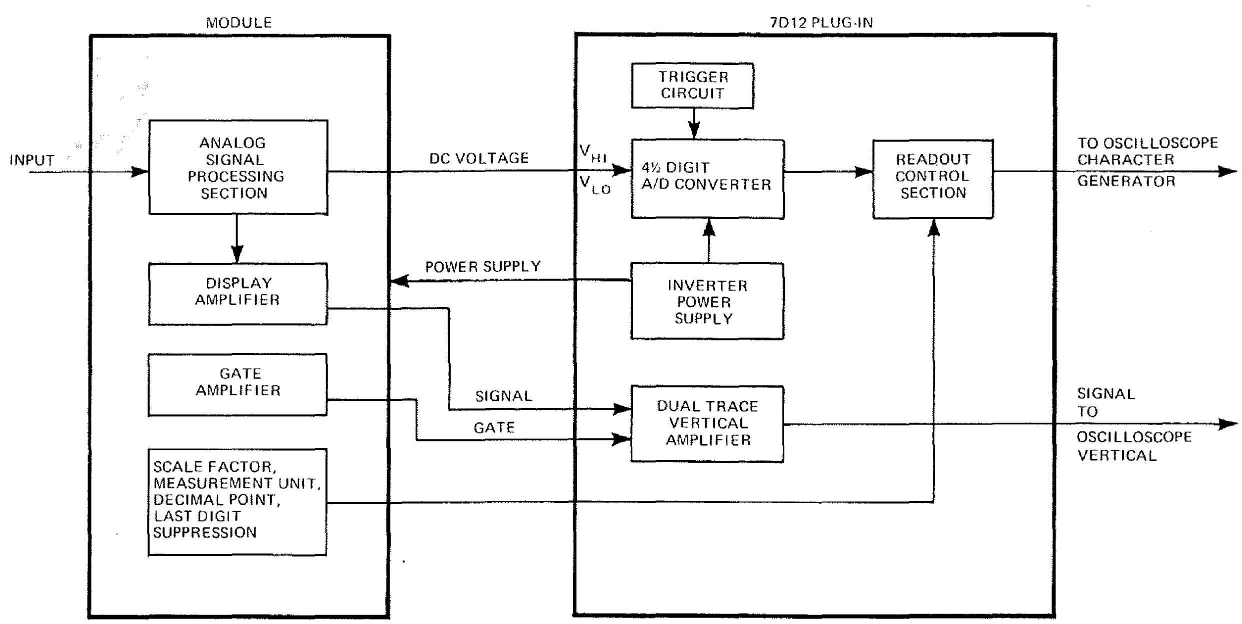


Fig. 1. Block diagram of plug-in module and 7D12 plug-in.

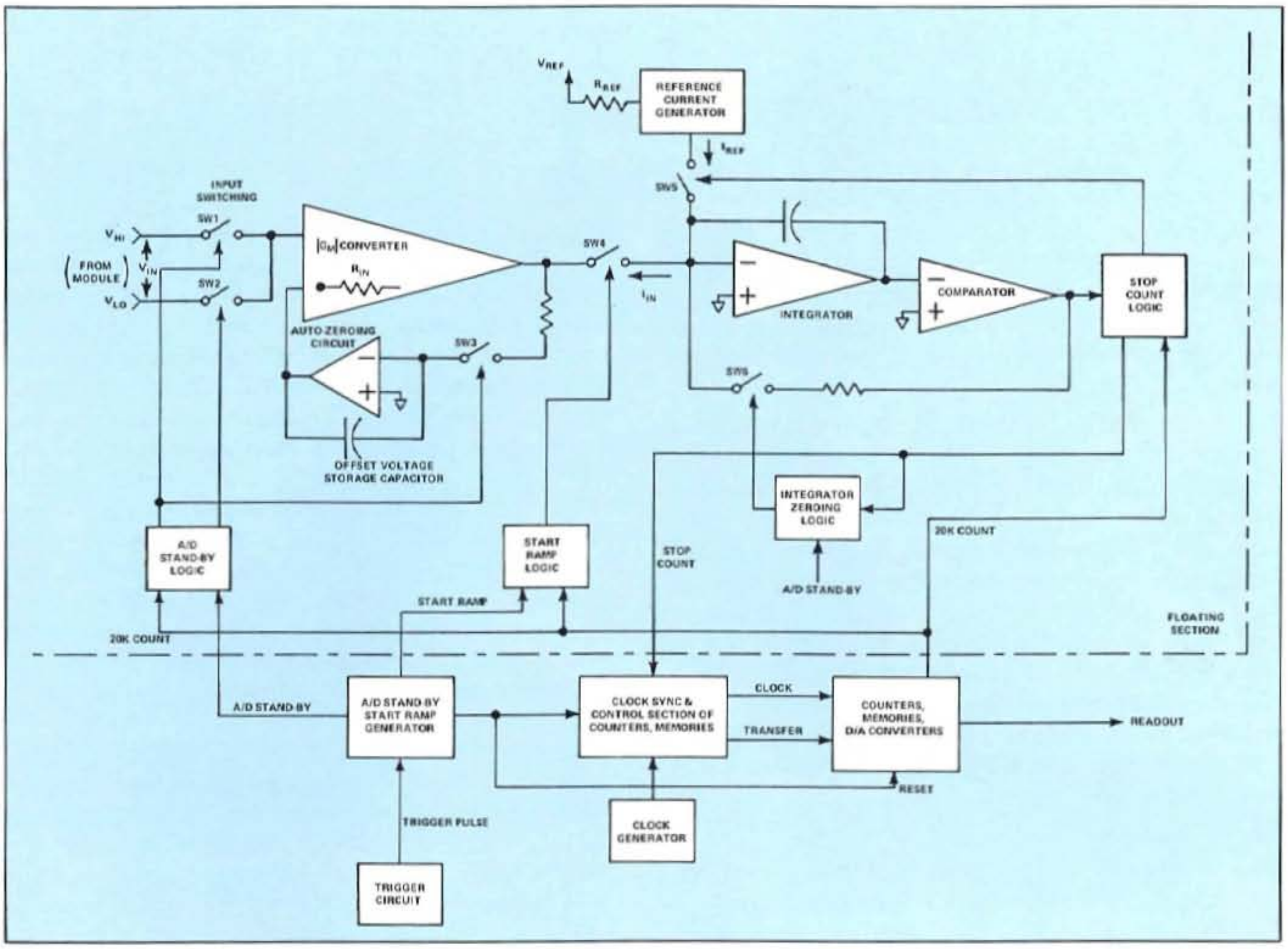


Fig. 2. Block diagram of the 7D12 A/D Converter.

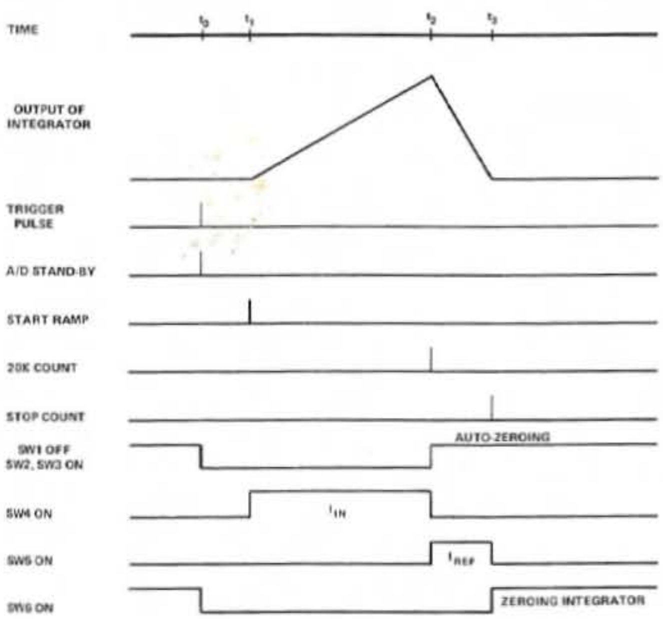


Fig. 3. Timing diagram for A/D conversion process.

The A/D Converter

The block diagram of the converter is shown in Fig. 2, and the associated timing diagram in Fig. 3. The converter produces 4½ digits with an accuracy of 0.01%. Basically, it is a dual-slope A/D converter with an auto-zeroing circuit. All of the switches shown in Fig. 2 are electronic switches such as MOS-FETs, JFETs and diodes. The circuitry enclosed by the dotted line is a floating section powered by the inverter power supply.

To help in understanding how the converter works, let's go through a normal sequence of events:

Before T_0—Before the trigger pulse arrives at the 7D12, SW2 and SW3 are closed, and SW1 is opened. The input to the $|G_M|$ converter, which has a current rectifier, is connected to V_{LO}. The $|G_M|$ converter and auto-zeroing circuit are nulled, and a capacitor in the circuit memorizes the input offset voltage of an input amplifier in the $|G_M|$ converter. SW6 is closed so that the integrator will start integrating at the proper voltage.

t_0 - t_1—When a trigger pulse arrives at t_0, the A/D Stand-by Start-Ramp Generator produces an A/D stand-by pulse to switch the states of SW1, SW2, SW3, and SW6 through the A/D Stand-by Logic circuit. The input of the $|G_M|$ converter is now connected to V_{Hi}. The input voltage V_{IN} is equal to V_{Hi} minus V_{Lo}.

t_1 - t_2—After 2 milliseconds, a start-ramp pulse is produced at t_1 to turn SW4 on through the Start Ramp Logic, to start integrating the input current, I_{IN}, and the counter is started by the clock pulse from the Clock Synch. and Control Section.

t_2 - t_3—At 20,000 counts of the counter at t_2, SW4 is opened, and SW5 is closed to start integrating down by the reference current, I_{REF}. At t_2, the auto-zeroing circuit is activated again by turning SW1 off and SW2 and SW3 on through the A/D Stand-by Logic.

After t_3—When the output of the integrator reaches the zero level, a stop-count pulse is produced, and the reference current is turned off at t_3. The counter stops. The content of the counter is then transferred to memory where the output is converted to an analog readout signal. SW6 is turned on again to prepare the integrator for the next measurement. The digital readout is equal to (I_{IN}/I_{REF}) x 20,000. I_{IN} is equal to $|V_{IN}|/R_{IN}$ where R_{IN} is a discrete resistor in the $|G_M|$ converter, and I_{REF} is equal to V_{REF}/R_{REF}. The readout can be expressed by the following equation:

$$\text{Readout} = ((|V_{IN}|/R_{IN}) / (V_{REF}/R_{REF})) \times 20{,}000 \ldots \qquad \text{Eq. 1}$$

With the use of the auto-zeroing circuit, the $|G_M|$ converter cannot drift more than 100 microvolts for the instrument's operating range of +15°C to +40°C. By using a precision input amplifer with high gain and high common-mode-rejection, V_{IN} in Eq. 1 is made equal to the voltage input to the 7D12. V_{REF} is a temperature-compensated zener diode with a temperature coefficient of 5 p.p.m./°C. The ratio of R_{IN} and R_{REF} can be tightly controlled by using matched resistors whose temperature tracking is better than 2 p.p.m./°C. Therefore, total maximum temperature coefficient is 7 p.p.m./°C. The required accuracy of ±0.01% over a ±5°C temperature range is easily achieved.

Now let's take a closer look at the plug-in modules.

The M1 Multifunction Module

The M1/7D12 combination forms a 4½-digit voltmeter and ohmmeter, and a 3½-digit temperature indicator. The DC voltmeter measures from 0 to 1000 V in four ranges with a resolution of 100 µV on the 2 V range. System accuracy is ±0.03% of reading ±0.005% of full scale over the ambient temperature range of 20°C to 30°C, or ±0.04% of reading ±0.005% of full scale from 15°C to 40°C. Either input connector can be elevated 1 kV above ground, and the input impedance is 10 MΩ on all ranges.

Resistance from 0 to 20 MΩ is measured in six ranges, with a resolution of 10 milliohms on the 200 Ω range. The accuracy is ±0.09% of reading plus ±0.01% of full scale from 15°C to 40°C.

Both temperature and DC voltage can be measured using the convenient P6058 voltage/temperature probe. Temperature from −55°C to +150°C can be measured with a resolution of 0.1°C and an accuracy of ±1°C up to 125°C and ±2°C up to 150°C. A pair of terminals on the M1's front panel provides an analog output of 10 mV/°C (0°C = 0 volts). This output is available regardless of the Mode/Range switch setting.

The M2 Sample/Hold Module

The M2/7D12 combination provides a unique measurement capability for the 7000 Series. You can measure voltage amplitudes from ground to a selected point, or the difference voltage between any two selected points with an accuracy of ±0.35% or better. The sample points can be triggered automatically, manually, or externally, with one of the most convenient sources being the delayed gate from a 7000-Series Time Base. With the delayed gate applied to the trigger Ext In connector, the leading edge of the gate determines the S_1 sample point, and the trailing edge determines the S_2 sample point. Fig. 4 shows a typical measurement using the S_2-S_1 mode. The reading at the upper left is the voltage difference between S_2 and S_1, upper center is the TIME/DIV, and the lower left reading is the vertical deflection factor for the displayed signal. The signal display is intensified during the delayed gate; however, at sweep rates of about 100 ns/div and faster, the intensified portion will not coincide with the displayed gate because of the delay line in the oscilloscope vertical amplifier. The time interval between S_1 and S_2 can be as short as 30 ns and as long as 5 ms. For single-shot S_2-S_1 measurements, the time interval must be 150 µs or longer.

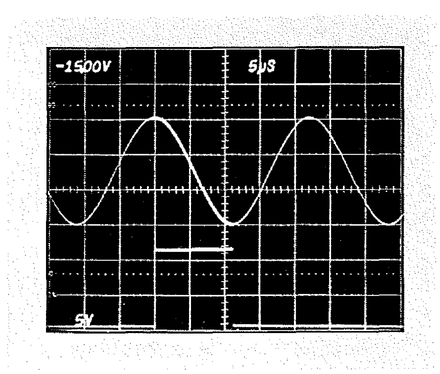


Fig. 4. Typical S2-S1 measurement showing peak-to-peak voltage of AC waveform. Reading is at upper left.

10 Nanosecond Aperture Time

One of the unusual features of the M2 is the 10 ns aperture time. This makes it useful for measuring high dv/dt signals such as the fast A/D converter waveform pictured in Fig. 5. Accuracy of the measurement is typically better than ±0.25% if 40 ns is allowed for settling time following an input signal step-function.

Fig. 6 illustrates an application of the M2/7D12 teamed up with a 7D15 Universal Counter/Timer plug-in to make accurate rate-of-rise measurements on a ramp signal. The M2 is operated in the S_2-S_1 mode. The delayed gate from the time base plug-in is used to gate both the M2/7D12 and the 7D15. The +2.35 V reading in the upper left corner is the change in amplitude during the brightened portion of the trace. The time interval as measured by the 7D15 is 20.92 μs and the 1X indicates the reading was taken during a single event rather than an average of several ramps. Accuracy of the M2/7D12 in this mode is ±0.35%. The linearity of the ramp can be quickly checked by moving the delayed gate along the ramp and noting any change in the amplitude reading provided by the M2.

The M3 RMS Volts Module

The M3/7D12 combination brings another unique measurement capability to the oscilloscope—measuring true RMS voltages. The M3 measures DC, the true RMS voltage of signals from 40 Hz to 100 kHz, and the true RMS value of AC + DC. The maximum input is 500 V RMS or 1000 V peak. Voltages are displayed digitally on the CRT with 3½-digit readout, with a resolution of 1 mV achievable on the 2 volt scale. Accuracy of the M3 is ±0.25% of full scale up to 40 kHz on the 2 V and 20 V ranges, derated to ±0.5% above 40 kHz. The maximum permissible crest factor $(\frac{E_{PEAK}}{E_{RMS}})$ is 5. Response time of the M3, that is the time required for the readout to reach its stated accuracy after a step voltage is applied, is less than 2 seconds.

The M3 can measure distorted sinewaves such as the outputs from SCR circuits, or non-sinusoidal waveforms such as pulse trains with duty cycles as low as 4%. The photograph in Fig. 7 shows the measurement of the RMS voltage from a silicon controlled rectifier. The RMS value of the displayed waveform is the reading at

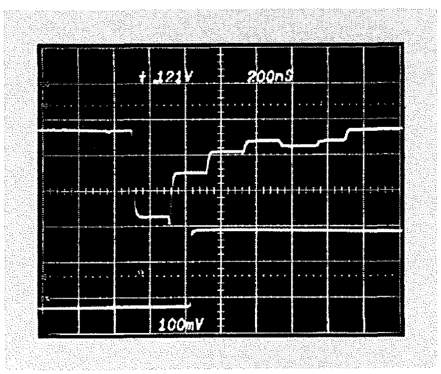


Fig. 5. Voltage level at any point on this A/D waveform can be made by positioning the gate to start at the desired point.

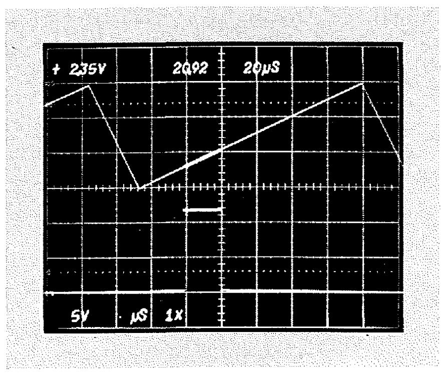


Fig. 6. The S2-S1 mode being used to accurately measure rate-of-rise on a ramp signal. The voltage difference is+2.35 V and elapsed time 20.92 μs.

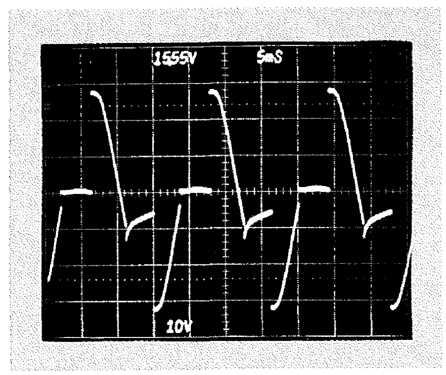


Fig. 7. True RMS value of SCR is measured by the M3/7D12.

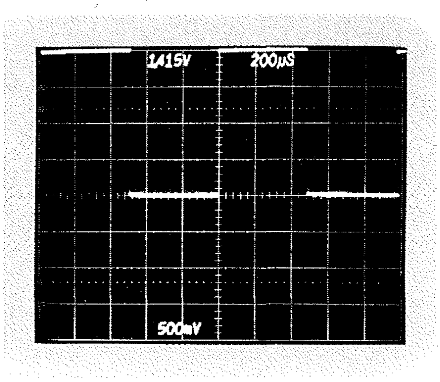


Fig. 8A. Measuring true RMS value of AC+DC waveform.

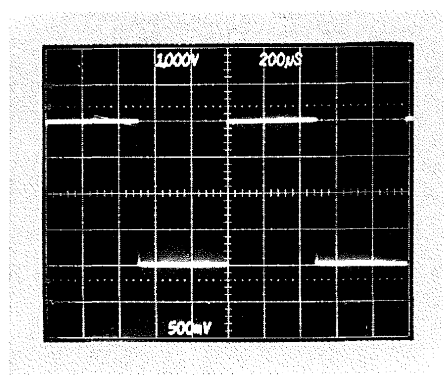


Fig. 8B. Measurement of same waveform with DC component removed by AC coupling.

upper left, and the lower reading is the vertical display sensitivity. Another example, showing the effect of DC on the RMS measurement is shown in Fig's. 8A and 8B. The waveform in Fig. 8A is a 2-volt pulse with a 1-volt DC component. Fig. 8B is the same pulse with the DC component removed by AC coupling the M3. If the pulse were symmetrical, the RMS value in the DC-coupled reading would be $\sqrt{2}$ times the AC-coupled reading since $E_{RMS} = \sqrt{(DC)^2 + (AC_{RMS})^2}$ and, in this instance, $AC_{RMS} = DC = 1$ volt.

Now, let's take a look at how the M3 functions. The block diagram of the M3 is shown in Fig. 9. Following the input attenuator, the signal progresses through two separate channels. The lower channel is an amplifier for conditioning the signal for display as an analog signal, or waveform, on the CRT. The modulator allows the floating input to be transformer coupled to the chassis-referenced 7D12 display amplifier. Bandpass of the analog channel is DC to 700 kHz.

The upper channel converts the input signal to a DC voltage equivalent to the RMS value, for driving the A/D converter in the 7D12. The operational rectifier and voltage-to-current converter, although shown as two separate blocks, are difficult to separate physically. A simplified circuit diagram of the two is shown in Fig. 10. When the input is a positive signal, the current path is through Q_1, R and CR_2; when negative, it is through Q_2, R and CR_1. The voltage across R is Ke_{IN} and you will note that the current flows unidirectionally in the output. The output current is thus proportional to the absolute value of the input voltage. To prepare the signal for squaring, the output current is divided into two equal parts for driving the multiplying circuit. These two equal currents then pass to the gain cell which squares, averages and takes the square root of the input currents. The output of the gain cell is equal to the RMS value of the input voltage to the M3, but is referenced to some positive voltage rather than the common buss. By using a summing amplifier this positive voltage is subtracted, bringing the output back to the common reference for driving the 7D12.

Summary

The 7D12, with its plug-in modules, adds important new measurement capability to your 7000-Series Oscilloscope. And, it is measurement capability with digital accuracy. True RMS voltage, DC voltage, resistance, temperature, and voltage difference between any two selectable points on a waveform are all measurements available to you using the 7D12 plug-in.

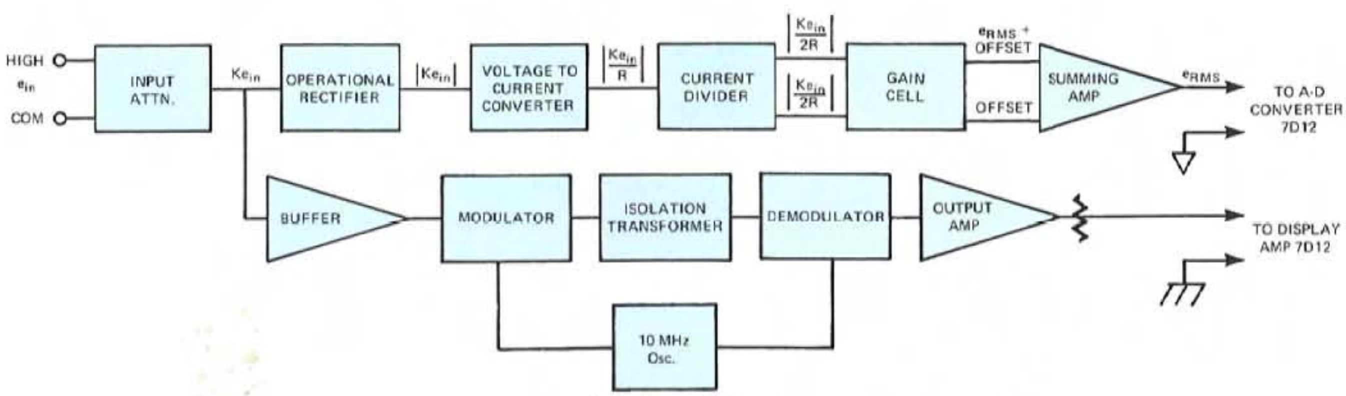


Fig. 9. Block diagram of the M3 true RMS volts module.

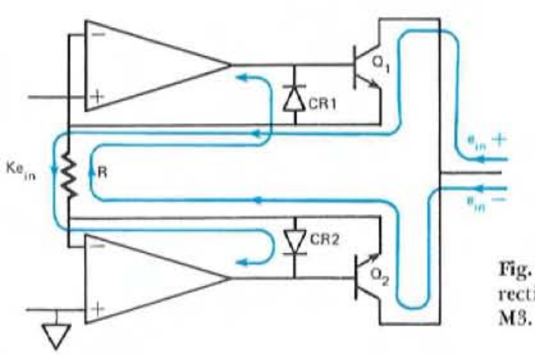


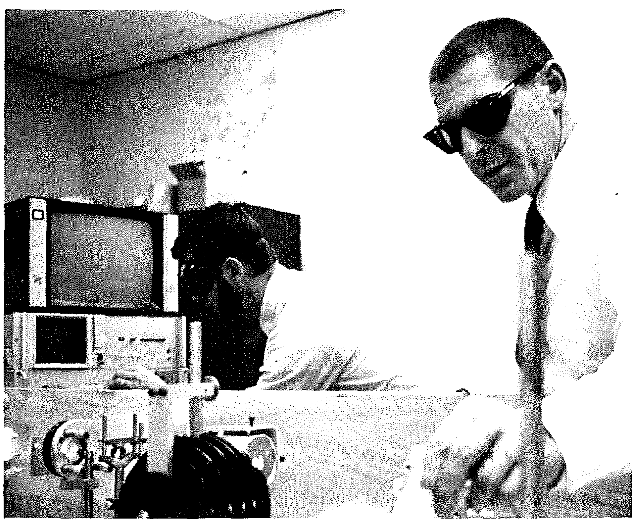
Fig. 10. Simplified block diagram of operational rectifier and voltage-to-current converter used in M3.

Teknique

Digitizing and displaying fast pulses

Hale Farley

Did you know that high-speed signals can be quickly made computer compatible? Or that they can be displayed on a large screen TV monitor in real time or stored on an X-Y monitor in a refreshed mode? The TEKTRONIX R7912 Transient Digitizer can digitize signals that occur in a few tenths of a nanosecond. The signal is captured on a diode-array target at sweep rates up to 500 picoseconds per division. In the DIGITAL mode, it is scanned off at a rate slow enough for a minicomputer to handle, with a maximum writing rate equivalent to 8,000 div/μs. The NON STORE mode provides bright, large screen displays at writing rates equivalent to 30,000 div/μs.



Dr. Gail Massey of the Oregon Graduate Center making adjustments to a pulsed neodymium YAG laser, using the R7912.

Just how fast is 500 picoseconds? The fastest entity known is light. In 500 picoseconds, light travels about six inches. One source of light pulses which is receiving increasing attention in many research laboratories is the laser. A laser (light amplification by stimulated emission of radiation) is a source of energy that occurs within a very short time frame.

The pulse train produced by a mode-locked laser often has fast pulses that are separated by only a few nanoseconds. A switching method such as a dye cell is used in conjunction with a mode-locked laser to permit only a single pulse train to leave the laser cavity. The individual pulses within the train can be as short as five picoseconds. The ability to capture and display a single pulse is limited by the response of the detector and the measurement instrument. With the R7912 and the 7A21N Direct Access Plug-in, instrument risetime is 350 picoseconds at a sensitivity of 4V/div or less.

Fig. 1 shows a very simple mode-locked laser which produces two basic waveforms which can be analyzed with the R7912. Response of the flashlamps can be measured with the R7912 by either of two methods. One is to place a current-sensing resistor in series with the power lead for each lamp. A drawback of this method is that multiple signal channels are needed, one for each lamp. A preferred method of measuring flashlamp response is with a light pipe and photo-diode detector. Now, the display shows the actual flashlamp output on a single channel. The R7912 can be operated in the NON STORE mode to provide a real-time display for adjusting the flashlamps and setting the pumping power. In the DIGITAL mode, the R7912 digitizes the waveform to allow computer action on the signal or for automatic computation. Some of the data that can be obtained from this setup is:

- Total light output.
- Duration of light pulse.
- Peaks, breaks, or other irregularities in the power curve.
- Area under the curve for indication of power (may be determined automatically by the computer).
- Auto-feedback calibration of the pumping power to maintain desired light output (under computer control).

Waveform B shown in Fig. 1 is the pulse-train output of the mode-locked laser. Normally, this signal is obtained using a beam-splitter mirror and a photo-diode detector. Again, the R7912 can be operated in the NON STORE mode to produce a real-time display which makes system setup easy. The large screen TV monitor allows you to view the detector output easily, even from across a brightly lighted room, while you make system adjustments. This waveform can also be computerized for measurement of output power, Fast Fourier Transform computations, or many other computer-aided functions.

A typical laser system is shown in Fig. 2. Some of the points where measurements could be made with an R7912 are identified by the detectors shown in this diagram. Typical waveforms that would result at these measurement points are also shown. A Pockel cell is a typical optical switch used in laser systems. It switches fast enough to select an individual pulse out of the mode-locked pulse train. The rejected portion of the pulse train can be sensed by photo-diode detector #1 and compared with the amplified output at photodiode detector #2 to see if a complete single pulse came through the optical switch and how cleanly this pulse was extracted from the pulse train.

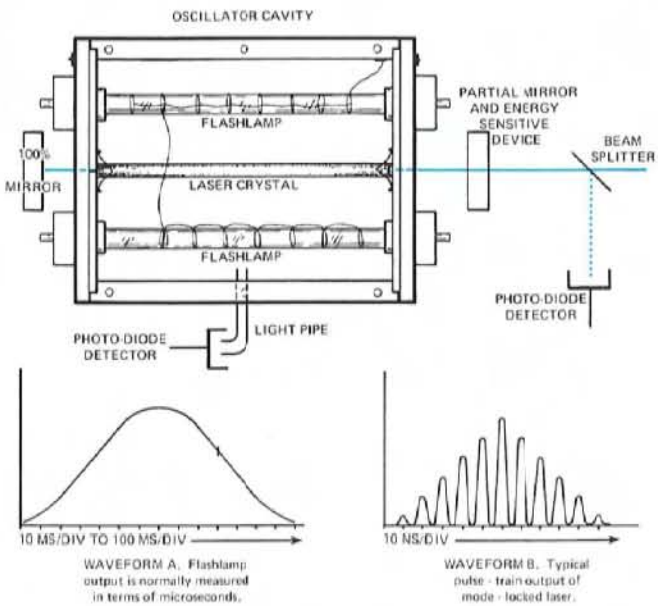


Fig. 1. Mode-locked laser.

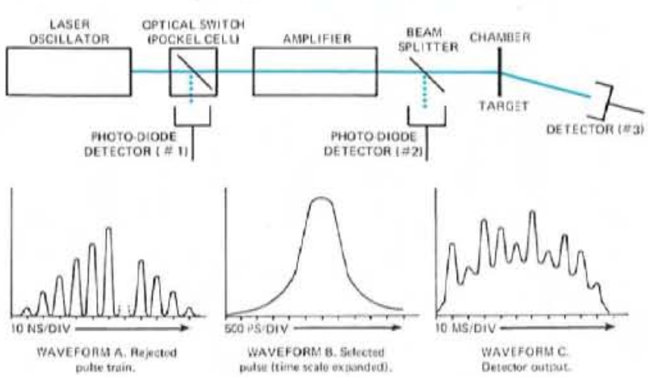


Fig. 2. Measurements in laser system.

A variety of detectors could be used to measure the effect of the pulse at the target. Choice of the detector would be determined by the phenomenon you desire to measure at the target. Some typical detectors used are:

- Photo diode—measures photon flux; i.e., photons of various energies and X-rays.
- Faraday cup—measures charge of particles.
- Energy/charge analyzer—measures energy versus charge.
- Beta spectrometer—measures electrons of various energies.
- Secondary electron detector—measures work-function characteristics of various materials.
- Neutron detectors—measures neutron activity.

Waveform C is a typical output waveform produced by any of the above detectors.

As in the previous measurement, the R7912 can be used either in the NON STORE or the DIGITAL mode. For system setup and alignment or real-time analysis of measurement results, the NON STORE mode used with a TV monitor provides a good display. However, some high-powered lasers must allow several minutes to elapse between pulses. In that circumstance, the DIGITAL mode used with a storage monitor provides the best display. This setup allows the display to be viewed and analyzed for extended periods. Also, new information can be written over the previous trace for direct comparison.

We mentioned previously that the output signal from the detectors can be digitized for computer analysis. It is not feasible in these limited pages to describe in detail the computations that can be made on these signals by the computer. The operating capabilities are mainly limited by the abilities of the programmer and physical limitations of the computer.

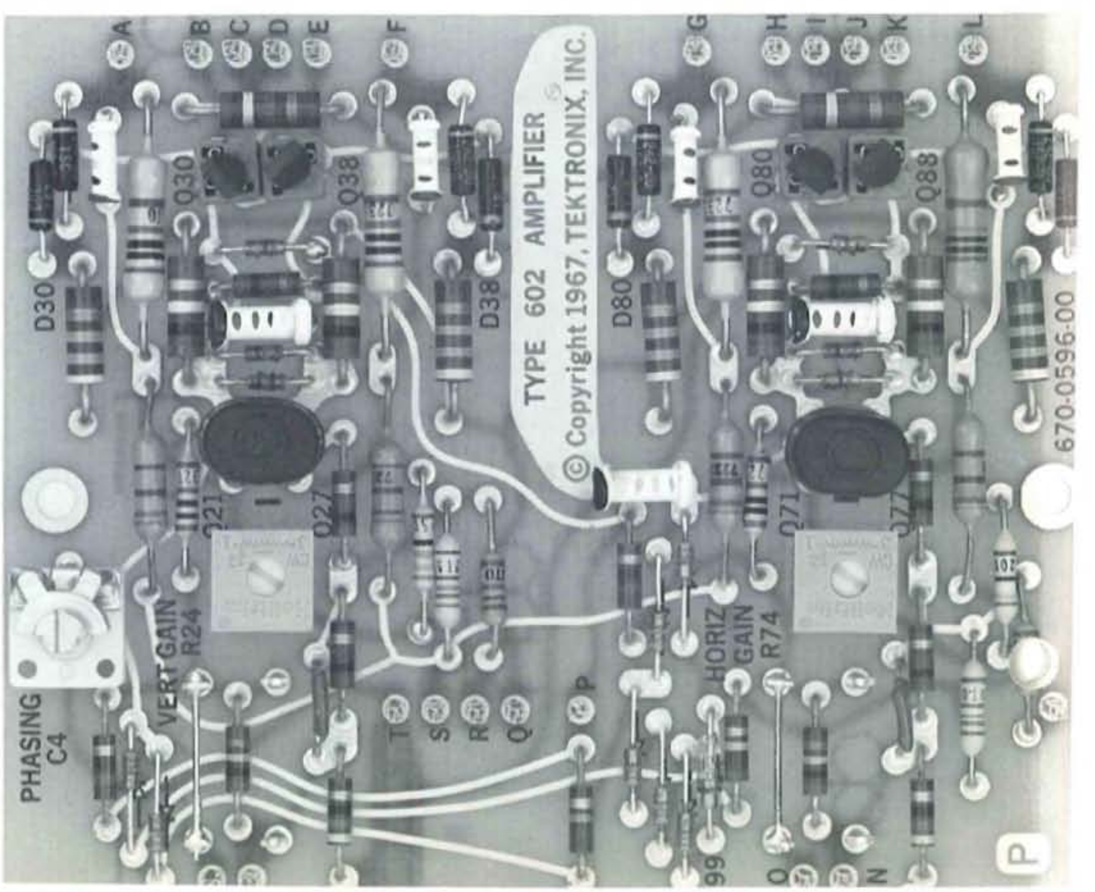
In this article, we have given only an over-view of the measurement capability of the R7912 Transient Digitizer. While we have not answered all of the questions you may have regarding measurements to be made with this system, we hope to have implanted the seeds of a few ideas which will germinate into solutions for your individual measurement problems.

Getting around in Tektronix Instruments

Most electronic equipment is pretty complex inside. Especially when it comes to locating specific components and circuitry while trouble-shooting the unit.

Serviceability has always been an important design consideration at Tektronix. Beginning with our first instrument, the Type 511 Oscilloscope, we endeavored to make components easy to locate and replace. And leads were soldered in, in a manner allowing them to be easily lifted for troubleshooting. The notched ceramic strips used in later instruments such as the 535 and 545 made servicing almost a pleasure.

Now, with the use of printed circuit boards and the automatic insertion and soldering of components, servicing has become a bit more difficult. Components are reduced in size and component density is vastly increased. Locating and replacing specific components on a crowded circuit board can be a real problem. Here are some of the things we are doing at Tektronix to make it easier for you.



Printed Circuit Board Marking

Much can be done to accommodate component marking if proper attention is given to this when designing the circuit board. With space limited, we assign priority to marking active devices such as transistors and IC's, adjustable components, plugs and connectors, and danger points. Both the circuit symbol and control name are usually shown for adjustments. Markings follow the A.S.A. code for component symbols—"Q" designates transistors, "U" integrated circuits, "CR" diodes, "K" relays and so forth. Incidentally, you will find most active devices mounted in sockets rather than soldered on the circuit board.

The location of the number one pin for IC's, and the proper orientation for multi-lead connectors are also noted on the printed circuit board. Some of the most useful markings are test points denoted by "TP". These correspond to test points shown in the manual schematics and usually have provision for easily attaching a probe. The instruction manual also contains photos of each printed circuit board with all components and adjustments labeled.

Connectors Play an Important Part

It's easier to take things apart if leads and cables terminate in connectors. You'll find some real innovations by Tektronix engineers in this area. The Peltola connector provides a compact, inexpensive means of connecting shielded leads to the printed circuit board. Harmonica connectors accommodate ten-lead ribbon cable in a minimum of space and are easy to put on or disconnect. And unique inter-board connectors provide direct connection between circuit boards without the need for cabling.

Color Coded Wires

This year Tektronix applied color-coding stripes to over 75 million feet of wire for use in our instruments. Another 6 or 7 million conductor feet of ribbon cable, also color coded, is supplied by outside vendors. These brightly colored leads enhance the internal appearance of Tektronix instruments, but that isn't the primary purpose for color coding. It serves a very useful function in building the instrument and in servicing it.

The color-coding scheme is basically in accordance with MIL-STD-681B. The color of the wire insulation identifies the function of the lead as follows:

Black — Grounds
Brown— Heaters and filaments
Red — B+ power supplies
Violet — B− power supplies
Gray — Internal AC Power
White — Signal leads

Color stripes are added to these solid-colored backgrounds to further identify the lead. For example, a floating ground is black with a white stripe. The red and violet power supply leads are coded to denote their deviation from ground or zero voltage as follows (the numbers corresponding to the standard resistor color code):

+	4th supply	2-4 & 2-4X Series
	3rd supply	2-3 & 2-3X Series
	2nd supply	2-1 & 2-1X Series
	1st supply	2-0 & 2-0X Series
0		
	1st supply	7-0 & 7-03 Series
	2nd supply	7-1 & 7-1X Series
	3rd supply	7-2 & 7-2X Series
—	4th supply	7-3 & 7-3X Series

For example, the 2-0 and 2-0X series are used for the first, or lowest, positive power supply. The 2-0 lead is the regulated bus. The 2-01 is the decoupled 2-0 supply. If another lead is needed the 2-03 code is used. The most unregulated lead in this supply is coded 2-09, and if another lead is needed, the next most unregulated lead is coded 2-08.

The gray base color is used for internal AC wiring. Conductors for the line (hot) side, starting at the AC input, are color coded 8-0, 8-01, 8-02 in sequence. The black stripe corresponds to the black lead in the power cord.

Conductors for the neutral (cold) side are color coded 8-9, 8-19, 8-29 in sequence; the white stripe corresponding to the white lead in the power cord.

Signal leads have a white base color. The stripes are used only for lead identification and have no significance.

The use of ribbon cable complicates the use of color coding to code wires according to function. In fact, it becomes a practical impossibility considering the variety of ribbon cables used. There is a practical coding scheme that is useful, however. Color can be used to denote the lead position in the cable. For example, all leads in a ribbon cable have a base white color. The first lead, which will be connected to slot number one in a connector, has a brown stripe; the number two lead has a red stripe and so on. This color scheme is used on ribbon cables with two or more conductors.

Summary

Getting around in electronic instruments can be frustrating and time consuming. Well-marked chassis and printed circuit boards, color-coded wiring, and innovative connectors are all designed to make it easier to get around in your Tektronix instruments.

1972-73 Tekscope Index

January 1972 Volume 4 Number 1

The 7L12 Spectrum Analyzer Plug-In/Frequency Stabilization Techniques/Optimizing Mixer Performance Using the 7L12/Servicing the 1401A Spectrum Analyzer

March 1972 Volume 4 Number 2

A Nanosecond Portable Oscilloscope/A Review of Basic Counter Principles/A Potpourri of Servicing Aids

May 1972 Volume 4 Number 3

A New Dimension in Plug-In Instrumentation/The 7704A—Extended Performance Plus Modularity/ Semiautomatic Testing with the Curve Tracer/Instruction Manuals, A Service Technician's Best Friend

July 1972 Volume 4 Number 4

Three New Instruments, Three Kinds of Storage/Tektronix Looks at Light/In-Circuit Testing of Tunnel Diodes/Washing Your Tektronix Instruments

September 1972 Volume 4 Number 5

The New Look In Portables/The Oscilloscope-Controlled Counter/Differential Amplifier Techniques Part I/Servicing the 432/434 Oscilloscopes

November 1972 Volume 4 Number 6

Progress In Semiconductor Testing/Linear IC Testing with the Curve Tracer/Oscilloscope to Curve Tracer with One Plug-In/Delaying Sweep Goes Digital/Differential Amplifier Techniques Part II/ Servicing 5100-Series Display Units

January/February 1973 Volume 5 Number 1

Tests and Measurements with TEKTEST III/Differential Amplifier Techniques Part III/Repairing Oscilloscope Probes

March/April 1973 Volume 5 Number 2

The Oscilloscope with Computing Power/Portable Power/Preserving Scope Bandwidth and Sensitivity/Servicing the 7T11 Trigger Circuit

May/June 1973 Volume 5 Number 3

A Simple Sampling Oscilloscope/TwoBright Dots on the Measurement Horizon/Dual-Trace Sampling Measurements/Servicing the 7T11 Sweep Circuit

July/August 1973 Volume 5 Number 4

The TEKTRONIX Calculator—It All Adds Up/The Calculator and You/A Close-Up Look/PROGRAMMING—As Easy As Writing A Formula/Reliable By Design

September/October 1973 Volume 5 Number 5

Philosophy of Product Design/A New Approach to Multi-Function Instrumentation/A New High-Speed Logic Pulser for Logic Testing/A Time Mark Generator with Error-Percentage Readout/ Operational Amplifier Applications/A New 225-MHz Universal Counter/Timer/Verification or Calibration? A Time Saving Decision

November/December 1973 Volume 5 Number 6

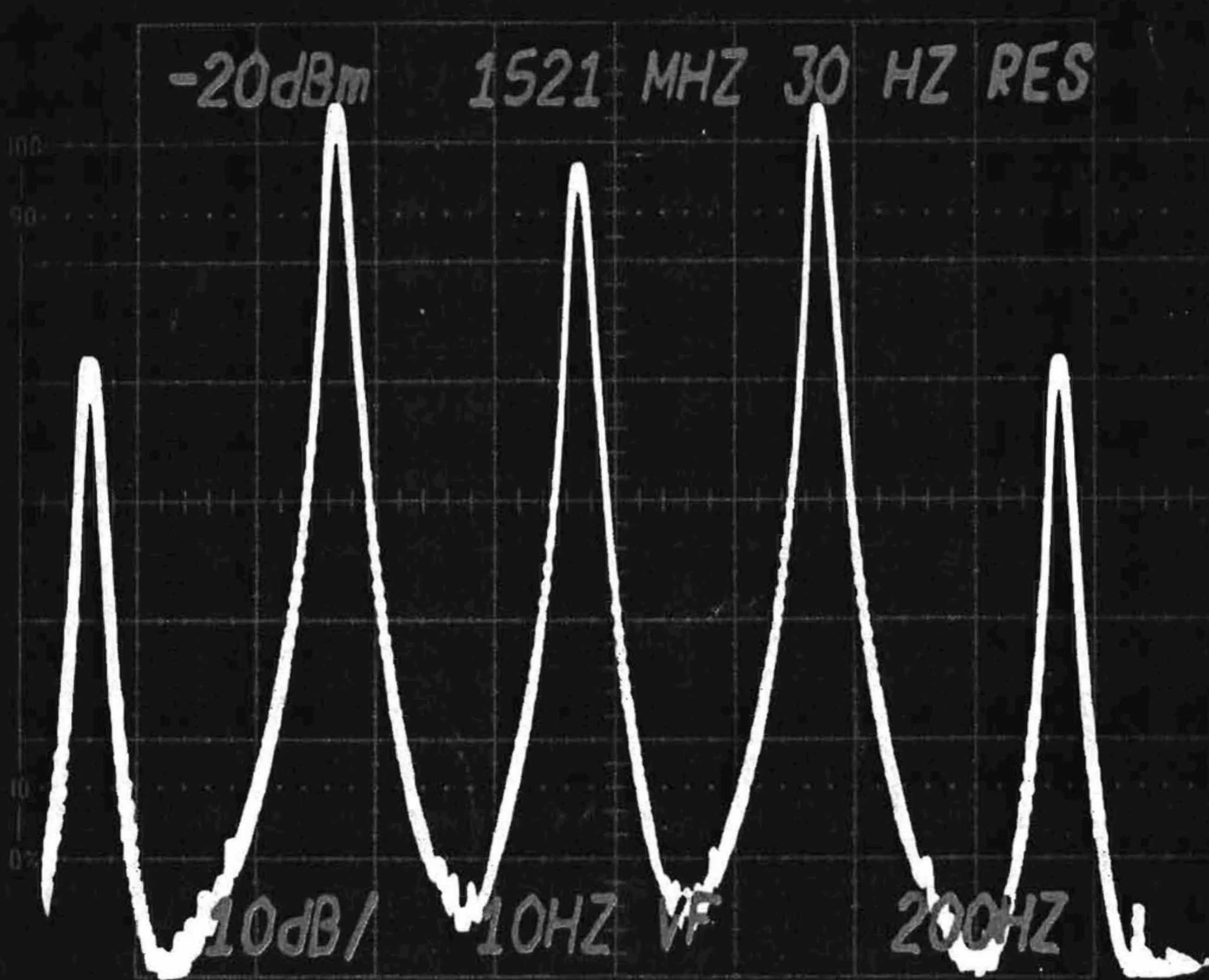
A New Way to Look at Transients/A Fast A/D Plug-In for the Oscilloscope/Digitizing and Displaying Fast Pulses/Getting Around in Tektronix Instruments/1972-73 Tekscope Index

TEKTRONIX®

committed to technical excellence

TEKSCOPE

Volume 6 Number 1 Jan/Feb 1974



TEKTRONIX®
committed to technical excellence

TEKSCOPE

Customer Information from Tektronix, Inc. ,
P.O. Box 500, Beaverton, Oregon 97005

Editor: Gordon Allison,
Graphic Designer: Tom Jones

Contents

3 **30 Hz resolution at gigahertz frequencies—a new direction in spectrum analysis**

Low incidental FM and excellent stability permit exacting measurements in the areas of spectral purity and close-in distortion.

8 **CRT READOUT—nicety or necessity?**

CRT READOUT offers many benefits to the scope user. Provision is made to insert your own data.

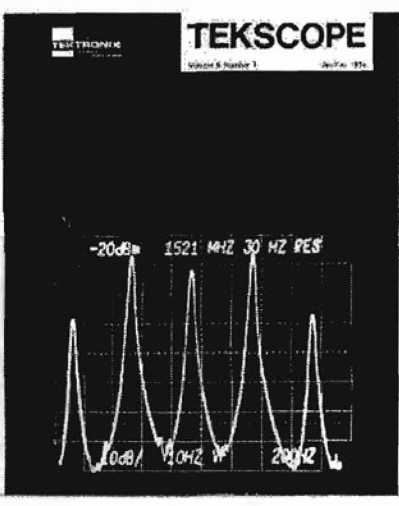
10 **Flexible disc measurements simplified by digital delay**

A digital delay plug-in for 7000-Series Oscilloscopes, used in the Delay-by-Events mode, takes the jitter out of rotating disc measurements.

13 **Servicing the 465 Portable Oscilloscope**

Some troubleshooting hints and typical problems you may encounter in servicing the 465 Oscilloscope.

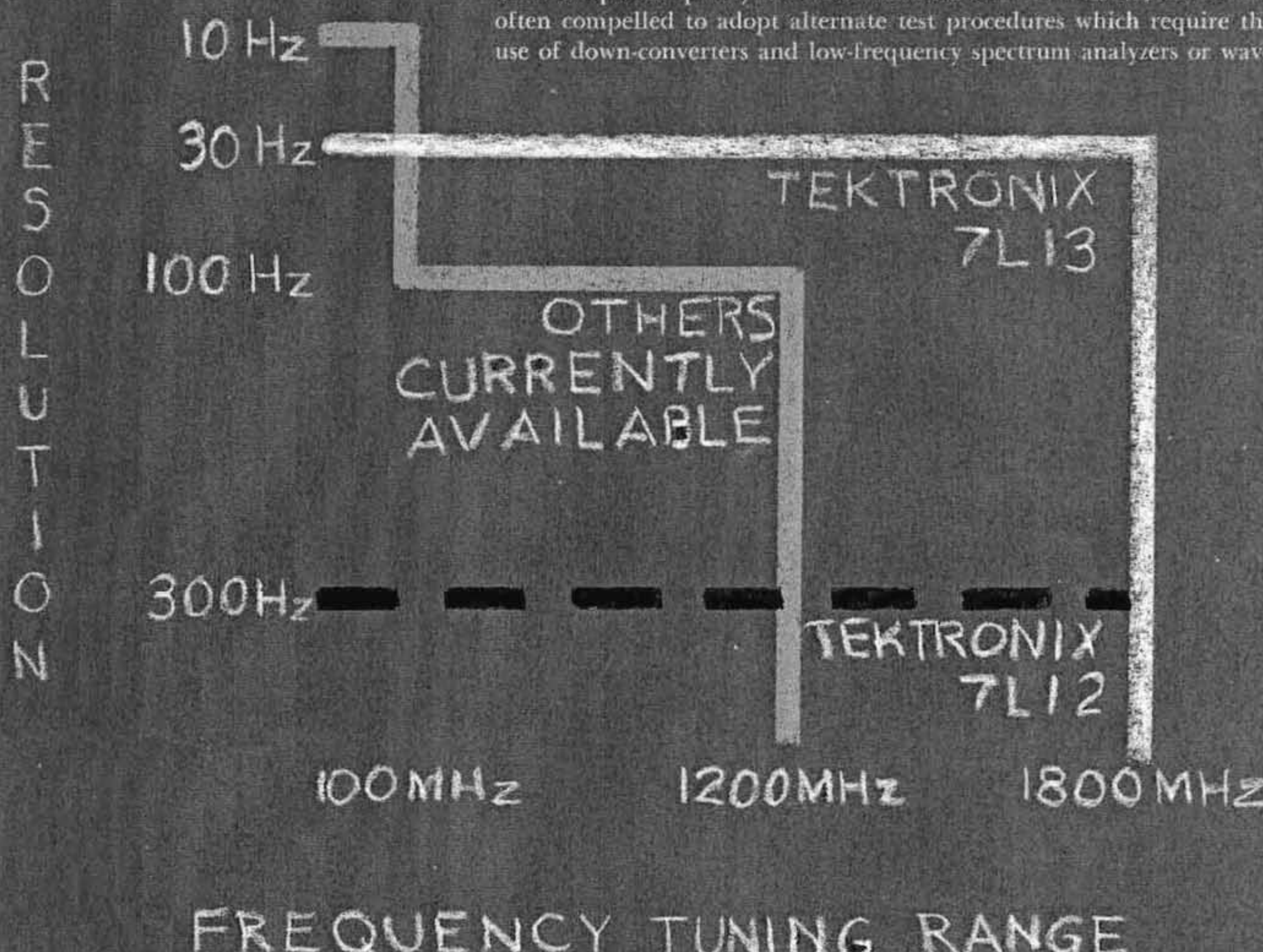
Cover: A close-up view of the display of the 7L13 Spectrum Analyzer. The CRT Readout displays the Spectrum Analyzer control settings. Center frequency is 1521 MHz, frequency span is 200 Hz/div, resolution is 30 Hz and the video filter is set at 10 Hz. The reference level at the top of the screen is −20 dBm and the vertical deflection factor is 10 dB/div.

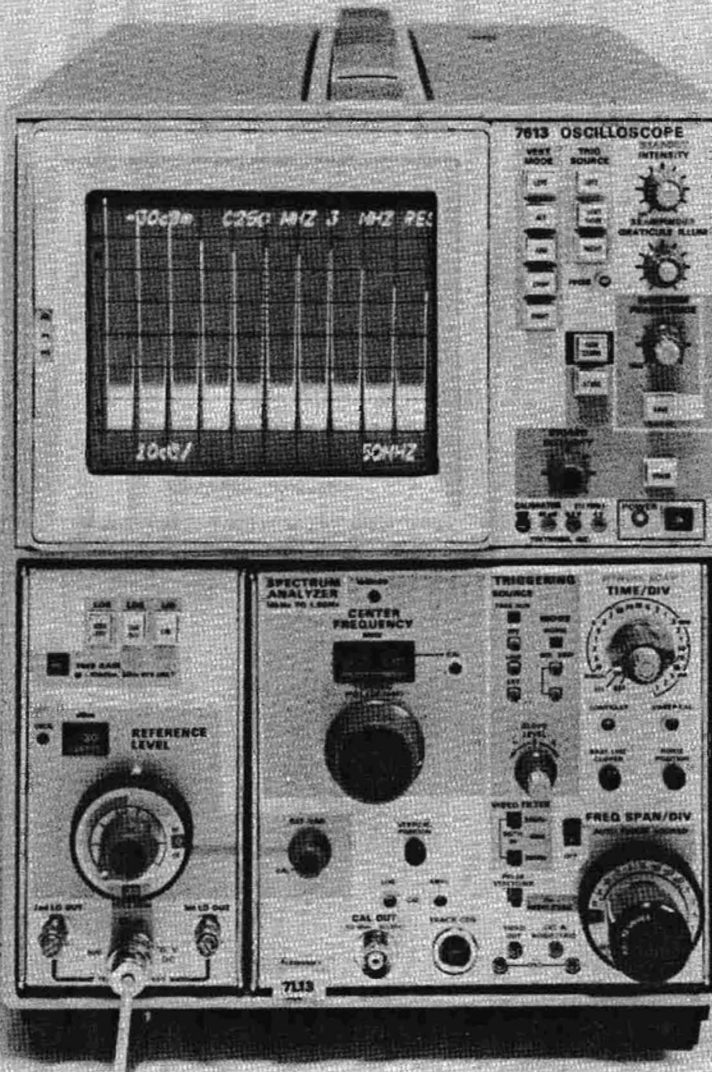


F. Telewski

30 Hz resolution at gigahertz frequencies— a new direction in spectrum analysis

For some years the needs of high-frequency spectrum analysis in the area of DC to 2GHz have been satisfied by a number of instruments whose incidental FM was in the order of 200 Hz. While these instruments have served well they do not permit exacting measurements in the areas of spectral purity and close-in distortion. As a result, the user is often compelled to adopt alternate test procedures which require the use of down-converters and low-frequency spectrum analyzers or wave





analyzers. The cumbersome nature of these measurement systems coupled with the tightening of signal specifications by governmental regulatory agencies has created a need for a high performance, high-frequency spectrum analyzer.

Performance Goals

At inception, the 7L13 program aimed at reducing internal FM and drift by an order of magnitude with commensurate improvement in resolution capability. Keeping in mind that most spectrum analyzers are already somewhat difficult to operate, these improvements could not be accomplished at the expense of operational ease. Indeed, additional improvements in operational simplicity should be sought.

First Local Oscillator

It is the local oscillator system that determines the performance achievable in most spectrum analyzers. An examination of the oscillator system reveals that there are basically two oscillators under consideration. These are the 1st L.O. (2.1 - 3.9 GHz) and the 2nd L.O. (2.2 GHz) as shown in Fig. 1. The 3rd L.O. being crystal-derived at 95 MHz contributes negligible FM ($<<1$ Hz p-p) to the system.

It is common practice, as the frequency span is reduced, to phase lock the 1st L.O. to a fixed crystal reference oscillator, thus stabilizing it while shifting the sweep function to the 2nd L.O.[1] The rate of the crystal reference oscillator determines the range over which the 2nd L.O. must be swept in order to complete the frequency coverage between the discrete lock points. Hence, a low-frequency reference is desirable from the viewpoint of design ease in the 2nd L.O. system.

The choice of a crystal reference rate is compromised by the high phase noise associated with low-frequency references. The increase in noise arises from the requirement for a higher multiplication rate of the fundamental oscillator, whose behavior is characterized by the following equation:

$$DEG_{dB} = 20 \log M,$$

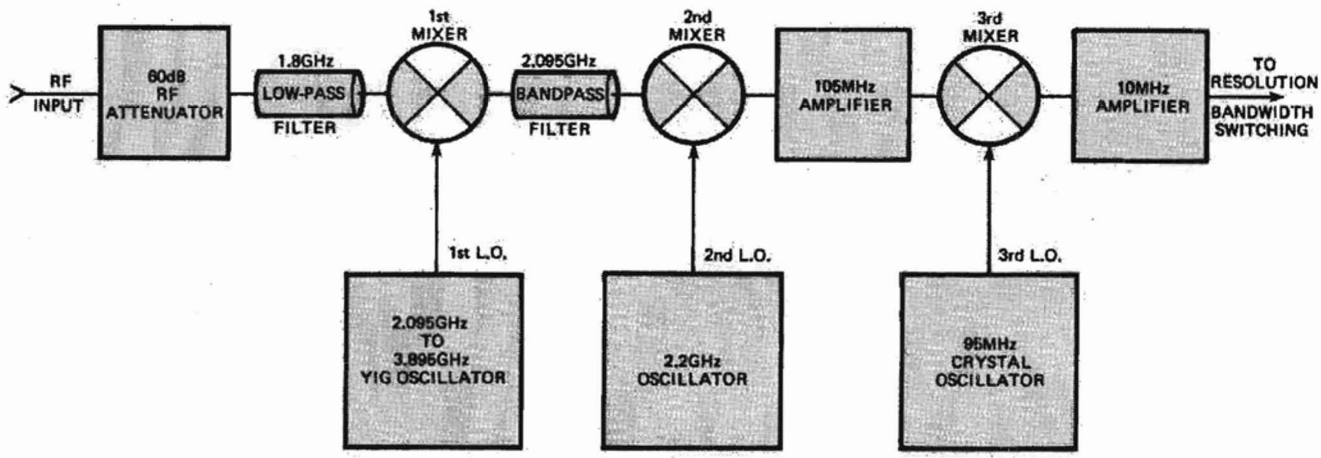


Fig. 1. Frequency conversion system of the 7L13.

Where: DEG is the degradation in spectral purity in dB and M is the multiplication factor. From the standpoint of phase noise it is desirable to choose a high rate for the crystal reference oscillator; however, conflicting requirements result. A 1-MHz reference rate is chosen as medium ground for the 1st L.O. reference. This permits a reasonable 2nd L.O. tuning range of 3 MHz as well as satisfying the phase noise constraint.

There is a unique bandwidth for any oscillator servo system which will yield optimum spectral purity. This bandwidth is determined by considering the relative spectra of the reference oscillator and the voltage-tuned oscillator (VTO) which is to be locked. In the 1st L.O. servo loop, the loop bandwidth is chosen such that the excellent line-width properties of the crystal reference are translated to the YIG VTO. The broad noise pedestal associated with the same reference is rejected in favor of the faster falling noise sidebands of the YIG VTO. The FM performance of this system, when operating in the lock mode, is in the 1 Hz p-p area.

2nd Local Oscillator

The 2nd L.O. usually consists of a varactor-tuned oscillator operating in the region of 1.5 to 2.5 GHz. Examination of the properties of this oscillator type indicates that under reasonable circumstances, 200 Hz is the minimum residual FM that can be expected as guaranteed performance without resorting to external stabilization techniques.

Improving the performance of the 2nd L.O. becomes a problem of designing an oscillator at a frequency where the desired stability and tuning range can be achieved. In this case a voltage-tuned oscillator operating from 16 to 19 MHz, and whose residual FM is approximately 1 Hz p-p, meets the requirements of a reference for the 2nd L.O. system. The stability properties of this reference oscillator are translated to 2.2 GHz by a type-two frequency servo system as indicated in Fig. 2. The unstable 2.2 GHz oscillator, collector tunable over a ± 1.5 MHz range, is heterodyned with a crystal-derived 2182.5-MHz (FM <1 Hz p-p) signal. The product at 17.5 (± 1.5) MHz is phase compared

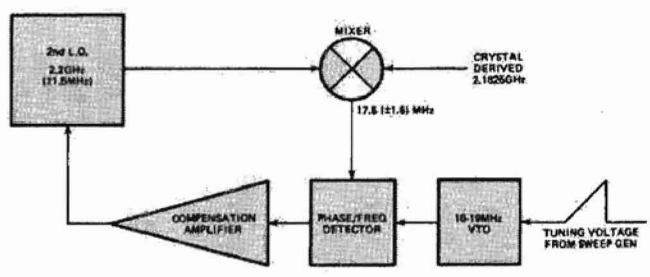


Fig. 2. Second L.O. stabilization system.

with the 16 to 19 MHz reference oscillator and the resultant error signal is amplified and fed back to the collector of the 2.2 GHz oscillator. Thus, the 2.2 GHz L.O. is synthesized in such a manner that it replicates the product of the 16 to 19 MHz oscillator and the 2182.5 MHz crystal-derived source within the bandwidth of the servo system. The complete 2nd L.O. system of the 7L13 exhibits a typical incidental FM of 1 Hz p-p.

A major distinction in the operation of the 2nd L.O. servo system (as opposed to the 1st L.O. loop) is that it is functional in all modes of 7L13 operation. The 2.2 GHz oscillator is never allowed to assume a free running mode and is under the control of the 16 to 19 MHz VTO from the time the instrument is turned on. Consequently, there is no mention of a 2nd L.O. lock mode on the analyzer front panel, and the stabilization of the 2nd L.O. in no way complicates the use of the instrument.

30 Hz Resolution Filter

In order to exploit the extraordinary stability of which the 7L13 local oscillator system is capable, a 30-Hz resolution position was made available to the user. In light of the fact that the widest resolution bandwidth in the instrument is 3 MHz, a center frequency of 10 MHz is chosen for the final IF. In order to keep system complexity to a minimum, this requires that the 30-Hz resolution filter be at 10 MHz as well.

This filter is of the well known lower sideband ladder design (Fig. 3). It employs three quartz resonators whose unloaded Q is in excess of one million and has a nominal 60:6 dB shape factor of 10:1. These resonators, when exposed to temperature variations encountered in the instrument (0°>50°C), are prone to alter their center frequency by a large fraction of the filter bandwidth. In order that the 30 Hz filter be able to maintain its bandpass characteristics under conditions of varying temperature, the quartz resonators are required to have matched temperature-versus-frequency properties.

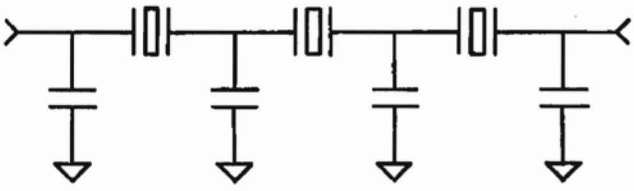


Fig. 3. Simplified circuit of the 30-Hz crystal filter.

Frequency Readout and Tuning

The availability of high linearity (typically .1%) YIG-tuned oscillators prompted the use of a digital frequency readout. This is accomplished by a digital voltmeter (DVM) which monitors the tune voltage of the 1st L.O. The frequency information obtained from the DVM is multiplexed and displayed both on the front panel, by a light-emitting diode display, and on the analyzer screen via the Tektronix CRT READOUT system. This permits the user to measure frequency to an accuracy of ± (5 MHz + 20% of the frequency span per division); 20% of a division being as close as one can typically judge the signal position, taking into account the effects of observation and the geometry of the display.

Simplification of operation was achieved through the development of a single-knob tuning scheme. Previous analyzers have often had two or more tuning knobs; and depending upon what mode the analyzer was operating in, inadvertent adjustments of the wrong tuning knob could cause severe frequency disturbances in the instrument. This problem is eliminated in the 7L13 through a mechanism employing two magnetic clutches and a self-centering potentiometer. When this system is operated in spans where the 1st L.O. is stabilized, the 2nd L.O. potentiometer clutch is engaged. Starting from a centered position, it prohibits one from achieving lock with the 2nd L.O. tuning control against one stop. Further, access to the 1st L.O. potentiometer is denied the user by disengaging the 1st L.O. potentiometer clutch so that he cannot mistakenly tune the 1st L.O., break lock, and lose his display. When returning to spans which do not require 1st L.O. stabilization, the clutches alternate state returning the 2nd L.O. potentiometer to its centered position and permitting tuning of the 1st L.O.

Convenience Features

We have come to expect such user conveniences as absolute amplitude calibration, freedom from spurious, automatic frequency stabilization, coupled span and resolution controls, display warning indicators and such in our high performance spectrum analyzers; and indeed they are all present in the 7L13. The 7L13 goes a step beyond and introduces the concept of full parameter readout to spectrum analysis (Fig. 4). All pertinent information, i.e., center frequency, resolution bandwidth, span, video filtering, vertical scale factor and power reference level may be viewed at a glance or permanently recorded by a photo of the display.

Performance

The graph of frequency tuning range versus resolution on page 3 shows the performance of the 7L13 and other instruments currently available. As is evident, the 7L13 represents a significant breakthrough in the area of high resolution, high-frequency spectrum analysis. The 7L13 has achieved a high degree of synergism with respect to spectral purity, resolution and drift. The instrument is not limited by the cleanliness of its oscillator system, as is so often the case with other high-frequency analyzers. As Fig. 5 shows, the shape of the 30-Hz resolution filter is clearly defined for well over 60 dB. This performance, familiar to users of low-frequency spectrum analyzers, is uncommon above a few hundred megahertz and due largely to the very conservative 10-Hz FM specification of the 7L13.

Resolution is a significant feature of a spectrum analyzer. Fig. 4 illustrates a 1476-MHz carrier, amplitude modulated at 50-Hz rate with both sidebands distinctly resolved. Fig. 6 shows the same carrier modulated at a 400-Hz rate along with residual 180-Hz line-related modulation on the carrier source 60 dB down.

The question of how long a given stable signal will remain on the display may be resolved by the drift specification. Just how well the 7L13 conforms to its 2 kHz/hr drift specification is evident in Fig. 7. This time-lapse photograph, made at hourly intervals, reveals a total drift of 4 kHz in 6 hours with 1.2 kHz occurring in the first hour.

All of the foregoing performance features of the 7L13 would lose much of their impact if the analyzer were not highly immune to intermodulation distortion. It is this property which in large part determines whether the display on the analyzer is real. Returning to Fig. 5, one can see that, in this 2-tone test at 1555 MHz with 500-Hz tone separation, there are no visible 3rd-order intermodulation products.

In general, it is instruments like the 7L13 which will ease the burden of making critical spectral measurements at high frequencies. And this ability will set the direction for future improvements in communication equipment performance.

Acknowledgments

As with any program embodying the complexity of the 7L13, there are more people involved than can be listed. All should feel a sense of satisfaction from their role in the development of this instrument. The principle contributors, other than the author as project manager, were electrical design: Mike McMahon and Jack Reynolds; mechanical project engineer: Leighton Whitsett; mechanical design: Jack McCabe and Jim Wolf.

[1]Telewski, "Freq. Stab. Tech.," TEKSCOPE, Jan. 72, pp. 10-11.

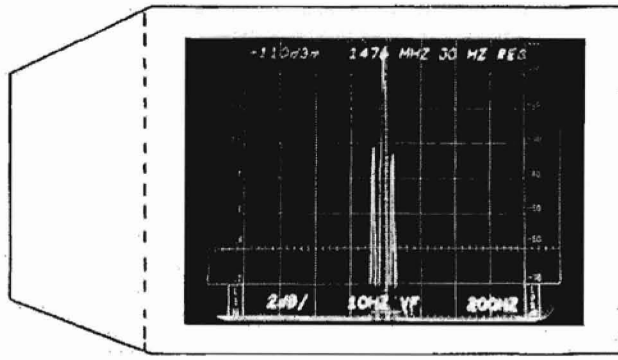


Fig. 4. 1476-MHz carrier modulated at 50 Hz. Note full parameter readout.

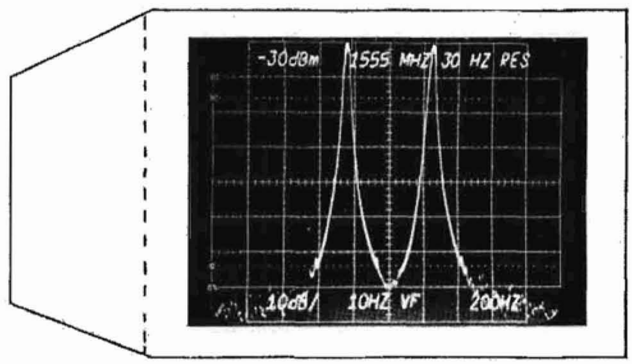


Fig. 5. Two-tone test at 1555 MHz shows freedom from distortion along with spectral purity and resolution filter shape.

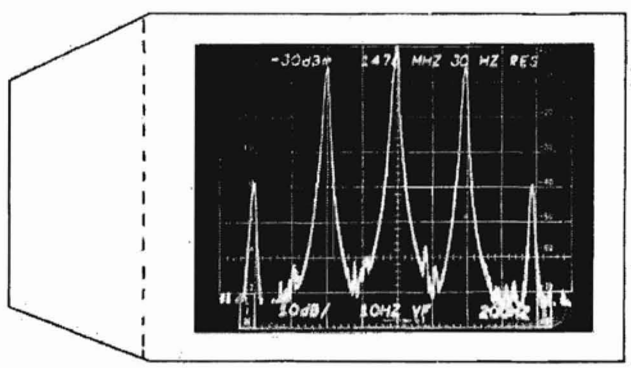


Fig. 6. 1476-MHz carrier 100% AM modulated at a 400-Hz rate.

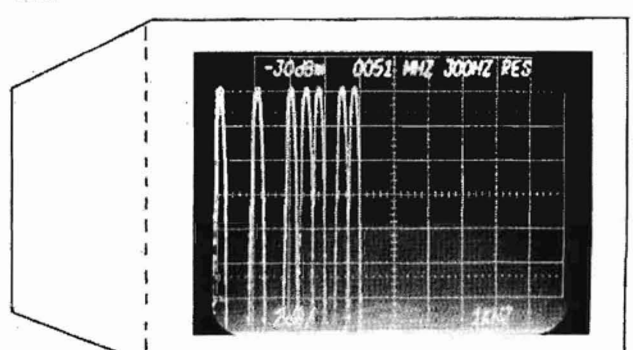


Fig. 7. Time-lapse photo taken over a 6-hour period shows excellent drift characteristics of the 7L13.

CRT READOUT – nicety or necessity?

When the 7000-Series Oscilloscopes were being conceived much discussion centered around a scheme to present alphanumeric information on the CRT along with the waveform. Would the benefits derived justify the engineering effort required? What about the added cost to the customer who didn't need or want readout? These and related questions consumed hours of discussion.

The question of added cost for those not needing readout was neatly resolved by placing the bulk of the readout circuitry on a single printed circuit board. Easily installed or removed, readout could be included at the time the instrument was ordered, or added later at the customer's preference. Only time could adequately answer the question of whether the benefits would justify the effort required.

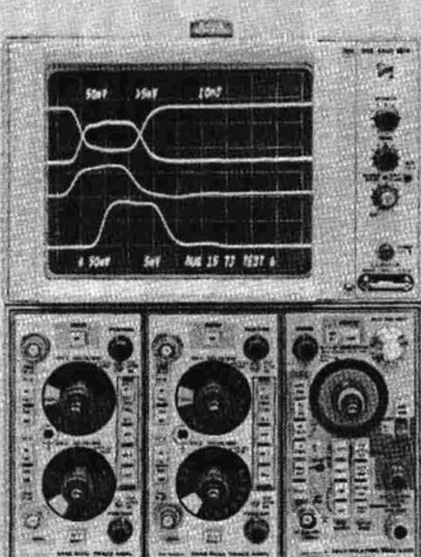
How It Works

Here, briefly, is how the readout system works. The system uses an electronic character generating circuit which time shares the CRT with the normal scope functions. The characters are formed by a series of X and Y analog currents developed by Character Generating I.C.'s. A set of 50 different characters are provided, with the capability to add others as the need arises. Included are all of the numerals, most of the alphabet in upper case, the symbols, p, n, μ, m and other special symbols.

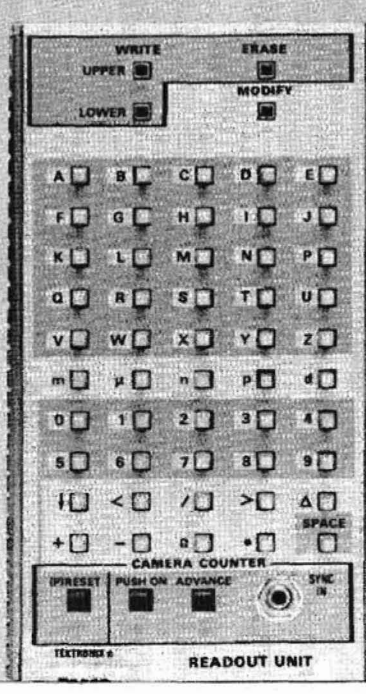
To minimize coding complexity an analog coding scheme was developed in which data is encoded by means of resistors and switch closures. This data is generated in the plug-in by connecting these resistors between time-slot pulses and data output lines via the appropriate switch. The coding scheme includes two channels for each plug-in so that dual trace amplifiers and delaying/delayed time bases can be accommodated. A maximum of eight words can be displayed, corresponding to two channels for each of four plug-ins. The position of each word on the CRT is fixed and related to the plug-in from which it comes. Each channel will display one word having up to ten characters. The characters are normally written without redundant spaces, but spaces can be called for in the code if desired. Only those channels in use have their readout displayed.

Some Benefits of Readout

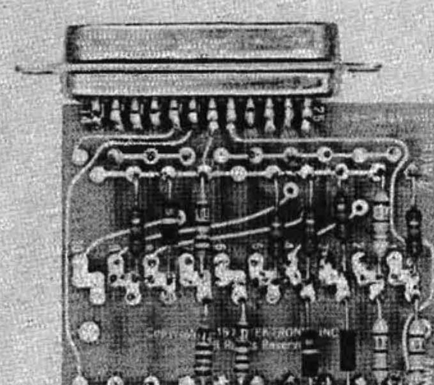
Now, what are some of the benefits afforded by CRT READOUT? To those whose work entailed photographing the waveform a major benefit was immediately apparent. The vertical deflection factors and sweep rates could be recorded right on the film with the



The 5403 Oscilloscope features 60-MHz bandwidth, plug-ins and CRT READOUT.



7M13 Readout Unit for the 7000-Series.



Optional readout programming board for the 5403.

displayed waveform. This would be a real convenience and time saver.

Another major benefit was the reduction of operator error in making measurements. More than one piece of research has had to be redone because of faulty data due to probe attenuation or uncalibrated knob settings going unnoticed. With CRT READOUT, the scale factor at the probe tip is automatically indicated when the proper probe is used. An uncalibrated knob setting is denoted by displaying < or > before the reading, e.g., <500 mV.

And then came a major breakthrough in oscilloscope capability. With the introduction of the 7D14 plug-in the oscilloscope became a 500 MHz digital counter[1]; the CRT READOUT serving as the display for the counter. And the oscilloscope/counter combination opened the door to previously difficult or impossible measurements. For example, selectively-gated counter measurements could now be made easily and accurately.

Another digital plug-in added digital voltmeter and temperature measuring capabilities. A digital delay plug-in provided a digital delaying time base and the ability to delay by a selected number of events. Spectrum analysis was included with reference level, dB/div, frequency span, resolution and other calibrated parameters all displayed by CRT READOUT.

Another significant measurement capability was introduced with the Digital Processing Oscilloscope. This instrument marries the oscilloscope to a computer or desk-top calculator. Here, again, CRT READOUT plays a vital role in displaying the parameters of the signal displayed on the screen, which may be considerably different from the signal fed to the oscilloscope input.

Getting a Word In

It didn't take long for customers to voice a need for putting their own words in the readout—information like the date, test number or the engineer's name. To accommodate these needs a "typewriter" plug-in was developed. The 7M13 Readout Unit provides a front-panel keyboard to write alphanumerics and a selection of symbols. Two ten-character words can be written on the CRT screen, one at the top and one at the bottom, in the position associated with the selected plug-in slot.

CRT READOUT in a Low Cost Scope

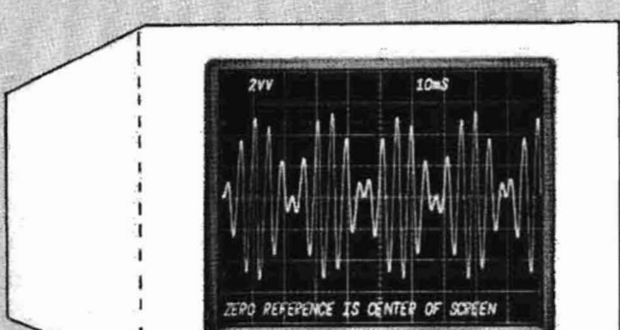
Because of its proven value, CRT READOUT is also included in the new 5400 Series, a line of low-cost, 60 MHz, plug-in oscilloscopes. Here again provision is made to insert two ten-character words of your own choice in the readout via a 25-pin connector on the rear panel of the scope. An optional plug-in program board makes it easy to build your own words.

Summary

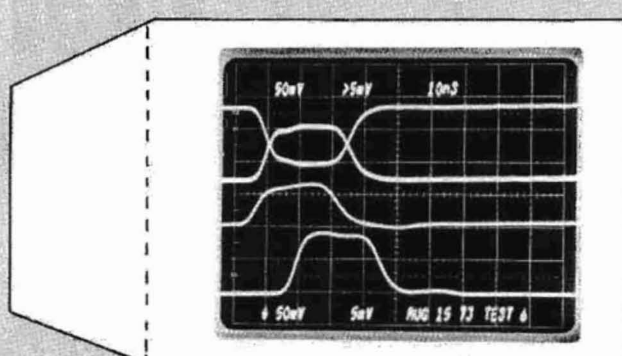
CRT READOUT has proven to be much more than just a convenience, it is the key that opens the door to new measurements for the oscilloscope user. Just what the total benefits will be remains to be determined. We're still discovering new ones right along.

[1]Tekscope, January 1973, "A new world of measurements for the oscilloscope."

TEST 10



The readout in this photo was programmed by the computer in a Digital Processing Oscilloscope system. The double V indicates the waveform is the resultant of two voltage signals multiplied together.



This photo was dated and identified as Test 6 using the optional readout programming board in the 5403.

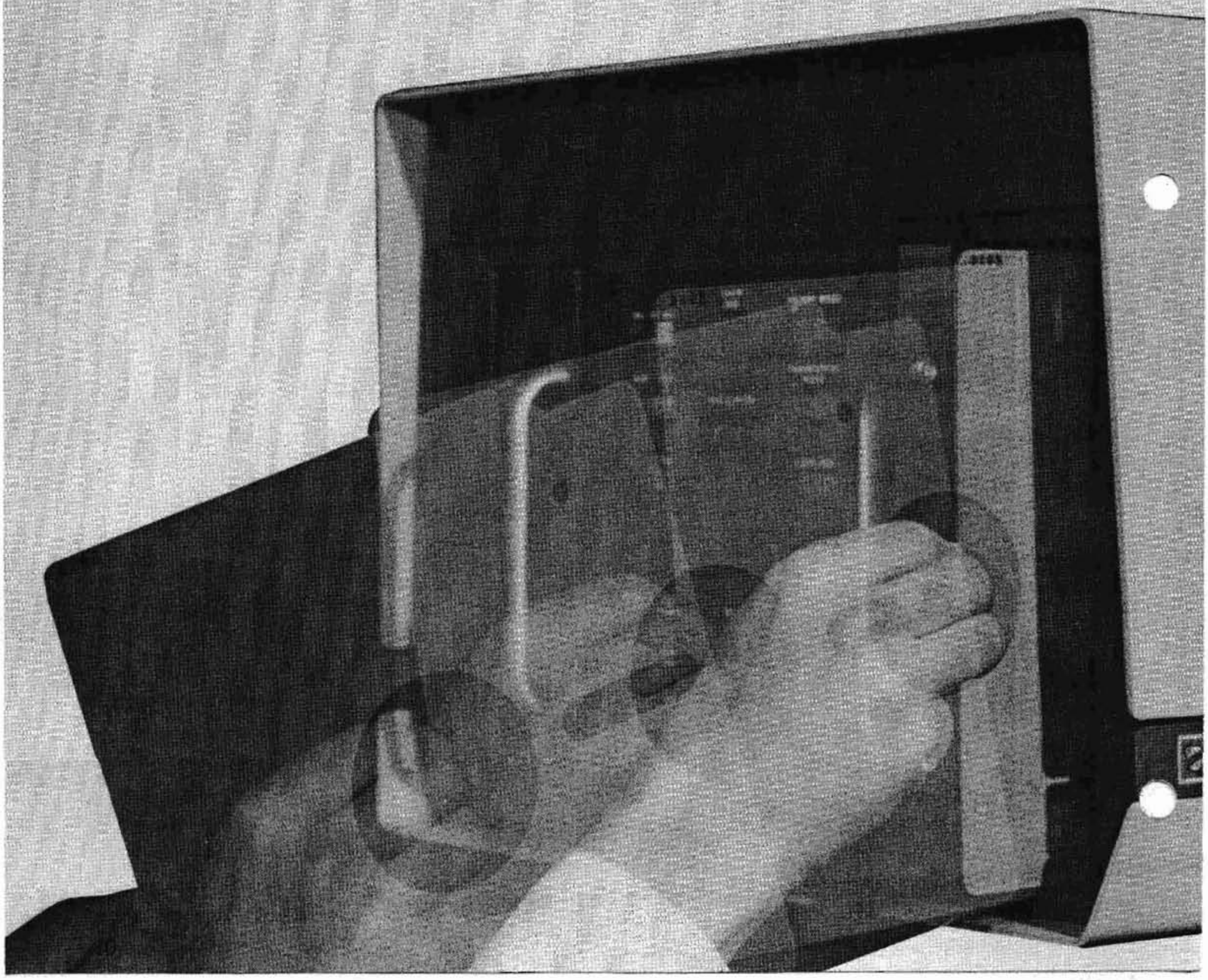
B ☐ **20mV**

Teknique

Flexible disc measurements simplified by digital delay

Signals from a flexible disc and its associated circuitry can be measured using a conventional delaying sweep. However, jitter caused by small speed variations in the rotating disc can make the display difficult to interpret. And when you consider that there may be 100,000 data bits on a single track you can appreciate the difficulty of locating a particular bit. The 7D11 Digital Delay Plug-in eases the task considerably.

The 7D11 can be used in any 7000-Series Oscilloscope having CRT READOUT. The plug-in has two basic modes of operation. The first is a Delay-by-Time mode, where a highly accurate internal clock is the time base from which delays are derived. Digital delays from 100 nanoseconds to 1 second,



in 100-ns increments, are available in this mode. A helidial-controlled analog delay provides an additional 0 to 100 ns of delay providing time delay resolution up to 1 ns.

The second mode of operation, Delay-by-Events, is the mode we're most interested in for this application. In this mode the 7D11 counts arbitrary trigger events, and delivers an output (notifies the delayed sweep) when the preselected number of events is reached. The unit can count events from 1 to 10,000,000 occurring at rates up to 50 MHz, and the events can be periodic, aperiodic, and contain instability such as jitter and drift.

To determine when to start counting the selected number of events, we need to provide a related synchronization pulse to the Events Start Trigger input of the 7D11. This could be the origin pulse, or, perhaps, a sector pulse from the flexible disc, depending on the measurement to be made.

Now let's take a look at some measurements on the flexible disc system. We will be working with the Memorex 651 Flexible Disc Drive. This system uses a disc speed of ≈375 RPM. Depending on user requirements, the data may be organized on the disc in multiple records per track (sector) or single record per track (index) format. There are 32 sectors and 64 tracks on the disc. Fig. 1 shows the format for each mode of operation.

The clock frequency used is 250 kHz. The clock is recorded on the track along with the data to permit accurate readout of data with variations in disc speed. Fig. 2 shows the relationship between the index and sector pulses, and the clock and data pulses. The READ

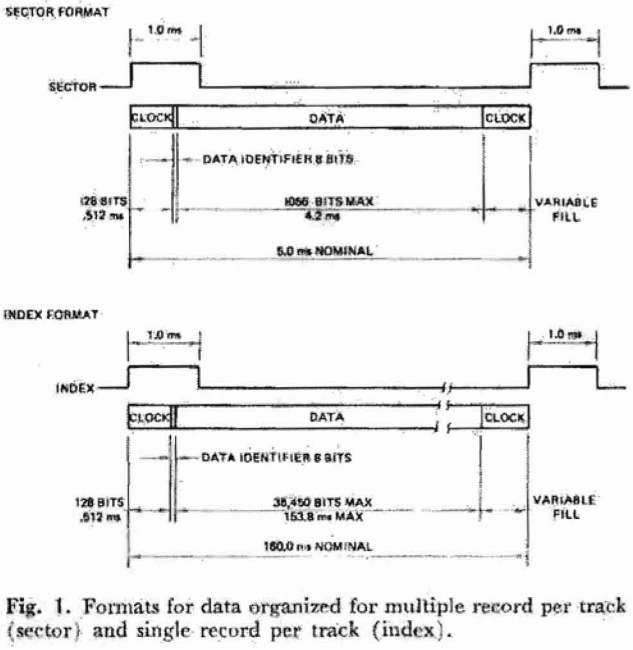


Fig. 1. Formats for data organized for multiple record per track (sector) and single record per track (index).

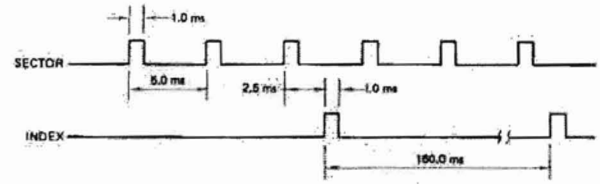


Fig. 2 (a) Timing relationship between the index and sector pulses.

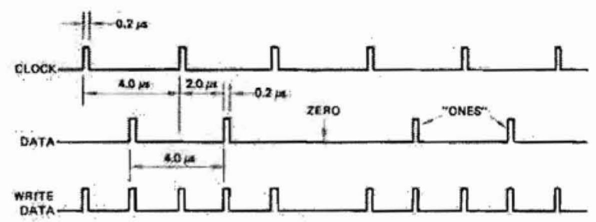


Fig. 2 (b) WRITE data timing and signal waveforms.

head reads the combined clock and data pulses recorded on the disc. The READ logic amplifies and separates them into two outputs: separated clock signals and separated data signals.

Signal Variations from Track to Track

One of the problems encountered in using a disc is the change in amplitude of the signal on the disc as you move from an outer track to an inner track. Fig. 3 (a) is the signal from Track 00 and 3 (b) the signal from Track 63. The bottom waveform in each photo is the analog signal from the READ head; the top waveform is the signal converted to a negative-going TTL-compatible pulse. You will note the events count is 1247. This indicates we have triggered the EVENTS START from one sector pulse and delayed out to permit us to view the start of data in the next sector. The shift of the data to the left in Fig. 3 (b) is due to the fixed spacing between the WRITE and READ heads causing us to miss more of the 136 bits between the start of the sector pulse and the start of data as we move toward the center

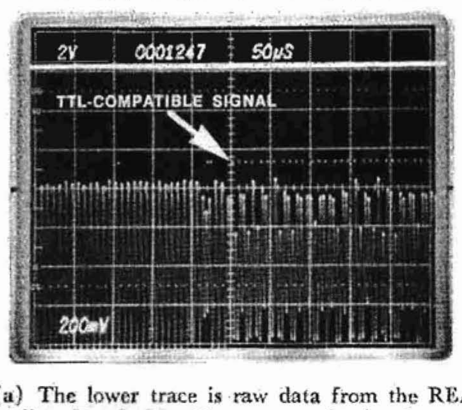


Fig. 3 (a) The lower trace is raw data from the READ head while reading Track 00. Upper trace is signal reconstituted in TTL-compatible format.

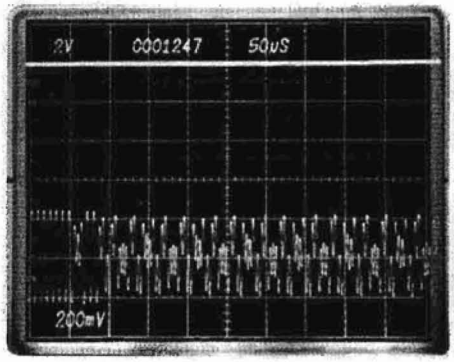


Fig. 3 (b) Same signal source as in Fig. 3(a) read from Track 63.

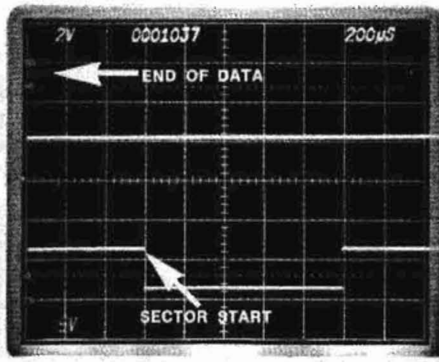


Fig. 5. Time interval from end of data in one sector to start of next sector pulse is easily viewed with the 7D11.

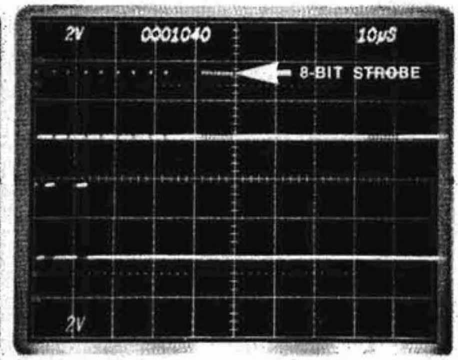


Fig. 7. An events count of 1040 takes us near the end of a sector to view the 8-bit strobe pulse moving data from the shift register to the computer terminal.

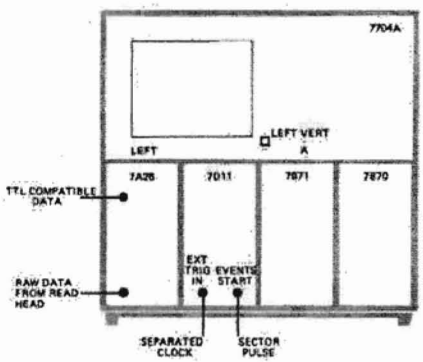


Fig. 4. Setup for making measurements displayed in Figs. 3(a) and 3(b).

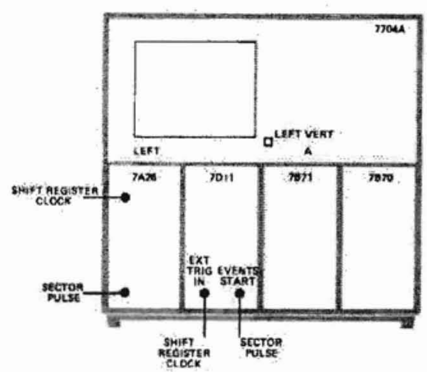


Fig. 6. Setup for making measurement displayed in Fig. 5.

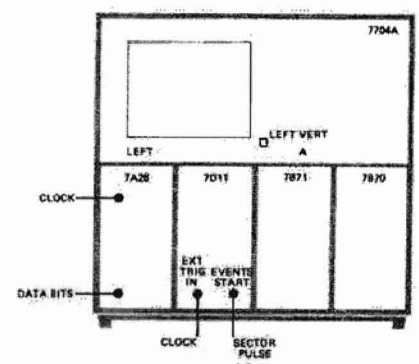


Fig. 8. Setup for making measurement displayed in Fig. 7.

of the disc. The setup to make this measurement is shown in Fig. 4.

Another point of interest in the system is the interval from end of data to the start of the next sector. This is shown in Fig. 5. The upper trace shows the data ending 100 μs from the start of the sweep. The lower trace shows the next sector pulse starting approximately 500 μs later. The events count of 1037 was selected to place the leading edge of the sector pulse conveniently on the vertical graticule line. Fig. 6 shows the 7704A setup for this measurement.

The photo in Fig. 7 shows some interesting sets of signals in the system. There are 1048 data bits recorded per sector. An events count of 1040 was selected so we could view the last data in the sector and check for the 8-bit strobing pulse that would transfer the data from the shift register to the computer terminal. The following 8-bit strobe pulse transfers the shift register to the next character. Fig. 8 shows the setup for this display.

Summary

These are just a few examples of the use of the 7D11 Digital Delay unit in making measurements in a flexible disc system. It provides a convenient means of locating and viewing any of the thousands, or in some cases, millions of bits of data present in the disc system.

Other digital plug-ins such as the 7D12 A/D Converter and the 7D15 Universal Counter/Timer are also valuable aids in making accurate voltage and timing measurements in a disc system.

Servicescope

Servicing the 465 portable oscilloscope

The first thing you need to know in servicing a product is how to get the cabinet off. This is less than obvious in much of the packaging used today. You will find it takes a little longer to remove the 465 cabinet than you're accustomed to with the 453. But there's a good reason. The 465 is six pounds lighter than the 453A. And part of the weight reduction is achieved by using the cabinet to mechanically strengthen the package. This is accomplished by extending the cabinet slightly beyond the rear panel of the instrument. When the rear ring assembly, with the feet attached, is installed and tightened down it compresses the cabinet and pulls on the main chassis member, stressing both of them. This stress adds strength to the package.

The best procedure for removing the cabinet is to put the front cover in place, set the instrument on the front cover and remove the six screws holding the rear ring assembly. Four of these serve as mounting screws for the rear feet. The cabinet is then slid off vertically. When replacing the cabinet on

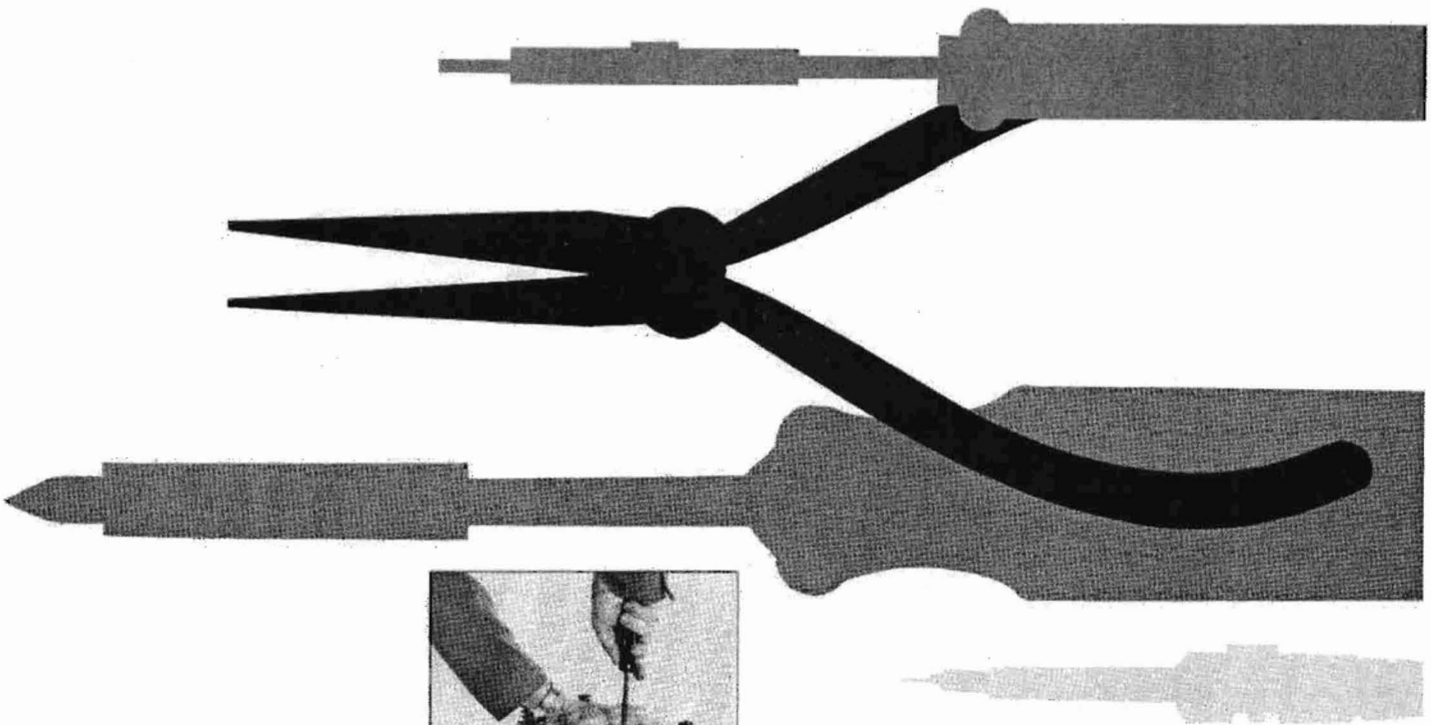


Fig. 1. The 465 cabinet is removed by loosening six screws on the rear panel.

earlier instruments, take care that the cabinet clears the components on the trigger-view board. In later instruments this circuitry is laid out on the trigger board.

It would be well at this point to make sure the instruction manual you are using matches the instrument you are servicing. Tektronix has always followed the policy of modifying the circuitry to improve performance and reliability as the occasion arises. Modification information is added in the back of the manual to keep it current with the instruments being shipped.

The Power Supplies

When a problem area is not readily apparent from front panel indications, a good place to start troubleshooting is the power supply. Temporarily-high line voltage sometimes causes the line fuse to blow. In instruments below SN B080000, circuits powered from the +120 V supply are protected from high line voltage by Q54 (Q1514 in some instruments). Should the line voltage exceed a given level, Q54 conducts placing a short across the transformer secondary and blowing the line fuse. When replacing the fuse you should use the specified value to prevent damage to the circuits protected by Q54. If the line voltage in your facility tends to fluctuate in the upward direction you may set the line Range Selector Switch Bar to the high position. The front-panel low-line light will come on should the line voltage fall below the lower limit of the regulating range selected.

Another problem you may encounter in the low-voltage supply is CR1512 shorting and taking out C1542. The cure for this is to remove CR1512. Do not discard this diode as it can be used in a modification to improve the high-voltage supply reliability.

The high-voltage supply is often difficult for many of us to troubleshoot. Here are some hints on servicing these circuits in the 465. The first step is to isolate the problem area. There are three major areas of concern: the high-voltage oscillator and DC-error amplifier, the over-voltage protection circuit, and the secondary load including the CRT and the high-voltage multiplier. By disconnecting the appropriate circuit the high voltage should come up. Try the following sequence:

1. Remove the CRT socket — this eliminates the CRT.
2. Disconnect CR1412—this eliminates the over-voltage protection circuit.
3. Remove Q1416 and place an 820 Ω to 1 kΩ resistor between the collector and emitter pins. This allows ≈ 8 ma of turn-on bias current to start the oscillator. If this does nothing, replace C1416 and C1419. (C1419 should be replaced anytime the high-voltage oscillator Q1418 is shorted.)

If at this point the high-voltage reading at TP1423 is ≈−400 volts, the high-voltage multiplier is most likely defective. In newer instruments this can be quickly checked by lifting the dummy resistor that connects the multiplier ground. Arcing from this point to adjacent circuitry sometimes occurs when this ground strap is lifted. For earlier instruments you will have to remove the vertical preamp board and the multiplier cover to get to the high-voltage transformer and multiplier connection. Lift the transformer lead and CR1421 from the mounting post on the multiplier, connect them together and dress them away from the mounting post to prevent arcing across. If the negative high-voltage supply comes up now, the multiplier is defective. A defective multiplier will also sometimes cause high-voltage fuse F1419 to blow.

Another condition that can effect the high voltage is leakage in diodes CR1482, CR1483, CR1487 or CR1488. These are in the CRT grid bias supply and can turn the beam on hard or turn it off so you have no intensity. Another point to check is pin 12 on the CRT; this should be +150 V. Leakage in C1427 may pull this point down in some instruments between SN B080000 and B130000.

Check to see whether R1427, which parallels C1427, has a zener diode in parallel with it. If not, your instrument doesn't have the high-voltage reliability modification and it should be installed. It consists of adding or changing just four components:

1. CR1476 located near Q1474 should be replaced by CR1512 which you removed from the low-voltage supply.
2. A 0.1 μF, 200 V capacitor should be added from the cathode of CR1476 to ground.
3. A 180 V zener, Tektronix part number 152-0289-00, should be paralleled with R1427 with the cathode to ground.
4. Lift the cathode end of CR1427 and add a 1.8 kΩ, ¼ W, 5% resistor between the cathode and the point to which it was soldered on the circuit board. This completes the modification.

The Sweep Circuit

The sweep circuit contains several feedback circuits and is difficult to troubleshoot unless you break the feedback loop. A convenient means of doing this is to pull the Disconnect Amplifier, Q1024. This causes one sweep to be generated and often provides a rapid clue as to what portion of the circuitry is in trouble.

The horizontal amplifier circuitry is push-pull and can be checked by the usual method of shorting the two sides by means of a jumper. Another useful technique is to swap transistors in each stage and see if the problem changes sides accordingly.

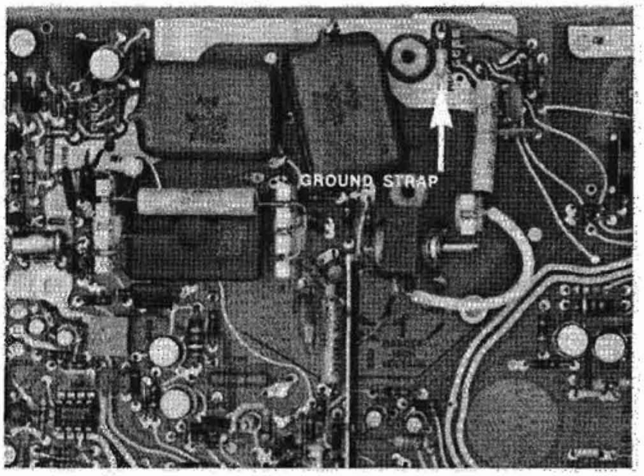


Fig. 2. A portion of the interface board showing location of the high voltage multiplier ground strap and other components.

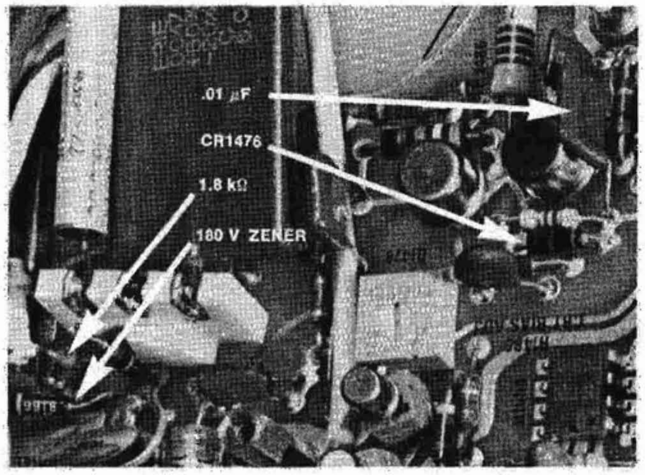


Fig. 3. A portion of the interface board showing the high-voltage reliability modification installed.

The Vertical Amplifier

If you have occasion to service several 465's you may note that some units have an integrated circuit output amplifier while others use discrete components. The front panel BEAM FINDER control provides a rapid means of detecting trouble in this circuitry. Pressing the BEAM FINDER button should bring the trace on-screen vertically. If it doesn't, look for the problem in the output amplifier circuitry.

Moving to the preamp, one of the more elusive problems you may encounter is an intermittent contact between transistors and their sockets. What usually happens, is the transistor is pulled from the socket, tested and found to be O.K. When the transistor is put back into the socket, the problem disappears. The basic cause seems to be a tendency for the contacts to "wick up" rosin and solder during the automatic flow soldering process. A change has been made in manufacturing procedures to overcome this tendency. If you suspect that you have this problem, you can clean the socket with isopropyl alcohol, using a wire to loosen the rosin inside. A camel hair brush works best in applying the isopropyl and a syringe is handy for blowing out dirt particles.

Another question often asked is how to get the transistor pairs used in the preamp, properly mounted in their heat sinks. The easiest way is to first insert the transistors in their sockets and then slip the heat sink loosely over them. Next, extract the transistors and heat sink together by gripping the heat sink firmly with a pair of pliers, and pulling. Continue to hold firmly with the pliers while tightening the screw in the heat sink. Then reinsert the transistors in their sockets.

While we're in the preamp area, another condition sometimes occurs that appears to be drift in the vertical attenuator compensation. In most cases this results from the technique used in making the adjustment. The compensation capacitors have a spring that provides tension. When making the adjustment it will help to "rock it in" to remove the torque portion of the spring tension. Just overshoot the desired setting a little and then back off to the proper point.

Mechanical Considerations

One of the unique components used in the 465 is the cam switch developed by Tektronix. These are relatively trouble-free but occasionally require cleaning of the contacts. Isopropyl can be used for this purpose. Here again you will find a camel hair brush handy. Do not use cotton swabs as they are prone to snag on contacts, damaging them.

Special care is needed when working on the vertical attenuator cam switches. The polyphenylene oxide boards are brittle and easily damaged by using too much force when tightening the screws holding the cam switch. Two fingers on the screwdriver will provide enough torque. These boards also are easily damaged by heat so when soldering on them, use a small iron and get on and off quickly.

Cleaning the Instrument

The same procedures and materials used to clean other Tektronix instruments can be used for the 465. For washing the entire instrument a solution of one part Kelite to twenty parts water can be used. For spot cleaning, especially in the area of the vertical attenuator boards, you should use isopropyl alcohol. Carbon-based solvents will damage the polyphenylene oxide boards used for the attenuators. This is also important to keep in mind when using spray coolants in this area.

INSTRUMENTS FOR SALE

360 Indicator, 126 Power Supply with cabinet, $145. Robert Kaplan, Ebasco Services Inc., 2 Rector St., New York, NY 10006. (212) 344-4400.

317, (2) 321A's. Lindsay Acuff, Cleveland Electric Co., 557 Marietta St. 1 N.W., Atlanta, GA. 30313. (404) 524-8422.

434 w/cart and accessories, unused. Roy Madison, 1606 18th Ave., PO Box 1088, Tuscaloosa, AL 35401. (205) 345-2990.

453A MOD127C in mint condition. $1750. Charles Boster, Box 2376, Apt. H-203, 635 Baker St., Costa Mesa, CA 92626. (714) 557-0792.

453, three years old, $1250. Fred Lindsey, Vallejo, CA. After 5:00 PM. (707) 644-7037.
503, good condition. $200. Ray Lefebrve, Electrical Eng., Louisiana State Univ., Baton Rouge, LA 70803. (504) 388-5241.

514D (7), 514AD, 511AD, 531 fair condition. Best offer. W. A. McConnell, Dutchess Community College, Poughkeepsie, NY 12601. (914) 471-4500, Ext. 268.

517, less power supply. Will trade for 530/540 Series vertical plug-in. Dr. Shuster, Box U125, University of Conn., Storrs, Conn. 06268.

517A w/power supply, no cables. As is $135. Type B plug-in, 122 preamp, 280 trigger. E.C. Fether, 8713 Marble Dr., El Paso, TX 79904. (915) 755-0226.

527 Waveform Monitor, MOD132. Thomas O'Brien, 2194 Coker Ave., Charleston, SC 29412. (803) 556-8824 (home), (803) 792-3030 (business).

531A, $400; 533, $450; B, $50; CA, $165. Exc. condition. Kurt Dinsmore, Box 67, Richardson, TX 75080. (214) 271-2431 or (214) 238-0591, evenings.

543B, 1A2 plug-in, good cond. $800 or best offer. Pat Young, (415) 654-6855.

545A w/cart, 2 ea. Best offer. Neria Yomtoubian, Master Specialties, 1640 Monrovia, Costa Mesa, CA 92627. (714) 642-2427, Ext. 218.

545A, RM 35A, 1A1, CA and two ea. 541's. Howard Baugh, Wyle Computer Products, Inc., 128 Maryland St., El Segundo, CA. (213) 678-4251.

547, 1A1, 1A5, like new, best offer. Paul Fincik, Automation Sys., Inc., 7031 Marcelle St., Paramount, CA 90723. (213) 634-5810.

INSTRUMENTS FOR SALE

549, 1A1. Maurice Bruneau, Nashua Corp., 44 Franklin St., Nashua, NH 03060. (603) 883-7711, Ext. 506.

549, $1000. Mike Surratt, OECO Corp., 712 S.E. Hawthorne, Portland, OR 97214. (503) 232-0161, Ext. 349.

561A/3A75/2B67, like new. Jack Gerylo, 5707 Santa Fe St., San Diego, CA 92109. (714) 453-4013.

661/5T4/4S1, clean, like new. Want Collins 30S1 linear or equiv. dollar value. Ed Valentine, Top-O-Hill Rd., Wappingers Falls, NY 12590. (914) 297-3461.

661/4S1/5T1, excellent cond. Sell or trade for real time scope around 10 MHz. George Capasso, 25 Quarry Dr., Wappingers Falls, NY 12590. (914) 297-7538.

3S7, 3T7 TDR plug-ins, never used. $950. Art Eberle, Columbia Gas Systems, 1600 Dublin Rd., Columbus, OH 43212. (614) 486-3681, Ext. 461.

2B67 and 3A74 to trade for 3B3 or 3B4 and 3A6. H. L. Beazell, 104 Key West Dr., Charlottesville, VA 22901.

202-2 Cart, $100; E Plug-in, $60. Neil Pering, 2803 Kipling, Palo Alto, CA (415) 321-2714 or Walt Sonnenstuhl, 41 Moraga Way, Orinda, CA 94563.

C-31 Camera, excellent condition. Reasonable. Mr. Sinclair, 160 E. 84th St., N.Y., NY 10028. (516) 234-0200 (days); (212) 861-9862 (evenings).

549 w/1A1. Bob Schmidhammer, Metric Data System, Rochester, NY. (716) 325-6550.

515, good condition, $300. Hal Greenlee, 430 Island Beach Blvd., Merritt Island, FL 32952. (305) 853-9991 (business), 636-0805, (home).

R5103N/D12, three 5A24N's. Almost new. Best offer. Maurice Asa, Box 2947, Rockridge Station, Oakland, CA 94618. (415) 654-2665.

2601, 26A1, 26A2, 26G3. John Foster, N/J Electronics, P.O. Box 577, Laramie, WY 82071.

211 (15). Richard Strickler, Storage Technology Corp., 2270 S. 88th St., Louisville, CO 80027. (303) 666-6581.

TELEQUIPMENT DM64, new. $1,000 or best offer. Alpha Labs, Inc., 2115 No. Piedras, El Paso, TX 79930. (915) 566-2927.

INSTRUMENTS FOR SALE

C-27R Camera, Polaroid roll film back and bezel. Good condition. $375. (203) 848-8614 after 7:00 P.M.

546 (2), like new, $1250 ea.; 543 w/CA, $750. Consider good cash offer. Ivan Sundstrom, 695 E. 43rd, Eugene, OR 97405. (503) 686-2380 evenings, weekends.

531A/CA/D. Wayne Siebern, St. Joseph Power & Light, 520 Francis, St. Joseph, MO. (816) 238-0025.

516, excellent condition. $500. Dave Friedman. (213) 837-3089.

564B w/2B67, 3A6, scope cart and C-27 Camera, new. Also 585A with 53/54G and scope cart. 661 w/4S1 and 5T1 and scope cart. Excellent condition. Chemistry Dept., Univ. of Bridgeport. (203) 384-0711, Ext. 382.

(3) 5103's. $450 ea. or best offer. Also (3) 5B10N's, (3) 5A18N's and (1) 5A21N. Jon Orloff, Elektros Inc., 10500 S.W. Cascade Dr., Tigard, OR 97223. (503) 620-2830.

INSTRUMENTS WANTED

160 Power Supply in working condition. Prof. Winthrop Smith, U46 University of Connecticut, Storrs, CT. (203) 486-4918.
321A. Marvin Loftness, 115 W. 20th, Olympia, WA 98501. (206) 357-8336.

422, 465 or any portable scope. H. O. Van Zandt, 18 Chandelle Dr., Hampshire, IL 60140. (312) 683-3690.

453 or 454. S. L. Shannon, G.T.W.R.R. Radio Shop, 105 Hampton, Battle Creek, MI 49016.

520 or 520A. Al Dodds, Applied Video Electronics, Inc., P.O. Box 25, Brunswick, OH 44212. (216) 225-4443.

555 with time bases, C-12 or C-27 Cameras. A. C. Smith, Jr., High Voltage Lab., Cornell Univ., 909 Mitchell St., Ithaca, NY 14850.

2-2A60's. Darwin Carner, General Electric, 3001 E. Lake Rd., Erie, PA 16501. (814) 455-5466, Ext. 2635.

2A63. Roy Schreffler, Box 531, Knox, PA 16232.

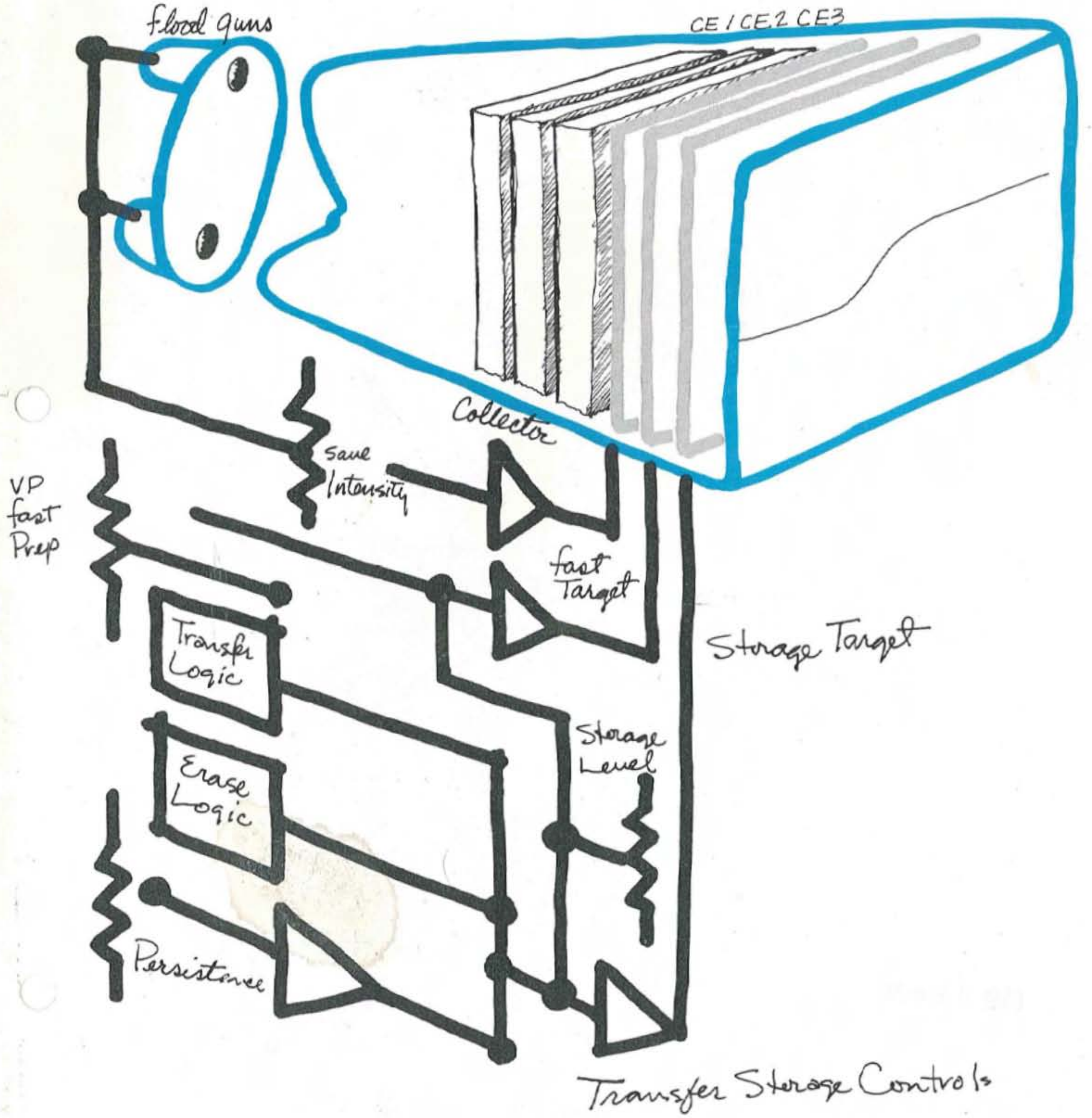
Plug-in vertical amplifiers for TELEQUIPMENT D43 scope. Wm. A. Richards, 46 Alderwood Lane, Rochester, NY 14615.

TELEQUIPMENT D67, D85. 453 or 422. Also 3B3 plug-in. Hal Greenlee, 430 Island Beach Blvd., Merritt Island, FL 32952. (305) 853-9991 (business), 636-0805 (home).

TEKTRONIX®
committed to technical excellence

TEKSCOPE

Volume 6 Number 2 Mar/Apr 1974



TEKTRONIX®
committed to
technical excellence

TEKSCOPE

Customer Information from Tektronix, Inc.
P.O. Box 500, Beaverton, Oregon 97005

Editor: Gordon Allison,

Contents

3 **A 1000 cm/µs storage oscilloscope**

Writing speed relationships and stored writing speed versus view time are discussed in this article on the new 7633 Storage Oscilloscope.

7 **Using your oscilloscope probe**

Part I of a two-part article discusses passive voltage probes. Knowing your probe's characteristics and how they affect the signals under test will help you make more meaningful measurements.

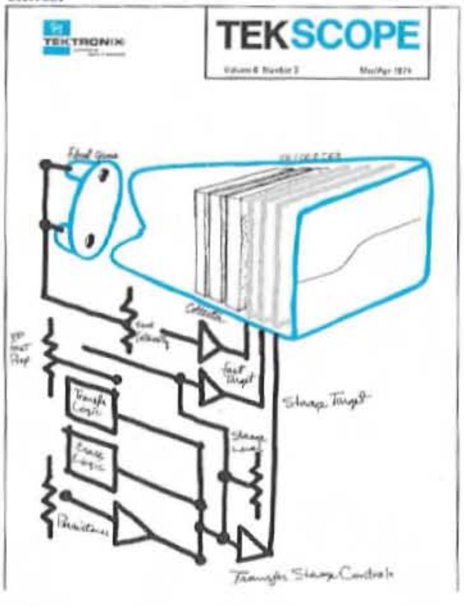
12 **Triggering the oscilloscope from logic signals**

A new low-cost instrument permits triggering your oscilloscope from any logic word up to four bits, and more by cascading instruments.

16 **Servicing the TELEQUIPMENT D67 oscilloscope**

Comprehensive trigger adjustment and sweep calibration procedures are included in this article on the low-cost D67 Oscilloscope.

Cover: New target designs and new operating modes yield direct-view storage writing speeds in excess of 1000 cm/µs. Transfer storage techniques produce fast writing speeds with relatively long viewing times.



A 1000 cm/μs storage oscilloscope

Gene Andrews

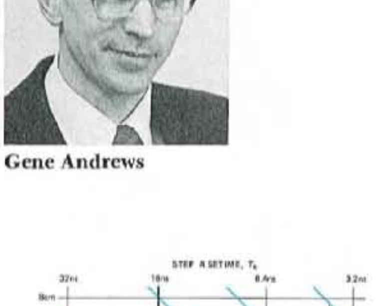


Fig. 1. This nomograph shows a writing speed of 1000 cm/μs will display a 3.5 ns risetime, 3.5 cm in amplitude and a 100 MHz sine wave of 3.2 cm.

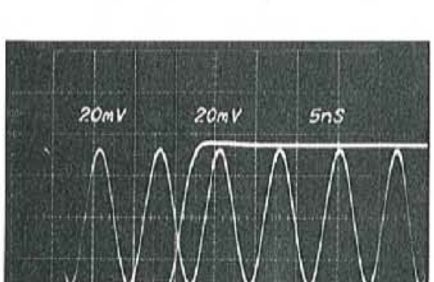


Fig. 2. A stored display of a sine wave and step of equal maximum speed. Note relative amplitude.

Just two years ago laboratory storage scopes with stored writing speeds from 100 cm/μs to 400 cm/μs were introduced. The fastest of these instruments could store single events having a risetime of 9 ns and 3.5 cm in amplitude. Now a new storage scope, the TEKTRONIX 7633, moves this performance up to 1000 cm/μs to capture single risetimes of 3.5 ns at an amplitude of 3.5 cm.

To relate this performance to your measurements let's review the speed needed for recording single sinewaves and steps.

Writing speed relationships

For sinewaves the maximum writing speed, WS, is measured in terms of frequency, f, and amplitude, $A_{\sim}$, as in Equation 1.

$$WS_{\sim} = \pi f A_{\sim} \quad (1)$$

$$WS_{\lrcorner} = k A_{\lrcorner} T_r \quad (2)$$

Equation 2 describes the maximum writing speed of the vertical edge of a pulse in terms of amplitude, $A_{\lrcorner}$, and 10 −90% risetime, T_r. The value of k ranges from 0.8 for a linear ramp, to 2.2 for single-pole RC response. A k value of 1.0 is suitable for typical step responses limited by a few poles.

A nomograph of Equations 1 and 2 is given in Figure 1, for the 10 MHz to 100 MHz range. Note that a 1000 cm/μs stored writing speed can record a 100 MHz sinewave 3.2 cm in amplitude, or a 3.5 ns risetime of 3.5 cm amplitude. From the nomograph one might say that 1000 cm/μs is 100 MHz storage, 100 cm/μs is 10 MHz storage, etc. (specifically for signals 3.2 cm in amplitude).

A sinewave and step of equal maximum speed are shown in Figure 2. The sinewave frequency is 70 MHz, and the step risetime of 5 ns corresponds to a system bandwidth of 70 MHz (from $T_r = 0.35/f$). The amplitude ratio, $A_{\lrcorner}/A_{\sim}$, equals 3.5/3.2. The displayed writing speed is:

$$WS_{\sim} = \pi f A_{\sim}$$

$$= 3.14 \times 70 \text{ MHz} \times 6.4 \text{ div} \times 0.45 \text{ cm/div}$$

$$= 630 \text{ cm}/\mu s$$

Thus far we have neglected the horizontal, or time base, component of speed. In Figure 2, where the horizontal speed is one-sixth that of the maximum vertical speed, only a 1% increase in speed results from including the horizontal component. If the time base speed is doubled, to one-third the maximum vertical speed, the increase goes up to 5%. These small corrections permit neglecting the horizontal component for most maximum speed considerations.

Although sinewaves are not typical of signals we normally record, they are used for speed verification for a couple of reasons—an accurate speed is easily set up by selecting frequency and amplitude; and speed through an area is verified in a single pass since the maximum speed occurs twice each cycle.

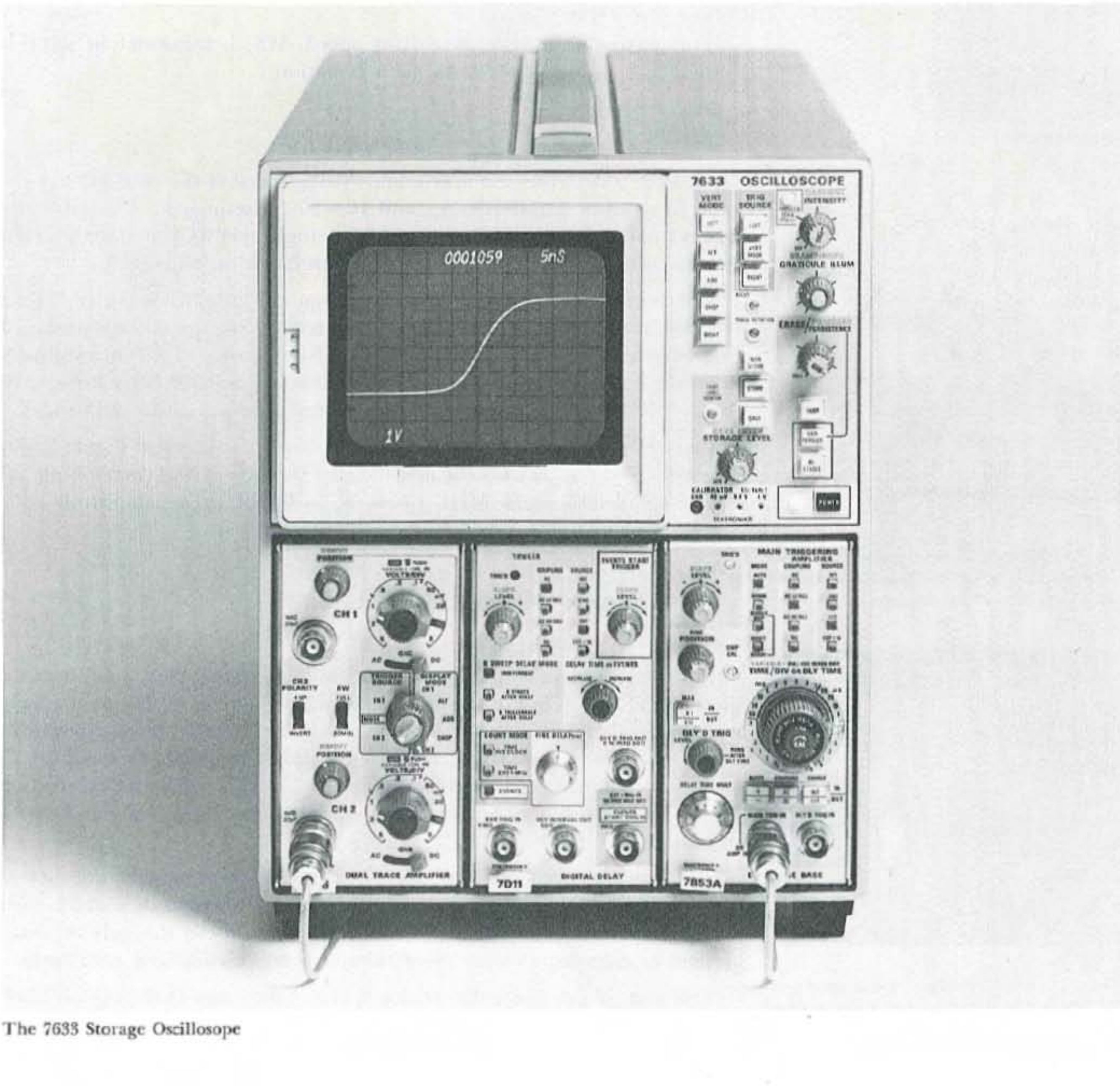
Now that we can relate the writing speed of the scope to the signals it will capture, let's look at the operation of the storage crt used in the 7633.

The transfer storage crt

The crt used in the 7633 is, in principle, a transmission-modulation reading direct-view storage tube. In more common terminology we know it as halftone transmission storage or variable persistence storage. One of the undesirable characteristics of the halftone transmission storage tube is that unwritten areas of the storage target begin to fade positive due to positive ion generation in the flood electron system of the tube. As a result, after a few minutes, signals can no longer be distinguished from the bright background.

To overcome this limitation in view time, we have added another storage target to the conventional halftone storage tube (see Figure 3).[1] The two targets are called the fast target and storage target, respectively. The image is first written on the fast target and is then transferred to the storage target which, by proper selection of operating voltage, can be operated in either a variable persistence mode or a bistable mode. In the bistable mode the image can be stored until you choose to erase it.

Perhaps at this point we should clarify the use of the terms "variable persistence" and "halftone." The crt can display shades of gray, but since both the instrument and the crt are optimized for high-speed variable persistence performance rather than multi-tonal performance, "variable persistence" is the more appropriate term.



The 7633 Storage Oscillosope

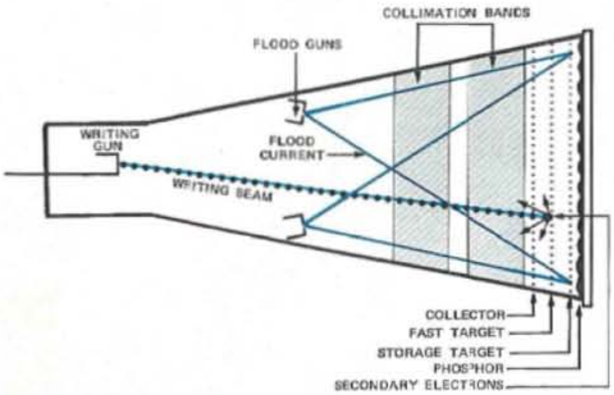


Fig. 3. The transfer storage tube contains two storage targets to achieve fast writing speeds with long viewing times.

Writing speed and view time

There is a direct relationship between writing speed and view time. To better understand this relationship let's look at the factors determining the writing speed of a storage crt as shown in Equation 3.

$$WS = \frac{(I_b/TW)(\delta\text{-}1)}{(\Delta V)(C/A)} \qquad (3)$$

Where:

WS is stored writing speed.

I_b/TW is the current density at the target—beam current, I_b, per trace width, TW.

$(\delta\text{-}1)$ is the net positive electron charge for each electron arrival—secondary emission yield, δ, minus the arriving electron.

ΔV is the minimum voltage change on the target surface that results in writing for the specified area.

C/A is the capacitance of the target surface to the target mesh per unit area.

For further discussion, the parameters ΔV and C/A are combined to $\Delta VC/A$, the charge sensitivity of the target.

We noted earlier that view time is limited by the number of residual gas atoms near the storage target, being ionized by flood electrons and collecting on the target surface charging it positive. The signal waveform "washes out" as the background increases in brightness until the signal can no longer be seen. The faster the writing beam moves across the target, the less the charge placed on the target, and the more rapidly the trace is obscured by ion activity.

Trading writing speed for view time

Figure 4 shows some of the writing speed versus view time trading to be made in using a given variable persistence scope and in choosing a particular crt target. Note that a range of writing speed and view times are available. At the highest writing speed we see the sensitivity limit where it is no longer possible to achieve more speed by accepting less view time.

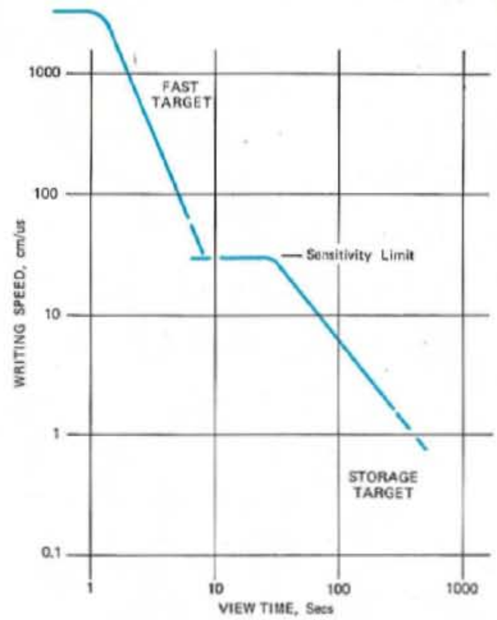


Fig. 4. Graph showing writing speed versus viewing time for two different storage targets.

The operating point along the WS and VT curve is determined by the storage mesh voltage. The storage level control, a front-panel control on TEKTRONIX variable persistence scopes, permits you to move down the curve by decreasing the storage mesh voltage, for a longer view time as less writing speed is needed.

As the fast target curve in Figure 4 suggests, it is possible to make targets with higher writing speeds. However, when this speed increase is a result of improved charge sensitivity, the rate of positive ion charging is increased and the view time suffers proportionately.

The charge sensitivities of the fast and storage targets in the 7633 crt are 5 picocoulombs/cm² and 500 picocoulombs/cm², respectively, giving the fast target a 100:1 charge sensitivity advantage. Looking at the fast target performance in Figure 4 we see a writing speed above 1000 cm/μs can be achieved. But the view time is below 1 second — much too short for useful viewing. It is evident we have traded too much view time for writing speed.

Transfer, don't trade

This is where the transfer technique becomes useful. During the 0.1 second following waveform capture by the fast target, the image is transferred from the fast target, to the storage target. A gain of about 1000X in the stored charge image accompanies this transfer. Now at the fastest writing speed of 1000 cm/μs we have a minimum view time of at least 30 seconds which is more than adequate for most high-speed applications.

New modes, new speeds

The fastest stored writing speed of the 7623 storage oscilloscope introduced in mid-1972 is 100 cm/μs (200 cm/μs for Option 12). Using basically the same crt, how is writing speed increased to 1000 cm/μs? This is accomplished with two new modes of operation—reduced scan selection and fast variable persistence.

In the reduced scan mode, the operating voltage on the crt write gun is increased from 1500 V to 3000 V. Referring to Equation 3, I_b/TW increases by about 2.5X and δ-1 is higher by about 1.6X for a total increase in speed of 4X. The useful display area is 8 × 10 div (.45 cm/div) in this mode.

Operating the storage target in the fast variable persistence mode rather than the fast bistable mode as in the 7623, provides a speed improvement of 3X. Referring again to Equation 3, the ΔV of the fast target is reduced by 3X due to the new operation of the storage target. This is because less change is required for storage, and gray scale signal levels are not discarded.

Combining the reduced scan with fast variable persistence, a typical speed increase of 12X is realized over the full-scan, fast-bistable mode of operation.

The 7633 storage controls

To conclude our discussion let's consider briefly the front panel controls for the 7633 (See Figure 5). A set of three push buttons selects display modes of NON-STORE, STORE and SAVE. The SAVE mode has three uses:

1) To prevent loss of the captured signal. Erase and sweep cycles are locked out in this mode.

2) For extended retention of the variable persistence displays. Turning the SAVE INTENSITY down reduces the flood electron current and extends the view time in proportion to the reduced intensity. It can be turned off for hours of retention.

3) To set up a "Babysitting" mode which will automatically give the above two performances after a future event. The "Babysitting" mode is entered by pressing the SAVE push button after ERASE.

Another set of push buttons selects storage modes of FAST, VAR PERSIST and BISTABLE. Note that the

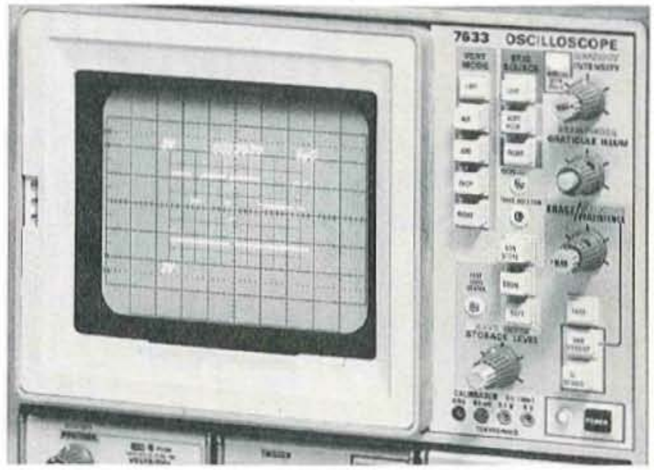


Fig. 5. Front-panel controls permit a choice of storage modes and operating conditions for optimum performance on your application.

PERSISTENCE and ERASE controls are located together and provision is made for periodic erase. This can be used in three ways:

1) To periodically erase independent of the number of waveforms stored during the period.

2) To accept one waveform for each erase period (time base set to single sweep).

3) To erase at the end of sweep (or sweeps). The period is adjusted to end during the sweep and the erase cycle is delayed to the end of that sweep.

The STORAGE LEVEL control, as mentioned previously, permits us to decrease the storage mesh voltage for longer view times as less writing speed is needed. The FAST LEVEL CENTER adjustment is provided to separately adjust the fast mesh voltage for the desired tracking of the STORAGE LEVEL on the two meshes.

The REDUCED SCAN switch operates independent of the display and storage modes and permits choosing full-scan operation when the last 4X writing speed increase is not needed. It is also convenient to set up the reduced scan display in nonstore before going to storage operation.

All of the 7000 Series advantages

In addition to high-speed versatile storage, the 7633 offers all of the advantages of the 7000-Series Oscilloscopes. Crt readout is standard equipment and you can select from 30 different 7000-Series plug-ins to "custom tailor" the instrument to your job and expand its capabilities as the need arises.

Acknowledgments

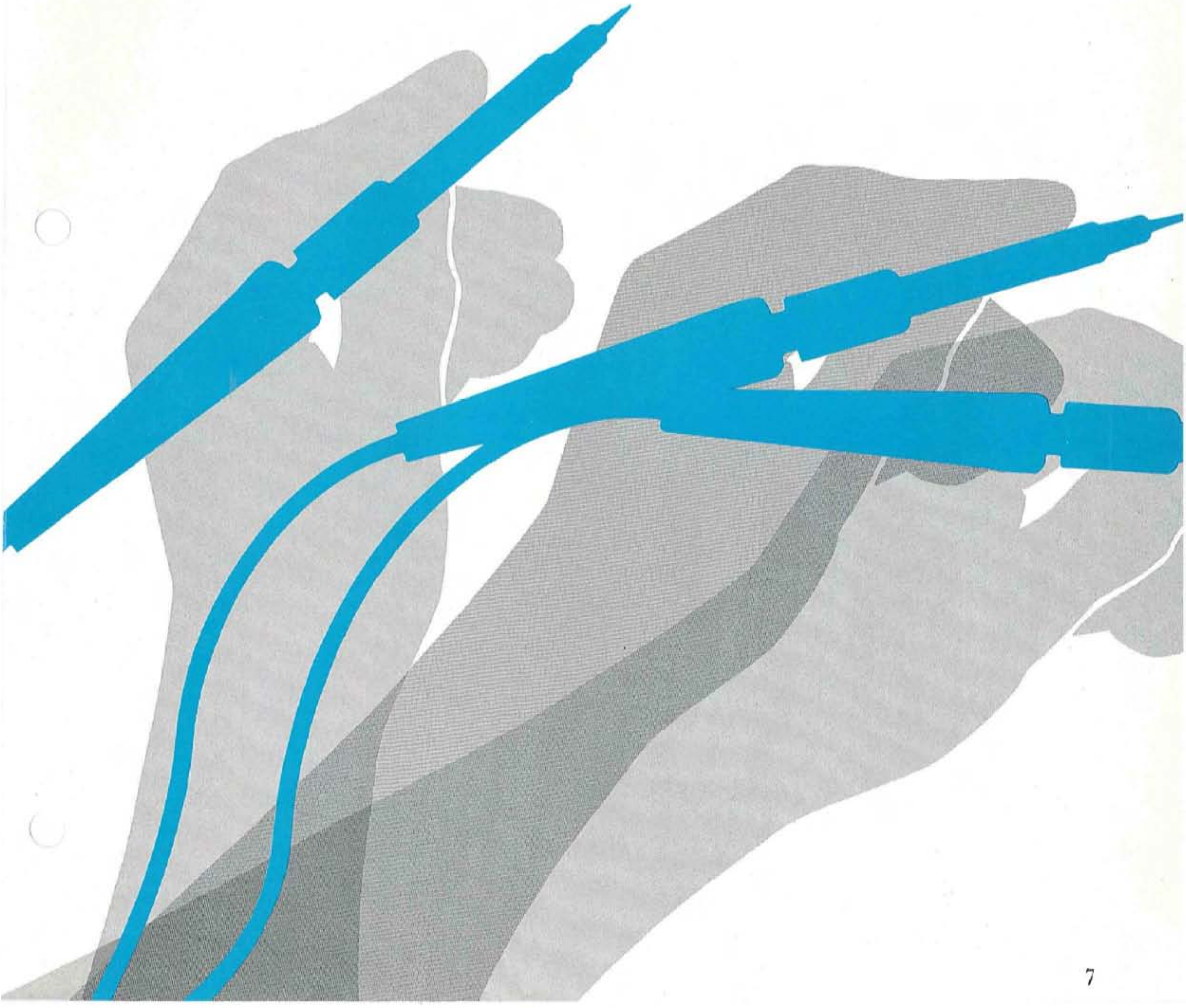
The author thanks everyone on the 7633 project for their dedication in making this a significant product.

1. "Three New Instruments, Three Kinds of Storage" Tekscope, July, 1972.

Using your oscilloscope probe

Riley Stock

This is the first of a two-part article which discusses oscilloscope probes, what happens when you attach them to your circuits, and some of the advantages offered by active probes and current probes. Part I deals with the type of probe familiar to most of us—the passive voltage probe.

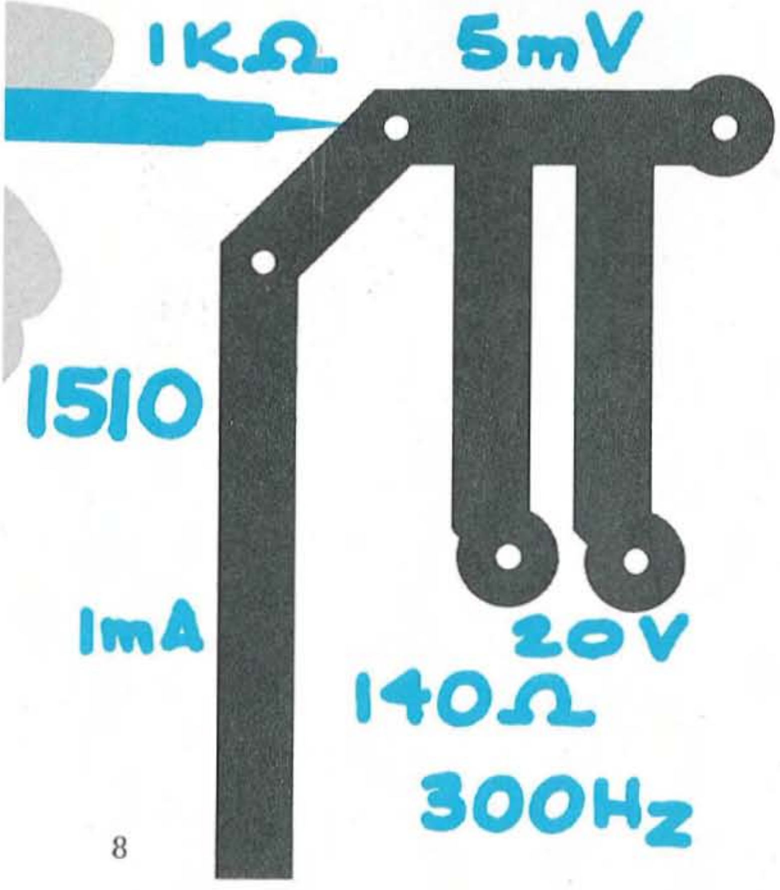


PART I The passive voltage probe

Seeing is believing. Or is it? No doubt there have been times when the signal you viewed on your oscilloscope didn't measure up to what you expected. After thoroughly checking out your circuitry you turned a suspicious eye on the scope—but did you stop to consider the probe?

The function of the ideal probe is to couple the signal of interest to the oscilloscope without affecting the signal source or the signal waveshape. As is often the case, the ideal probe for every measurement doesn't exist. However, a knowledge of probe characteristics and how they affect the circuit under test will help you approach the ideal for your particular application.

The passive probe is, by far, the most common type in use today and provides the greatest convenience for general purpose work. It is also the least expensive. The term "passive" is used to distinguish this type of probe from one that uses active devices, such as FETs, to achieve high input impedance and low input capacitance, even in a 1X mode.



Passive probes come in a variety of sizes and shapes, with differing characteristics. The typical probe consists of a probe assembly, a ground lead and a shielded cable equipped with a suitable connector for the oscilloscope input. Most probes feature interchangeable tips and ground leads for easy connection to various test points. A unique feature of most Tektronix probes is the Tektronix-patented coaxial cable with a resistance-wire center conductor. This distributed resistance suppresses ringing due to the mismatch between the cable and its terminations, when viewing fast pulses on wide-band oscilloscopes.

Probes load the circuit

Low and medium frequency oscilloscope inputs are usually one megohm shunted by 8 to 50 pF of capacitance. Many instruments with bandpass above 200 MHz have a 50-ohm input impedance and some have both a 50-ohm and one-megohm input.

When the scope is applied to the circuit under test, the input capacitance and resistance loads the circuit and may alter the signal to be viewed. Sometimes, the loading alters the operation of the circuit itself. These loading effects can be minimized by using an appropriate probe. If the signal amplitude permits, an attenuator probe can be used, reducing both dc loading and capacitive loading. Figure 1 shows a schematic representation of an attenuator probe and oscilloscope input. The probe and scope input essentially form an RC divider. Since $R_1 C_1$ must equal $R_2 C_2$ for equal attenuation at all frequencies, we can see that as R_1 increases, C_1 must decrease. Thus, the capacitance at the probe tip can be reduced by going to higher values of attenuation. Common probe attenuations are X10 and X100, with some probes having provision to switch between X1 and X10. Others have plug-on attenuators covering a wide range of attenuation from X1 to X100.

Now, just what changes occur when we attach a probe, how will these changes affect the signal, and can we determine the desired information from the display? One of the primary considerations in determining what the probe will do to the signal and circuit under test, is the impedance of the signal source. In modern circuitry source resistance varies from a fraction of an ohm to greater than hundreds of kΩ and source capacitance from 1 pF to greater than 100 pF. To minimize probe loading effects, a low impedance test point should be selected for viewing when possible.

Two types of signals should be considered when dealing with probe loading effects: (1) pulse or step-function sources dealing with amplitude, risetime (t_r) and transient response; and (2) sine wave sources concerned with amplitude and phase relationship distortion.

Measuring pulse signals

Let's consider what happens to a typical pulse signal source (Figure 2 (a) when we apply a probe. If the generator had a t_r of 0, the output t_{r1} would be limited by the integration network of R_s and C_s and would be equal to 2.2 R_sC_s, or 8.8 ns. If a typical passive probe, such as the P6053B (10X, 9.5 pF, 10 MΩ) is used to measure this signal, the probes' input capacitance and resistance are added to the circuit (Figure 2 (b)). Since R_p is $>>R_s$, R_p may be disregarded. Using the risetime formula, 2.2 R_s (C_s+C_p), the circuit risetime, t_{r2} becomes 13 ns. The loading effect of the P6053B to this signal source is the percentage change in risetime:

$$\frac{t_{r2}-t_{r1}}{t_{r1}}\times 100=\frac{13\text{ ns}-8.8\text{ ns}}{8.8\text{ ns}}=48\%$$

The percentage change that results from adding a passive probe to this pulse source is directly related to the capacitance added. The calculation to determine the amount of change in risetime would be:

$$\frac{C_p}{C_s}\times 100=\frac{9.5\text{ pF}}{20\text{ pF}}=48\%$$

This is a valid approach if the probe resistance, R_p, is large when compared to the source resistance.

Now let's see what happens if we use a probe such as the P6048 (10X, 1 pF, 1 kΩ) to measure this same signal source. In this instance R_p is not ten times greater than R_s and must be considered. R_p and R_s form a dc divider, reducing the amplitude and modifying the source impedance. Using Thevenin's theorem a new generator source voltage and a new source resistance (Figure 2(c)) is calculated resulting in: $t_{r3}=2.2\ R_2\ (C_s+C_p)=7.7$ ns. Note that in relating this risetime to the risetime of Figure 2 (a), our original circuit, the P6048 caused a change from 8.8 ns to 7.7 ns. The percentage of change is less than that caused by the P6053B.

$$\text{Percent change}=\frac{7.7\text{ ns}-8.8\text{ ns}}{8.8\text{ ns}}\times 100=-12\%$$

It is interesting to note that rather than degrading the signal by slowing the risetime, the probe modified the source resistance and decreased the risetime making it faster than it should be. But take a look at the output amplitude; it has been decreased to 83.3% of the value without the probe, due to the voltage divider formed by R_p and R_s. In the first example, there was no change in the signal source amplitude when the probe was applied.

And so we see that the choice of probe depends to a large extent on which signal parameter we desire to measure. Low capacitance is desirable when measuring risetime, but high resistance is more important when measuring amplitude. Choosing a low impedance test point is desirable for both risetime and amplitude measurements.

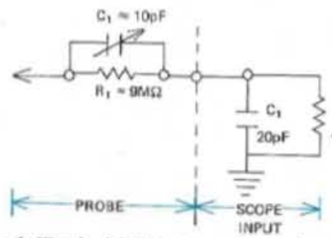


Fig. 1. Typical 10X attenuator and scope input.

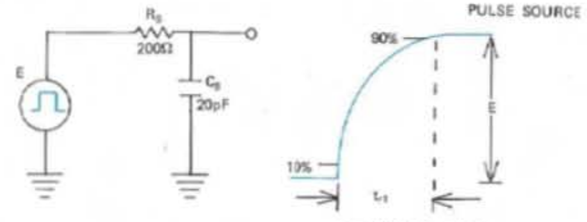


Fig. 2 (a). Typical pulse signal source.

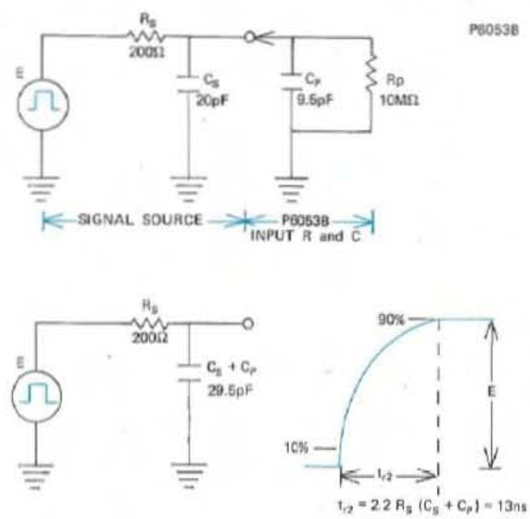


Fig. 2 (b). P6053B probe added to typical pulse source.

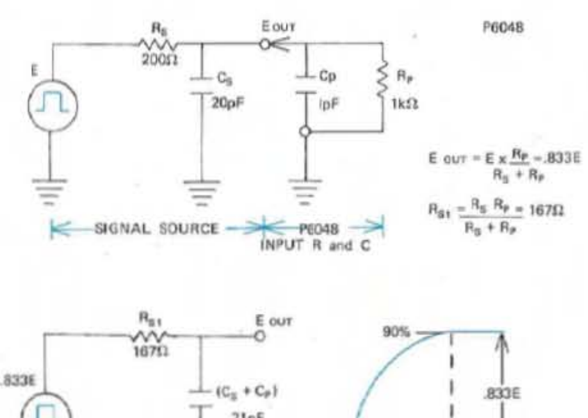


Fig. 2 (c). P6048 probe added to typical pulse source.

Measuring sine wave signals

Now let's consider the effects of using the same probes and the same source resistance and capacitance, with the generator supplying sine waves rather than pulses. Here we will be concerned with amplitude changes and phase relationships.

We should keep in mind that the specified probe input capacitance and resistance, e.g., 10 MΩ and 10 pF, were measured at dc or low frequency (<1 MHz). However, as signal frequency increases, the equivalent probe input impedance changes. Figure 4 shows how the input X_p and R_p of the P6053B probe change with frequency.

Let's assume a source frequency of 10 MHz and a generator voltage of one volt, and see what the source output voltage will be before any probe is applied (Figure 3 (a)). We see that E_{out} of the source only, is 97% of the generator voltage. Now let's apply the P6053B (10X, 9.5 pF, 10 MΩ) probe and see the effect on the source voltage. (See Figure 3 (b)). From the graph in Figure 4 we find that R_p is 40 kΩ and X_p is 1.7 kΩ. Since R_p is $>>R_s$, it can be disregarded in the calculations. X_p is in parallel with X_s giving us a total reactance, X_{ct}, of 545 Ω. From Figure 3 (b) we see that with the P6053B applied, the source output voltage has decreased to 94% of the generator voltage. This represents a 3% change from the unloaded source output voltage.

Now let's see what happens to the source voltage when we apply the P6048 (10X, 1 pF, 1 kΩ) probe. (See Figure 3 (c)). Since R_p is 1 kΩ and $<10R_s$, we must consider it in our calculations as in the case of the pulse signal source. X_p is 16 kΩ and in parallel with X_s resulting in X_{ct} of 760 Ω. We find that with the P6048 applied, the source output voltage is 81% of the generator voltage, for a change of 16% from the unloaded source voltage.

Comparing Figures 2 (b) and (c) with Figures 3 (b) and (c), we can see that for risetime measurements, the low-capacitance P6048 yields better accuracy than the P6053B, while for sine wave amplitude measurements the dc loading of the P6048 causes a larger error than the capacitive loading of the P6053B. Note from Figure 2 (c) that the P6048 also causes a substantial amplitude error.

Phase relationships

Since most attenuator probes have a capacitive element it is evident that the probe will introduce phase shift in the signal being viewed. Source impedance is an important factor in determining the amount of phase shift that occurs. For example, consider an amplifier driven from a 10 MHz, 50 Ω source and having an output impedance of 2 kΩ. (See Figure 5 (a)). Let's look at the input and output using two 10 MΩ, 10 pF probes. Referring to Figures 5 (b) and (c) we see there is a difference in phase of about 49° due to the impedance difference in the points being measured.

Now let's look at the same two points using two 1 kΩ, 1 pF probes. (See Figures 5 (d) and (e)). The phase difference has been reduced to about 2°. However, the 1 kΩ probe causes a 67% signal loss due to resistive loading. Depending on the application, it may be desirable to select a probe which offers a better compromise between phase shift and signal loss, or we may use a different probe for the respective measurements.

Summing it up

From this brief discussion we can see that what seemed a relatively unimportant part of our measurement system, actually determines to a large extent what we see displayed on our oscilloscope screen. All probes do not have the same effect on the signal. And one probe is not the ideal for all measurements.

Here are some general rules we can follow to make better measurements when using a probe:

1. Always check the probe compensation on the oscilloscope being used to make the measurement.
2. Choose the lowest impedance test point possible to view the signal.
3. When making risetime measurements:
   a. Choose a probe with R and C as low as possible.
   b. Scope and probe risetime should be short relative to the signal risetime.
   c. Observed risetime is approximately equal to the square root of the sum of the squares of all the risetimes in the system. These risetimes include the risetime of the signal source, the specified probe risetime, the specified scope risetime, and the calculated risetime of the scope/probe input system, including the effect of the source impedance.
4. When making amplitude measurements:
   a. For sine wave measurements, choose a probe which has the highest input impedance at the frequency of interest. Remember, loading error changes with frequency.
   b. For pulse measurements, choose a probe which has a large input resistance relative to the source impedance. Input C is of no concern if pulse duration is about five times longer than the input RC.

In the second part of this series we will discuss active probes and current-measuring probes. While not as widely used as the passive voltage probe, they provide a valuable extension to the signal measuring capabilities of your oscilloscope.

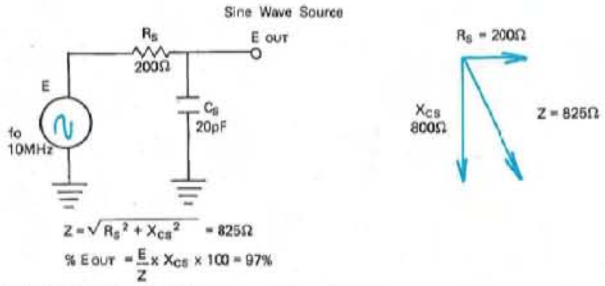


Fig. 3 (a). Typical sine wave signal source.

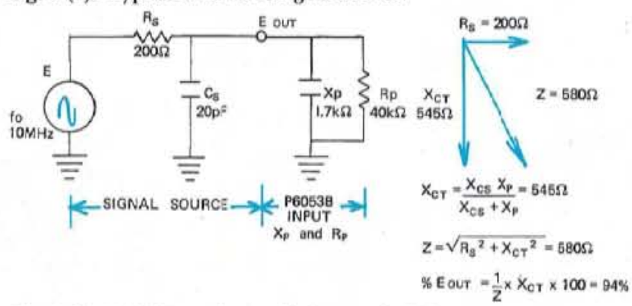


Fig. 3 (b). P6053B probe applied to typical sine wave source.

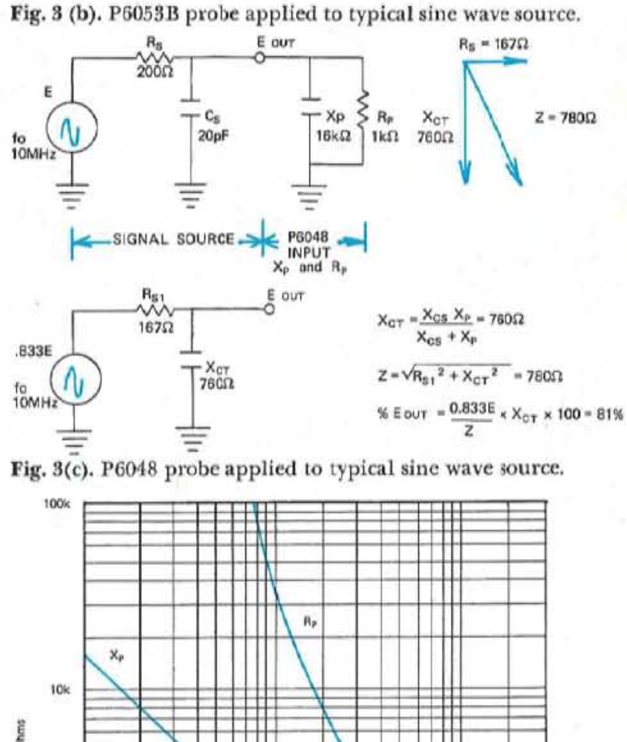


Fig. 3(c). P6048 probe applied to typical sine wave source.

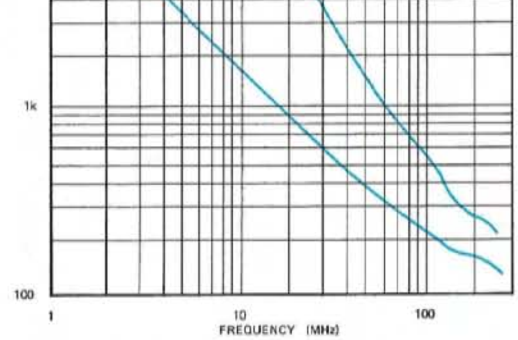


Fig. 4. P6053B probe (3.5 foot cable), typical X_p, R_p versus frequency curves.

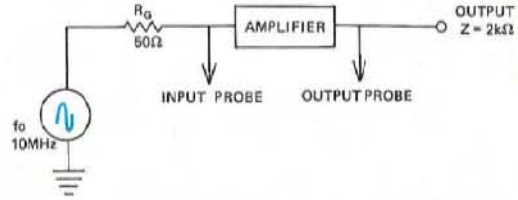


Fig. 5 (a). Typical amplifier circuit with differing input and output impedances.

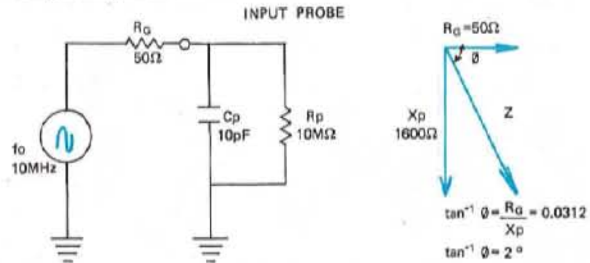


Fig. 5 (b). Phase shift caused by applying P6053B probe to the amplifier input.

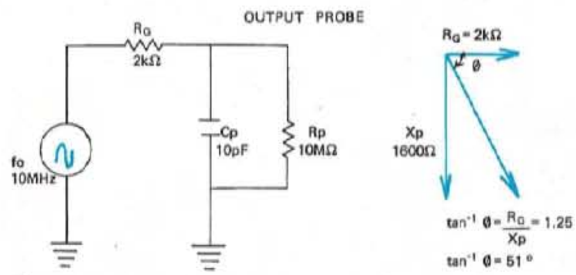


Fig. 5 (c). Phase shift caused by applying P6053B probe to the amplifier output.

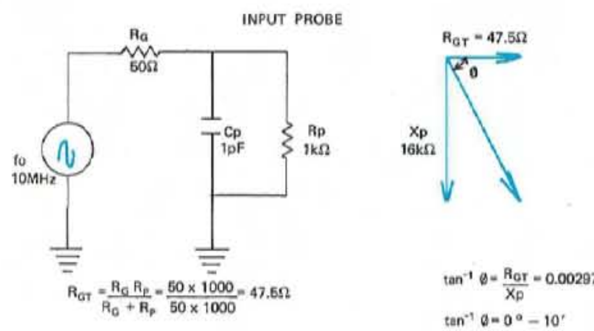


Fig. 5 (d). Phase shift caused by applying P6048 probe to the amplifier input.

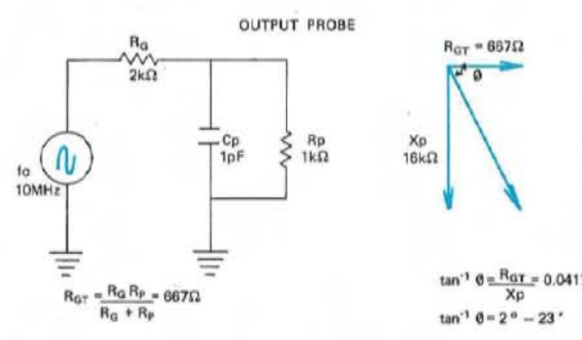


Fig. 5 (e). Phase shift caused by applying P6048 probe to the amplifier output.

Teknique

Bob Beville

Triggering the oscilloscope from logic signals

The triggering circuits of conventional oscilloscopes leave much to be desired when attempting to analyze logic signals. While the dual triggering afforded by delaying sweep operation permits you to view long pulse trains in detail, it doesn't fully meet the needs associated with making digital measurements.

Logic designers will recall that in designing digital circuits it is routinely necessary to construct frame pulses, index pulses or other event-signifying markers to initiate specific circuit functions. These signals make ideal trigger points for the test oscilloscope and are often made available for that purpose. Sometimes special trigger-trap circuits are designed into the equipment expressly to facilitate servicing. Field engineers servicing a piece of malfunctioning digital machinery resort to such items as extender cards, latch cards and word-recognition circuits to construct a "trigger trap" near, in time, to the point they wish to observe.

One of the techniques used in troubleshooting digital circuitry is appropriately called "babysitting." This usually employs the single-sweep feature of an oscilloscope to indicate, circuit block by circuit block, that the equipment is functioning to that point. It is a time-consuming procedure and yields marginal information. Another technique, equally time-consuming, involves single-stepping the machine clock and recording the status of input and output functions.

Such needs and techniques as these have led digital designers and service personnel to request digital triggering features on their oscilloscopes — features that accommodate the many special problems of digital designing and troubleshooting.

A Better Way

The new TEKTRONIX 821 Word Recognizer is designed to meet just such needs when working with Transistor-Transistor Logic (TTL). It is a small instrument powered from the probe-power outlets of the 7000 Series, 475 or 485 Oscilloscopes, or five-volt logic supplies. The 821 contains a four-input AND gate, a babysitter flip-flop, and light-emitting diode (LED) input and output indicators. A 50-ohm TTL output permits cascading up to four 821's to achieve a word length of 16 bits. Strobing ability is included. And a front-panel switch changes the function of the unit from word recognizer to that of logic driver.

Serving mostly as an AND gate, the 821 has four color-coded input probe leads for connecting to the desired logic points. The Word Selector switches, one for each input, select the logic level: positive TRUE (1), negative TRUE (0) or an off position labelled "X" for 'don't-care' situations or applications requiring less than four inputs. The output of the 821 is a TRUE TTL level at 50 ohms, ideal for externally triggering an oscilloscope.

As with any AND gate, the 821 output remains TRUE for as long as the inputs comply with the selected switch pattern. The leading edge is the triggering edge in most cases. The output will fall following the first input that disables the AND gate, indicating the AND function is over. This is useful in some applications. For example, in a 4-bit binary counter, the only unique triggers normally available are at the count of 8 or 16 (carry). With the 821, a trigger can be derived on each of the counter states. See Figure 1.

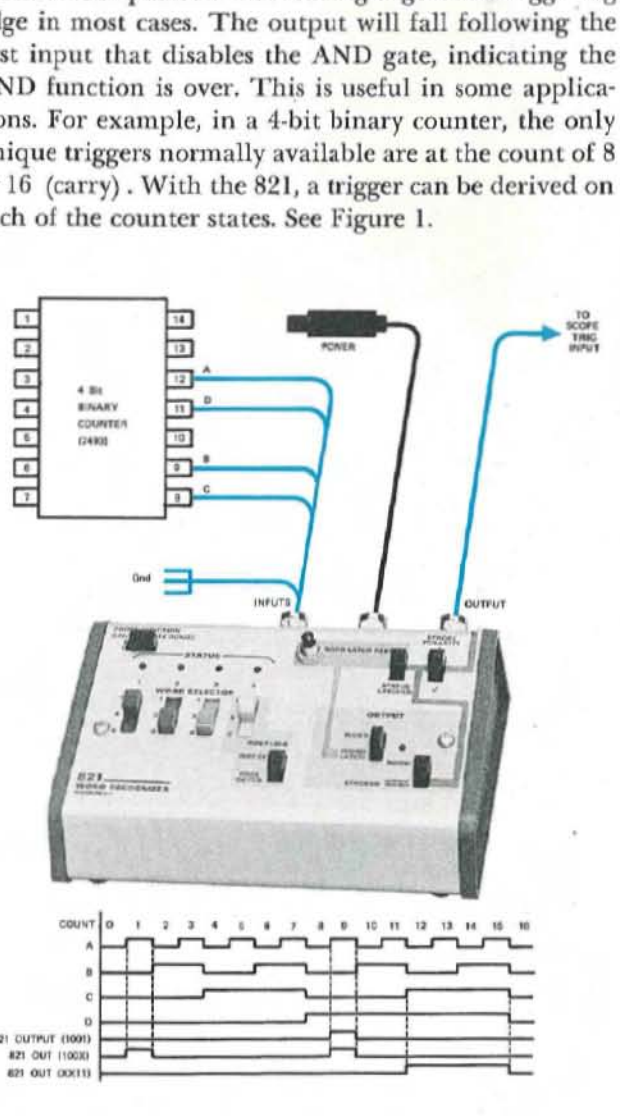


Fig. 1. The 821 connected to a 4-bit counter and set to output at the count of nine (1001). Bottom three waveforms show output of 821 set at 1001, 100X and XX11.

Expanded bit capability

Since the output is TTL compatible, 821's can behave as TTL components if desired. An 821 then, can be used to drive another 821. Should an application requiring more than four inputs arise, such as on tape readers, printers, teletypes, terminals or other byte-oriented machinery, the ability of one 821 to enable another would be useful. An input called EXPANDER INPUT is provided for this mode. When this input is left disconnected or driven TRUE by a positive TTL level from another 821 or other TTL logic, the AND function is enabled. This is valuable in constructing the 8-input AND gate. The output of the first 821 provides the enabling signal to the second 821, provided the first 821 performs its portion of the eight-bit AND function. This configuration is useful in triggering on control characters, escape characters, End of Block, or any ASCII character that is set into the Word Selector switches. See Figure 2.

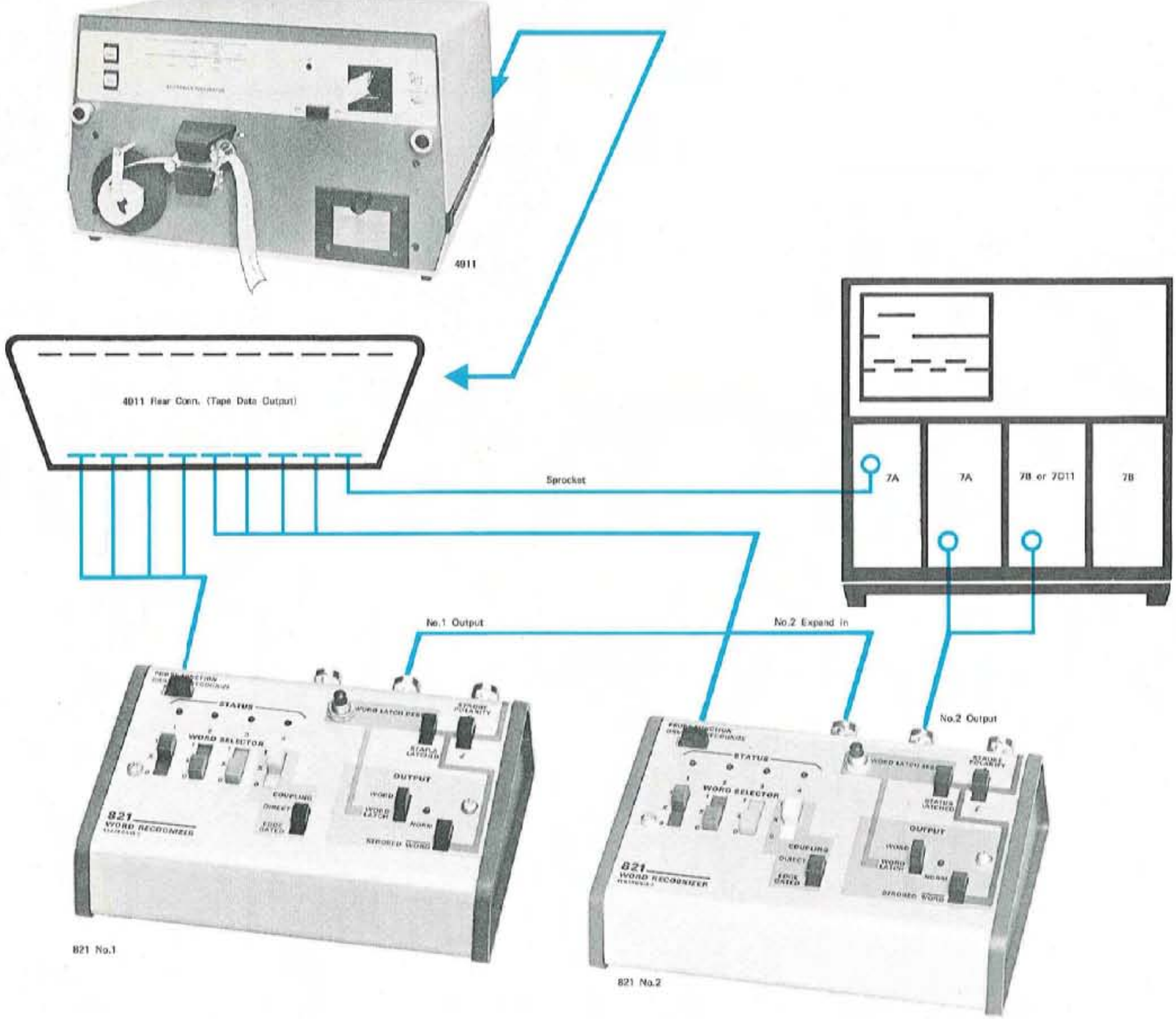


Fig. 2. Two 821's connected in EXPANSION configuration perform an eight-input trigger trap.

The status indicators

Activity on the output of the Word Recognizer is shown on the front panel by an LED indicating the occurrence of the selected word. The LED remains on if the input word is quiescently at the word being recognized.

The logic states of each input is indicated by LEDs above the respective Word Selector switches. Each input, through a buffer, is applied to a bistable latch. The status-indicator LEDs are connected to the latch outputs and normally follow the input levels. Dynamic inputs are indicated by the flashing on and off of these LEDs. Static conditions are displayed, as are sequenced conditions such as those experienced when operating digital equipment in single-clock-single-instruction mode. The 821 can also acquire data presented in parallel format. In this mode, the STROBE INPUT, with suitable choice of strobe polarity, can be driven to capture and store the input's status. See Figure 3.

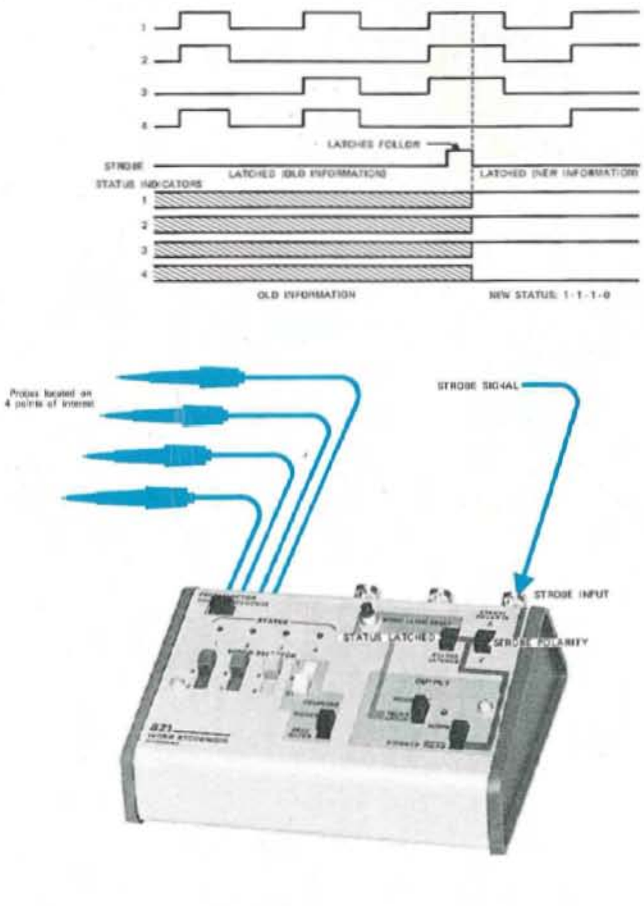


Fig. 3. In a data stream, the information on four lines may be strobed into the Status Indicator Latches after the active edge of the strobe signal.

Latch on to the affirmative

A feature to assist troubleshooting techniques such as "babysitting" monitoring and single-clock-single-instruction operation is the WORD LATCH. In this mode the output of the 821 (and its LED indicator) will go TRUE if the expected word comes and sets a flip-flop internal to the 821. Figure 4 illustrates this application.

Using the WORD LATCH in conjunction with the EXPANDER INPUT the 821 becomes a multipoint condition indicator. An 821, in conventional WORD mode, enabling another 821 in WORD LATCH mode, becomes an 8-input latch. Two 821's in WORD LATCH mode, each applied to the same four points, one enabling the second, can indicate if one four-bit word preceded another.

Measuring time between non-adjacent words

Occasionally we find it useful to measure the time duration between two non-adjacent words or timing points. The WORD LATCH RESET feature is applicable here. As illustrated in Figure 5, the WORD LATCH would be set by the first word. A second 821, outputting on the second word, is applied to the WORD LATCH RESET of the first. The WORD LATCH output waveform then will be set from the time of the first word until the second. This waveform can then be observed on a scope or applied to a universal counter in Time Interval mode. A push button is provided for manually resetting the latch.

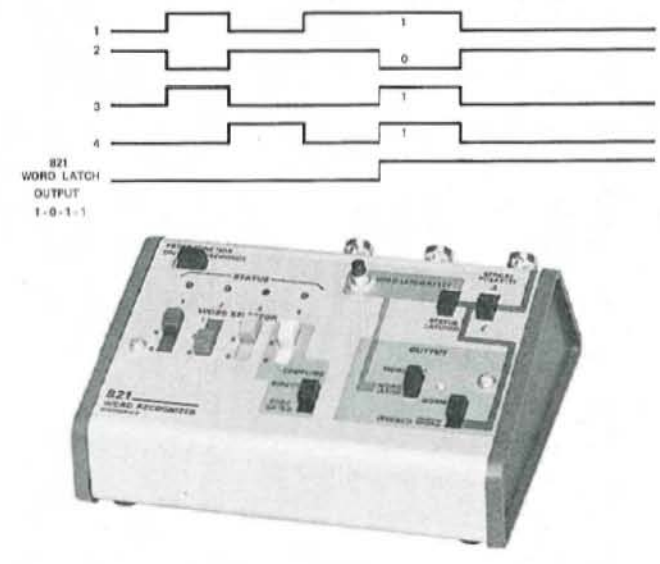


Fig. 4. An 821 in WORD LATCH modes sets and remains set once it recognizes the desired word.

Display the negative

Yet another mode of the Word Recognizer is the ability to be strobed to determine if the word present on the inputs is the desired word or not. This is useful when the desired word, a known pattern of bits, is subject to occasional faulting or dropouts. When the word pattern is good, the circuit must not be misbehaving, hence there is no object in triggering a scope to observe good information. The STROBED $\overline{\text{WORD}}$ (not WORD) function, in effect, interrogates the AND gate and determines at the strobe time if the inputs have indeed AND'd and conform to the pattern of bits set by the Word Selector switches. On the outcome of this decision: "Do the inputs and Word Selector switches mismatch?", the 821 output will go TRUE signifying "YES, they do mismatch" or remain FALSE, indicating a match was found. This configuration will be useful around sector preamble decoders and similar READ oriented circuits. Also malfunctions of circuits being subjected to temperature or power supply tolerancing can be observed in this mode.

Again, the expansion mode for strobing more than four inputs is applicable. It is required that only the last 821 be placed in the STROBED $\overline{\text{WORD}}$ mode and is the only one that need be strobed. The 821's before it are in the conventional WORD mode because of the 'pass it on' nature of the expansion configuration. This application is shown in Figure 6.

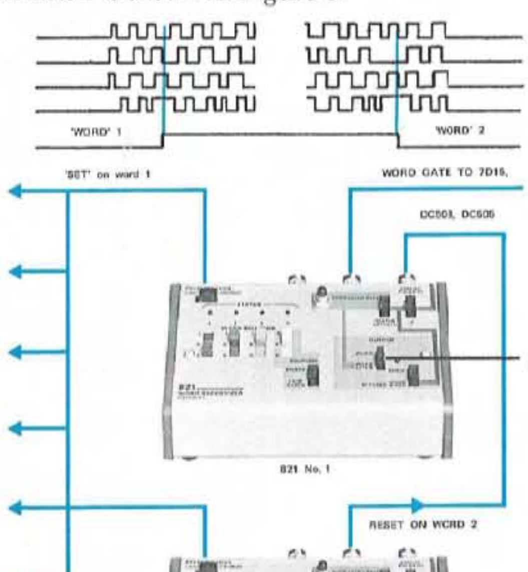


Fig. 5. A pair of 821's can construct a gate waveform from the occurrence of one "word" to another, for measuring the time interval between them.

The 821 can serve as more than just a source for externally triggering scopes. Other applications attendant to, or independent of, triggering a scope sweep are: deriving the EVENTS START signal for 7D11 Digital Delay or DD 501 Digital Delay plug-ins; and deriving the START (A) or STOP (A,B) signal for universal counter measurements using the 7D15, DC 503, or DC 505 Universal Counter plug-ins.

The 821 as a logic driver

Thus far we have discussed the 821 as a word recognizer. Switched into the DRIVE mode, the input probes of the 821 become outputs capable of driving up to six TTL loads each. This is useful in situations where inputs are to be manually stepped through their logic truth tables. The Word Selector switches determine the levels of the driving outputs, 1 for HIGH or TRUE, 0 for LOW or FALSE. The 'don't care' (X) position opens that particular probe line. The LED status indicators, as do the Word Selector Switches, show the word chosen.

Summary

Some problems and methods of troubleshooting digital circuits have been discussed. The success of some techniques require the ability to contrive the proper trigger signal in order to look closely at the problem. A few applications using the 821 Word Recognizer to construct a more desirable trigger were described. The 821 should help solve untold numbers of triggering problems and speed isolation of the actual equipment malfunction.

Acknowledgments

Assisting the author in the 821 program were: Sandra Lowe, prototype support; Bob Smesrud, mechanical design; Paul Hanchett, evaluation; Allen Wright, industrial design, and many, many others.

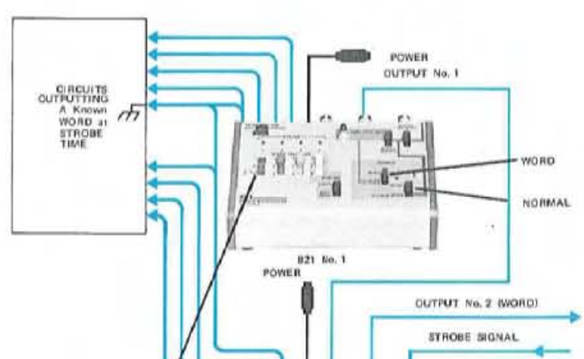


Fig. 6. Two 821's in an 8-bit STROBED WORD configuration will output if the "word" is not in the expected word pattern.

Servicescope

Sherwin Feetham

Servicing the TELEQUIPMENT D67 oscilloscope

The D67 is manufactured in England by Telequipment, a wholly-owned Tektronix, Inc. subsidiary. It is a low-cost instrument featuring dual trace, delaying sweep operation and a bandwidth of 25 MHz.

If you are unfamiliar with the TELEQUIPMENT line, it would be well to take a few minutes to review the front panel controls. Most of the controls and operating modes are similar to those you find on TEKTRONIX instruments. The vertical consists of two channels with alternate, chopped and summing modes and each channel can be turned on or off independently by push buttons. Note also that you can select the trigger from channel 1, channel 2 or both.

Moving to the trigger mode section for A sweep you will see a couple of modes that may be unfamiliar—TV F and TV L. These are used when viewing composite video signals and permit you to trigger at the frame rate or the line rate. When not viewing television signals the normal mode of operation is to depress the INT and + slope buttons, leaving the top three buttons out. The LEVEL control selects the level at which triggering will occur and turning the control fully counterclockwise puts you in the AUTO triggering mode. Pulling out the Variable Time/CM control will give you a free running sweep.

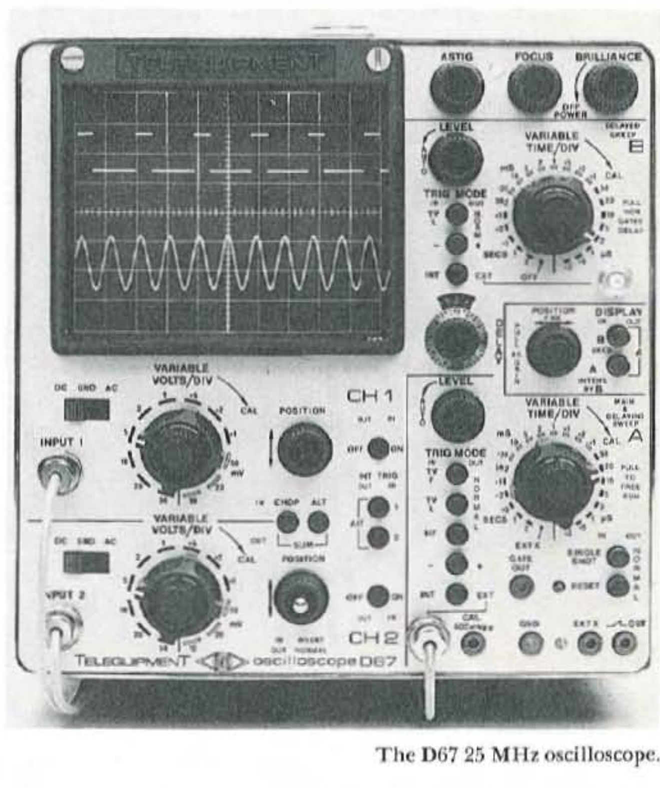
The horizontal section is comprised of A and B sweeps. The A sweep is the main or delaying sweep, while B sweep serves as the delayed sweep. The sweep to be displayed is selected by two front panel push buttons. With both buttons out, only A sweep is displayed. The displayed sweep can be magnified by pulling out on the FINE position control. This is a 5X magnification of the center two centimeters of the display. With either the A intensified by B or B Delayed push button depressed, you must have A sweep running and the B sweep Variable Time/CM knob pulled to the Non-Gated Delay position to enable B sweep to run. (If you are feeding a trigger to B sweep the variable does not have to be in the Non-Gated Delay mode.)

Now that we're acquainted with the front-panel controls, let's make a quick check of the control settings before turning on the instrument. Depress both CH 1 and CH 2 push buttons to turn on both vertical channels and depress INT TRIG push button for channel 1. Make sure both horizontal DISPLAY buttons are out. (A common mistake is to have B Delayed push button depressed.) Set A sweep TIME/CM to .2 ms, pull out the VARIABLE knob and set the LEVEL control counterclockwise. The INT trigger mode button should be depressed. Set the ASTIG, FOCUS and BRILLIANCE controls to center position and you're ready to turn on the scope. You should have two traces on screen. If you only have one trace and CH 2 position control has no effect, check to see that either the CHOP or ALT button is depressed. The CH 2 position control does not function in the SUM mode.

It would be helpful at this point to apply a known signal to the vertical inputs and check out the various controls and operating modes. This will give you a quick picture of the condition of the instrument and often provide clues to circuits that may be in trouble.

A look inside

Now let's take a look inside the D67 and locate the adjustments we will be tweaking during calibration. The side panels are easily taken off by removing the two screws in the carrying handle and pulling the panels away and down from the instrument. Note that the transistors are mounted in sockets to facilitate servicing. The TIME/CM switches for A and B sweeps are



The D67 25 MHz oscilloscope.

convenient "landmarks" for locating the circuitry associated with the respective sweeps and you will find the adjustments marked on the printed circuit board by symbol number.

Check the power supplies

Before starting our calibration we should check the power supplies. There are three regulated supplies: +12 V, −12 V and +115 V. The high voltage is −1450 V with an unregulated +8.5 kV to the anode. Make sure the voltage selector plug on the back of the instrument is set to most nearly correspond with the actual line voltage. Then set the power supplies to their proper value in the following order: +12 V, −12 V, +115 V and −1450 V. The +8.5 kV should be checked but does not have an adjustment. Ripple on the low voltage supplies should be less than 10 mV and should be checked with the A sweep TIME/CM control in EXT X position.

A trigger set up

Since the triggering must be working properly to calibrate the rest of the instrument, it should be set up first. Set the D67 controls as follows:

A TIME/DIV to EXT X

B TIME/DIV to OFF

A and B LEVEL controls to AUTO (full ccw)

All push buttons to OUT

CH 1 and CH 2 inputs to GND

Connect a test oscilloscope with 10X probe to test point 124 located beneath the A TIME/DIV switch on printed circuit board PC75. Set the test scope vertical sensitivity to 5 mV/div and the sweep rate to 10 ms/div. The adjustments are R12 and R33 located just below the A TIME/DIV switch. Turn R33 fully counterclockwise and set R12 to the approximate center of the range in which an oscillation is observed on the test scope. (Note which direction you are turning R12 when the oscillation appears.) If you want to check the oscillation, speed up the test scope TIME/DIV and notice the frequency is about 1 MHz. Reset the test scope TIME/DIV to 10 ms. Every movement of R12 and R33 should now be very slight. Turn R33 clockwise until the oscillation just disappears. Turn R12 in the direction noted in parenthesis until the oscillation appears again. Then turn R33 clockwise slightly until the oscillation again disappears. Repeat these two steps until a triangular waveform of about 20 to 40 Hz appears. Carefully adjust R12 and R33 until the waveform is a symmetrical triangle approximately 70 to 75 mV peak-to-peak in amplitude and at a frequency between 20 - 40 Hz. The ideal frequency is 30 Hz. (See Fig. 1)

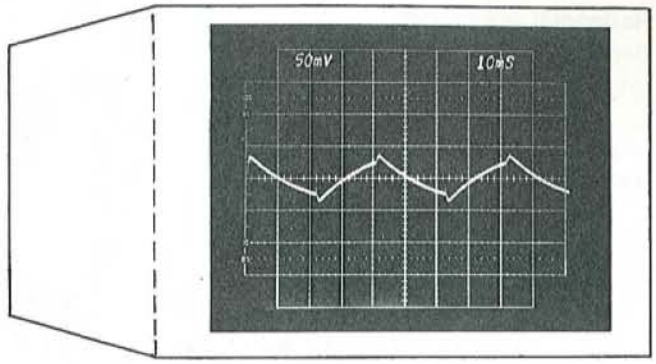


Fig 1. Typical waveform at TP124 when R12 and R33 are properly adjusted.

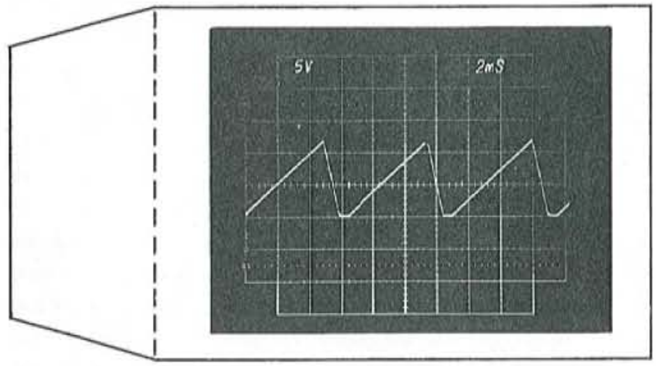


Fig. 2. Front-panel sawtooth output with proper holdoff adjustment.

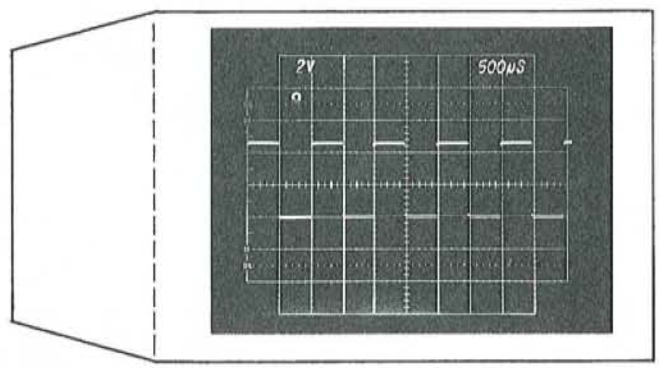


Fig. 3. Typical waveform at TP125 when R62 and R82 are properly adjusted.

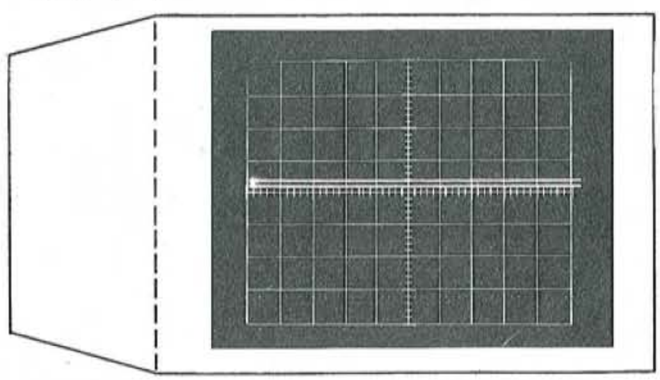


Fig. 4. Appearance of trace while setting sweep B stability and holdoff. Bright spot is caused by disconnecting link from TP153.

Horizontal amplifier balance

Before setting the hold off, the horizontal amplifier should be balanced. Set the A TIME/DIV switch to EXT X position. Connect a DC voltmeter across the collectors of TR277 and TR278 and adjust horizontal position and FINE controls for a meter reading of 0. Now put the negative lead to ground and the positive lead to the collector of TR278 and adjust R297 for a reading of approximately 53 V. Pull out the FINE position control for X5 horizontal gain, and center the spot with the position controls. Push in FINE and recenter the spot with R292. Repeat these last three steps until there is no spot movement and the amplifier is balanced.

Setting A holdoff time

The next step is to set the holdoff time. Set the A TIME/DIV switch to .5 ms and pull the A VARIABLE control out. The variable control should be fully clockwise. Check to see that the horizontal FINE control is pushed in. You should now have a free-running trace on screen. Adjust R109 on PC75 for a trace length of 10.2 divisions. Now observe the front-panel sawtooth output waveform with your test oscilloscope and adjust R113 to make the duration of holdoff equal to the duration of flyback; that is, the horizontal portion of the waveform equal to the negative going portion. (See Fig. 2)

Setting A stability

Apply a 1 kHz squarewave signal to CH 1 input of the D67 and set the controls as follows:

CH 1 input to AC

VOLTS/CM to 10 mV

CH 1 push button ON

INT TRIG push button 1 IN

TRIG MODE to INT

Adjust the 1 kHz signal for one division of deflection. Set R125, located on PC75, fully counterclockwise and watching the trace, turn R125 clockwise slowly until the display locks in. Pull out A VARIABLE to make sure the sweep free runs. If not, turn R125 clockwise slightly until it does free run. Push A VARIABLE back in and recheck for a locked-in display. R109, R113 and R125 interact so this procedure should be rechecked and set until the holdoff, trace length and stability are correct. Now depress the SINGLE SHOT push button and note that a single sweep occurs each time the RESET button is depressed.

Setting A timing

The next step is to set A sweep timing. Apply .1 ms time marks to CH 1 input and adjust the controls for a stable display.

Set A TIME/DIV to .2 ms

Adjust R143 for 2 markers per division

Pull out FINE position control

Adjust R285 for 2 markers per 5 divisions

Push in FINE position control

Apply 1 μs markers to CH 1 input

Set A TIME/DIV to .2 μs

Adjust C219A on TIME/DIV switch for 1 marker per 5 divisions

B trigger set up

Before setting up the B trigger you need to turn off the scope and unplug the link from TP153 located near the top middle of PC75. Turn the scope back on and set the controls as follows:

A TIME/DIV to EXT X

B TIME/DIV to OFF

Both LEVEL controls to AUTO

B TRIG MODE to INT and + slope

DELAY dial to 5.0

CH 1 VOLTS/CM to 10 mV

INT TRIG to CH 1

Apply a 1 kHz squarewave to CH 1 input and adjust the squarewave for a .2 division display. Connect the test scope probe to test point 125 located just behind the B TIME/DIV switch on PC75. Adjust R62 and R82 in the same manner as was done in setting up A trigger, the difference being, the signal on the test scope should be a 1 kHz squarewave of about 4 V peak-to-peak. (See Fig. 3)

Setting B stability and holdoff

With the A TIME/DIV still in EXT X, set B TIME/DIV to .5 ms and pull out B VARIABLE control. A trace should now be seen with an amplitude of about .2 divisions. You will note a bright dot appears on the front of the trace (Fig. 4). This is normal until the wire link is put back on TP153. If a trace is not displayed, adjust R179 until a trace appears.

Connect the probe of the test oscilloscope to the collector of TR165 and observe a sawtooth waveform of approximately 36 V. Adjust R168 for a holdoff equal to the flyback or negative slope. Adjust R165 for 10.2 div of trace length. Push in B VARIABLE control, and set R179 for a locked-in trace; then pull out B VARIABLE and make sure the trace free runs. R179, R168, and R165 interact so this procedure should also be rechecked and set until holdoff, trace length, and stability are correct.

Setting B timing

You can use the same procedure for B timing as was used for A with the exception that R186 is the adjustment for the .2 ms timing and C219B for the .2 μs timing. There is no adjustment for X5 on the B sweep. When timing is completed, turn off the scope and replace the wire link on TP153.

After replacing the link set A TIME/DIV to .1 ms and B TIME/DIV to 20 s. Depress the A intens by B DISPLAY push button and check for proper operation of the A intensified and B delayed modes of operation. This concludes the sweep calibration procedure.

The vertical section

Calibration of the vertical section is relatively easy and the manual procedure is adequate so we will not cover it here. However, there is one item of interest that should be mentioned. If CH 1 and CH 2 have unequal inputs and the SUM mode is selected, the sum of the two inputs will be seen on the crt. If the INVERT switch on CH 2 is depressed, then the difference of the two signals will be displayed, thus acting as a differential amplifier. Remember that in the SUM mode only CH 1 position control will position the trace.

Some service hints

There are two different versions of the D67. One has printed circuit boards that are soldered through to the outside; the other is soldered from the back side only. If you are removing parts or doing any soldering on the latter version, it would be advisable to do so from the back of the board. This is the side with the circuit runs on it and the crt should probably be removed for accessibility. When soldering on these boards it is important to avoid applying excessive heat for long periods. Excessive heat will damage the runs and lift pads and eyelets away from connections.

The crt is removed by taking off the back panel (4 screws), unplugging the crt socket and removing the three mounting screws on the left hand side of the crt shield as viewed from the front of the scope. Disconnect the neck pins and the anode lead, and slide the crt and shield assembly toward the back until the crt clears the front panel. It can now be removed by pulling it to the left and forward.

A note of caution is in order when troubleshooting the unblanking circuit. This circuit is elevated to −1450 V and it is easy to short out several transistors when probing around with your test scope leads. Using an isolation capacitor of approximately .01 μf, 3-5000 V rating at the tip of your test probe will limit the possibility of shorting.

Cleaning of the D67 should be done with compressed air and a soft brush. It is not recommended that you wash the instrument.

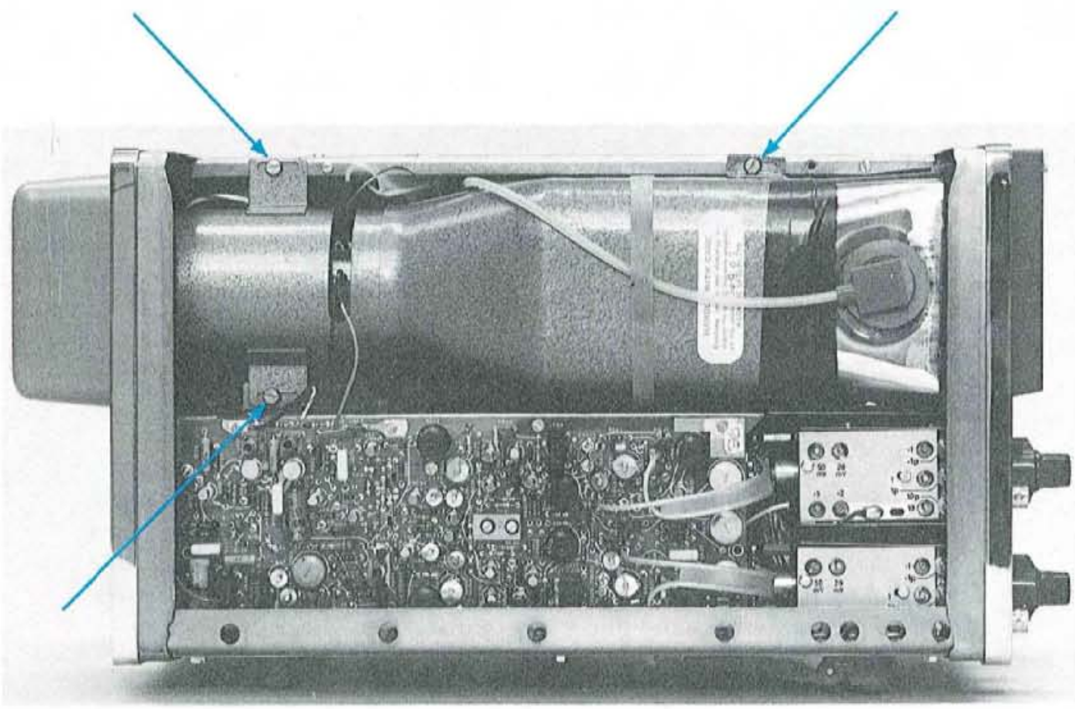


Fig. 5. Arrows indicate three mounting screws holding crt shield.

TEKTRONIX®
committed to
technical excellence

1350 cm/μs Storage Portable

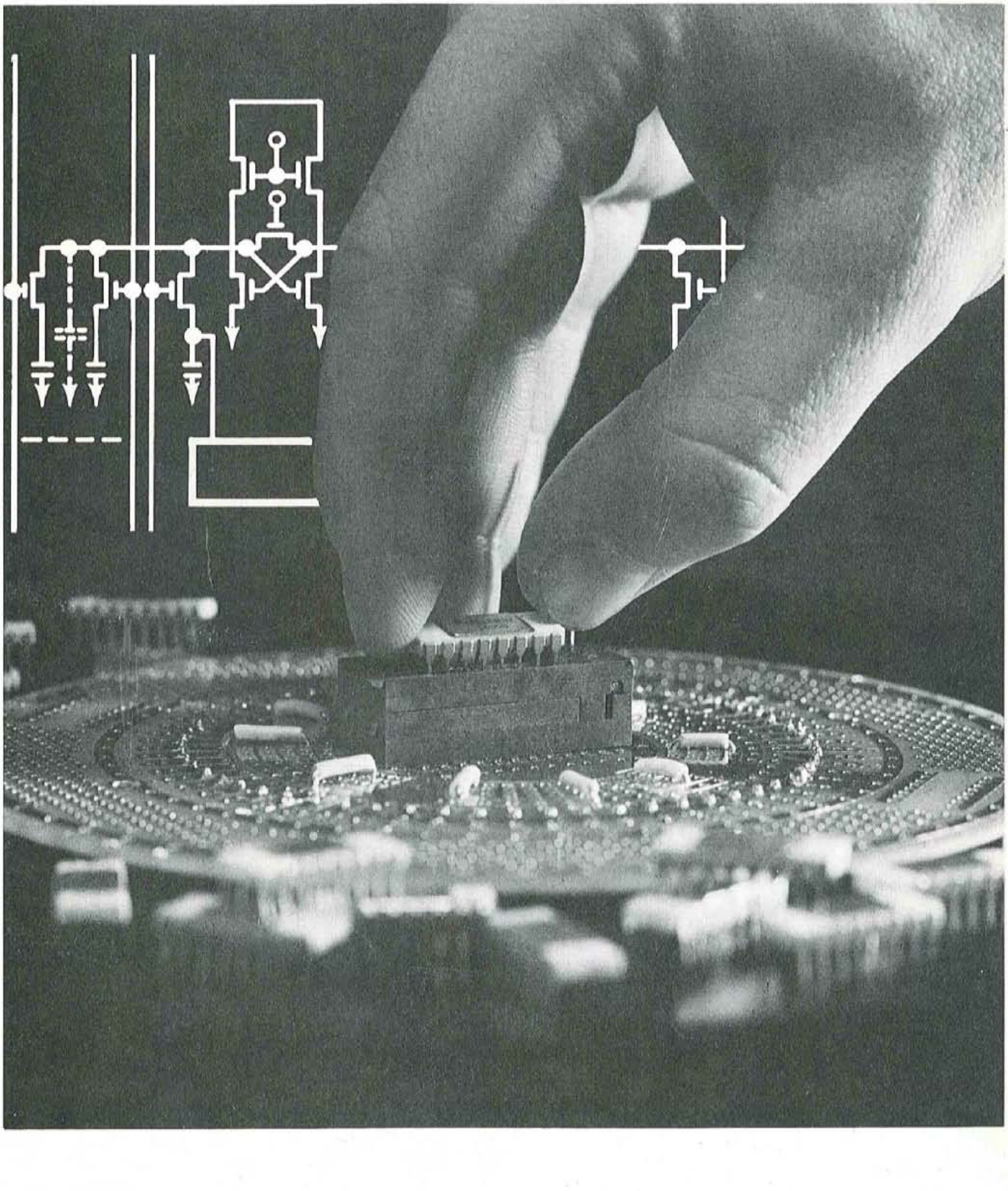
The TEKTRONIX 466 Storage Portable Oscilloscope adds fast-writing storage to the operating convenience and many features of the popular 465 portable. Storage modes include variable persistence, fast and save. With dual trace vertical, DC to 100 MHz bandwidth, delaying sweep and fast storage, the 466 packs unequalled measurement performance in a ready-to-travel package weighing just thirty pounds.

A-2939

TEKTRONIX®
committed to technical excellence

TEKSCOPE

Volume 6 Number 5 Nov/Dec 1974



TEKTRONIX®
committed to technical excellence

TEKSCOPE

Customer Information from Tektronix, Inc.,
Beaverton, Oregon 97077

Editor: Gordon Allison
Ass't. Editor: John Mulvey

Contents

3 **What you need to know about testing 4k MOS memories.**

Some basics on how 4k MOS memories are structured, how they work, and how to test them. Test system requirements are also discussed.

8 **The logic probe and the oscilloscope.**

The logic probe complements the oscilloscope in designing and servicing digital circuitry. Strobe and store capabilities enhance the logic probe's usefulness.

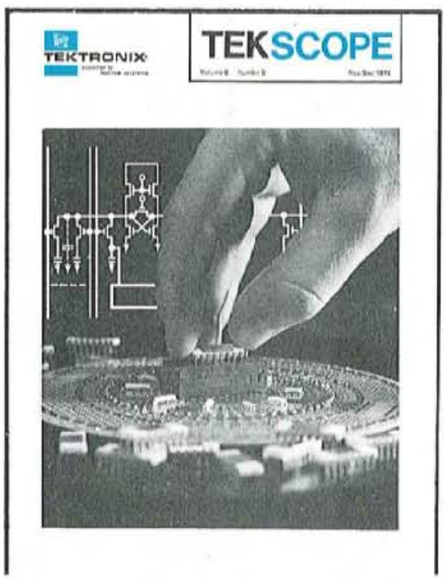
11 **Understanding oscilloscope trigger controls.**

Modern oscilloscopes offer a wide choice of triggering mode, source and coupling. A knowledge of the function and capabilities of the various triggering controls takes much of the "guesswork" out of triggering your oscilloscope.

14 **Troubleshooting digital circuits.**

An increasing portion of our time involves working with digital circuitry. A knowledge of the basic logic elements is essential to proficiency in digital servicing. Part I of a two-part article describes the characteristics of one of these basic elements — the flip-flop.

Cover: A close-up view of an activity taking place with increasing frequency — testing of a 4k MOS memory. The lead article in this issue discusses this timely subject.



What you need to know about testing 4k MOS memories

William A. Hodge   David H. Flaningam

It's getting so you can't tell a component from a system. Now we have integrated circuit memories in flat packages about an inch long and half an inch wide, able to store 4096 binary bits of information. And the size of the chip in such a package is very small, of course.

But more dramatic than the small size are the low price and the downward price trend. The typical price for these 4-kilobit memories (in large quantities) is between \$4 and \$8 each. That's 0.1 to 0.2 cents per bit. Regardless of the quantity of 4k MOS memories used to build bigger memories, the price per bit remains essentially constant. With core memories the price per bit decreases when memory size increases. There is a price crossover favoring MOS for the smaller memories and cores for the bigger memories.

The combination of small size and low price is bound to be a winner. The demand for these memories is skyrocketing. For one thing they fill the need for small, inexpensive memories to go with microprocessors, a fast expanding LSI circuit technology itself.

Even though the 4k MOS memory typically has only 22 pins or less, it isn't simple to test. It looks like a small component but resembles a small digital system when you consider what it takes to test one thoroughly. Unlike ferrite core memories the individual components and conductors cannot be tested separately first. And unlike ferrite core memories, failures are not usually catastropic, as a cracked core would be, for example. Sometimes certain combinations of bits won't store, or a bit may not remain stored as long as it should.

The number of possible failure mode combinations is astronomical. Testing all of them is seldom practical because a point of diminishing returns is quickly reached in the test process. An acceptance quality level (AQL) that tolerates up to 1% faulty memories may not be good enough for a user. But a memory manufacturer's AQL that is much better than that may be hard to find, hard to believe, or the product very costly. We should bear in mind, however, that the manufacturer's AQL is based on an extensive set of specifications. Not every user will operate the memory over the full temperature range, nor is he likely to encounter all of the "worst-case" conditions.

It seems clear that part of the money saved in purchasing 4k MOS memories will need to be spent testing them. The question is, how to minimize that expense. Troubleshooting defective electronic equipment at the end of a production line is very costly, and after shipping the equipment the troubleshooting cost is sometimes impossible to calculate. We need to test the device before installing it. Here are a few words about how the 4k MOS memories work and how to test them.

How 4k MOS memories work

MOS memories are built using insulated-gate field effect transistor elements. They have such low leakage that the small stray capacitance associated with each element may be used as a bit storage medium for several milliseconds at a time. The memories are built so that any one of the 4096 storage cells may be examined for a high or low state, or altered to the opposite state when necessary. This means we have a random access memory (RAM) that we can read or write into at will. It usually takes about 0.5 μs to examine or alter one cell, so it takes about 4000 times as long (2 ms) to examine or alter all cells. Like other semiconductor memories, it completely forgets what was last stored when power is turned off. Furthermore, any cell that has a high level stored in it may discharge to an ambiguous level in a few milliseconds if it is not refreshed. How quickly charge is lost is referred to as memory volatility. That it must be refreshed makes it a dynamic RAM; a static RAM would not have to be refreshed. The leak-down is slow at low temperatures so the maximum refresh period is specified at the maximum allowable operating temperature: for example, 2 ms at 70° C. Figure 1 shows a typical curve of time versus temperature for a type MF7112 memory made by Microsystems International Ltd.

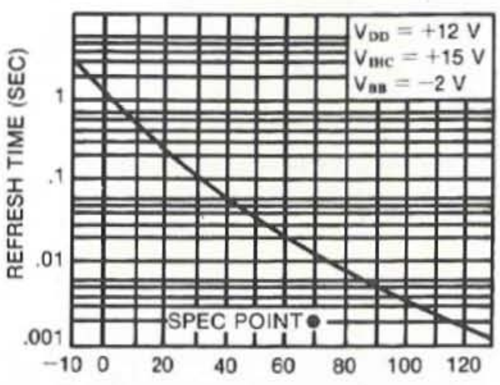


Fig. 1. Shows the effect of temperature on refresh time. Although at 70°C each cell should be refreshed every 2 ms or less, you might be able to wait 10 ms. At 25°C the curve shows refresh time can typically be ten times longer than at 70°C.

Memory configuration

A 4096-bit memory may be arranged with its cells in 64 rows, with 64 cells per row. Or it may have a different configuration, like 32 rows of 128 cells per row. It takes about 0.5 μs to refresh a cell, but an entire row may be refreshed at the same time. The more cells you can refresh at one time, the smaller the percentage of time you need to devote to that part of the business. If you had to refresh only one cell at a time in a 4k memory you would have a full time job just keeping all cells refreshed every 2 ms.

The location of any cell can be identified. First assume that they are all physically arranged in a matrix of rows and columns. The combination of row number and column number may then constitute an address for any cell. To detect the high or low voltage state of a particular cell, or to cause it to go to a particular state, you must first identify the cell by its address. To do that with only 22 pins on the memory, the memory must have two built-in address decoding circuits, a row decoding circuit and a column decoding circuit. A 64 x 64 matrix will usually have six pins on the IC devoted to addressing rows and another six pins devoted to addressing columns. There are 64 possible combinations of high and low states on six lines ($2^6 = 64$) and 4096 possible combinations of high and low states on twelve lines. In other words, each cell would be addressed by a unique combination of states on the twelve address pins on the IC. Some memories have only six address lines and therefore can be built with only 16 pins instead of 22. To address a particular cell with only six lines you must identify the column and row in two sequential steps, with the first half of the address temporarily stored in a latch built onto the memory chip.

For you to write a high or low level into one of the cells, that level must exist on one of the IC input pins reserved for the purpose while the cell is addressed. The line to that pin is usually called Data In. See Figure 2 for a typical set of labels for the different pins on a 4k MOS RAM, a Motorola MCM6605.

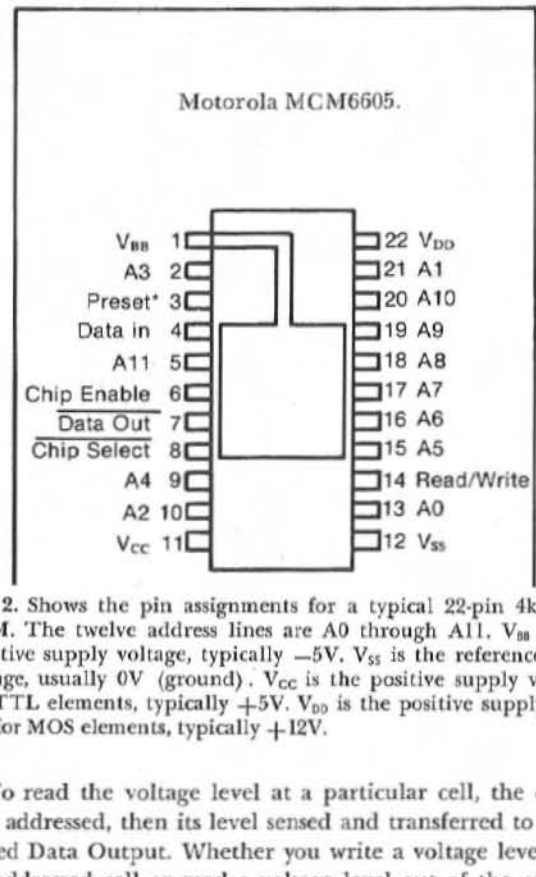


Fig. 2. Shows the pin assignments for a typical 22-pin 4k MOS RAM. The twelve address lines are A0 through A11. V_{BB} is the negative supply voltage, typically −5V. V_{SS} is the reference level voltage, usually 0V (ground). V_{CC} is the positive supply voltage for TTL elements, typically +5V. V_{DD} is the positive supply voltage for MOS elements, typically +12V.

To read the voltage level at a particular cell, the cell is first addressed, then its level sensed and transferred to a pin called Data Output. Whether you write a voltage level into an addressed cell or read a voltage level out of the cell depends on the level you apply to another input pin. That pin is usually called Read/Write or $\overline{\text{Write}}$. One level on that pin makes it possible to read and the other to write. The act of reading should not change the level in a memory; reading is non-destructive. In fact, in some memories, reading a cell also refreshes the cell.

In addition to reading or writing in a MOS memory, an operation called read-modify-write is common. This mode is used when you want to write new data immediately after reading the data already there. The operation makes it unnecessary to wait for a new clock pulse—a big time-saver when you realize how much time you might spend waiting.

Clock pulses mark the moments when the various input conditions will be examined or the level on the Data Out pin considered valid. The clock line is usually called Chip Enable. On some memories the data output line is able to drive TTL logic circuit directly. In those cases the output line may have three states: High, Low or Floating. Floating is essentially the same as disconnected—unable to influence the circuit it drives.

One or two other inputs are required to make a MOS memory function properly, but precisely what these inputs do and what they are called differs with the type of memory and the manufacturer. In general, however, when these lines are driven with pulses that have the proper timing relationship to pulses driving the other inputs, they make it possible to read, write and refresh in the way intended.

All inputs to some MOS memories may be driven directly by TTL circuits. Other memories may require a drive higher than 5 volts on some inputs. MOS memories that drive TTL circuits directly or accept the drive from TTL circuits usually require a +5-volt supply. A +12-volt supply and a negative supply of −2 volts to −9 volts are also required.

What testers should do

Now let's consider what's involved in testing these memories. In recent years two kinds of tests on digital devices have been identified— functional tests and parametric tests. The merits of the two categories have been debated repeatedly. A simple example of a functional test is what you do when you substitute a new transistor for one you suspect is no good in a circuit that isn't operating properly. If the new transistor restores the circuit to normal operation, it is reasonable to say that the new one functions satisfactorily. Because that's the main thing you want a component to do, some will argue that functional tests which closely simulate the end use of a component are the most important tests a user can make. Others will argue that simulation is seldom perfect, and that the only justification for calling a component defective is that it does not do what the manufacturer claims it will do. When a component is tested to determine whether a particular characteristic (parameter) meets the claims of the manufacturer, the test may be said to be a parametric test. Parametric tests may be categorized as dc tests or ac tests, depending on whether the characteristic being tested applies to a steady state (dc) condition or a dynamic (ac) condition. Both parametric and functional testing are usually advisable for users of complex components like 4k MOS memories.

Testing a memory to see whether it will work satisfactorily in your equipment includes being sure every cell can store both a high level and a low level. There are several ways to test for this. You might write a high into each cell, then check that you read a high from each cell. After that you would write a low into each cell and check that every cell read low. The cells can be addressed in any sequence when writing or reading. Another way of making this test is to alternate between writing a level and reading that level, progressing from cell to cell. To read and write both a high and a low state on every cell takes 16,384 operations (4 x 4096).

Other similar tests that take more operations, and consequently more time, should follow this test. If a given memory did not pass this fundamental test, however, further testing might be pointless. It is desirable to have the testing equipment able to discontinue a test and reject a part at any time. It is also desirable to segregate defective memories according to the fault that is the basis for rejection. Suppliers who accept them for credit want to know why you consider them defective.

Test patterns

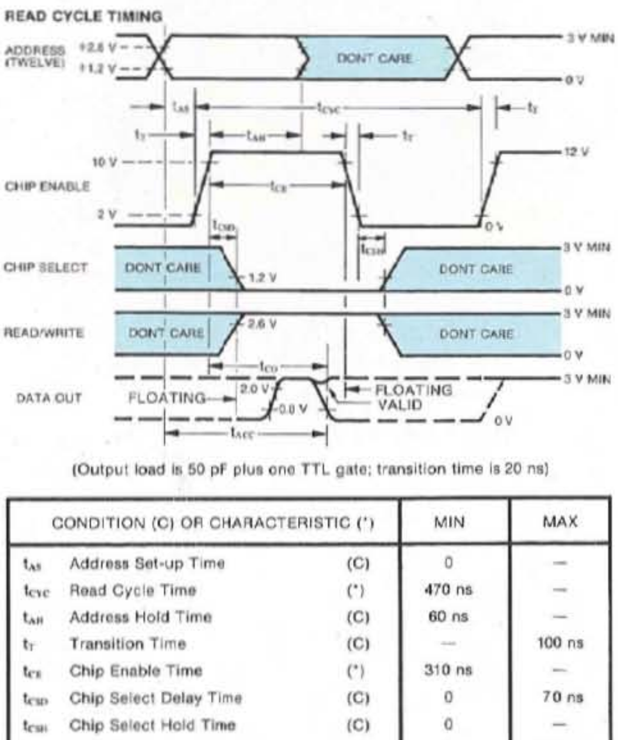
Some MOS memory cells may write and store properly under all conditions except one following a particular sequence of memory operations. For example, because MOS memory cells rely on stray capacitance as a storage medium, the charge status of a cell can sometimes be altered when an adjacent cell switches states. To exercise a memory in a way that tests this possibility requires a particular test pattern. Some patterns for testing 1024-bit memories have become fairly common and are given names like Walk Data, March, Ping-pong. The Ping-pong pattern addresses successive memory cells in all possible combinations and takes about 2 seconds (over 4 million operations) to exercise a 1k MOS memory. To test a 4k MOS memory using the same pattern would take about 32 seconds, 16 times as long. Such patterns require an amount of time proportional to the square of the number of cells and are, therefore, called N^2 patterns.

Incidentally, N^2 test patterns don't always exercise even 1k MOS memories the way you think. In some memories a particular cell (the one with the highest address number) is addressed by the mere act of disabling the address inputs to any other cell. That, in effect, makes each new address follow the same old address, limiting the number of combinations to N instead of N^2.

Thirty-two seconds for a single test may be prohibitive from an economic standpoint. Different test patterns have been developed to test 4k MOS memories so they may be tested in shorter, more reasonable periods of time with comparable certainty of detecting faults. New and better test patterns will be developed. Some patterns work better on one type of 4k memory than another because of differences in construction. A knowledge of the layout (topology) of the thousands of microscopic parts of a memory helps. It is also helpful to be familiar with the most likely causes of failures. The test program can then be written to disclose the greatest number of faults in a minimum of test time.

Technical requirements

There are a few important technical requirements a MOS memory tester should meet. Some of these requirements may be more fully appreciated by taking a look at the read-cycle timing waveforms that are a part of a typical 4k MOS memory spec sheet, Figure 3. All but the last of these pulses must be generated by the test equipment and delivered to the device input pins, free from overshoot and ringing, with accurate amplitude excursions and transition time (slew rate). There are also some critical timing relationships between input pulses that must be observed. For example, the leading edge of the Chip Enable pulse must not occur ahead of the leading edge of any of the twelve address pulses. It is not easy to generate and deliver fifteen pulses so that they arrive simultaneously. The tester must be able to receive and examine the state of the Data Out pulses, as well as deliver properly timed input pulses in a programmed test pattern. To test the validity of any output pulse, the tester must know beforehand what the proper state of the output pulse is, and be able to test for it at precisely the right moment. Knowing the input conditions lets you predict what the output pulse state should be for any test cycle, so the actual output is compared with the predicted output. The moment of comparison (strobe timing) is critical because in most MOS memories the output pulses don't remain in a high or low state long in each cycle but quickly change to a floating state. It is also critical because of the transmission delay time introduced by the cable that connects the test system to the memory test fixture. Delay time is constant, however, and a well-designed tester takes this into account.



(Output load is 50 pF plus one TTL gate; transition time is 20 ns)

CONDITION (C) OR CHARACTERISTIC (*)			MIN	MAX
t_{AS}	Address Set-up Time	(C)	0	—
t_{CYC}	Read Cycle Time	(*)	470 ns	—
t_{AH}	Address Hold Time	(C)	60 ns	—
t_T	Transition Time	(C)	—	100 ns
t_{CE}	Chip Enable Time	(*)	310 ns	—
t_{CSD}	Chip Select Delay Time	(C)	0	70 ns
t_{CSH}	Chip Select Hold Time	(C)	0	—
t_{CO}	Chip Enable-To-Output Time	(*)	—	280 ns
t_{ACC}	Read Access Time	(*)	—	300 ns

Fig. 3. Shows input and output waveforms, their timing relationships, and timing requirements for a read cycle.

Comparison of the state of an actual output pulse with the state of the predicted output pulse is done in a digital comparator. When the states are not alike, an error is detected and the component judged defective. To make sure that comparisons only occur when they should, the comparators are strobed. Strobe pulses are generated by the tester at moments when valid memory output data should be arriving back in the comparator. Those moments begin in each cycle when the specified maximum access time has expired, and they end at some specific later time depending on whether the cycle is a read or write cycle. A tester should be able to generate fast, clean comparator strobes that begin and end with precise timing.

Digital comparators basically tell whether two levels are the same or not the same: that is, both high or both low, or one high and the other low. But there are limits to what may be called a high level and what may be called a low level. The better digital comparators check highs and lows against different reference levels. These comparators are called dual-level comparators. The high and low reference levels should be programmable, in small, accurate increments over an adequate range, to correspond with the memory manufacturer's definitions of high and low limits. With dual-level comparators you can test for the effects of noise voltage spikes on output data. For example, noise spikes big enough to alter a +2.4 volt high level to a +1.7 volt level would go undetected if +1.5 volts were selected as both the lower limit of a high level and the upper limit of a low level. See Figure 4.

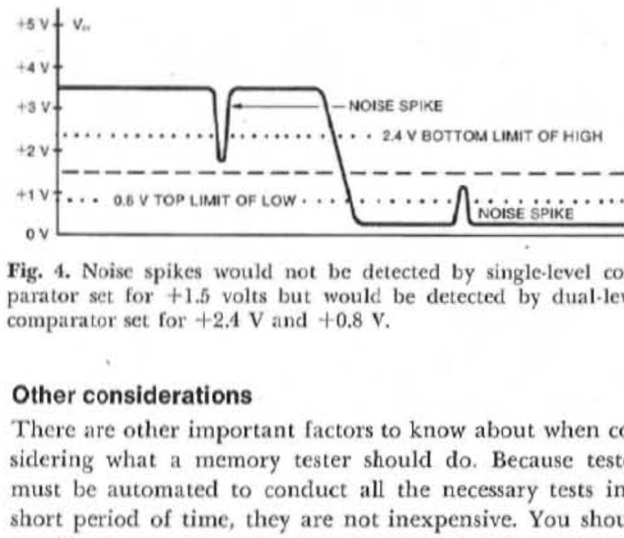


Fig. 4. Noise spikes would not be detected by single-level comparator set for +1.5 volts but would be detected by dual-level comparator set for +2.4 V and +0.8 V.

Other considerations

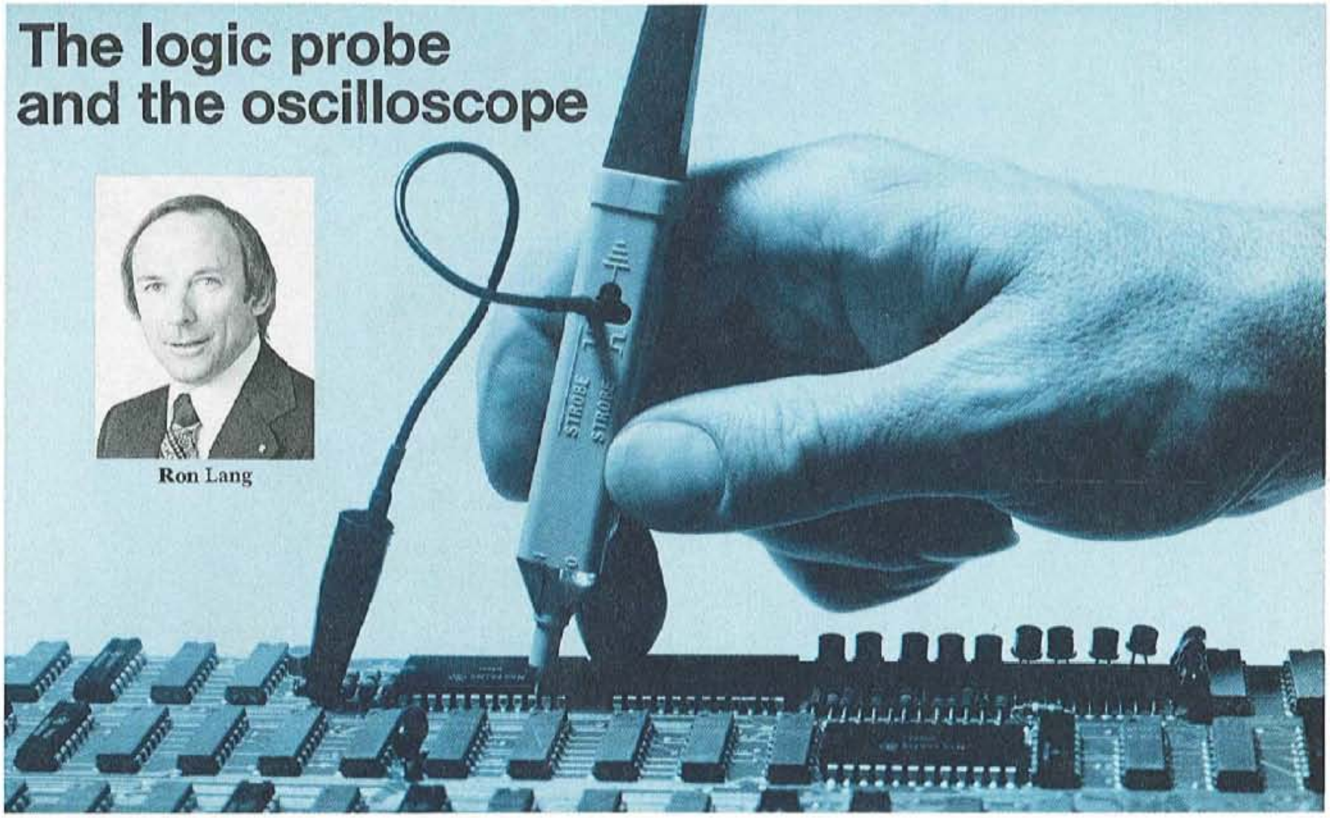
There are other important factors to know about when considering what a memory tester should do. Because testers must be automated to conduct all the necessary tests in a short period of time, they are not inexpensive. You should consider how many other jobs they may do when you look at the price. You should also consider obsolescence and expandability. Data bus construction helps assure versatility and expandability, and insures against obsolescence. Data bus construction merely means that all the controllable modules, sections, and pieces of equipment get instructions from the system controller section on common data lines. To add a piece of equipment means that you connect it in parallel to the other pieces on the same lines (data bus), and that it ignores all data until it is addressed by the system controller.

You spend a good part of the time required for testing devices like MOS memories in handling the devices—inserting them into and removing them from the test fixture. To avoid wasting time, two test fixtures may be used with one test system. One fixture is involved with the removing and inserting process while the other conducts tests. A system

which can switch its tests automatically in this way should pay for itself much more quickly than one that can't. These considerations are only samples. There are numerous others.

We believe 4k MOS memories will have a dramatic influence on the design of new electronic equipment. We also think most engineers, technicians and managers will need at least a good conversational knowledge of how MOS memories work and some of the basic problems in testing them. However, you may need to know more than most people about testing these memories, and probably much more than has appeared here. In that case, our Application Engineers would be glad to talk to you. They will want to tell you all about the TEKTRONIX S-3400 series of test systems that we believe do an outstanding job of testing MOS memories and similar devices. You'll find them good listeners, too.

The logic probe and the oscilloscope



Ron Lang

When the logic probe first appeared on the measurement horizon, it was touted by some as a low-cost replacement for the oscilloscope in troubleshooting and servicing digital logic circuitry. Time has, indeed, proven the logic probe to be a valuable tool in working with digital logic: not as a replacement for the oscilloscope but rather as a valuable adjunct.

The province of the logic probe is fast failure detection, that of the oscilloscope in-depth analysis — a perfect complement. With the logic probe the user can often quickly locate a circuit fault or failure. The oscilloscope is then brought into play to analyze the character of the fault or failure.

Although designed primarily for fast checking and troubleshooting of existing digital circuits on location by service personnel, the logic probe is also a time-saver for designers of circuits being breadboarded.

A digital logic probe's sole function is to indicate the state of the logic: high, low, or faulty, i.e., open or in the indeterminate range. There are many logic probes that do this. They use incandescent lamps or light emitting diodes as indicators. Some probes have a one-light readout using a bright and a dim indication; others have two, three, or four light systems; and at least one uses four LEDs as the readout.

There is also a variety of options to choose from. In some cases, these options are attached to the probe externally. Included are storage or memory, fast response or slow response, strobe input, and accessory packages.

The TEKTRONIX P6401 TTL Logic Probe combines all the features needed to verify any logic condition in one small, lightweight package. Two lights, red and green, are located in the nose of the probe. There they can be easily viewed without moving your eye from the point under test. The red light indicates logic 1 (2.15 to 5 V dc) and the green light logic 0 (0 to 0.7 V dc) in the following manner:

Logic State	Indication
Steady high state	Steady red light
Steady low state	Steady green light
Pulse trains (normal switching)	Blinking red and green lights at full intensity
Abnormal state (between high & low)	No lights
Open circuit (greater than 10 kΩ)	No lights
Excessive input voltage (greater than 6 volts)	Both red & green lights lit
Alternating between high state and indeterminate state	Blinking red light
Alternating between low state and indeterminate state	Blinking green light
Single pulse (+)	Green, red, then green
Single pulse (−)	Red, green, then red.

The P6401 has a fast response time and recognizes pulse widths as short as 10 ns. The circuitry controlling the indicator lights has a built-in stretch feature. Once a light is turned on, the circuitry holds it on for 100 ms; once extinguished, it won't allow it to turn on again for 100 ms. In the observation of rapid pulse trains, this gives time to turn the light on and time to let the eye recognize that the light has come on and turned off. If the signal repetition rate is below 5 Hz, the blinking of the lights will follow the signal repetition rate. When the point being observed exceeds about 6 V dc, both red and green lights will glow steadily. This lets the operator know that an over-voltage condition exists in the circuitry being checked. Built-in protection for the probe input permits momentary overloads up to ±150 V dc or rms without damage to the probe. At high-input voltages, an easily resettable fuse in the input will open and prevent circuit damage. Probe input impedance is high in all states (7.5 kΩ paralleled by 6 pf) so as not to disturb the circuit under test.

The length of ground path returns is an often overlooked consideration in the use of logic probes. The P6401 has provision for plugging a short ground lead directly into the probe. This is the same ground as the negative, or black, power lead, but provides a considerably shorter path for the fast-signal acquisition encountered in TTL circuitry. This eliminates ringing and overshoot that could cause false light indications. Short ground leads should be used in all measurements.

Many features that are optional or even add-on modules on other logic probes are standard on the P6401 — for example, the "store" mode. This holds the light readout on until manually reset and is a valuable aid in single-pulse detection. As mentioned previously, pulse widths as short as 10 ns can be detected and indicated by the readout lights. Another feature, the "strobe" or gate mode, is employed when the coincidence of logic levels at two points needs to be confirmed.

The P6401 at work

Let's put the P6401 to work in actual circuits and see how it performs. Power is usually applied to the probe from the circuit under test through convenient clip leads attached to the probe. The red lead attaches to the +5 V dc bus and the black lead to the ground reference bus. Now simply touching the probe tip to the point under investigation will indicate the logic condition.

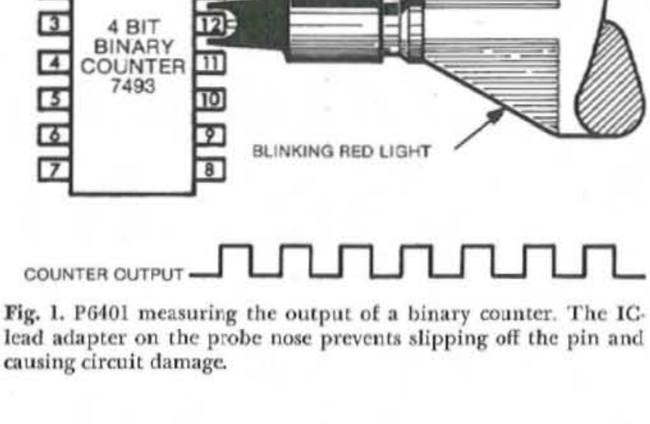


Fig. 1. P6401 measuring the output of a binary counter. The IC-lead adapter on the probe nose prevents slipping off the pin and causing circuit damage.

In Figure 1 the logic probe is being used to check the output of a binary counter. The red and green lights will blink on and off at a 5-Hz rate indicating that the logic level is transiting from logic 0 to logic 1 and back.

The IC Test Lead Adapter used in this application was designed especially for IC chip leads. It prevents the probe tip from slipping from the lead under test and causing faulty indications or disrupting circuit operation. It is also convenient for probing components mounted on circuit boards, such as resistors, capacitors and diodes.

Figure 2 shows the logic probe being used to verify the inputs and outputs of a positive NAND gate. When the two inputs are low, the output is high; when pin 8 is probed, the red light will come on. If the inputs, pins 9 and 10, are probed the green light will come on, indicating a low state.

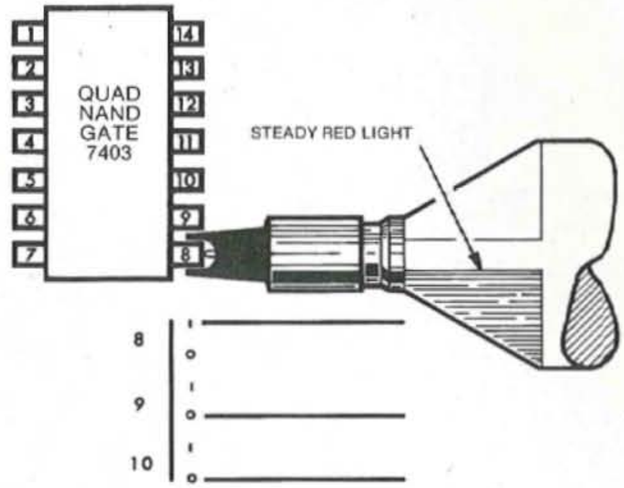


Fig. 2. The P6401 indicating the output of a NAND gate.

Often it is necessary to know if an event has happened. This may be a pulse that happens only once in several minutes. Here the "store" feature of the probe is used to capture a single pulse that may be as narrow as 10 ns. Switch the logic probe to the "store" mode with the switch located on the probe. It can now be attached to the test point to be monitored. (See Figure 3.) The green light comes on and stays on when pin 8 is probed; this is a logic 0. The red light turns on when the four inputs become positive, causing the output, pin 8, to go positive, a logic 1 state. The two lights will stay on even if the probe is removed from pin 8. To reset the probe, slide the "store" switch back. If the "store" mode is needed again, simply push the "store" switch forward. If desired, the probe may be attached to the circuitry and left unattended. When the event happens, the appropriate light will come on and remain on indefinitely for a record of the event.

Many times it is desired to detect the coincidence of two pulses. The P6401 has this capability as a standard function. To determine coincidence, the strobe input of the probe is connected to the strobe point that the event is to coincide with, such as a gate or strobe pulse. If the gate or strobe is a negative pulse, connect the strobe lead to the $\overline{\text{strobe}}$ (strobe not) input on the probe. With the probe tip, monitor the point in question. (See Figure 4.) If the indication of the event is to be retained, the "store" mode may be used in combination with the strobe.

The probe recognition circuitry is gated off until the advent of the strobe pulse. Therefore, whatever transitions occur at the probe tip will not turn on a light. When the strobe does occur, the probe is gated on. An event at the probe tip will be indicated by the lights and retained if the "store" mode is used. If the event does not happen for at least 2 ns after the strobe, the green light will come on first, and stay on if in "store" mode; then the red light will come on and stay on. Because of the short, 2-ns, period both green and red lights will appear to come on together.

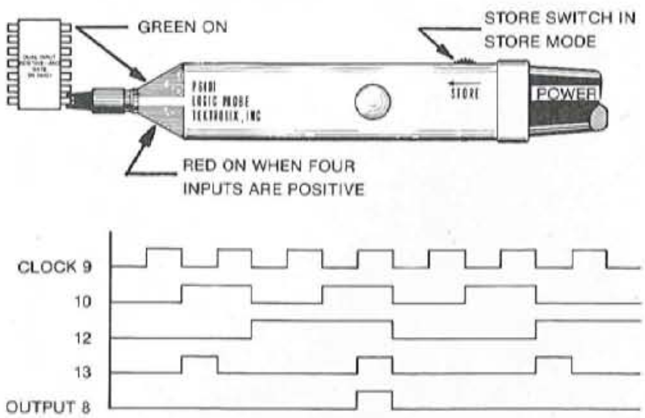


Fig. 3. The P6401 used in the "store" mode to indicate coincidence of four events. Pulses as narrow as 10 ns can be captured in the "store" mode.

If, as in the techniques shown, the desired event does not materialize, the problem can be traced to a faulty component such as an IC chip having the appropriate inputs but a wrong output. The faulty component can then be replaced and the circuit put back into correct operation, or an oscilloscope can be used to examine exact wave shapes and voltage levels for an in-depth analysis of the problem.

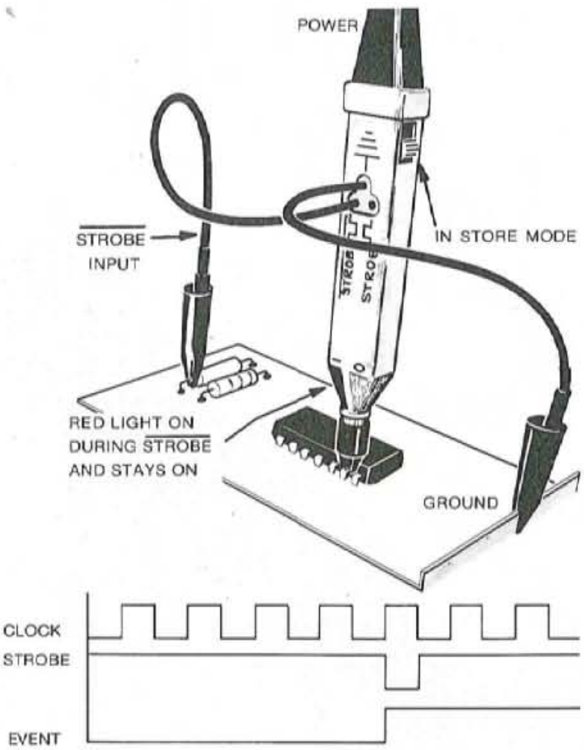


Fig. 4. The STROBE function is used to determine if an event occurs during a strobe, or gate, interval.

In summary, the P6401 Logic Probe is a lightweight, dynamic, decision-making tool that derives its power from the circuit under test to determine logic states. It can quickly find faults that can be corrected on the spot. Used alone or with an oscilloscope the logic probe is finding increasing use in designing and troubleshooting systems such as point-of-sale terminals, computers, inventory control systems, video tape record and playback systems, readout systems, or any other system using TTL logic, singularly, or in combination with any other logic family.

Teknique

Understanding oscilloscope triggering controls

Modern oscilloscopes offer a wide choice of triggering controls that enable us to trigger on almost any signal. One recently introduced portable oscilloscope has twenty controls on the front panel. The popular TEKTRONIX 465 and 475 portables each have twelve — more than you would expect. Why so many triggering controls and what do they all do?

The modern oscilloscope is a versatile, general purpose instrument used in many disciplines. We want to display and measure a wide variety of signals and we need to "stop" them to do so. That means we have to be able to trigger on them. There are also many applications, such as photographing single-shot transients, that call for special triggering controls. You may never need to use them in your work, but many people do, so you find these controls on most scopes.

Another factor contributing to the large number of triggering controls is that many scopes have two sweeps — a delaying and a delayed, each with its own set of triggering controls.

Now let's look at each control: what does it do and when should it be used? Triggering controls can be divided into four groups: triggering source, coupling, mode, and variable controls such as trigger level and holdoff.

Trigger source

As the name implies, the trigger-source controls determine the origin of the signal that will be used for triggering. There are usually three sources:

1. Internal — part of the signal fed into the vertical amplifier, and the source most commonly used. In multichannel or dual-beam scopes you also need to choose which channel, or beam, you will trigger from internally. This choice is often a source of triggering problems. What typically happens is we feed the vertical signal into one channel and fail to notice that the trigger selector is set to the opposite channel. Another pitfall is trying to operate in the ALTernate mode with only one input signal.
2. External — from a source external to the scope. This signal is fed into the external trigger input connector. The most common problem here is that the signal amplitude often exceeds the range of the trigger level control. Some scopes have an EXT ÷ 10 position to attenuate the external signal. An alternate solution is to use a probe on the external input. Use of a probe has the added advantage of minimizing loading on the trigger source.

   External triggering is convenient when you're viewing a series of events keyed to a single pulse, such as the index pulse on a disc memory, or to a stable source like the clock pulse used in digital circuits. It also allows for the use of an external device, such as the TEKTRONIX 821 Word Recognizer, to generate a single trigger pulse from a selected pattern of pulses such as a digital word.
3. Line — derived from a low-voltage winding on the scope power transformer. The line source is especially useful when viewing small ripple voltages on power supplies. It is also useful for viewing the fields in a television signal and other events related to the power line frequency.

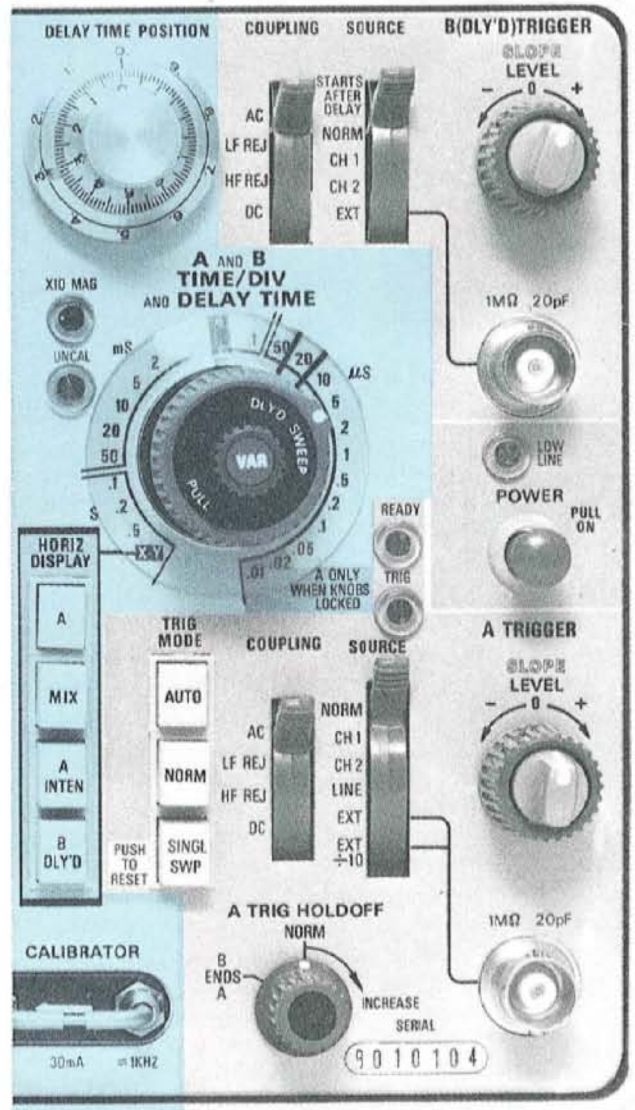


Fig. 1. Triggering controls on the 475 are kept at a minimum by using multi-position switches for trigger source and coupling. The SINGLE SWP pushbutton also serves as the RESET control for single-shot sweeps.

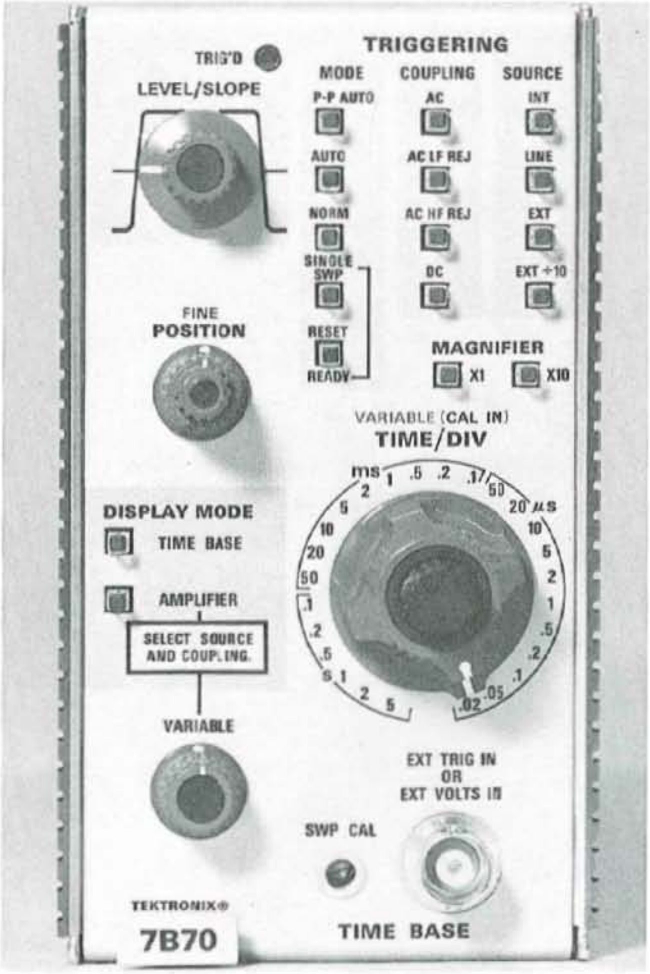


Fig. 2. The 7B70 Time Base uses separate pushbuttons for selecting triggering mode, source and coupling. Hands-off triggering is accomplished by actuating the three uppermost pushbuttons. Trigger level and slope.

Trigger coupling

The trigger coupling controls are, basically, passive filters that eliminate unwanted signals. Choices of coupling usually include dc, ac, ac low-frequency reject, and ac high-frequency reject. The frequency range of the various coupling positions on the TEKTRONIX 475 are shown in Figure 3.

Dc coupling is used to trigger on slowly changing signals such as a slow ramp, on low-repetition-rate signals, or to trigger at a given dc level. On most scopes, when you use internal triggering, you can set the trigger level control for triggering at a dc level represented by some point on the crt screen. You can easily verify the setting by rotating the vertical position control and noting that triggering takes place at the desired point. On other instruments the trigger takeoff is ahead of the vertical position control, and you can't predetermine the dc trigger level setting without using an external signal. This configuration has the advantage that the vertical position control has no effect on the dc triggering point.

The ac coupling positions avoid the effects of dc present in the triggering signal. In the AC position, signals from about 60 Hz to the upper bandwidth limit of the vertical amplifier are passed to the trigger circuits. In some instances, undesirable frequencies riding on the triggering signal cause problems. Low-level signals often contain hum induced by stray magnetic fields. You can get rid of the hum by using AC LF REJECT coupling. Conversely, you can eliminate high-frequency noise causing triggering problems, by using AC HF REJECT coupling. You will, no doubt, use the AC coupling position most often, but you will also find the other positions valuable in difficult triggering situations.

Trigger modes

There are at least three triggering modes available on modern oscilloscopes: automatic, normal and single-sweep. Peak-to-peak automatic, a special form of automatic, is included on some instruments. High-frequency sync is usually found on wide bandwidth and sampling instruments.

In the automatic, or AUTO, mode the sweep free-runs in the absence of an adequate trigger signal. This provides a convenient reference trace on-screen. Early scopes with AUTO triggering had no trigger level control in the AUTO mode. The signal being viewed was superimposed on a regenerative trigger signal generated in the trigger circuitry. When the combined signal reached the appropriate level the sweep was triggered. This permitted you to look at different amplitude signals in a circuit without having to readjust the trigger level control. With the AUTO mode in today's instruments, trigger level control is maintained. When the signal is outside the range of the level setting, the sweep free-runs. This type of free-running display is useful when measuring the peak-to-peak amplitude of a signal without observing the waveshape, as in bandwidth measurements.

In the P-P AUTO mode the peak-to-peak amplitude of the trigger signal is impressed across the trigger level control. If you have an adequate trigger, the sweep will be triggered regardless of the level control setting. So you can look at different signal levels without adjusting the level control, but you maintain control of the point at which triggering occurs.

The NORMAL mode is so called because it handles the widest range of triggering signals. It is the mode normally used when you have a complex waveform to trigger on, or when the signal frequency is outside the range handled by the AUTO mode. In the NORMAL mode, the sweep will not run in the absence of a trigger, so you have no reference trace.

HF SYNC is typically used when the amplitude of the high-frequency signal is too low to trigger on solidly, or when the frequency is beyond the bandwidth capabilities of the trigger circuit. The TRIGGER LEVEL and TRIGGER HOLDOFF controls usually serve as the sync control in this mode.

The SINGLE SWEEP mode is used when you want to photograph transients or low-repetition rate events. Here's the usual procedure. Set up the triggering controls in the NORMAL mode, using the calibrator as a signal source to simulate the transient. Then, with the calibrator signal still applied, go to the SINGLE SWEEP mode and adjust the intensity and focus controls while pressing the RESET button repeatedly. Once the setup is completed, remove the

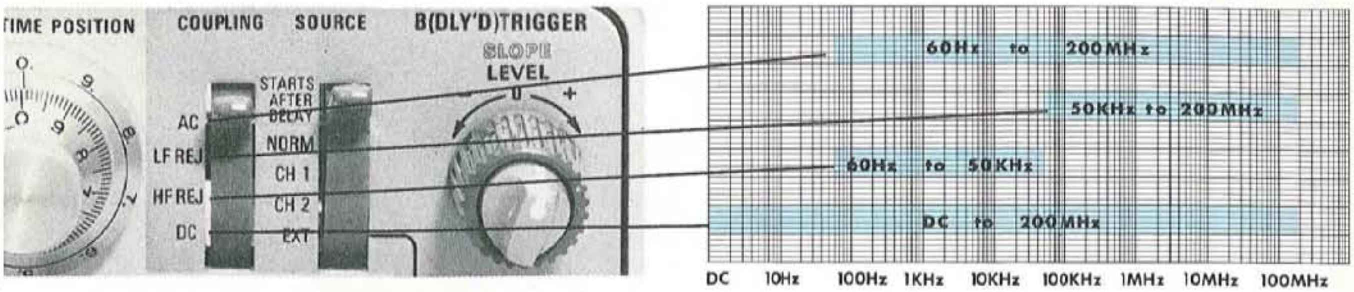


Fig. 3. Frequency range of each position of the COUPLING switch.

calibrator signal and apply the signal input lead, open the camera shutter, and press the RESET button. The READY light will come on, indicating that the sweep is ready to receive a trigger. When the event occurs and the sweep is triggered, the READY light goes out, indicating that a sweep has occurred. The camera shutter is then closed. Clearly, this procedure is much easier than trying to synchronize the camera shutter to the event.

Trigger level, slope and holdoff

Trigger level and slope selection are sometimes combined in one control, as in Figure 4. More often they are separate controls. Trigger slope refers to the direction the leading or trailing edge of the signal traverses when triggering takes place. It does not refer to the dc level of the signal. For example, if the SLOPE control is in the plus (+) position, triggering will occur on the rising portion of the waveform. In the minus (–) position, triggering will take place on the falling portion.

The TRIGGER LEVEL control selects the point on the slope where triggering will occur. When triggering internally you should be able to trigger at any point on an on-screen display. If you have a display several divisions in amplitude, the TRIGGER LEVEL control will have a wide range over which the sweep can be triggered. For low-amplitude displays triggering will occur near the 0 setting of the LEVEL control and triggering will seem to be very touchy. That's because

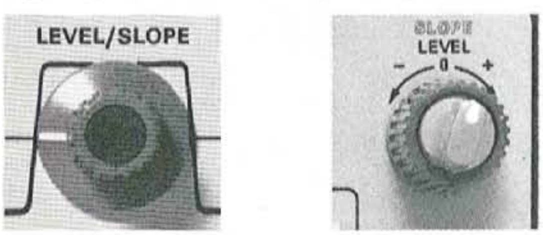


Fig. 4. Two methods of handling the TRIGGER LEVEL and SLOPE function. Both functions are accomplished with one control shown at left. Concentric controls at right accomplish both functions and occupy about the same front-panel space.

the LEVEL control doesn't have much signal over which to range. The range of the TRIGGER LEVEL control when triggering externally is different for different instrument types. It will typically be at least +1.5 V to –1.5 V in the straight-through position and +15 V to –15 V in the EXT ÷ 10 position.

The TRIGGER LEVEL control cannot discriminate between pulses of the same amplitude. This is where the TRIGGER HOLDOFF control comes into play. You may want to trigger on a particular pulse in a pulse train, but the pulses normally have the same amplitude. When the sweep recovers and is ready to be triggered, the next pulse will trigger it. Depending on the TIME/DIV setting and the sweep recovery time, triggering may or may not occur at the same point in the pulse train each time, and the display will be unstable. The holdoff control lets you adjust holdoff time to avoid this condition. If your scope doesn't have a holdoff control, you can achieve the same effect using the VARIABLE TIME/CM, but the sweep will be uncalibrated. If the scope has a delaying sweep, SWEEP LENGTH can serve as a holdoff control.

Summary

Oscilloscopes typically have many triggering controls. But each serves a useful purpose. For most of your work, you probably need only a few trigger controls. But when you run into a less-than-ideal triggering signal, you will find those "extra" controls indispensable.

On Tektronix instruments we make it as easy as possible to use the triggering controls. For example, with all of the trigger switches in the "up" position, or the top row of trigger pushbuttons depressed, you should have a trace on screen. If the display is not stable, a slight adjustment of the TRIGGER LEVEL control may be all that is necessary. In most cases it's that simple.

Triggering controls may seem numerous, but each one is there to make your scope easier to use; put them all to work for you.

Servicescope

Troubleshooting digital circuits

If you haven't had much cockpit time troubleshooting digital circuits, you probably think it's a tougher job than it is. Most every experienced troubleshooter you talk to who knows both analog and digital circuits agrees that digital circuits are much easier to troubleshoot.

Just as the analog man needs to know about transistors, gain, feedback, dividers, etc., the digital man needs to know about AND gates, OR gates, inverters, flip-flops, and multivibrators. The vast majority of digital integrated circuits are made up of these elements or combinations of them. Of the group, flip-flops and multi-vibrators are probably the toughest to learn and retain. Therefore, Part I of this discussion will review flip-flop fundamentals.

PART I Fundamentals of flip-flops

Most flip-flops have two outputs, designated Q and $\overline{Q}$, or sometimes 1 and 0. The two outputs are complements of one another; if Q is at a high level $\overline{Q}$ will be at a low level and vice-versa. Sometimes only one of two outputs is used and in that case the unused output line may not even be drawn on your schematic. Don't let that confuse you. The distinguishing symbols are the input symbols. All lines except Q and $\overline{Q}$ are input lines.

T flip-flops

The simplest flip-flop is the T flip-flop, sometimes called the triggered flip-flop. It has only one input; others have at least two. The purpose of the T type flip-flop is to provide an output which switches to its opposite state each time a trigger pulse is introduced. When the outputs reverse from a given state the IC is said to toggle. A T type flip-flop can be made by connecting together several inputs on the J-K flip-flop.

D flip-flops.

Next in simplicity is the gated D type flip-flop, sometimes called a latch. This type of flip-flop allows binary data to be transferred from the D input to the Q output when the gate input (G) is at the proper level but blocks the transfer of data when the G input is in the opposite (unasserted) state. When the G input goes to the unasserted state the outputs remain (latch) in their existing states.

Clocked D type flip-flops only transfer data when a clock pulse arrives. The level at D is then transferred to the Q output and the level at Q remains until the next clock pulse arrives. If the data input level is the same as when the last clock pulse arrived there will be no change in output. You could say the output is updated just the same. The symbol for the clock input is usually CK, with the input marked with an arrow point (-▷). CP, CL or C are also used and the arrow point is sometimes omitted.

Clocked R-S and J-K flip-flops

Practically all R-S flip-flops and J-K flip-flops are clocked. The J-K inputs on a J-K flip-flop are the data input lines. The R-S inputs on an R-S flip-flop are the data input lines. The state of the outputs on an R-S or J-K flip-flop depends on the combination of states of the two data input lines when a clock pulse arrives. For an R-S flip-flop there are four combinations: (1) S HIGH and R LOW, (2) S LOW and R HIGH, (3) both LOW, and (4) both HIGH. For a J-K flip-flop the same combinations of J and K inputs apply.

There is no difference in behavior between an R-S and a J-K flip-flop except for the combination where both data inputs are HIGH. For R-S flip-flops the output levels of both the Q and $\overline{Q}$ lines are indeterminate when both data inputs are HIGH when clocked. For J-K flip-flops both output levels switch (toggle) from their existing states if both J and K are HIGH when clocked. The outputs of R-S and J-K flip-flops do not change if both data inputs are LOW when clocked.

If the two data inputs are in opposite states when clocked, the Q output should go to the same state as the S input of the R-S flip-flop, and to the same state as the J input of the J-K flip-flop. Schematically the output lines are normally drawn directly opposite the inputs to which they correspond. That is, Q is drawn opposite the S input on R-S flip-flops and opposite the J input on the J-K flip-flop, while the $\overline{Q}$ output is drawn opposite the R input or K input.

Edge-triggering and pulse-triggering (Master-Slave)

Clocked flip-flops are said to be edge-triggered or pulse-triggered. When pulse-triggered the outputs should not change until the trailing edge of the clock pulse occurs. When edge-triggered, no reference is made to the leading or trailing edge of the clock pulse. Input data is transferred to the output during and immediately following the activating transition of the clock pulse. An activating transition may be up-going or down-going, but not both, depending on the flip-flop.

Both up-going and down-going transitions of the clock pulse activate something in master-slave flip-flops. One edge stores the levels of the data inputs in the flip-flops and the other edge transfers the stored data to the output lines. Each output transfer has to be preceded by input storage, so you can say the leading edge stores and the trailing edge transfers. This must be kept in mind when a master-slave flip-flop is checked for proper operation because input data sometimes switches in the interval between the leading and trailing edges of the clock pulse. That is not usually the case but when diagnosing a trouble it may be particularly confusing.

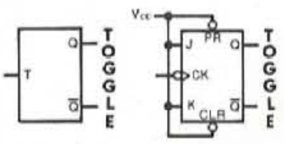
Complicating diagnosis even further is the fact that some master-slave flip-flops will always store the high level if the data input level changes between leading and trailing edges. This happens whether the high level occurs first or last and is called "ones catching". Master-slave flip-flops with "data-lockout" store only the level seen during and immediately following the leading edge transition.

The accompanying diagrams for the various flip-flops should help clarify their operation for you.

In the next issue of Tekscope we will discuss some basic techniques for troubleshooting digital circuitry.

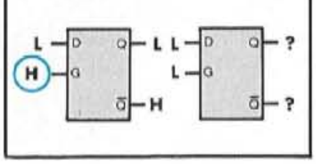
T Type Flip-flops

Each input pulse causes the outputs to reverse.



Gated D Type Flip-flops

The Q output follows the data (D) input when and only when enabled by the gate (G) input.



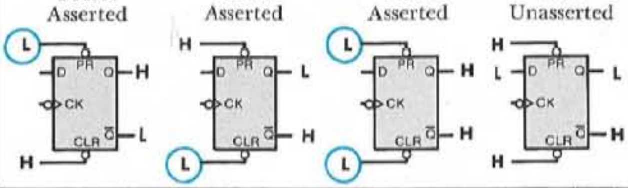
Clocked D Type Flip-flops with Preset and Clear

Asserting Preset or Clear overrides all other inputs.

Asserting both produces two HIGHS at the output, but both HIGHS will not persist even if Preset and Clear are unasserted at the same time.

When both Preset and Clear are unasserted clock pulses transfer the D input state to the Q output.

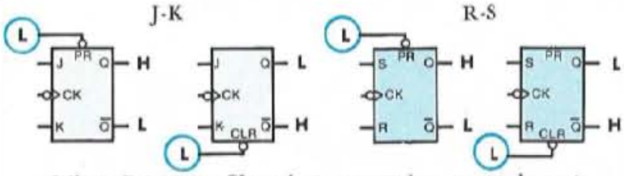
Preset Asserted | Clear Asserted | Both Asserted | Both Unasserted



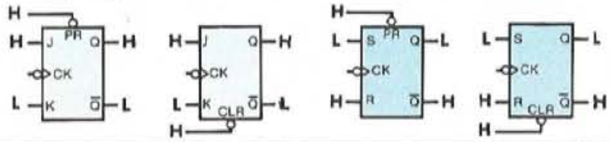
J-K and R-S Flip-flops with Preset or Clear

Asserting Preset or Clear overrides all other inputs.

J-K | R-S



When Preset or Clear is unasserted outputs do not change until clock pulse arrives then outputs change to correspond with inputs as in other J-K or R-S Flip-flops.

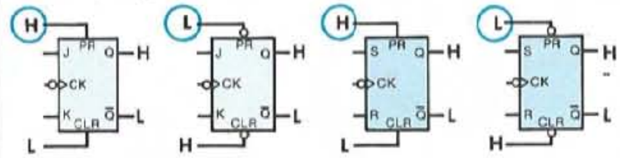


J-K and R-S Flip-flops with Preset and Clear

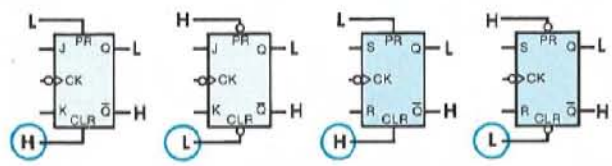
Asserting Preset or Clear overrides all other inputs.

When Preset is asserted (but Clear is not) Q goes HIGH and all other inputs are irrelevant.

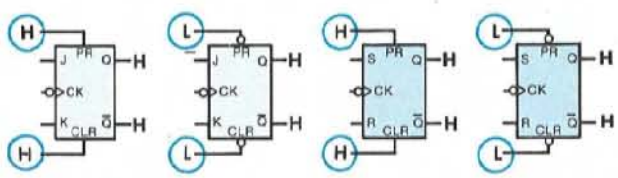
J-K | R-S



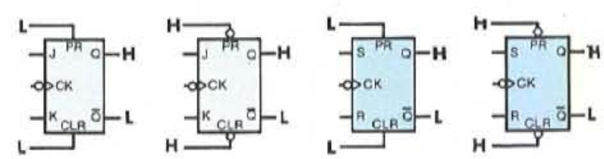
When Clear is asserted (but Preset is not) Q goes LOW and all other inputs are irrelevant.



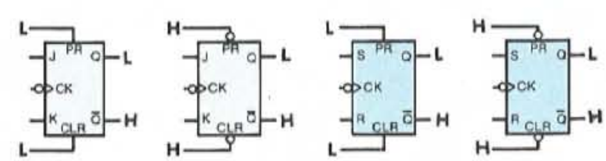
When Preset and Clear are both asserted both outputs are HIGH but will not persist even if both Preset and Clear are unasserted at the same time.



When Preset is unasserted after Clear has been unasserted Q will remain HIGH until a clock pulse arrives.



When Clear is unasserted after Preset has been unasserted Q will remain LOW until a clock pulse arrives.

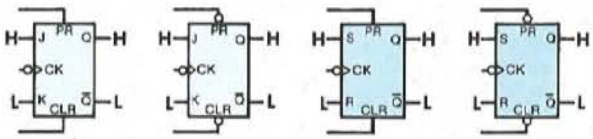


J-K and R-S Edge-triggered Flip-flops

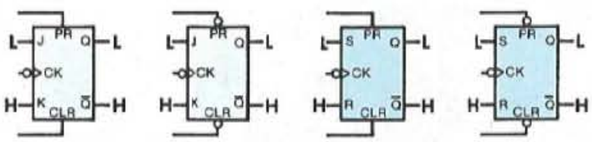
Assuming both Preset and Clear have been unasserted.

If the J-K or R-S (data) inputs are in opposite states the outputs change to correspond with the inputs when the down-going edge of a clock pulse arrives.*

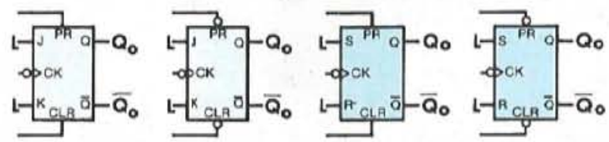
$J = Q$ and $K = \overline{Q}$ $S = Q$ and $R = \overline{Q}$



Same as above but with inputs reversed.



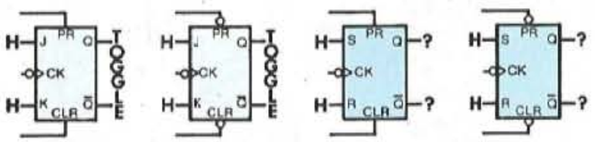
If the J-K or R-S (data) inputs are both in the LOW state the outputs do not change from the existing states when the down-going edge of a clock pulse arrives.*



If the data inputs are both HIGH when the down-going edge of a clock pulse arrives:*

The outputs of a J-K flip-flop will reverse, toggle.

The outputs of an R-S flip-flop will be indeterminate.



NOTES: Positive LOGIC: HIGH is TRUE (1) and LOW is FALSE (0).

Preset (PR) is sometimes called Set (S).

Clock (CK) is sometimes symbolized Cp.

Clear (CLR) is sometimes called Reset (R).

A function is asserted when HIGH except on input lines terminated with a small circle (-o|).

Asserted inputs are circled: (H) (L)

***When the up-going edge of a clock pulse transfers data to the outputs the clock input is symbolized without a small circle**

Master-slave Flip-flops

Master-slave flip-flops recognize and store the states of the data inputs during and following one edge of a clock pulse and transfer those states to the outputs during and following the next edge. The clock pulse edge that causes a transfer is symbolized on the clock input line.*

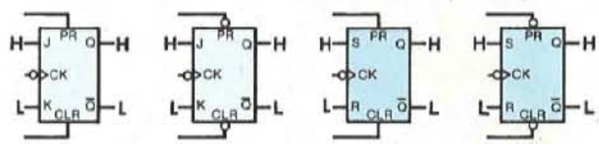
The state of a data input line should normally not change during the interval between the leading and trailing edge of a clock pulse. If the state does change during this interval a HIGH level probably will be stored and transferred. This is called "ones-catching." Master-slave flip-flops with "data-lockout" will store only the level that exists during and immediately following the leading edge transition.

J-K and R-S Pulse-triggered (Master-slave) Flip-flops

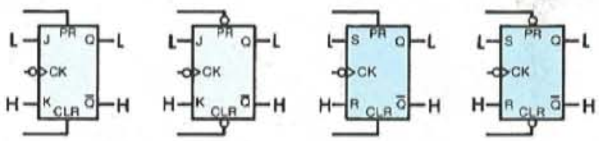
Assuming both Preset and Clear have been unasserted.

If the J-K or R-S (data) inputs were in opposite states during the arrival of the up-going edge of a clock pulse the next down-going edge will transfer those stored states to corresponding outputs.*

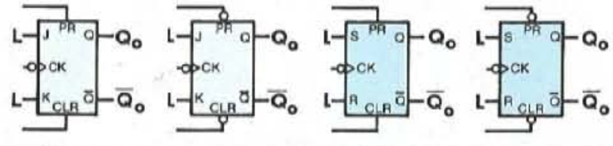
$J = Q$ and $K = \overline{Q}$ $S = Q$ and $R = \overline{Q}$



Same as above but with inputs reversed.



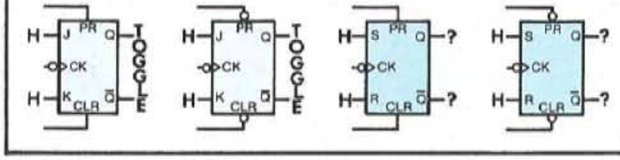
If the J-K or R-S (data) inputs were both in the LOW state during the arrival of the up-going edge of a clock pulse the next down-going edge will transfer no change to the outputs.*



When the down-going edge of a clock pulse arrives following an up-going edge that occurred while both data inputs were HIGH:

The output of a J-K flip-flop will reverse, toggle.

The outputs of an R-S flip-flop will be indeterminate.



A-400B

TEKTRONIX®

committed to technical excellence

TEKSCOPE

Volumn 6 Number 1 Mar/Apr 1975

TEKTRONIX®
committed to
technical excellence

TEKSCOPE

Customer Information from Tektronix, Inc.,
Beaverton, Oregon 97077

Editor: Gordon Allison
Ass't. Editor: John Mulvey

Contents

3 **A hand-held DMMiniscope**

A full-fledged digital multimeter and oscilloscope are both housed in a single, hand-held, battery powered package designed for maximum portability.

7 **Sweep delay today**

Digital sweep delays offer better accuracy, are easy to use, and have less jitter than analog sweep delays for many applications.

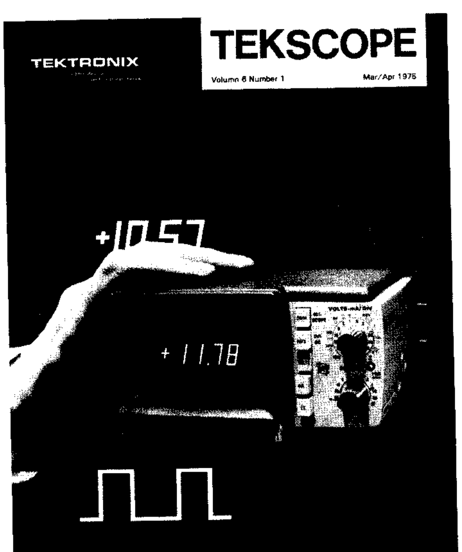
12 **Digital delay and time base in one plug-in**

A single plug-in for 5000-series oscilloscopes contains both digital delay and a time base. A unique circuit yields 10 ns jitter from a 1-MHz clock.

15 **Troubleshooting digital circuits**

Part II gives some practical pointers on isolating problem areas, and some do's and don'ts in logic troubleshooting.

Cover: Two of the electronics industry's most widely used instruments are merged into one in the TEKTRONIX 213 DMM Oscilloscope. The instrument weighs less than four pounds, including batteries.



A hand-held DMMiniscope

Dave Allen

How do you pronounce DMMiniscope? Some may say "DMM miniscope," others "DMM in-a-scope." Either way it accurately describes the new TEKTRONIX 213 DMM Oscilloscope which combines a 3½-digit digital multimeter and a 1-MHz oscilloscope in one compact instrument weighing only 3.7 pounds and measuring 3.0 x 5.2 x 8.9 inches. You can hold it easily in the palm of your hand or suspend it from a convenient neck strap. It's battery powered and ready to make measurements wherever you take it.

The DMM

The 213 makes all of the measurements associated with a high performance, 3½-digit multimeter and displays the results in large clear numbers on the crt (1 cm x 4 cm for the four digits, plus sign and decimal point). The brightness of readout is set by the side-panel INTENSITY control.

Dc voltage and current are measured on five ranges from 0.1 V full scale to 1000 V full scale, and 0.1 mA to 1000 mA full scale. True rms readings of ac voltage and current are provided over these same ranges for frequencies up to 40 kHz. If dc coupling is used in the rms mode, the readout will show the true rms value of ac plus dc. Since rms and dc voltage measurements are made using the oscilloscope probe, you can view the waveform, or measure the voltage at the same point by simply pressing a front-panel pushbutton. That's all it takes to transform the oscilloscope into a DMM, or vice versa.

In the DMM mode, resistance is measured with an accuracy of 1% or better over five ranges extending from 1 kΩ full scale to 10 MΩ full scale.

Excellent overrange capability of 200% full scale is provided for all ranges except the 1000 V, where input is limited to 800 V because of probe and input component considerations.

The oscilloscope

Although small in size, the 213 offers many of the features of much larger oscilloscopes, and some even the larger scopes don't offer; for example, a built-in capability for viewing current waveforms, with calibrated deflection factors from 5 μA/div to 100 mA/div. Current waveforms are viewed using the mA-Ω input on the instrument side panel. Input shunt resistance ranges from 0.3 Ω to 1000 Ω depending on the current range.

Why combine a DMM and scope?

There are basic similarities between a DMM and an oscilloscope. Both have calibrated sensitivities, or measurement ranges; both require some form of readout, or display; and both are used by those engaged in designing, manufacturing and servicing electronic equipment. These few similarities make it worth considering means to combine the two instruments, especially for those applications demanding portability.

The TEKTRONIX 200-Series Oscilloscope package was selected as ideal from the standpoint of portability. It was small enough to hold in the hand, had a rugged, double-insulated case for elevated voltage measurements, and was battery operated. The crt would make an excellent readout device for digits as well as waveforms. The major problem was space. How do you get the circuitry required for a DMM inside a package already designed for the minimum volume needed to house the oscilloscope circuitry?

A partial answer is to make the circuitry do double duty—serve both functions. While an obvious solution it's not as simple to achieve as it appears. For example, both instruments need an input attenuator but the requirements are quite different. The oscilloscope needs a wide-band, "clean" attenuator; the DMM a higher precision attenuator, 10 megohm input impedance, and not much bandwidth. A self-imposed requirement dictated using the same probe for both oscilloscope and DMM voltage measurements, for operator convenience.

Common input circuitry

The 213 uses a straight-through (1X) probe working into a 10-megohm attenuator. A Tektronix-designed cam switch provides five ranges for DMM voltage, current and resistance measurements, and 14 calibrated steps for oscilloscope voltage and current waveforms.

The input amplifier also serves both the DMM and oscilloscope. Discrete component design was selected to obtain sufficient bandwidth for the oscilloscope and achieve the 0.1% gain accuracy required for the DMM. The output of the input amplifier is connected to either the DMM or oscilloscope circuitry by a front-panel switch. The same switch applies operating voltage to only those circuits needed to perform the function.

The DMM circuitry is similar to that used in other TEKTRONIX DMM's, with special attention given to achieving maximum performance within the space and power available. Overrange indication serves as an excellent example of the value engineering found in the 213. There are basically three possible sources of error due to an overrange signal: the Input Amplifier, the A/D Converter, and the RMS Converter when the permissible crest factor is exceeded. Overrange indication is provided in each of these circuits, with overrange indicated on the readout display as scrambled plus and minus character segments, and 8's.

The DMM readout

Readout for the DMM is provided by a novel Tektronix-designed character generator IC that produces X, Y and Z signals to drive the crt deflection and blanking system. The X and Y signals always form the seven-segment display character 8. To form the characters 0 through 9, the character generator converts serial BCD data inputs into Z-axis (or blanking) output signals to blank the necessary segments. The BCD data consists of four groups (one group for each character) supplied from a 4-decade counter IC. Also supplied from the counter are four outputs that provide spacing current to the horizontal amplifier to properly position each character displayed. The character generator also produces plus or minus polarity signs and the decimal point. A portion of the Y output signal is fed to the horizontal amplifier, giving the displayed numerals a slight tilt for a more pleasing appearance.

The power supply

One of the most challenging design goals of the 213 was to power the instrument from just two nickel-cadmium D cells providing 2.4 volts dc. These two batteries power a high-efficiency supply producing voltages of 0.6 volts ac, and +6.5, −6.5 +15, +75, and −1000 volts dc. Efficiency is about 78%.

The inverter is a switching regulator type in which the amount of energy transferred to the transformer secondary is determined by the on-time of the switching transistor. On-time is controlled by the frequency of an astable multivibrator. As battery voltage decreases, the operating voltages decrease. This results in a change of the astable multivibrator frequency

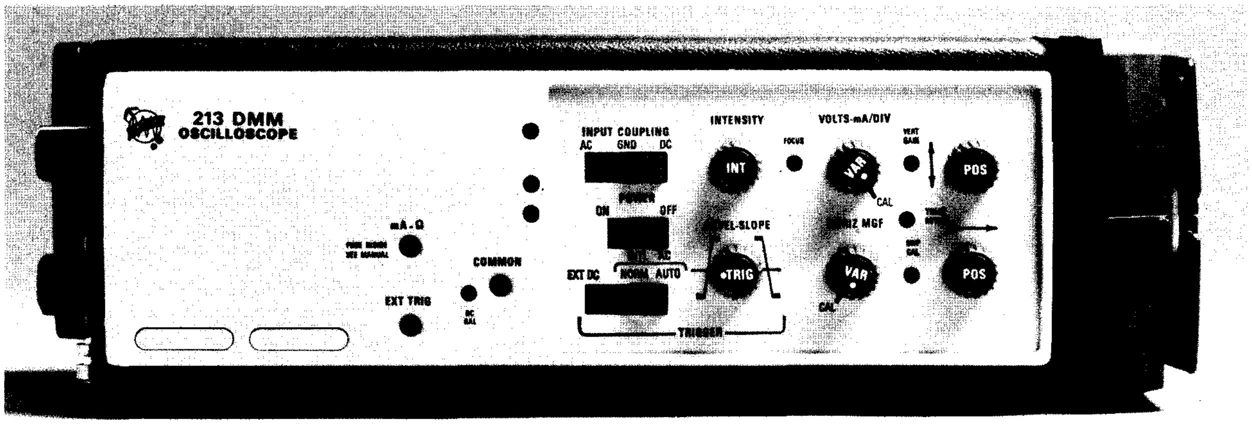


Fig. 1. Side view of the 213 showing the current and ohmmeter inputs, and other instrument controls. The oscilloscope probe and power cord are wrapped in place at the rear of the instrument.

which alters the on-time, restoring operating voltages to normal.

Low-voltage shutdown

A low-voltage shutdown circuit operates as a battery condition indicator and battery deep-discharge protector. When battery voltage drops to +2.12 volts, the power indicator LED extinguishes. Operation will continue until battery voltage reaches about +2.02 volts. At this point an SCR conducts, effectively shutting down the astable multivibrator and, thus, the supply.

Low voltage supplies

The low-voltage rectifier-filter circuitry uses Schottky-barrier diodes which provide low power dissipation because of reduced junction voltage. The Schottky-barrier diodes also provide fast recovery needed at the high multivibrator frequency (≈60 kHz), resulting in an increase in power supply efficiency.

High voltage supply

High voltage is generated by an 8-stage multiplier that takes about 190 volts peak-to-peak from the inverter and produces about 1300 to 1400 volts across the multiplier. The crt accelerating voltage is obtained after the seventh stage of multiplication and is set to −1000 volts and regulated to within 1%.

The battery charger

The 213 contains a battery charger converter that enables the batteries to be charged when connected to the power line. Charging occurs with the instrument turned on or off. The converter is frequency controlled, with the battery charge current regulated by a saturable reactor. As current flow changes in the saturable reactor, its inductance changes causing a shift in the operating frequency of the converter. As the converter frequency shifts away from resonance, the output voltage decreases, regulating the charge rate.

Mechanical considerations

One of the outstanding achievements in the 213 design is the packaging. Nearly every cubic inch inside the package is occupied. There is no main chassis in the unit. Five printed circuit boards surrounding the crt are interconnected by square pins mounted on one printed circuit board, inserted into jacks on the adjoining board. Only a few interconnecting cables are needed. The two-piece insulated cabinet fits snugly around the assembly, maintaining the boards securely in place and providing operator protection for elevated voltage measurements.

Servicing the 213

Troubleshooting the 213 is simplified by using extender cards for the A/D Converter Board and Power Supply Board. Extending these two boards opens up the 213 for easy access to circuitry while the instrument is operating. The extender boards are available from Tektronix.

Acknowledgements

A project such as the 213 requires the closest of cooperation between the mechanical and electrical designers. The result describes better than words, the dedication each brought to the task.

As Project Engineer my special thanks go to Ilmars Smiltins for mechanical design; John Pace, who did the input attenuators, input amplifier, Gm Converter, Ohms Converter, and scope preamplifier; Jim Knowlton for design of the high-efficiency power supply; Wayne Thomas, who did the horizontal and vertical amplifier; and Wendell Damm for the character generator, RMS converter, and A/D converter design. John Eskeldson was the Electrical Evaluation Engineer and George Kolibaba, Manufacturing Coordinator. My thanks also to the many others who contributed to the success of the 213 program.

Specifications on the 213

DMM

True rms readings of voltage and current are provided for all waveforms with a crest factor of 5 or less.

Dc and Ac Voltage

Range—0.1 V to 1000 V full scale in 5 ranges.
Overrange Capability—At least 200% of full scale. Except for 1000 V range.
Resolution—100 μV at 0.1 full scale.

Dc Voltage Accuracy*—For 25°C ±5°C. Beyond these limits add temperature coefficient.

0.100 V Range	Within 0.1% of reading ± 3 counts. Temp Coef is (within 0.015% of reading + 0.04% of full scale) per °C.
1.000 V Range	Within 0.1% of reading ± 1 count. Temp Coef is (within 0.01% of reading + 0.01% of full scale) per °C.
10.00 V and 100.0 V Ranges	Within 0.15% of reading ± 1 count. Temp Coef is (within 0.015% of reading + 0.01% of full scale) per °C.
1000 V Range	Within 0.2% of reading ± 1 count. Temp Coef is (within 0.02% of reading + 0.01% of full scale) per °C.

*Accuracy for battery operation. For ac line operation add 10°C before computing DMM accuracy temperature coefficient.

RMS Voltage Accuracy*—For 25°C ±5°C. Beyond these limits add temperature coefficient. Temp Coef is within 0.05% of reading +0.1% for full scale per °C.

	Within % of reading shown ±5 counts at frequency shown.		
	Dc	40 Hz to 4 kHz	4 kHz to 40 kHz
0.100 V Range	2.5%	1.5%	3.5%
1.000 V Range	2%	1%	1%
10.00 V Range	2%	1%	1%
100.0 V Range	2%	1%	1%
1000 V Range	2%	1%	2%

*Accuracy for battery operation. For ac line operation add 10°C before computing DMM accuracy temperature coefficient. Accuracy limit increases linearly for crest factor greater than 2. Up to twice indicated limit for crest factor of 5.

Input Resistance—10 MΩ.
Input Capacitance—Approx. 150 pF on 0.1 V to 10 V ranges, 100 pF on 100 V and 1,000 V ranges.
Settling Time—1.5 seconds within 0.1% of reading in dc mode, 2 seconds within 1% of reading in rms mode.
Maximum Input Voltage—
500 V (dc + peak ac) for 0.1 V to 10 ranges dc coupled,
800 V (dc + peak ac) for 0.1 V to 10 V ranges ac coupled,
800 V (dc + peak ac) for 100 V and 1000 V ranges.

Dc and Ac Current

Range—0.1 mA to 1000 mA full scale in 5 ranges.
Overrange Capability—At least 200% of full scale.
Resolution—100 nA at 0.1 mA full scale.
Input Shunt Resistance (Approximate)

Scale	Resistance
0.100 mA	1000 Ω
1.000 mA	100 Ω
10.00 mA	10.2 Ω
100.0 mA	1.2 Ω
1000 mA	0.3 Ω

Dc Current Accuracy*—25°C ±5°C. Beyond these limits add temperature coefficient. Temp Coef is (within 0.02% of reading +0.04% of full scale) per °C.

0.100 mA Range	Within 0.5% of reading ± 3 counts
1.000 to 1000 mA Range	Within 0.25% of reading ± 3 counts

*Accuracy for battery operation. For ac line operation add 10°C before computing DMM accuracy temperature coefficient.

RMS Current Accuracy*—For 25°C ±5°C. Beyond these limits add temperature coefficient. Temp. Coef is (within 0.05% of reading +0.1% of full scale) per °C.

	Within % of reading shown ±5 counts at frequency shown.		
	Dc	40 Hz to 4 kHz	4 kHz to 40 kHz
0.100 mA Range	2.5%	1.5%	4.5%
1.000 to 1000 mA Ranges	2.5%	1.5%	3.5%

*Accuracy for battery operation. For ac line operation add 10°C before computing DMM accuracy temperature coefficient. Accuracy limit increases linearly for crest factor greater than 2. Up to twice indicated limit for crest factor of 5.

Settling Time—1.5 seconds within 0.1% of reading in dc mode, 2 seconds within 1% of reading in rms mode.
Maximum Input Current—2 A rms or 3 A peak on any scale.

Resistance

Ranges—1 kΩ to 10 MΩ full scale in 5 ranges.
Resolution—1 Ω on 1 kΩ scale.

Accuracy*—For 25°C ±5°C.

1 kΩ	Within 0.5% of reading ± 3 counts. Temp Coef is (within 0.03% of reading + 0.04% of full scale) per °C.
10 kΩ to 1 MΩ	Within 0.5% of reading ± 1 count. Temp Coef is (within 0.02% of reading + 0.02% of full scale) per °C.
10 MΩ	Within 1% of reading ± 1 count. Temp Coef is (within 0.05% of reading + 0.02% of full scale) per °C.

*Accuracy for battery operation. For ac line operation add 10°C before computing DMM accuracy temperature coefficient.

Settling Time—2 seconds within 2 counts.

Readout

Number of Digits—3½ digits plus decimal point and sign.
Display Size—1 cm high by 4 cm wide (5 characters).
Overrange Indication—Readout displays scrambled characters.

OSCILLOSCOPE

Vertical Deflection (Voltage)

Deflection Factor—5 mV/div to 100 V/div in 14 calibrated steps (1-2-5 sequence). Accurate within ± 3%. Uncalibrated, continuously variable between steps and to at least 250 V/div.
Bandwidth—Dc to 1 MHz (−3 dB point) for 20 mV/div to 100 V/div deflection factors. Dc to 400 kHz (−3 dB point) for 5 mV/div and 10 mV/div. Lower bandwidth limit (−3 dB point) for ac coupling is 1 Hz or less.
Input R and C—10 MΩ paralleled by approx. 150 pf for 5 mV/div through 1 V/div and 100 pf for 2 V/div through 100 V/div.
Maximum Input Voltage—

Input Condition	Maximum Input Voltage
Dc coupled, 5 mV/div to 1 V/div	500 V (dc + peak ac) at 1 MHz or less
Ac coupled, 5 mV/div to 1 V/div	800 V (dc + peak ac) 500 V peak ac component
2 V/div to 100 V/div	800 V (dc + peak ac) at 1 MHz or less

Vertical Deflection (Current)

Deflection Factor—5 μA/div to 100 mA/div in 14 calibrated steps (1-2-5 sequence. Accurate within ± 3%. Uncalibrated, continuously variable between steps and to at least 250 mA/div.
Bandwidth—Dc to at least 400 kHz (−3 dB point) for 20 μA/div through 100 mA/div deflection factors. Dc to at least 200 kHz −3 dB point) for 5 μA/div and 10 μA/div.
Maximum Input Current—2 A rms or 3 A peak for any range.

Horizontal Deflection

Sweep Rate—2 μs/div to 500 ms/div in 17 calibrated steps (1-2-5 sequence). Accurate within ± 5%.
Horizontal Magnifier—Provides continuously variable sweep rate settings between calibrated settings. Extends fastest sweep rate to at least 0.4 μs/div.

Trigger

Internal Ac Coupled (Auto)—Triggers on deflection of 0.5 div or more from 7 Hz to 1 MHz. Sweep free-runs in absence of trigger signal or for frequencies below 7 Hz.
Internal Ac Coupled (Normal)—Triggers on deflection of 0.5 div or more from 7 Hz to 1 MHz.
External Dc Coupled—Triggers on signals of 1.0 V or more from dc to 1 MHz.

Crt

6 X 10 div display area, each div is approx. 0.2 in. Internal black line, non-illuminated graticule. P43 phosphor is standard.

OTHER CHARACTERISTICS

Power Sources—Internal Ni Cd batteries provide a typical operating period of 3.5 hours at maximum trace intensity for a charging and operating temperature between 20°C and 30°C. Internal charger provides for charging batteries any time the instrument is connected to an ac line even if the instrument is turned off. Dc operation is automatically interrupted when battery voltage drops below 2 V to protect batteries against deep discharge. Full recharge requires approximately 16 hours. External operation from 90 to 136 V ac (48 to 62 Hz). Option 1 allows operation from an external 180 to 250 V ac (48 to 62 Hz) or dc supply. Power consumption, 8 watts or less.
Insulation Voltage—500 V rms or 700 V (dc + peak ac) when operated from internal batteries, with line cord and plug stored. When operated from ac, line voltage plus floating voltage not to exceed 250 V rms; or 1.4 × line + dc + peak ac not to exceed 350 V.

Dave Dunlap

Sweep delay today

Oscilloscopes with calibrated sweep delay have been around a long time. And most users are probably quite familiar with conventional sweep delay. There are, however, some important new ways to delay sweeps. Have you used digital delay? Do you know when to use digital delay instead of analog delay? Do you know what kinds of digital delay units are available? What are the different ways to minimize display jitter on your crt screen? How much does sweep delay improve time measurement accuracy?

Scope users and buyers should understand this subject to make intelligent selections of the instruments they will need, and to make good use of the instruments they have. We hope to help you understand the subject more clearly.

Fig. 1. The TEKTRONIX 475 provides analog sweep delay using a calibrated ten-turn potentiometer. On some scopes this control is called the DELAY TIME MULTIPLIER. The number of dial divisions between the start and the end of delay is multiplied by the TIME/DIV setting, to compute delay.

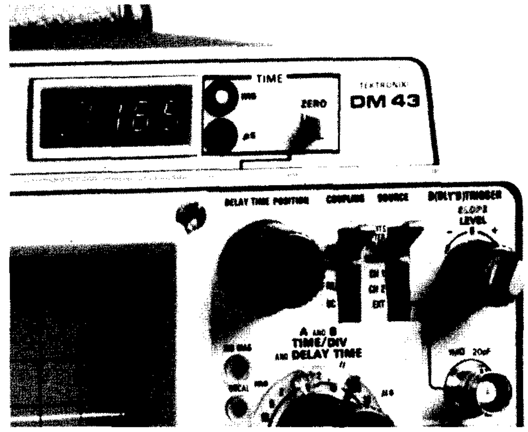


Fig. 2. The TEKTRONIX 475 with DM40 or DM43 provides analog sweep delay with LED readout. The readout is set to zero at start of the delay and the readout shows the delay time when the DELAY TIME POSITION control is set to the end of delay. No calculations are necessary.

Conventional calibrated sweep delay

Conventional sweep delay is most often used for the same reason you sometimes use a sweep magnifier . . . to get a better look at something not near the beginning of the sweep. When you magnify a sweep most of the former display goes off screen. To see any of those regions again you merely adjust the horizontal position control. To accomplish the same thing using conventional sweep delay you switch to delayed-sweep operation and rotate the delay control to see what you want. In effect, the amount of magnification is equal to the ratio of the delay range to the duration of the sweep being delayed and is frequently greater than 1000 to 1. Without either sweep delay or sweep magnification, the only time you can see what you want, at the sweep speed you want, is when that event immediately follows the instant of trigger recognition. To see events that happen considerably later requires considerable delay.

The conventional way to delay a sweep is to (1) initiate a ramp signal that (2) generates a secondary trigger signal when it crosses a selectable voltage level, and (3) let that trigger initiate the sweep you need to display the later events. The delay you need is selectable with two controls: one sets the slope of the ramp and the other sets the voltage level the ramp must cross. By generating linear ramps, and by using a linear multi-turn potentiometer for the delay control, delay can be accurately calibrated.

Now when you are looking for a particular freightcar in the middle of a wave train you will not always know how to recognize what you are looking for. Bright zones on the trace, indicating the point of delay, often help, but sometimes don't when you are unable to distinguish by waveshape or appearance what part of a wave train to look for. You will, however, sometimes know how much delay time is needed to display what you want. Then having *calibrated* sweep delay is important; you just crank in the numbers you need, to see what you want.

That is fine when you know the speed of the train and the length of the cars. But what if you don't know all that and only know that the 138th car is the one you want to put in the scope window? Then you can count them as you parade them past the crt window if need be. When that is so, you probably don't want to personally parade 138 pulses past your crt window counting them as they go, with the possibility of being interrupted somewhere in the middle of the count. And what if the count is 13801?

Digital Delay

Fortunately, there is a better way. Digital delay-by-count plug-ins are available that will count the pulses for you more quickly, more reliably, and with far less frustration. The 5B31 is one such plug-in. It is used with 5400 Series Oscilloscopes. The 7D11 and DD 501 are two others.[1] The 7D11 is used in 7000 Series scopes; the DD 501 is for use with any scope.

Delay-by-count is digital delay. When you count cycles of a timing waveform before you trigger a sweep, you have digital time delay the same as counting seconds before blast-off. Digital delay makes particularly good sense when working with digital circuits. One waveform often looks so much like another that other means of identification are called for. The count, the number, is sometimes the only identification.

Display Jitter Eliminated

Delay by count does other things for you. For one thing it follows time jitter. It follows jitter so well, in fact, that it can make you believe your jittery signal has no jitter. With conventional sweep delay using the Triggerable After Delay mode, you can also sometimes stop display jitter. What's the difference? Mainly that the Triggerable After Delay mode doesn't work where the amount of jitter is greater than the time between adjacent pulses in the region you want to investigate. In such a case if you were trying to trigger the delayed sweeps on the 138th pulse you would find that some were triggered on the 137th or 139th pulse, producing a confused display. The likelihood increases for relatively long delay periods, for example when trying to look at pulse number 13801.

Even when your signal is not jittery, conventional sweep delay can contribute enough of its own jitter to be a problem at times. With analog delay, delay-generated jitter is proportional to the delay range used, not the delay used, and is usually spec'd at either 1/20,000 of the range or 1/50,000 of the range. A delay range of 20 ms (2 ms/div x 10) might contribute as much as 1 μs of jitter and still meet a 20,000:1 specification. An effective magnification of 2000 is all it takes to produce one division of jitter with a 20,000:1 spec. If the displayed pulses were less than 1 division apart in such a case and you used the Triggerable After Delay mode to stop jitter, about half of the sweep would be triggered on one pulse and the other half on an adjacent pulse. If all the displayed pulses were identical in shape and spacing you could not tell the difference; but if the pulse shape or spacing was different the display would be confusing. What is worse, the display may even be a little deceptive. For example, you may see a narrow pulse among others but fail to notice that some sweeps run through its baseline, indicating the pulse is only there part of the time.

Delay by count works like Triggerable After Delay to ignore jitter, except that time variations between counts are *completely* ignored. Pulses produced by rotating devices, such as a magnetic disc, usually have widely-varying time intervals from one cycle to the next. Furthermore, the cycles occur at a relatively low rep rate. Jitter is one thing and low rep rate jitter is another. And to make matters worse, alternate sweep operation cuts any basic rep rate in half. Few conditions are worse for a scope operator than to attempt to interpret jittery dual-trace displays using fast sweeps that are blinking at you. Storage is a big help when there is no jitter. And delay by count will stop the jitter.

You don't have to know the right count to delay by count if you can recognize what you are looking for. You can range from one event to the next and parade your wave train past your crt window the same as with conventional sweep delay.

Time Measurement Accuracy

Digital delay by count provides very accurate time delay intervals whenever it counts very accurate timing signals. Whereas most analog delay systems have a specified accuracy between about ±3% and ±0.5% of the reading, digital time delay accuracy depends largely on the accuracy of the timing signal. The TEKTRONIX 7D11 has a built-in 500 MHz timing signal phase-locked to a 5 MHz crystal oscillator that is accurate within ±1 part in 2 million. It will count up to 10 million internally generated 100 ns pulses to provide up to 1 second of delay. You can add from 0 to 100 ns of analog delay to the selected number of 100-ns increments, with an accuracy of ±2 ns. Two nanoseconds amounts to ±2% when the delay is close to one 100 ns increment, but is only ±0.2% or less when the delay is 1 μs or more.

Usually more important than accuracy of delay, however, is accuracy of delay *difference*. For all time interval measurements except those less than about 50 ns, sweep delay can be used to reduce time measurement errors. As most scope users know, to make such a measurement with conventional sweep delay, the difference between two delay dial readings is multiplied by 1, 2, or 5 . . . usually in your head. We call such measurements differential time measurements.

The first dial reading is made after the delay control has been used to position the waveform so the beginning point in the waveform for the time measurement coincides with some vertical graticule line. The second reading is taken after the delay control has been rotated to position the ending point in the waveform to the same graticule line. You must always be able to identify the beginning and ending points of a time interval measurement regardless of how the measurement is made. Although this technique is a little more time consuming than making the measurement directly from the crt scale, it is independent of crt non-linearities and possible gain errors of the horizontal amplifier. The technique typically improves accuracy to about ±0.5% to ±1.0% of the reading.

Accuracy invariably falls off for measurements of very short time intervals, and precisely where it starts to fall off depends on the particular oscilloscope. It falls off for the same reason that time measurements scaled directly off a crt suffer in accuracy as the distance scaled gets smaller and smaller. The difference is that smaller sections of a potentiometer have to be used instead of smaller sections of the crt scale.

There is no point whatever in trying to use calibrated sweep delay to improve measurement accuracy beyond the crossover where reading directly from the crt (scaling) yields better accuracy. Even with the speed and convenience of a method of making differential time interval measurements, described in the next paragraph, accuracy improvements for short time intervals are marginal when compared to directly scaling the crt. The crossover depends on what kind of error you are apt to make when scaling the crt directly, compared to matching points in the waveform with a graticule reference line. Few people would consider the difference to be greater than 1/10 major division. That error would be an additional 1% for a 10-division crt measurement, or an additional 2% for a 5-division measurement, etc. See the discussion on time measurement accuracies on page 11.

Digital readout of time delay

TEKTRONIX 464, 465, 466 and 475 Oscilloscopes are available with digital multimeters DM40 or DM43 integrally attached[2], and one thing these multimeters do is provide 3½-digit LED readout of differential (delay) time measurements. No dial numbers need to be read, logged, subtracted or multiplied. By merely pressing a ZERO button when the first point in the measurement is positioned on a reference graticule line, the time difference may be read out directly from the four LED's as soon as the second point is positioned to that reference line. Although the technique provides only marginal improvements in accuracy over the conventional method, human errors in mental arithmetic and reading the dial are minimized, and measurement time is reduced dramatically. The reduction in measurement time practically eliminates errors due to delay drift. Delay drift can easily be observed, when it is significant, because it requires continued readjustment of delay to keep the measurement beginning or ending point in the waveform, on the reference graticule line. Delay drift can sometimes appear to be significant when it is not, because the delayed sweep speed is faster than it needs to be.

For time interval measurements more accurate than about $\pm 0.5\%$, digital delay plug-ins may be used. The 7D11 can be used to measure 1 μs intervals with an accuracy of $\pm 0.2\%$, 10 μs intervals with an accuracy of $\pm 0.02\%$, etc. Only digital counters have comparable accuracy and, unlike most counters, the measurements can be made between two points on a waveform that may differ in voltage.

Not all digital delay generators have built-in timing signals like the 7D11. In those cases, to delay by counting cycles of a timing signal instead of by counting cycles of a signal from the equipment under test requires an external time mark generator or similar instrument. If you are looking at digital equipment that has its own clock signal, that signal is usually the best delay reference you could get. Be sure the clock frequency is not higher than the delay generator can count or that the maximum count required does not exceed the count or readout capabilities of the delay generator. The TEKTRONIX 7D11 will count up to 10,000,000 cycles of a signal having a frequency up to 50 MHz; the DD 501 will count up to 100,000 cycles of a signal having a frequency up to 80 MHz; and the 5B31 will count up to 100,000 cycles of signals up to 35 MHz. The signal cycles you count may be part of the signal you later display, so the scope bandwidth can limit the maximum frequency your delay generator gets to see.

Word Recognizers[3]

No discussion of sweep delay should ignore the subject of Word Recognizers. The two basic reasons to delay a sweep are to make time measurements more accurately, or to get a clear, magnified look at something happening later than your available triggers. In many digital circuits the proper moments to trigger to get a clear magnified display cannot be predicted. For example, you may want to display only what happens immediately after the last of all inputs to a logic gate go true, and can't tell which input that will be. The simple solution is to simultaneously probe several points in the circuit under test, with an equal number of probes that go to a device that will recognize the moments when the unique combination of logic states occur. If you can recognize those moments, you can generate the special sweep triggers needed. How many points you have to probe to recognize specific digital words depends on the equipment you are probing. Most digital words are expressed in multiples of four bits (4, 8, 12, 16, etc.) and the TEKTRONIX 821 Word Recognizer is designed with that in mind.

Usually the trigger generated by a Word Recognizer is used to initiate a sweep, but it is also useful to initiate a period of delay before the sweep is initiated. That delay can be digital or analog, depending on your needs. The output from a Word Recognizer is usually applied directly to the external trigger input of a scope or sweep plug-in. If that scope or plug-in has delayed sweep operation you can easily cue the delay you need off of that trigger. When you want to use digital delay the output of the Word Recognizer is routed to an external trigger input to that unit instead.

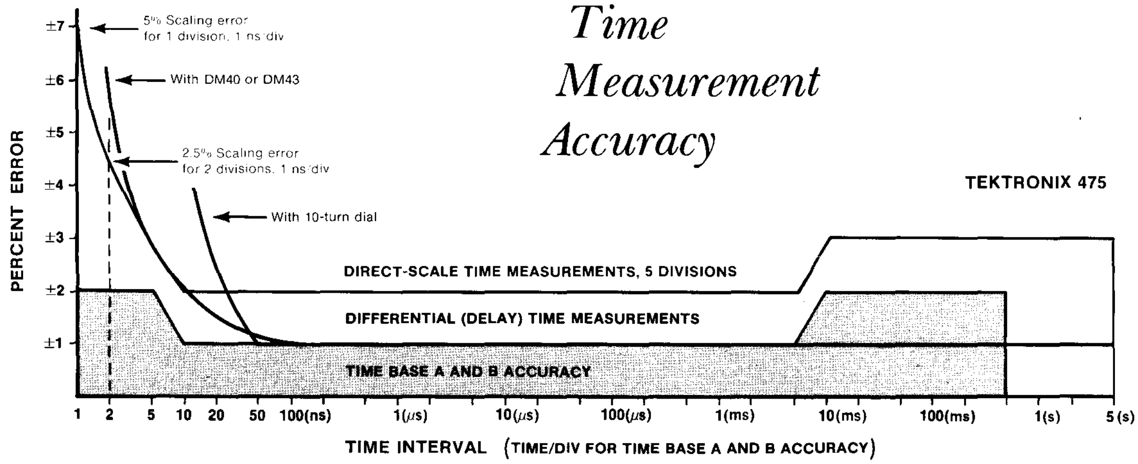
The new digital delay units offer improved measurement ease and accuracy for many applications. Analog sweep delay is still the best solution in other areas. Tektronix plug-ins provide you the option of choosing either, or both, delaying capabilities.

[1] Delay by count is discussed in the Jan/Feb 1974 issue of Tekscope, and the 7D11 is discussed in the Nov. 1972 issue of Tekscope.

[2] See Tekscope for Sept/Oct 1974

[3] See Tekscope for Mar/Apr 1974

Time Measurement Accuracy



Time interval measurements made with an oscilloscope are made between two points on the displayed waveform that represent the beginning and end of the interval to be measured.

One way to make such a measurement is to scale the distance between those two points directly from the crt graticule. The distance will be proportional to the time interval.

Another way is to use a sweep delay control to position first one then the other of the two points to the same reference line on the crt graticule. The two numbers read from a dial or window represent the time interval measured. The difference between the two numbers will be proportional to the time interval. This method is called a differential time measurement. Both points in the waveform don't have to appear on the crt screen at the same time when making differential time measurements. Nor does the time/div selected, or sweep speed accuracy of the displayed sweep, have a direct bearing on the accuracy of the measurement.

When measurements are made by directly scaling the crt, special care must be used when reading and interpolating the scale to assure best measurement accuracy. Most observers agree that, with reasonable care, most measurements can be kept within ±1/20 major divisions by interpolating the scale to the nearest 1/10th major division. That amounts to a scaling error of ±5% for one division of separation between two points in the waveform, but only amounts to ±1% for five divisions of separation, etc. When the time/div on an oscilloscope is calibrated in a 1-2-5 sequence all time measurements can be spread over four divisions or more, except for time intervals less than four divisions of the fastest sweep. Because most measurements can be spread over more than five divisions, a ±1% scaling error is a conservative figure for most measurements made with care.

Scaling errors should be algebraically added to the accuracy of the time base used for the measurement. You should assume time base accuracy is at the margin of the specified accuracy. The time base accuracy for the 475 is specified as ±2% for the 1, 2 and 5 ns per division settings and ±1% for the other time/div settings. The blue curve on the graph shows time measurement accuracy when you combine scaling error with time/div errors.

The black curves show the accuracy you can expect when making differential time measurements with the TEKTRONIX 475 oscilloscope. The 475 is available with either the conventional 10-turn calibrated delay dial or with a digital multimeter, DM40 or DM43, integrally attached. The DM40 and DM43 allow you to set the first delay reading to zero so the second reading may indicate the time measurement directly. Pushing a button is all it takes. Numbers representing the time interval measured appear with 3½ digit resolution on four LED's. Curves for both types of 475's are shown.

The improvement in accuracy offered by the DM40 or DM43 over the conventional 10-turn dial is primarily for time intervals less than 1/10 of the delay range used. For the shortest delay range that amounts to 50 ns or less. The reason accuracy is better is primarily that the DM40 and DM43 provide five times better time resolution than the 10-turn dial. Accuracy with the 10-turn dial is ±0.1% of the full 10-turn range for measurements involving a difference of less than one turn. Accuracy with the DM40 or DM43 is ±1% of the reading, ±1 count, with one count being equal to only 0.02% of the full range. Below about 5 ns, directly scaling the crt should improve accuracy.

When making differential time measurements, visual errors involved in positioning the trace are generally considered insignificant because the displayed sweep can be made very much faster than the delaying sweep. For example, a 50 ns time interval measured using the differential method can be displayed at 1 ns/div, and a visual error of ±1/20th division would amount to only ±50 ps (±0.1%). For similar reasons delay jitter or drift on the order of 1:20,000 or less seldom interferes significantly with the accuracy of a differential time measurement.

The convenience, speed, and freedom from human error with which accurate measurements may be made with the DM40 or DM43 recommend it most.

James Wagner

Digital delay and time base in one plug-in

What you see through a window depends, to a large extent, on when you look through it. The oscilloscope is sometimes called the "window to electronics", and timing is of the essence in determining what will be viewed through this window. Most electrical events happen in milliseconds or microseconds, and some in nanoseconds or picoseconds. How can we view these events and their relationship to neighboring events?

Tektronix neatly solved this problem with the introduction of an oscilloscope with a delaying sweep. Delaying sweep enables you to look at a relatively long "time window", select any portion of that time window, and then view the selected portion in detail on a second time base called the delayed sweep. Delayed sweep can be thought of as a magnifying glass permitting you to view in great detail the events displayed in the long time window.

If you have ever looked through a hand-held magnifying glass you know that the greater the magnification, the more trouble you have holding it steady enough to view the object clearly. In electronic jargon we call this jitter. And we experience jitter to some degree when using delayed sweep to achieve a large degree of sweep magnification. Now, a new means of generating the time delay substantially reduces the jitter experienced in this type of measurement, and facilitates other kinds of delay measurements.

Digitally delayed sweep

Electronic circuitry is becoming increasingly digital. In most digital systems the time relationship between events is determined by clock pulses. A convenient means of viewing a particular event in such a system is to count the clock pulses that must occur before the event takes place. The sweep is then triggered and the event we desire to view is displayed. Since the delay tracks the event regardless of its timing variation, jitter is eliminated or greatly reduced.

Delay by event

The new 5B31 Digitally Delayed Time Base brings just such a capability to TEKTRONIX 5400 Series Oscilloscopes. Operating in the delay by events mode, five thumbwheel switches permit you to select delays up to 99,999 events. The events can be as short as 20 ns in duration and at frequencies up to 20 MHz.

Delay by event is particularly useful when working with "floppy" discs* or other rotating devices. Counting can be initiated by the index pulse on the disc, and the thumbwheels set to count the number of clock pulses to take you to that portion of the disc you're interested in viewing. Since you are triggering from the pulses recorded on the disc, jitter caused by variations in disc speed will not be apparent in the display.

Delay by time

For many applications delay by time is more suitable than delay by event. The 5B31 brings the benefits of digital delay to time delay measurements by means of an internal 1-MHz crystal-controlled clock. In delay by time operation we are again counting events but the events occur at precisely one microsecond intervals. The five thumbwheel switches provide a choice of delay times from 0 to 99,999 μs. Differential delay time, that is, the difference in delay between two points on the same sweep, can be measured to an accuracy of 2 parts in 10^5, or within 0.002%, considerably better than that achieved using analog sweep delay.

Reducing display jitter

Figure 1 shows how jitter originates in a simple clock and counter delay system where the clock is not triggered from the signal. Total delay time can vary as much as one clock period because there is a random interval between the trigger and the first clock transition counted. This random interval causes jitter. One way to minimize jitter is to select a high clock frequency. But this requires a fast counter in addition to the fast clock, and is expensive.

The 5B31 uses a unique circuit to achieve 10 ns or less of jitter using a 1 MHz clock. You would normally expect up to 1 μs of jitter with this clock frequency.

A single fixed-rate ramp, referred to as the "held ramp", is used to absorb the random time between the trigger and the first count. Figure 2 shows the relationship between the main trigger, the clock and the held ramp. The simplified block diagram in Figure 3 shows the major circuit elements used in generating the held ramp, and achieving digital delay.

In delay by time operation the μs pushbutton is depressed. When a trigger from the Main Trigger Generator occurs it gates the 1-MHz clock to the counter and, in conjunction with the Ramp Flip-Flop, turns on the Ramp Current Generator (held ramp). The ramp runs up until the Transition Detector senses the first change in the state of the counter. At this point the Ramp Flip-Flop switches, interrupting the ramp charging current. The ramp holds at the interrupted level until counting is completed. The End of Count Detector then switches the Ramp Flip-Flop, restoring the charging current. The held ramp then continues its run-up to the level set by the Comparator. Total run-up time is 1 μs, excluding "hold" time.

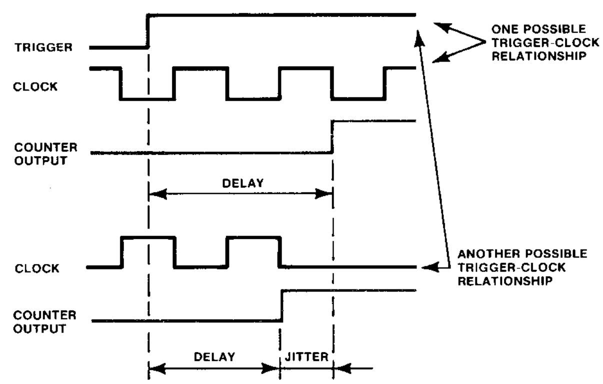


Fig. 1. Diagram illustrating why jitter occurs in a digital delay system when the clock is not triggered from the signal.

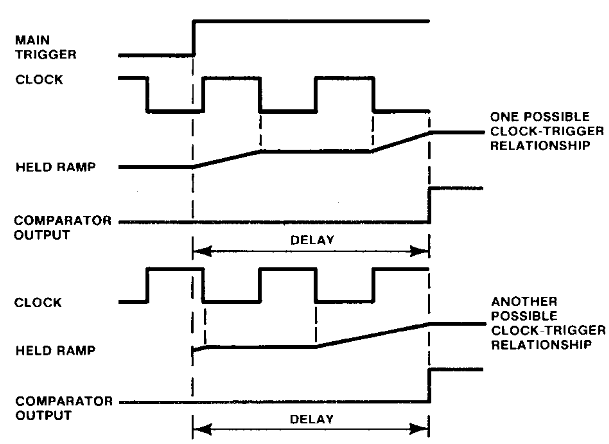


Fig. 2. Diagram illustrating how held-ramp operation accommodates differences in the clock-trigger relationship to reduce jitter to 10 ns or less.

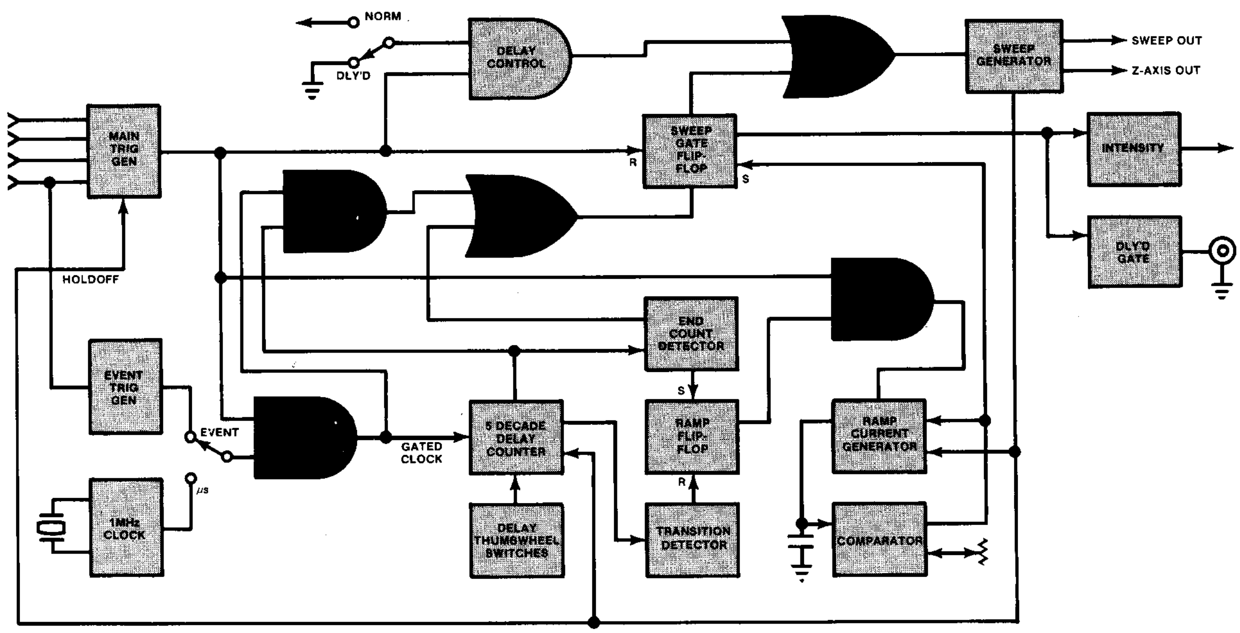


Fig. 3. Simplified block diagram of the 5B31 Digitally Delayed Time Base.

The Comparator output drives the Sweep Gate Flip-Flop which enables the Sweep Generator, and provides a signal for trace intensification and a Delayed Gate.

At the end of the sweep interval, information from the Delay Thumbwheel switches are loaded into the counter, and the Main Trigger Generator and the held ramp are reset.

The held ramp operation reduces jitter from the expected 1 μs to 10 ns plus 1 part in 10^7 of selected delay. For time delays longer than 200 μs, the 5B31 has less jitter than an analog sweep delay having a jitter spec of 1 part in 20,000 of delay range.

In delay by event operation, triggers from the Event Trigger Generator substitute for the 1-MHz clock. The Transition Detector, Ramp Flip-Flop and Ramp Current Generator are inoperative in this mode.

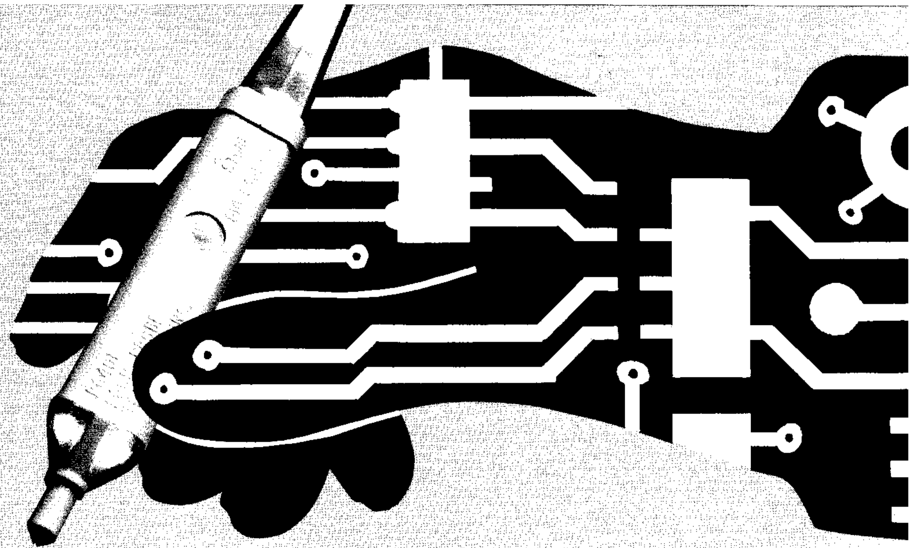
Operation begins with a trigger from the Main Trigger Generator. The Counter counts pulses from the Event Trigger Generator. At completion of the count, the End of Count Detector enables the clock input of the Sweep Gate Flip-Flop. The next pulse from the Event Trigger Generator switches the Sweep Gate Flip-Flop, thus eliminating the propagation delays associated with the Delay Counter. The outputs of the Sweep Gate Flip-Flop perform the same functions as in delay by time operation.

In normal (undelayed) operation the trigger from the Main Trigger Generator passes directly through the Delay Control AND gate, and an OR gate, to start the Sweep Generator. With the μs or EVENT pushbutton depressed the trace will be brightened at the end of the delay set by the thumbwheels if the delay is within the range of the displayed sweep.

Summary

The 5B31 is the first time base plug-in to include digital delay. While the time delay range is not as broad as some analog delays available, the ease of operation, low jitter, improved delay time accuracies, and delay by event capability make the 5B31 Digitally Delayed Time Base a valuable addition to the 5400 Series Oscilloscope family.

*See "Flexible Disc Measurements Simplified by Digital Delay", Jan/Feb 1974 Tekscope.



Trouble-shooting digital circuits

Roger Allen

Troubleshooting digital circuits ....

In the Nov/Dec 1974 issue of TEKSCOPE we introduced the subject of troubleshooting digital circuits with a summary of the fundamentals of flip-flops. That was because flip-flops are one of the basic microcircuits used in digital I.C.'s and are the most formidable of the basic circuits to become familiar with. If you are going to develop your troubleshooting skills beyond mere replacement of suspect circuit boards it is essential that you get to know basic logic circuits.

PART II There are some good, practical tools around to help you trouble-shoot digital circuits. They range in sophistication from logic probes to logic scopes, but the more sophisticated instruments are usually limited to production testing or engineering design work. The ordinary oscilloscope is usually the most sophisticated instrument practical to use for field service. Logic probes are the least expensive, the smallest, and with their indicator lights right on the probes, the handiest. Oscilloscopes are needed to show timing relationships between signals and show their precise voltage levels.

The approach

There is such a variety of electronic products using digital circuits that you wonder how much you need to know about each product to find troubles fairly quickly. The answer depends on how much experience you have and what the products are, but we think beginners must understand at least enough to operate the product. Your ability to operate the equipment will have a great effect on where you begin the troubleshooting task.

There are usually several things you can do to test the operation of defective equipment that will help in isolating the problem area. You will need block diagrams and circuit diagrams to get acquainted with how the various parts of the equipment work together. When you have not had a chance to learn the equipment, taking time to read the titles of the blocks in a block diagram, and to read the names and labels of the important input and output lines gives you better information than you might suppose. You will surprise yourself.

The normal task of isolating a failure is to try to identify the section or area that probably contains the defect. In equipment that has lots of circuit boards one should first try to isolate the defective board. If replacement boards are not available, the next task is to find the specific defect, usually an I.C. Sometimes a defective I.C. may be quickly located by merely touching it with your finger to see if it is very hot. Power must be on, of course, and if there is any shock hazard possibility whatsoever you should not reach into the circuits to do this.

The place to start troubleshooting is at the symptom, the point where you are witnessing improper performance. You should try to create several symptoms of the problem because a comparison of symptoms will usually give a good clue to what basic function is not being performed. Knowing that and knowing the board that performs the function will get you close. Extra time spent at the outset with the symptoms will usually pay off by eliminating large sections of the circuits from consideration. For example, you may find that the equipment always misses a certain count, or that it only fails in one mode. Remember, however, that the problem cannot be fixed from the front panel unless it's an operator error. Once you have explored the symptoms thoroughly it is time to get inside the equipment.

The first shot

If you are able to reason where the trouble may be located you should change the board, if a spare is available. If normal operation is restored, you have identified the defective board and may confine further troubleshooting to that board. If it doesn't, you should change the remaining boards, one at a time, replacing each board in its original position.

In some cases you will not have any spare boards or be able to reason what board is most apt to be faulty from the available symptoms. In this case it is best to treat the equipment as if it were one unit and track the symptom back to wherever it leads you. Start at the point where you see the error. You might have a light that doesn't come on, or a wrong reading, etc. Starting at this point you should work your way back through the circuits, in fairly large steps, toward the normal origin of the missing signal or erroneous signal. Follow the circuit diagrams. Maybe the origin is a switch on the front panel that normally turns on a light that isn't working. Pick points to place your probe where the signal goes through fairly simple gates, if possible. These are the easiest points to check for proper operation. Eventually you will either find a point where the signal is blocked or you will wind up at the switch. Perhaps the switch is faulty.

When taking large jumps it is easy to skip the point where the problem is located. But once you find the signal you are looking for, you can stop going toward the origin and follow the signal in small jumps, checking each gate in the signal path until you find the point where the signal is blocked.

Now the signal can be blocked for several reasons. The component where it is blocked could be faulty, or another signal be missing at that point that would allow your signal to go through. A third possibility is that there are signals present which should not be there such as Preset, or Clear, or an Inhibit signal. If the component plugs in, it is usually simplest to replace it and see if that solves the problem. If it doesn't, or if the IC is soldered in, you may need to do some more troubleshooting. Probe all the input and output lines, Vcc and ground. If one input does not have the right level, or right signal, you should pursue the cause for that in exactly the same way you started out.

If the schematic diagram or service manual does not show the basic make-up of that IC you will need to refer to the data book that the manufacturer of the IC supplies. Probe the pins of the device itself, not merely the socket, if it plugs in. Occasionally contacts in the socket are defective. In cases where a replacement component is not handy you may sometimes temporarily borrow one from another part of the equipment or from some other equipment. Be sure to put good components back in their original sockets.

Sometimes a Preset or Clear line is tripped so fast that you may not detect it with your logic probe or scope, if set up to look at slower signals. Sometimes you will need to increase the sweep speed of your scope to see these signals. At other times you may need to use the Single Sweep Ready light as an indicator that a single or low rep rate signal occured. The Strobe mode or Hold mode on the TEKTRONIX P6401 Logic probe may be used for a similar check.

The second shot . . . shorted outputs

There are times when an IC may appear to be defective but is not. At such times your troubleshooting may have just begun and you will have to take a second shot. HIGH levels are never quite as high as the supply voltage level when things are working right. In a TTL circuit with a +5 volt Vcc supply level, for instance, HIGHs would normally be some level between about 3.5 to 4.5 volts depending on the load, although they theoretically can be as low as 2.4 volts. Measure the voltage level. If it measures the same as Vcc there is probably a short between Vcc and the output pin. The same simple test can be done for a LOW. If you can't find a few hundred millivolts on an output when it is LOW, it may be shorted to ground. If you have a HIGH at the output of an IC where there should be a LOW, it may be because the output is shorted to Vcc.

If you think you have found an output that is shorted, disconnect the circuit component that should be driving that line, lift the pin on the component that drives the line (as described later) and try again. If normal operation is restored at the floating pin, that component is OK. Bend the pin back and replace the component.

An output that is shorted may be the input to several other components and any one of them may be causing the trouble. If they are easy to disconnect, try one at a time, being sure to get them back right. That bears repeating. Get them back right! Any trouble you accidentally put into a circuit that is already not working right will vastly complicate the problem. Two troubles at one time is more than double trouble. For this reason, avoid having two people troubleshoot the same job unless they work together closely and cooperate every step of the way. If someone besides yourself has been troubleshooting, *look* for double trouble. Suspect IC's to be plugged in backward or to be the wrong type.

Sometimes a shorted output may not be caused by a faulty component or socket. Solder "bridges" are a common kind of short. Look closely at all soldered points on the circuit board that are in close proximity to another conductor. Check any adjacent pair of solder points that look too close. Solder "tails" or lodged pieces of wire can usually be found by close inspection.

If you still can't find the short try using an ohmmeter with milliohm resolution. This is how: You turn off the power and remove the circuit board if convenient. Then you put the ohmmeter on the lowest scale and put one probe on the output pin and the other on ground or Vcc, depending on the nature of the short. You will measure only a low resistance if there is still a short. If you move the probe from the output along the circuit board run that connects to the pin, you should notice a decrease in resistance as you approach the locality of the short, and an increase in resistance as you move away from the short. Holding one probe lead very steady, move the other up and down the run to the point of minimum resistance. Stop at that point and repeat the procedure using the other probe lead. The short should be very close. You may have to use a magnifying glass to see some hairline shorts. Sometimes the sharp point of a scriber gently scraped between runs will remove a short.

The ohmmeter technique is especially good for locating shorts on a run that wanders all over the place, like if Vcc was shorted to ground.

In some cases it is hard to pinpoint a trouble because most everything indicates a particular IC should work, but it doesn't. These cases are usually caused by the IC output being overloaded or because input pulses are arriving that are hard to detect.

Lift a pin or two

If your IC's plug-in you can unplug any one, bend one of its pins out of the way of the socket, replace it and try again. To do this you should always use a pair of long-nose pliers and bend the pin right at the point where it comes out of the package. You will only need to bend it about 45° to clear the socket. See figure 1.

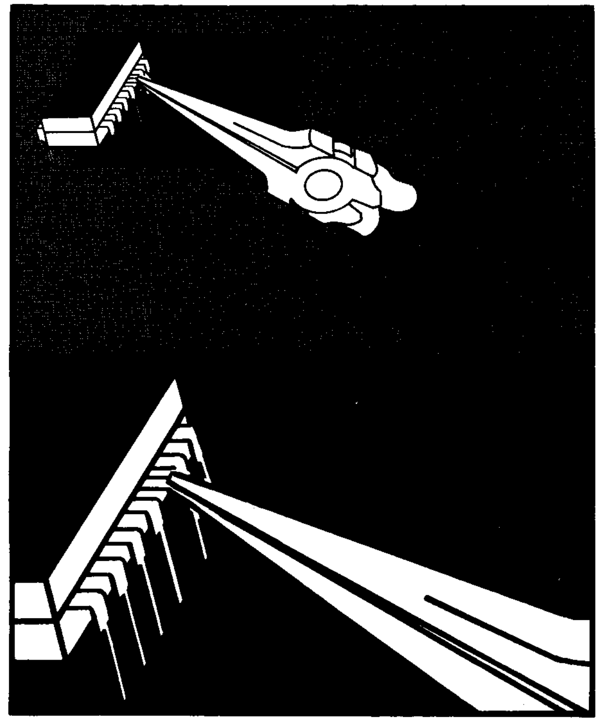


Fig. 1. When IC's are plugged into sockets you may isolate any lead by temporarily unplugging the IC and unbending the lead about 45° at the same region it was originally bent.

On flip-flops that don't seem to be working right (except that a new one doesn't fix the problem) you often need to lift more than one lead at a time. Narrow pulses are sometimes fed back to the Preset or Clear pin by a faulty IC elsewhere and will upset your attempt to go on. By lifting one, or both, of those pins you can usually tell where to look next. It will be necessary to tie some inputs either HIGH or LOW when they are lifted.

Temperature sensitive intermittent problems

You can't find troubles that are not there. The trouble that goes away when you start looking for it is the most elusive kind. Often that condition is a temperature sensitive one and you can make it occur by raising the temperature of one of the boards. The heat from a bench lamp or hand-held hair dryer is usually enough to do the job. But take care; you can sometimes quickly overheat a board that way.

When you can get a trouble to come and go by applying and removing heat to a whole area, you can usually finish the job quite quickly by combining the heating act with a cooling act. What you do is use a pressurized can of circuit coolant and spray different components while the board is hot. When the defective one is cooled the trouble will come on immediately.

When others are cooled it makes no difference. The blast of coolant should be brief and closely confined to the component suspected of being faulty. Sometimes you will think you have located the trouble spot when you are actually only close.

Summary

1. Know basic AND gates, OR gates and flip-flops.
2. Know how to operate the equipment being serviced.
3. Study block diagrams and labels of input and output lines.
4. Create as many symptoms of the problem as you can to get the best clues about where to look.
5. Substitute good circuit boards for ones suspected to be faulty if they are available and can be changed quickly.
6. Carefully check temperature of components with your finger if there is no shock hazard.
7. Substitute good components for ones suspected to be faulty if they are available or can be borrowed.
8. Trace back through signal path from symptom toward normal origin of missing or faulty signal.
9. Take large steps toward origin until you find a normal signal, then small steps in direction of signal-flow to find where the signal is blocked.
10. Try to pick points to probe that are outputs of simple logic gates.
11. At point where signal is blocked look for defective component, missing or fautly input signal, or extra input signal.
12. Put original component back in socket if it is not defective.
13. Be sure to put boards and components back correctly.
14. Trace source of missing, faulty, or extra input signal the same way as when you first started at a primary symptom.
15. Probe pins on device not pins on socket.
16. Look carefully for single or low rep rate pulses.
17. Check for shorts or excessive load on output of I.C. where signal is blocked, when other factors seem normal.
18. Lift I.C. output pin to isolate from load if I.C. is not soldered in.
19. Lift I.C. input pins to identify faulty inputs of I.C. if it is not soldered in.
20. Heat boards to cause intermittent faults to occur.
21. Cool one component at a time and observe results on heated boards.

*See Nov/Dec 1974 issue of TEKSCOPE

INSTRUMENTS FOR SALE

53/54D; $40; Instruments, Inc., 3432 Midway Dr., San Diego, CA 92110. (714) 223-7156; c/o D. C. Kalbfell.

160, 161, 162, 163 & rack adapter; Sell or trade for 130 LC meter; Terry Perdue, 1470 Wilson Rd., St. Joseph, MI 49085; (616) 429-7566.

190, 105, 107, 180; $500 total. 511AD; $200; Dan Love; (213) 359-9141 X583.

211; $650; Mark Kimball, Control Engineering Assoc., 1702 Riverdale St., W. Springfield, MA 01089; (413) 732-2936.

212; 10X attenuator pkg; BNC adapters; case; manuals; $700; James Branchaud, Bell & Howell Co., Honolulu, HI; (808) 847-4056.

310 with access.; $300 or best offer; Tony Thomas, 3303 E. Denny Way, Seattle, WA 98122; (206) 655-4470.

422; Ceavco Audio-Visual Co., Inc.; 7475 W. 16th, Denver, CO 80215; (303) 238-8463. Ask for Steve or Paul.

422 with 2 probes; $1000; Hugh Hansen; (213) 640-1291.

453 w/EMI Mod & miniature probes; $1800; David Rimi, (214) 337-5454 or (214) 941-1255.

453, $1250; 454, $1800; RM561/2A60/3B1, $575; D & K Plug-ins, $35 ea.; W. A. Shirer, 9350 Carmichael Dr., La Mesa, CA 92041; (714) 466-3578.

465; $1550; S. L. Shannon, (616) 965-8087; Battle Creek, MI.

465; $1600; George Coomes, 16801 Veronica E Detroit, MI 48021; (313) 775-0843 Home or (313) 273-5855 Bsns.

507 (3); $2300 ea; A. R. Miller, Electro-Craft Inc., 1124 Dorchester Ave., Dorchester, MA 02125; (617) 825-0980.

512; $200; Mr. Singhmanan, 122 Nelson Ave., Peekskill, NY 12550; (914) 737-6502.

514A; missing pwr. cord & probes; $450; John L. Lenzo, 14 Hoffman Ave., Poughkeepsie, NY 12603; (914) 454-5335.

514D, 160A, 161, 162, 163; Best offer; Al Royce; (714) 734-0623.

517A (3); $250 to $400; Gene Wilkerson, Photographic Consultants, Inc., 10 Brookhill Rd., East Brunswick, NJ 08816; (201) 257-2794.

531 (2) with plug-ins & carts. Best offer over $300 ea.; 422 (2). Best offer over $475 ea.; General Kinetics Inc., 12300 Parklawn Dr., Rockville, MD 20852; (301) 881-2044.

531 with 2 plug-ins; $350; R. Tsubota, Rt. 2, Box 442, Ontario, OR 97914.

531A, $400; 533, $400; CA $165; 127 plug-in power supply, $200; Kurt Dinsmore, Box 67, Richardson, TX 75080; (214) 238-0591.

531A, 1A1, B; $600 or best offer; Eric Greenstein; 218 Foster St.; Brighton, MA 02135; (617) 783-0881.

532 with spare CRT & Access.; Wayne Burkhardt, RFD 2, Spencer, MA 01562; (617) 765-9711 X2318.

535-S2; 53/54C plug-in; Marty Planthold, Science Press, 300 W. Chestnut St., Ephrata, PA 17522; (717) 733-7981.

535, 53/54C, 53G, $200; 105, $40; misc plug-ins & Equip.; (215) 648-2477 Bsns; (215) 933-8175 after 5 p.m. Home, Ask for Roy Russell.

535A; $850; Terry Barnum, Communications Systems of Albany, 6 Highland Ave., Albany, NY 12205; (518) 482-4435.

535A, CA; Bill Telekamp, MSI Data, 3180 Red Hill, Costa Mesa, CA 92626.

535A (2), CA (2); $300 ea. scope with plug-in; Seymour Hamer, Telemet, 185 Dixon Ave., Amityville, NY 11701, (516) 541-3600.

545A/1A6/CA/P6013, C-27 Camera, cart; $1000; F. H. Bratton, 2133 Birchwood Ave, Wilmette, IL 60091; (312) 256-2440 (eves.)

545 w/CA; $715; Mr. Richard Stan, 26177 6 Mile Road, Redford, MI 48219; (313) 533-6700 (Bsns), (313) 422-7698 (Home).

545A, G, 500/53A cart, 2 probes & hood; $1100 or best offer; K. A. Murphy, Johns-Manville Prod. Corp., 814 Richmond Ave., Richmond, IN 47374; (317) 966-1561.

545L, $695; 585-82, $950; 661-5T3-4S2A, $850; Frank Chance, S&C Sales Co., 319 Market St., Camden, NY 08101; (609) 963-5700.

549, 1A2 202-1 cart, best offer; Jim Warner, McGraw Edison, Olean, NY 14760; (716) 372-7700.

561, 2B67, 2A61; $700; Leo Larsen, 4659 Is. Sh. Dr., Pinckney, MI 48169; (313) 229-4651 (eves.)

564B Mod 121N w/3A6, 3A7, 3B3, 2B67; John Forster, Consulting Engineer, PO Box 48, M.I.T. Branch P.O., Cambridge, MA 02139.

564B w/3A6, 3B3, $1800; 3A7, $350 or best offer; Jairus Lincoln, 44 Chandler St., Somerville, MA 02144.

R568/3A2/3B2; $1067; E.D.A., Box AE, Cupertino, CA 94014; Attn: F. Shriver; (415) 941-3968 or (415) 948-8812.

(3) 611; $2750 ea.; G. Payne, Hughes Aircraft Co., 2020 Oceanside Blvd., Oceanside, CA 92054; (714) 757-1200 X314.

647 w/10A1 & 11B2; $800; Solidstate Controls, Inc., 600 Oakland Park Ave., Columbus, OH 43214; Call Jeff Powell (614) 263-1886.

647A, 11B2A, 10A1; below ½ price; Michael Sherman; (213) 363-4401.

2901; Call (203) 446-0280.

4002A w/Joy Stick; Connie Shea, GTE Sylvania; 189 13th St., Needham Heights, MA 02194; (617) 449-2000 X2617.

7503 w/7A12 & 7B52, 181, 516, CA, 53/54B, R, Z, L plug-ins, 160/161/162/163; (213) 348-5524.

7504, 7A16, 7A15, 7B50, 7B51; best offer; Audrey Jackson, Epps Air Service; DeKalb Peachtree Airport, Chamblee, GA 30341; (404) 458-9851.

7504, 7T11, 7B53A, 7S11(2), S3A (2); best offer; Charles McQuire c/o Dynamic Measurements Co., 6 Lowell Ave., Winchester, MA 01890.

7613 w/7B53A, 15% off list; Gregory E. Peacock, Telaid Systems, Inc., 6725 Variel Ave., Canoga Park, CA 91303; (213) 884-5440.

7A15, Henry Kallina, 5th & Walnut, Atlantic, IA; (712) 243-2901.

7B51; $275; Richard Baum, Electronic Instrument Labs Corp., PO Box 208, North Olmsted, OH 44070; (216) 779-7766.

7T11, 7S11; Sid Sanders, COMCO, 300 Greco Ave., Coral Gables, FL 33134; (305) 445-2671.

(5) C12-P. $375 ea; (3) C12-PE, $690 ea; (5) projected graticule 016-204-00, $120 ea; John Belicka; (203) 348-5381.

C30A w/case, $300; Ed Phillips, Programmed Power; (415) 323-8454.

C30A-P, 454; A. Okaya, Optical Data Products, 38 Vitti St., New Canaan, CT 06840; (203) 966-1432 or (203) 966-5968.

DC 502; Allen Drabicki, AJ Electronics, 7870 Hawthorne Dr., Liverpool, NY 13088; (315) 652-7425 (eves.)

INSTRUMENTS WANTED

DM 501, TM 503; 25% off list price; Jim Kavitz, Washington Electronics Service, 3368 Lee Highway, Bristol, VA 24201; (703) 466-9036.

DM 503 Opt 1, TM 503, FG 501, PS 503, 2601, 26A1, 26A2, 26G3; John Foster, N/J Electronics, PO Box 577, Laramie, WY 82070.

(4) FM 122, (1) RM 125 for FM 122, rack mount; $100; Barry Fox, Optronics International, Inc., 7 Stuart Road, Chelmsford, MA 01824; (617) 256-4511.

TLD67 w/probes; $700; Robert Rahn; (213) 360-0785.

TLD67, Don Relyea, Hoffrel Instrument, Norwalk, CT; (203) 866-9205.

106, 191; Frank Redder, Cornell Univ.; (607) 256-3552.

317; Dan Rasmussen, Jr., 323 Fuller St., Richland, WA 99352; (509) 943-3369.

324; Jerry Staab, Autometrics, 4946 N. 63rd St., Boulder, CO 80301; (303) 449-1662.

453 or 454; Cash; Dr. Gordon, 1435 W. 49th Place, Hialeah, FL 33012; (305) 822-1100.

533A, cart 202-2 or 202-1; Bob McKibben; (509) 943-9141 X31.

575 for 530 or 540; J. E. Fivecoate, Centaur Electronics, 743 S. Webster, Kokomo, IN 46901; (317) 452-2739.

4551, 4701; Robert Krause, Medical College of Pennsylvania, Cardiology Section, 3300 Henry Ave., Philadelphia, PA 19129.

1S1; Mike Levitt, Systems Concepts, 524 2nd St., San Francisco, CA 94107, (415) 494-2221.

1S1; Stuart Nelson, Systems Concepts, 524 2nd St. San Francisco, CA 94107; (415) 433-5400.

3A3, 3A9; Jerry Hall, Iowa State Univ.; (515) 294-1423.

3A9; Peter Costigan, 10 Quinton Drive, Nashua, NH 03060; (603) 882-7940 (eves).

3A73, 3A3; Dr. Ronald Hoy, Cornell Univ.; (607) 256-7473.

3A74; Jim Godwin, ROH Corp., 107 Technology Park, Norcross, GA 30071.

3B4; Dale W. Fitting, Memorial Hospital, Radiology Dept., 1924 Alcoa Hwy, Knoxville, TN 37920; (615) 971-3701.

7A15 or 7A18; Henry Kallina, 5th & Walnut, Atlantic, IA 50022; (712) 243-2901.

10A1; cash or trade for 11B2; Jeff Cook; (805) 962-1080.

82 & 81A plug-in; G. W. Hui, 5807 Gomer Pyle, San Antonio, TX 78240; (512) 696-6501 (Bsns), (512) 684-3940 (Home, weekends).

P6038; Mr. Leo Berries; GTE Sylvania, Box 360, Muncy, PA 17756; (717) 546-3191 X134.

Scope, 20 MHz, single trace minimum sensitivity 5 mV/div; Duane Johnson; (206) 624-7498.

1974 Tekscope Index

Jan/Feb 1974:	**Volume 6 Number 1**	30 Hz resolution at gigahertz frequencies — a new direction in spectrum analysis CRT Readout — nicety or necessity? Flexible disc measurements simplified by digital delay Servicing the 465 portable oscilloscope
Mar/April 1974:	**Volume 6 Number 2**	A 1000 cm/μs storage oscilloscope Using your oscilloscope probe Triggering the oscilloscope from logic signals Servicing the TELEQUIPMENT D67 Oscilloscope
May/June 1974:	**Volume 6 Number 3**	The 31/53 calculator-based measurement instrumentation package Using your oscilloscope probe Servicing the 7904 high-efficiency power supply
Sept/Oct 1974:	**Volume 6 Number 4**	A 400-MHz dual-beam oscilloscope The oscilloscope with the digital multimeter Op amp bandwidth approximations . . . using the 577/178 curve tracer Troubleshooting the 7B70 and 7B71 time bases
Nov/Dec 1974:	**Volume 6 Number 5**	What you need to know about testing 4k MOS memories The logic probe and the oscilloscope Understanding oscilloscope triggering controls Troubleshooting digital circuits

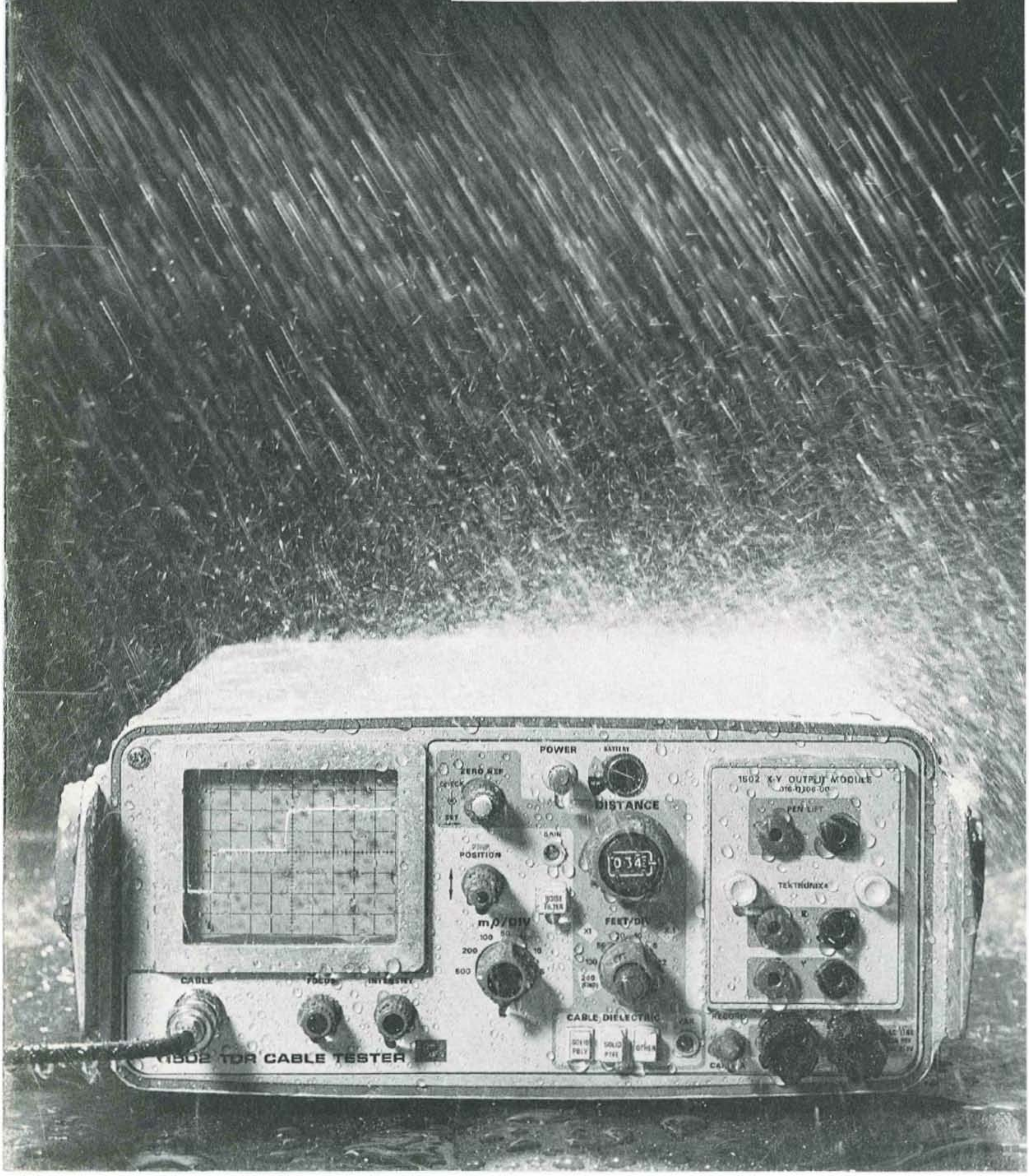
TEKTRONIX®
committed to technical excellence

A-3115

TEKTRONIX®
committed to technical excellence

TEKSCOPE

Volume 7 Number 2 1975



TEKTRONIX®
committed to technical excellence

TEKSCOPE

Customer Information from Tektronix, Inc.,
Beaverton, Oregon 97077

Editor: Gordon Allison
Ass't. Editor: John Mulvey

Contents

3 **Two weatherproof TDR cable testers for field use**

The 1502 provides high resolution with moderate range, and the 1503 long range with moderate resolution. Both are compact, lightweight, battery operated, and designed for hostile environments.

9 **A new 50-MHz oscilloscope**

"Designed from the ground up" best describes the new 455 Portable Oscilloscope. It features dual-trace 50-MHz, delayed-sweep performance with the reliability needed for a host of general purpose applications. And at a cost compatible with tight budgets.

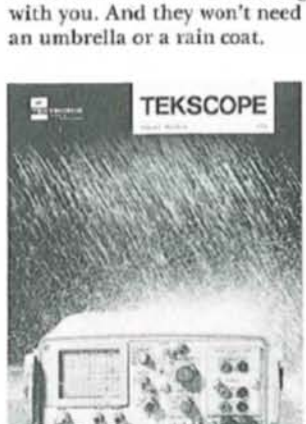
12 **The TM 500 mobile test lab**

A new level of measurement mobility, flexibility and usability is achieved by combining a Scope-Mobile Cart, oscilloscope and your choice of over 25 instruments from the TM 500 line of signal generators, counters, DMM's, etc.

16 **Transmission line characteristics . . . a review**

Reviewing the fundamentals often helps in understanding the importance of the characteristics of instruments we are called on to service. An understanding of transmission line characteristics will be helpful in servicing TDR Cable Testers.

Cover: We hope you won't have to work on cables under the conditions shown on the cover. But if you do, the 1502 and 1503 TDR cable testers will work right with you. And they won't need an umbrella or a rain coat.



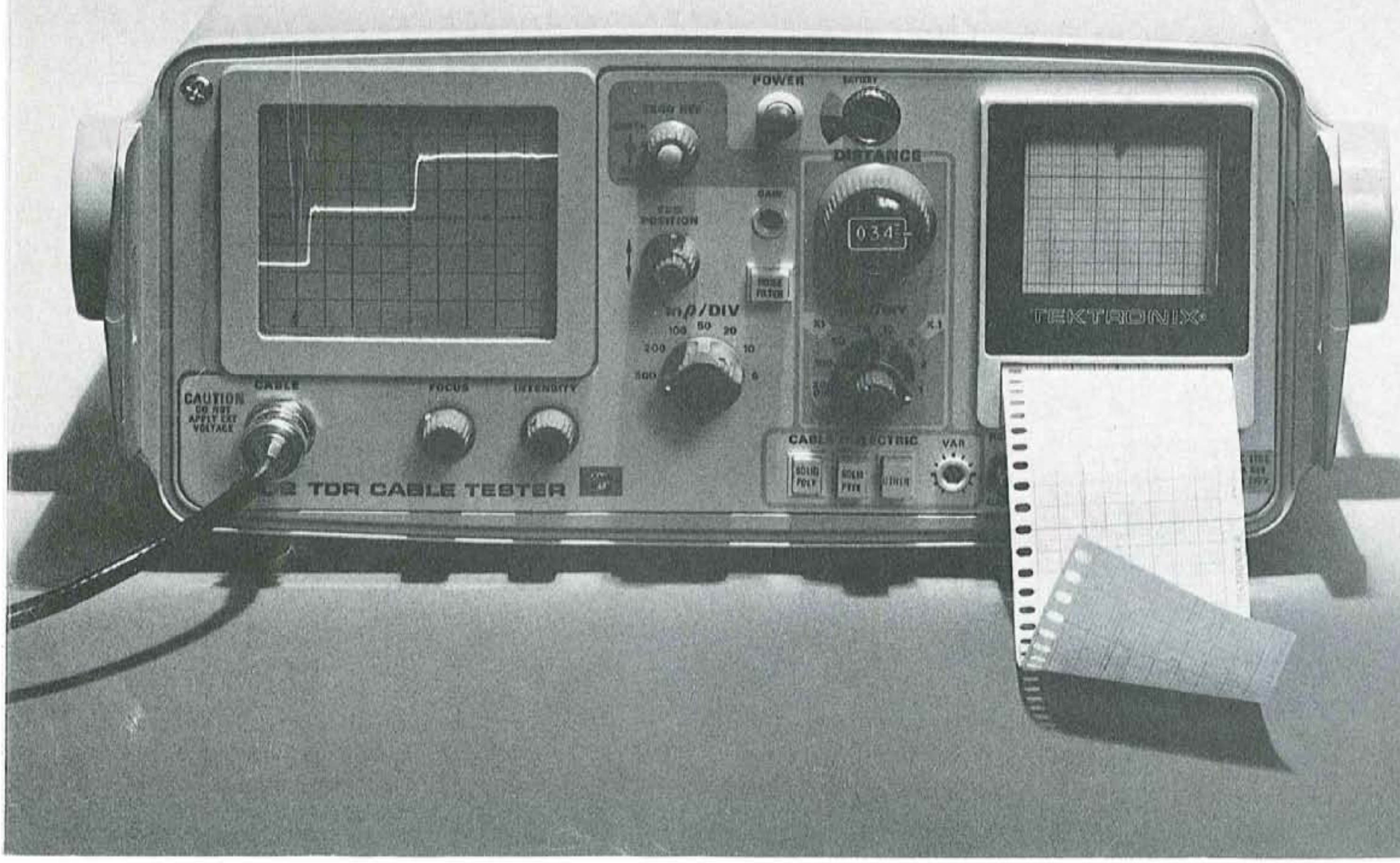
Ivan Ivanov

Two weatherproof TDR cable testers for field use

Electrical transmission lines and cables go most everywhere. You see them on poles and towers and coming out of the wall. But mostly they are out of sight. Like the arteries and capillaries that carry blood to our body cells they lace our cities, ships and airplanes and keep the parts perking, healthy and unified. Some are more vital and critical than others. Some have to be carefully placed and cared for. Others need to be fixed only when they fail. But whether you are testing a new installation, guarding against deterioration, or finding a fault, the need for quick, simple diagnostic cable testing is the same. Here is the story of the development of two new state-of-the-art TDR Cable Testers for the field.

Why two testers

The need for a high resolution (100 ps to 150 ps risetime) battery operated, portable TDR cable tester of moderate price was recognized shortly after introducing the 1501 TDR for the CATV market in 1971. Market studies then also showed the need for a portable TDR tester for lines longer than 2000 feet, where 150 ps risetime is too fast for their bandwidth. Therefore, we developed two reflectometers at the same time . . . the 1502 for high resolution and the 1503 for long range. The two instruments resemble each other physically but have some important electrical performance differences.



Exceptional ruggedness and complete protection from bad weather are vitally important in the field. The 1502 and 1503 are both designed to be operated outdoors in the worst kind of weather . . . wind, rain, sleet, snow, ocean spray, or dust storms.

For guidelines on safety, ruggedness and weatherproofing, we used the detailed criteria in a U.L. Safety Standard and in the new US Military document MIL-T-28800A for Type II, Class 2, Style A Test Equipment. Equipment of that Type, Class, and Style qualify for use on aircraft flight lines, for example, and, incidentally, aircraft cable testing is one of the foremost applications for the 1502. The 1503, mechanically equivalent to the 1502, is primarily for testing telephone lines and communications cabling. Both reflectometers meet practically all of the requirements specified in MIL-T-28800A. The table to the right is extracted from that document to show the requirements specified for Class 2, Style A Test Equipment.

The weatherproof package

Style A instruments are ones which have a case that serves for storage and shipment, as well as adverse environments. Called a combination case, it has to be very rugged to withstand all kinds of weather and the shocks of rough handling and shipment. What material is best for such a case? After careful consideration of various metals and plastics, CYCOLOY KHP® plastic was chosen. That material is 41% ABS plastic and 59% polycarbonate. It combines the outstanding strength and resilience characteristics of ABS, with the flame retardant characteristics of some polycarbonates. Although MIL-T-28800A does not specifically require the case material to be flame retardant, a consciousness of UL safety standards convinced us of the value. The main thing favoring a metal case was that it is a good shield against electro-magnetic interference, either due to radiation from the Reflectometer or radiation into it. But that problem was solved by using metal shielding around the chassis and frame of the instrument, inside the plastic case. Both the 1502 and 1503 meet the Electromagnetic compatability requirements of MIL-T-28800A.

To operate either Reflectometer you must remove the watertight cover. Two easily operated, spring loaded, over-center latches are built into a recess in the cover. They engage notches on the inside of two front panel knob-protecting guards that are part of the front panel casting. The latches, being recessed, can't be accidentally released. When snapped into place, the cover makes a water-tight pressure seal against the panel with a gasket surrounding the edge of the cover. When unsnapped, the cover contains useful accessories for operation and a small, waterproof, operator's manual. These items are kept secure by a hinged door and latch inside the cover. The cover matches the one-piece case and is made of the same material. The cover and case form the entire enclosure for the waterproof instrument. Four screws attach the case to the instrument chassis and hold pressure against the seal on the back side of the front sub-panel. The one-piece, metal handle is attached to the sides of the case by adjustable allen-screws that apply smooth, friction-loaded pressure so the handle may be used as a tiltable support. It also lets you rotate the handles out of the way for stacking several instruments.

CLASS 2 REQUIREMENTS		1502/1503 PERFORMANCE
Temperature Non-operating (degrees Celsius)	−62 to 85	Same; batteries excepted.
Temperature, Operating (degrees Celsius) at Relative Humidity to 100%	−40 to 55 (Portable: −15 to 55)	Same; battery hours reduced at extremes
Altitude Non-operating	50,000 ft.	Same
Altitude Operating	10,000 ft.	Same
Vibration Limits (Maximum)	3g	Same
Minimum Vibration Test Time/Axis	45 min.	Same
Shock, Pulse (Level)	15g	Same
(Test Shocks)	18	Same
Bench Handling	Yes	Same
Crash Safety (Mounting Base)	N/A	Same
Fungus Inert Material	Yes	Same
Salt Atmosphere Structural Parts	Yes	Same
Explosive Atmosphere	Yes	Same
Sand and Dust Resistance	Yes	Same

STYLE A REQUIREMENTS		1502/1503 PERFORMANCE
Transit Drop	30 inches	12 inches
Watertight (3 feet)	Cover On	Same
Splashproof	Cover Off	Same*
Dripproof	Cover Off	Same*
Salt Atmosphere Exposure Salt Solution	48 hours 20 Percent	Same Same
Sand and Dust Resistance	Yes	Same*

*Not with optional chart recorder

® Registered Trademark of Borg-Warner Corp.

Battery pack pocket

Because the 1502 and 1503 are battery-operated there will be occasions when continuous use for more than 6 hours requires substituting a fresh battery pack for one that is discharged. A discharged battery pack is easily removed by loosening two thumb screws on the rear of the case and unplugging the entire pack. The battery compartment is an integral part of the plastic case, a waterproof pocket that contains the entire pack and isolates the instrument circuitry against the possibility of contamination from chemicals leaking from defective cells. When plugged-in, with the thumb screws tightened, the battery pack is isolated from the weather by a waterproof seal.

Putting the battery pack in its own pocket posed a problem to calibration and maintenance people, however. How do you power the instrument with the case off? Although the reflectometers may be operated from AC line voltage, the battery pack is used for filtering rectified voltage so it must be connected. The problem was solved without requiring a special adapter cable by making the cabinet pocket connectors a feed-through type with plugs on one side and matching receptacles on the other. That way the chassis mounted connectors have the correct spacing, style, and sex to mate directly with the battery pack connectors. Standard banana plugs and jacks were combined and used to maintain watertight integrity.

An identical problem applies to the power cord receptacle. You would like to be able to power your instrument with the case off, using the same power cord as stored in the front cover. A special feed-through power cord receptable-and-plug was designed and mounted in the rear of the case.

Prepared for the worst

With the front cover off, a 1502 or 1503 is ready to go to work. But it may have to work in the rain and wind without water getting inside, so all front panel openings had to be sealed. Some special seals were developed for the push-buttons, crt, and power switch shaft, but conventional commercial seals were available for the rotary controls. The POWER switch must be pulled to turn the instrument on and pushed to turn it off. The instrument is totally sealed by attaching the front panel cover, and that automatically turns the power off by pushing the switch in. Good waterproofing measures keep sand and dust out with no additional attention.

Portable maintenance equipment has to withstand inhuman treatment and the MIL-T-28800A test sequence required the instrument to maintain its water tight properties after being subjected to a sequence of 26 twelve-inch drops.

The main problem withstanding drops was supporting the crt. At no point is it rigidly connected to the chassis. Instead, its faceplate is forced against a silicone-

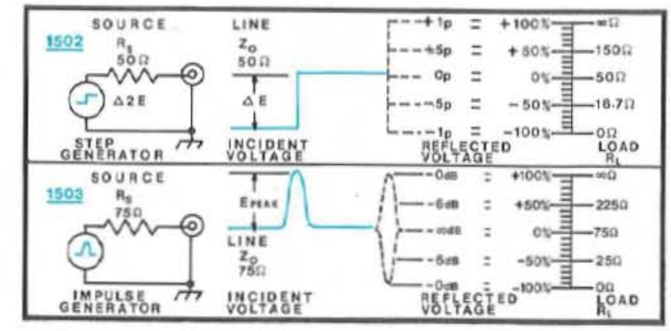


Fig. 1. Test signals generated by the 1502 and 1503 and how reflections are measured and expressed.

rubber cushion by pressure against a thick cushion at its base. The crt neck is protected against lateral shock by a doughnut-shaped plastic piece supporting it. A weak point in the crt gun structure itself was discovered and corrected while conducting the drop tests. The bench handling drop tests were mild compared to the other drop tests. Now let's take a look at some of the measurement capabilities of the 1502 and 1503.

1502 . . . widest bandwidth battery-operated portable TDR

The step-pulses generated in a 1502 have the shortest risetime of any known battery-operated portable TDR. And the bandwidth of the instrument is greater than any other portable TDR. The displayed risetime of a (nearby) reflection is 140 ps or less and that defines the limit of distance resolution. Since transmitted pulses propagate at a rate close to 1.5 ns per foot in cable having a dielectric of solid polyethelene, it takes 3 ns to go one foot and return, or 300 ps to go 0.1 foot and return. The shortest distance scale on the 1502 is 0.1 foot per division so the scales and the bandwidth are adequate to accurately diagnose all cable faults and imperfections that are not so distant that they are masked by high frequency attenuation of the cable itself. Faults separated by as little as 0.6 inches can be resolved over short distances.

Common cable faults are opens, shorts, kinks, frayed shielding, poor splices, bad connectors, wrong impedance cable, water soaked sections, defective loads, etc. The 1502 lets you examine up to 101 feet of cable at 0.1 foot per division or up to 1010 feet at 1 foot per division. To get a preview of where to look for a fault, the FIND position of the FEET/DIV switch lets you see a full 2000 feet at one time. Optional models of the 1502 may be ordered that are calibrated in METERS/DIV.

The vertical scale of the 1502 is calibrated in dimensionless units that correspond to the ratio of the amplitude of the reflected signal to that of the test pulse. The Greek letter ρ (Rho) represents the fractions. The knob that controls the vertical scale is labeled mρ/DIV (millirho per division) rather than ρ/DIV so the units may be whole numbers. The seven position switch goes from

500 mρ/DIV to 5 mρ/div, covering a 100 to 1 difference in sensitivity.

1503 . . . long range impulse TDR

Time Domain Reflectometers use step-signals, impulse signals, or bursts of RF sinewaves. Step-signals have signal components covering the widest bandwidth and, therefore, offer the best diagnostic stimulus to a fault for responses in graphic form. But long lines typically attenuate high frequency components so much that high peak power must be transmitted or the attenuated reflections will be buried in noise. Step-signals with high peak power suitable for testing very long lines require such high average power that a light, portable TDR cannot be operated very long without discharging the battery pack. For this reason and others, narrow half-sine shaped pulses (impulses) are generated in the 1503 and applied to the transmission line being tested. You have a choice of 10 ns, 100 ns or 1 μs impulse width.

Narrow pulses are attenuated more than wide pulses over a given length of transmission line, so wide pulses are used where narrow pulses would be attenuated too much. Very long transmission lines usually call for use of the wider pulses. Fortunately the accuracy of fault location is not significantly degraded by use of wider pulses as long as the width is only a very small percentage of the two way propagation time of the distance measured. Somewhat shorter but lossier lines, like twisted pair phone lines, may also require the wider pulses.

Impulse return loss

Sinewaves of a given frequency are attenuated by a predictable amount in a given type of transmission line. Such losses are usually expressed in dB per unit distance, as dB/100 ft. That figure lets you easily calculate how much signal amplitude to expect at any point along the cable and how much a reflection will be attenuated before arriving back at the input, knowing only the kind of cable. Impulses of controlled width and shape are also attenuated by a predictable amount, although calculating the amount is not as simple as for a single-frequency sinewave. Use of a table or graph corresponding to the kind of cable and the character of the impulse is a practical solution. Any signal energy that gets reflected back doesn't have the opportunity to go directly through, so is "lost" by being returned. Since reflectometers indicate reflected energy it has become common practice to express the relative magnitude of such reflections in terms of dB of Return Loss. You should keep in mind, however, the distinction between the measured amplitude of a reflection and the original amplitude of that reflection. Reflections undergo attenuation coming back to the signal source the same as the original signal is attenuated going down the cable.

Impulse amplitude in the 1503 is 5 volts into a transmission line having an impedance that matches the selected source impedance of the 1503. A choice of 50, 75, 93, or 125 ohms is selected by pushbuttons on the front panel. In some applications such as testing long antenna cables, where RF pickup may be very large, the 1503 may be used in place of the 1502 because the high amplitude pulse helps override the stray pickup. Also the input circuits of the 1503 are protected from most accidentally introduced external signals of high amplitude.

Set your own zero reference

The multi-turn DISTANCE dial on the 1502 and 1503 has 3-digit readout, with four graduated divisions between the digits of the least significant row of digits. Distance measurements made with this dial are like differential time measurements made with the multi-turn delay time dial on some oscilloscopes. However, the dial can be set to zero (000) and the zero-distance reference point in the TDR waveform positioned to the desired graticule line on the crt. The ZERO REF SET control is used for that purpose. It is especially handy for making distance measurements that begin at the end of an interconnecting test cable instead of at the CABLE connector on the front panel of the reflectometer. In other words, distance measurements don't have to start where the TDR pulses emerge from the reflectometer, they can start where the pulses emerge from the output end of a patch cable and enter the cable being tested. That way the propagation velocity of the patch cable doesn't need to match that of the cable or transmission line being tested. Nor do you need to remember to subtract its length from the distance measured. The impedance of the patch cable should match that of the cable being tested, however.

To complete the measurement, the DISTANCE dial is rotated until the fault or imperfection of interest moves to the selected graticule reference line. Then the distance to the fault is indicated directly by the numbers on the dial. The decimal point position for the indicated distance will depend on which multiplier and scale is used.

Zero reference check—something new

The multi-turn DISTANCE dial really doesn't have to be set at 000 before positioning the starting point in the TDR waveform to the reference graticule line. Pushing the ZERO REF CHECK button does the same thing as setting the dial to 000. If you think you may have bumped a knob or changed the setting of the FEET/DIV switch since positioning the beginning point to the reference line, or don't remember for sure which graticule line was chosen for reference, you only need to push the ZERO REF button to be sure. Should there be an error it may be corrected while the button is pressed, rather than rotating the multi-turn dial all the way back to 000.

Chart recordings, easier, easiest

What may be viewed on the screen of the 1502 or 1503, may be easily and inexpensively recorded by an optional plug-in strip chart recorder. Or an external X-Y recorder may be used.

The standard plug-in module supplied with a 1502 or 1503 supplies standard amplitude X and Y deflection signals and a pen-lift signal to drive an external commercial X-Y recorder. But the simplest way to make a recording is with the plug-in strip chart recorder. No skill is required, no external equipment is required, and the cost of a recording is less than that of a photograph. Any time the condition of a cable should be documented on the scene, this recorder is recommended. A strip chart 4 cm wide by 25 cm long is available in about 20 seconds after moving the RECORD-CAMERA switch to the RECORD position.

In the optional strip chart recorder the duration of the scan is automatically adjusted to correspond with the speed of the paper. The recorder makes a momentary pause while the stylus heats up, counts holes in the edge of the paper to adjust the crt beam scan speed, turns off the stylus heat when the right number of holes pass a photo-cell, turns off the paper drive motor when the chart has completely emerged from the recorder, and electrically brakes the motor so it stops in the right position to draw the next graph.

CRT phosphor flooded for taking pictures

It is important for some customers to take pictures of TDR "signatures" of cables and terminations in good condition. That is so they may prepare documented instructions on how to recognize faults and gradual deteriorations for technicians using the 1502 and 1503. But the power required to edge-light the crt graticule for photographing is excessive in some battery operated portable instruments. Total operating power required by the 1502 and 1503 is only 2.5 watts, one third of the power of one small Christmas tree bulb! So a new idea was perfected—flood the crt phosphor during retrace instead of blanking the crt beam. By gating on a high frequency oscillator connected to the vertical deflection circuits, and controlling the retrace speed, all the phosphor crystals on the entire crt screen may be excited by the one crt writing beam during retrace. The effect is to illuminate the phosphor so the parallax-free internal graticule lines stand out in good contrast. A three-position toggle switch on the front panel, labeled CAMERA in one position, selects that mode of operation. An optional camera bezel adapter accommodates the TEKTRONIX C30A oscilloscope camera.

Low amperes, long hours

Several techniques were used to extend the battery operating time. Using sampling principles conserves power because the fast, wideband circuits are operating only a small portion of the time and low bandwidth circuits generally don't require much power. Extensive low power CMOS IC technology was used in the design. In addition current for the circuits requiring high peak power is turned off most of the time and turned on only shortly before being required each sampling cycle. That helps reduce power requirements further. The 1502 and 1503 will operate on batteries for at least 5 hours, including twenty strip charts.

Battery pack protection

Nine rechargeable size C cells are connected in series to make the battery pack. Complete discharge of any one of the cells in a series-connected pack can be a serious problem because further discharge of the other cells tends to reverse the polarity of the charge for the weakest cell and ruins it. Then, because there is no practical way to replace one cell at a time in a battery pack, the whole pack must be replaced. That is expensive. To protect the battery pack, a voltage-sensing circuit automatically switches power off when the battery pack voltage drops below a safe level. A battery charge meter on the front panel gives you an indication of when the charge level is getting low.

In summary

Design of the 1502 and 1503 Time Domain Reflectometers combined several divergent fields of highly technical expertise to provide practical, rugged, exceptionally easy to use instruments capable of coping with the installation and maintenance problems of a vastly increasing number of cables and transmission lines. The designs have been completed after extensive consultation with some of the most knowledgeable of our potential customers.

Acknowledgments

Packaging the 1502 and 1503 so they would be very rugged and waterproof was a pioneering enterprise led by Darrel Pfeifer, mechanical design, with help mainly from Larry Tucker and Brent Anderson. Circuit layout and prototype support, with all the repeated revisions, were patiently provided by Bob Culver and Lena McIntosh. Bob Conchin and Dean Hager chased production evaluation and coordination problems with their special but different ways of unraveling knots and tying up loose ends. Jack Piercy did our documentation and manual writing. Special credit should go to Hans Geerling, presently on leave of absence, who did most of the circuit design on the 1502. Our various trials in completing the project have been matched by good humor and hard work at every turn.

Ivan Ivanov
Project Engineer

R. Michael Johnson

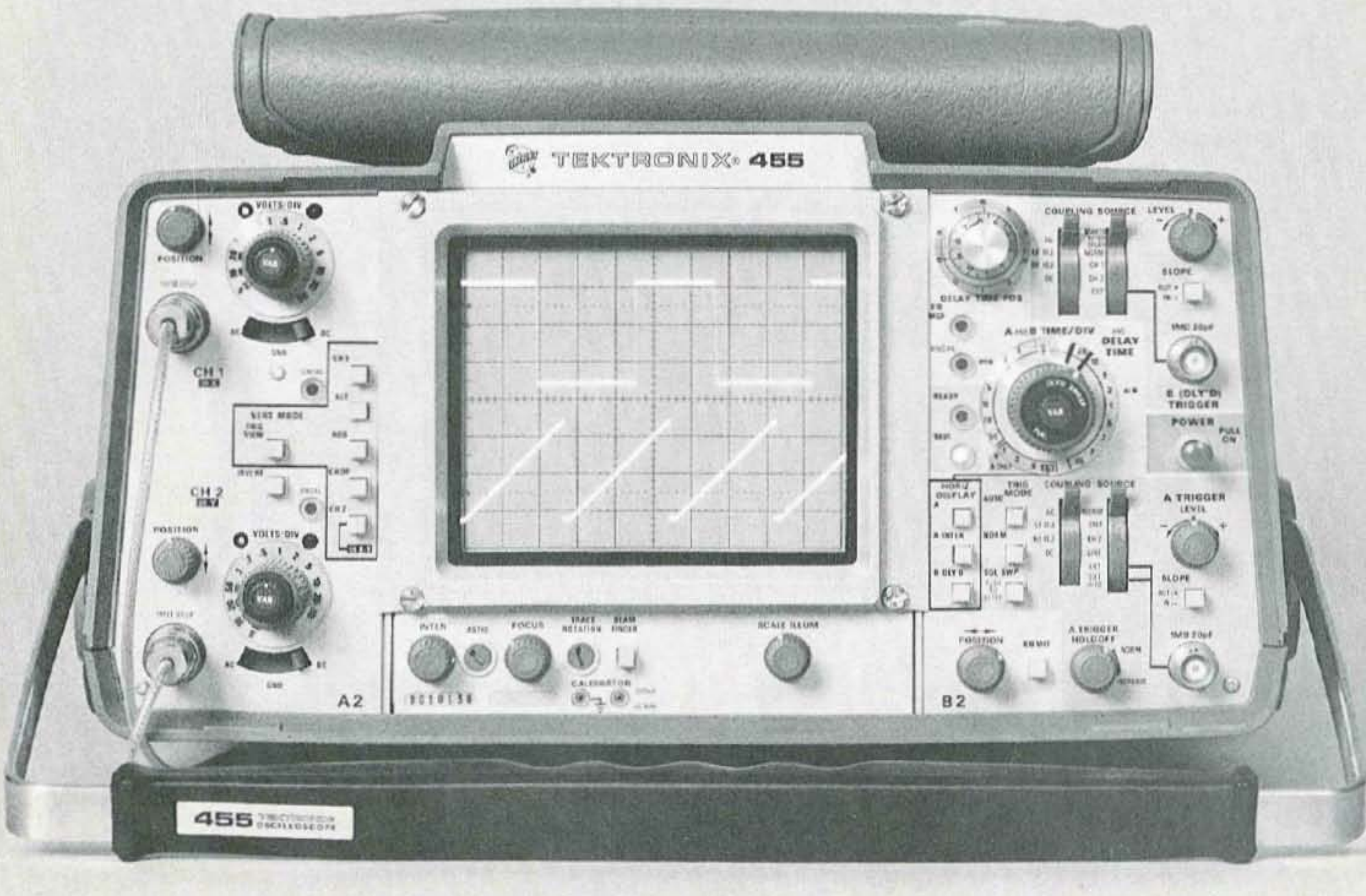
A new 50-MHz oscilloscope

New things should be exciting. But what can be exciting about a 50-MHz oscilloscope — we've had this measurement capability for a long time. Removing the cabinet from the TEKTRONIX 455 uncovers much that's new, and much that is exciting when we consider the impact on the 455 and instruments that will follow.

From an exterior viewpoint, the all-plastic cabinet, and its shape, is new to the 400-series portables. The contoured design and tough, glass-filled, shock resistant plastic result in a light, exceptionally rugged case. The material is CYCOLOY KHP®, the same as that used in the field-proven 200-Series instruments.

While newness is exciting, some things are better left unchanged — front panel layout, for instance. The controls on the 455 are just where you find them on the popular wider-bandwidth 465 and 475 oscilloscopes. There are some subtle changes, such as smaller pushbuttons, giving the front panel a more open appearance. Included are the same operating conveniences found on the wider bandwidth portables — automatic indication of the deflection factor, whether the signal is applied directly or through a 10X probe, and the ability to view the external trigger signal simply by pressing a front-panel pushbutton.

The vertical and horizontal sections look as though they may be plug-ins. They are not. Rather, they are bolt-in modules for ease in manufacturing and servicing. Both result in lower cost for you.



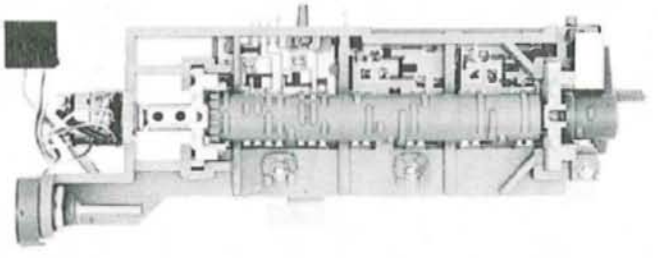


Fig. 1. Vertical attenuator switch used in the 455. Two-piece plastic frame and laser-trimmed thick-film attenuator resistors greatly reduce assembly and test time.

It may be appropriate at this point to discuss the 455 design goals. The key target was to build a quality 50-MHz portable oscilloscope at minimum cost. Serviceability was high on the list of priorities. Two major alternatives were available: 1) use existing components from wider-bandwidth instruments, thereby shortening engineering time but increasing component cost, and 2) design new components specifically for the 50-MHz bandwidth. The latter approach was adopted with one major exception — the cathode ray tube is the same as that used in the 465. Newly designed, the crt offered little room for improvement in cost savings.

The vertical section

Wideband attenuators are typically difficult and expensive to build. Here was a prime candidate for attention. The vertical attenuator assembly in the 455 is radically different from that used in other TEKTRONIX instruments. The actuator assembly, contacts, and attenuator components are mounted in a two-piece molded plastic frame. The attenuator components are assembled on two ceramic substrates. One substrate contains the 1X, 10X and 100X attenuators; the other, two 2X gain-switching attenuators. The attenuator resistors are thick-film, laser trimmed to the precise attenuation ratio. Using the new construction techniques, assembly and calibration time is reduced substantially, and the ability to service the attenuator once it is installed in the instrument is greatly enhanced. The ten-step attenuator provides calibrated deflection factors from 5 mV to 5 V per division in a 1-2-5 sequence. The two vertical channels can be cascaded by feeding the output of channel 2 into channel 1, giving a sensitivity of 1 mV/div at 20 MHz bandwidth.

A glance at the vertical amplifier section reveals a large ceramic substrate (1" x 1.5") and relatively few discrete components. The substrate is a hybrid containing twenty thick-film resistors and two chips comprising about 60% of the vertical amplifier circuitry. Both vertical channels are accommodated on the single substrate. Channel switching, variable gain, and positioning circuitry are located on the substrate, with the switching logic supplied external to the hybrid.

In addition to providing these functions, the hybrid provides an output signal of 0.4 mA/div to the delay

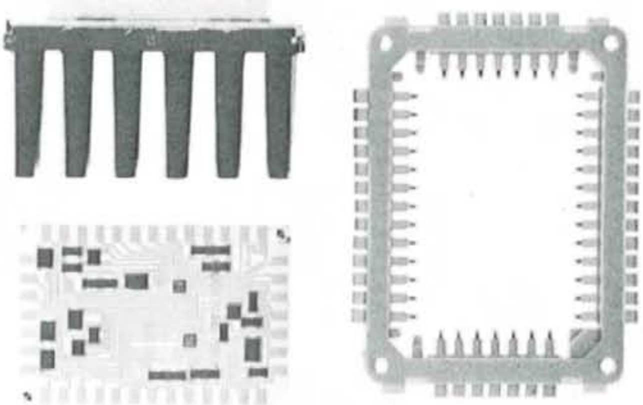


Fig. 2. The hybrid at lower left contains about 60% of the 455 vertical amplifier circuitry. At top left is the completed package. The 40-pin mounting socket is at right.

line driver transistors, and a 50 mV/div trigger output signal from each channel. It is interesting to note that a dc level change of only 3 volts occurs between the input and output of the hybrid. It is powered by +5 volts and −5 volts, and consumes about 2 watts. Thermal dissipation is accomplished by an aluminum multi-spoked heat sink bonded to the hybrid. The spoke design assures adequate cooling regardless of the scope's position.

Some of the techniques used in manufacturing the hybrid are of interest. High-frequency processes are used to achieve a clean amplifier response without the need for numerous peaking adjustments. After the chips are mounted on the substrate, the unit goes through a series of burn-in cycles to stabilize the circuitry and weed out marginal units. Following this operation, laser trimming is performed to match channel gains to within 0.5 per cent. Trimming takes place with power applied to the hybrid, eliminating time-consuming trial and error.

With the increasing popularity of integrated circuits one may logically ask, "Why isn't the entire vertical integrated?" It could be. But it would not be compatible with the design goals for the 455. Some circuits are difficult to fabricate with current processes, hence expensive. Providing optimum performance at minimum cost dictated the use of discretes for some portions of the circuitry such as the FET input source followers and the output amplifier.

The horizontal section

The horizontal section consists of five circuit boards: one each for trigger, sweep, horizontal, time base A, and time base B. The boards interconnect directly without the need for cabling.

Several new components are used in this section. Most prominent is the new timing switch (Fig. 3). The timing boards for time bases A and B are integral parts of the switch. The actuator is mounted between the two boards, with the entire assembly removable as a unit. Accessibility to all of the timing components is excellent even with the switch in place.

Four new integrated circuits were developed for the horizontal section: trigger, sweep control, sweep generator and horizontal preamplifier. Identical units are used for both time bases, with slight variations in function for delayed sweep operation. The Miller integrator uses discrete dual FET's in a run-down configuration. The horizontal preamplifier IC converts the sweep to push-pull signals and provides the X10 magnifier and positioning circuitry. The horizontal output amplifier, located in the main module, provides the final signal amplification to drive the horizontal deflection plates.

Twenty-two calibrated sweep rates for time base A range from 0.5 s/div to 0.05 μs/div in a 1-2-5 sequence. Time base B ranges from 50 ms/div to 0.05 μs/div in nineteen steps. The X10 magnifier extends both sweeps to 5 ns/div.

The power supplies

The low-voltage power supply provides three of the regulated low-voltage sources (+5 volts, −5 volts, +32 volts) used to operate the main, vertical and horizontal modules. High-gain amplifier cells with differential inputs monitor variations in the output voltages and provide correction signals to the series regulating transistors. Short-circuit protection is provided for each of the supplies. A fourth low-voltage supply (+95V) is produced in the crt circuit.

The crt circuit contains the Z-axis circuitry, crt intensity, focus and astigmatism controls, and high-voltage supply. A unique high-efficiency type supply is used to generate the high voltage. Energy from the unregulated +32 volt supply is stored in an inductor during a portion of the oscillator cycle, and then discharged into the primary of the high-voltage transformer later in the cycle. The supply operates at the resonant frequency of the high-voltage transformer, which is about 45 kHz. Accelerating voltage is 12 kV, providing a bright trace even when the faster sweeps are running at a low rep rate.

An available option includes a dc to ac inverter permitting operation from either a 12 or 24 volt dc source, such as the TEKTRONIX 1106, or from standard ac line voltages.

Mechanical innovations

Much of what's new and exciting in the 455 is the result of mechanical innovation. The vertical attenuator, timing, and trigger switches were designed to minimize production and assembly time, and maximize serviceability. The modular construction also simplifies assembly, testing, and servicing. The seven printed circuit boards comprising the entire unit interconnect directly, eliminating extensive cabling. As a convenience in servicing, extender cables are available for remoting the horizontal and vertical sections. Ready

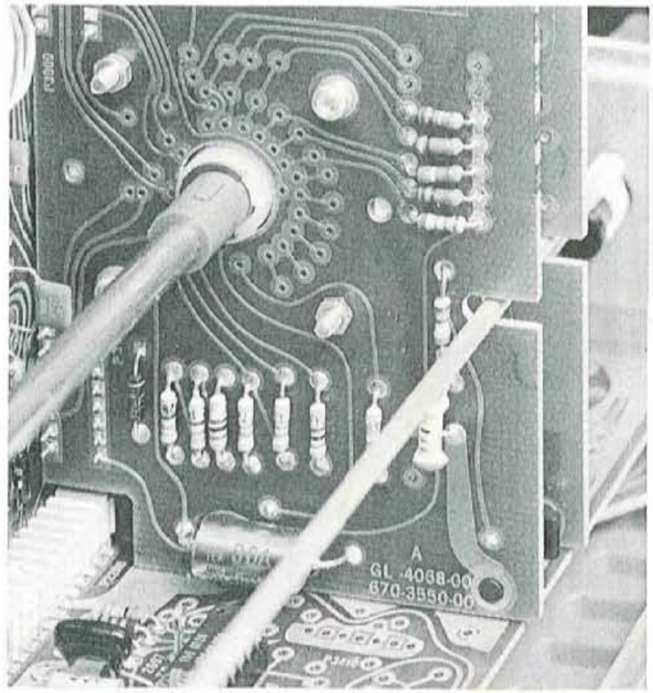


Fig. 4. The timing boards for both time bases form an integral part of the TIME/DIV switch.

access to the power supplies is provided by removing just four rear-panel screws.

Modularity was even extended to the 10X attenuator probes supplied with the 455. The probe body, cable, and attenuator box are separate assemblies that plug together. Accidentally yanking the probe cable causes no damage. The probe tip, often damaged from extensive use, is easily replaced without disassembling the probe body, or use of a soldering iron.

These, and other innovations in the 455, are the result of an intensive engineering effort to provide you with state-of-the-art 50-MHz measurement capability at the lowest possible cost. We are pleased with the results and confident you will be, too.

Acknowledgements

Encouragement and direction were provided by Leon Orchard. Electrical design was done by Jim Woo, George Reis, and Ken Holland, vertical; Jim Godwin, Larry Gagliani, and Al Schamel, horizontal; Walt Strand and Dennis Bratz, low voltage and crt circuit. Mechanical design leader was Glen Sorum with contributions from Bob Leith, Bill Cottingham, Len McCracken, Dave Curtis, Dave Hargis, Scott Long, and Ric Meyer. Al Hill and Jerry Wrisley were the industrial designers. Pat Simonson constructed numerous prototype instruments and kept the parts list correct. George Ermini and Dennis Fuhrman evaluated the instrument.

Many other people deserve to be mentioned. They know who they are. Unfortunately space is limited, so to all of you I say thank you and congratulations on a job well done. — **Bob Johnson, Project Manager**

Dick Brown

The TM 500 mobile test lab

In 1949 Tektronix designed and offered the first Scope-Mobile®, our registered trade name for a mobile cart for oscilloscopes. It was an instant success. Later models have a tilt-top, making them convenient to use whether you are sitting or standing. They are functional, rugged, and good-looking. We are proud to say they have been almost universally preferred to other makes and are probably the most widely used kind of cart made especially for electronic test instruments. Scope-Mobiles have a historical significance in the development of the TM 500 Mobile Test Lab.

The right kind of mobile cart does more for you than you might imagine. Even if you have used a Scope-Mobile, and like it, you may not have stopped to consider all the benefits. Let's take a look at a few. Keep in mind that what the right kind of cart can do for a scope it can do for other test instruments.

Bench space savings is fairly obvious. Any instrument you can wheel up to your bench you can power while still on wheels. But a cart is an extra bench that doesn't take *extra* floor space permanently. It won't crowd you except when you want to be surrounded by your work. Properly barricaded you can even avoid some of the friendly conversation that interrupts you when you least want to be. And it's easy to wheel the cart out of the way when you don't need it.

A mobile test bench

When you can't bring the work to your bench a mobile cart lets you bring the bench to the work. There are numerous instances when you would like to test somebody's work with your own instruments, even if inspecting is not your job. Maybe you're uncomfortable with someone's conclusions, diagnosis or test methods. They won't think kindly of any challenge that requires direct substitution of your instruments for theirs. A side-by-side comparison is more tactful, more scientific and more convincing.

Sometimes there is little or no choice about taking your instruments to the job. The job may be to test an X-ray machine that is bolted to the floor. Small, portable instruments usually come to mind in that situation. But if the job is within your own plant, laboratory, or institution, instruments on wheels may be more practical. You may find no bench or table available otherwise. And what if you need more instruments than you can carry in both hands?

Borrowed instruments return

Borrowed instruments come back quicker when they have wheels. Ever notice that when a cart seems a part of the instrument the two tend to stay together? People don't ask to borrow merely your cart. When they borrow the instrument, the cart goes with it, naturally. Now when somebody needs to borrow your instrument he needs it, and he would gladly tote it away himself if

Fig. 1. A TM 500 Mobile Test Lab is pictured at right being used to service an automatic component insertion machine. The lab includes a storage oscilloscope, DMM, counter, function generator, pulse generator, power supply and digital delay unit.

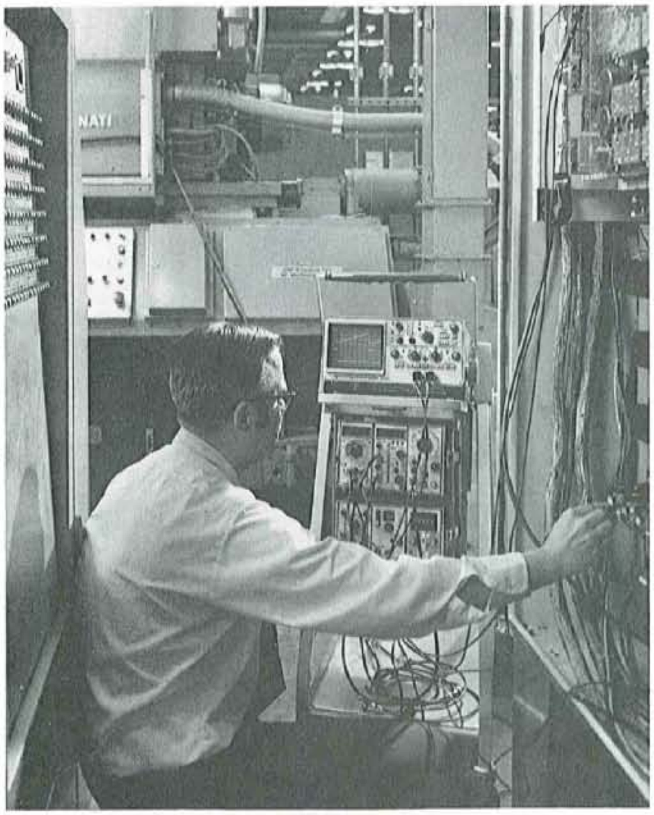


Fig. 2. Checking out a sophisticated machine control unit, using a TM 500 Mobile Test Lab.

necessary. But what about bringing it back? He never has a need to bring it back; and if that is inconvenient you may hit a snag getting it back when you need it. You are much more likely to get your instrument back as soon as his need is satisfied if it has wheels.

A mobile test lab

If you know the benefits of a Scope-Mobile you can readily understand the significance of a compact *laboratory* on wheels, having only one power cord and a built-in way of minimizing test cable clutter. For years many of our customers have designed their own mobile test labs using TEKTRONIX Scope-Mobiles. Now, with the TM 500, we can offer a whole series of plug-in test and measurement instruments that work together neatly on wheels as well as bench tops. The importance of this idea, when it embodies precisely the capabilities you have needed but couldn't afford in a customized mobile test lab, is just now becoming fully apparent. The concept is enthusiastically welcomed by a wide base of customers. They are telling us, in a spirit of discovery, how much they like what they see, how much they use what they buy.

A TM 500 Mobile Test Lab looks like an ordinary Scope-Mobile with a bunch of spare plug-ins suspended from the tilt-top tray, a familiar sight. But a closer look reveals (1) that the plug-ins don't even work in a scope, (2) that the plug-ins are basically separate, independent instruments that merely share the same mainframe and regulated DC supplies, (3) that they will work together with internal patch cords as well as front panel jumper cables to reduce test-lead confusion and clutter, and (4) that the whole mobile lab, including an oscilloscope, will operate from one AC power outlet. An available option permits coupling signals between plug-ins located in separate power mainframes, via rear-panel connectors.

Some people who need a mobile lab have given up on the idea because the variety of instruments they require is so great they don't believe they could put them all together and have a system small enough to wheel about. The small size and big variety of the TM 500 series of test instruments will surprise you. There are over 25 plug-ins to choose from at present, including signal generators, amplifiers, counters, timers, multimeters and a do-it-yourself plug-in chassis. We know we won't be able to supply every "widget" some people can't do without. And if you need a "widget" custom-designed, your designer will be far ahead by having the hardware and the DC supply voltages he needs, at the outset. The rest of the design will be the most fun for him, so you can expect quicker results as well as lower cost. Speaking of costs—the modular idea behind the TM 500 plug-ins is like that two edged sword: one edge lets you do your job better, the other edge cuts our costs so we can cut your costs.

You may need a mobile test lab if you are involved with any of the following:

- —Maintenance or calibration of equipment that can't be moved
- —Verification of performance of equipment that can't be spared
- —Production check-out of equipment on the floor
- —Quality assurance at the other fellow's station
- —Process control equipment that's all over the place
- —Presently toting or carting armloads of miscellaneous instruments with you

A mobile medical system

A good example of a TM 500 Mobile Test Lab is one called MICS, a Medical Instrumentation Calibration System. See Figure 3. This system is ideal for the maintenance and calibration of various medical instruments found in hospitals. These include Electrocardiographs and Electrocardiographic Monitoring Systems, Coronary Resuscitation Carts, Diagnostic X-ray Systems, Infant Incubators, Electrocautery, and Diathermy Equipment.

In the six slots that are part of the two TM 503 mainframes there is a multimeter, time-mark generator, counter, function generator, ramp generator and a differential amplifier. On the tilt-top tray is a storage oscilloscope. This particular set of instruments has been carefully selected to meet the requirements of a large number of hospitals, but variations are easy to make.

An industrial mobile system

Consider another example — final assembly and test checkout of large equipment on the production floor. Here is a typical picture: A manufacturer of computer peripherals has a large production area with twenty or thirty pieces of equipment being built in place, with one or two technicians assigned to each station. A few oscilloscopes on Scope-Mobiles are already being shared between different stations. Some counters, digital multimeters, generators, etc., that you can't afford to have at every station are also shared. Where do you put them? You may stack them on top of the equipment, then on top of each other where they sometimes get bumped, fall and break. Or you may put them on the floor where you kick them, stumble over the power cords, or have to stretch the test leads to make your hook-up. Test leads get intermittent that way. Or maybe you have to unplug several pieces of equipment to find all the AC outlets you need, and turn off somebody else's equipment by mistake in the middle of a test. Not being able to distinguish between the equipment which is purchased to be shared and that which goes with each station, questions will arise about who owns which instrument and whose job it is to keep the instrument in good condition. The mobile test lab straightens out such disorder.

A large variety of combinations of instruments can be selected to make up a TM 500 Mobile Test Lab. Selecting the right combination for a given requirement takes a little thought, but not nearly as much as if you had to specify the entire requirements for a customized mobile lab. Free assistance in making such a selection is available from your Tektronix Field Engineer or Representative.

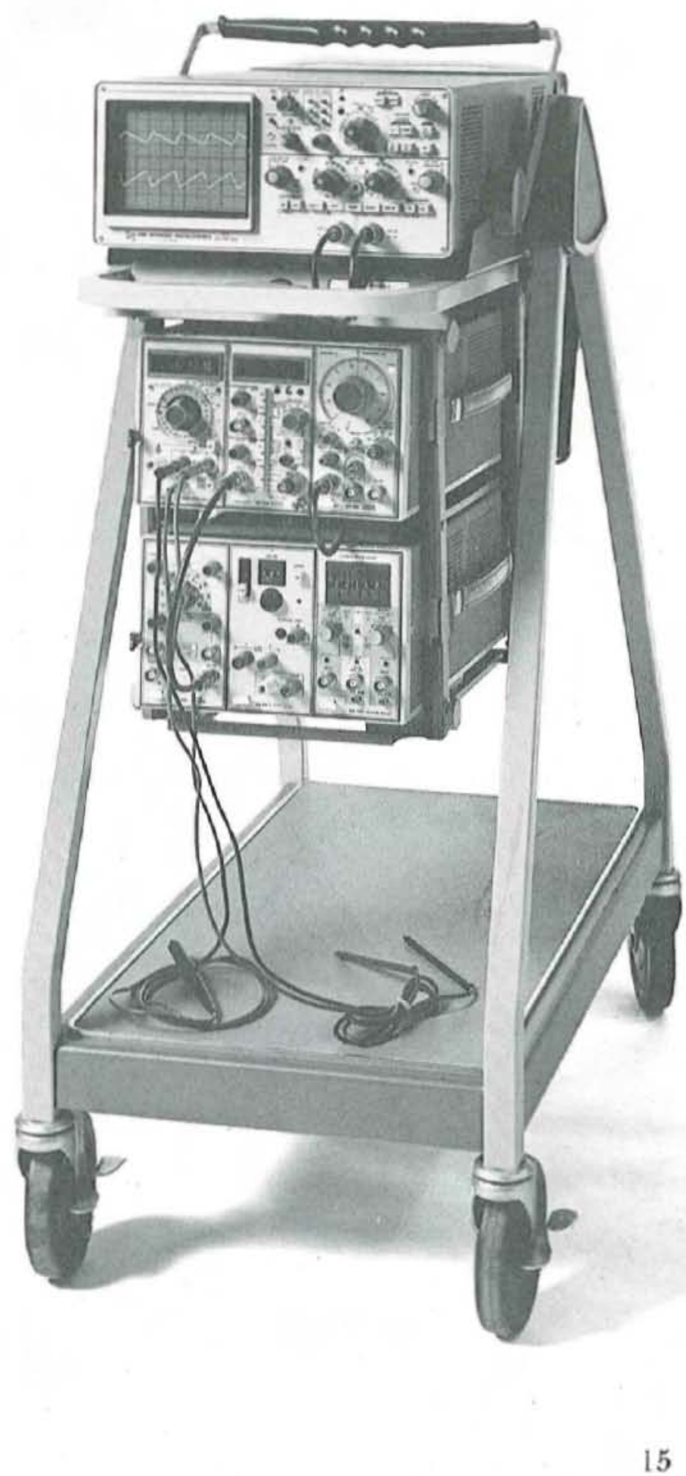


Fig. 3. Pictured at right is the TM 500 Medical Instrument Calibration System (MICS) with test instruments selected for servicing the instrumentation used in hospitals and other medical facilities.

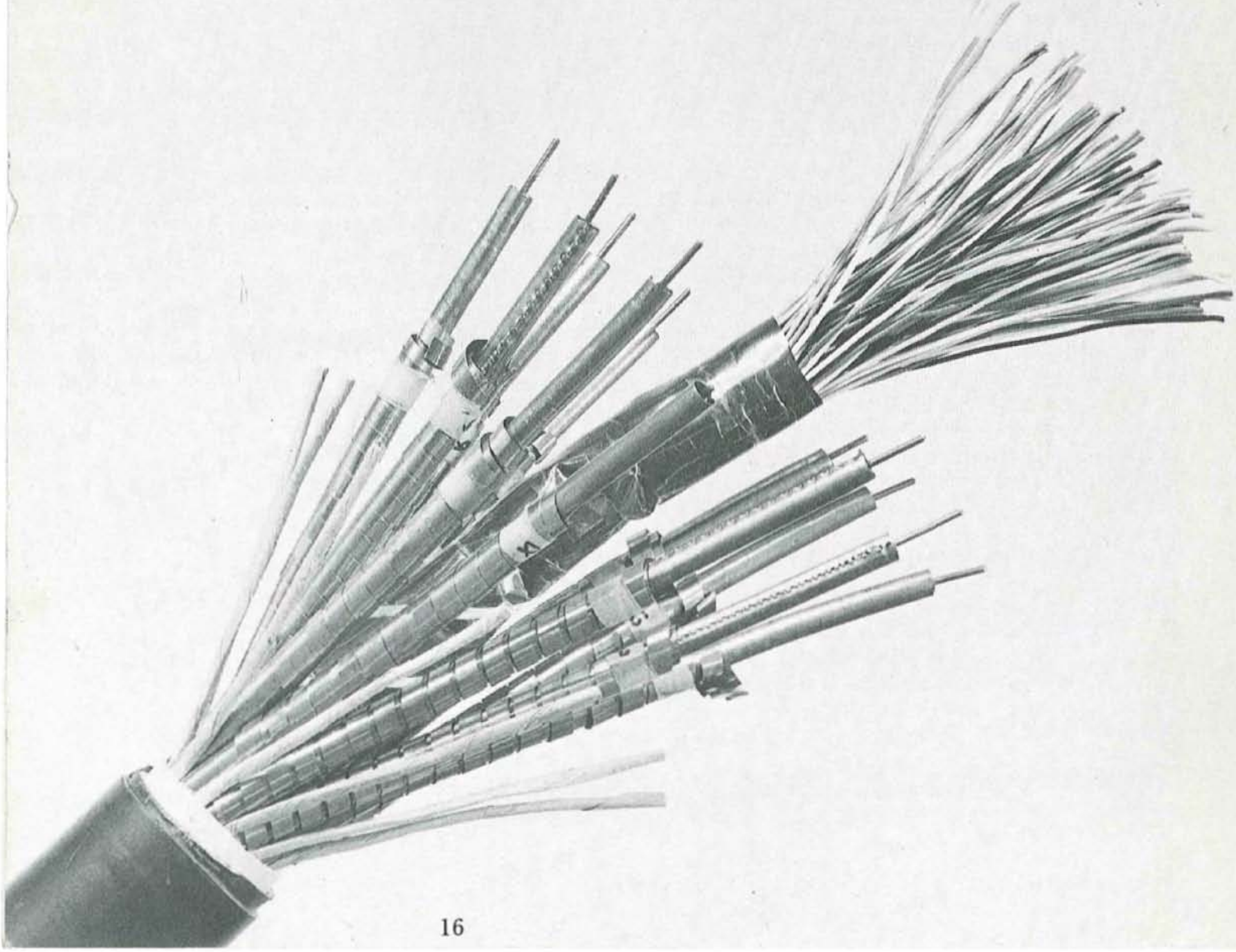
Servicescope

Transmission line characteristics ...a review

All electrical transmission lines have what is called characteristic impedance, or Z_O. We're aware of the importance of this characteristic when we want to assure maximum transfer of energy between a transmitter and antenna, or some other signal source and its load. However, we may not all be aware of the significance of this characteristic in locating faults in transmission lines, or may not have developed a clear understanding of the differences between transmission lines, and why they behave as they do. This review of basic transmission line characteristics may help.

Use of the term "impedance" usually implies a frequency dependence, so it is a little surprising that the characteristic impedance of a cable is not a frequency dependent characteristic. To say characteristic "resistance" would be erroneous, however, because power is dissipated when current passes through a resistance, and there is no power loss in a transmission line that may be attributed to its characteristic impedance. The term "impedance" is a better choice, because its value is determined by the inductance and capacitance of the cable, as we shall see later.

Fig. 1. Underground cable used in wide-band data transmission systems contains twelve coaxial lines and over fifty twisted pairs.



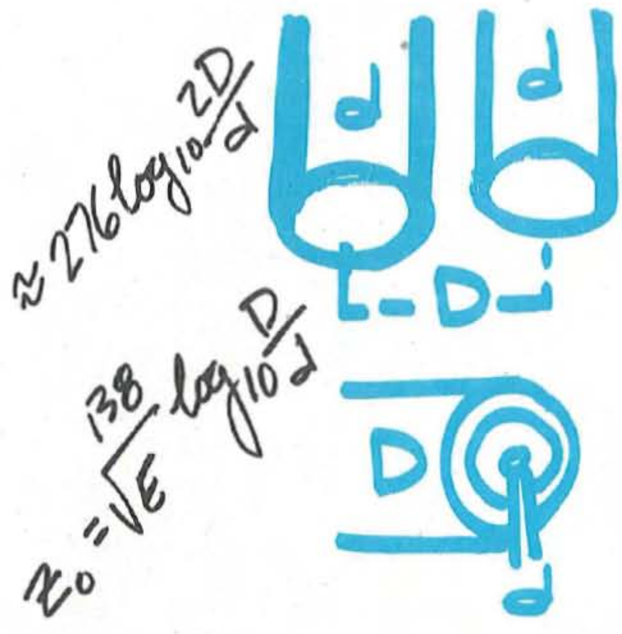


Fig. 2. Formula at top yields characteristic impedance of parallel lines with air dielectric; bottom formula is for coaxial lines.

Consider what takes place if we apply a step function of voltage to a cable. If we suddenly apply 50 volts across a 50-ohm cable, one ampere of current starts to flow. All of this initial current is used to charge the capacitance between the conductors of the transmission line. That capacitance exists uniformly along the entire length of the line, and a change in voltage on one end of the cable cannot cause a change at the other end any faster than a voltage wave front can propagate down the cable. The cable is charged at a uniform speed to a uniform voltage as the wave front moves through. This speed ranges between 66% and 100% of the speed of light for common dielectric materials, depending on the dielectric used between the conductors. The speed of light is 30 centimeters per nanosecond so the propagation velocity is between 20 and 30 centimeters per nanosecond. Since 30 cm is very close to 1 foot you can also express the speed as 1 to 1.5 ns per foot. After the capacitance in the entire length of cable has been charged, voltage is available to apply across the load. You might say that is when the applied voltage arrives at the load.

Factors determining Z_O

Since even straight wires have inductance, and every inch of cable capacitance is charged by current passing through the two cable conductors, it is not difficult to visualize how inductance and capacitance are the two factors that determine the characteristic impedance of a cable. As you would expect, cable impedance increases as the inductance per unit length increases. And, as you would expect, cable impedance decreases as capacitance per unit length increases. These two factors jointly determine how much current will flow when a given voltage is suddenly applied.

Characteristic impedance is equal to the square root of the L/C ratio ($Z_O = \sqrt{L/C}$), where L is the inductance of a given length of cable, and C is the capacitance of the same length. The actual length doesn't matter because capacitance and inductance are directly proportional to length.

Two things determine the capacitance per foot of a coaxial cable: the dielectric constant of the material separating the conductors, and the ratio of the diameter of the conductors. The inside diameter of the outer conductor and the outside diameter of the inner conductor are the dimensions of interest. Inductance per foot is determined only by the ratio of the diameters when the conductors are non-ferrous. Therefore, usually only two physical factors determine the capacitance and inductance and, consequently, the characteristic impedance: (1) the ratio of the diameters and (2) dielectric constant. Their relationship is expressed by the formula $Z_O = (138/\sqrt{\varepsilon}) \log_{10} D/d$, where Z_O is the characteristic impedance, D the inside diameter of the outer conductor, d the outside diameter of the inner conductor, and ε the dielectric constant.

You can't tell the impedance of a coaxial cable by its appearance but you can be sure its impedance is comparatively high if its inner conductor is relatively small. In a similar way parallel twin-lead and twisted-pairs which have conductors that are widely spaced, compared to their diameter, will have a higher impedance than if the same conductors are closely spaced.

Propagation velocity

We touched briefly on propagation velocity earlier in this article. It is interesting to note that propagation velocity is not dependent on the physical size of a cable, the impedance of the cable, or the capacitance per unit length. It is dependent only on the dielectric material, or materials, separating the conductors. Polyethylene is the most common dielectric material used in coaxial cables and underground power lines, and the material that reduces propagation velocity most . . . to 66% of the speed of light in air. Polytetrafluoroethylene (PTFE or TFE) is even more stable than polyethylene and will not melt or flow at temperatures up to 200°C. This material is also known as Teflon®, a DuPont trade name.

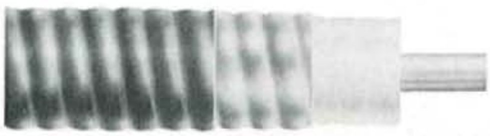
Velocity is inversely proportional to the square root of the dielectric constant ($V \propto 1/\sqrt{\varepsilon}$). Cables with mostly air or gas for a dielectric have a propagation velocity close to the speed of light. When the dielectric is a mixture of two materials, such as polyethylene and air, the propagation velocity is between that for the two materials. Polyethylene foam is an example of such a mixture. When the electrical field between parallel conductors extends into the surrounding air the effective dielectric constant is also some value between that for air and that for the solid material. Twin-lead TV cable and twisted pair phone lines are examples.

Single Braided Shield and Stranded Center Conductor

Double Shield and Stranded Center Conductor

Double Shield and Solid Center Conductor

Armored Jacket over Single Shield—Solid Center Conductor Supported in Hollow Polyethylene Tube by Twisted Polyethylene Threads



Polyethylene Foam-Filled Corrugated Copper Shield

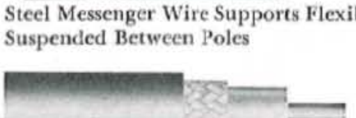
Polyethylene Helical Support for Center Conductor

Hollow Polyethylene Tubes Support Center Conductor

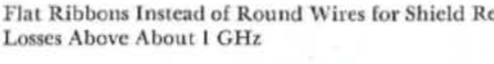
Pressurized Rigid Line 7/8" to 6 1/8"

Two Insulated Shields for Better Shielding or "Guard" Voltage on Inner Shield

Steel Messenger Wire Supports Flexible Cable When Suspended Between Poles



Flat Ribbons Instead of Round Wires for Shield Reduce Losses Above About 1 GHz



Solid Shield Over Solid TFE Insulation—Rugged, Stable, Gigahertz Cable

Characteristic impedance and TDR

The capacitance of 50-ohm coaxial cables using non-ferrous conductors and solid polyethylene for a dielectric material is close to 1 pF per centimeter (30 pF per foot). That is true regardless of the size of the coax because it is the ratio of the conductor diameters that determines the capacitance per unit length once you have settled on the dielectric material and the kind of conductors.

If a coaxial line is sharply bent or compressed in some region there will be an increase in capacitance in that region and, consequently, a reduction in characteristic impedance there. If part of the outer conductor is worn away there will be an increase in impedance at that point. Anything that causes the characteristic impedance of the transmission line to deviate from its normal value will cause a signal passing through the cable to be partially reflected at that point. It is at this point that Time Domain Reflectometry or TDR enters the picture. If we know the propagation velocity of the line, we can use a TDR to measure the distance to the fault, greatly simplifying the task of locating the problem. A good deal of information about the nature of the fault can also be determined by even a relatively inexperienced operator. Now let's look at some other cable characteristics.

Signal attenuation factors

Voltage and power losses in a cable are caused principally by the resistance of the two conductors, at low frequencies, and by skin-effect and dielectric losses at high frequency. Losses due to skin-effect increase as frequency increases, and so do dielectric losses.

Skin-effect is a high frequency phenomenon which limits current to the surface region, or skin, of a conductor. As frequency is increased, less and less of the available metal does any conducting. In effect, the skin gets thinner, increasing the series resistance of the conductors as frequency increases. In coaxial cables the inner surface of the outer conductor and the outer surface of the inner conductor carry most of the current at high frequencies. Some large diameter coaxial cables have a hollow center conductor to avoid wasting the metal in the middle. Dielectric losses are relatively small for most dielectric materials and usually can be ignored for frequencies below about one gigahertz.

Attenuation of a high frequency signal passing through a transmission line is proportional to the square of the length of the line. Therefore, attenuation is usually expressed in decibels per unit length, as dB/100 feet. The frequency must also be stated because attenuation increases with frequency and is approximately proportional to the square root of frequency. When expressed in decibels, attenuation may be easily calculated for any specific length. For example, a kind of cable which attenuates a 100 MHz signal 2 dB/100 feet could be expected to attenuate the same signal 0.2 dB if it were ten feet long. When wideband signals are carried over a transmission line the waveform is distorted by the greater attenuation of the higher frequency components. The distortion may be mostly corrected by passing the signal through an amplifier having complementary characteristics. Cable TV line amplifiers and telephone relay amplifiers provide such a function.

Coaxial cables have a practical upper frequency limit, the frequency at which the cable starts to act like a waveguide. Waveguides will propagate signals with much less attenuation than coax but they are narrow band transmission lines. When wideband signals are applied to a coax and some frequency components extend beyond the frequency where the coax behaves like a waveguide, the coax begins to act a little like a frequency selective filter.

The cutoff frequency is inversely proportional to the sum of the conductor diameters ($f_{CO} \propto 1/D+d$) for any given dielectric, so the smaller the cable the higher the frequency. Since high frequency signals and small diameter cables produce the most signal attenuation, signals above about 10 GHz simply can't be carried very far over coax without severe attenuation. The cutoff frequency for a 50-ohm cable with polyethylene dielectric (a D/d ratio of 3.6 to 1) and a 1 cm diameter (D), is close to 10 GHz. A cable having the same dimensions, but with air for a dielectric, would have a cutoff frequency close to 15 GHz, 50% higher. Some cable manufacturers are conservative in their claims and state the cutoff frequency to be 90% of these figures, or less.

Designing for minimum loss

Ordinary transmission lines range in impedance between about 50 ohms and 300 ohms. The impedance is rather critical in some applications and of only minor importance in other cases. The 300 ohm twin-lead on a TV antenna matches the antenna impedance and thereby transfers the most signal power to the receiver. However, the "neutral" wires surrounding the insulation on a power line directly buried in the ground only act as a protective shield. Although their presence makes the line a coaxial cable, these wires ordinarily carry little or no current. The impedance of the power line as a coax is nearly inconsequential unless being tested with a reflectometer. By contrast the 75-ohm, 3/8-inch diameter coaxial lines used extensively for wide band telecommunications are meticulously designed and manufactured for minimum signal loss and the most economical use of materials and equipment.

Where minimum signal loss per foot is most important, a coaxial cable having an impedance of 77 ohms, with air for a dielectric, is best. It is not possible to use air exclusively, however, because the center conductor must be supported somehow. Discs, beads or spiral windings are used to support the center conductor in many cables having mostly air for a dielectric. The optimum impedance for lowest signal loss per foot is achieved when the ratio of diameters (D/d) is 3.6 to 1. With that ratio, use of any ordinary dielectric material will result in the cable having an impedance between 51 ohms (polyethylene) and 77 ohms (air).

Loss per foot is reduced by using larger cables, of course, but then cost is also greater. Sometimes the cable diameter is dictated by the amount of current the conductors must carry, or the peak voltage that may sometimes be applied. Excessive temperature rise in a center conductor can melt the dielectric and cause a short between the shield and center conductor. Because of skin-effect, high frequency current heats up the conductors more than an equal amount of low frequency current.

Sometimes high impedance cables are chosen so that a high impedance signal source may deliver the maximum amount of voltage. For example, only about half as much voltage would be delivered over a 50-ohm cable to a 50-ohm load, as you could deliver to a 100-ohm load over a 100-ohm cable. But small diameter high impedance cables are fragile and difficult to build to a close tolerance because of the extremely small diameter of the center conductor. The D/d ratio of a 100-ohm cable with a polyethylene dielectric would be 14 to 1, but a 200-ohm cable of the same sort would have a D/d ratio of more than 100 to 1.

INSTRUMENTS FOR SALE

C27, $400; Bob Oppelt, (203) 265-2361.

D43R, D42, J, G; Jerry Somer, (507) 835-5235 (home) or (507) 353-2050 X320 (Work).

D67 (2), Bob Heim, Delta Bsns Mach, 1723 Hancock, Gretna, LA, (504) 368-3402.

FM122 (4), RM125 for FM122, rack mount, $100; Barry Fox, Optronics Int'l, Inc., 7 Stuart Rd, Chelmsford, MA 01824, (617) 256-4511.

H unit (2), $35 ea.; T unit, $45; Don, Washington Avionics, Seattle, WA, (206) 762-0190.

P6013, $75, Jim Crites, CH Electronics, 5300 Castlebrook Dr., Raleigh, NC 27604, (919) 833-2250.

R149A Op 1, $3,375; Harold Dougherty, Satterfield Electronics, (608) 257-4801.

RM567 w/6R1A, 3T5, 3S2 w/o sampling heads, trade for 25 MHz realtime scope; C. B. Wilson, Box 32, Richardson, TX 75080 (214) 826-4503.

S54, $300; Arthur G. Albin, 18209 167th Ave. NE, Woodinville, WA 98072, (206) 486-0618.

TLS54, $350; Joe Lucas, Seattle, WA, (206) 655-3331 (Work), (206) 746-9435 (Home).

TLS54; Syro Steel Co, Mr. James Raynish, 1170 N. State St., Girard, OH 44420.

1L5, $995; Charles Black, 3138 Fairview Ave East, Seattle, WA 98102, (206) 324-3950.

3S1, $400; Bill McCune, (408) 736-1060.

7B51; Jerry Foster, Mangood Corp., Streeter Amet Div., Grayslake, IL 60030, (312) 223-4801.

7B53AN, $725; A. V. Center, 6116 N. Lincoln Ave., Chicago, IL 60659, Attn: Mr. Paul Roston, (312) 539-7700.

114; L. L. Glemser, 6829 Shenandoah, Allen Park, MI 48101, (313) 381-5708.

122; G. W. Ewing, Seaton Hall Univ., Dept. of Chemistry, South Orange, NJ 07079.

211, $500; Mr. Stanley Lester, Boice Div., Mech. Tech., Inc., Hyde Park, NY 12538, (914) 229-2171.

262, 190A, 105, 130, 330, 291, P6046; Bill Groschen, Circuit Supply Co., 15109 Minnetonka Industrial Blvd., Minnetonka, MN 55343, (612) 933-2281.

310A; call Joe Lucero (208) 342-2711 X446, between 8:30 to 5:00.

422, $1000 w/std. access.; John Smith, Columbian, PO Box 180, Vancouver, WA 98660, (206) 694-3391.

422, $900; Robert Gardner, Times Publishing, Co., 205 W. 12th St., Erie, PA 16501, (814) 456-8531.

422, $900 - $1200; R. Corley, Baird-Atomic, Inc., 125 Middlesex Tpk, Bedford, MA 01730, (617) 276-6202.

454, $2000; George Jannery, Ridgefield, CT, (203) 438-5226.

465/DM43; Ronald M. Lord, 110 Ilima Lane, APO San Francisco, CA 96553; (808) 423-1104.

465, $1850; Terry Melinder, (916) 258-2661.

491 Mod 139L; David Hostetler, Antenna Specialists, 12435 Euclid Ave., Cleveland, OH 44106, (216) 791-7878.

TM501 (2), DC502 (2); L. Giovannangelo, GE Co., 2379 John Glenn Dr., Chamblee, GA 30341, (404) 458-2231.

INSTRUMENTS FOR SALE

503, $350; Larry Myhre or Bob Custer, Hallidie Machinery, 4975 3rd South, Seattle, WA 98134, (206) 762-7600.

507 (3), Surge Scope $2,300 ea.; A. R. Miller, eci, 1124 Dorchester Ave., Dorchester, MA 02125, (617) 825-0980.

514D; Warren King, Rt. 3, Box 27, Silverton, OR 97381, (503) 873-4959.

517A, pwr sply, Scopemobile, $600; Jeremy Seeger, Hancock, VT 05748, (802) 767-5152.

519 w/access., $2250; Mr. Lizec, R & D Consult, Inc., 3133 Hodler Dr., Topanga, CA 90290.

519, $2500; Paul Thomas, High Voltage Eng., Burlington, MA 01803, (617) 272-1313 X283.

531A, E, CA; Howard Gourneau, Medtronics, (213) 843-1770.

531, 53/54C, $450; Steven K. Roberts, Cybertronic Systems, PO Box 18064, Louisville, KY 40218.

531, B; Geo. Breindel, 3518 1st Ave. NW, Seattle, WA 98107.

531 plug-ins: D, G, R, S (12 ea); Jim Knoall, El Camino College, Hawthorne, CA 90250.

535, K, $450; Jay Staiger, Jerrold Electronics, 200 Witmer Road, Horsham, PA 19044, (215) 674-4800, X454.

547 w/cart, 1A1, 1L40, 132 pwr. sply, P6008 (2), P6028 (2), 115 (5), Mr. J. Johnson, General Research Corp., 7655 Old Springhouse Road, Westgate Research Park, McLean, VA 22101, (703) 893-5900.

547, 1A2, cart, Pat Phillips, Data 100 Corp., 7725 Wash. Ave So., Edina, MN 55435, (612) 941-6500.

549, 547, 546, 1A1; Wes Miller, 3845 Birch Ave., Newport Beach, CA 92660, (714) 540-5231.

545B, $1000; Mr. Peterson, Remote Recording Services, #19 Hillcroft, Cherry Hill, NJ 08034, (609) 547-4796.

551, CA, D (2); 605; 502A; Norman Altman, B.A.I. Corp., Magee Ave., Stamford, CT, (203) 348-4277.

561A/3A72/2B67, cart, hood, manuals, Mr. Johnson, (617) 583-0160.

561A, 3A6, 3B4, $900; Fred Wong, Kaitronics, 870 Mahler St., Burlingame, CA 94010, (415) 697-9102.

564, RM567, $300 ea; 2B67 (2) $100 ea., C. W. Jenkins, 2231 W. 4520 South, Salt Lake City, UT 84119, (801) 299-4262.

567 w/3S76, 3T77, $2,395; 565, $595, 532, $365; Lee Lab, 13714 So. Normandie Ave., Gardena, CA 90249.

INSTRUMENTS FOR SALE

575 w/adapters, $580; Fred Davis, Yale Univ., (203) 436-8949.

585, 81, K, $1000; 661, 5T3, 4S3, $1000; Pete Edwardson, DAB Associates, 312 9th Ave., Haddon Hgts, NJ 08035, (609) 547-4796.

602, w/std or P7 phosphor; Mr. Norman Lantz, 22234-1 James Allen Circle, Chatsworth, CA 91311.

611 (2), $2,000 ea., 4610; Ron Kocher, Process Control, PPG Industries, POB 11472, Pittsburgh, PA 15238, (412) 362-5100.

611 (2), 4601, $2,100 ea.; Dr. S. J. Mustric, Denver, CO (303) 255-4677.

1401A-1, $1,582.50; Mel Jenschke or Jim Lancaster, Big Springs Cable TV, Box 1871, Big Springs, TX 79720 (915) 263-6259.

4010-1; Dr. Willard Graves, Towson State College, Towson, MD 21204 (301) 823-7500 X611.

4010-1; Thelma Trageser, Johns Hopkins Univ., Baltimore, MD (405 Ames Hall), (301) 366-3300 X319.

5103N/D10, 5A18N, 5A21N, 5B12N, Dennis Luther, Wilhite Instruments, 7685 Wash. Ave. So., Edina, MN 55435 (612) 944-2535.

7313, 7A18N, 7B53AN, probes (2), $2,800; Chuck Ullman, 13130 S. Yukon Ave., Hawthorne, CA (213) 973-4191.

7704, 7A16A, 7A15A, 7B70, 7B71, list less 25%; John Newby, Union Drug, 136 Bus Terminal Rd., Oak Ridge, TN 37830 (615) 483-8429.

INSTRUMENTS WANTED

3B4; Paul Laramee, Tektronix, Inc. 31, Haight Ave., Poughkeepsie, NY 12603 (914) 454-7540.

3L5, Dr. Ray Hefferlin, Southern Missionary College, Box H, Collegedale, TN 37315, (615) 396-4363.

3L5; Mr. Bentov, I. B. Development Co., 241 Glezen Lane, Wayland, MA 01778 (617) 358-7619.

53/54C, 1A1, CA; Walt Williams, 14585 Berry Way, San Jose, CA 95124 (408) 337-2850.

556 w/(2) M; Larry Traylor, 733 E. Edna Place, Covina, CA 91723 (213) 966-7431.

4701, 4501, 4551; Dr. Krause, Medical College of Penn., 3300 Henry Ave., Philadelphia, PA 19129 (215) 839-1645.

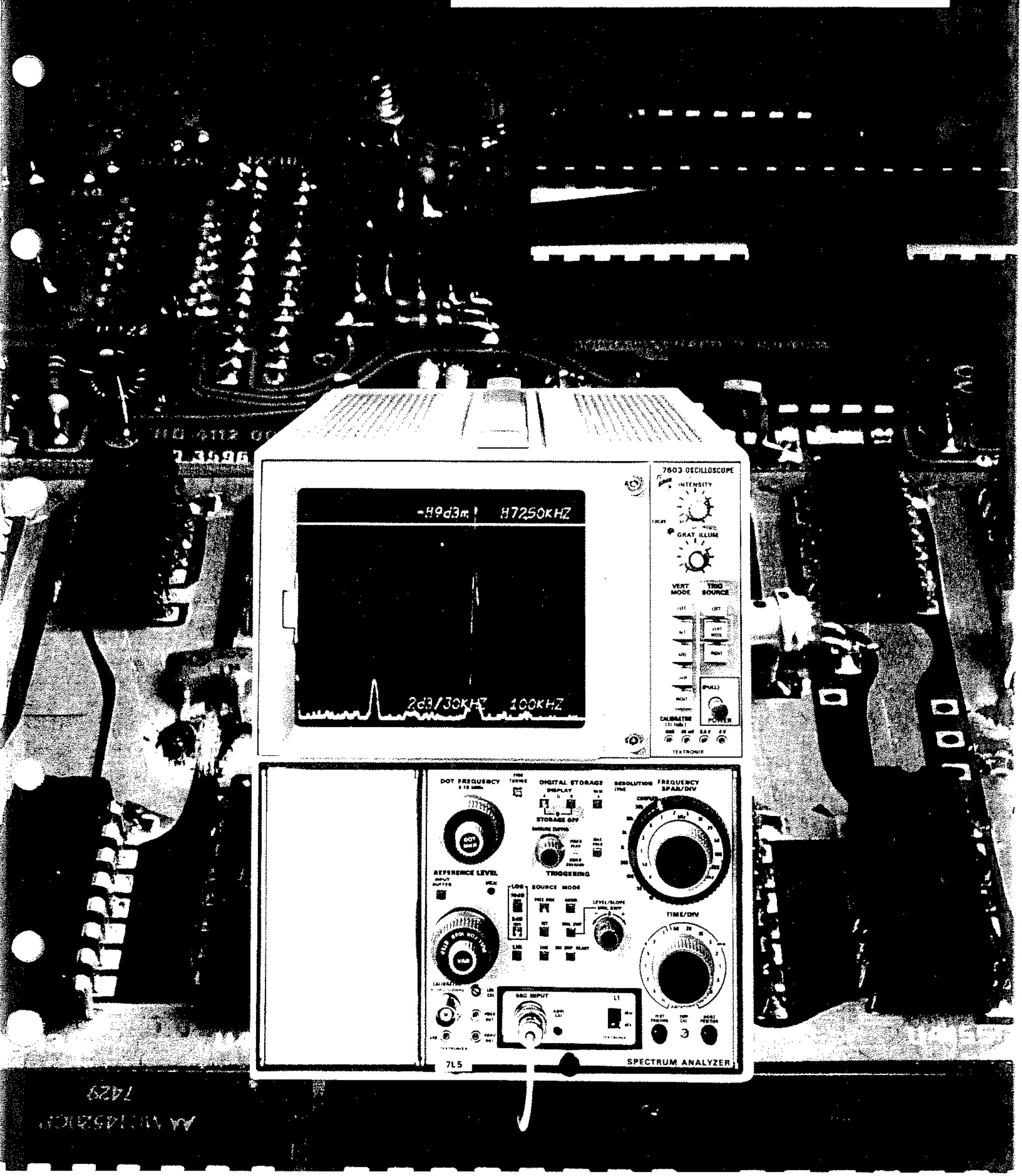
5403, 5A48, 5B42; Andy Samchuck, Balsom Grove, NC 28708 (704) 655-2970.

TEKTRONIX, INC.
P.O. BOX 500
BEAVERTON, OR. 97005

TEKTRONIX®
committed to
technical excellence

TEKSCOPE

Volume 7 Number 3 1975



TEKSCOPE

TEKTRONIX®
committed to technical excellence

Customer Information from Tektronix, Inc., Beaverton, Oregon 97077

Editor: Gordon Allison
Ass't. Editor: John Mulvey

Contents

3 **A 5 MHz digitally controlled spectrum analyzer.**

A new concept for front panel controls, coupled with two custom MOS processors, yields new operating ease and measurement capability.

8 **Transition counting with an oscilloscope**

A powerful new technique for troubleshooting digital circuitry speeds servicing by even relatively inexperienced technicians.

12 **Storage expands your oscilloscope measurement capabilities.**

An assist in choosing the storage scope best-suited to your application.

16 **A potpourri of modifications and service notes.**

Some simple modifications to enhance the usefulness of your TEKTRONIX instruments for particular applications, and service hints on several products.

18 **New Products**

A new section of Tekscope providing a brief description of products recently introduced by Tektronix.

Cover: The digital character of the 7L5 Spectrum Analyzer is reflected in the background showing a portion of the digital section in the 7L5.

To our Tekscope readers:

Beginning with this issue, a new section entitled "New Products" will appear in Tekscope. It includes the information formerly contained in the New Product Supplement that accompanied Tekscope. To simplify printing and distribution, product prices are shown on the attached inquiry card rather than as a part of the product description. We invite you to use the card for further information or a demo of any of the products discussed.

The "Classified Ad Supplement" that accompanied, or appeared as an integral part of, Tekscope is also available through the use of the inquiry card. We plan, by this means, to give you more up-to-date information on TEKTRONIX instruments our customers wish to buy or sell.

We trust these changes will increase the value of Tekscope to you, and welcome your comments.

Sincerely,

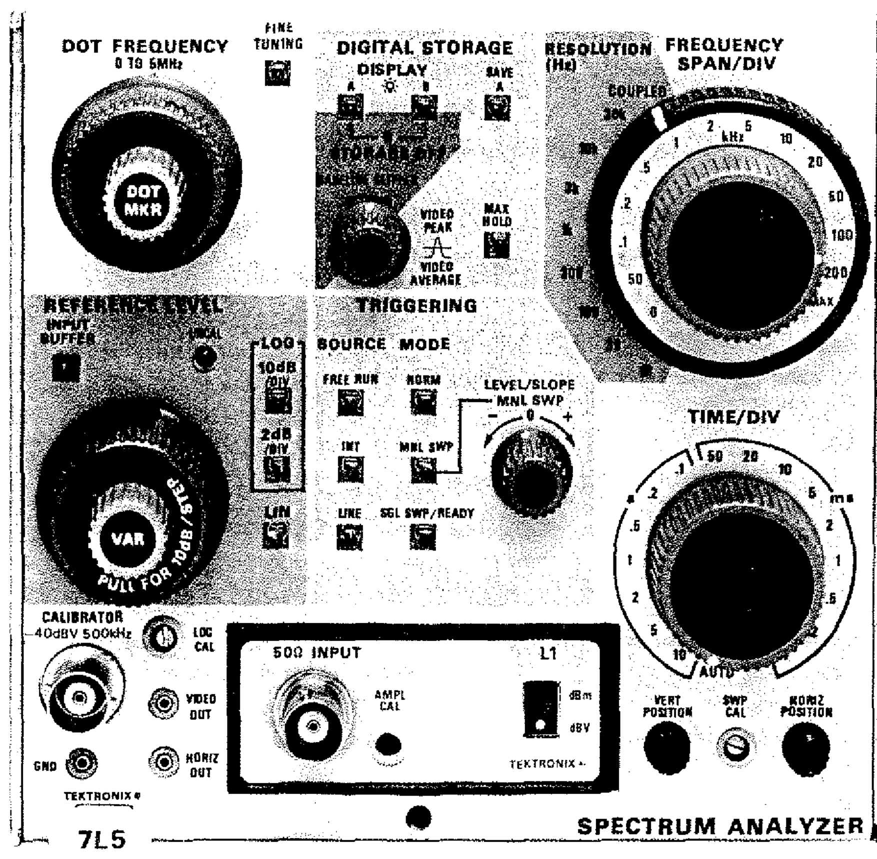
Gordon R. Allison
Tekscope Editor

A 5 MHz digitally controlled spectrum analyzer

Digital control of instrumentation is rapidly coming into vogue. Besides being the popular thing to do, what are the advantages to users of spectrum analyzers? One important advantage is the operating ease achieved by simplified controls, and the ability to place those controls for maximum operator convenience. But there is much more.

The *more* includes an automatic start-up mode that switches in full attenuation to protect against inadvertent overloads damaging the input mixer, and sets the center frequency at zero with the 0-Hertz marker displayed on-screen for a quick operational check. *More* also includes new capabilities to measure signals masked by noise, and more precise measurements made with greater ease. These are just a few of the benefits in store for users of the 7L5 Spectrum Analyzer. Others will be apparent as we discuss the 7L5 in greater detail.

The 7L5 is a 0 to 5 MHz spectrum analyzer designed to operate in any 7000-Series mainframe having crt readout. It occupies two plug-in compartments, leaving the other two compartments in a 4-hole mainframe available for time shared time domain measurements. A unique plug-in front end overcomes the performance limitations imposed by trying to accommodate a wide range of input impedances, and permits an 80 dB dynamic window over a



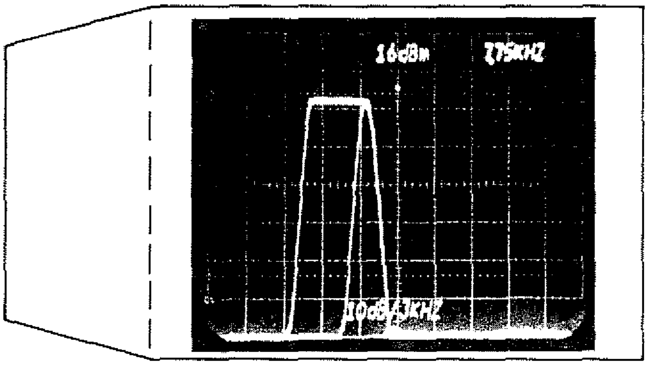


Fig. 1. Signal drift is easily observed using the max hold function. Split memory is used to display frequency excursion over time interval, and frequency at time photo was taken.

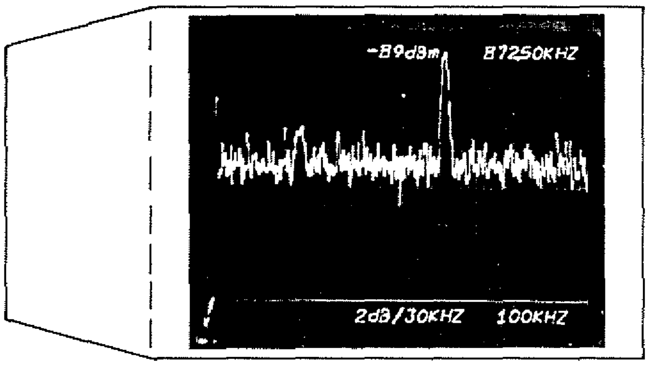


Fig. 2. Two small signals in presence of noise with no digital averaging.

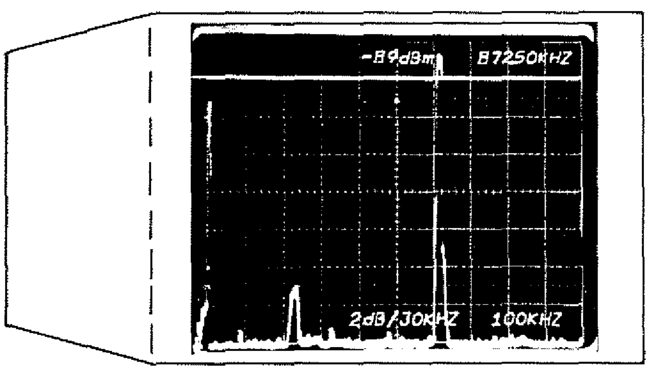


Fig. 3. Same signals as in Fig. 2 with the signals below the sweep cursor digitally averaged. Noise is greatly reduced and true small signal amplitude of —102 dBm is indicated.

reference level range of —128 dBm to + 21 dBm. Calibrated displays are maintained for both dBm and dBV measurements, selected by a front-panel switch.

Front-panel controls

The uncluttered front panel of the 7L5 gives the impression that the unit is easy to operate. And it is. Digital controls yield many benefits in the design, manufacture, and usability of the instrument. They allow placing the controls for operator convenience, and give a much wider range than is usually available with conventional analog controls. For example, the Reference Level control has a range of 149 dB in 1 dB and 10 dB steps, and the Dot Frequency control covers a range of 0 to 4999.75 kHz in 250 Hz and 10 kHz steps. Digital operation also simplifies the coupling of two or more controls, eliminating expensive and complex mechanical configurations. With the Resolution control in the COUPLED position and the TIME/DIV in AUTO, optimum sweep rate and resolution are automatically selected for each position of the FREQUENCY SPAN/DIV control, giving one-knob control of these three functions for many applications.

One of the factors that makes the 7L5 easy to operate is familiar nomenclature and function for the front-panel controls. The major function that may be unfamiliar to you is digital storage, so let's take a look at this section first.

Digital storage

Four pushbuttons and one variable control handle the digital storage functions of the 7L5. With none of the pushbuttons actuated, the unit operates as a conventional analyzer. With either DISPLAY A or B actuated, the digital storage section is activated, and the bright, steady displays and measurement capabilities afforded by digital storage come into play. The memory is split into two sections of 256 X-axis locations each. When both A and B pushbuttons are actuated, the sections are interlaced allowing updating of all 512 horizontal locations. Information in both memory sections is updated every sweep unless the SAVE A pushbutton is actuated. With SAVE A and DISPLAY A actuated, data in A memory are displayed, but not updated, serving as a reference against which the contents of B memory can be compared.

A maximum hold function is available by actuating the MAX HOLD control. In this mode, the maximum amplitude stored in every horizontal position of the memory is displayed. The information is updated every sweep, with the resultant display a cumulative envelope as a progression of time. Figure 1 shows such a display. Using split memory, the flat top pedestal shows the frequency excursion of an oscillator as it shifted about one and one half divisions across the screen, while the second half of the memory displays the oscillator frequency at the time the photo was taken. This function is useful in checking for signal drift as in Figure 1, or for unattended monitoring for the presence of short-duration signals.

A unique feature of the 7L5 digital storage is the ability to digitally average the amplitude of the displayed signal. The threshold for averaging is continually adjustable from the bottom of the display, for no averaging, to the top of the display, for averaging all displayed signals. The averaging threshold selected is indicated by a sweep cursor displayed on the crt (Fig. 2, 3). The cursor control serves as a baseline clipper

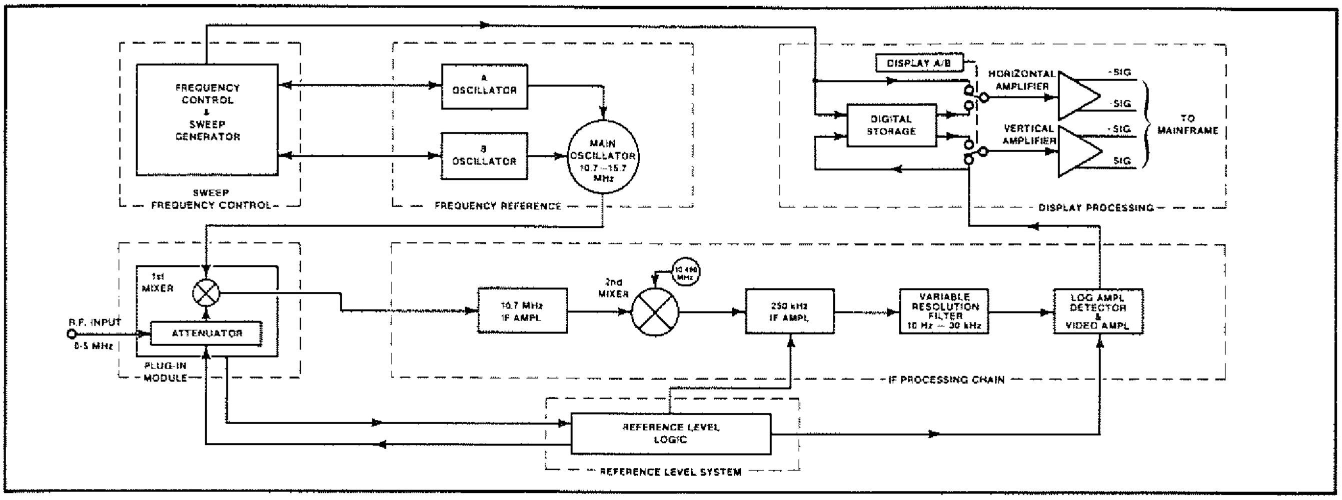


Fig. 4. Simplified functional block diagram of the 7L5.

control in the non-storage mode. The averaging circuitry has a bandwidth equivalent to a 2.5 Hz to 12.5 kHz filter, as a function of the sweep speed selected, and sweep rates are not as limited as with conventional video filters.

Now let's consider the conventional functions of the 7L5.

Processor control simplifies operation

Two custom MOS processors developed by Tektronix control the frequency tuning (horizontal axis) and reference level (vertical axis) functions. These chips decode the front-panel controls and serve as an interface to the remainder of the circuitry.

The vertical processor detects which plug-in front end is in use and selects the proper dynamic window and the appropriate vertical readouts. It decodes the reference level selected and chooses the appropriate attenuation and gain settings. Four attenuators are available: 4, 8, 16, and 32 dB. These are selected in conjunction with gain steps of 1, 2, 4, 8, 16, another 16, and a post variable resolution gain of 60 dB, to achieve the desired reference levels. For example, to select a 1 dB change in gain, (above a reference level of —29 dBm), we insert 4 dB of attenuation and 3 dB of gain.

The Reference Level control is a 16-position, 360° rotating switch consisting of two circuit-board switch sections having eight pads each. The output of these two sections generates two square waves 90° out of phase developing what we call a 4-level, 2-bit gray code; a gray code being a binary number which changes one bit at a time. Whether the number increases or decreases depends on which direction the knob is turned. The output of the Reference Level control is fed into an 8-bit up-down counter that, in conjunction with other inputs, provides the 8-bit code for the vertical processor to set the reference level. A ROM contains attenuation and gain information for each reference level selected, and switches attenuation in or out by means of TEK-made relays. Gain is inserted or removed by CMOS analog switches in the IF, Variable Resolution (VR), and post-VR stages.

The front panel INPUT BUFFER pushbutton provides a quick, easy check for intermodulation (IM) distortion and reduces the likelihood of IM products. Activating the input buffer inserts 8 dB of attenuation at the analyzer front end, and compensates by inserting 8 dB of post-VR gain to maintain a constant display amplitude for input signals. It also provides a cleaner 50-ohm termination (than a mixer) at the input, for those applications requiring it.

Frequency selection

The frequency control system combines a synthesizer with digital techniques that permits setting the frequency with six-digit resolution and excellent stability immediately after turn-on. A dot is displayed on-screen to indicate the point on the display that corresponds to the 6-digit readout. With the DOT MKR control fully counterclockwise the dot is at center screen. The dot can be positioned to the left side of the screen to operate in a "start" mode, with the readout always displaying the frequency at the dot position.

The 1st L.O. consists of three phase-locked oscillators. Two of the oscillators (A and B) control a third oscillator to generate a digitally stepped, or synthesized, 10.7 to 15.7 MHz output. The A and B Oscillators use divide-by-N synthesizer loops to generate 100 kHz and 10 kHz signal steps respectively. In addition, the B Oscillator output frequency is divided by 40, thus generating steps of 250 Hz. The A and B Oscillators are swept by the shaped sawtooth input to generate a swept frequency output across the full frequency span. To achieve an 80 dB dynamic window and exceptionally low residual FM, A Oscillator is swept when using frequency spans of 500 kHz/div to 5 kHz/div, and B Oscillator when using spans of 2 kHz/div to 50 Hz/div. High stability is maintained by phase-locking the system during sweep retrace, or every 100 seconds when operating in a non-sweeping mode.

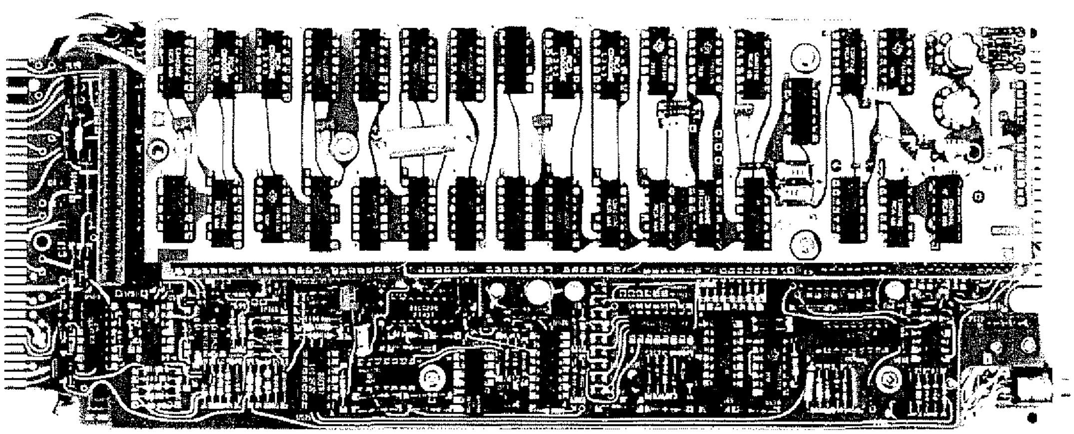
The output of the 1st L.O. goes to the 1st Mixer located in the front-end plug-in module. The resultant 10.7 MHz signal is fed to the 1st IF Located in the main plug-in. There it is amplified and then mixed with the 10.45 MHz signal from the phase-locked 2nd L.O., giving a 2nd IF frequency of 250 kHz. Passing through the 250 kHz gain switched amplifier, the Variable Resolution circuitry, and the Log Amp, which provides up to 60 dB of switched gain, the signal is then detected and passed to the logic circuitry for display along with the frequency dot and the averaging cursor (Fig. 4).

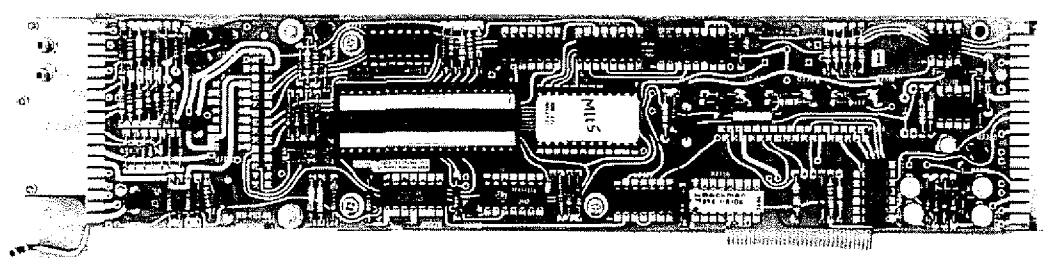
Careful attention to design at every stage yields excellent intermodulation performance with IM products for two on-screen —40 dBm signals down at least 80 dB. Internally generated spurious signals are —130 dBm, or less, referred to the input mixer. Noise specifications are equally impressive: —105 dBm at 30 kHz resolution and improving to —135 dBm, or less, at 10 Hz.

Now let's turn our attention to the mechanical aspects of the 7L5.

Mechanical innovation

The design goals for the 7L5 provided challenge and opportunity for many mechanical innovations. One of the major goals was to develop front panel controls to satisfy a concept of instrument architecture having a plug-on front panel for ease of manufacturing, assem-





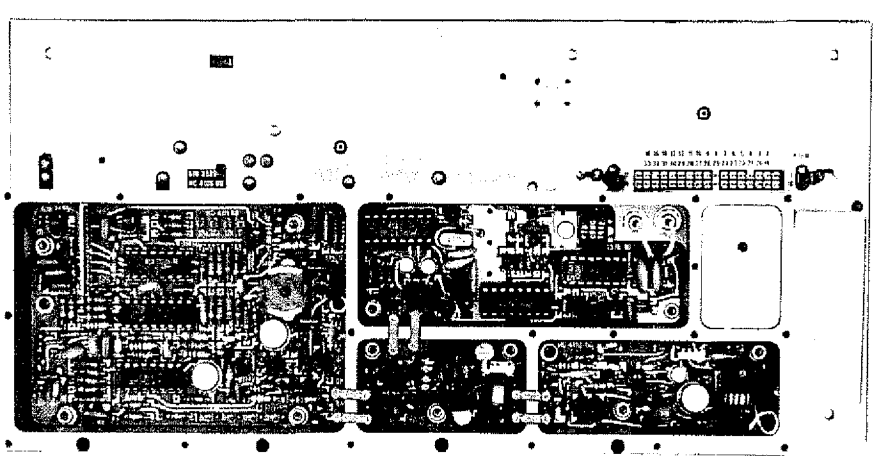


Fig. 5. Digitally controlled circuitry allows construction techniques for ease of manufacture and service.

bly, and servicing. To meet this need, a rotary switch using optoelectronic concepts (no mechanical contacts) was developed. The switching elements were to be localized in the knob, and the entire assembly was to plug into the front panel. Further requirements dictated a minimum of 30 positions, smallest possible size, capability of mass production, high reliability and ease of repair. The end result of many designs is a switch contained in a knob shell 1" in diameter and ¾" long. The separate parts of the switch are shown in Figure 6. Basically the switch consists of a detent mechanism, a 5-element LED light source, a slotted shutter wheel, and a 5-element phototransistor assembly. The 5-element optoelectric array gives a capability of 2^5, or 32 switch positions.

Both the LED's and the phototransistors had to be positioned very accurately in relation to one another and in relation to the shutter wheel. A package was developed for them with the five LED's in series instal-

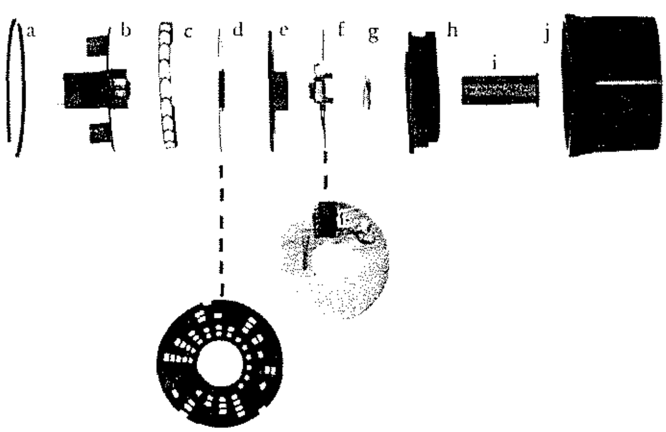


Fig. 6. Elements of the optoelectronic switch-in-a-knob that generates a 5-bit code for control of time/div and frequency span. (a) retainer ring, (b) phototransistor holder assembly, (c) spacer ring, (d) shutter, (e) light baffle, (f) LED array holder assembly, (g) spring washer, (h) detent assembly, (i) shaft assembly, (j) knob shell.

led on a lead frame, and encapsulated in transparent epoxy with integrally molded focusing lenses. The phototransistor chips are also mounted on a lead frame, wired in parallel, and encapsulated in the same manner as the LED's. The shutter wheel is chemically milled for economic precision production.

The output of the switch is a 5-bit code at a level which interfaces directly with CMOS logic. Two switches of this type are used in the 7L5. They are the TIME/DIV and FREQUENCY SPAN/DIV Controls.

The RESOLUTION, DOT FREQUENCY, AND REFERENCE LEVEL controls also are knob switches, but of a different type. They are circuit board switches, with the switching elements located inside the knob. The DOT FREQUENCY and REFERENCE LEVEL controls are identical except for the number of positions. They generate a 4-level, 2-bit, gray code as discussed previously.

Other mechanical techniques contributing to the outstanding performance of the 7L5 include numerical-controlled milling of the honeycomb chassis, and chemical milling of mumetal gaskets for effective shielding of some areas. A unique U-shaped feedthrough device reduces cost and complexity by coupling signals between compartments without the need for cables and connectors.

The outboard chassis on the left side of the 7L5 swings out, providing easy access for servicing without extension boards or cables. The entire unit can be disassembled in minutes, into the major components pictured in Figure 5.

Summary

The 7L5 combines frequency synthesis with digital technology to produce a 0 to 5 MHz spectrum analyzer with exceptional accuracy and frequency stability. Crt readout of measurement parameters and simplicity of operating controls assures easy, error-free operation. Digital storage provides a bright display, and averaging techniques that allow peak levels and averaged signals to be displayed together. Plug-in front-end modules yield low-noise levels and an 80 dB dynamic display range. Digital controls give precise selection of measurement parameters, simplify mechanical construction, and speed servicing.

Acknowledgments

Fendall Winston was Project Leader for the 7L5 and along with Craig Bryant and Steve Morton, provided much of the electrical design. Bill Benedict and Don Kirkpatrick did the digital circuitry. Steve Skidmore coordinated mechanical design, with Carlos Beeck doing the optoelectronic switch-in-a-knob. Morris Engelson provided overall engineering direction for the program. Our thanks to these and many others who provided material and assistance in writing this article.

Bob Beville

Transition counting with an oscilloscope

Many people involved with troubleshooting digital circuits are continually looking for a better way to do the job. And people building instruments to test digital circuits are likewise looking for better ideas so their instruments may do a better job. A very powerful technique called transition counting has been used by some manufacturers of circuit board test equipment, and a transition counter has now been combined with the most popular Tektronix oscilloscope, the 465, for servicing digital circuits. This technique and this instrument are undoubtedly just the kind of "better way" many people have been looking for. The time-saving, money-saving potential is vast. We would like to tell you about the technique, how we have combined a transition counter with an oscilloscope, and what that can do for two groups of people.

The first group is comprised of those who are concerned about the great expense of their inventory of replacement circuit boards, the long shipping delay for repaired boards, or, perhaps, the red-tape and delay uncertainty through Customs when exchanging boards between countries. The second group: those people who are concerned about the high percentage of training time required to keep their highly qualified technicians familiar with new equipment.

Truth tables vs count comparison

Most engineers and technicians become familiar with truth tables when they first learn about logic circuits. In school you get a pretty strong impression that the state of an output is dependent on the combination of HIGH or LOW states on the various inputs. That is a way of envisioning the operation of a logic circuit that is like taking a snapshot . . . it freezes the action. Although we are aware that the inputs normally change states, and that the outputs normally change states as a consequence, there is little point in trying to envision the action. The action of going from a LOW to a HIGH, or from a HIGH to a LOW, is simply called a transition. If you go from LOW to HIGH and back to LOW, you have had two transitions.

A simple two-input AND gate which has one input repeatedly going between HIGH and LOW should have an output which goes through an equal number of transitions during any interval when the second input remains at the asserted level.

By using the signal at the second input to gate a digital counter, the transitions at the output and at the first input may be counted and the numbers compared. If the AND gate is functioning properly the two will be the same. In other words, with the right digital counter and a suitable set of input signals, you can determine whether the AND gate is functioning properly by counting transitions.

This principle does not seem very important until you realize it applies to complex IC's and large sections of digital circuits, as well as to individual gates and flip-flops. Using the principle, entire circuit boards may be tested, and faults isolated to the component causing the trouble.

If a circuit board is tested and found to be faulty what then? The trouble may be isolated and the faulty element identified and replaced on the spot, using the same transition counting technique. You don't have to be testing boards; you may be troubleshooting a portion of a board, or the entire equipment the board is used in.

The main data needed when counting transitions is a set of numbers showing the proper number of transitions to expect at any point. Such data may be written on the circuit diagrams adjacent to the corresponding points. Figure 2 shows a circuit diagram labeled for using the transition counter technique of troubleshooting.

For the numbers to be valid, the time intervals during which transitions are counted must be identified. In most cases such intervals correspond to either the period of one cycle of the signal at some point in the circuits being tested, or the width of a pulse at that point. When a probe is connected to the identified point, and the counter set to recognize the proper gating interval from the signal there, only one other probe is needed: the troubleshooting probe. With that probe you may check counts at any other point.

For the gating intervals to be correct and the numbers to be valid, the equipment must be operated in the proper mode. For some equipment the proper mode may be a special diagnostic routine. For other equipment it may be merely how the controls and switches are set. Either way, a few informative sentences, or a set-up procedure, can identify the mode.

So transition counting depends on knowing three things: (1) the right number of counts to expect, (2) the right count-gating time intervals to select, and (3) the

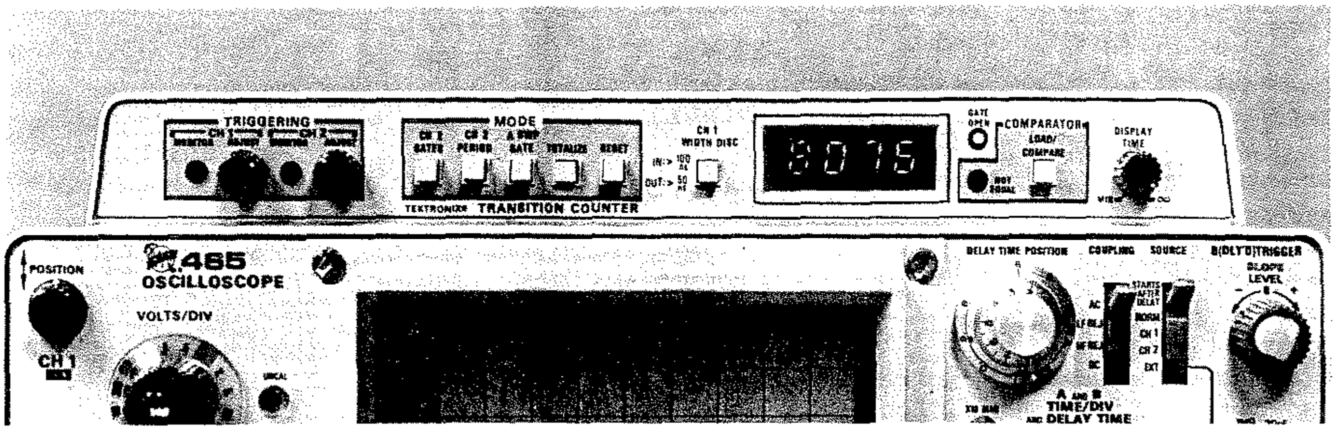


Fig. 1. The top of a 465 MOD 719A Oscilloscope, showing the controls and display window of a built-in digital counter. The oscilloscope probes may be used with the counter at the same time they are used for the scope. Input attenuators for the scope reduce the signals to the right size for the counter when they are the right size for the crt screen. MOD 719A counts signal transitions not signal cycles. Signal cycles will be one half of the number indicated.

right mode of operating the equipment containing the circuits being tested. The equipment designer is probably in the best position to supply this information because of his familiarity with the various operating modes and circuit functions. When the designer has a TEKTRONIX 465 Oscilloscope Mod 719A, it is no chore at all for him to compile the information. He merely picks an appropriate operating mode to exercise most, if not all, inputs, identifies the count-gating signal, measures the counts with his 465 at all the various points, and logs the counts on a circuit diagram. Forever after, troubleshooting is fast, simple, and convenient for anyone who has a 465 Mod 719A.

The information does not have to be supplied by the designer. A skilled service technician can do a comparable job. Nor does the information have to be compiled at the time the equipment is designed. It will pay many service organizations to compile such information as a supplement to the service manuals they presently use. It will also pay equipment manufacturers to compile and furnish such data on equipment introduced years ago, if it is still being supplied and posing a service problem.

Making a transition counter part of an oscilloscope makes good sense. Very little extra room or cost is required because many of the circuits are common. That says the price for the combination can be less than a separate counter and oscilloscope. Of equal importance to most people is the convenience of having one piece of service equipment that will do most jobs. Even the scope probes serve a double role. See Figure 1 for how we combined a transition counter with the 465.

Capturing the counts

The vertical input signals are routed internally to the transition counter circuits, as well as to the scope circuits. The transition counter always looks at the signal that arrives at channel 1 on the dual-trace scope. Transitions of that signal are what you count. The signal that arrives at channel 2 may be used to gate the counter on and off whenever the CH2 GATED pushbutton, or the CH2 PERIOD pushbutton, is pressed.

When the A SWP pushbutton is selected, counting is enabled during those time intervals when the A sweep is moving the crt beam. And when the TOTALIZE pushbutton is pushed, counting is enabled each time the RESET button is pressed.

To count transitions of the signal at channel 1, you trigger the counter on that signal. To gate the counter on and off with the signal at channel 2, you trigger the counter gating circuits with that signal. Proper triggering for each channel is indicated by a monitor light located next to each TRIGGERING ADJUST control.

The scope sweeps don't have to be triggered except when the A SWP GATE is used for the count gate. But when they are triggered, you can display the signal being counted, the signal doing the count-gating, or both. The channel 1 and channel 2 VOLTS/DIV controls govern the amplitude of the displayed signals and, also, the amplitude of the signals arriving at the counter trigger circuits. The scope may always be used as a signal monitor if count-triggering should be difficult or unstable.

Transition counting can be done using the A sweep gating signal as the count-gating signal by pushing the A SWP GATE pushbutton. That allows you to use only one probe anytime you can be sure that every transition you want to count is displayed on a particular sweep. A continually variable count-gating signal may be simulated by varying the length (duration) of the A sweep. The length is controlled with the 10-turn DELAY TIME POSITION control when the B ENDS A mode is selected. The duration may also be controlled with the VAR (Variable) TIME/DIV control.

When the equipment is not apt to have a count-

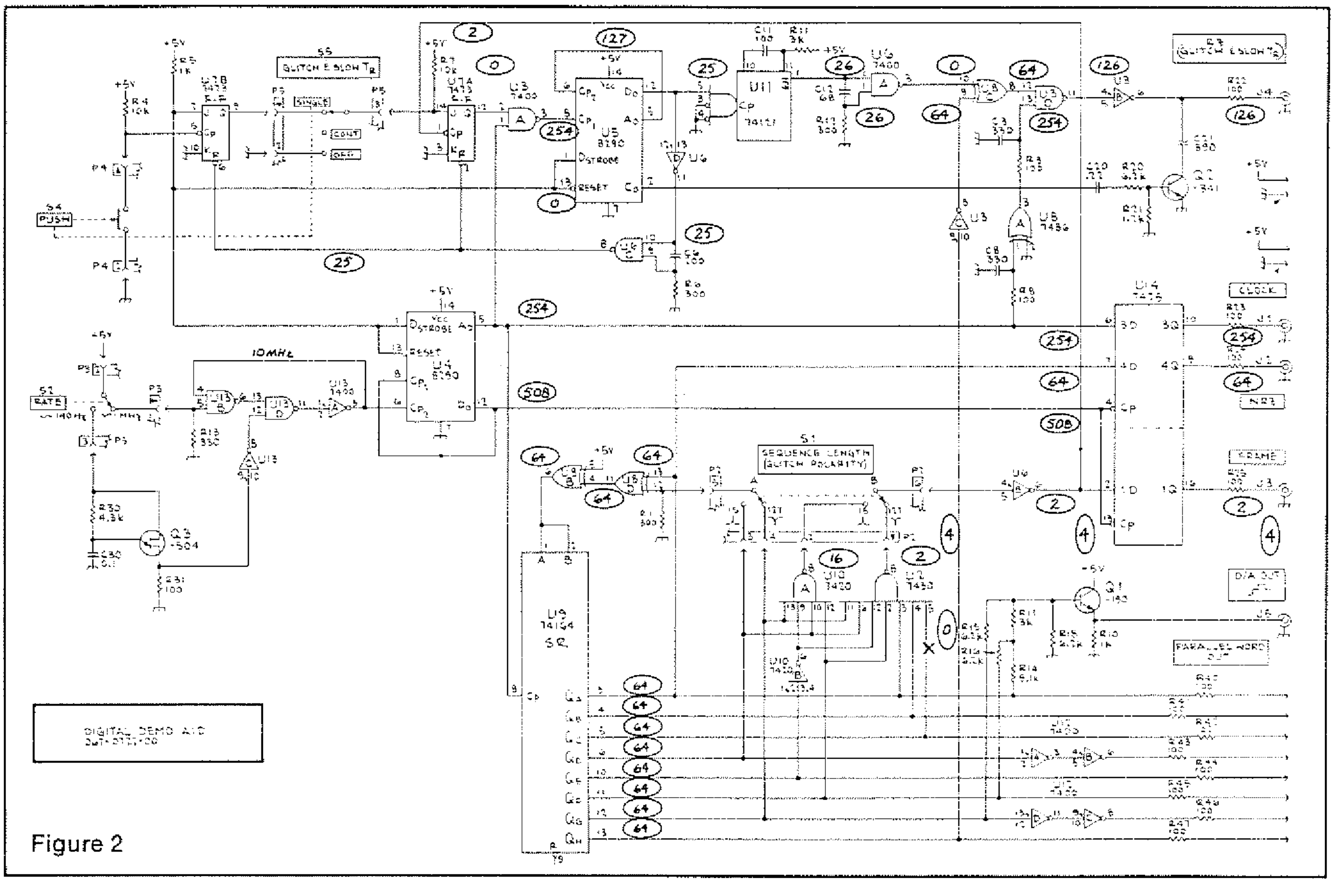


Figure 2

By labeling each signal lead on a circuit diagram with the number of transitions that should occur on that lead during identified time intervals, the cause of a wrong number may be traced to its source. Wrong counts are traced to the source of error back along any signal path where there is also an erroneous count. Any path where there is a correct count is ignored.

The proper time intervals during which transitions are to be counted must be identified. That is sometimes done by indicating the source of the gating signal, and what portion of the signal corresponds to the correct intervals. If the time interval signals in your equipment are apt to be faulty you may simulate the right interval with the scope.

The scope sweep gate signal may be used to gate the counter when the pulses occur in easily recognized groups. Or the sweep gate signal may be set to have a duration determined by a given number of clock signal transitions. You merely trigger on the clock signal, count clock signal transitions, and vary the sweep length until the right number of transitions are indicated. That sweep gate signal is then used for all the rest of the transition counts.

You can simulate a faulty IC in the equipment shown in the above diagram by lifting pin 5 of U2. The result will be an erroneous count of 4 at its output, that appears at all points along the path to the FRAME signal output. Anyone that can use an oscilloscope and follow a circuit diagram can find the fault in a matter of minutes even without knowing what the equipment is supposed to do, or how to operate it.

Troubleshooting Instructions might read like this:

Equipment Operating Mode:

Set the three toggle switches to position shown on diagram.

Oscilloscope Operating Mode:

Horizontal . . . B Sweep at .05 μs/DIV, A Sweep at 20 μs/DIV, A INTENS pushbutton in.

Triggers . . . A Trigger in NORM mode, AC Coupled, CH2 source, + Slope, Holdoff in B ends A position.

B (DLY'D) Trigger AC Coupled, CH2 Source, + Slope.

Vertical . . . CH1 Mode, 1 V/DIV with probe, AC Coupled.

Probes . . . Troubleshooting probe on CH1, triggering probe on CH2, both connected to resistor R8, the clock signal.

Control Settings . . . Set A TRIGGER LEVEL near middle of triggered range as indicated by the TRIG light.

Set B (DLY'D) TRIGGER LEVEL near middle of triggered range for triggered B sweep, as indicated by a shortened sweep when DELAY TIME POSITION control is moved to about mid range. Set Delay Time Position control and CH1 Triggering Adjust for a displayed count of 254.

Troubleshooting

All points may now be checked for the proper number of transitions indicated on the circuit diagram, using only the troubleshooting probe.

gating signal that is much more trouble-free than signals in other parts of the equipment, a reliable gating signal may be simulated in the scope by varying the sweep length. You do that by counting a specified number of signal cycles in the equipment, usually clock signal cycles. An example is the equipment shown in Figure 2. The FRAME signal output from that circuit would normally make an ideal gating signal, because the period of one cycle (2 transitions) is properly related to all the other inputs and outputs. But nearly any fault, including the one introduced by lifting pin 5 of IC U2, changes that signal period and therefore makes it unsuitable. Instead, the scope is operated in such a way that a gating signal of equal length is produced in the scope. You know it's the right length when you set it to give you the right count of clock signal transitions.

It is important to note that the particular defect chosen would not have been detectable with a logic probe because no output was locked up HIGH or LOW.

Transition counting can also be done on a one-shot basis by selecting the TOTALIZE pushbutton and pushing the RESET pushbutton each time a count is ready to be made. This mode is very useful for troubleshooting non-repetitive signals, such as you may find in a calculator when a particular calculation is in error. With this mode only one probe is required.

The DISPLAY TIME control will hold and display any count indefinitely, or enable fresh counting to occur frequently.

Noise spikes as wide as 50 ns or 100 ns may be ignored by a count-pulse width discriminator pushbutton.

A very unique and useful feature is a count COMPARATOR mode of operating the 465 Mod 719A. Many times circuit troubles are intermittent, so erroneous counts only occur occasionally and, therefore, only occasionally may be recognized. By storing a correct count once for a particular point, all subsequent counts for that point may be compared electronically. Any discrepancy between a new count and the stored count will immediately be indicated by a NOT EQUAL light on the 465 Mod 719A, and the erroneous count will be displayed until intentionally replaced.

Even if you have never used transition counting as a troubleshooting technique for digital circuits its simplicity and speed will be apparent once you understand the principle. The main bottleneck most people perceive is compiling the count data and getting the information included in their service manuals and circuit diagrams. Once you try the 465 Mod 719A for acquiring that data you can see how much more time and money will be saved servicing the equipment, compared to the investment in acquiring the data.

Complex digital equipment deserves special attention in the design and early production stages to profit most from transition counting principles. Here are the things to consider doing:

1. Add sockets, connectors, or special circuits to accommodate jumper cables, resistors, ROM's, etc., that are to be part of the diagnostic plan.
2. Characterize the product's performance early in the first production stages, with transition signatures recorded while the product is exercised according to the diagnostic routine.
3. Document the signatures on the circuit diagrams and in troubleshooting procedures.
4. Start a fault-and-repair reporting system.
5. Build a library of erroneous counts and associated faults.
6. Document any new signature which is caused by a circuit modification.

SPECIFICATIONS 465 MOD 719A

Display: 4 digits; up to 9999 counts.

Input signal amplitude, CH 1 or CH 2: 10 mV p-p or greater when displayed over 2 divisions or more.

Input signal frequency: 10 MHz or less.

Time between transitions: At least 50 ns or 100 ns depending on WIDTH DISCRIMINATOR selected.

Gating signal: Channel 2 signal period or pulse width; A SWP GATE duration; manual RESET (TOTALIZE).

Count Comparator: Detects intermittent fault by storing and indicating any count that is not equal to the pre-loaded correct count.

Triggering Monitor Lights: Indicate when the counter is triggered on the CH 2 count-gating signal and triggered on CH 1 signal transitions.

Dave McCullough

Storage expands your oscilloscope measurement capabilities

Fast moving events—how do you view them? If the events are electrical signals, the best way is to use an oscilloscope. For convenient viewing on a conventional oscilloscope the signal must have a fairly high repetition rate. But what if you want to view single events, or slowly changing signals such as those created by a difference in temperature? Then the conventional oscilloscope alone isn't your solution. You could use a camera, or you could take advantage of a storage oscilloscope.

Storage, in an oscilloscope, is the ability to retain the image of an electrical event on the cathode ray tube, after that event ceases to exist. Image retention may be for only a few seconds, or for weeks, depending on the type of storage. Different applications often require different types of storage. To ensure full coverage of your measurement applications Tektronix provides three types of storage:

Bistable
Variable Persistence
Fast Transfer

Each type has advantages and limitations that make one more suitable than the other for a particular application. A look at the different storage types applied to typical applications may help you select the one best suited to your needs.

Bistable storage

The most important characteristic of Bistable storage is long retention or view time. View times range from one hour to weeks, depending on the technique used to achieve Bistable storage. Long view times allow extended signal analysis without fear of losing the display. They also extend your ability to compare signals. Two or more repetitive signals occurring at essentially the same time can be easily compared, but when there is a considerable time lag between the two signals, one must be stored until the other occurs. A typical application is the need to compare signals before and after making circuit design changes or adjustments. In such cases, we need to keep the reference signal stored, while repeatedly storing and erasing the signal we're adjusting. For these applications Bistable Split-Screen storage is available. In this type, the phosphor storage screen is divided into two independent sections, upper and lower, with independent storage controls allowing you to erase either half of the screen without affecting the other half. This split-screen capability is unique to Bistable storage where the phosphor is the storage medium. It is not available in the Bistable storage discussed later, where the storage medium is a mesh.

If you need to display waveforms of slow, repetitive signals with fast risetimes, that appear as a slow-moving spot traveling across the crt, you should choose Bistable storage. Such a signal is displayed in Figures 4 and 5 using two different types of storage. When the spot velocity of the risetime portion of this type of signal is approximately twenty times the horizontal spot velocity, you will find it difficult to get a satisfactory display using Variable Persistence storage (see Fig. 4) . Adjusting the Variable Persistence storage controls will only cause the horizontal line to bloom more (at one extreme) or cause the risetime to disappear or fade quickly (at the other extreme) .

If your application fits into one of the following categories and you want storage that is the lowest cost, most rugged and easiest to operate, your choice is Bistable storage:

- Comparing signals that occur at greatly differing times
- Viewing non-repetitive events
- Displaying slow moving waveforms, or
- Requires the split-screen versatility.

Now let's consider another type of storage.

Variable Persistence storage

Producing high contrast displays is the most outstanding capability of Variable Persistence storage. This allows you to view signals that are beyond the display capabilities of conventional (non-storage) or Bistable storage instruments. The dim conventional oscilloscope displays produced by fast, low rep rate signals (see Fig. 6) can be converted to bright, easy to view displays with Variable Persistence storage (see Fig. 7).

The high contrast ratio (stored image to background brightness ratio) of Variable Persistence provides much greater contrast than the 4:1 best-case contrast ratio of Bistable storage. This high contrast ratio comes at the cost of view time. While Bistable storage techniques provide up to weeks of view time, Variable Persistence is limited to a few minutes. View time available is proportional to the stored writing speed needed, as illustrated in Figure 2. Also, as shown in Figure 2 you can increase view time by using the SAVE mode of operation.

For many applications, limited view time offers a measurement advantage. With Variable Persistence, once a signal is stored it automatically starts to fade away. This characteristic automatically erases the display. It also illustrates the sequence in which the events occurred (Fig. 8). A persistence control allows you to choose the rate at which the stored signal fades. The controllable range varies from the specified view time at maximum writing speed (see Fig. 2), to almost instant disappearance.

Here are some typical applications where the ability to control the persistence, or view time, is a valuable aid to measurement.

- Identifying the order in which signals occurred (Fig. 8)
- Observing the change in the signal while making calibration adjustments (Fig. 9)
- Suppressing signal noise
- Producing bright displays (Fig. 7).

If one of these categories describes your measurement needs, Variable Persistence storage is your best bet.

Fast storage

A third type of storage is provided by Tektronix to meet your needs for viewing very fast, low repetition rate or non-recurring signals. It is called Fast storage.

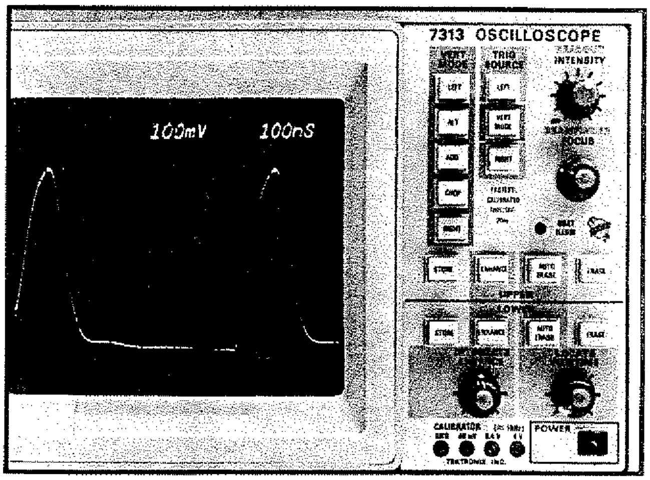


Fig. 1. Portion of split-screen Bistable storage oscilloscope front panel showing storage controls.

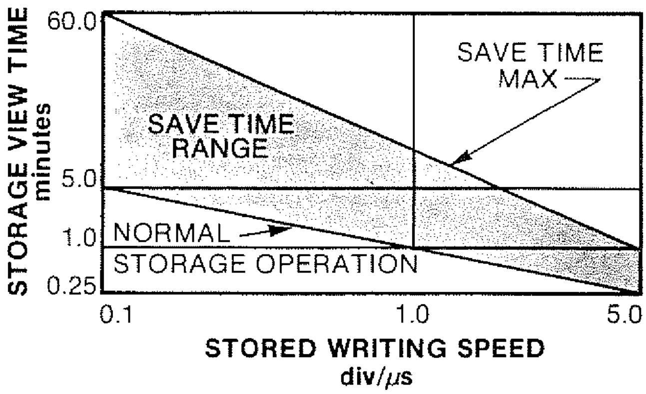


Fig. 2. Graph showing extended view time available in SAVE mode. The higher the stored writing speed needed, the shorter the view time.

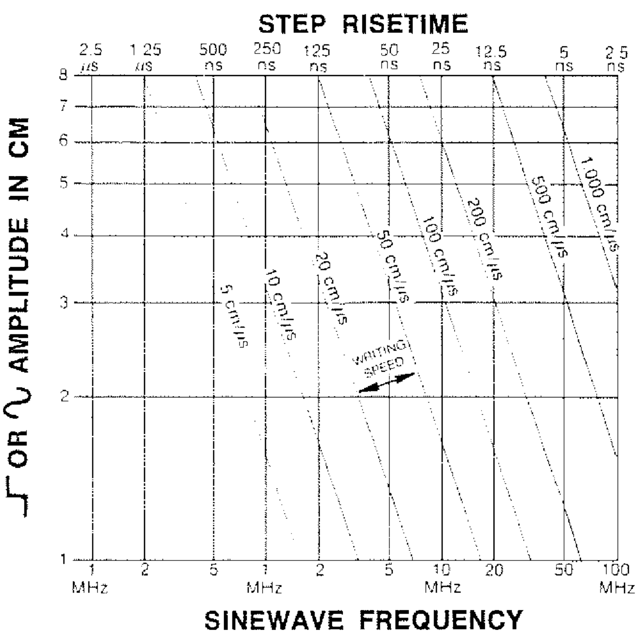


Fig. 3. Graph showing the stored writing speed needed to display a given sinewave or step risetime at a given amplitude.

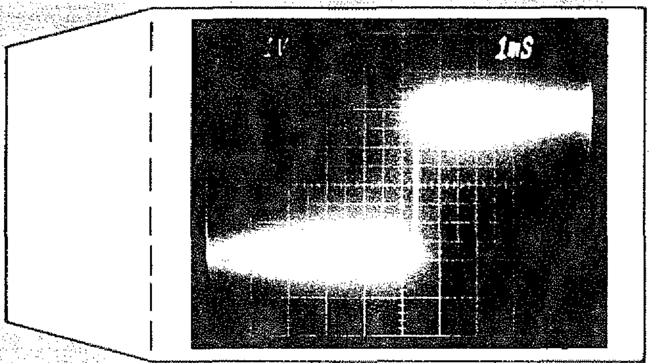


Fig. 4. Slow repetitive signals with fast risetimes are difficult to display using Variable Persistence storage as in this photo.

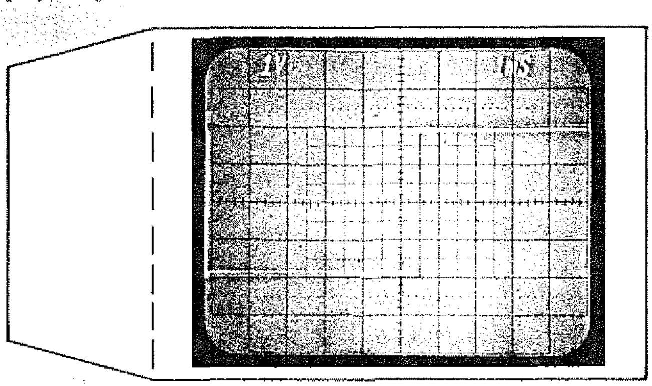


Fig. 5. The same waveform as in Fig. 4 displayed using Bistable storage.

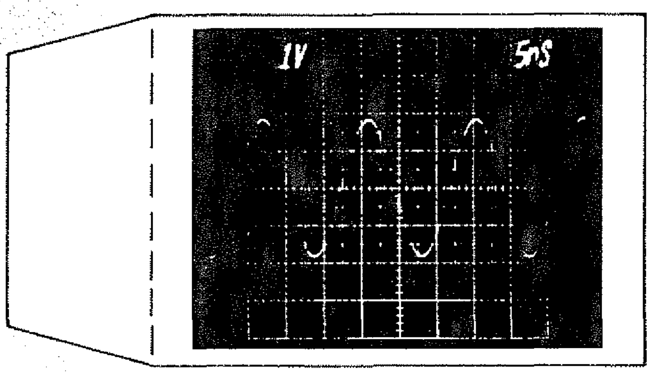


Fig. 6. Fast, low rep rate signals are difficult to view with a conventional (non-store) oscilloscope.

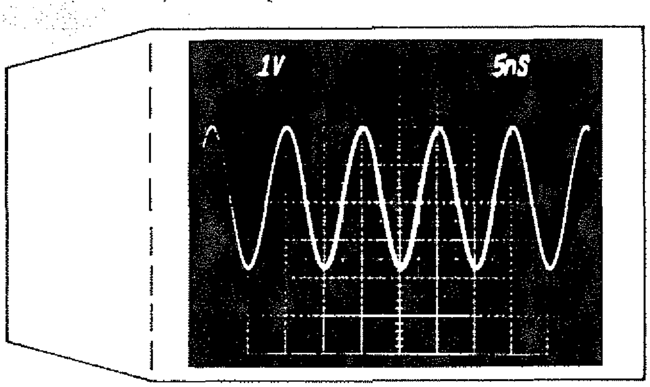


Fig. 7. The same signal as in Fig. 6 displayed using Variable Persistence storage.

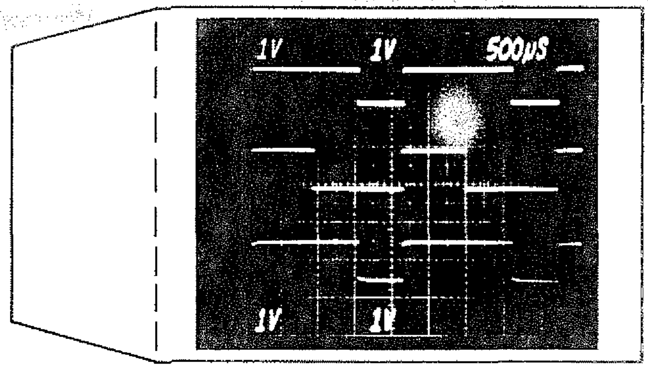


Fig. 8. Sequence of events is handily displayed by the fading characteristic of Variable Persistence storage displays.

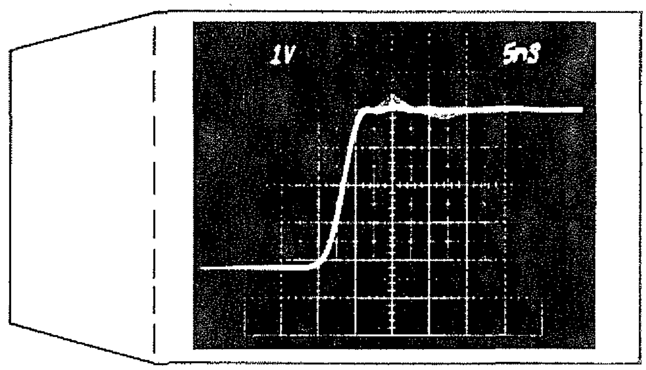


Fig. 9. Changes in the waveform as calibration adjustments are made are readily discernible in this Variable Persistence display.

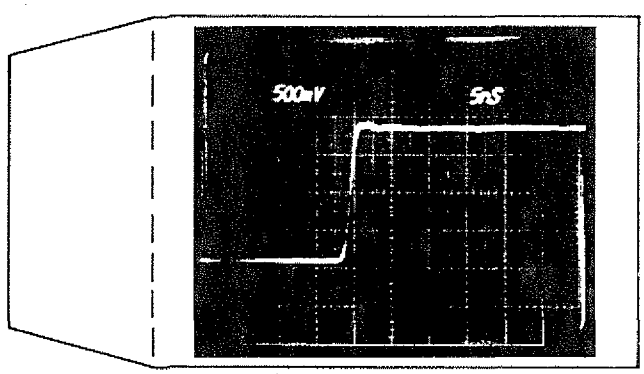


Fig. 10. The outstanding stored-writing capability of Fast Variable Persistence is dramatically illustrated in this photo of a single event having a risetime of 3.5 ns.

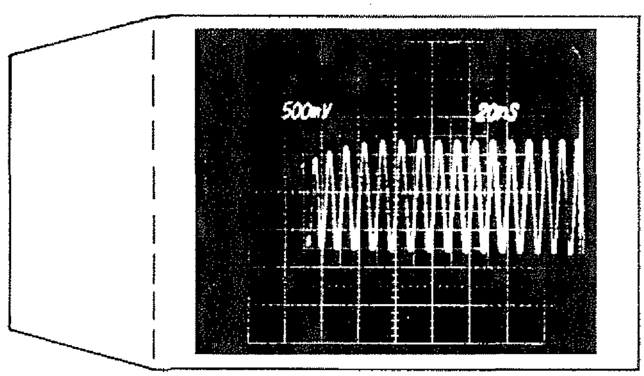


Fig. 11. A single burst of 100 MHz noise is captured by Fast Variable Persistence storage.

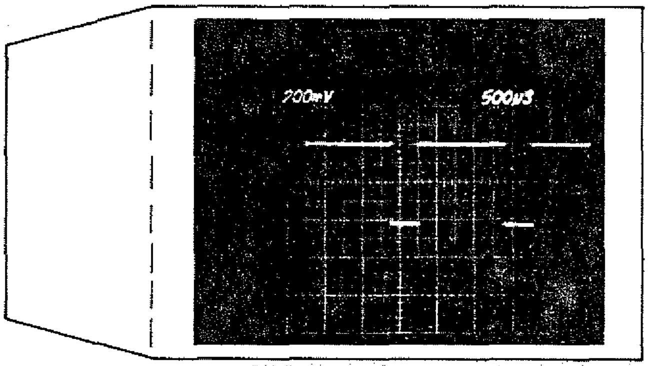


Fig. 12. Signal displayed using Variable Persistence storage. Note rising and falling portions are not visible.

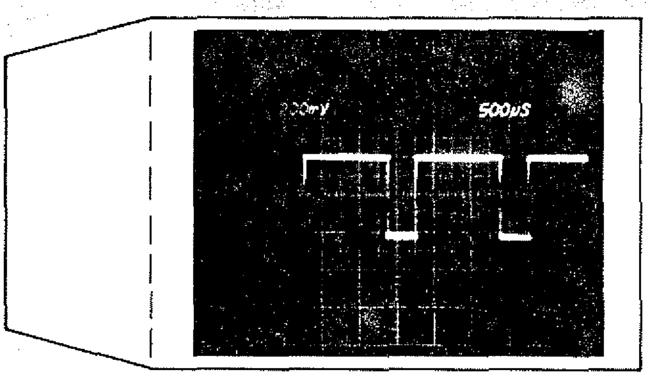


Fig. 13. Same signal as in Fig. 12 displayed using Fast Variable Persistence. Rise and fall times are clearly visible.

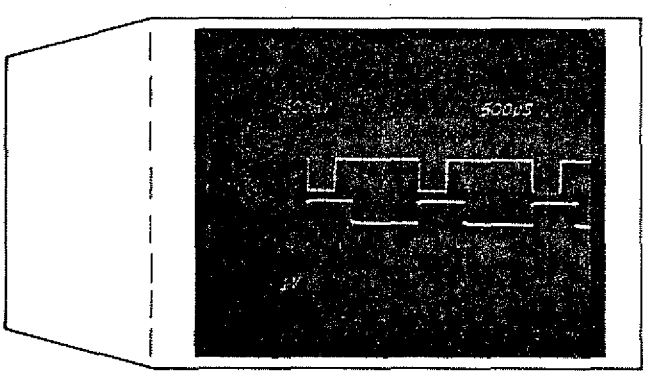


Fig. 14. Two fast signals occurring one minute apart are easily displayed using Fast Bistable storage.

In this type of storage the signal is first stored on a mesh in the crt, that is optimized to achieve maximum writing speed. The signal on this mesh is then transferred to a second mesh which can be operated in either a Bistable or Variable Persistence mode. These two modes are called Fast Bistable and Fast Variable Persistence.

Writing speed is the most important consideration for choosing Fast storage, and stored writing speed is increased up to 1350 cm/µs using Fast Variable Persistence. The Tektronix Bistable and Variable Persistence storage types discussed earlier have approximately the same writing speed (5 cm/µs), so writing speed was not a consideration for selecting one type over the other. However, in Fast Bistable and Fast Variable Persistence, that writing speed relationship is no longer true. Fast Variable Persistence can exceed Fast Bistable capabilities by more than seven times. The same basic trade offs, long view time in Bistable and high contrast displays in Variable Persistence, are still true for the Fast Bistable and Fast Variable Persistence modes.

The nomograph in Figure 9 is useful for selecting the writing speed needed to display a given sine wave or step risetime (t_r) at a certain amplitude. For example, to display a 16 ns risetime signal three centimeters in amplitude requires a writing speed of 180 cm/µs.

Figures 10 and 11 show the ability of Fast Variable Persistence to store a single event having a risetime of 3.5 ns, or a single burst of 100 MHz noise. A comparison of the ability of Variable Persistence and Fast Variable Persistence to display the same waveform is shown by Figures 12 and 13. Two fast signals occurring one minute apart are displayed in Figure 14 using Fast Bistable storage.

If these are typical of your measurement needs, your choice should be fast storage.

Summary

Each type of storage has advantages and limitations that make one more suitable than the others for a particular measurement application. *Bistable storage* offers long view times, a low cost, and rugged, split-screen operation. *Variable Persistence* provides high contrast and the ability to display different stored intensities. *Fast storage* offers increased Bistable and Variable Persistence writing speeds. Only at Tektronix will you find all three types of storage, and they're available in the plug-in oscilloscope or portable oscilloscope that's right for you. If you can't choose, we have multi-mode oscilloscopes that include the best of all three types.

Servicescope

A potpourri of modifications and service hints

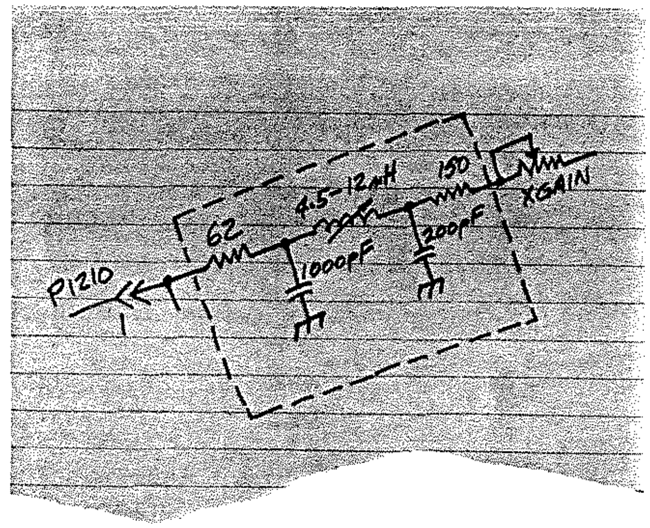


Fig. 1. Components within dashed lines replace R1211 on original diagram.

THREE EASY MODIFICATIONS TO MAKE YOUR 465 OSCILLOSCOPE DO SOME JOBS BETTER

When the 465 was designed, some special performance features were omitted because they would be of little or no value to most customers. But for those who need the features and are able to make the mods themselves we can offer parts and instructions. Mod descriptions follow:

Equalize X-Y Phase to 2 MHz

By adding two resistors, two capacitors, and a small variable inductor you can modify the horizontal deflection circuits so the phase difference between the horizontal and vertical deflection circuits may be adjusted to be less than 3 degrees to 2 MHz. The circuit card where the parts are installed comes with holes to make it easy to install the additional components. The components are located next to the X Gain adjustment pot, R1215. Resistor R1211, in the original circuit, is removed and discarded. The changed section of the circuit diagram is shown in Fig. 1. Following is the list of required parts:

1—321-0077-00, Resistor, 62 Ω, 1%, 1/8 watt
1—283-0594-00, Capacitor, 1000 pF, 1%, 100V, mica
1—114-0278-00, Inductor, 4.5 to 12μH, variable
1—283-0672-00, Capacitor, 200 pF, 1%, mica
1—317-0151-00, Resistor, 150 Ω, 5%, 1/8 watt

1 kHz Calibrator Frequency Made Accurate to ±1%

This mod requires adding a small potentiometer and changing five resistors and one capacitor to have a different value, tolerance, or temperature stability. The amplitude calibrator signal may then be set to precisely 1 kHz and used as a timing reference for sweep calibration checks as well as a voltage reference for vertical deflection checks. The following capacitors and resistors are needed and used to replace those used in the original circuits:

1—285-0758-00, Capacitor C1592, .05 μF, 2%, 400 V Poly carb
1—321-0365-09, Resistor R1591, 61.9 kΩ, 1%, 1/8 watt
1—321-0381-00, Resistor R1592, 90.9 kΩ, 1%, 1/8 watt
1—321-0268-09, Resistor R1593, 6.04 kΩ, 1%, 1/8 watt
1—321-0385-00, Resistor R1594, 100 kΩ, 1%, 1/8 watt
1—317-0622-00, Resistor R1596, 6.2 kΩ, 5%, 1/8 watt

One component, a small potentiometer, must be added:
1—311-1224-00, 500 Ω Variable resistor, 0.5 watt

When R1593 is soldered into place the bottom end should not be connected to ground as shown in the original circuit diagram but wired in series with the 500 Ω variable resistor. The bottom end of the variable resistor is connected to the +5 volt supply instead of ground. Varying the resistor sets the calibrator signal frequency.

Dual Trace Chopping Rate Increased to 1 MHz

This mod requires eight parts, three of which replace original components. It reduces trace brightness somewhat in the chopped mode.

Capacitors C356 and C368, and resistor R356, should be replaced with ones shown in the parts list below. These parts are shown on the Vertical Switching diagram in the service manual (070-1861-00). R370 should be removed and not replaced.

Now modify the CRT Circuit diagram in your service manual according to the partial diagram in Fig. 2. The remaining five parts should be soldered into the circuit according to the diagram.

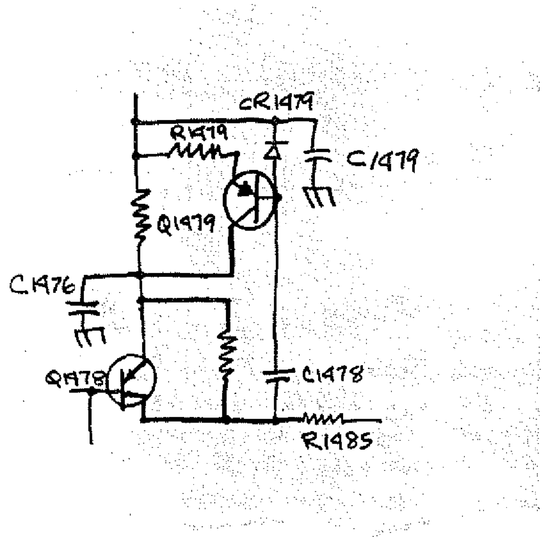


Fig. 2. Circuit changes to increase chopping rate to 1 MHz.

Here are the parts you will need:

1—281-0629-00, Capacitor, C356, 33 pF, 5%, 600 V
1—283-0100-01, Capacitor, C368, 0.0047 μF, 10%, 200 V
1—315-0303-00, Resistor, R356, 30 kΩ, 5%, 0.25 watt
1—281-0557-00, Capacitor, C1478, 1.8 pF, 500 V, NPO
1—283-0057-00, Capacitor, C1479, 0.1 μF, +80%−20%
1—315-0470-00, Resistor, R1479, 47 Ω, 5%, 0.25 watt
1—152-0141-02, Diode, CR1479, IN4152
1—151-0301-00, Transistor, Q1479, 2N2907

CHANGE YOUR 5L4N TO HAVE A 20 Hz TO 20 kHz LOG SPAN

The log span is normally 100 Hz to 100 kHz for the 5L4N Spectrum Analyzer. But it is easy to change the span to cover 20 Hz to 20 kHz to fit the audio frequency spectrum. Here is what to do if your 5L4N has a Serial Number below B030313:

1. Change R1204 to 1.01 kΩ, ⅛ w, metal film (321-0222-00)
2. Change R1202 to 11 kΩ, ⅛ w, metal film (321-0293-00)
3. Change R1200 to a 2 kΩ, 0.5 w, 10%, trimmer, (311-1265-00)
4. Adjust R1200 for the proper span at 20 Hz.

You can change the span by adding or removing a jumper wire if your 5L4N has a serial number higher than B030312.

PLUG-IN EXTENDER CABLE PRECAUTION

You can save hours of repair time by observing two simple precautions when using plug-in extender cables.

1. Be sure power is turned off when connecting either end of the extender.
2. Be sure both ends of the extender are connected properly.

7300, 7400, 7600 SERIES −50 V SUPPLY FAILURES

There has been a higher than normal number of failures of transistor Q896 in the power supply of scopes in the above series. By adding a diode between the base of Q896 and ground it will be protected. A silicon diode is installed in parallel with diode CR894 with its anode grounded. We use a diode having the characteristics of a 1N4152, part number 152-0141-02.

464, 465, AND 466 ERRATIC TRIGGERING

When a display is sometimes erratic when triggering on low amplitude signals it may be caused by part of the sweeps being triggered from the opposite slope than the one selected. The condition can be corrected by changing four tunnel diodes from one type to another. Diodes CR550, CR552, CR650, and CR652 should be changed from a type having part number 152-0125-00 to a type having the part number 152-0125-01. A good way to recognize diodes having the right part number is that the letters GE appear on them.

575, 576, 577 CURVE TRACERS

When the brushes on the variable transformer (used to control the peak collector voltage) wear out they may be replaced with new brushes for about 1/10th the cost of a new transformer. For the 575 or 576 use a brush with part number 118-0032-00. For the 577 use part number 118-0033-00.

TM 504 GROUND LOOP

When TM 504 mainframes with serial numbers below B011370 are used to power an SG 502 signal generator the signal distortion may exceed normal limits. The problem appears on the SG 502 only when the signal frequency is an even multiple of the line voltage frequency but may appear on other plug-ins as very low level hum. To prevent the condition remove the top and bottom cover of the TM 504. Locate the section of the circuit card shown below and cut through two circuit board conductors as shown. Remove the connection between the ±33 V COMMON and chassis ground (at the junction of C-20 and C-22 via a solder lug). Connect the junction of C-20 and C-22 of the circuit board at the point between J10 and J20 marked COM.

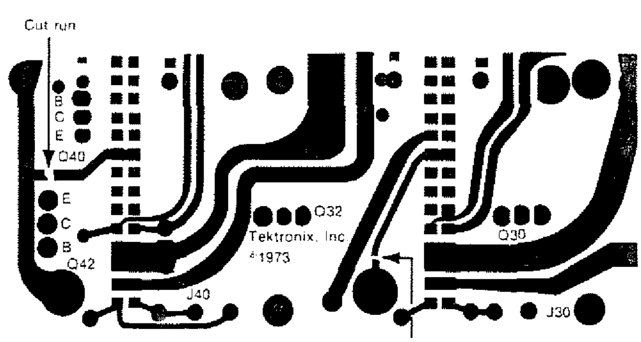
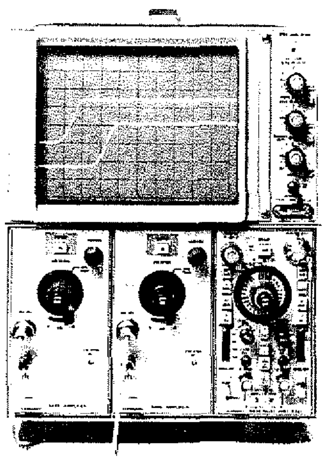


Fig. 3. TM 504 circuit board changes to remove ground loops.

New products
New products
New products



5444 Dual-Beam Oscilloscope

The 5444 Dual-Beam Oscilloscope is a new member of the 5000 Series. Used with the 5B44 Dual Time Base plug-in and two plug-in vertical amplifiers, it is virtually two oscilloscopes in one. Both beams can write anywhere on the 8 by 10-division screen.

The 5444 will display a one-shot signal at two sweep speeds or two one-shot signals at any sweep speed. Only a dual-beam scope with two sets of horizontal deflection plates can do this.

If you need to compare more than two signals, the 5444 can display up to four repetitive waveforms in the alternate or chopped mode, or up to 8 at reduced bandwidth. Four single-shot events may be displayed at sweep speeds up to 100 μs/div in the chopped mode.

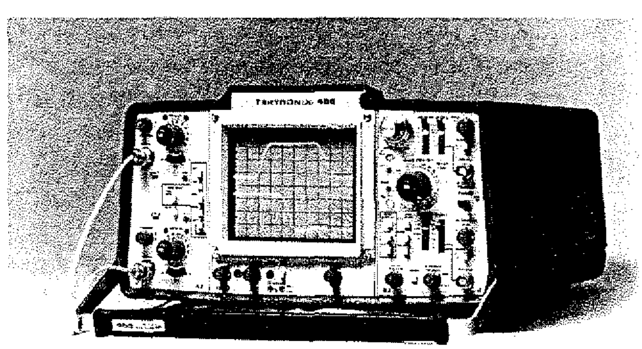
The crt provides a bright display, has an illuminated parallax-free internal graticule, and provides readout that automatically documents the sweep speed and vertical deflection factor for each beam. A user-addressable readout option allows you to write up to two 10-character words of your choice to identify the photograph, the device under test, etc. The TEKTRONIX C-27 Option 1 Camera with 10,000 speed film and the Writing Speed Enhancer (or P-11 phosphor option) make it possible to photograph a one-shot display to the full 60 MHz bandwidth of the system.

1502 and 1503 TDR Cable Testers

The 1500 Series meets the most stringent environmental specifications for flight-line rated test equipment. These portable TDR Cable Testers are at home operating in a deluge or a sand storm. January in Alaska or August in Texas doesn't bother them. Bouncing around in an off-the-road repair vehicle or being doused with salt spray on board ship doesn't stop them either. They're small, self-contained, rugged, and battery operated.

The two Cable Testers use TDR, a proven technique, to pinpoint faults to a fraction of an inch in short lines. In longer lines they resolve faults to within a yard as far away as 50,000 feet, depending on the cable characteristics. What can you test with this series? Just about any cable assembly from lamp cord to coax, plus a variety of broadband components (antennas, connectors, equalizers, sensors, etc.)

The 1502, for lines up to 2000 feet, provides fractional inch resolution. It uses a 110 ps step test signal into 50 ohms. The 1503 works out to 50,000 feet. It uses an impulse test signal into 50, 75, 93, or 125 ohms. Both versions are equipped for recording a "signature" of line characteristics using most any external X-Y Recorder. Signatures can be checked on a routine basis allowing problems to be identified and corrected before catastrophic failures can occur. An optional plug-in strip chart recorder is available (option 4).



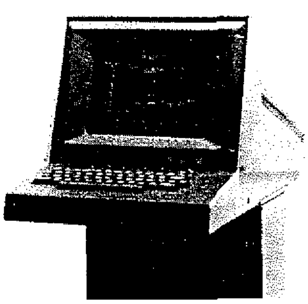
455 Portable 50-MHz Oscilloscope

The 455 combines 50-MHz bandwidth, dual traces, and delayed sweep in a rugged, value-leading portable oscilloscope. This instrument provides a cost-effective means of bringing needed performance features and accuracy to field service applications and to many production applications as well.

Accuracy and measurement range of the 455 are suitable for virtually all servicing of digital and analog equipment. Vertical sensitivity ranges to 5 mV/div with ±3% accuracy (1 mV/div with channels cascaded). Sweep rates extend to 5 ns/div (2% accuracy for 50 ns/div and slower, 3% for 5 ns/div, 10 ns/div, and 20 ns/div). Differential time measurement accuracy is ±1.5%.

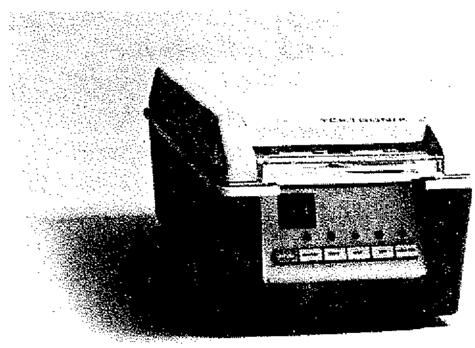
In addition, the 455 offers features designed to make measurements faster, easier, and more error free. These include: lighted deflection factor indicators, trigger view, variable trigger holdoff, color-coded modular probes, modular construction for easy serviceability, and an easily understood color-coded control panel. To further enhance its use in service and industrial environments, the 455 is housed in a rugged, shock resistant plastic case. Optional battery operation frees the 455 from dependence on ac lines.

The 455 is an ideal choice for servicing small to medium scale computers, computer peripherals, industrial control equipment, military or commercial communications gear, office machines, and point-of-sale terminals.



E4010 and E4010-1 Graphic Display Terminals

These two terminals are economy models of the popular TEKTRONIX 4010 computer graphics terminal and have all the 4010's features except for the traditional thumbwheels to control the cross-hair cursor. Graphic input is through the keyboard. The E4010, and its hard-copy compatible version, the E4010-1, have 11-inch flicker-free storage tubes, 63-character ASCII set (upper case), and 1024 x 1024 addressable points. All TEKTRONIX interfaces, options and peripherals are compatible with the terminals, including the graphics tablets and disc memory units.



The 4923 Digital Cartridge Tape Reader

The 4923 Digital Tape Reader is the perfect storage device to team up with the TEKTRONIX 4010 family of Computer Display Terminals or the 4023 Terminal. In fact, any product using RS-232-C data communications lines can be used with the 4923 Option 1.

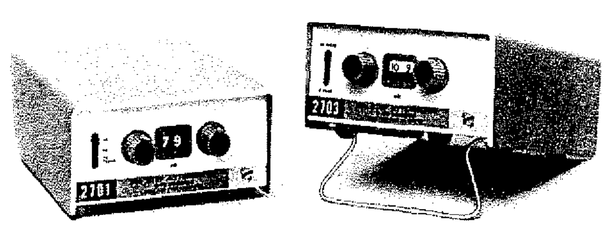
Information is stored on a DC300A 3M Data Cartridge with a data capacity of 200,000 8-bit bytes. Data format is 128 8-bit byte records with variable length files. The standard model operates up to 10K baud, depending on the terminal environment. Option 1 lets you select a baud rate from 110 to 9600.

Operating the 4923 is as simple as one, two, three. You have front panel controls for Reverse, Write, Stop, Run and Forward.

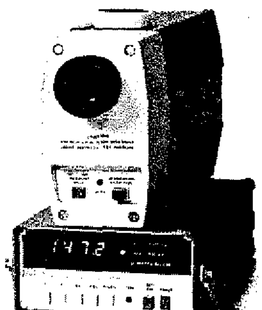
The computer can access START READ (DC1) and STOP READ (DC3). During a READ operation the 4923 provides a line-turn-around character if a DC3 is encountered in the data. Once a DC3 is read, the following stored character is read and sent, and the unit stops.

2701 and 2703 Step Attenuators

The 2701 and 2703 Step Attenuators are small, laboratory-quality, wideband bench-top instruments for attenuating large value radio- and video-frequency signals. The 2701 is a 50 ohm attenuator particularly useful in making receiver sensitivity and distortion measurements. Its range of attenuation is 0 to 79 dB, in 1 dB steps. A front-panel slide switch selects dc (direct coupling), ac (protects against dc offsets), or dc TERM (a 50 ohm precision termination).



The 2703 is a 75 ohm attenuator for television, CATV, telephone, and radio applications. A front-panel switch extends the range from 79 dB to 109 dB, making an ideal accessory for wide-range measurements of cross modulation, signal-to-noise ratio, receiver sensitivity, etc. Attenuation can be selected in 1 dB steps with tens and units cam switches. The value selected is shown in the display window. A block has been incorporated on both rear panel ports to protect against accidental burnout from high dc offsets or ac power on center conductors.

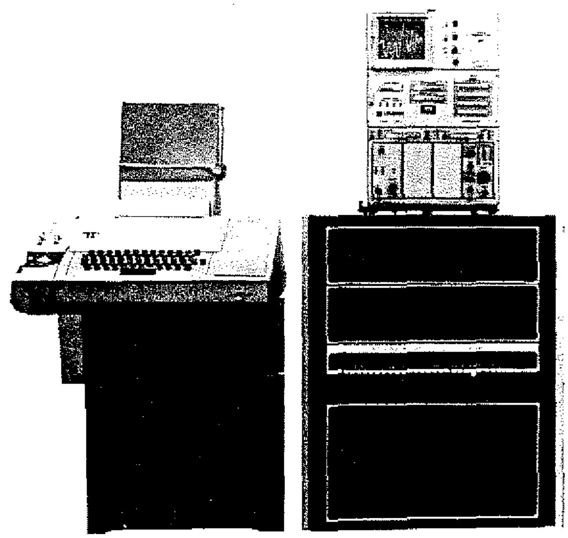


1° Luminance Probe

The J6523 1° Luminance Probe is the newest probe for the J16 Photometer/Radiometer. The J6523 is especially useful for measuring a very small spot or a small, distant area of light.

Now you can take a precision light-measurement tool into the field and make measurements in difficult situations. The J16/J6523 is tough, compact, light (about 5.5 pounds), battery operated, and stabilized for reliable indoor or outdoor use.

The J6523 has a measurement range of 0.1 to 19,900 foot-lamberts (1 to 199,900 nits for the metric version), will measure a spot as small as 0.23 inch (smaller with commercially available close-up lenses), and has an optical sighting system with a 9-degree field of view. Its rugged, stable silicon photodetector incorporates accurate photopic spectral correction.



WP 1205 Digital Processing Oscilloscope (DPO)

The WP 1205 DPO is a low-priced starting package for customers with a restricted budget. The package includes one 7A16 vertical plug-in, one 7B70 time base plug-in, a CP1151 controller with a 16k memory, a modified ASR-33 teletype, and paper tape DPO TEK BASIC software.

The WP1205 has an internal 1k semiconductor memory, adequate to acquire and display one waveform with scale factors. But a standard option is available providing a 4k memory. The CP1151 controller with 16k memory provides adequate program space for most user applications since specific software routines may be selected when initially loading DPO TEK BASIC software.

Option 02 deletes plug-ins, option 08 substitutes a 4k processor memory for the 1k memory, and option 09 changes the line voltage connections for 230-V operation.

Most of the products pictured here are making their initial appearance in Tekscope. Others have been announced by Tektronix in the last few months and are included here because of their wide range of application. We invite you to use the inquiry card accompanying Tekscope if you would like more complete information on any of these products.

A-3169

TEKTRONIX, INC.
P.O. BOX 500
BEAVERTON, OR. 97005

BULK RATE
U.S. POSTAGE
PAID
Tektronix, Inc.

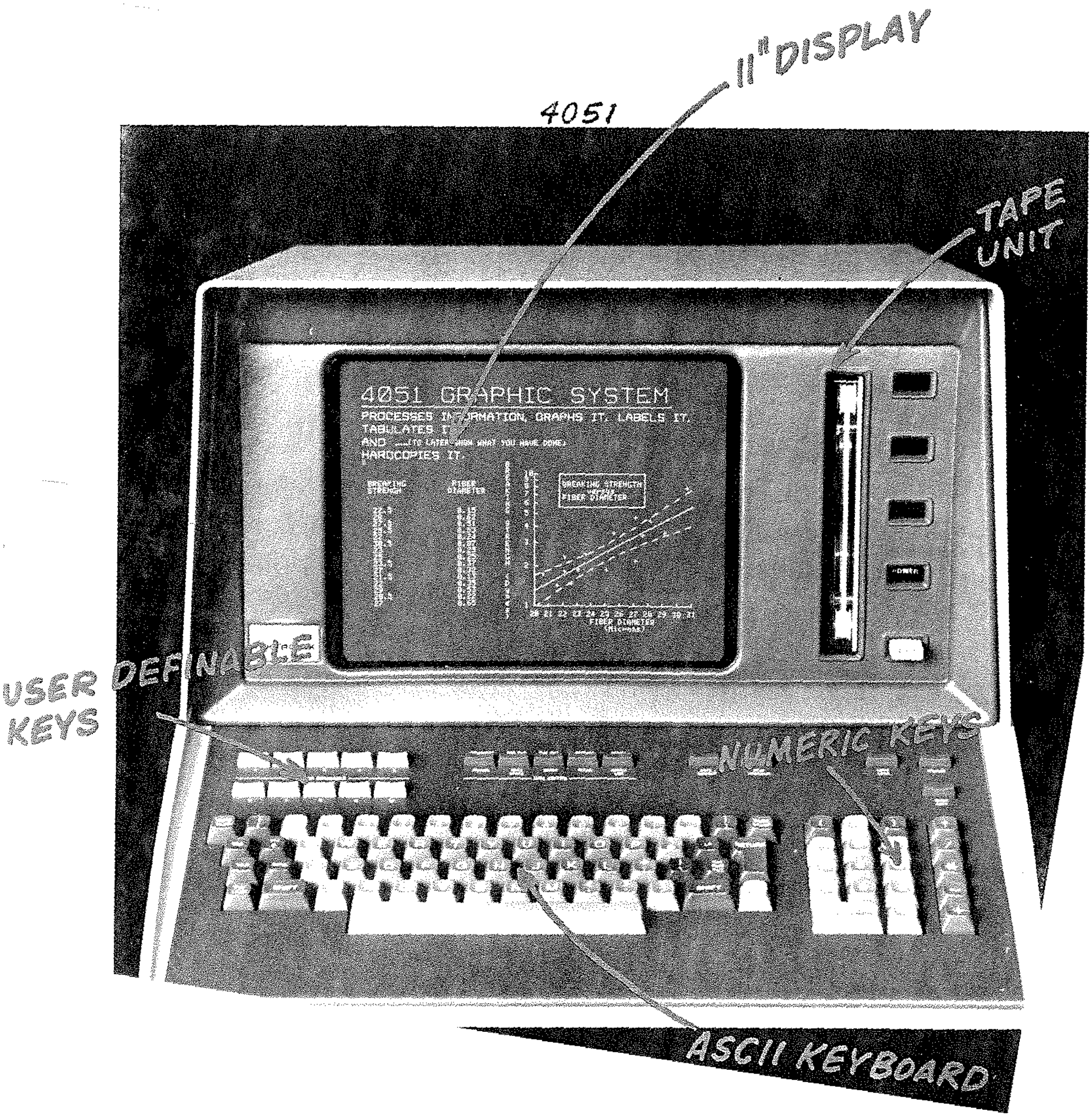
0544304
MR FRANK CAPELLUPO
NEW YORK TELEPHONE CO
8838 75TH AVE
GLENDALE NY 11227

TEKTRONIX
committed to technical excellence

TEKSCOPE

Volume 7, Number 5

1975



TEKSCOPE

TEKTRONIX®
committed to technical excellence

Customer Information from Tektronix, Inc.,
Beaverton, Oregon 97077

Editor: Gordon Allison
Ass't. Editor: John Mulvey

Contents

2 **A desktop graphic computing system**

The TEKTRONIX BASIC Graphic Computing System combines high-level BASIC-language interaction, built-in computing, and local tape memory—plus the unique graphing capabilities of the Tektronix display.

8 **Graphing with the 4051 Graphic Computing System**

Graphing with the 4051 makes sense. You graph using your own data units, with the Interpreter converting your data units to Graphic Display Units for plotting on the 4051 crt or a peripheral device.

11 **A high-stability 100 kHz to 1.8 GHz tracking generator**

A companion to the 7L13 Spectrum Analyzer, the TR 502 Tracking Generator provides a highly-table, leveled signal for characterizing devices and systems up to the full 1.8 GHz bandwidth of the 7L13.

15 **Delayed gate aids oscilloscope digital measurement**

Using the delayed gate to control digital plug-ins in a 7000 Series Oscilloscope, opens the door to some unique measurement capability.

17 **Repairing probe tips, bodies, and boots**

Some hints for keeping your probes in good operating condition at minimal cost.

19 **New products**

A brief summary of what's new from Tektronix.

Colin Barton

A desk-top graphic computing system

With the cost of memories and processors on the decline, the economies of scale of big computers are slowly diminishing. Communications costs are high. There are often long waits for results, and the system can take as much as 40% of its time trying to figure out what to do next. Like big cities, big computers are fraught with problems. In the future, more and more computing will be done locally at the desk of engineers, business analysts, scientists, etc.

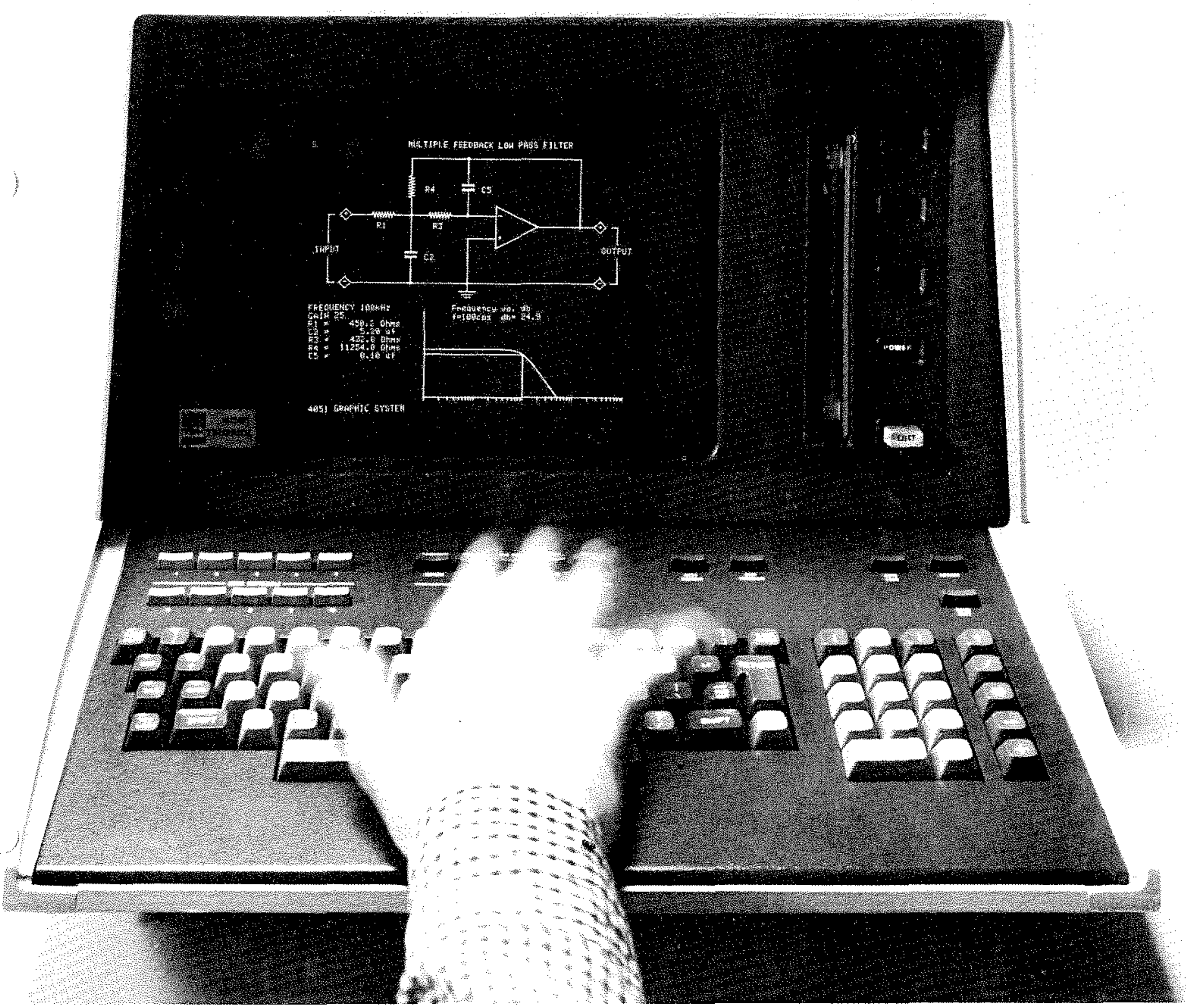
As society progresses technologically the problems faced in all fields increase in complexity. People need to devote all their energy to whatever is facing them. Having to understand the problems of putting together a computer system should not be one of their tasks. So the 4051 is not a collection of hardware and paper tape for a user to get along with somehow. Instead, it is designed so all of its facilities are easy to use. It avoids user perceived complexity. A desktop system should be an extension of a user's mind. The 4051 does this in four ways:

1. It is a machine using a people-oriented higher-level language . . . extended BASIC.
2. It uses graphics to help a user perceive a problem more naturally, see a solution in perspective.
3. The acquisition of data by and from instrumentation can be handled using the same language . . . extended BASIC.
4. The 4051 can efficiently access host computer files.

The language

For those who already know BASIC as a programming language little needs to be said about its simplicity and conversational character. A lot of very careful, capable thinking went into the development of the language to make it simple to learn as well as suitable for a wide range of disciplines. Today it is widely used. Only a few hours with a self-study book gives you a feel for the language. A few days of study will make you an apprentice programmer.

The main thing experienced programmers question is whether BASIC is adequate to solve their toughest programs. When you already know a more complicated language and have access to machines that use it, there may be little opportunity or reason to learn about the limits of BASIC. That


MULTIPLE FEEDBACK LOW PASS FILTER
R4
C5
R1
R3
INPUT
C2
OUTPUT
4051 GRAPHIC SYSTEM
POWER

factor will probably retard wide-spread understanding of its great power. However, counterbalancing that factor will be people who recognize the comparatively small investment necessary to develop the expertise with BASIC to know, instead of guess at, its limitations. For people who already know a language like FORTRAN, learning BASIC is a snap. There is even a tutorial tape cartridge for the 4051 that is like a programmed instruction course. It is good for beginners as well as experienced programmers.

There probably is no "pure" form of BASIC in practical use. Most equipment uses extended forms that differ somewhat from one manufacturer to the next, and even from one kind of equipment to the next from the same manufacturer. But these differences typically don't cause big problems. Many programs already written in BASIC can be used with little or no alteration in the 4051. And alterations are simple to make right from the keyboard, using the edit facilities.

Language extensions for graphics

The ability of the 4051 to depict information in graphic form, as distinguished from simply displaying alphanumeric characters and a few straight lines, may be its most valuable feature. But many who need computer data in graphic form may not even know it. You need to think about it a little to know. And if you have always expected computer output in the form of letters and numbers, because that is all you have seen you haven't seen enough. When it comes to your pay check, for example, characters you call take-home pay may be clear enough. But how does your take-home pay over the past 120 months compare to the cost of living? You might be shocked but if this were a scientific business statistic, it would be far better to know than to guess. Would you like that information in a column of 120 figures, or would you prefer a graph?

The need to *compare* data is just as real as the need to have data. A computing system that doesn't help you with the comparisons you need to make may be doing only half its job. And graphs provide a versatile means of comparing data in an easy to understand form.

Only eleven keywords are added to BASIC to handle graphics. Here are a few key concepts represented by keywords:

VIEWPORT: Controls how much of the output surface is used for a graph and where the boundaries will be.

WINDOW: Controls what portion of the available X-Y coordinate data will be placed in the viewport.

SCALE: Divides the X-Y coordinates of the viewport into segments corresponding to the proper numeric values for the graph.

POINTER: Causes the machine to display an arrow positionable with the optional Joystick.

DRAW: Draws a straight line between the present position of the cursor and a specified point in the WINDOW.

RDRAW: (Relative draw) Draws a straight line between the present position of the cursor and a point in the WINDOW specified relative to the position of the cursor.

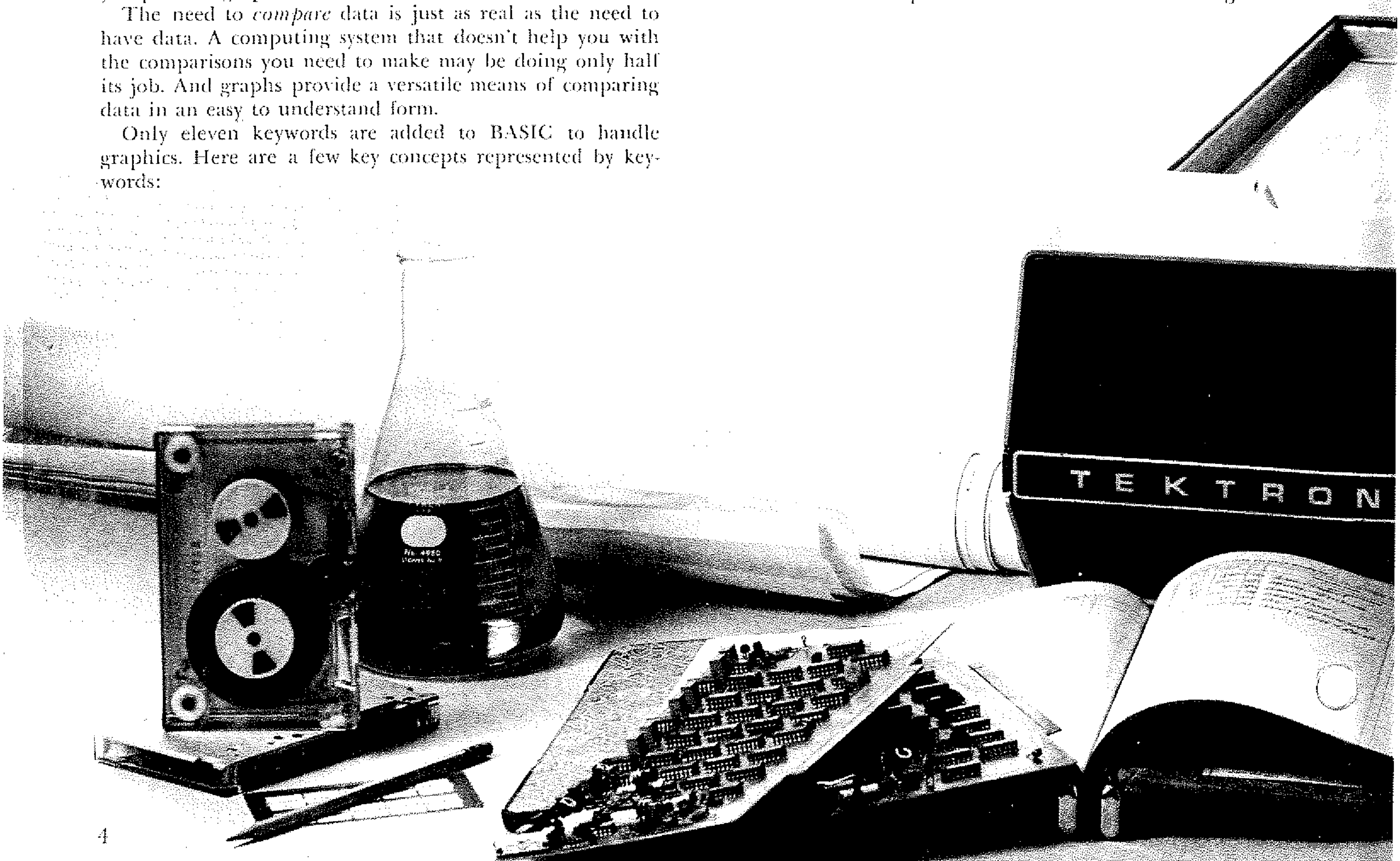
MOVE: Like DRAW except no line is produced.

RMOVE: Relative move. Like RDRAW except no line is produced.

AXIS: X and Y axis lines are drawn and scale tic marks located.

GIN: Graphic Input. Records the location of the graphic point: either the point of the arrow or the lower left corner of the normal 5 x 8 dot matrix rectangular cursor.

ROTATE: Causes relative draw or relative move to follow a path that departs from the normal by a specified number of radians or degrees.



Listener, talker, controller

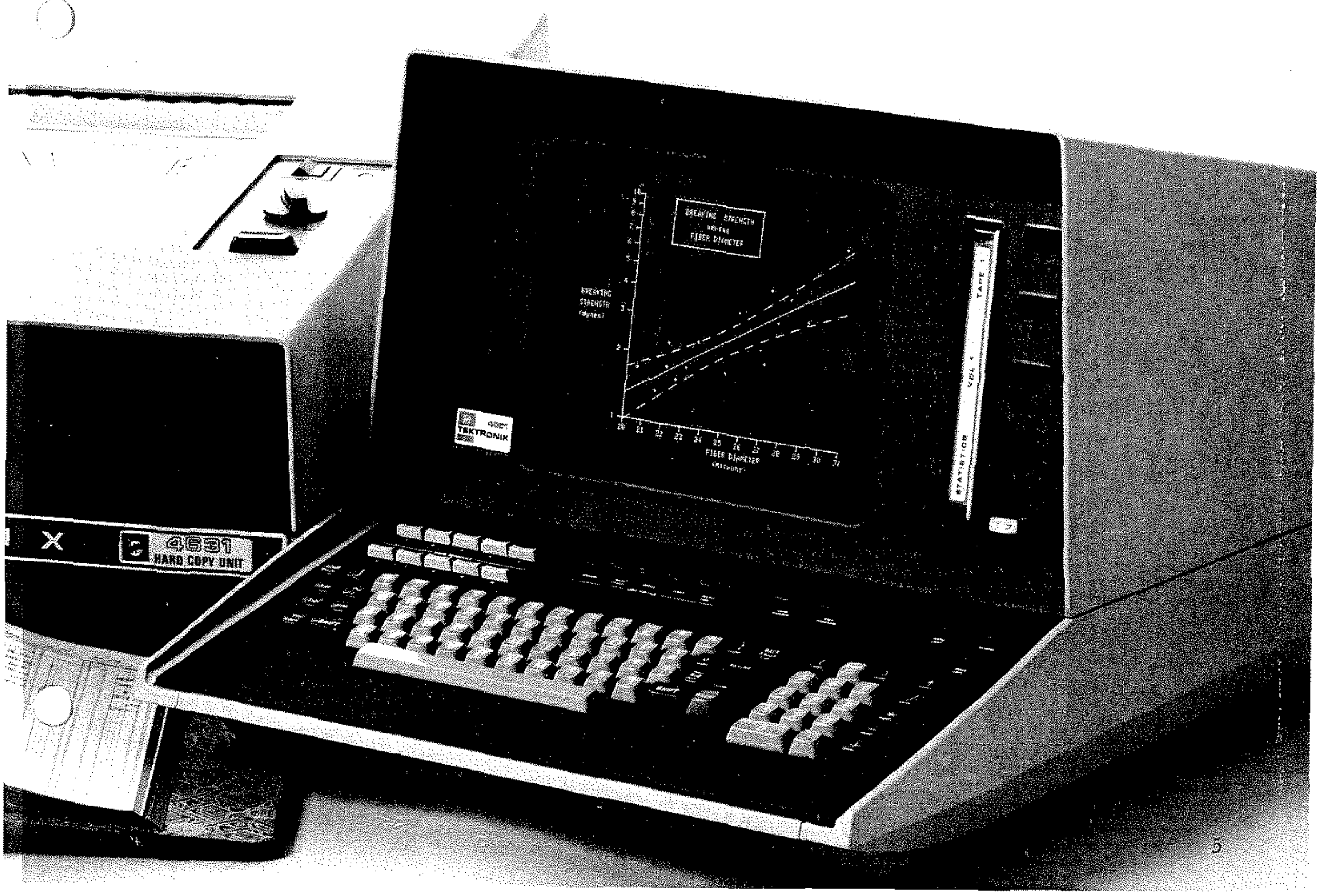
The 4051 is designed to control the operation of instruments in the same sort of way as larger computer-based systems. Whether you want to simply monitor and analyze processes, or control processes, the capability is built in. Perhaps top on the list of the advantages the 4051 offers over former test and process controllers is that it has a new standardized, general-purpose, interfacing system (GPIB). This system, now standard in the U.S., is close to being an international standard. Peripheral instruments under control of the 4051 may be classified as Talkers, Listeners, or both. The 4051 may talk, listen, or control, according to its program and signals on the GPIB. The way in which it goes about this is what has been standardized. Commercially available Talkers or Listeners are already compatible. Future designs will be. The 4051 is at the forefront of a new era of instrument test, measurement, and process control. The U.S. Standard is called IEEE Std 488-1975. It was adopted this year. This standard was sponsored by the IEEE Instrumentation and Measurement Group and is based on work initiated by Working Group 3 of Technical Committee 66 of the International Electrotechnical Commission (IEC). The full title is IEEE Standard Digital Interface for Programmable Instrumentation.

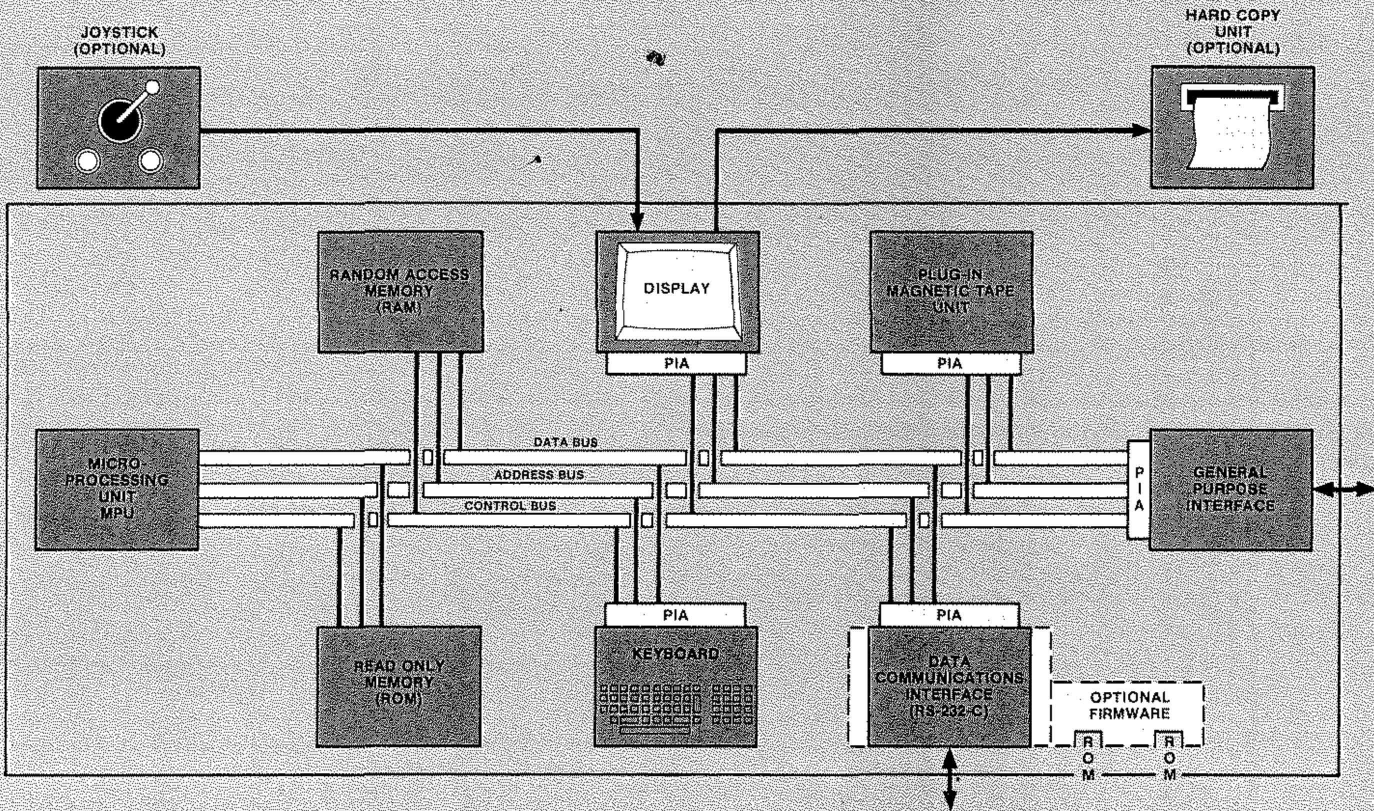
The importance of the standard to many customers is hard to overestimate. It means that equipment built to comply with the standard should work together as a system regardless of who made it. It doesn't mean that any combination of compatible pieces constitutes a worthwhile entity, but it does eliminate the costly, confusing need to do custom interface design work to make some pieces of equipment work together that were not originally intended to.

IEEE Std 488-1975 is for digital data interchange between as many as fifteen pieces of equipment that are separated by no more than a total of 20 meters of interconnecting cables. Data is exchanged with the 4051 at any rate up to 7000 bytes per second and is transmitted in 8-bit bytes over the 8-line Data Bus. Each data byte transfer is controlled by a handshake routine over a 3-wire bus. Five other signal lines are devoted to interface management. Figure 1 shows the bus structure that is shared between different devices that can be connected together in a system. Although any of the devices may talk or listen, only one may control the others and itself. The 4051 has that capability. It constitutes an exceptionally universal tool for controlling sophisticated processes by continually acquiring and analyzing data before issuing new program instructions to its listeners. A copy of the Standard may be purchased from: Standard Sales, IEEE, 345 East 47th Street, New York, NY 10017.

Data communications

The 4051 rear panel has connectors that provide standardized data transfer paths with peripheral equipment in the outside world in *two* standard ways. One is via IEEE Std





Functional description

Microprocessing unit (MPU): Directs systems operations. Solicits one instruction at a time from the ROM by placing a 16-bit address on the ADDRESS BUS. Decodes and executes the instruction received on the DATA BUS, then fetches the next instruction.

Read only memory (ROM): A semiconductor memory with 36K 8-bit byte capacity containing full permanent set of BASIC instructions for the microprocessing unit.

Random access memory (RAM): A semiconductor memory for temporary storage of intermediate results of arithmetic operations and BASIC instructions for the microprocessing unit. Contains 8K, 16K, 24K, or 32K 8 byte storage capacity.

Display: Rectangular, flat-faced, 11-inch diagonal, direct-view storage crt. Serves as the primary output device for alphanumeric characters, graphs, and line drawings.

Keyboard: Primary user input. Statements in BASIC are typed here and each alphanumeric character appears on the crt as it is typed. Appropriate calculations and other responses to each completed statement immediately follow the last keystroke in each statement. Editing keys allow programs to be altered and typing errors to be corrected. User-definable keys make it simple and fast to execute any one of up to 20 preprogrammed sub-routines by pushing the right key.

Plug-in magnetic tape unit: A 3M® Data Cartridge with capacity of 300K 8-bit bytes. It allows the operator to make a permanent record of whatever may be stored in the RAM and allows data and programs to be placed in the RAM from the tape.

General purpose interface: Provides asynchronous communications with and control of instruments and other peripheral devices designed to be compatible with the IEEE Std 488-1975.

Data communication interface: Provides communications with data terminal equipment or data communication equipment designed to be compatible with EIA Standards RS-232-A, B, or C. A second RS232 output-only interface is available for control of printers. Both are optional.

Optional firmware: Another part of the Data Communications Interface. Contains receptacles for one or two specialty plug-in ROM's that may be bank-switched under program control to substitute for the internal ROM.

Peripheral interface adapters (PIA): IC's that are part of a family of components that includes the MPU, ROM, and RAM. Integral sections of the 4051, such as the Keyboard, Magnetic Tape Unit, GPIB Interface, and Display Unit, are connected to the DATA, ADDRESS, and CONTROL buses through these adapters. Although such sections are integral parts of the 4051 they are considered peripheral with respect to the MPU. Each adapter has unique 16-bit addresses that it responds to when the MPU wants to communicate with the peripheral at those addresses.

Joystick: A single handle control for arbitrarily positioning the axis of a graph to a particular point on the crt screen.

Hard copy unit: A unit for copying all the data displayed on the crt screen at any particular time.

488-1975, just discussed. The other is optional and is part of what is called a Data Communications Interface. It works with equipment that complies to EIA Standards RS-232 A, B, or C, transmitting data serially one binary bit at a time to such peripherals as line-printers, keyboard terminals, and to host computers.

A Data Communication Interface is made optional to avoid having to charge all customers for both kinds of interface circuits. It is for two-way communications, full duplex, or half duplex, odd, even, or no parity. The baud rate can be either 110, 150, 300, 600, 1200, or 2400 selectable by the user under program control.

Intelligent graphic terminal

It is easy to see the value of the 4051 as an intelligent terminal. The lion's share of the charges for time-shared computers usually falls into three categories: the number of seconds the computer is working for you, the number of minutes you are connected to the computer, and the number of minutes you are using the phone lines. In most cases the connect charges are the most expensive part of the bill. You can reduce these charges by taking programs off the host or by using the plug-in 4051 tape to transfer data to the host. That saves accessing it through the keyboard at the slow typing speed of the operator. Reductions in connect charges alone will typically pay for a 4051 in less than a year.

When your desk-top machine has access to the vast amount of data that you may store in a large computer, it is a great convenience. That way the data doesn't have to be duplicated in other storage devices and may be updated as frequently as necessary. When you can conveniently give your computer only those problems too big for your desk-top machine you also save money. That becomes an inviting practical possibility if your local terminal has enough intelligence to communicate directly with a host computer. It lets an operator interact only when he needs to, instead of acting as interpreter between his local desk-top machine and a remote wall-to-wall computer.

The new technology

Several recent technological advancements have made it possible to reduce the size, cost, and complexity of the 4051. The 3M® Data Cartridge is a small, fast, inexpensive magnetic tape cartridge that plugs into the front, containing 300 feet of tape able to store up to 300K 8-bit bytes of data or program instructions. This tape reads from, or writes into, an integrated circuit random access memory that is part of a family of IC's that make up a commercially available microcomputer family. The microprocessing unit that is the head of the family, is also the workhorse of the 4051. The architecture of the whole system is based on it. A wired-in 36K byte read-only memory contains a full, permanent set of instructions that are responsive to BASIC language statements made from the keyboard or the program in progress. Part of that memory is reserved for bank-switching to one or more plug-in ROM's to expand on the primary set of instructions if needed. This feature makes it possible to add special-purpose functions to the machine in response to a particular application problems.

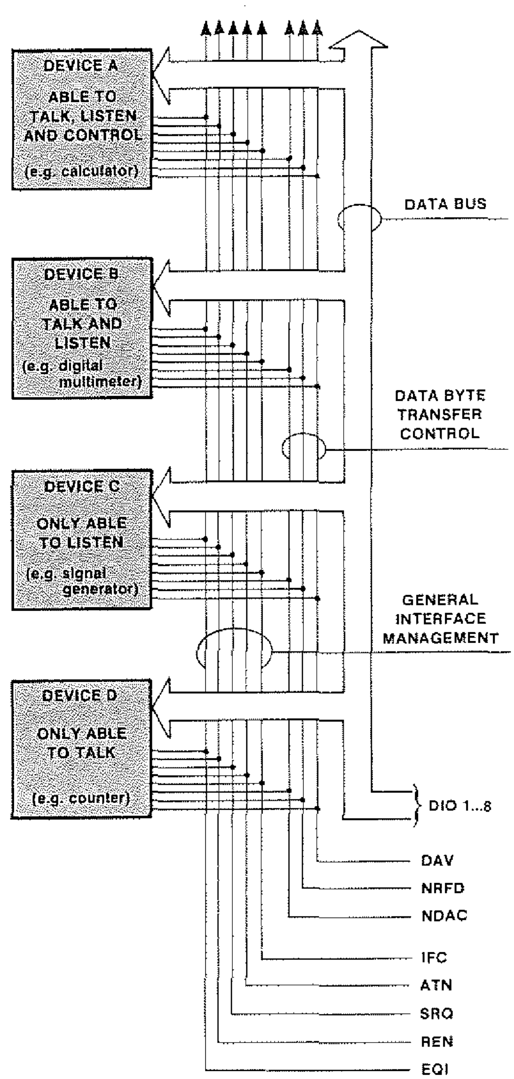
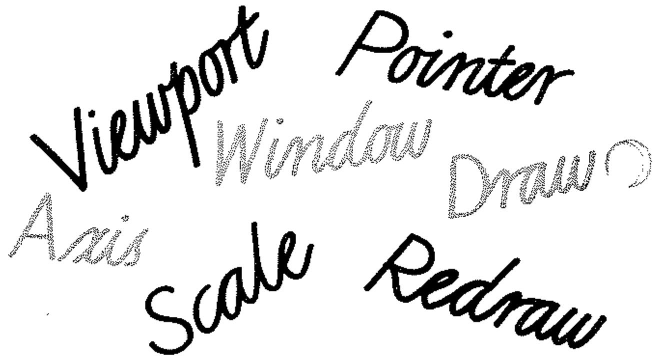


Fig. 1. The 4051 uses the IEEE Standard Digital Interface for Programmable Instrumentation portrayed here.

Tom Needham



Graphing with the 4051 graphic computing system

Until a few years ago the equipment necessary to make graphic displays with a computer was extremely expensive. Then the invention of the bi-stable storage crt at Tektronix led to the development of crt computer terminals and software that gave the world a simple, inexpensive graphic system. Until the 4051 came along, however, graphing required the help of a host computer or calculator. The 4051 has great computational power built-in. It can do computations and display the results graphically all on its own. And it can be made compatible with host computers through an optional RS-232-C standard interface, making it easy to use existing programs and the huge data-bases that some people have on tap at a host computer.

Operating the 4051 so it will display data graphically, as well as with alphanumeric characters, is much easier to learn than you would suppose. If you already know BASIC as a programming language, the task will be especially easy. There are only eleven additional keywords to learn. And once you understand their meaning and function, the whole process of plotting graphs will probably be clearer than it ever was before. If you have used TEKTRONIX PLOT-10 software with a Graphic Computer Terminal you will already be familiar with most of the words. For the 4051 they are:

VIEWPORT	DRAW	AXIS
WINDOW	RDRAW	GIN
SCALE	MOVE	ROTATE
POINTER	RMOVE	

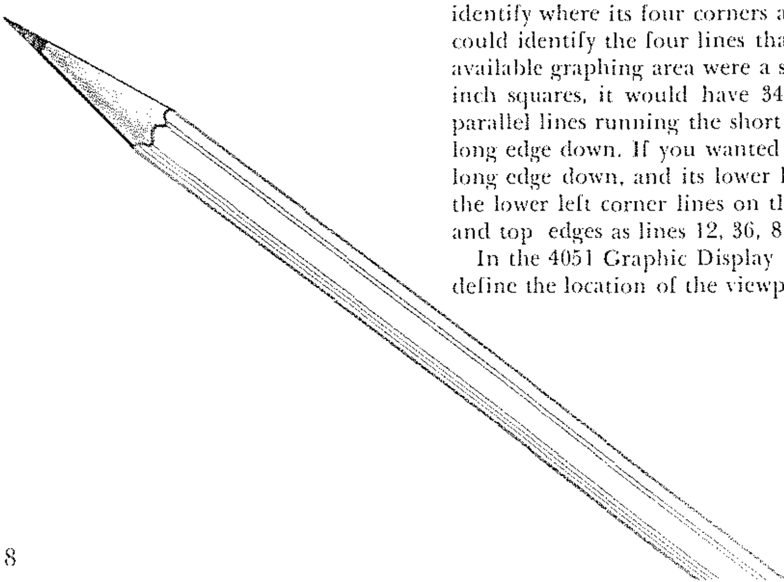
The Cartesian Coordinate system is a way of identifying the location of any point on a plane by first drawing and scaling two straight perpendicular lines in the plane. The lines are called axes. A unique pair of numbers corresponding to the scalar distance between any point and each line, will tell you where that point is.

After scaling the axes with appropriate numbers, the relationship between two variables, X and Y, can be shown graphically by calling one axis X, the other Y. (See Fig. 1)

The viewport

What things should you decide first when you proceed to make a graph of this kind? For one thing you decide what portion of the available graphing area you want to use. We call that portion the viewport. How would you describe it? You could identify where its four corners are. That would take four pairs of numbers. Or you could identify the four lines that are the sides of the rectangle. For example, if the available graphing area were a sheet of 8½ by 11 inch graph paper consisting of ¼ inch squares, it would have 34 parallel lines running the long direction, and 44 parallel lines running the short direction. Let us say the paper was placed with its long edge down. If you wanted the viewport to be a 5 by 6 inch rectangle with its long edge down, and its lower left corner 3 inches to the right and 2 inches above the lower left corner lines on the paper, you could describe the left, right, bottom, and top edges as lines 12, 36, 8, and 28 respectively.

In the 4051 Graphic Display System we use the Graphic Display Unit concept to define the location of the viewport (see Fig. 3.). A Graphic Display Unit is defined



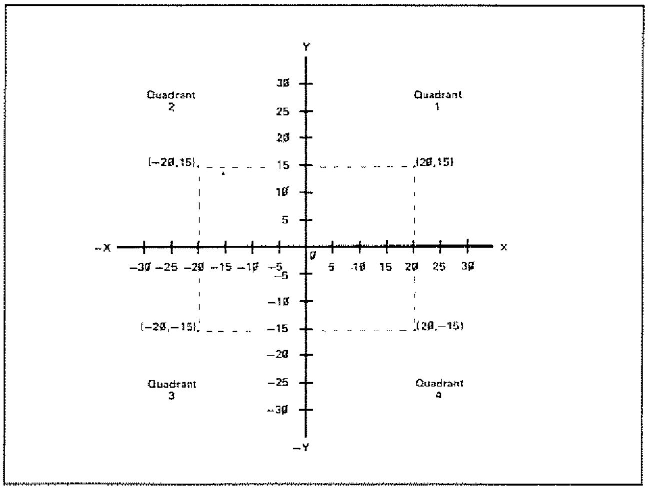


Fig. 1. The Cartesian Coordinate System provides a convenient way to locate any point on a two-dimensional plane. An example is shown below.

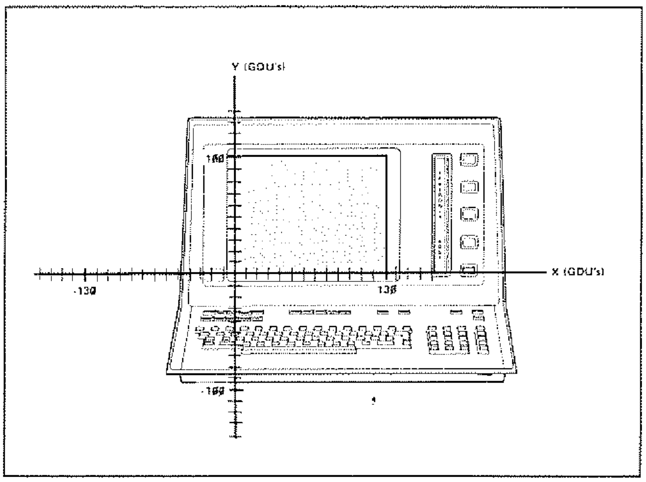


Fig. 2. The drawing surface of the 4051 crt display represents the first quadrant in a Cartesian Coordinate System as illustrated. The lower left corner of the display represents the point of origin. The X and Y axes are marked off in Graphic Display Units to illustrate this concept.

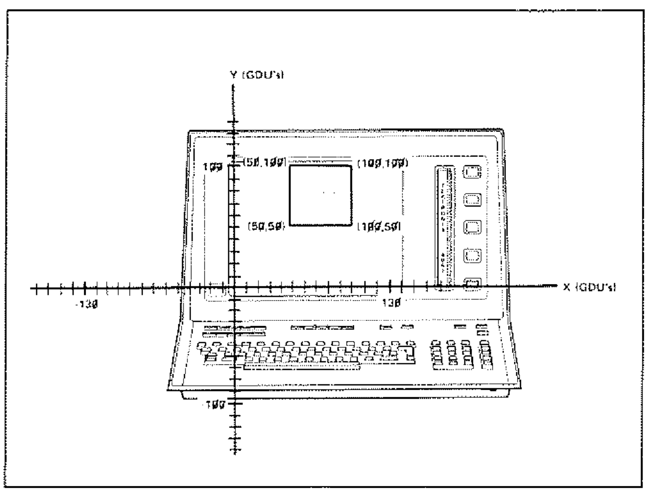


Fig. 3. The VIEWPORT statement controls the boundaries of the drawing surface. Sometimes it is necessary to reduce the size of the drawing surface to leave room for printed messages. The statement for the above viewport would be VIEWPORT 50, 100, 50, 100

to be 1% of the shortest edge length of a given graphic device. It can be thought of as a percentage of a distance rather than as a discrete indivisible unit. For example, a distance of 23.12 GDU's is different from 23.13 GDU's. The use of GDU's permits using the same program to place a graph on the 4051's display screen, an external X-Y plotter, or any future display device in the 4050 family.

It is important to differentiate between Graphic Display Units and the user's data units. The only time you, as a 4051 user, will work with GDU's is when you use the VIEWPORT command to locate your graph on the display device. At all other times you deal with your own data units whether they be fortnights, furlongs, or whatever.

When you use an appropriate set of four numbers with the VIEWPORT statement, the 4051 will automatically confine its graphing within the boundaries described by the numbers. You may still choose to write outside that area with alphanumeric characters, however.

Resolution

The choices of boundaries for the viewport are limited to 100 by 130 Graphic Display Units when graphing on the 4051 crt. But that should not be understood as being the resolution limits of the 4051. The resolution limits depend primarily on the characteristics of the graphic readout device. When the readout device is the 4051 crt, the resolution limit is determined by 10-bit digital-to-analog converters in the 4051. This translates to 1024 increments in the horizontal direction and 780 increments vertically. When the 4051 addresses an external graphic readout device, like an X-Y digital plotter, resolution will be limited by that device.

The window and the scale

The Cartesian Coordinate graphing world of the 4051 extends to numbers as high as 10^{308} for points in all four quadrants. That is an extremely vast plane compared to the portion occupied by any ordinary graph. For most data it is much more than adequate. What portion of that vast plane the data you want to examine fits into can be regarded as the window you wish to look at. When the WINDOW statement in the 4051 is followed by the minimum and maximum values for the horizontal and vertical data that you want to graph, you are prepared to fill the viewport with the graphic data you want. It doesn't matter what units the data is in, or whether some data entered may fall outside the limits. Any graphic data entered that falls outside the limits will be automatically ignored, but the rest will be displayed.

An alternate way of fitting the data you want to view, to the viewport where it will be displayed, is to use the SCALE statement. Then the graphic data is scaled down to the area for the graph by specifying how many user units fit into one Graphic Display Unit.

Axis and tic marks

Once the minimum and maximum values for each axis has been identified, the window is defined and the location of each axis can be determined. The AXIS command automatically draws horizontal and vertical axes, with tic marks if desired.

If the range of numbers on either axis extends both sides of zero, the other axis line will be drawn through the point corresponding to zero. Otherwise, when all values are positive, the axis intercept point will be at the lower left corner of the window area. The 4051 will draw axes in the customary way simply by default, once it has the window informa-

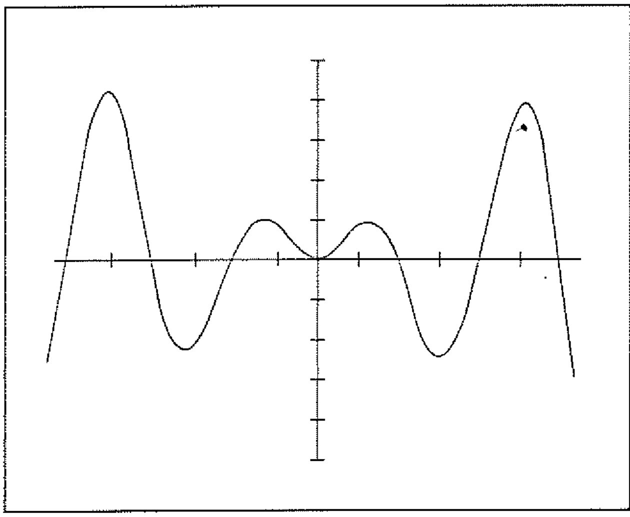


Fig. 4. The ease with which graphics can be generated on the 4051 is illustrated by this graph which was drawn using just seven program steps.

tion and receives the AXIS statement. Tic marks on one or both axes will be added automatically if the AXIS statement is followed by numbers for the desired size of the increment. The tic marks are automatically spaced and located on each axis to correspond with the user's units for each axis. Numbers can be added adjacent to the tic marks later if desired. Logarithmic axes, however, require a different technique.

Absolute and relative moves and draws

In one sense you draw a graph with the 4051 very much the same way as you would by hand, with a piece of chalk on a blackboard. The chalk can be moved from one point to another without drawing a line, if you lift it. On the 4051, the crt beam is turned off for MOVE statements and turned on for DRAW statements. The same is true for relative move (RMOVE) and relative draw (RDRAW) statements. The difference between absolute and relative moves is that absolute moves are stated with respect to the last point the beam was moved to. The same is true about the difference between absolute and relative draws.

A line is drawn each time a simple DRAW command is executed. From that, it is easy to make the assumption that the 4051 takes a lot of time to draw a complex curve. But not so. By storing data points in two matrices, even a long series of draws is executed very rapidly. The array variables representing the two matrices are specified in the DRAW statement.

How really simple it is to draw a complex graph on the 4051 is best illustrated by considering the graph in Fig. 4. It took just seven program steps to construct the graph:

```
100 VIEWPORT 10, 120, 10, 90
110 WINDOW –10, 10, –10, 10
120 AXIS PI/2,2
130 MOVE –10, 10*SIN (10)
140 FOR I=10 to 10 STEP 0.2
150 DRAW I, I*SIN(I)
160 NEXT I
```

The VIEWPORT statement was used to reduce the size of the graph on the display. If we had wanted the graph to fill the screen, the VIEWPORT statement could have been omitted as the viewport parameters are automatically set to 0, 130, 0, 100 by default on system power up and after the execution of an INIT statement.

Dot matrix, pointer, gin

When the 4051 crt is producing an alphanumeric or graphic readout, the position of the last character or point is identified by a blinking marker. The marker is a small 5 by 8 dot matrix the same size as the outer limits of an alphanumeric character. The POINTER command places a small arrow on-screen. The position of the arrow can be controlled by an optional Joystick, or selected by the user definable keys. Using the GIN command, the X-Y coordinates of the point selected by the arrow are assigned to two variables and can be used by a program to keep track of its position.

About speed

Everyone wants to know how fast his computer or calculator is. It is a natural, important question that is very difficult to answer satisfactorily. The same question applies to the 4051, and is even a little harder to answer. If the 4051 is controlling peripheral instruments and is waiting for data from one of them before finishing a computation, it would be misleading to talk about how fast or how slow the 4051 was. On the other hand, if it is merely calculating 50 factorial, or doing a similar bench mark computation, you would like to know how the time it takes to perform this function compares with other similar equipment. But what are you to conclude when some of the bench marks are met better by equipment A than by equipment B, but other bench marks are met better by B than by A? You can start by being selective about which bench marks are more typical of your work. That is not a bad way. It leads you to the conclusion that the speed question may be answered satisfactorily by comparisons on each job. The main thing we want to know is whether a machine is fast enough for our job. If, on the average, it is slower than what we are used to, it follows that it should be more economical to be worthy of consideration. If, on the other hand, it does the things you want it to do, as fast as you expect, and has the price and advantages you can't equal elsewhere, it is fast enough.

For most jobs, the 4051 speed is comparable to a minicomputer executing a BASIC program. The graphic capability, ease of programming, and low cost of the 4051 Graphic Computing System can be important factors in solving your application problems in a more effective and productive way. It certainly bears looking into.

Fred Telewski

A high-stability 100 KHz to 1.8 GHz tracking generator

Tracking generators, working with spectrum analyzers, offer significant advantages over other frequency-response measurement techniques. A continuous, well-defiined display, freedom from distortion, wide dynamic range, and operating ease are all benefits derived from using a tracking generator/spectrum analyzer system.

These advantages arise from the fact that the tracking generator's output frequency is synthesized from the spectrum analyzer's local oscillators. The tracking generator's output frequency is always the same as the instantaneous frequency of the analyzer, and the frequency stability is essentially equal to that of the analyzer.

High-resolution, high-stability measurements up to 110 MHz have been possible for some time using tracking generator/spectrum analyzer systems. Now, two new tracking generators, the TR 501 and TR 502, designed to work with the 7L12 or 7L13 Spectrum Analyzer, extend this measurement capability to 1.8 GHz. The TR 501 and TR 502 are essentially the same instrument with the exception of the output attenuators and logic interface in the TR 502. For purposes of brevity we will confine this discussion to the TR 502.

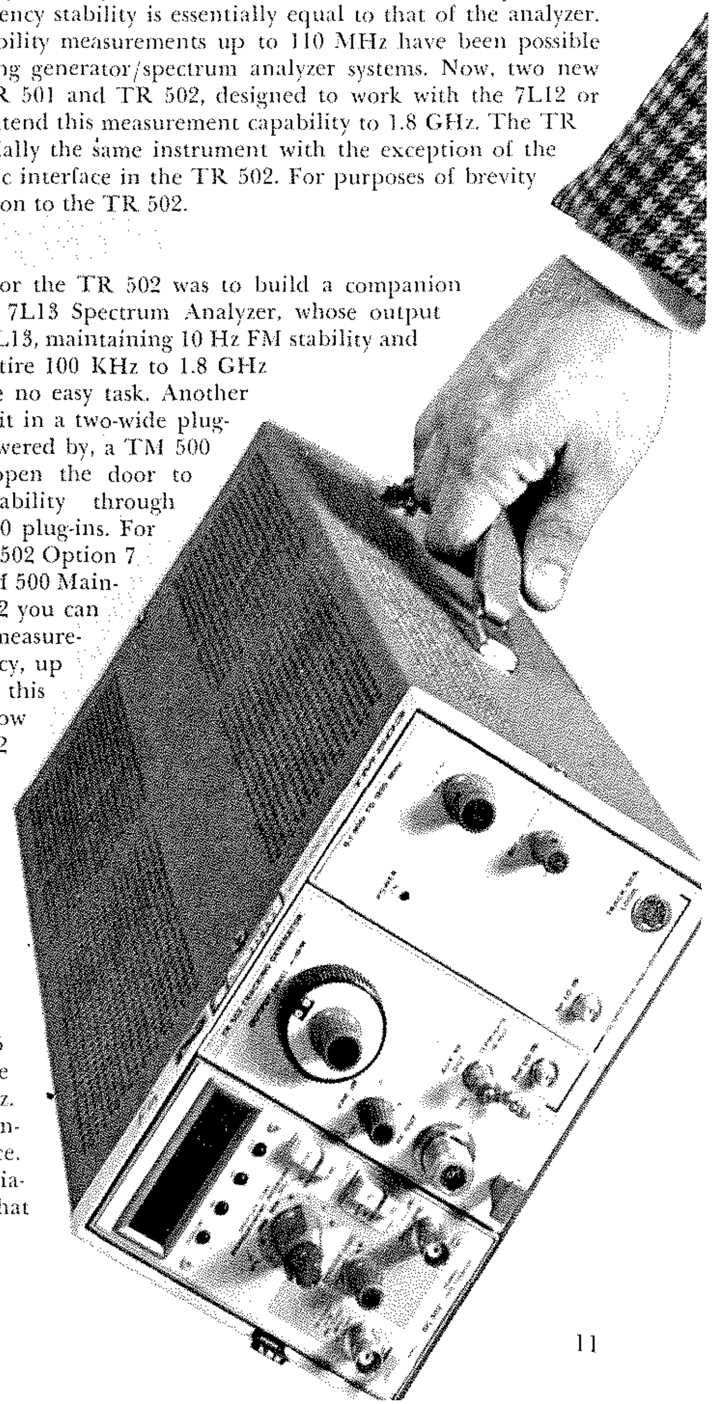
Design goals

The primary design goal for the TR 502 was to build a companion tracking generator for the 7L13 Spectrum Analyzer, whose output would faithfully track the 7L13, maintaining 10 Hz FM stability and display flatness over the entire 100 KHz to 1.8 GHz range. This promised to be no easy task. Another goal was to package the unit in a two-wide plug-in to be housed in, and powered by, a TM 500 Mainframe. This would open the door to added measurement capability through working with other TM 500 plug-ins. For example, by plugging a DC 502 Option 7 Digital Counter into the TM 500 Mainframe powering the TR 502 you can make selective frequency measurements, with counter accuracy, up to 550 MHz. We'll discuss this in greater detail later. Now let's look at how the TR 502 works.

Theory of operation

The spectrum analyzer (7L12, 7L13) up-converts its input signal frequency to a 1st IF of 2.095 GHz by mixing with the 1st LO (local oscillator). It then down-converts the 2.095 GHz to an IF of 105 MHz by mixing it with the 2nd LO frequency of 2.2 GHz.

The TR 502 Tracking Generator reverses this sequence. Referring to the block diagram in Figure 2 we see that



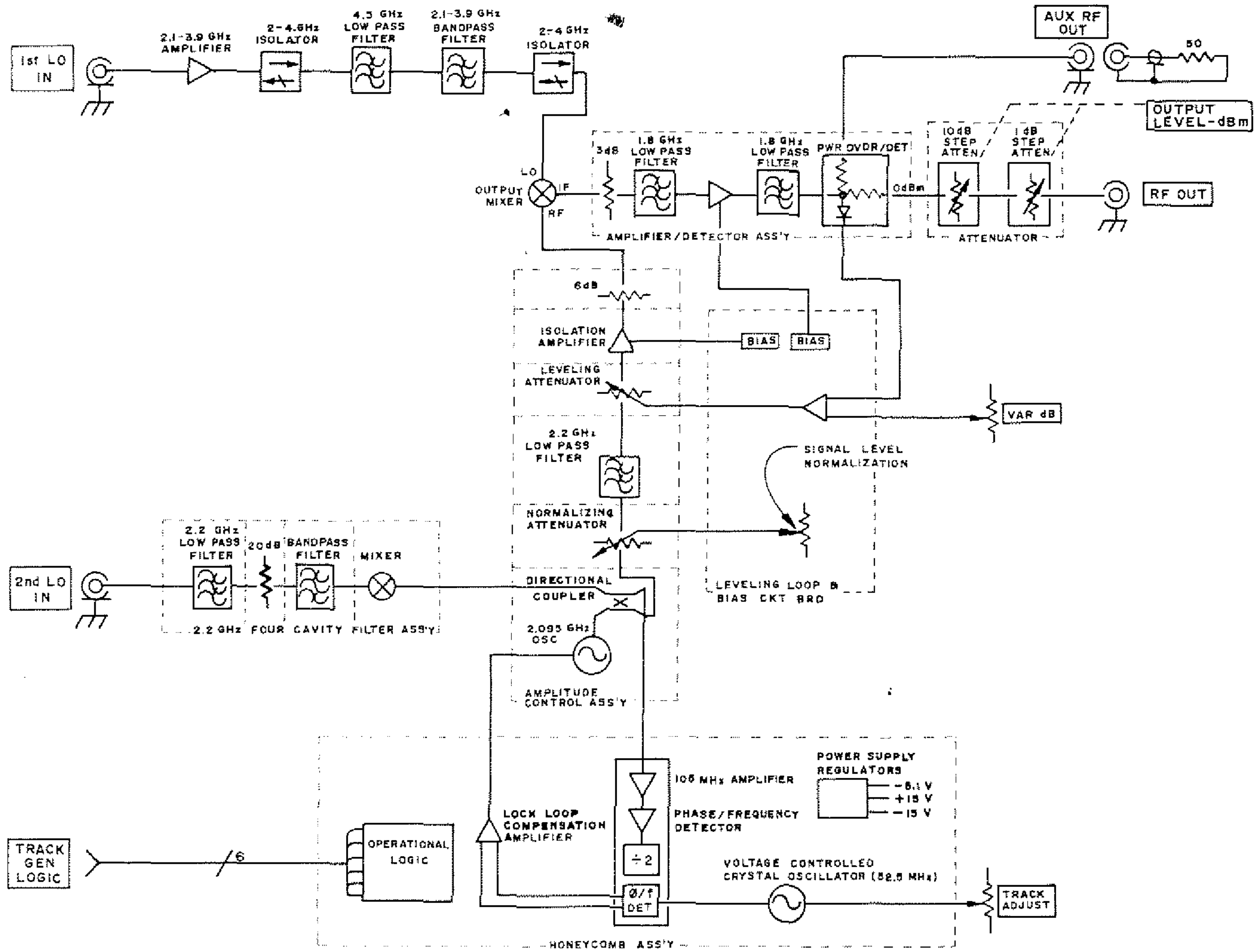


Fig. 1. Block diagram of the TR 502 Tracking Generator.

the 1st LO and 2nd LO from the spectrum analyzer are fed into the TR 502. A voltage controlled oscillator running at 2.095 GHz is mixed with the 2nd LO input of 2.2 GHz. The resultant 105 MHz difference frequency is used in a phase lock loop to keep the 2.095 GHz oscillator in step with the 2nd LO.

The 1st LO input signal ranges from 2.1 to 3.9 GHz and may be either a constant or swept frequency depending on the operating mode of the spectrum analyzer. The 1st LO signal is mixed with the 2.095 GHz signal, with the resultant lower difference frequency becoming the output signal frequency of the tracking generator. The output signal is filtered, amplified, automatically leveled, and applied through a step attenuator to the output connector of the tracking generator. Now let's look at the block diagram in greater detail.

The 1st LO signal

The input signal from the spectrum analyzer 1st LO is amplified to a level of about 6 mW by the 2.1 GHz to 3.9 GHz limiting amplifier. From the limiting amplifier the signal passes through a series of isolators and filters to the output mixer. The LO signal level at the output mixer is about 5 mW.

Several different types of filters are used in the TR 502, each chosen for its particular characteristics. The 4.5 GHz low-pass filter is a tubular type, while the 2.1 to 3.9 GHz bandpass filter is a 16-element interdigital filter. An interesting side-point is that in manufacturing the interdigital filter, combined tolerances are held to less than 0.001 inch to eliminate the need for tuning the filter.

The role of the 2nd LO

Turning to the 2nd LO input, we see that the signal passes through a 20 dB attenuator, to a 2.2 GHz low-pass filter, and thence to a two-diode balanced mixer. All of which are housed in the four-cavity bandpass filter assembly pictured in Fig. 2.

The 2.2 GHz signal is mixed with the 2.095 GHz oscillator signal to generate the 105 MHz signal used to phase lock the 2.095 GHz oscillator. The 105 MHz signal is divided by two and compared to a 52.5 MHz crystal-controlled oscillator to develop the compensating phase lock signal.

The 2.095 GHz oscillator uses a resonant micro-strip line in the collector of a common-base transistor oscillator to establish its frequency. It is tuned over a range of about 20 MHz by varying the collector voltage to change the collector-to-base capacitance.

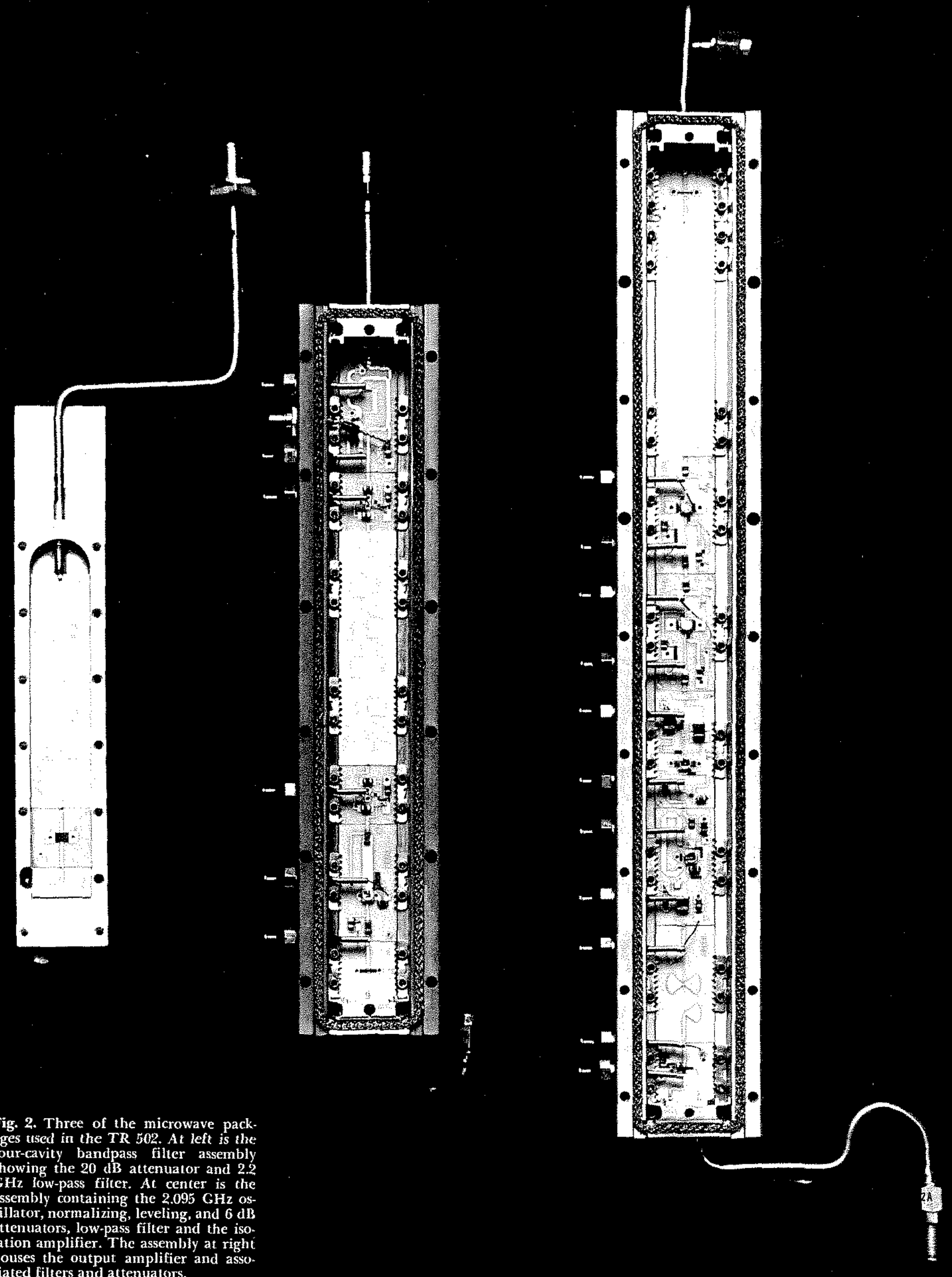


Fig. 2. Three of the microwave packages used in the TR 502. *At left is the* four-cavity bandpass filter assembly showing the 20 dB attenuator and 2.2 GHz low-pass filter. *At* center is the assembly containing the 2.095 GHz oscillator, normalizing, leveling, and 6 dB attenuators, low-pass filter and the isolation amplifier. The assembly at right houses the output amplifier and associated filters and attenuators.

The 2.095 GHz signal passes through a directional coupler to a PIN-diode attenuator where initial adjustment of the output level range is made. The signal then passes through a 2.2 GHz low pass filter to a second PIN-diode attenuator, where automatic leveling of the TR 502 output signal occurs. Since the IF amplitude level out of the mixer tracks the rf signal level (with about 6 to 8 dB of loss), we control output signal amplitude by controlling the rf signal level into the mixer. From the leveling attenuator, the rf signal passes through an isolation amplifier providing about 7 dB of gain and greater than 20 dB of reverse isolation. Its output drives the output mixer through a 6 dB attenuator.

The 2.095 GHz oscillator, normalizing, leveling, and 6 dB attenuators, the low-pass filter, and isolation amplifier are constructed in a comprehensive hybrid and microwave package (dubbed CHAMP by the project engineers). This type of construction offers tremendous flexibility and economy compared to earlier techniques.

The output amplifier

The output amplifier section also uses the same type of construction (See Fig. 2). The lower conversion frequencies from the output mixer pass through a 3 dB attenuator and 1.8 GHz low-pass filter to the wideband amplifier. The 3 dB attenuator provides a wideband termination for the mixer. The 1.8 GHz low-pass filter is an elliptic function filter, flat to 1.8 GHz and rolling off with a sharp notch at 2.095 GHz. The 0 to 1.8 GHz signal is amplified by about 40 dB by the four-stage wideband amplifier, then passes through another 1.8 GHz low-pass filter to the power divider and level detector. Each stage of the output amplifier is supplied by a separate bias supply. The bias circuits and amplifiers are connected as a feedback loop with the collector load current of the amplifier sensed by the input resistor to the operational amplifier. This voltage is compared to a +10V reference. The operational amplifier output drives the base of the rf amplifier to set the bias, holding the collector voltage constant at +10 volts. The 1.8 GHz low-pass filter following the amplifier attenuates frequencies above 1.8 GHz which may be generated by the amplifier.

The level detector is a directional peak detector that senses the forward power but not the reflected or reverse power. Forward power is independent of the load. The output attenuator provides calibrated 1 and 10 dB steps of output power over the range of 0 dBm to −59 dBm, with a variable control adding up to 2 dB of attenuation between steps. The output amplitude is flat within ±0.5 dB from 100 KHz to 1.8 GHz. The TR 502/7L13 system is flat within ± 2dB over the same frequency range.

Operational innovations

We mentioned earlier that the TR 502 could be used with the DC 502 Option 7 Digital Counter for making accurate frequency measurements. Through an innovative technique, using dual rf outputs, frequency can be measured accurately at spectrum analyzer sensitivities. The theory of this powerful convenience is very simple. The sweep generator in the analyzer stops at mid-screen, and a command is sent through the tracking generator to the counter to count. When counting is completed (in 10 or 100 ms), the counter commands the analyzer to continue the sweep. The user sees the momentary pause as a bright dot at mid-screen. The count time, and hence the resolution of the measurement, is determined by the phase lock mode of the analyzer.

When the analyzer is operated in manual, external sweep, or a non-sweep mode, the counter will count continuously. The DOT INTENSITY control on the TR 502 enables the logic circuitry for counter measurements and sets the dot intensity on the analyzer display.

Mechanical innovations

The bulk of the rf circuitry is housed in the left-hand portion of the plug-in. We have already mentioned the comprehensive hybrid and microwave package used for the 2.095 GHz oscillator and associated signal path components, and the 0 to 1.8 GHz amplifier. Pretesting of the individual substrates in these units saves considerable final test time and substantially reduces the likelihood of encountering a defective unit in final test. The cost of repairing these units is also minimal since a failure does not necessitate replacing the entire unit. The defective substrate can be quickly isolated and replaced at a fraction of the cost of the entire assembly. The right hand half of the plug-in contains a 6-compartment honeycomb casting that houses the 105 MHz amplifier, 52.5 MHz oscillator, the ø/f detector, and the bias and leveling circuits. Excellent shielding, good rf environment, ruggedness, and good serviceability are provided by the honeycomb structure.

Summary

The TR502/7L13 Tracking Generator, Spectrum Analyzer system provides highly accurate frequency response measurements over the range of 100 KHz to 1.8 GHz with resolution to 30 Hz. This narrow bandwidth resolution yields a wide dynamic range (> 110dB) permitting measurements well down on the skirts of device responses. The system can be used with the DC 502 Option 7 Digital Counter to select and accurately determine frequencies up to 500 MHz. As a CW source, the TR 502/ 7L13 offers a stability of 10 Hz when the analyzer is in a zero-span (non-sweep) mode.

Acknowledgements

Fred Telewski was Program Manager for the TR 502 project. Assisting in electrical design were Glenn Bateman, Michael McMahon, David Morton, and Phillip Snow. The mechanical design team included Carlos Beeck, Jack McCabe, and Leighton Whitsett.

For complete specifications on the TR 502 we invite you to return the inquiry card accompanying this issue of Tekscope.

Dave McCullough

Delayed gate aids oscilloscope digital measurements

The oscilloscope is basically an analog measurement device. We say "basically" because, with the introduction of digital plug-ins for the TEKTRONIX 7000-Series Oscilloscopes, digital measurements were added to the oscilloscope's repertoire.

One of the major advantages of making digital measurements with an oscilloscope is the ability to view, and select, the precise portion of the signal to be measured. The dual time base capabilities of a plug-in like the 7B53A, with Delayed Gate output, permit some highly selective digital measurements. Typical applications include accurate time measurements between two points on the same waveform, an accurate count of events in a sudden burst, or accurate voltage sampling between any two points on a waveform. Figures 1 through 3 illustrate these measurements. In each instance, the Delayed Gate is used to control the digital plug-in.

The brightened portion of the trace corresponds to the time and duration of the

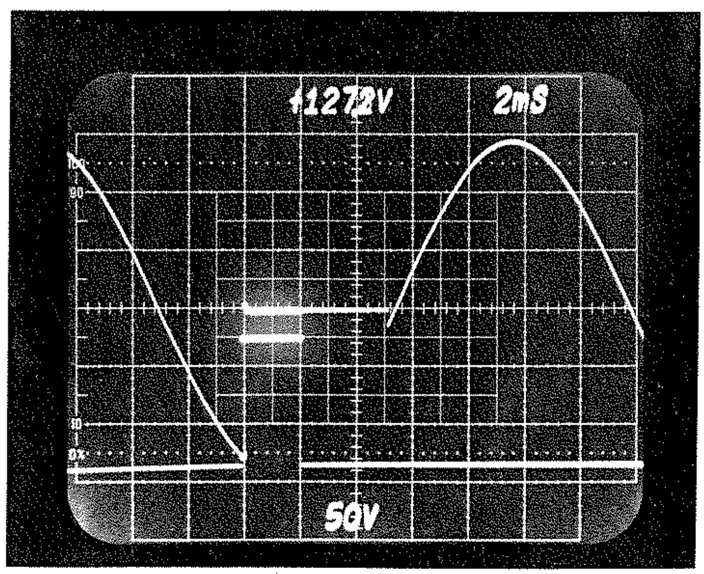


Fig. 1. The 7D12 A/D converter plug-in with an M2 Sample/Hold Module measures the voltage excursion on the anode of a silicon-controlled rectifier at the instant it is gated on. The period of measurement is selected by the Delayed Gate, displayed on the lower trace.

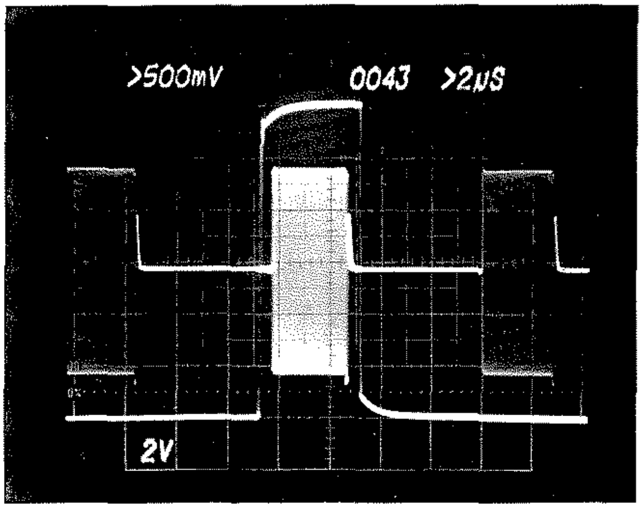


Fig. 2. The number of pulses in a burst are readily counted by bracketing the burst with the Delayed Gate to gate a digital counter plug-in such as the 7D14 or 7D15.

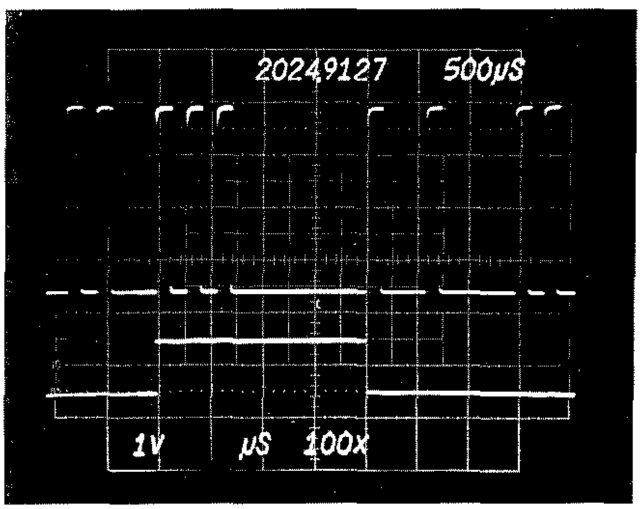


Fig. 3. The time between two selected events can be accurately measured by using the Delayed Gate to start and stop a counter such as the 7D15 Universal Counter/Timer. In this photo CH A of the 7D15 is armed by the Delayed Gate rise and CH B is armed by the fall. The count is started by the rise of the third pulse and stopped by the rise of the sixth pulse. The lower trace is the 7D15 pseudo gate display showing the counting interval.

Delayed Gate, and to the period during which the digital measurement will be made. The start of the Delayed Gate is controlled by the Delay Time Multiplier, while gate width is selected by the Delayed Sweep TIME/DIV (for the coarse adjustment). The Delayed Sweep VARIABLE serves as the fine width adjustment.

Internal GATE and VARIABLE selection

To simplify operation and reduce front-panel complexity yet maintain versatility, some controls and connectors on the 7B53A front panel are made to perform dual functions, as selected internally. Figure 4 shows the VARIABLE functions available by relocating the Variable Selector Connector, and the Delayed Gate Out Connector that applies the Delayed Gate Out to the DLYD TRIG IN connector. It takes just a few minutes to make the changes needed to obtain a variable Delayed Gate at the front-panel.

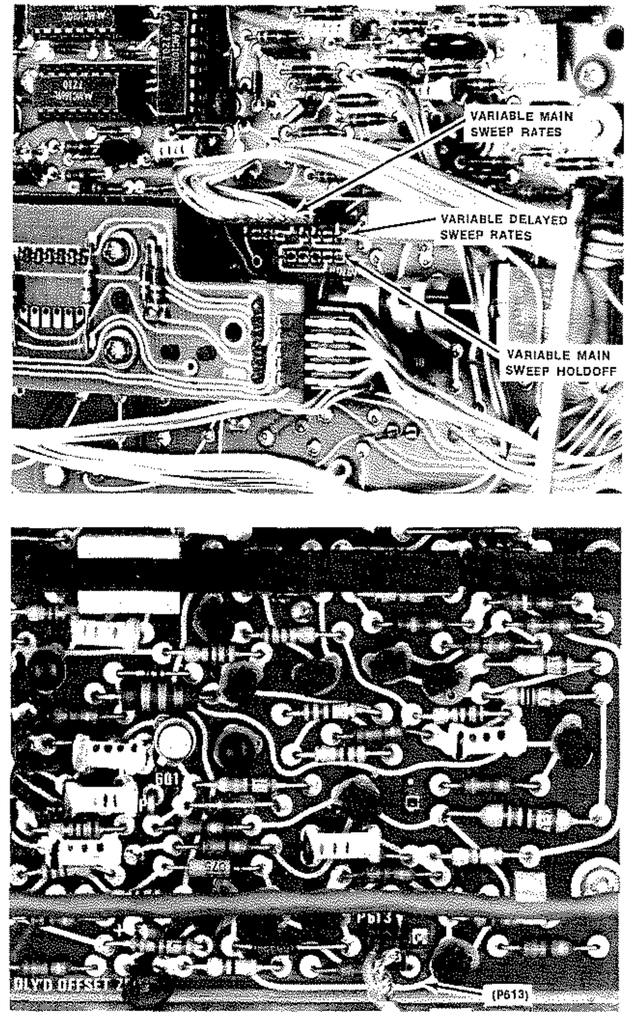


Fig. 4. The function of the front-panel VARIABLE control is determined by the position of the Variable Selector Connector shown in the upper photo. The Delayed Gate Out Connector shown in the lower photo applies the Delayed Gate Out to the DLYD TRIG IN connector.

Summary

Digital measurements on analog signals are greatly enhanced by combining digital instruments with an oscilloscope. The Delayed Gate, available with most dual time bases, is a powerful tool for making precise gated digital measurements.

Servicescope

Ron Lang

Replacing probe tips, bodies, and boots

Oscilloscope probes take a beating. Not because scope users abuse them, but because they get a lot of use. And since today's circuitry contains many small components mounted in as little space as possible, probes have to be physically small to work on them. The probe cable also must be small to minimize the weight we hang on the circuits.

The smaller the probe and cable, the more subject they are to damage. When a probe is damaged, it can often be repaired for much less than the cost of replacing it. Here are some service hints that will help you make those repairs.

Tips

Most new TEKTRONIX probes accommodate small interchangeable slip-on tips. But many of us make a practice of using the probe without a slip-on tip and that makes the unprotected built-in tip subject to breaking or bending. Trying to straighten a bent tip will sometimes break it. Then either the built-in tip or the entire probe body must be replaced. The built-in tips are less expensive but on some probes they are not replaceable. It is simple to tell which may be replaced, however. Unless the cylindrical metal ground sleeve extends all the way to the edge of the tip-holder the point is replaceable. See Figure *1a* and *1b*.

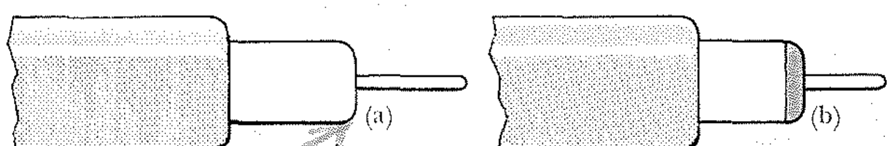


Fig. 1. Two types of probe tips commonly used on TEKTRONIX probes. The one at left is not replaceable, while the one at right is.

There are two types of built-in tips but they are not interchangeable. The following table shows which tip is for which probes.

Use tip 206-0187-00 with these 200-Series scope probes:

010-0262-01
010-0262-02

And with this probe:

P6055

Use tip 206-0191-01 with these 200-Series scope probes:

010-0262-03
010-0262-04
010-0262-05

And with these probes:

HZ-25	P6063A
P6049B	P6065A
P6053B	P6075A
P6062A	

Two different methods can be used to remove replaceable tips. The first method, which can be used for all replaceable tips, is pictured in Fig. 2. A sharp pair of wire

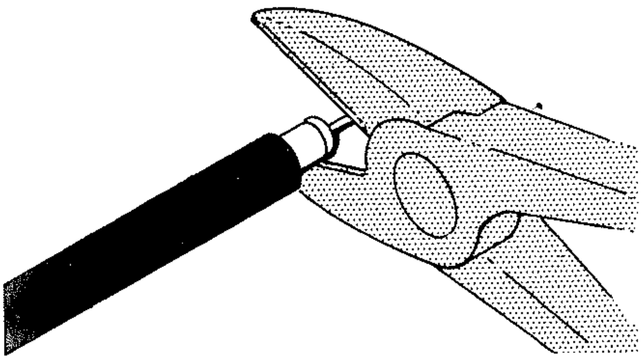


Fig. 2. The replaceable probe tip can be removed as illustrated here. Care should be taken not to squeeze or nick the grounding sleeve.

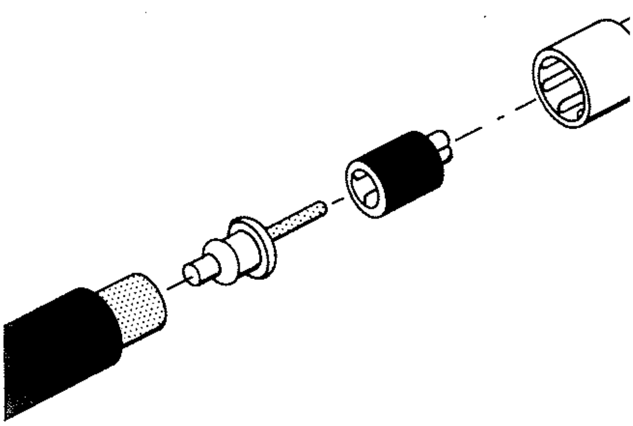


Fig. 3. The replacement tip can be pressed into position by tapping sharply with a 3/16″ hollow shaft nut driver (or similar tool) as shown here.

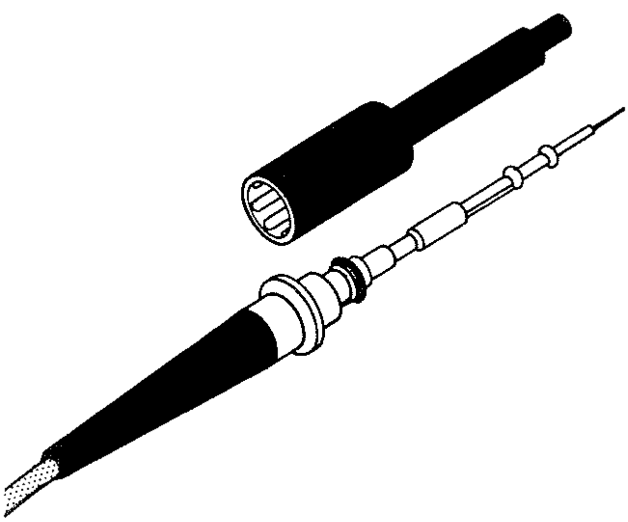


Fig. 4. The new style probe body can be distinguished from the old style by noting the six raised ribs inside the end near the threads.

cutters is used to separate the plastic tip from the grounding sleeve. Gripping the probe tip between the plastic and grounding sleeve with the cutters, pull the tip free from the grounding sleeve with a sideways rocking motion of the cutters. Care should be taken not to squeeze or nick the grounding sleeve.

The second method can be used for removing some tips, and avoids the possibility of damaging the grounding sleeve with the cutters. It involves using a small rod to drive the tip out from the rear. Different size rods are needed for different probes. For the following probes a rod with a diameter of about 0.15 inches should be used:

P6049B	P6055
P6053B	P6065A
P6054B	P6075A

For the following 200-Series scope probes use a rod with a diameter of about 0.05 inches:

010-0262-00
010-0262-01
010-0262-02

Other replaceable tips cannot be removed with a rod.

To remove a tip with a rod, insert the rod into the rear of the probe body making sure that the rod is seated on the plastic tip-holder, and drive the holder out.

To replace a probe tip, use the procedure shown in Fig. 3. The IC test tip is placed over the probe tip, and a 3/16″ hollow shaft nut driver is used to press the tip into position.

Bodies

The screw-on probe bodies on some of the early models of the probes listed below may loosen and cause intermittent contacts. When that happens a new style body should be ordered. A new style body may be distinguished from the old style by six raised ribs inside the end near the threads in the new style. See Fig. 4.

For—

P6049A	use	204-0447-03
P6053A	use	204-0579-00
P6054A	use	204-0579-03
P6065A	use	204-0579-01
P6075A	use	204-0579-02

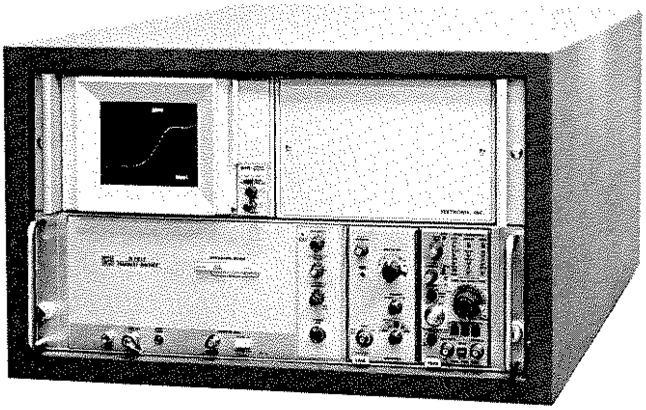
Boots

If you are encountering probe cable breakage near the strain relief boot on the scope-end of the following probes you should know that replacement cable assemblies have longer boots (50 mm) making the new assemblies more reliable. Here are the probes and assembly numbers:

P6053A			
	3.5 ft 010-6053-01	use	175-1101-01
	6.0 ft 010-6053-03	use	175-1139-01
	9.0 ft 010-6053-05	use	175-1311-00
P6053B			
	3.5 ft 010-6053-11	use	175-1435-00
	6.0 ft 010-6053-13	use	175-1139-02
	9.0 ft 010-6053-15	use	175-1311-01
P6054A			
	3.5 ft 010-6054-11	use	175-1173-03
	6.0 ft 010-6054-13	use	175-1383-01
	9.0 ft 010-6054-15	use	175-1400-01
P6061			
	3.5 ft 010-6061-01	use	175-1173-02
	6.0 ft 010-6061-03	use	175-1174-01
	9.0 ft 010-6061-05	use	175-1205-01
P6065A			
	6.0 ft 010-6065-13	use	175-1383-01
	9.0 ft 010-6065-15	use	175-1400-01
P6075A			
	6.0 ft 010-6075-13	use	175-1383-01

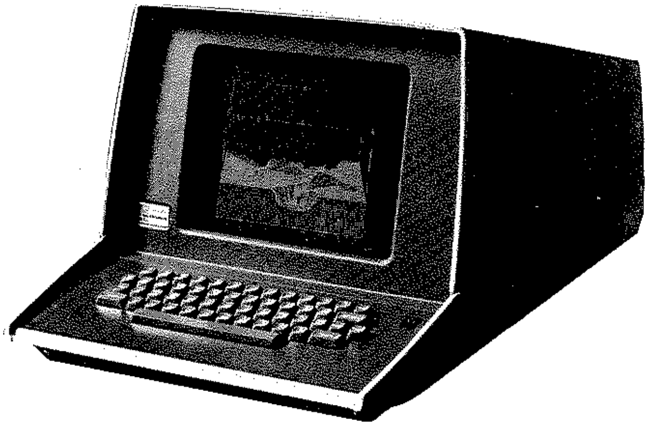
Replacement parts may be ordered through your local Tektronix Field Office or Representative.

New products
New products
New products



WP2005 Waveform Digitizing Instrument

The WP2005 Waveform Digitizing Instrument is a high-speed waveform viewing package that features bright, stored displays of transient or repetitive waveforms. Its high performance includes bandwidth of 500 MHz at 10mV/div or 1 GHz at 4V/div (using the 7A21N Direct Access Unit), sweep speeds to 0.5 ns/div, and stored writing speed to 8,000 div/μs. The new 605 Storage Monitor with its bright, variable persistence storage display makes it feasible to offer the WP2005 without the 1350 Memory Display Unit used in other WDI viewing packages. The result is the least expensive viewing package for those wishing only to see the shape of a transient, or to overlay successive transients and observe changes or anomalies.



4006-1 Computer Display Terminal

The new TEKTRONIX 4006-1 Computer Display Terminal brings graphic display capability right to your desk top at a new low cost. The 11-inch storage tube provides crisp, clear displays with 800,000 viewable points (1024X by 780Y). It has an on-screen capacity of 2590 alphanumeric characters. You can transmit or receive data at selectable rates of 75 to 4800 baud.

The 4006-1 is supported by extensive software products, and is compatible with the 4631 Hard Copy Unit for dry, high-quality, 8½ x 11-inch copies of any information displayed on the 4006-1 screen. The Digital Cartridge Tape Recorder, a low-cost off-line data storage device, is also compatible with the 4006-1. For more complete details on the 4006-1 use the reply card accompanying Tekscope.

Newliterature
Newliterature
Newliterature

A new TEKTRONIX TM 500 Catalog is now available. It contains the most up-to-date data on new TM 500 products, such as the SC 502 dual-trace oscilloscope and TM 515 Traveler Mainframes, and is the most complete compilation of performance specifications for the entire line. Also included are thirteen articles discussing the application of TM 500 instrumentation in areas varying from field servicing of digital equipment to the vibration analysis of turbines.

A new 32-page booklet entitled "Portable Oscilloscopes For all your Servicing Needs" provides complete specifications on Tektronix extensive line of portable oscilloscopes. Included is a discussion of the factors to be considered in selecting the portable best suited to your needs.

Curve Tracer Application Note 48K1.0 entitled "Testing Optoisolators" describes the use of the TEKTRONIX 577/177 Curve Tracer to check most of the important opto-isolator specifications. Testing these devices before they are installed can save many costly hours of troubleshooting in the prototype, productions, and test stages of manufacturing.

To receive copies of this literature use the inquiry card accompanying Tekscope.

A-3261

TEKTRONIX, INC.
P.O. BOX 500
BEAVERTON, OR. 97005

1893? 7C
MR DEN INGRAM TECH STAND LAB
MILGO ELECTRONICS CORP
8600 NW 41 ST STREET
MIAMI FL 33166

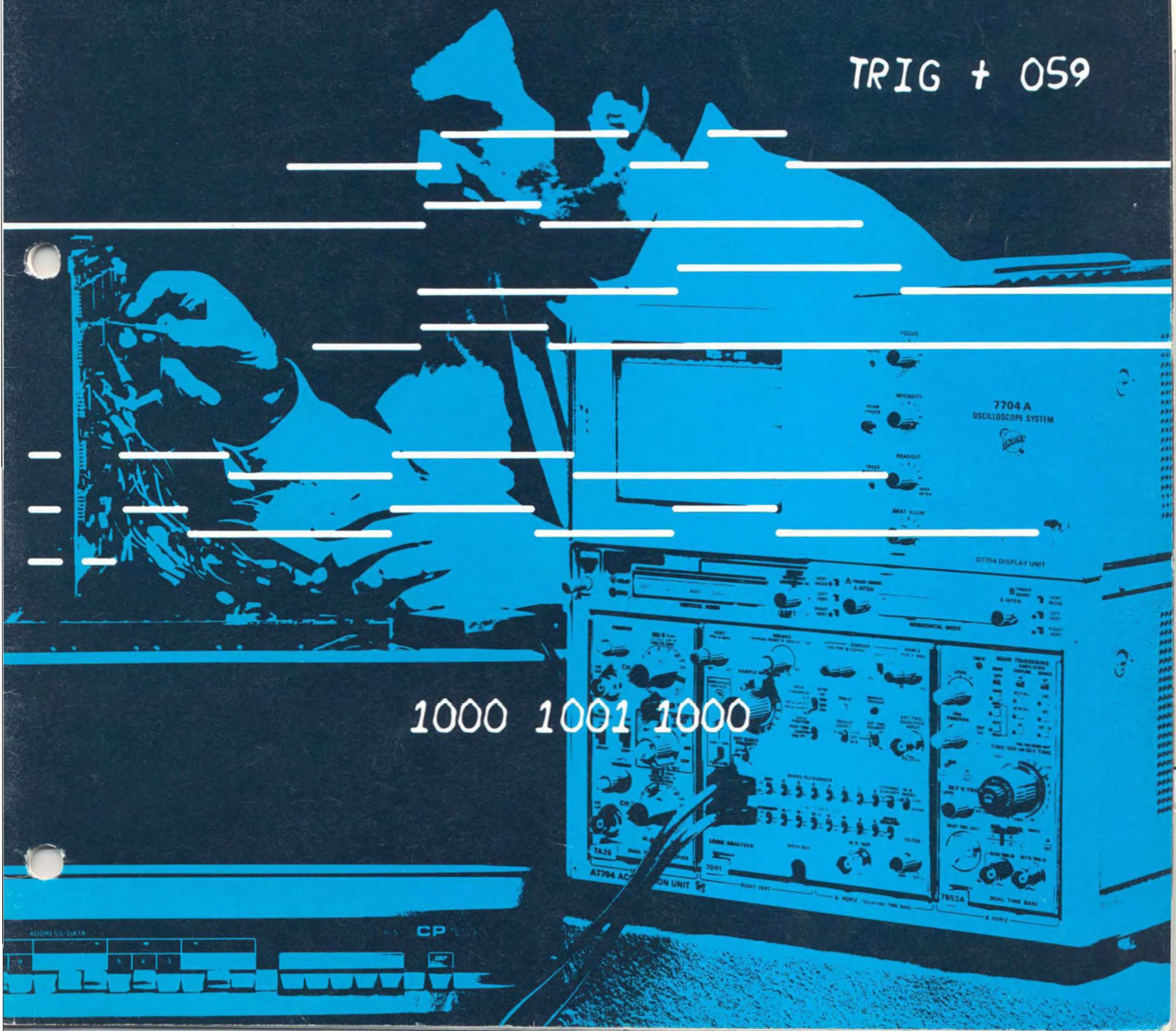
BULK RATE
U.S. POSTAGE
PAID
Tektronix, Inc.

TEKTRONIX®

committed to technical excellence

TEKSCOPE

Volume 8 Number 2 1976



TEKSCOPE

TEKTRONIX®
committed to technical excellence

Customer Information from Tektronix, Inc.,
Beaverton, Oregon 97077

Editor: Gordon Allison

Contents

2 **A 16-channel logic analyzer for the 7000 Series**
A plug-in logic analyzer with built-in 16-bit word recognizer transforms your 7000 Series Oscilloscope into a high-performance logic analysis tool for working in the digital domain.

8 **A plug-in word recognizer with digital delay**
A companion plug-in for the LA 501 provides data acquisition with high-impedance active probes, 16-bit word recognition, and digital delay.
The WR 501 can also operate as a stand-alone word recognizer or digital delay unit.

12 **The FG 504—a new standard in function generators.**
A 40-MHz function generator with 6-ns rise time, 30-volt peak-to-peak output, and phase lock offers a new level of operating convenience, versatility, and signal generation.

16 **A new low-cost 500 MHz probe**
The circuit-loading effect of a new FET probe is compared with that of high-impedance passive probes. Designed to work into 50 Ω or 1 MΩ, the probe features dc offset and wide dynamic range.

19 **New products**
Included are a host of new products for TV and CATV broadcasters & designers.

Servicescope, a regular feature, does not appear in this issue because of space considerations. It will resume in the next issue.

Cover: Some of the unique features of the 7D01/7000 Series logic analyzer system are presented in this artistic treatment. The digital readout above the traces shows the number of clock pulses occurring between the trigger and cursor positions. The readout below the traces is the binary word present at the cursor position. (The trigger and cursor position are not shown in this display.)

Keith Taylor

A 16-channel logic analyzer for the 7000 Series

More than just an oscilloscope. This is the phrase often used to describe the 7000 Series. And for good reason. Plug-in versatility transforms 7000 Series Oscilloscopes into counters, digital multimeters, spectrum analyzers, time-domain reflectometers, curve tracers, rapid-scan spectrometers, etc. Now, with the introduction of the 7D01 plug-in, 7000 Series Oscilloscopes become state-of-the-art logic analyzers.

The 7D01 is a 16-channel, logic timing analyzer that presents data in the familiar oscilloscope-type, time-related diagram pictured in figure 1. But, as you can see, there's much more that meets the eye in figure 1 than just the usual multi-trace, logic timing diagram. Several features have been added to aid you in analyzing the displayed data.

Note the two vertical rows of bright dots. The row at the left indicates the triggering point. In this instance, we have selected the post-trigger position, which means that 90% of the data displayed occurs after the trigger. Pre-trigger and center-trigger positions are available at the flip of a switch, to give you a wide range of data to view.

The second row of bright dots in the display provides a reference point for making time comparisons between displayed channels. This row of dots can be positioned anywhere on the horizontal axis by means of the cursor controls. The fine control moves the dots one bit at a time, and the coarse control in 16-bit increments. The readout at the top of the screen shows the number of bits occurring between the trigger and the cursor. In the asynchronous mode, this number multiplied by the sample interval equals the time difference between the trigger and the cursor position. When using an external clock, the readout shows the number of clock pulses occurring between these two points. The cursor is especially convenient for locating a particular bit or point in time relative to the trigger.

There has been much discussion as to whether the logic state or the logic timing display is the most useful in performing logic analysis. Each has advantages for specific applications. The 7D01 resolves this issue for many applications by providing both types of display.

You will note that the readout at the bottom of the screen in figure 1 is in the format usually displayed by logic state analyzers. The binary word displayed corresponds to the logic word present at the cursor position. This unique feature makes the 7D01 useful for many software and firmware applications. It is often a convenience also in hardware applications.

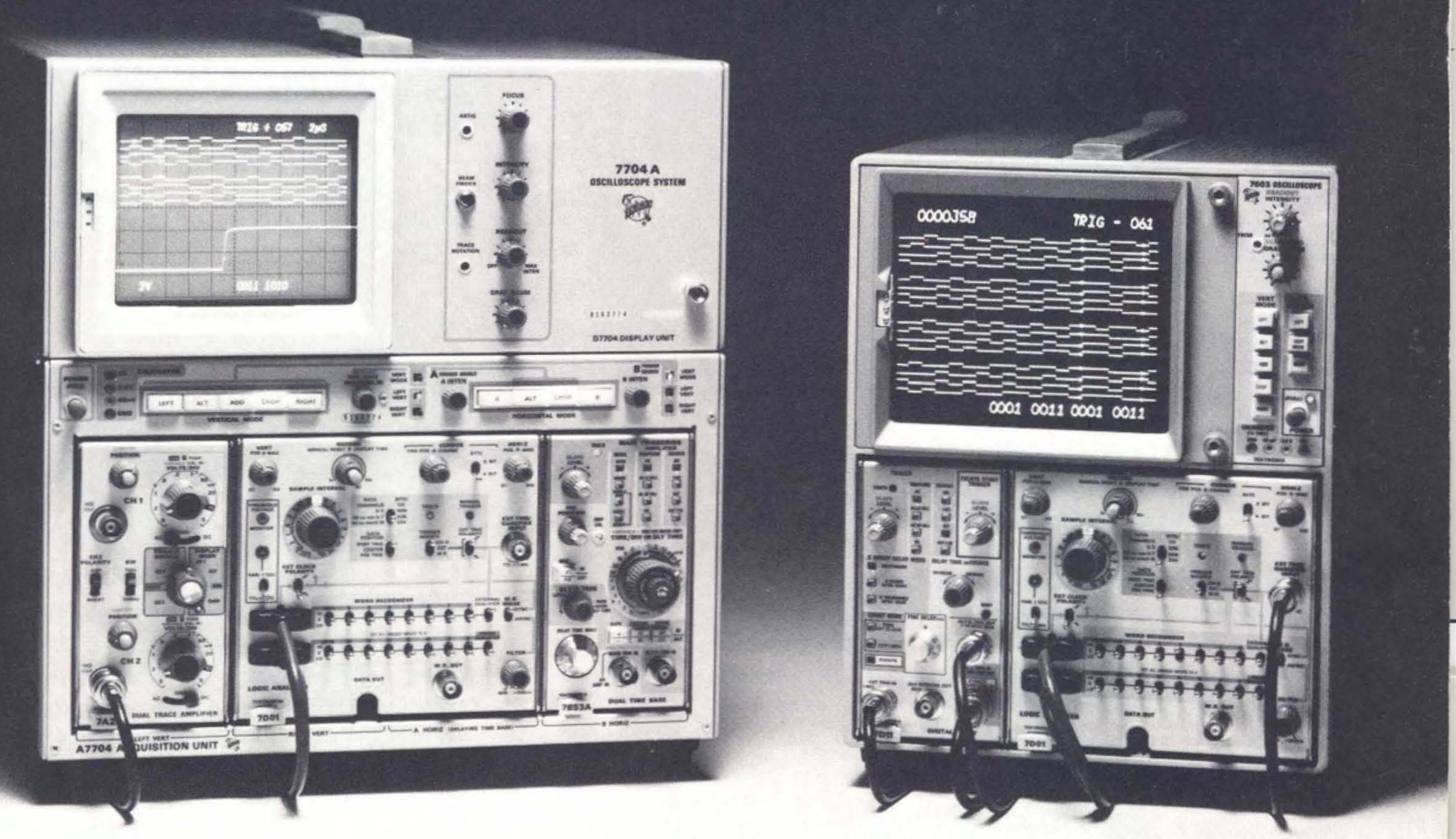
A versatile trigger

Trigger versatility is one of the most important characteristics of a logic analyzer. We have already discussed the ability to view data preceding the trigger, following the trigger, or both preceding and following the trigger. Now, let's consider the sources of trigger.

A choice of three sources is provided by a front-panel switch: channel 0 of the probe input, external via BNC input, or from the built-in, 16-bit Word Recognizer. A fourth choice is manual triggering by front-panel pushbutton.

The 16 data-input channels also serve as inputs for the Word Recognizer. Front-panel switches allow you to select any pattern of up to 16 parallel bits as the trigger word.

Two additional inputs, the Probe Qualifier and the External Qualifier, provide still further selection of the triggering point, giving us, in essence, an 18-bit Word Recognizer. The External Qualifier may be the output from another Word Recognizer, a time delay or digital delay generator, or another signal from the system under test. The signal should be TTL level and have a minimum duration of 15 ns.



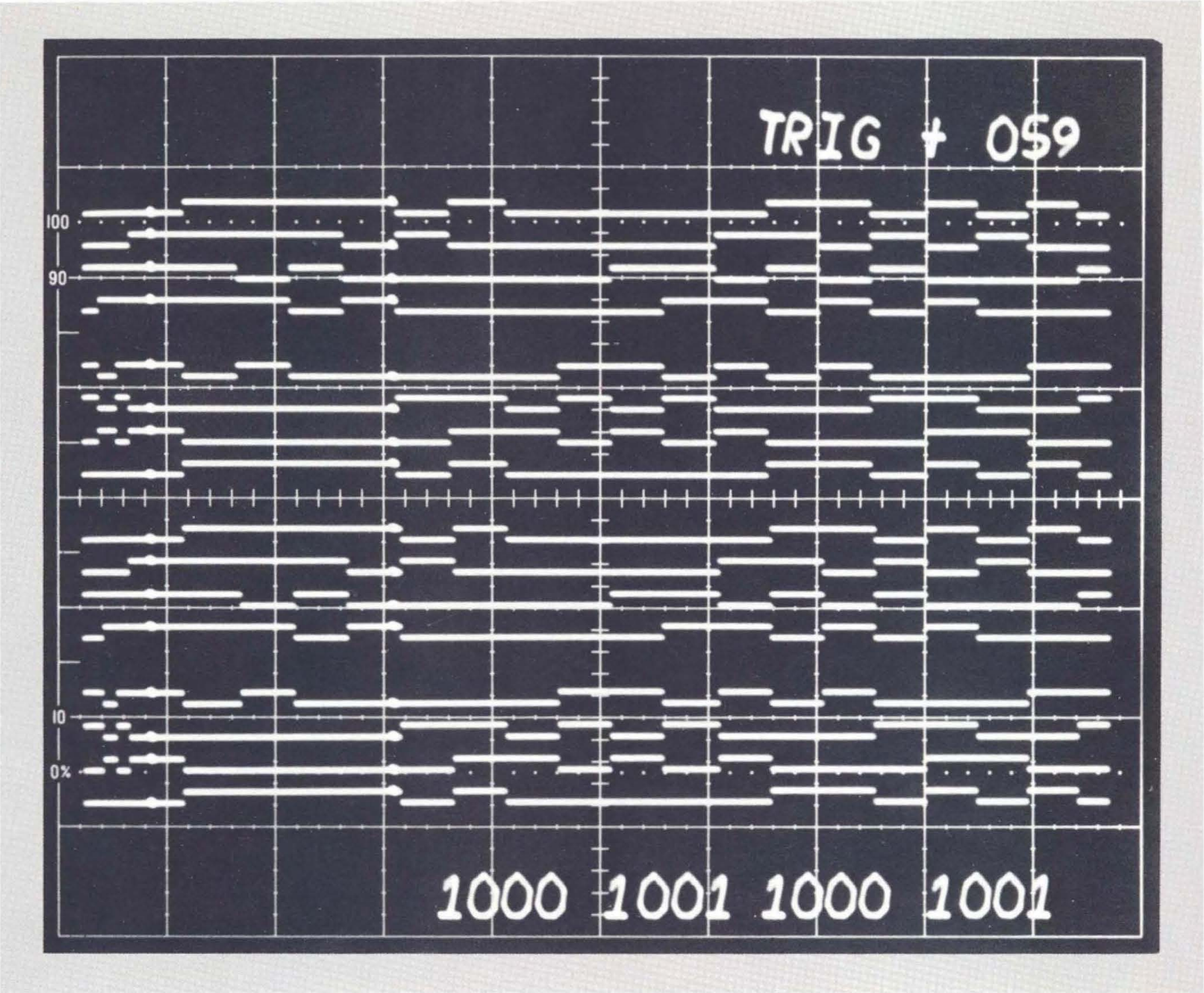


Fig. 1. A wealth of information is available from the display generated by the 7D01. The intensified dots at left show the trigger point. The dots about two divisions to the right are a movable cursor. The number of clock pulses occurring between the two bright dots is displayed at the top of the screen. The 16-bit binary word at the cursor position is displayed at the bottom of the screen. Right to left corresponds with top to bottom.

There are two paths through the Word Recognizer, synchronous and asynchronous, selectable by a front-panel switch. In the asynchronous mode, a variable filter is inserted in the trigger path that prevents glitches and other anomalies from causing false triggering. Word recognition of bit combinations of shorter duration than the filter setting is inhibited. Maximum filter width is at least 300 ns.

The trigger point indicated on the display is most accurate when operating the Word Recognizer in the asynchronous mode with the filter set at minimum, or when using an external sampling interval. The trigger position indication is less accurate when triggering from channel 0, or when the asynchronous filter is advanced clockwise.

The built-in Word Recognizer operates independent of the rest of the logic analyzer. When all of the conditions required for word recognition are met, the data acquisition circuits are enabled and a HI signal is supplied to a front-panel connector, for triggering an oscilloscope or other associated equipment. A Word Recognizer output occurs each time the conditions are met, whether the logic analyzer is operating in the store or display mode.

For applications where it is desirable to page through a long sequence of events, a companion plug-in, the 7D10, provides digital delay by up to 10^7 events. The delayed trigger output of the 7D10 serves as an external qualifier or trigger for the 7D01. The 7D10 counts events at rates up to 50 MHz.

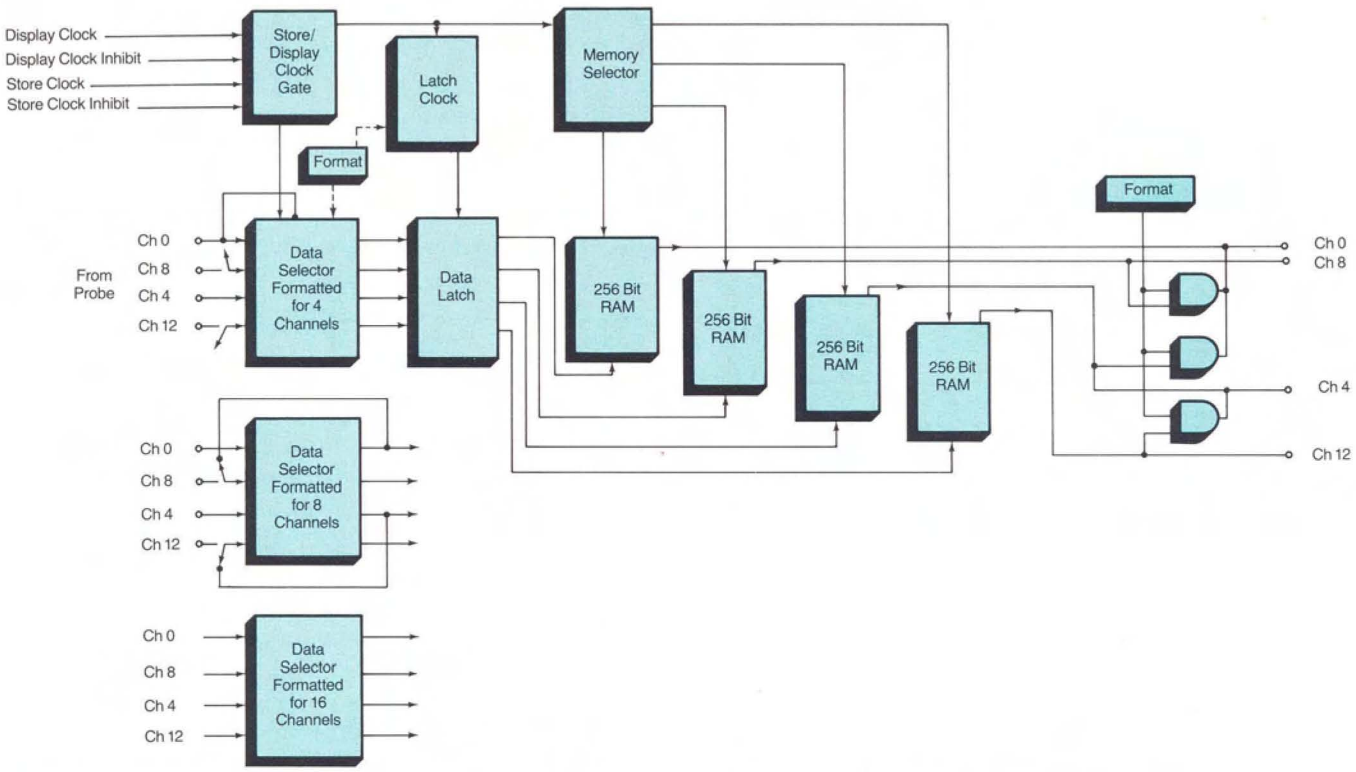


Fig. 2. The 4-k memory in the 7D01 is formattable. One of four 4 x 256-bit sections is shown. It can store 1024 bits from one channel, 512 from two, or 256 from four channels. In 4-channel operation the Data Selector functions as a 4-bit shift register, in 8- and 16-channel operation as 4-bit latches.

Data inputs

Up to 16 channels of parallel data can be acquired simultaneously by the 7D01. Minimum loading (1 MΩ, 5 pF) on the circuit under test is achieved by two active probes with multiple inputs. Probe qualifier and external clock inputs are also provided for in the active probes.

You have a choice of threshold levels for the probe inputs — a preset +1.4 volts for TTL applications, or selection over a range of ± 12 volts by a front-panel variable control.

Data can be clocked into the 7D01 in either a synchronous or asynchronous mode. In asynchronous, the clock may be either internal or external at rates up to 100 MHz depending upon the number of channels in use. To match the resolution of the measurement to your specific application, sample intervals derived from the internal clock may be selected over the range of 5 ms to 10 ns, in a 1-2-5 sequence.

A formattable memory

One of the most useful features of the 7D01 is the formattable memory. Consisting of sixteen 256-bit random access memories (RAMs), the memory can be formatted by a front-panel switch to store four channels with 1024 data bits per channel, eight channels with 512 bits per channel, or sixteen channels with 256 bits per channel.

Let's take a look at how this is accomplished (see figure 2). The 16 data inputs are arranged in groups of four, each group coupled to a corresponding 4 x 256-Bit RAM. In the 4-channel mode of operation, the Data Selector functions as a 4-bit shift register, acquiring four bits of data input from channel 0. The Data Latch transfers the data from the outputs of the Data Selector to the inputs of the four, 256-Bit RAMs. Through a three-gate arrangement controlled by the DATA CHANNELS switch, the outputs of the RAMs can be added to give us a single 1024-bit memory, two 512-bit memories, or four 256-bit memories. The function of the Data Selector is also controlled by the DATA CHANNELS switch to pass four bits of data from one channel, two bits from each of two channels, or one bit from each of four channels, to the Data Latch.

Data acquisition and display

Figure 4 is a simplified block diagram of the 7D01. Let's refer to it and go through a cycle of acquiring and displaying data. A good point to start is when reset occurs.

When display time ends, a reset signal is generated by the reset circuitry. This resets the trigger flip-flop, trigger and address counters, and the store/display flip-flop, switching the memory from the display mode to the store mode. Data, which is clocked into the Data Latch at the high-frequency clock rate, is transferred to the

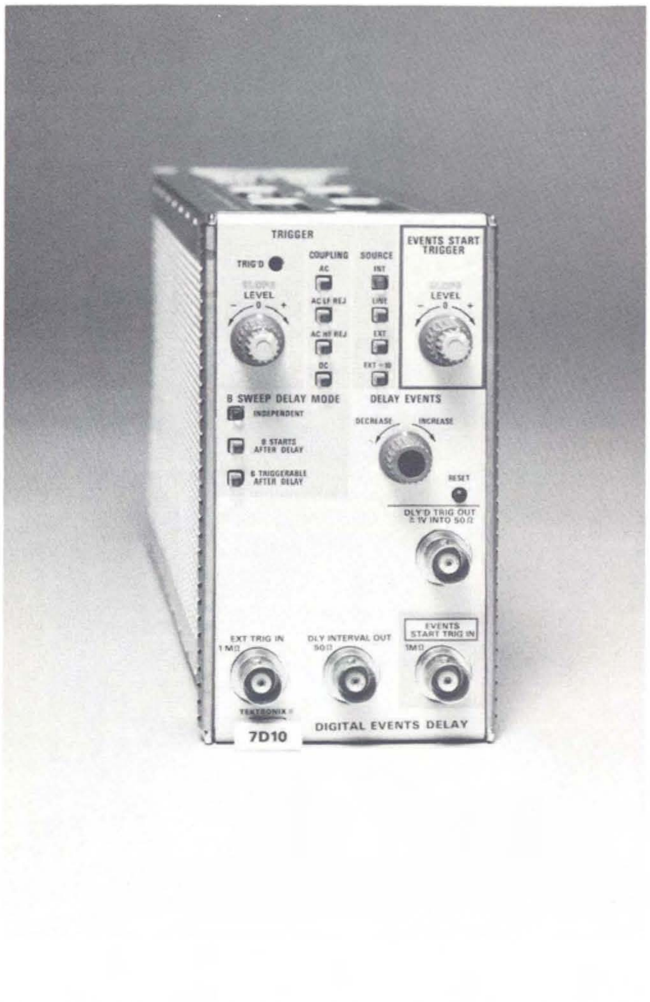


Fig. 3. The 7D10 Digital Delay plug-in is an ideal companion for the 7D01. It will count up to 10^7 arbitrary trigger events, periodic or aperiodic, and deliver an output after the preselected count has been reached.

memory at the memory low-frequency clock rate, starting with the end of reset. The high-frequency clock rate is determined by the SAMPLE INTERVAL switch setting, and is divided by 1, 2, or 4 times to establish the low-frequency clock. Data is clocked into the memory until a trigger occurs, and for a period following the trigger as determined by the DATA POSITION switch setting. For example, in the CENTER position, half of the memory fills after the trigger occurs.

The input steering and latch circuitry determines how data will be input to the memory. In the 4-channel mode, the data from channel 0 is clocked serially into one 4 x 256 section of the memory, as previously discussed. The data from channels 1, 2, and 3 are clocked into their respective memories simultaneously, in a similar manner.

Occurrence of the trigger, switches the trigger flip-flop, gating on the trigger low-frequency clock. The low-frequency clock is the store clock (high-frequency clock) divided by 1, 2, or 4 times, depending upon the setting of the DATA CHANNELS switch. A separate 1-, 2-, or 4-times divider is used for the trigger low-frequency clock because of phasing considerations related to the memory low-frequency clock.

The trigger counter counts 16, 128, or 240 counts (depending upon trigger position selected) and then generates the first flag. During this flag, the memory clock is summed with a gate derived from the trigger clock, to generate a gate that switches the Store/Display Flip-Flop to the display mode. Transition from store to display is thus made in phase with the memory low-frequency clock.

The display clock, which runs at 2 μs, now becomes the high-frequency clock. It, in turn, is divided by 1, 2, or 4 to become the memory and trigger low-frequency clocks. During display time, the outputs of the sixteen, 256-Bit RAMs are displayed in serial fashion, as determined by the Output Steering and Multiplexer circuitry.

In the display mode, the trigger counter counts through 256 counts of the display clock (equivalent to one display line) and generates a second flag. This flag resets the sweep, blanks the crt, and selects the next channel to be displayed. This flag also goes to a divide-by-16 counter that sets a flag when sixteen channels have been displayed. When the display time ends, a reset pulse is generated and the store/display cycle starts again.

To further enhance the flexibility of the 7D01, a choice of two display modes – Full Display or First Trigger – can be selected by positioning an internal jumper. In the Full Display mode, the trigger to the Trigger Flip-Flop is inhibited until the Address Counter has completely cycled. This assures that the memory is filled with valid data.

In the First-Trigger mode, it is conceivable that a trigger may occur before the memory is completely filled. If this occurs, the display is blanked during the time that invalid data would be presented.

Data outputs

Data from the memory is available in both parallel and serial format from an internal 25-pin connector. Also available are the display/store, flag, frame, trigger intensify, and master reset outputs.

Two inputs are made via the connector: record enable and external display clock input. An external display clock is required if the data are to be output to computer for further analysis.

Summary

The 7D01 is designed to offer high-performance, 16-channel logic analysis to 7000 Series users. Used with conventional oscilloscope plug-ins in a four-hole mainframe, you can have both an oscilloscope and a logic analyzer in a single package. The formattable memory offers unparalleled flexibility, and the high-speed data

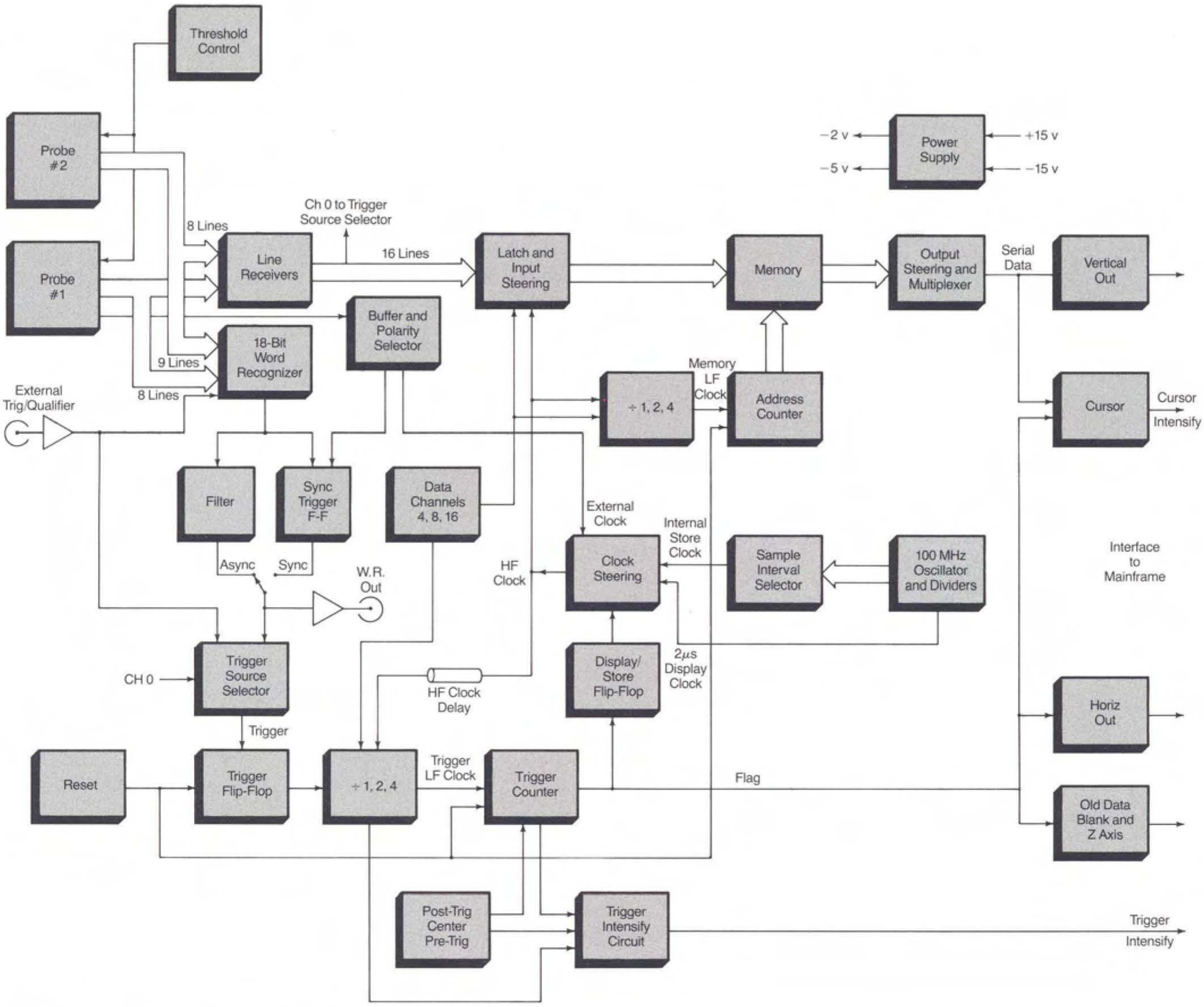


Fig. 4. Simplified block diagram of the 7D01.

acquisition and minimum loading afforded by active probes makes the 7D01 ideal for working with higher speed logic families.

Acknowledgments

Murlan Kaufman as Project Manager provided overall direction for the 7D01. Project Leader was Keith Taylor, with Morris Green and Jeff Bradford doing electrical design, and Ed Wolf mechanical design. Dick Anderson, Group Technician, provided valuable assistance, as did Beverley Kateley and Dona Fricker on prototype assembly and circuit board details. Roy Kaufman, Evaluation Engineer, and Dave McCullough, Marketing Program Supervisor, also made valuable contributions. Our thanks to Wendell Damm for his work on the active probe, and to the many others who contributed to the completion of the project.

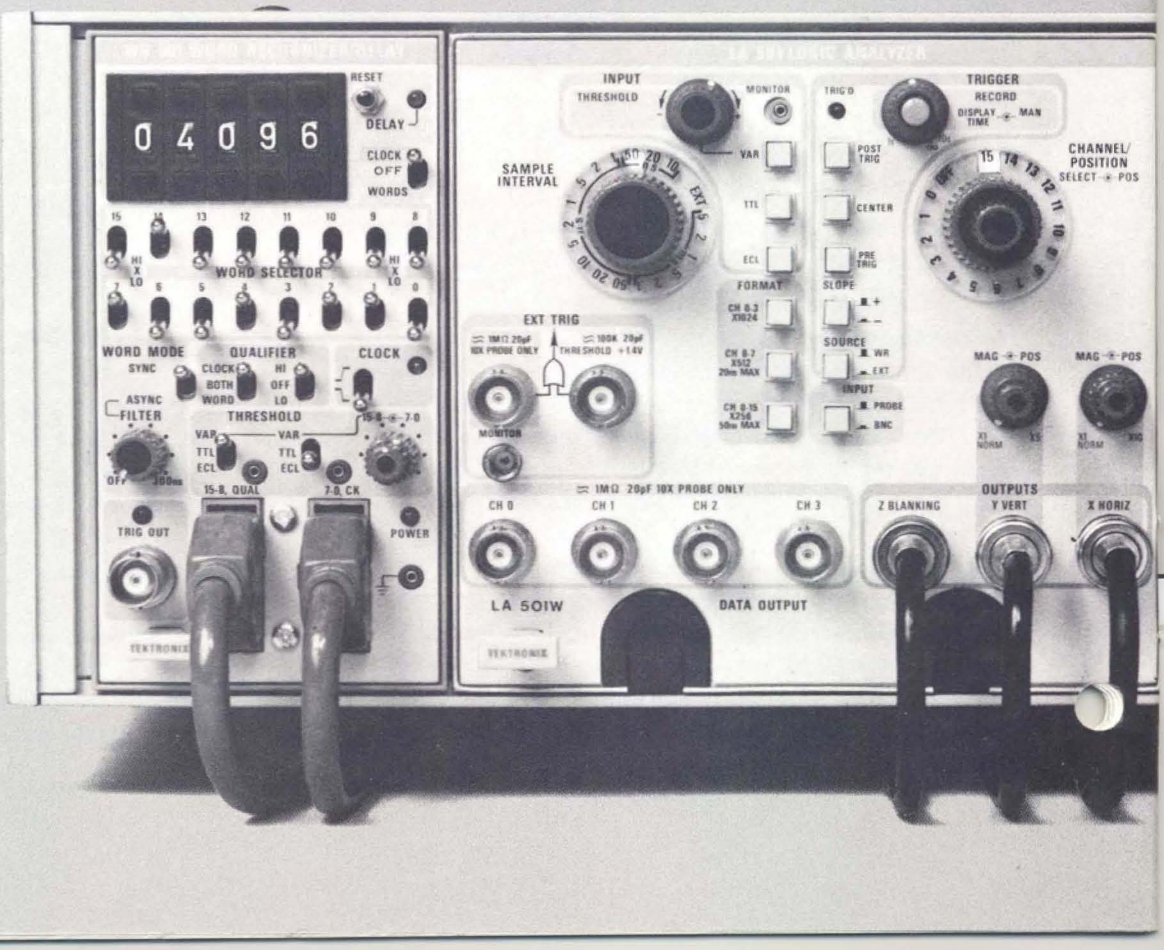
Pete Janowitz

A plug-in word recognizer with digital delay

For sports fans, instant replay quickly became one of the most appreciated improvements in televised sports programming. Engineers have long had the ability to view critical "happenings" in their electronic circuitry, with the aid of oscilloscopes.

Now, with the introduction of logic analyzers, an engineer has not only acquired instant-replay capabilities, he can instantly replay and view sixteen channels simultaneously. It's a companion tool, the word recognizer, that enables him to recapture the action at any point he chooses.

Sometimes the word recognizer is an integral part of the logic analyzer. In other instances, it's a separate entity – like the new TEKTRONIX WR 501 Word Recognizer. Designed primarily to work with the LA 501 Logic Analyzer, it occupies a single plug-in compartment in a TM 500 mainframe. When ordered with the LA 501, the package is called the LA 501W and includes all of the interfacing hardware needed to couple the WR 501 and LA 501 mechanically and electrically.



The WR 501 can also function as a stand-alone word recognizer/digital delay unit for those needing to expand the triggering capabilities of their logic analyzer, oscilloscope or other equipment. For example, WR 501s can be cascaded to obtain greater word width, dual word recognition/delay, or delay "nesting" (delay within a delay).

Using the new P6451 high-impedance (1 MΩ, 5 pF) active probes, the WR 501 can acquire up to sixteen channels of data, plus an external clock and qualifier signal. Maximum flexibility is afforded by using two probes, each with nine inputs. Separate threshold controls for each probe facilitate working with systems using mixed logic families, with preset threshold voltages for TTL and ECL signals selectable by front-panel switches. Variable controls provide a choice of threshold voltage over a range of ± 10 volts.

The Qualifier input can be used to expand the word recognizer to 17 bits, gate the external clock, or do both. In the LA 501W, the external clock can be gated by the Qualifier input, allowing you to selectively clock data into the memory.

Synchronous or asynchronous operation

In some applications it is advantageous for word recognition to be synchronous with the system clock. For others, it is desirable to generate a trigger whenever the word pattern occurs. With the WR 501, the choice is yours at the flip of a switch.

In the synchronous mode, the external clock signal acquired by the probe clocks the Sync Flip-Flop to generate a word recognizer output in step with the system clock.

In the asynchronous mode, a word recognizer output is generated whenever the selected word pattern occurs. A selectable-pulse-width filter with a range of 5 to 300 ns is automatically activated, to reduce the possibility of false triggering due to glitches or data skew.

A built-in digital delay

Another useful feature incorporated in the WR 501 is digital delay. You have a choice of delaying by up to 99,999 clock pulses or words at clock rates up to 50 MHz. Delay by words generates a trigger at the *n*th occurrence of the word so we can see what happens at the end of a program loop, for example. The count is set by convenient push-button thumbwheel switches.

The delay count is started by an output from the word recognizer when word recognition occurs. For those applications where you want to use the delay without the recognizer, you can start the count by using a single bit from one of the data inputs. Just set the appropriate WORD SELECTOR switch. A front-panel push-button lets you reset the delay counter manually at any point in time. Reset is automatic when the selected delay is reached.

The trigger output pulse generated by word recognition, or word recognition plus selected delay, is brought out to a front-panel BNC connector, and also routed to the LA 501 via an internal multi-pin connector. The output pulse is TTL compatible, with duration a function of the operating mode and signal inputs.

Interfacing to the LA 501

Special provisions are made to interface the WR 501 and LA 501 without the need for external connections. The sixteen data inputs, external clock, and word recognizer output are coupled internally through a short cable assembly, to the 25-pin probe-input connector in the LA 501, in place of the P6450 passive probe. The sixteen data inputs to the WR 501 are always present at the interface connector, irrespective of front-panel control settings. This arrangement of the WR 501, interface, and LA 501 make up the LA 501W.

The threshold controls on the WR 501 now control the probe inputs, with the threshold control on the LA 501 affecting only the front-panel external trigger and the BNC probe inputs. Attenuator probes can still be used with the BNC inputs for channels 0 through 3 on the LA 501 by setting the INPUT to BNC. Data channels 4 through 15 will be supplied from the WR 501 inputs. This gives you three individual threshold controls and the ability to view inputs separated some distance. The attenuator probes can handle signals up to ± 500 volts to accommodate many real time situations.

If you have a need for 16-bit word recognition while viewing more than four other data channels, you can remove the interface cable and use the WR 501 as a stand-alone word recognizer. The optional P6450 passive probe can then be used with the LA 501 for data acquisition. The output signal from the WR 501 is coupled externally to the LA 501 external trigger input in this instance.

Technical details

The WR 501 performs two major functions — word recognition and digital delay. The simplified block diagrams in figures 1 and 2 will be useful in understanding how each function is performed, and how they relate.

The sixteen data channels acquired by the WR 501 probes pass through a differential FET pair, with one output going to the word recognizer, and the other output through delay lines to the interface connector. The delay lines provide zero hold time for the LA 501 data inputs.

The Qualifier can gate either the word recognizer or external clock, or both, or can be turned off when not needed. The delay line in the word recognizer signal path provides zero hold time for synchronous operation.

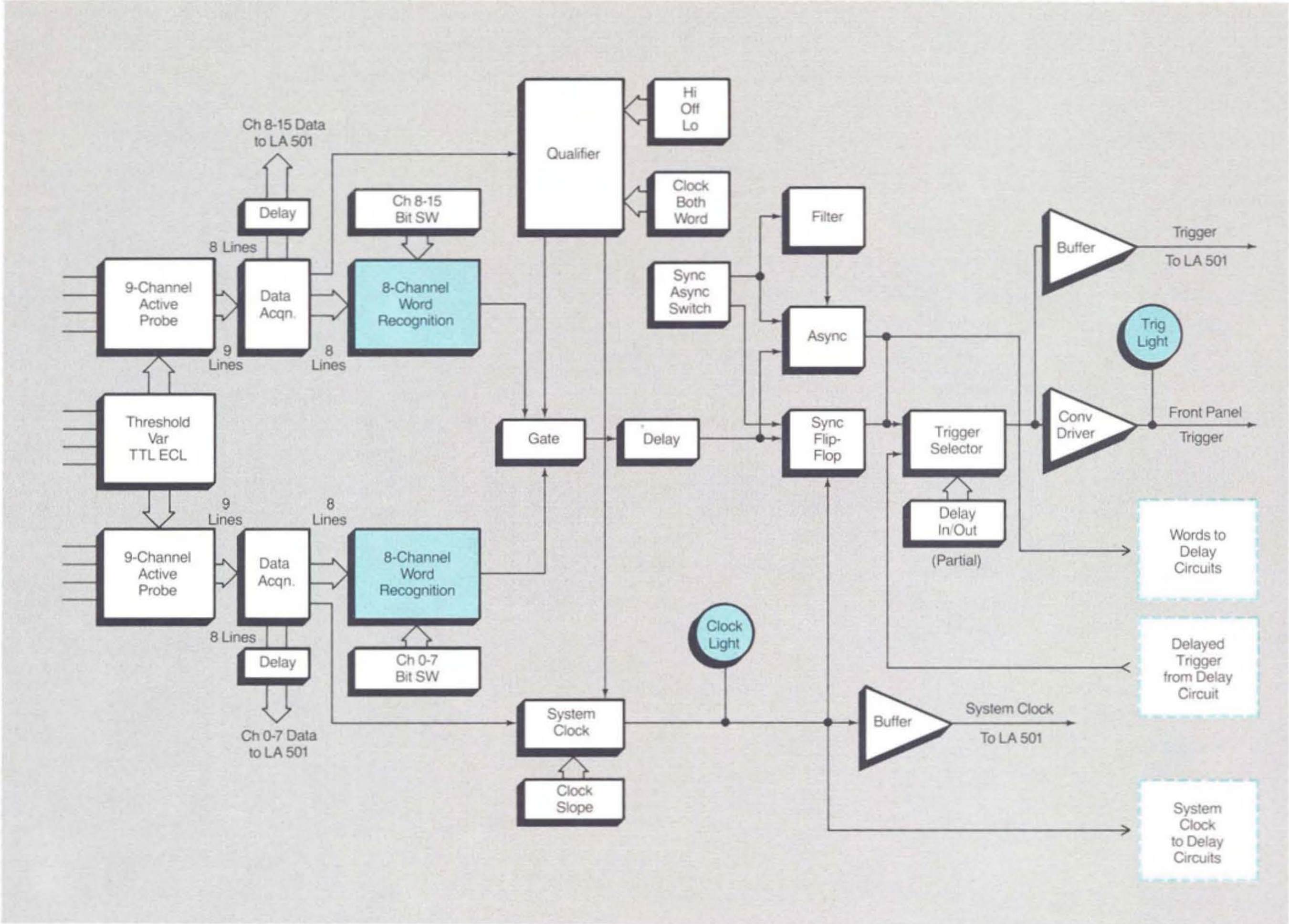


Fig. 1. Simplified block diagram of the word recognizer portion of the WR 501. Signals from the sixteen data input channels can be coupled directly to the LA 501W independent of word recognizer operation.

The 5 to 300 ns filter is activated whenever asynchronous triggering is selected, and can be set to assure valid word recognition.

Output trigger selection is controlled by the front-panel switch labelled CLOCK-OFF-WORDS, which corresponds to the Delay In/Out blocks in the diagrams. In the delay OFF position, the word recognizer output goes directly to the output buffer and output converter driver. The converter transforms the output signal from ECL to TTL level.

In the delay IN position, which corresponds to either delay by word or delay by clock, the delay circuitry is inserted in the trigger output path and no trigger output signal is generated until after the selected delay has been accomplished.

Moving along to the delay circuitry block diagram shown in figure 2, we see that the Delay By Selector routes either the system clock or the output from the word recognizer to the counter circuitry. The word recognizer output also goes to the start circuitry to initiate counting.

Five decade counters are used. The least-significant-bit (LSB) counter is ECL, with the remaining counters TTL. Counter operation is essentially straight-forward, using a 9's complement scheme. The Hold block is a latch that holds the 9999 Detector output level until the LSB counter reaches the nine count, while allowing the TTL counters to be reset.

When the selected count is reached, the Delay Output Flip-Flop is switched, generating a delayed trigger signal. The delayed trigger is routed to the Trigger Selector for availability as the output trigger signal.

Summary

The TM 500 Series family is designed to allow you to configure your measurement package to fit your measurement needs. The high-performance LA 501 has been meeting many of your logic analyzer needs. Now, the WR 501 with its high-impedance probes, 17-bit word recognition, and digital delay expands your logic analysis capabilities to include even the more sophisticated measurements. And you are not limited to the en-

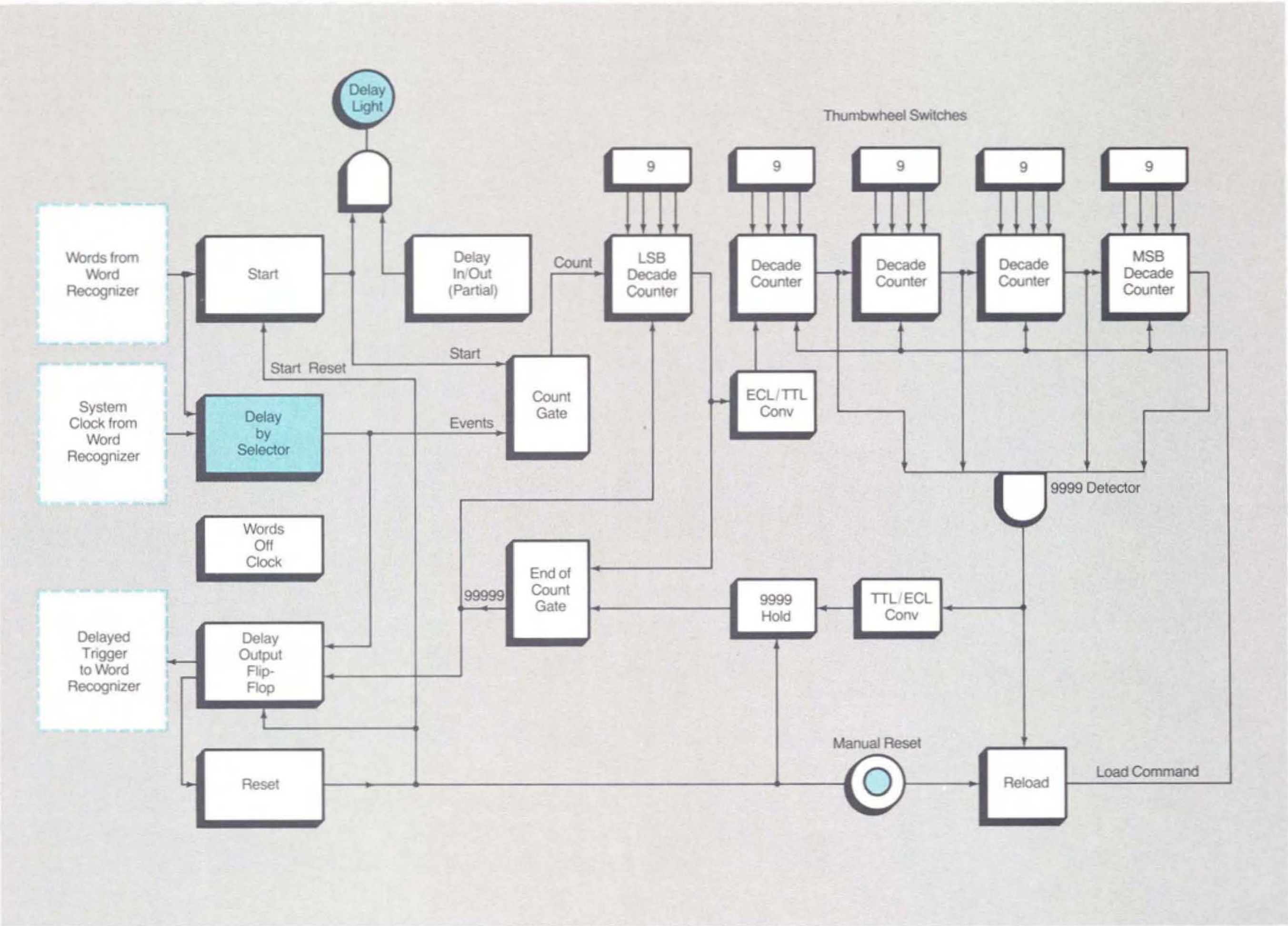
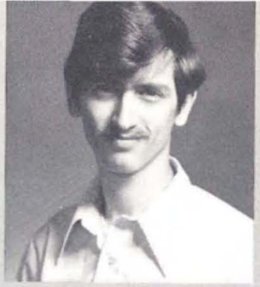


Fig. 2. Simplified block diagram of the digital delay portion of the WR 501. Delay is enabled by the word recognizer output. Manual reset provides for resetting the counter whenever the full count has not been reached.

gineering and production environment. The LA 501W, WR 501, and the SC 502 packed into a TM 515 mainframe give you a complete logic analysis system in a suitcase. They will help you solve those tough logic problems, wherever you encounter them.

Acknowledgments

Overall planning for the WR 501 was coordinated by Rod Bristol, Program Manager, with Pete Janowitz, Project Manager, responsible for translating the plans into physical reality. Milt Klaudt and Dennis Glasby performed electrical design, with Mike Lancaster fitting all of the pieces together in a very functional package. Jaime Navia contributed valuable inputs to mechanical design. Prototype support was provided by Helen Steinmetz; electrical and mechanical evaluation by Carl Matson and Merle Nielsen. Yvonne Hallock did the instruction manual. Our thanks to these and the many others who assisted in the WR 501 project.

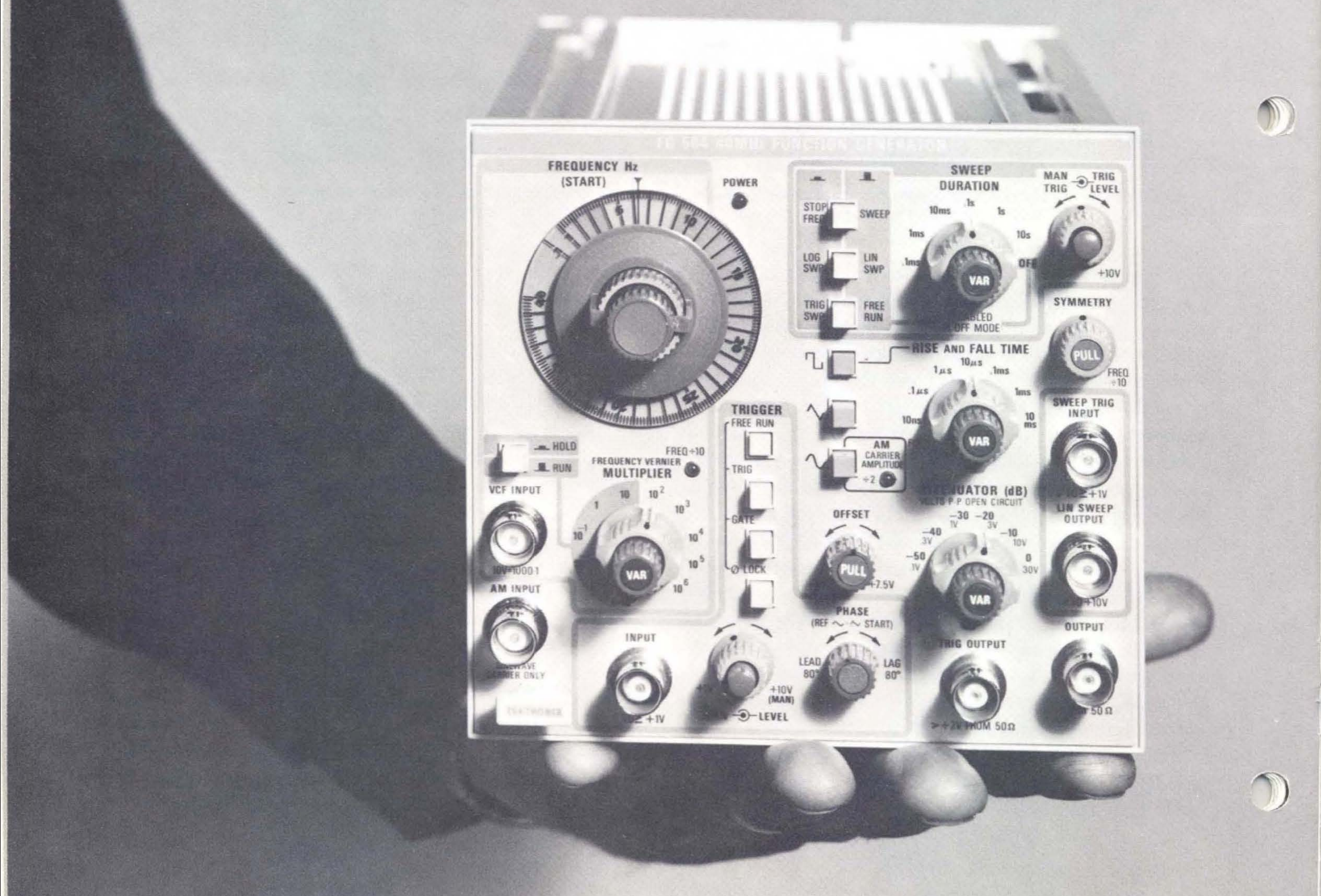


Ira Pollock

The FG 504--a new standard in function generators

At 40 MHz, with 6-ns rise time, Tek's new FG 504 is the fastest function generator available today.

But what should really get function-generator users excited is that the FG 504 combines more features than any other generator on the market. Most of the operating modes are independent. And the front-panel controls allow *simultaneous* usage. Yet it is no more complicated to operate than your average function generator.



What all of this refinement and versatility will mean to many users is an opportunity to make one instrument do the job of several, to a degree never before possible. For example, many users will not have to buy a separate pulse generator.

A few specs. The TEKTRONIX FG 504 is a two-module-wide, 40-MHz, 6-ns rise time function generator with 30-V p-p output, variable rise and fall, log and linear sweep, phase lock, and amplitude modulation capability. Its calibrated frequency range is 0.001 Hz to 40 MHz in ten decades, with an extra range from 20 Hz to 20 KHz for audio applications. The audio range can be changed to an intermediate or custom range by replacing an internal capacitor.

A clean sweep

Using this one instrument, customers can sweep test audio amplifiers, speakers, tone controls, filters, and graphic equalizers. With sweep widths to 1,000:1, the FG 504 can sweep the entire 20-Hz to 20-KHz audio band.

The audio band, of course, is not the only frequency range the FG 504 will sweep: mechanical resonances at low frequencies and slow sweep rates are as easy to investigate as the center frequency of an IF filter. Both internal logarithmic and linear sweeps allow the user to sweep up to the 1,000:1 frequency range as fast as 100 μs, or as slow as 100 seconds. Setting the lower and upper limits is quickly accomplished with concentric START and STOP dials.

Now here's convenience. If you're involved in an application that requires frequent switching between two frequencies — such as checking filter or amplifier bandwidths — you simply pre-set your upper and lower frequencies. Hit TRIG SWEEP and you get the lower frequency. Hit the STOP FREQ button and you get the upper frequency.

The internal sweep can be manually or externally triggered, with settings ranging from +1 V to +10 V. A linear sweep output voltage (0 to +10 V) simplifies log frequency plots when sweeping the main generator logarithmically. Semi-log paper can then be used on a chart recorder.

A welcome feature is the HOLD button that allows you to "freeze", or stop, the output voltage at all frequencies below 400 Hz. People using sub-audio frequencies are often involved with analog simulations or electromechanical experiments, such as mechanical stress analysis or servo-system testing. If, in the course of an experiment, it is desirable to stop the progress and examine some intermediate result, the FG 504 allows the user to do so, retaining the voltage. This simplifies testing where you want to stop and measure a slowly changing voltage, or stop a system that you're controlling with the FG 504's output. Releasing the button lets the generator resume operation from the point of interruption.

External modulation capabilities

External control of frequency over the 1,000:1 frequency range is available via the voltage-controlled frequency (VCF) input. Signals applied to this input cause frequency modulation. The carrier frequency can be as high as 40 MHz, with a modulation bandwidth of dc to 16 KHz at maximum frequency deviation (higher with less than 1,000:1 deviation).

Digital data is often transmitted using Frequency Shift Keying (FSK). FSK can be generated by applying the digital pulse train to the VCF input and manipulating the "1" level, and setting the carrier frequency to the appropriate "0" frequency.

Automatic AM

Complementing the FM capabilities is a dc-coupled AM input that provides either external voltage control of the sine wave amplitude or standard AM.

On the FG 504, AM is automatic. Just plug the signal into the AM input and the carrier amplitude is cut in half. A positive-going signal increases the amplitude, and a negative-going signal decreases the amplitude to full, 100% modulation.

With a dc offset on the modulating signal, double-sideband, suppressed-carrier modulation is possible. Modulation bandwidth is dc to >100 KHz.

Dynamic reaction of AGC, squelch, or other amplitude-sensitive circuits, such as Dolby systems, are easy to test with a square wave on the AM input, which varies the output between two different signal levels.

For classroom use, the FG 504 can be used to demonstrate modulation theory. Modulation ability is also of great interest in the fields of receiver design, testing, service, and analysis.

Phase lock — a new feature

Until now, phase lock has been largely ignored by designers of function generators. This is rather surprising when one considers how much the ability to lock the frequency and phase of a signal generator to that of a reference signal increases the versatility of the generator.

Applications for a phase-locked function generator abound in both the analog and digital world. The design of push-pull amplifiers, for example, is greatly facilitated with signal generators that can produce both sine and square waves that are 180° out of phase.

Measuring the square-wave response is a convenient method for deriving frequency-response information: risetime—upper 3-dB frequency; sag—lower 3-dB point; overshoot—damping and pass-band flatness. This is an ideal application for a phase-locked FG 504 and another function generator such as the FG 503. The same setup can be used to analyze quadrature-phase detectors by changing the phase difference to 90°.

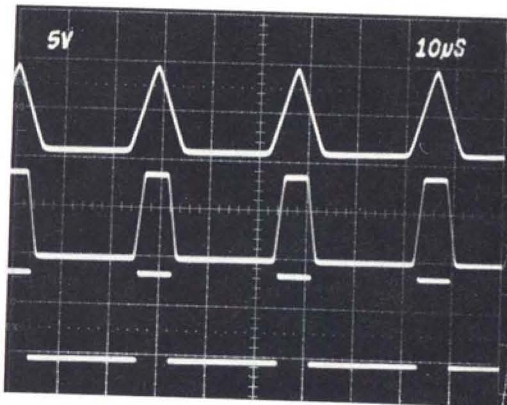


Fig. 1.

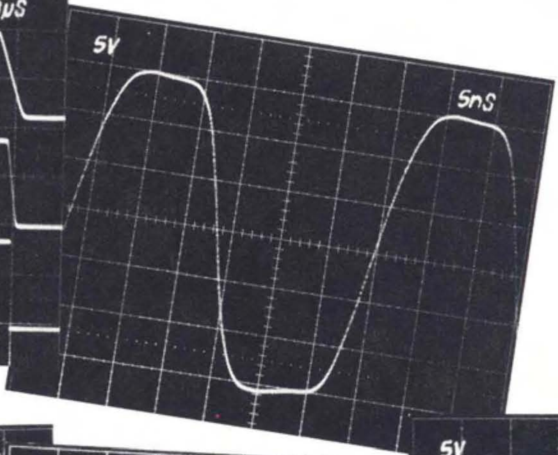


Fig. 2.

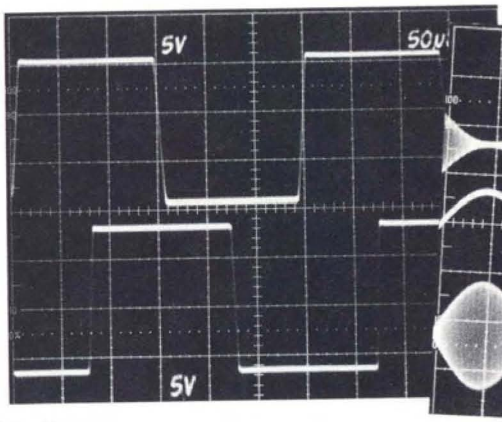


Fig. 3.

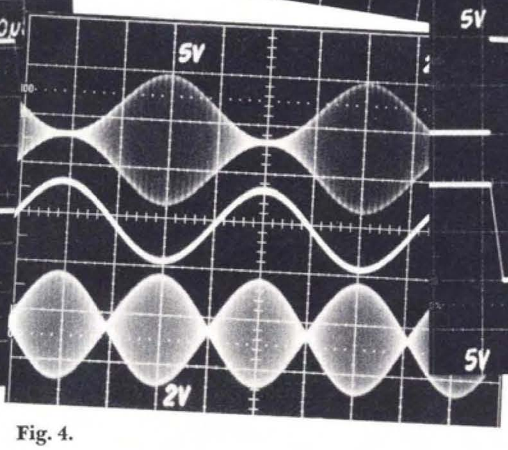


Fig. 4.

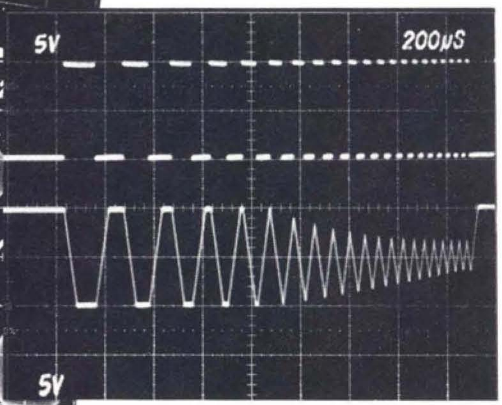


Fig. 5.

Fig. 1. Variable rise and fall times increase pulse flexibility as shown in this photo.

Fig. 2. The FG 504 provides 30 V output with 6 ns rise and fall times, ideal for design in MOS and other logic families.

Fig. 3. Generating multi-phase clock signals is greatly facilitated by the phase-lock capability in the FG 504. Slaved to a master generator, the FG 504 will follow over a wide rep rate range.

Fig. 4. A true four-quadrant multiplier permits normal AM or double-sideband, suppressed-carrier modulation.

Fig. 5. The upper trace is a frequency-swept square wave signal to an op amp. The lower trace is the op amp output, showing slew-rate limitation.

The obvious application for phase lock is to lock an FG 504 to a house standard or crystal oscillator, and have an extremely stable source of high-amplitude sine, square, and triangle waves. Adding a DD 501 to the FG 504 permits integer-frequency division, for limited synthesizer applications. For example, a 20-MHz reference divided by 247 yields a 12.35-μs period, within 0.05% of the time for a radar mile.

With a digital logic signal for a reference, and the variable phase used to set relative timing, the FG 504 output can be adjusted to give a bi-phase clock. A bi-phase clock can help to solve logic-race problems. Most microprocessors use bi-phase clocks. Using a phase-locked function generator, instead of a pulse generator with delay, has the advantage that changes in the master-generator frequency will not perturb phase relationships.

The FG 504 can be phase-locked from 100 Hz to 40 MHz. Lock and capture range is ± 10 major dial divisions (± 10X frequency multiplier setting). With the dial set at 11, for example, the lock range is from 1 on the dial to 21.

Gated and triggered modes

Another feature that adds to the versatility of the FG 504 is the gated mode. An external signal or the manual push button can control the number of cycles that are generated in a burst, as well as the time that the burst is initiated. The use of a DD 501 with the FG 504 makes counted-burst operation possible where the user selects thumbwheel switches in the DD 501 to determine the number of cycles to be generated in the burst.

In addition to use with digital logic, gated operation is used in such acoustic applications as tone-burst testing of loud speakers, sonar, ultrasonic imaging, and anomaly detection. The starting phase of the output waveform is adjustable over a ± 80° range.

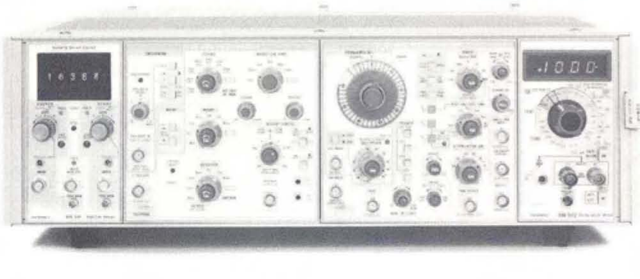


Fig. 6. Typical logic package consisting of a TM 506 Mainframe, DD 501 Digital Delay, PG 508 Pulse Generator, FG 504 Function Generator, and DM 502 Digital Multimeter.

In the triggered mode, the FG 504 generates a single cycle of the selected waveform for each cycle of the input signal, or every time the manual button is pushed. As in the gated mode, the starting phase of the selected waveform is variable over a ± 80° range. With square waves, the phase control acts as a delay control with a range of about 90% of the pulse duration.

Triggered operation is particularly useful in logic applications such as pulse shaping and level shifting. For example, a short-duration, ECL-amplitude pulse can be converted to a CMOS-level pulse of longer duration, or a sine wave can be turned into a TTL-level square wave.

Square waves are not the only useful type of triggered waveform. Triggered triangles and sine waves are used in mechanical-impulse tests. With the phase control at one end, sine-squared pulses are approximated. Sine-squared pulses find wide application in such areas as transmission-line testing, or testing the impulse response of bandwidth-limited systems, since the energy in a sine-squared pulse is concentrated in a narrow band.

The Dirac Delta function, in comparison, ideally requires infinite bandpass, and so rules itself out of these applications.

A unique output amplifier

The output section of the FG 504 is unique for a function generator. As in most function generators, the output amplifier acts as a voltage source behind 50 ohms. *Unlike* most other function generators, the signal swing at the output amplifier is a constant 30 V peak-to-peak.

Past generators have placed the variable control in front of the output amplifier and also summed the offset terminal at the amplifier input. This is an excellent scheme, due to its simplicity and low cost, for a low-performance generator.

However, in high-performance instruments problems arise. Fast output amplifiers tend to change rise time and aberrations with signal amplitude and offset. These problems are avoided in the FG 504 by running a constant-amplitude signal into the amplifier and doing all of the attenuation and offsetting after the amplifier.

The signal can be attenuated up to 50 dB, in 10 dB steps, by a step attenuator, and a constant-impedance variable attenuator can add another 20 dB.

A post-attenuator offset

Probably more important to the user than the post-amplifier attenuators is the post-attenuator offset. Dc offset is generated with an adjustable current source wired in parallel with the amplifier and attenuators. Offset range is ± 7.5 V, independent of signal level.

Users will find this arrangement particularly convenient in determining optimum bias points for amplifiers, logic thresholds, and comparator hysteresis limits.

The 50-ohm output impedance has a low-reactive component, providing minimum aberrations to signals delivered to reactive loads or at the end of unterminated cables. This allows the user to take advanage of the full 30-V signal swing, even with 6-ns rise time pulses, to drive MOS circuitry or to observe the large-signal transient response of linear circuits.

Not all pulse generator applications call for fast-rise pulses. The variable rise- and fall-time feature of the FG 504 facilitates testing of circuit parameters such as amplifier slew rate or comparator response time.

Most of the logic families now in use have a linear region in the middle of their swing. Observation of the effects of traversing this region is made easier with longer transition times on the input signal. In the FG 504, the rise and fall times of the square wave are adjustable from 10 ns to 100 ms.

Finally — independence means versatility

A major way of insuring the versatility of the FG 504 was to make the features as independent as possible. For example, the sweep operates independent of the other sections, so it can be used to trigger or gate the function generator.

By taking advantage of the 1-V to 10-V trigger level on the input and using the triggered sweep with the FG 504 in the triggered mode, the user has a simple delay generator. Delay times from 10 μs to 100 s are possible.

Using the free-running sweep as the gating signal, the user can have a free-running burst generator with either single-frequency bursts (sweep width set to zero) or swept bursts. An external signal can be used to trigger swept bursts.

The FG 504 is currently available as a stand-alone unit, complete with mainframe and power supply; or as part of a measurement system comprising other TM 500 modular instruments.

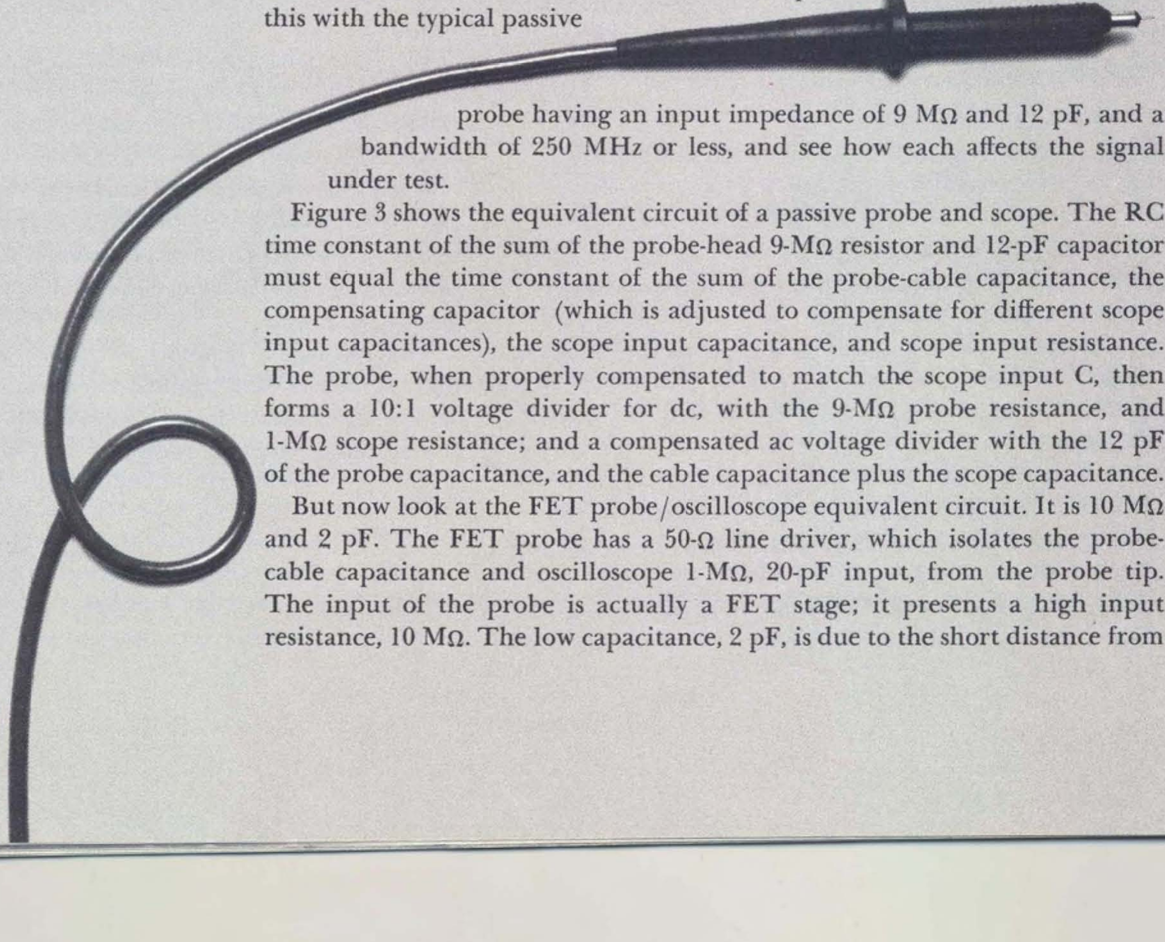
Ron Lang

A new low-cost 500 MHz probe

Many of us take for granted that an oscilloscope display is an accurate representation of a circuit waveform. This is not necessarily true. An oscilloscope has an input impedance of typically 1 MΩ paralleled by 15 to 20 pF. A probe of some sort usually is used to extend the input of the scope to the circuit under test. There is also a certain resistance and capacitance associated with the probe. When the probe is connected to the oscilloscope, an overall impedance of the probe/oscilloscope system is presented to the circuit being measured. This loading of the circuit under test can appreciably alter the signal to be measured, as evidenced by the photo in figure 1.

There are three main characteristics of a probe that determine its ability to couple the signal to the oscilloscope without altering it: input resistance, input capacitance, and bandwidth. The input resistance should be high enough to prevent changing the signal amplitude; input capacitance should be low enough to have negligible effect on signal rise time; and bandwidth should be wide enough to faithfully reproduce the signal waveshape.

An active probe is best-suited to meet all of these requirements. For example, the new P6202 FET probe has an input impedance of 10 MΩ and 2 pF, and a bandwidth of dc to 500 MHz. Let's compare this with the typical passive



probe having an input impedance of 9 MΩ and 12 pF, and a bandwidth of 250 MHz or less, and see how each affects the signal under test.

Figure 3 shows the equivalent circuit of a passive probe and scope. The RC time constant of the sum of the probe-head 9-MΩ resistor and 12-pF capacitor must equal the time constant of the sum of the probe-cable capacitance, the compensating capacitor (which is adjusted to compensate for different scope input capacitances), the scope input capacitance, and scope input resistance. The probe, when properly compensated to match the scope input C, then forms a 10:1 voltage divider for dc, with the 9-MΩ probe resistance, and 1-MΩ scope resistance; and a compensated ac voltage divider with the 12 pF of the probe capacitance, and the cable capacitance plus the scope capacitance.

But now look at the FET probe/oscilloscope equivalent circuit. It is 10 MΩ and 2 pF. The FET probe has a 50-Ω line driver, which isolates the probe-cable capacitance and oscilloscope 1-MΩ, 20-pF input, from the probe tip. The input of the probe is actually a FET stage; it presents a high input resistance, 10 MΩ. The low capacitance, 2 pF, is due to the short distance from

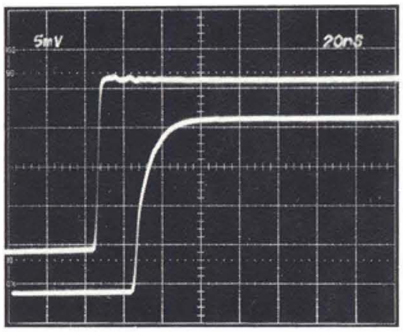


Fig. 1. The lower waveform shows the rise time of a circuit as measured using a passive probe with 10 pF input capacitance. The upper waveform shows the result using an active FET probe with less than 2 pF input capacitance.

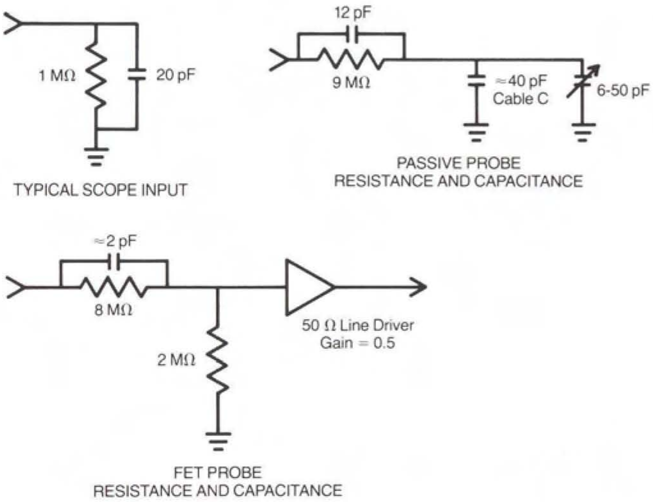


Fig. 2. Typical input resistance and capacitance of a scope, passive probe, and FET probe. Both probes provide 10 X attenuation.

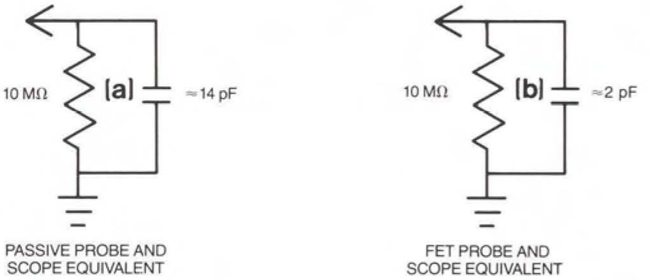


Fig. 3. Equivalent input resistance and capacitance of (a) passive probe and scope, and (b) FET probe and scope.

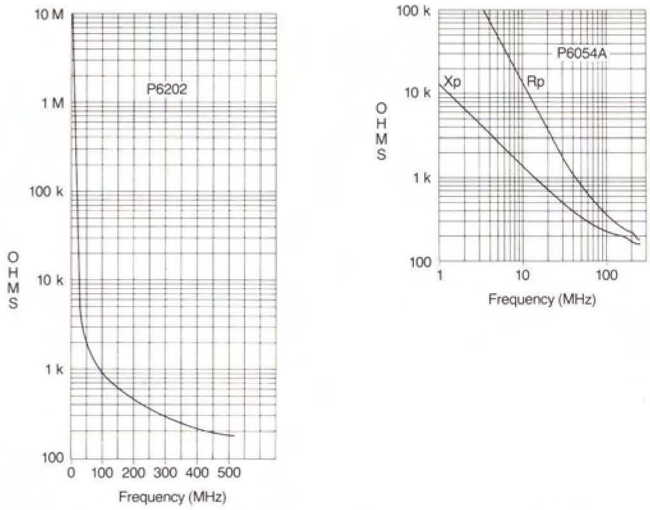


Fig. 4. Input impedance versus frequency for a P6054A passive probe, and an active FET probe. R_p of the FET probe remains essentially constant throughout its bandpass.

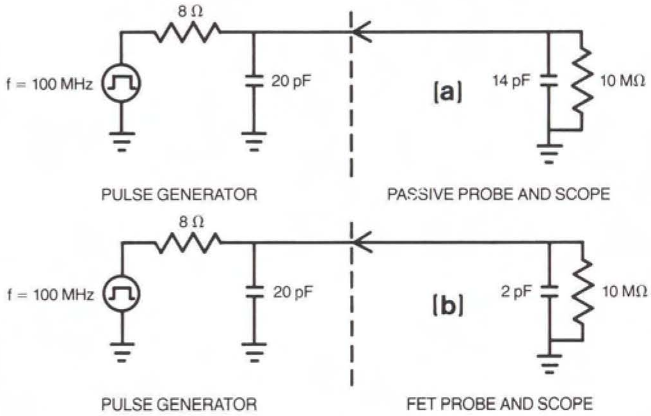


Fig. 5. Equivalent of (a) passive probe and scope, and (b) FET probe and scope applied to a fast-rise pulse generator.

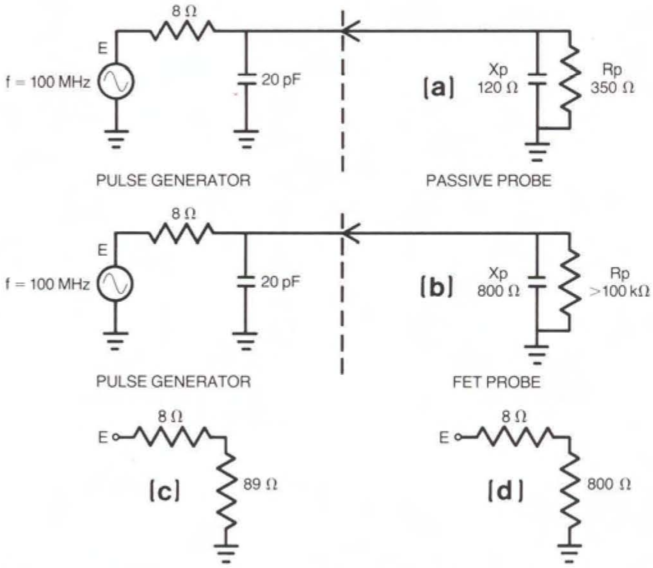


Fig. 6. Change in output amplitude of 100-MHz signal is greater with passive probe than with FET probe due to reactive elements in probe. Equivalent circuit (c) is with passive probe, and (d) is with FET probe.

the probe tip to the FET, plus the low input capacitance of the FET. The FET drives a 50-Ω line-driver stage that drives the cable from the probe head to the compensation box. The compensation box contains the output amplifiers, dc offset controls, and a switch to "switch out" the 50 Ω load if the scope input is 50 Ω instead of a high impedance.

Figure 4 shows the effects of input resistance, R_p, and input capacitance, X_p, versus frequency, for a passive probe and a FET probe. The passive probe R_p falls to about 350 Ω at 100 MHz; X_p is about 120 Ω at 100 MHz. The R_p of the FET probe remains fairly constant throughout the frequency range and is high enough in resistance to not enter into the circuit-loading calculations. The X_p is 800 Ω at 100 MHz.

Assuming a circuit source impedance of 8 Ω and 20 pF, consider rise time and amplitude effects of a passive probe and a FET probe on the circuit. See figure 5. In a pulse circuit, the t_r of the circuit is:

$$t_r \text{ circuit} = 2.2\,RC \qquad \text{Assume } t_r \text{ of pulse is } 0$$
$$= 2.2 \times 8 \times 20\text{ pF}$$
$$= 0.35\text{ ns}$$

With the passive probe attached, the t_{rpp} is:

$$t_{rpp} = 2.2 \times 8 \times 34\text{ pF} \qquad t_{rpp} = t_r \text{ of circuit}$$
$$= 0.6\text{ ns} \qquad \text{with passive probe}$$

With the FET probe attached, the t_{rFET} is:

$$t_{rFET} = 2.2 \times 8 \times 22\text{ pF} \qquad t_{rFET} = t_r \text{ of circuit}$$
$$= 0.39\text{ ns} \qquad \text{with FET probe}$$

$$\frac{t_{rpp} - t_r \text{ circuit}}{t_r \text{ circuit}} \times 100 = \frac{0.6\text{ ns} - 0.35\text{ ns}}{0.35\text{ ns}} \times 100 = 71\%$$

$$\frac{t_{rFET} - t_r \text{ circuit}}{t_r \text{ circuit}} \times 100 = \frac{0.39\text{ ns} - 0.35\text{ ns}}{0.35\text{ ns}} \times 100 = 11\%$$

With the passive probe there is a 71% change in rise time due to the input C of 14 pF, but only an 11% change with the FET probe due to the lower input C of 2 pF.

Now consider the amplitude effects with the passive and active probes. When the passive probe is attached to the circuit (see figure 6 (a)), it presents an impedance of the R_p and X_p at 100 MHz. Ignoring the phase angle because it is small, the equivalent circuit looks like figure 6 (c). The waveform presented to the scope is then, $\frac{E \times 89}{89 + 8} = 0.92E$, an 8% change.

Now consider the FET probe attached to the same circuit (see figure 6 (b)). The X_p is equal to 800 Ω at 100 MHz. The equivalent circuit with the probe attached is as figure 6 (d), $\frac{E \times 800}{808} = 0.99E$, a 1% change.

The higher input impedance of the FET probe has a smaller effect on t_r and amplitude.

FET probe advantages

The first advantage of a FET probe, then, is very low input capacitance and very high input resistance, resulting in less circuit loading and truer signal representation.

The FET probe has an active input that provides low input capacitance and a higher frequency response than a passive probe. The frequency response of the P6202 FET probe is dc to 500 MHz (-3dB).

The P6202 also has dc offset capabilities. This means that any dc voltage up to ±55 volts can be offset without any degrading of the probe response. The advantage is to measure a small ac voltage on a large dc component, at the full bandpass capabilities of the probe. A switch on the compensation box allows the dc offset to be switched in or out.

Another switch on the output connector of the compensation box allows the probe to be used with either 50-Ω or high-impedance inputs. When used with a 50-Ω input, the 50-Ω load in the output of the probe is switched out. When using high-impedance inputs, the 50-Ω load is switched in.

A built-in power supply allows the P6202 to be used on any instrumentation, including counters, without having an external power supply or accessory power available. It can be used with 115 or 230 VAC, 50 to 60 Hz power sources.

Optional accessories are a slip-on ac coupling cap to block unwanted dc components (above the 55 volts of dc offset), and a slip-on 10X attenuator to make the input 100 times attenuation, still at 10-MΩ and 2-pF input impedance.

Summary

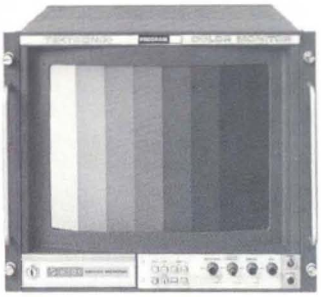
The new low-cost P6202 FET probe offers several advantages over the passive probe for many applications: wide bandwidth, very low input capacitance, high input resistance, dc offset, usable with either 50 Ω or high impedance inputs.

Small and rugged, the P6202 can get into tight places and yet stand the rigors of production and testing.

The 0 to ±6 volt dynamic range and ±55 volt offset capability make this low-cost probe applicable to a diversity of measurement needs. The optional 10X attenuator and ac coupling heads extend the operating range of the P6202 still further.

The P6202 includes a BNC connector that provides scale readout on the 10X mode to instruments having readout capability, yet maintains compatibility with non-readout instruments.

New Products
New Products
New Products



670A Picture Monitors

The new 670A Series consists of precision color picture monitors for NTSC and PAL Television standards. The series uses a 17-inch Triniton to present a picture whose sharpness is enhanced by a new feature — variable aperture control. The monitors are factory set for an accurate white balance at D6500°, however, you may choose to adjust to your own standards.

Consistency between TEKTRONIX Monitors is a major benefit. In the 670A Series consistency is achieved through use of the simple-to-converge Trinitron, excellent clamp stability, and a highly regulated EHT. Less than 1% change in raster size will occur with large APL changes, and blanking and black level are extremely stable, too.

Individual lines in the vertical interval can be examined in detail using the expanded vertical delay mode. Horizontal delay is also provided. The 670A features inputs isolated from ground, eliminating the need for special hum-bucking transformers. Optional outputs are available that take advantage of the precision decoding circuits of this monitor series, to provide an accurate vectorscope display using a low-cost x-y monitor. The monitors are compact, requiring only 15.75 inches of rack space.

1405 Television Sideband Adapter

The 1405 Television Sideband Adapter is used with a spectrum analyzer, such as the 7L12 or 7L13, to analyze the sideband response of a television transmitter.

Connected to the 7L12 or 7L13, the 1405 generates a composite-video signal, the picture portion of which is a constant-amplitude sine wave signal that sweeps from 15-0-15 MHz. When this signal is used to modulate the TV transmitter, the sideband response of the transmitter will be displayed on the spectrum analyzer.

The 1405/Spectrum Analyzer combination can be used to display the frequency-response characteristics of RF and IF stages of any VHF or UHF transmitter used today in the world. Six crystal marker positions are provided.

In addition to sideband testing, typically done in a TV station once a week, the 1405/Spectrum Analyzer combination can perform the following tests: log amplitude display of sideband response, in-service testing, spectrum analysis of the transmitter, differential gain measurements, aural transmitter deviation, antenna VSWR (with directional coupler), baseband response, and complete loop testing including STL.

1410 Series NTSC Generators

The new 1410 Series of NTSC Sync Pulse and Test Signal Generators are high-performance instruments offering all the advantages of modularity, at prices generally associated with units of single-piece construction. To suit your specific needs, you may choose from a wide selection of sync-pulse and test-signal generator functions to be combined with the mainframe providing the color standard of your choice. Should you develop additional test-signal requirements in the future, plug-in card construction insures a quick and easy retrofit for you. Any combination of five test-signal generator modules driven by one sync-pulse generator is feasible.

The Sync Pulse Modules and the Test Signal Modules plug vertically onto the 1410 Mainframe interface board. Front-panel controls and switches are mounted on the module with easily-removable extenders projecting through the front panels. Available modules include three sync-pulse generators, a color-bars generator, a convergence pattern generator, a linearity signal generator, and a VIRS/Black Burst generator.

1470 and 1474 CCTV Signal Generators

Two new signal generators, the 1470 and 1474, are designed specifically to economically meet the needs of CCTV operations.

The first generator, the 1470 CCTV Color Sync and Test Signal Generator is a compact, economical unit designed to provide gen-lock sync plus a selection of high-quality full-field test signals. Among the sync and timing features of the 1470 is the ability to color gen-lock to composite video from all normal sources, including most helical scan video tape recorders. (When gen-lock operation is not required additional savings will be gained by ordering Option 1.)

The second generator, the 1474 CCTV Color Sync Generator, has the performance features of the 1470 but does not produce test signals.

Sync pulse generation

The sync pulse functions of the 1470 and 1474, like those of other TEKTRONIX generators, are of broadcast quality. These generators can operate as master sync generators or as units fully or partially timed from external sources. Color gen-lock of the highest quality is a standard feature.

Front-panel push button selection of external subcarrier and sync is provided for your convenience. If external subcarrier is lost, the 1470 and 1474 start monochrome operation automatically and a warning light appears.

Test signals

Push-button selection of test signals in the 1470 simplifies your testing operations. When you select color bars, multiburst, convergence, or window; each test-signal push button used cancels any other test signal selection. To make a linearity test with a staircase signal, you use only two buttons: Subcarrier on/off and high, low or medium APL. For flat-field testing the 1470 has the unique ability to produce red, green or blue signals to simplify color picture monitor adjustment by eliminating the need to turn beams on and off. Flat-field white is produced by depressing all three buttons. Yellow, cyan, or magenta fields are available by just depressing two of the three buttons. Each test signal is of the highest standards of the industry, providing essentially aberration-free transitions and accurate, flat levels.

AM 511 CATV Preamplifier

The AM 511 CATV Preamplifier is a TM 500 Series plug-in unit designed to operate as an accessory for the 7L12 and 7L13 Spectrum Analyzers. It is particularly useful for measuring-signal-to noise, radiation, and field intensity to FCC specifications on CATV, television, and FM installations. Other uses include radio-system servicing and measurements, as well as increasing sensitivity for EMI measurements within the 30- to 890-MHz frequency range.

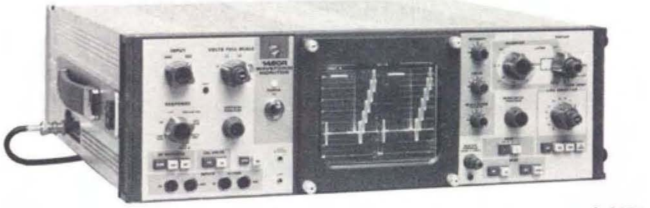
The AM 511 is also an excellent amplifier for use with any wideband scope such as the 475 or 485, or with the 7A16 or 7A19 where low-noise nanovolt sensitivity is desired.

Input impedance is 75 Ω. Reference level is calibrated in 1-dB steps from +79 dBmV to 0 dBmV. Intermodulation distortion is at least 70 dB down. VSWR is 2:1.

1480 Option 6 Waveform Monitor

The 1480R Option 6 is a high-performance television waveform monitor designed for use in your television operating center or by your field service force. Option 6 is especially designed for measurements in long-distance, video transmission systems using 124-Ω balanced lines. Self-normalizing WECO-style input jacks allow this instrument to operate in a 75-Ω system without externally terminating the ring input. With these features the 1480R Option 6 has been designed to operate in either a 124-Ω balanced or 75-Ω unbalanced system.

Vertical sensitivity, with automatic bandpass limiting, has been increased to 0.05 volts full scale for making differential phase and gain measurements with Bell Kelley or Telemet Test Sets. A 5- to 12-second, variable sweep has been added to measure low-frequency distortions and system bounce caused by large APL changes in the video signal.



A-3374

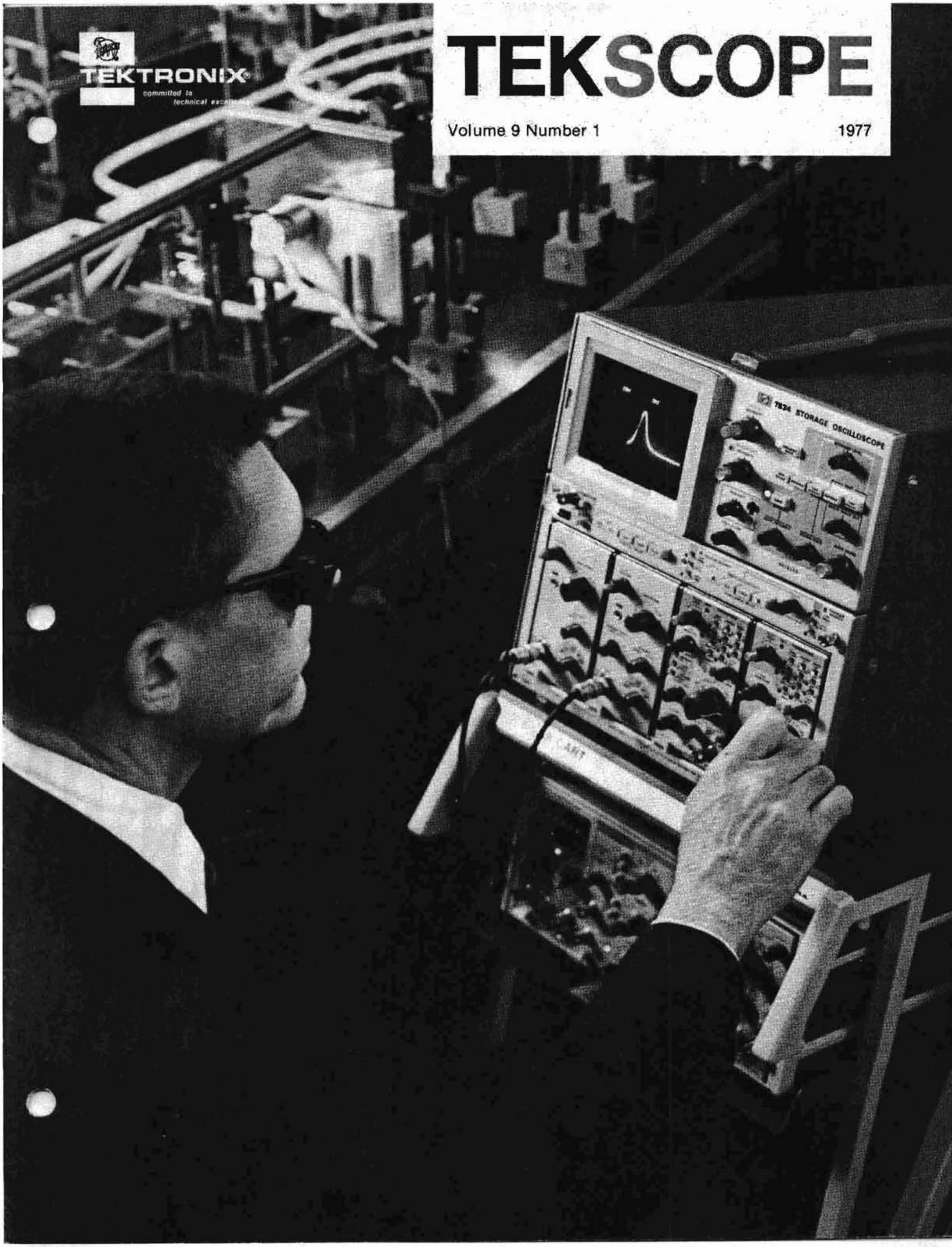
TEKTRONIX, INC.
P.O. BOX 500
BEAVERTON, OR. 97005

1893270
MR DON INGRAM TECH STAND LAB
MILGO ELECTRONICS CORP
8600 NW 41ST STREET
MIAMI FL 33166

TEKTRONIX®
committed to technical excellence

TEKSCOPE

Volume 9 Number 1 1977



TEKSCOPE

TEKTRONIX®
committed to technical excellence

Customer Information from Tektronix, Inc.,
Beaverton, Oregon 97077
Editor: Gordon Allison

Contents

2 **A big step forward for direct-view storage.**

The new 7834 Storage Oscilloscope combines 400 MHz bandwidth and 2500 cm/μs stored writing speed in a four plug-in 7000 Series mainframe to bring you a new high in performance and versatility in a general purpose oscilloscope.

6 **Counter and oscilloscope combination makes difficult measurements.**

Selective counter measurements are easy to make using an oscilloscope with delaying sweep and dual trace algebraic add functions.

11 **Testing three-terminal regulators with a curve tracer.**

A 577/178 Curve Tracer provides an ideal answer to the need for performing short run incoming inspection tests, circuit design, or device characterization of three-terminal regulators.

14 **Tektronix products get dirty, too!**

Part II describes "dry cleaning" techniques for those users who can't release their instruments long enough for a thorough wash job.

Cover: Dr. Gail Massey of Oregon Graduate Center studies a YAG laser pulse stored and displayed on the 400 MHz 7834 Storage Oscilloscope.

Jerry Rogers   Ken Hawken

A big step forward for direct-view storage

State of the art direct-view storage takes a big step forward with the introduction of the TEKTRONIX 7834 Storage Oscilloscope. Up to now the maximum stored writing speed has been 1000 cm/μs in the 7633 plug-in oscilloscope and 1350 cm/μs in the 466 portable. Both are 100 MHz instruments.

The new writing speed mark is 2500 cm/μs, and it's coupled with 400 MHz bandwidth in the new 7834. This means you can now capture a 3.5 cm high, single-event risetime of 1.4 ns.

The 7834 is a general-purpose laboratory oscilloscope with all of the synergistic measurement power produced by the four plug-in capability of the 7000 Series. For example, real time and spectrum analyzer plug-ins can be housed to simultaneously present both time and frequency domain displays for a given signal. Using the 7834's variable persistence storage mode, a steady display of the time domain can be viewed while observing slow changes in the spectral content. In another configuration, logic analyzer and real time plug-ins can be combined to zero in on a logic fault and then display that fault in real time, even though it may occur only once.

Multimode storage

The 7834 features multimode storage—bistable, variable persistence, and fast modes for each, pioneered in the 7623 a few short years ago.

The bistable storage-display is characterized by having two intensity levels—the stored-image intensity and the background level. There are two such modes: BISTABLE and FAST BISTABLE. The chief advantage of both of these modes is long view-time. Once an image is stored, it can be viewed for an extended period. The BISTABLE mode is the simplest of all to use, with no adjustments for storage sensitivity other than the intensity control. Also, with a high resistance to blooming, this mode is unsurpassed for storing extremely low-frequency events that require a slow-moving spot on the crt. This mode, therefore, can capture waveforms with extreme differences in spot movement speed. The chief limitation is writing speed. The FAST BISTABLE mode also is resistant to blooming and overcomes the low writing-speed limitation. It is the second fastest mode of the instrument, with a writing speed of 350 cm/μs in reduced scan, and is useful in capturing single-shot information.

Variable-persistence storage displays are characterized by controllable persistence (the rate at which the stored display fades). Typically, this rate of fading may be adjusted from 1 or 2 seconds to well over a minute. There are two such modes: VARIABLE PERSISTENCE and FAST VARIABLE PERSISTENCE. The chief advantage of these modes is high writing speed. When the storage controls are optimized, writing speed is many times greater than in the corresponding bistable modes. The storage controls may also be adjusted to provide high-contrast displays that are especially advantageous for photography. In both variable persistence modes, view time (the length of time a stored trace is distinguishable from the background) is less than in the bistable modes, and is shortest of all when adjusted for highest writing speed. View time can be increased by using the SAVE mode as on other storage oscilloscopes.

The VARIABLE PERSISTENCE mode in the 7834 can convert a dim display of a fast, low-repetition-rate signal, into a bright, flicker-free display for easy viewing of signals that are beyond the display capability of non-storage instruments. By varying the persistence (or rate of fading), the best compromise can be reached between lack of flicker and ability to follow changes in the waveform.

The FAST VARIABLE PERSISTENCE mode provides the highest writing speed of all, 2500 cm/μs in reduced scan. This mode is most useful for capturing high-speed single-shot events such as fast rise pulses encountered in laser fusion research, destructive testing, and high speed computer development, that occur only once, or at very low rep-rates at best. The 7834 offers an unprecedented ability to display these pulses.

New operational features

The 7834 has several features not found on other storage oscilloscopes. These features add convenience and flexibility. For example, the MULTI-TRACE DELAY control extends the usefulness of the transfer-storage modes (FAST BISTABLE and FAST VARIABLE PERSISTENCE). When a time base operates in a repetitive manner (rather than single sweep), this control varies the display time between successive sweeps. An "infinite" position provides the same effect as single-sweep operation. One application of the multi-trace delay control is in making calibration adjustments. The operator simply sets the delay equal to the time required to change an adjustment. The new result is then automatically displayed (along with the old), freeing the operator from manually resetting the oscilloscope time base for each trace. Another application is to store a periodic waveform that occurs in a longer sequence of events. The multi-trace delay may be adjusted to blank out unwanted events and allow triggering only on the desired waveform.

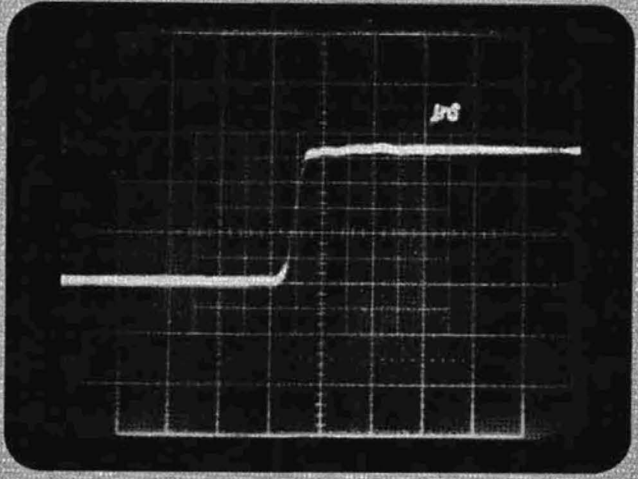


Fig. 1. Stored display of a single-shot, fast rise time signal.

The Remote-Storage inputs give the user control over several essential storage functions. With Remote Erase, Reset, and the new Remote Save inputs, the operator can conveniently conduct experiments at a distance from the oscilloscope, or control these functions automatically from other equipment.

A new Remote-Storage Gate input provides the user additional capability in the fast-storage modes. Use of this input, along with a second time base, permits capturing several closely spaced events on the same display, an ability not possible in fast-storage modes on previous instruments.

Two types of Auto Erase are available in the 7834. One is an adjustable periodic function that erases on a regular basis whether or not a stored display is present. The other type provides an adjustable display time after each stored event, and will not erase unless the time base has been triggered.

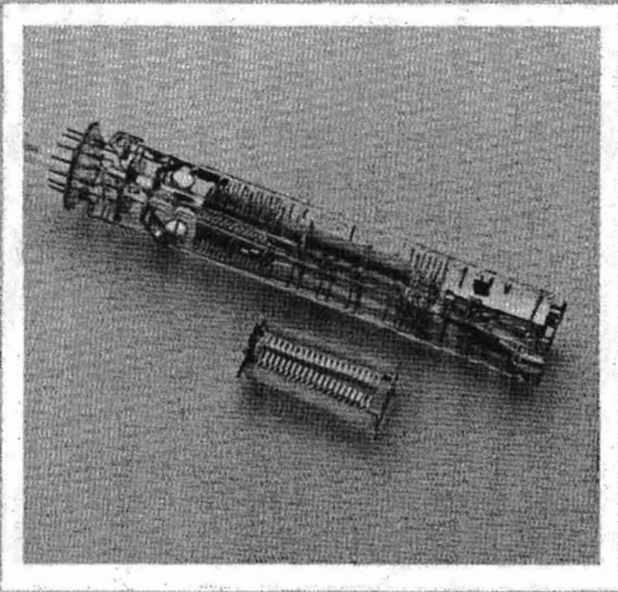


Fig. 2. Electron gun structure of the 7834 cathode ray tube. The vertical deflection structure, with the shield removed, is shown below the vertical deflection portion of the gun.

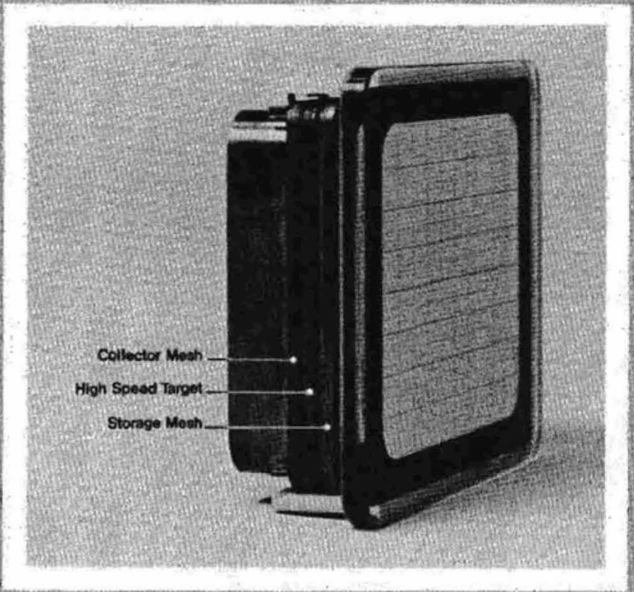


Fig. 3. A cutaway of the front portion of the 7834 cathode ray tube, showing the three-mesh structure used to achieve transfer storage.

Gated or Free Run readout selection is located on the front panel. This feature is especially convenient when switching between storage (where Gated is often used) and non-storage operation (where Free Run is typically more desirable). Previously, the Gated/Free Run switch had been located inside the mainframe, requiring removal of a sidecover to change modes.

Fast X-Y storage is possible in the 7834 because of a horizontal-mode selector switch and the availability of two horizontal plug-in compartments. Previously, X-Y storage was possible only in the slower, or non-transfer, storage modes.

Cathode ray tube

Much of the 7834's advanced performance is achieved through extending the capabilities of the cathode-ray tube (crt) to provide multi-mode storage. Both bistable and variable persistence designs are incorporated into the crt. In addition, a new focusing structure and improved electron-gun design are used to reach the high stored writing-rate. Further, a more sensitive deflection system was needed to reach the 400-MHz design goal for the vertical system passband.

In designing the crt, we built upon the experience gained with the 7633 transfer-storage tube. Transfer storage is the technique whereby two storage meshes are used to capture and display information, especially fast transients.

The writing beam stores an image on a highly sensitive short-view-time target. The image is then transferred to the second storage mesh, which has lower sensitivity but much longer view times. This second mesh can be operated in either a bistable or a variable persistence mode.[1]

A number of performance improvements were required of the crt to be suitable for a 400-MHz storage oscilloscope. These include both improved gun design and storage uniformity.

The gun design changes include a traveling-wave deflection system similar to that used in the TEKTRONIX 7904 Oscilloscope, the deflection sensitivity is improved to 1.7 V/cm/kV (a 50% improvement over the 7633 crt). To obtain a faster stored writing speed, an improved gun system was designed to deliver greater charge density to the target. The gun voltage was increased to improve the secondary-emission yield at the target and to reduce the space charge spreading of the writing beam. Independent X- and Y- focusing systems were designed, together with a vertical-only scan expansion lens, to obtain the required vertical-deflection sensitivity. The new focusing system results in improved trace width for the same beam current. More sensitive horizontal plates were designed to help in obtaining faster sweep speeds. An overall improvement in gun performance of 2.5 times was realized.

Additional gain in writing speed was obtained by improving the background uniformity of the display. Since a trace that will store on one part of the target may not store on another part, the writing speed specifications are quoted for the slowest portion of the target within the display area. To this end, the flood-gun collimation system was computer designed to improve landing characteristics and consequently improve background uniformity. This typically reduced the ratio between reduced scan and full scan variable persistence writing speeds from 8:1 to 6:1. Some performance gains over the previous fast-storage crt used in the 7633 are shown in Figure 4. This shows the typical writing speed expressed as tracewidths/second as a function of Intensity for the two fastest storage modes (variable persistence fast and bistable fast, in reduced scan). The reduced-scan mode of operation typically results in an eight-times improvement in writing speed over the full scan operation, due to the increased gun voltage and the reduced effect of target uniformity on writing speed. In the fastest mode, the writing speed approaches 10^{11} tracewidths/second. This compares with the photographic writing speed of the 7904. These stored traces are viewable for tens of seconds and are easily photographed.

Writing speed

Unless someone is very familiar with storage terminology, a writing speed specification may not be very meaningful except in a relative sense, where one storage oscilloscope is better than another. Therefore, a review of some basic storage concepts will better relate what the high performance of the 7834 does for your measurement needs. Writing speed is defined as the highest rate of spot movement on the crt face that will leave behind a stored image. Spot movement that is faster than writing speed will not leave an image, resulting in step response displays with no vertical edge, or sine wave displays with the center missing.

To be more precise, writing speed can be related to common waveforms by the equations:

$$(1)\ WS = \pi fA$$

$$(2)\ WS = \frac{kA}{T_r}$$

Equation (1) is for a sine wave of frequency, f, in megahertz, and peak-to-peak amplitude, A, in centimeters, yielding writing speed in cm/μs. Thus, a writing speed of 2500 cm/μs will store a 250 MHz sinewave with 3.2 cm peak-to-peak amplitude.

Equation (2) describes writing speed in terms of the vertical edge of a pulse or step response. The value of k ranges from 0.8 for a linear ramp, to 2.2 for a single-pole rc response. A value of 1.0 applies to a Gaussian or typical step response. T_r is the 10-90% rise time in μs and A is the amplitude in cm, to yield writing speed in cm/μs. Thus, a writing speed of 2500 cm/μs will store a 2.5 cm Gaussian step response with 1-ns rise time.

The 7834 achieves its maximum specified writing speed of 2500 cm/μs in a reduced scan mode, with 0.45 cm divisions. Writing speed in divisions is calculated by dividing by 0.45; thus, a 3.2-cm sine wave will be 7.1 divisions peak-to-peak. In these relationships, horizontal movement is not taken into account. However, for beam movement of more than three vertical divisions for every horizontal division, the effect of horizontal movement is less than five percent, and can usually be neglected.

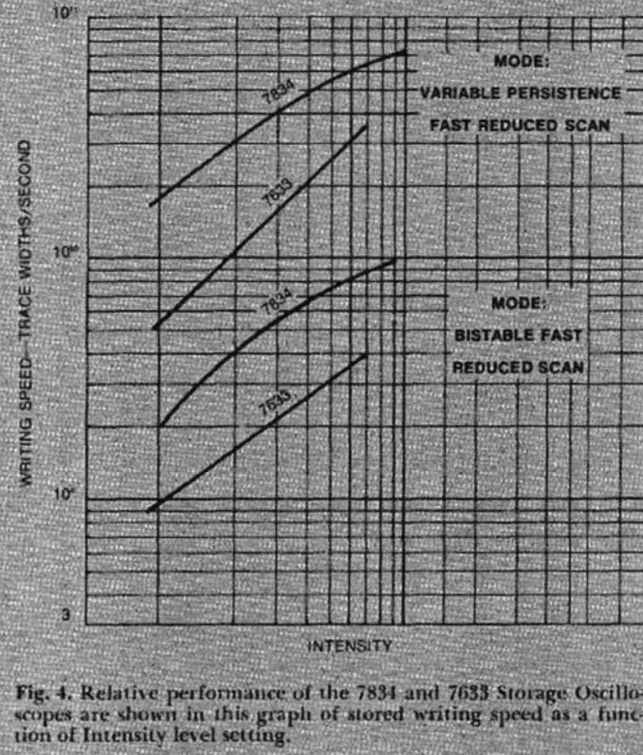


Fig. 4. Relative performance of the 7834 and 7633 Storage Oscilloscopes are shown in this graph of stored writing speed as a function of Intensity level setting.

General design features

Construction of the 7834 is much like the modular 7704A. The instrument is divided into two main modules that may be easily separated for ease of service. Like other 7000 Series four-plug-in mainframes, the 7834 has a high-efficiency power supply. This supply runs cooler and is much lighter than a conventional regulated supply. It is also more immune to electro-magnetic interference through the power line. The 7834 circuitry is highly protected from overloads such as a spurious short between various crt electrodes.

Acknowledgments

Project Engineer Chuck Scott directed the 7834 design. Electrical design was by John Durecka, Dave Morgan, Joe Peter and Jerry Rogers. Mark Anderson did the mechanical design. Gene Andrews was Project Manager.

The 7834 CRT development was headed by Project Manager Pete Perkins who did the collimation studies. Ken Hawken was CRT Project Engineer and Steve Blazo did the new CRT gun design. Dave Coffey did the CRT Manufacturing Engineering.

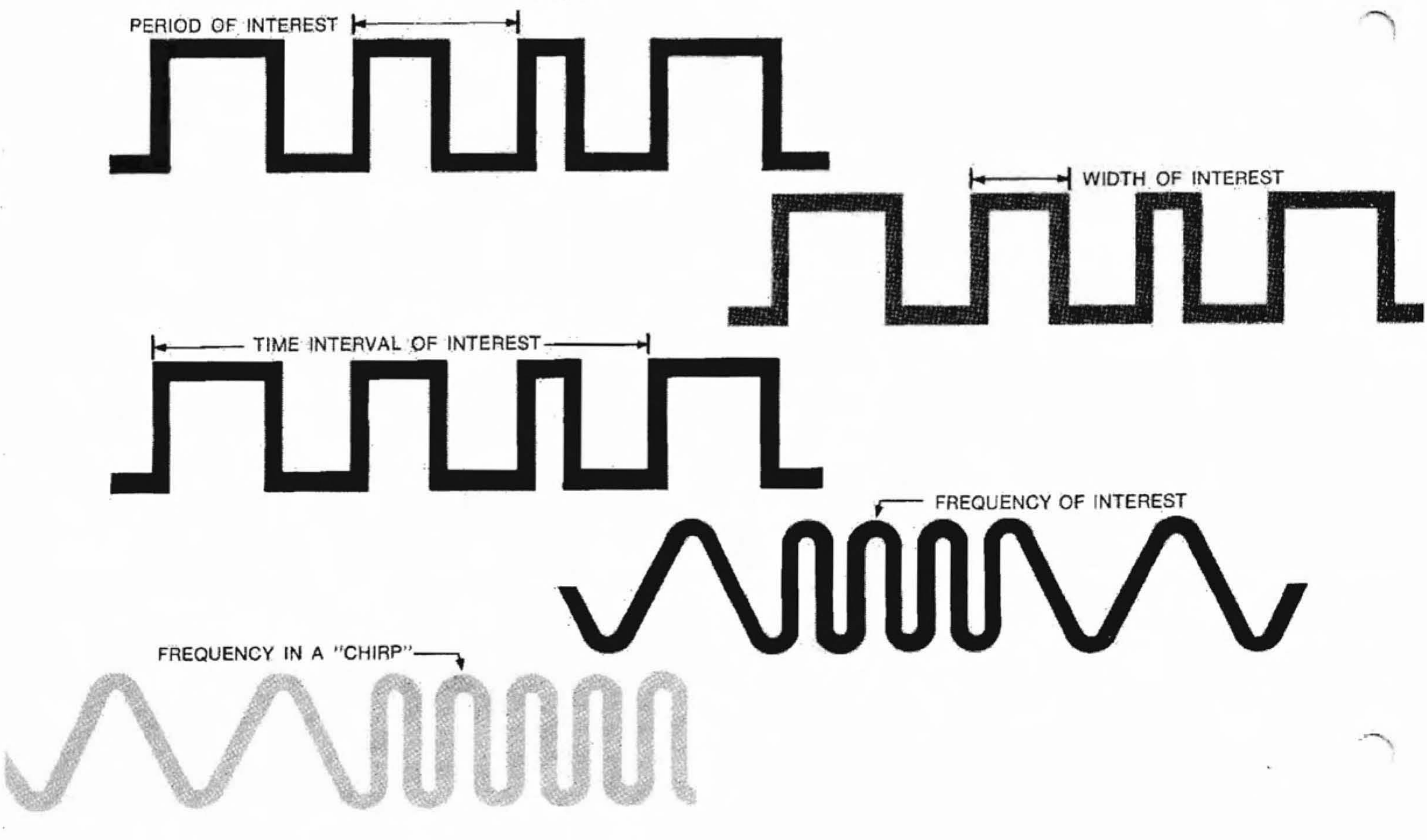
Marketing planning was done by Dave McCullough, and Mike Hurley is the Marketing Program Supervisor. Dwayne Wolfe is Manufacturing Manager.

1 See Tekscope July 1972

Emory Harry

Counter and oscilloscope combination makes difficult measurements

Modern electronic counters are versatile, accurate instruments used in a wide variety of applications. However, many measurements are difficult or even impossible to make with conventional counters. Here are a few examples:



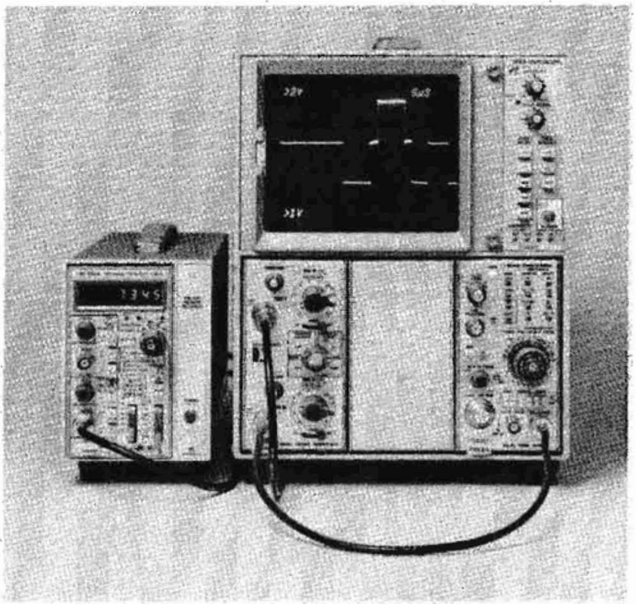


Fig. 1. A counter and oscilloscope set up to measure the width of the elevated pulse displayed on the oscilloscope crt.

VERTICAL SIGNAL OUTPUT

Mainframes	Bandwidth	Amplitude
7900 Series	140 MHz with 7A24 or 7A26 75 MHz with 7A18	500 mV/div into 1 MΩ 25 mV/div into 50 Ω
7700 Series	70 MHz with 7A24 or 7A26 55 MHz with 7A18	500 mV/div into 1 MΩ 25 mV/div into 50 Ω
7600 Series	75 MHz with 7A18	500 mV/div into 1 MΩ 25 mV/div into 50 Ω
7503/7504	55 MHz with 7A12	500 mV/div into 1 MΩ 25 mV/div into 50 Ω
7313/R7313	20 MHz with 7A18	500 mV/div into 1 MΩ 25 mV/div into 50 Ω
549	≥ 5 MHz with 1A1	1.5 V/div into 1 MΩ
544/546/547/ RM544/RM546/ RM547	15 MHz with 1A1	300 mV/div into 1 MΩ
535A/R535	5 MHz with 1A1	1.5 V/div into 1 MΩ
545A/B/ RM545A/B	≃ 20 MHz with 1A1	1.2 V/div into 1 MΩ

Fig. 2. TEKTRONIX oscilloscopes having delayed gate and vertical signal outputs suitable for this application.

In each example, the counter's trigger circuits cannot discriminate between the part of the waveform of interest and the part not of interest.

A few counters offer input gating that allows the input signal channel of the counter to be gated on and off with an external gate or control signal. This makes most of these difficult measurements possible; however, the appropriate gating signal is rarely conveniently available. A few counters offer Variable Hold-Off or Delay, which introduces a variable delay in the Time Interval mode, between when Channel A triggers and Channel B is permitted to trigger. This feature also makes some of these difficult measurements possible, but it can only be used in the Time Interval mode, and the approximate amount of delay required must be known.

Almost all of these difficult measurements can, of course, be made directly with an oscilloscope, but not with the same degree of accuracy a counter offers.

Counter and oscilloscope

A counter and an oscilloscope can be combined into a powerful measurement tool that can conveniently make these otherwise difficult or even impossible measurements. With the technique to be described, the counter can be made to measure any selected portion of the waveform displayed on the oscilloscope. Thus, the flexibility and visual verification offered by an oscilloscope is combined with the accuracy of a counter.

The technique involves summing or algebraically adding the portion of the waveform of interest with a pulse, so that the pulse creates a voltage pedestal upon which the portion of interest rides. With a portion of the waveform elevated, the counter's trigger threshold (triggering level) can be set so that the counter triggers only on the desired portion.

If a Dual-Trace, Delayed Sweep Oscilloscope with a Vertical Signal Output and a Delayed Gate Output is used in conjunction with the counter, no other equipment is required. The Delayed Gate serves as the necessary pulse, the Dual-Trace Amplifier performs the summing function, and the Vertical Signal Output (a waveform identical to that displayed on the crt of the oscilloscope) is connected to the input of the counter. Figure 1 shows a 7603 Mainframe, 7A18 Dual-Trace Amplifier, 7B53A Delayed Sweep Time Base, and DC 505A Universal Counter/Timer in the described configuration. Figure 2 is a chart of TEKTRONIX Oscilloscopes with the necessary combination of features, and the bandwidth and amplitude of the Vertical Signal Outputs.

Making the measurement

The waveform, a portion of which is to be measured, is connected to Channel 1 vertical input of the oscilloscope and the controls are set for a stable display approximately two divisions in amplitude. The wide range of input amplitudes a laboratory oscilloscope can accept offers the added advantage of signal conditioning; amplifying or attenuating a waveform prior to being connected to the counter input.

With the waveform portion of interest displayed on-screen, the oscilloscope's Horizontal Mode switch is placed in the Intensified mode and the brightened portion of the trace is adjusted to intensify the portion of interest. The Delayed Gate Output, a pulse whose width and position relative to the oscilloscope trigger point is identical to the intensified portion of the trace, is then connected to Channel 2 vertical input. The Vertical Mode switch is set to Channel 2 and the controls adjusted for a display two divisions in amplitude. Switching to the Algebraic Add mode, the two waveforms (the delayed gate and the input waveform) will now be summed and the combination will be approximately four divisions in amplitude as in Figure 1. If the delayed gate is positioned properly, the portion of the input waveform of interest will be elevated approximately two divisions.

The oscilloscope's Vertical Signal Output is now connected to the counter input and the counter's Trigger Level control is set so the counter triggers only on the elevated portion.

Setting the counter trigger level

If the counter has a DC Trigger Level Output, the trigger level can be set by monitoring this output with a DMM, setting it to the desired voltage level as read from the oscilloscope's crt. If the counter does not have a DC Trigger Level Output, the following technique will aid in setting the counter trigger level.

The amplitude of the voltage pedestal is lowered approximately 50% by adjusting the oscilloscope's Channel 2 Variable Volts Per Division control for a display about three divisions in amplitude. Adjusting the counter's Trigger Level control in the positive direction until the counter quits triggering, then in the negative direction until the counter just starts counting, or counts erratically, will set the counter to trigger on the positive-most portion of the input waveform. Now, returning the Channel 2 Volts per Division control to its original position (a four division display) will result in the counter triggering at the 50% point on the elevated portion of the waveform. This same technique can be used to set the counter's trigger level at other than the 50% point if desired.

Counter modes

Now let's consider making selected pulse or cycle measurements in the various counter modes available. Universal counters, as opposed to single function or frequency only counters, offer a variety of modes such as Period, Width, and Time Interval, as well as Frequency. Each mode requires that the width of the oscilloscope's delayed gate—the elevating pulse—be set a little differently.

Period

If a period measurement is to be made, the pedestal must be wide enough and so positioned in time that the entire period of interest is elevated as shown in Figure 3. In the Period mode, the counter will trigger at a point on the first positive or negative going slope, whichever is selected, and at the same point on the following slope of the same polarity.

Employing this technique, the Period mode can be used to measure frequency ($F = \frac{1}{T}$) when the frequency varies, or when it is a burst or chirp. In the Frequency mode a counter measures the average input frequency during the gate time. However, with this technique, frequency can be measured for as short a period as one cycle. The linearity of a swept frequency can even be measured cycle by cycle.

Width

If a width measurement is to be made, the set-up is the same as for a period measurement, except that the elevating pedestal must only be wide enough to elevate the width of interest as shown in Figure 4. The counter in the Width mode will measure the time between a point on the first slope of the selected polarity and the same point on the following slope of the opposite polarity.

Time interval

A counter that offers a Time Interval mode has two input channels and measures the time between when the first channel, Channel A, triggers and the second channel, Channel B, triggers. The slopes and trigger levels for each channel can be selected independently. In the Time Interval mode, Channel B is held off (not permitted to trigger) until A triggers; however, Channel B cannot normally be held off or prevented from triggering the next time the input waveform reaches its trigger level. With this technique, B can be held off as long as required to permit the counter to measure the time between any desired points on the input waveform. Unlike the Period and Width modes, the width of the pedestal or elevating pulse is adjusted to be slightly narrower than the time interval of interest. As shown in Figure 5, the A trigger level is set to trigger just as it was in the Width or Period modes, but the B trigger level is set below the level of the pedestal. Therefore, B will not trigger until the elevating pulse has returned to the lower level and the input waveform passes through the B trigger level. B can be held off or prevented from triggering as long as desired by increasing the width of the pedestal.

Small variations in pedestal width should cause no variation in counter reading if the pedestal is properly positioned. If the counter display varies directly with pedestal width, an erroneous reading is being obtained.

The two input channels can be connected to a single waveform or to two separate waveforms, and a portion of either waveform can be selected and elevated. A portion of each of two waveforms can also be elevated and thereby selected, however, this would require an additional pulse and summing amplifier.

Frequency

Making frequency measurements directly is not practical using this technique because the counter's gate and

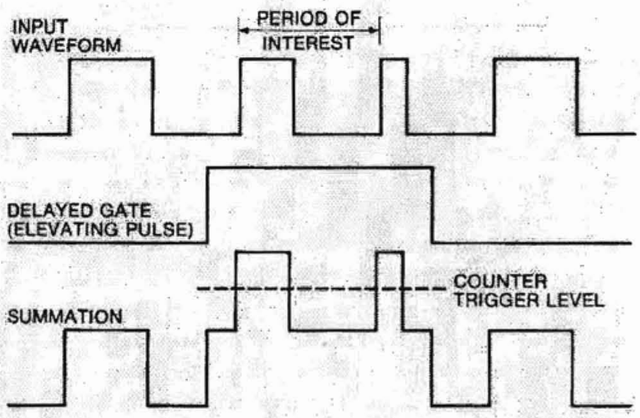


Fig. 3. In period measurement, delayed gate width must be wide enough to elevate entire period of interest.

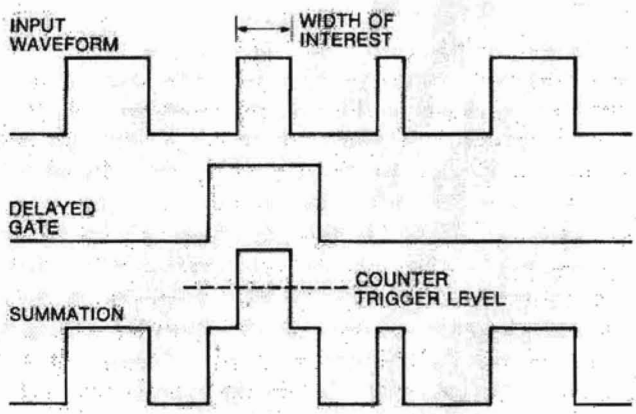


Fig. 4. Delayed gate set properly for width measurement.

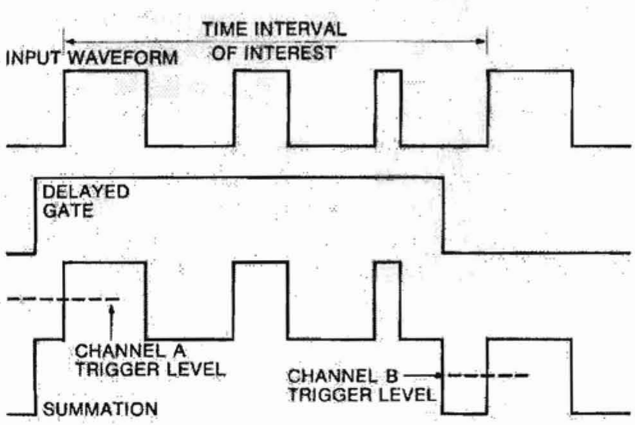


Fig. 5. For time interval measurements, delayed gate is set slightly shorter in duration than time interval to be measured.

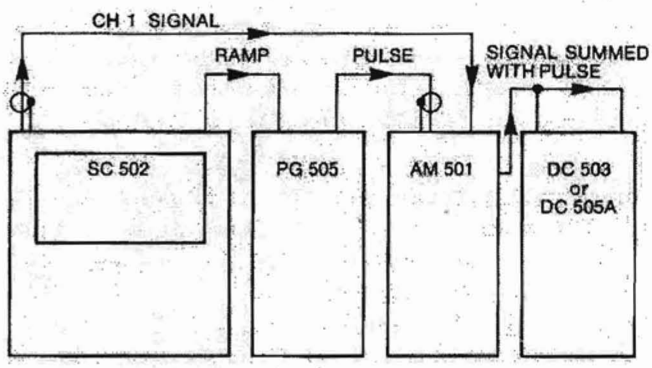


Fig. 6. TM 500 Series configuration for making gated counter measurements with a non-delayed sweep oscilloscope. The AM 501 performs the summing function normally provided by the oscilloscope.

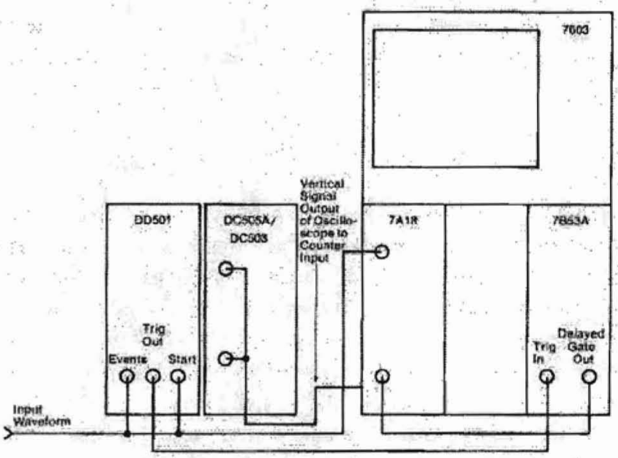


Fig. 7. The DD 501 Digital Delay simplifies trigger selection when delaying the triggering of the counter for several pulses or cycles.

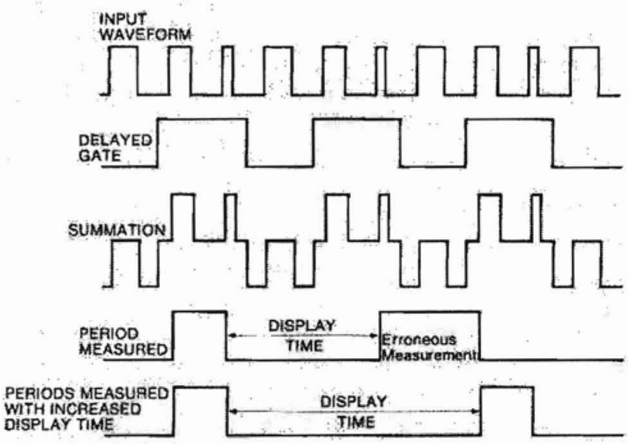


Fig. 8. Erroneous readings can occur at some display time settings. If the counter readout is erratic or too large a number, increase the display time with the Display Time Control.

the elevating pulse would have to be synchronized. Frequency measurements can be made, as mentioned earlier, in the Period mode, and, because frequency is the reciprocal of time, the conversion is simple.

Averaging

In the Period, Width, and Time Interval modes, it is often desirable to average to achieve the desired accuracy. If the counter offers Width Averaging and Time Interval Averaging, it is simply a matter of switching to that mode. The counter will accumulate readings in decade multiples and average them. No change in the procedure for a single Time Interval or Width measurement is necessary. For period averaging, however, an alteration to the technique is necessary. In period averaging, the number of periods to be averaged must all be elevated. To average 10 periods, 10 or more successive or continuous periods must be elevated. To average 100 periods, 100 or more successive or continuous periods must be elevated. A larger number of averages can be selected, but since the purpose of this technique is to make a selective measurement of a small portion of a signal, it is unlikely that higher averaging factors will be commonly used in the Period mode.

Using a non-delayed sweep oscilloscope

If a Non-Delayed Sweep Oscilloscope is used, a separate pulse generator with delay, like the TEKTRONIX PG 505 or PG 508, must be incorporated to generate the necessary pulse. The pulse generator must have delay so its output can be positioned in time relative to the input waveform.

If the oscilloscope does not have an Algebraic Add mode, a separate amplifier like the AM 501 can be incorporated to serve this function.

The TM 500 product line provides an ideal solution to the problem. Figure 6 is a diagram showing the SC 502 Non-Delaying Sweep Oscilloscope, PG 505 Pulse Generator, AM 501 Amplifier, and either the DC 503 or DC 505A Universal Counter/Timer with the appropriate interconnections in the TM 500 Mainframe. This particular system is usable from dc to between 50 kHz and 100 kHz, limited by summing amplifier bandwidth and pulse generator rise times.

Digital delay

When it is necessary to delay the triggering of the counter for a large number of pulses or cycles, it can become impractical due to the limited resolution offered by the crt of an oscilloscope, even with a magnifier. For example, it would be almost impossible to position the pulse or pedestal on the one thousandth input pulse to measure its period, width, or time interval. Even with a times ten magnifier, there would be ten input pulses or cycles per division on the crt. The DD 501 Digital Delay solves this problem. It can delay by up to one hundred thousand events and generate a trigger at the selected number of events.

When the DD 501 is used with this technique, it is connected as shown in Figure 7. The input signal is connected to the DD 501 Start and Events inputs and the input of the oscilloscope. The output of the Digital Delay is connected to the External Trigger input of the oscilloscope, and the appropriate number of events, pulses, or cycles to be delayed is dialed up on the DD 501 front panel. The counter is driven by the summed pedestal and signal from the scope vertical output or by a separate summing amplifier. When the selected number of events takes place, the DD 501 puts out a trigger that triggers the scope and the delayed gate. A faster oscilloscope sweep speed can now be used, which offers enough resolution to position the elevating pulse.

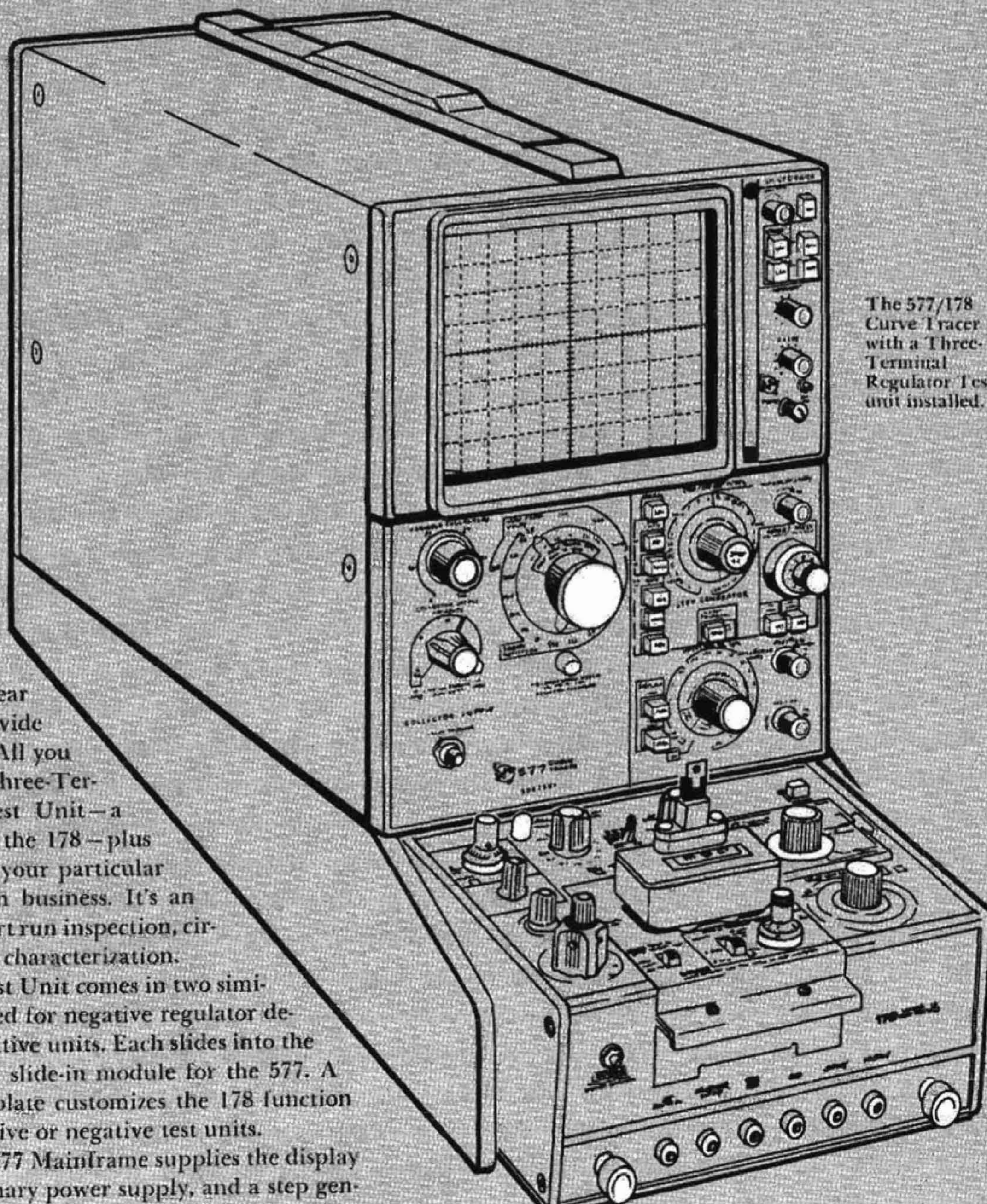
If it is necessary to delay by time, the counter's time base output can be connected to the DD 501 input. The counter's time base acts as a clock that the DD 501 counts.

Erroneous reading

Some ranges of input repetition rates can cause an oscilloscope to trigger on different pulses on each sweep, however, this can be corrected with Trigger Hold-off if the oscilloscope has this feature, or with the Variable Time Per Division if it does not. In either case the basic repetition rate of the oscilloscope's sweep generator is changed so that the oscilloscope triggers at the same point or on the same pulse for each sweep. With the technique described in this note, it is possible to have essentially the same problem with a counter. The counter has a measurement cycle time or repetition rate which is determined by the length of time it takes to make the measurement, plus the display time. As shown in the period measurement in Figure 8, if the counter's measurement cycle time results in the display time ending in the middle of the period to be measured, an erroneous period measurement results. And the same thing can occur in the Width or Time Interval modes. The indication is an erratic reading or a reading that is too large. The fourth waveform from the top in Figure 8 shows an erroneous, too long, period. To correct the problem, the counter's display time is increased with the Display Time Control as shown in Figure 8. The counter now has a slower repetition rate or longer measurement cycle time and does not reset in the middle of the period, width, or time interval to be measured.

Ralph Livermore

Testing three-terminal regulators with a curve tracer



The 577/178 Curve Tracer with a Three-Terminal Regulator Test unit installed.

The increasing cost of on-board three-terminal regulators has created a need for a fast and easy means of testing these devices. Many of you already possess that capability and may not realize it.

The Tektronix 577-D1 Storage Curve Tracer and 178 Linear IC Test Fixture provide the basic capability. All you need to add is the Three-Terminal Regulator Test Unit—a plug-in accessory for the 178—plus a socket adapter for your particular device, and you're in business. It's an ideal solution for short run inspection, circuit design, or device characterization.

The Regulator Test Unit comes in two similar models—one wired for negative regulator devices and one for positive units. Each slides into the 178, which is itself a slide-in module for the 577. A snap-on escutcheon plate customizes the 178 function switch to either positive or negative test units.

Functionally, the 577 Mainframe supplies the display and its controls, primary power supply, and a step generator that serves as a variable load. The 178 further regulates the supply voltages and provides the function selector switch, which sets up the internal circuits for the appropriate tests. The 178 also has provision to sweep the input supply voltages at a selected rate and amplitude for line regulation and other tests.

Four basic tests on three-terminal regulators can be performed on the 577/178: load regulation, line regulation, quiescent or common current, and dropout voltage. A fifth test, ripple rejection, can also be performed, depending on how it is specified. The devices can be tested over an input range of 0 to 60 volts, with load currents up to 2 amperes (pulsed).

Load regulation

Load regulation is the change in regulator output voltage over the specified range of load current, with provision made to keep chip temperature constant.

This test is done on the curve tracer using the step generator as a current sink or variable load. The step generator is operated in the pulse mode to provide a load that is active for only a small part of the duty cycle, thus keeping chip dissipation low and possible temperature rise small.

The display in Figure 1 shows the change in output voltage (vertical axis) as the load current is stepped over the specified range (horizontal axis). In Figure 2 the vertical sensitivity has been increased to improve the resolution of the measurement. The Output Voltage Comparison Dial is set so the trace crosses the bottom graticule line precisely at the rated load current point. The change in output voltage is then easily determined by multiplying the VERT UNITS/DIV setting by the indicated change in output voltage on the vertical axis.

Line regulation

Another important specification we need to check is line regulation—the change in regulator output voltage over a specified range of input voltage—with provisions made to keep the chip temperature constant.

The curve tracer provides the necessary test conditions by adding a swept voltage to the input voltage supply, while providing a constant, short duty-cycle load for the output.

In the display in Figure 3, the vertical axis represents regulator output voltage deviation from the comparison voltage, and the horizontal axis represents regulator input voltage.

Line regulation characteristics at different values of load current can be checked by setting the step generator to step through the desired range of load currents as in Figure 3.

Quiescent or common current

A third characteristic often of interest to the circuit designer is the current used by the regulator for its internal functioning. It is called quiescent or common current. The regulator test unit uses a common-terminal supply to produce an artificial ground through which the device-under-test quiescent current is measured.

The curve tracer can display quiescent current under three different conditions: steady state, with constant load and line (input) voltage change, and with constant input voltage and changes in the load. Changes in input voltage are provided by the sweep generator on the 178 Linear IC Test Fixture. Load changes are produced by using the 577 step generator in the current-sinking mode.

The display in Figure 4 plots quiescent current on the vertical axis, versus load current on the horizontal.

Dropout voltage test

The fourth characteristic of interest that can be checked with the 577 Curve Tracer is dropout voltage. The dropout voltage test is similar to the line regulation test except, in this instance, we are concerned with the minimum input voltage at which the regulator no longer regulates. Figure 5 is an illustration of the dropout voltage test. The input-output voltage differential at which the circuit ceases to regulate is dependent upon load current and junction temperature, and is typically two volts.

Ripple rejection test

Ripple rejection tests can also be performed on the curve tracer as displayed in Figure 6. The supply voltage is swept at a frequency just below 120 Hz to produce the display. Each trace represents a different load current as presented by the step generator. Storage is a necessity in achieving this display since it takes about a second to produce.

Conclusion

The 577-D1 Storage Curve Tracer with a 178 Linear IC Test Fixture and Three-Terminal Regulator Test Unit provides a low-cost, versatile means of performing incoming inspection tests, circuit design, or device characterization of three-terminal regulators. Most of the specified tests can be performed. The 577 also serves as a valuable analytical tool to evaluate those devices rejected by highly automated incoming inspection systems, and to analyze performance under operating conditions other than those specified on the spec sheet.

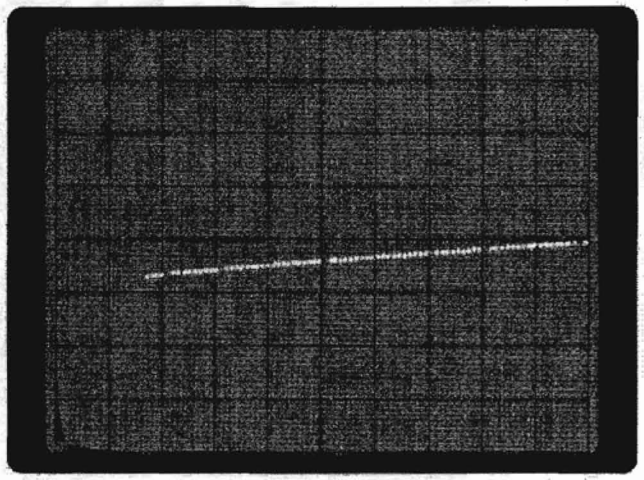


Fig. 1. Load regulation test. Output voltage displayed vertically at 50 mV/div, offset to +5V; load current displayed horizontally at 20 mA/div.

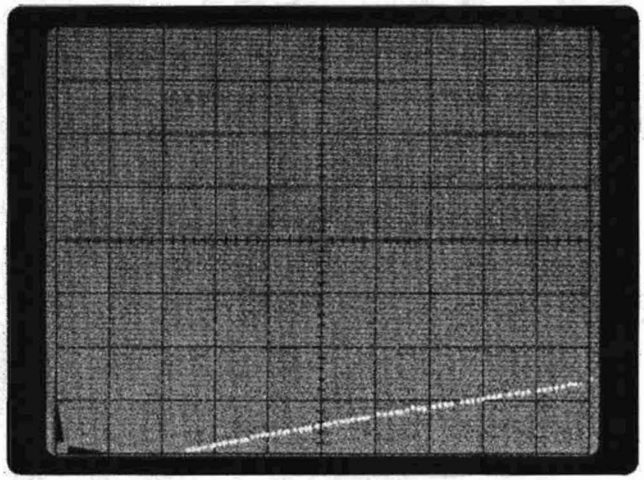


Fig. 2. Same measurement as Fig. 1. except vertical sensitivity increased to improve resolution, and trace moved to bottom of screen for easier reading.

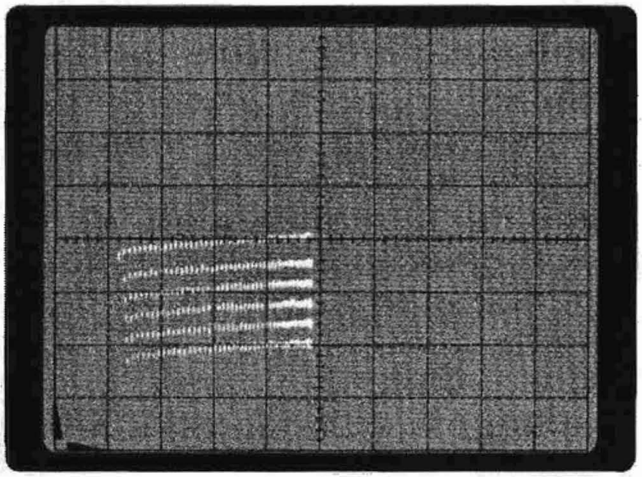


Fig. 3. Line regulation test. Output voltage displayed vertically at 5 mV/div; input voltage displayed horizontally at 5V/div, load currents are 100 mA/step.

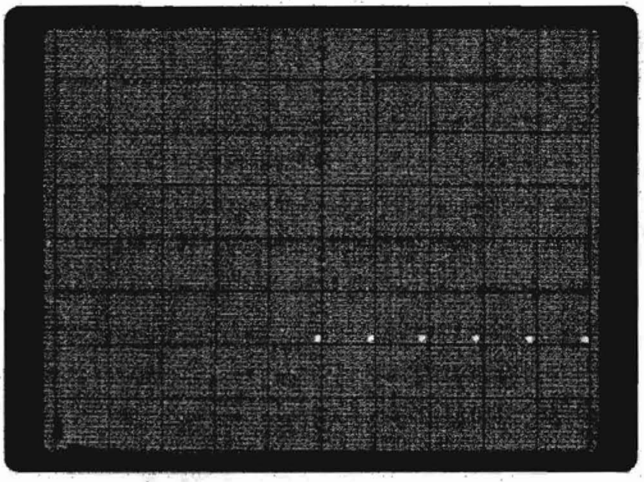


Fig. 4. Quiescent current test. Quiescent current displayed vertically at 2 mA/div, zero current at center-screen; load current displayed horizontally at 100 mA/div.

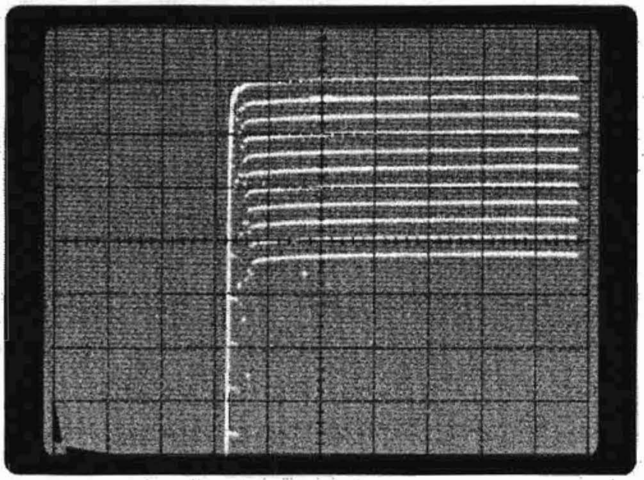


Fig. 5. Dropout voltage test. Output voltage displayed vertically at 10 mV/div, top trace is offset to 5V; input voltage displayed horizontally at 2V/div.

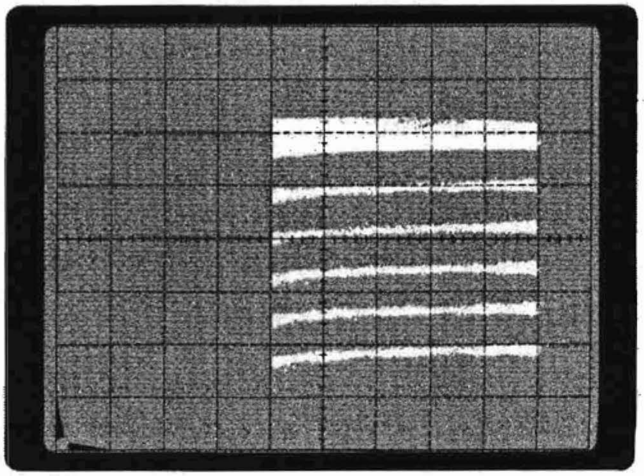


Fig. 6. Ripple rejection test. Output voltage displayed vertically at 5 mV/div; input voltage displayed horizontally at 2V/div; load currents are 100 mA/step. Rejection is about 76 dB.

Charles Phillips

Servicescope

Tektronix products get dirty, too!

Part II—Dry cleaning

In Part I of this article we described the tools and techniques used to give your Tektronix instrument a bath, or perhaps "shower" would be a more appropriate term. There are times when the customer needs quick turn around on an instrument and can't tolerate the 24-hour drying time needed for a wet wash. In this instance, dry cleaning may serve as a reasonable alternative.

The wash booth makes a convenient place to perform the dry cleaning operation. With the side and bottom panels removed, compressed air and a small paint brush will remove most of the interior dust, unless the instrument has been in a greasy environment.

To clean the front panel you should reinstall the side covers and lightly spray the front panel only, using the 5% Kelite solution and rinsing with water. Be careful not to get excess water in the instrument. Just a little spray applied on an angle works best.

Use a toothbrush and detergent to clean the knobs and connectors, and rinse with warm water. The side covers can be removed and, along with the bottom panel, be washed separately after removing the instrument from the booth. They should be placed in the oven to dry. Compressed air is used to remove as much water as practicable from the front panel area, and the instrument is then placed in the oven for 15 to 20 minutes, or until you're ready to work on it.

The graticule and graticule cover may be cleaned as described in Part I. A word of caution regarding the use of glass cleaner—some leave a static charge on the graticule, which will distort the crt trace until it bleeds off. Soap and water is the best solution.

Air filters can be cleaned easily with detergent and hot water. A cleansing powder, such as Ajax, sprinkled on a wet filter and allowed to soak a minute or two, will help on extra greasy ones. We recommend not using oil or filter coat on any filters as there is the possibility of oil getting inside the instrument.

Cleansing cam switches

Unless you are having problems with the cam switches in the instrument, we do not recommend removing the switch covers during the cleaning procedure. You should also take care not to spray detergent into the switches.

If a cam switch needs cleaning, this can best be accomplished by removing the switch cover and spraying the switch with a 5% solution of Kelite spray white with an equal amount of ammonia (non-sudsing, non-soapy type). The switch should then be thoroughly rinsed with soft or distilled water. The switch contacts should then be sprayed with isopropyl alcohol, let set for 60 seconds, and blown out with compressed air. Occasionally operate the switch in all positions while the alcohol is still on the contact area, and while blowing out the instrument. Oven dry in the usual manner.

Cam switches need no lubrication as the switch pads are designed to operate dry for the life of the instrument.

Conclusion

Whether you wet wash or dry clean an instrument will be determined by how dirty the instrument is, and the time available to do the job. Solid state instruments can be washed as easily and safely as vacuum tube types. Precautions against spraying detergent and water directly on power transformers and covered cam switches should be diligently observed. Cleaning agents such as trichlorethylene, Freon, and others containing halogens, should not be used. They can damage aluminum electrolytic capacitors and some printed circuit board materials used in critical applications.

It takes valuable time to properly clean an instrument. However, the improvement in maintainability and the increase in user satisfaction makes the investment a worthwhile one.

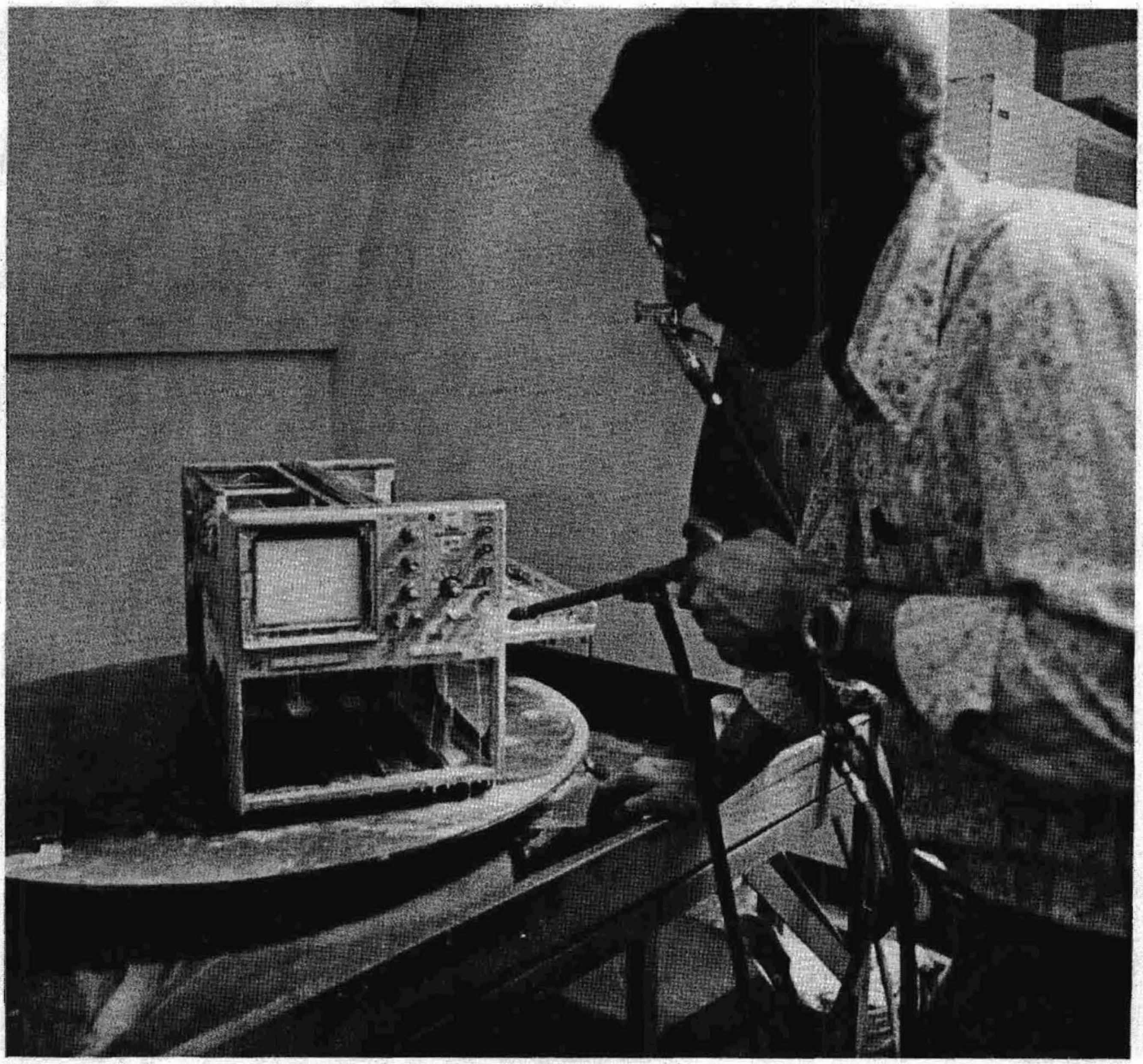


Fig. 1. Dave Phillips, Factory Service Center, washes a 7000-Series Oscilloscope.

Customer maintenance training classes for '77

All classes will be conducted at Beaverton, Oregon. There is no fee for classes except as noted.

All maintenance classes teach operation, signal flow, calibration, trouble-shooting and repair of the representative instrument. A combination of lecture and lab sessions are the usual format for maintenance training. Any prestudy literature besides maintenance manuals will be mailed directly to you.

7704A/7904/7633

The 7000 series classes are a combination of the 7704A/7904/7633 oscilloscopes. The prerequisite for the 7904/7633 class is training on the 7704A. Class duration is two weeks, first week devoted to 7704A, second week devoted to 7904/7633. Plug-ins taught are representative of the most frequently purchased units with these main frames.

Class dates: June 13-24, 1977
Aug. 8-19, 1977
Oct. 17-28, 1977
Dec. 5-16, 1977

465/475

The 465/475 oscilloscopes maintenance class is taught to the component level of troubleshooting and repair. The student is encouraged to study the circuit description portion of the respective manual. Class duration is one week.

Class Dates: June 27-July 1, 1977
Aug. 22-26, 1977
Oct. 31-Nov. 4, 1977

5100/5400

The 5100/5400 oscilloscopes are new products on the 1977 customer training schedule. Representative plug-ins are selected for these products. Class duration is one week.

Class dates: July 11-15, 1977
Nov. 7-11, 1977

Logic Analyzers

The 7D01/DF-1 logic analyzer is a new product on the 1977 customer training schedule. The prospective student is encouraged to study the circuit description in the 7D01/DF manual. Class duration is one week.

Class date: Sept. 12-16, 1977

TM503/DC503/DM502 TG501/PG501/FG501

The TM500 products selected for instruction represent each of the major categories in the Test and Measurement area. Class duration is one week.

Class dates: June 6-10, 1977
Aug. 1-5, 1977
Oct. 10-14, 1977

WDI—R7912/1350

The student must have operational knowledge of the 7704A series oscilloscope; he also must have satisfactorily completed study of the Audio Circuit description training program on the R7912. This package (062-2708-00) is available for $175.00 through the local Tektronix field office; it should be ordered at least 60 days prior to class participation as the subject material is quite lengthy. Class duration is one week. A class fee of $700 per student is charged for this training.

Class dates: July 11-15, 1977
Oct. 3-7, 1977

DPO—P7001/CP1151

No customer maintenance classes are scheduled for 1977. An audio circuit description training package is available for $185.00 through your local Tektronix field office. Part number (062-2707-00)

4051/4631

The 4051 intelligent terminal is a new product on the 1977 customer training schedule. Understanding of microprocessor is necessary for full appreciation of class content. Class duration is two weeks.

Class Dates: June 20-July 1, 1977
Dec. 5-16, 1977

4010/4014/4631

The 4010/4012/4014/4006 graphic display terminal class is taught to board level maintenance; greater depth is taught when signal flow concepts are necessary. Class duration is one week.

Class Dates: June 6-10, 1977
Oct. 3-7, 1977
Nov. 7-11, 1977

4081/4905/4641

The 4081 intelligent terminal system is a new product on the 1977 customer training schedule. Understanding of microcomputer and microprocessor theory is necessary for full appreciation of class content. Class duration is two weeks.

Class Dates: July 18-29, 1977
Sept. 26-Oct. 7, 1977

A-3549

TEKTRONIX, INC.
P.O. BOX 500
BEAVERTON, OR. 97005

Microwave Technology at Tektronix

A High Performance Transportable Microwave Spectrum Analyzer

Digital Storage for a Microwave Spectrum Analyzer

A Phase Lock Stabilization System for 30 Hz Resolution at 12 GHz

Two New Graphic Display Modules for the OEM System Designer

Volume 9
Number 3
1977

Tekscope

Tektronix®

CONTENTS

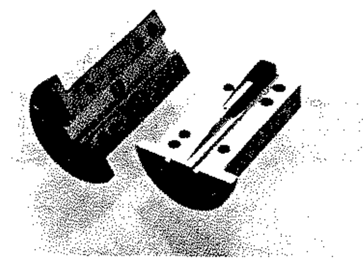
Tekscope

Customer information from
Tektronix, Inc.
Beaverton, Oregon 97007

Editor: Gordon Allison

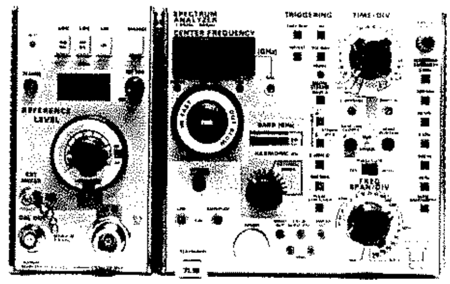
Microwave Technology at Tektronix

Before you can build state-of-the-art microwave products, you must be able to build state-of-the-art microwave components. This requires both innovative people and sophisticated processing facilities to implement exotic microwave designs.



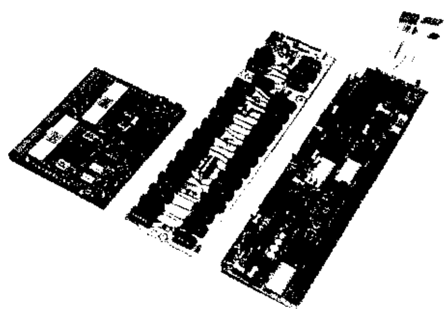
A High Performance Transportable Microwave Spectrum Analyzer

Technical innovations combined with microprocessor control enhance the ease and accuracy with which microwave measurements can be made.



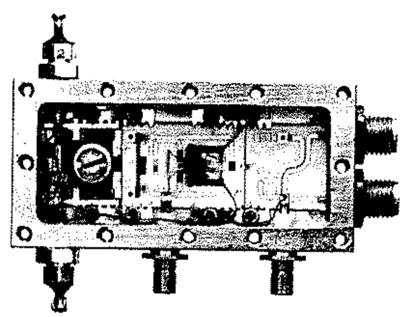
Digital Storage for a Microwave Spectrum Analyzer

Custom-designed LSI chips and an old technique for performing the divide function are employed to provide a versatile storage system for the 7L18 Microwave Spectrum Analyzer.



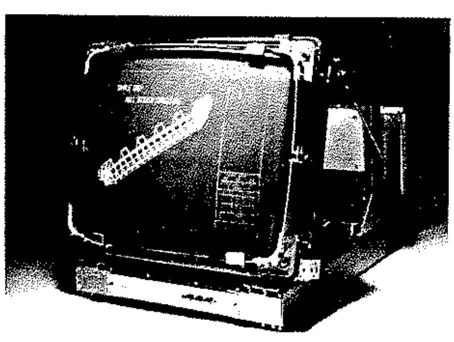
A Phase Lock Stabilization System for 30 Hz Resolution at 12 GHz

Multiple crystal resonators, a dual phase lock loop, and strict attention to environmental control yield a stability that allows 30 Hz resolution measurements at 12 GHz.



Two New Graphic Display Modules for the OEM System Designer

Business, engineering, science, and education are all looking more and more to the computer to solve specialized problems. The ability to interact with the system and graphically display words, images, or complex phenomena is vitally important to these applications.



Tekscope is a bimonthly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique. A new products section gives a brief description of products recently introduced and provides an opportunity to request further information.

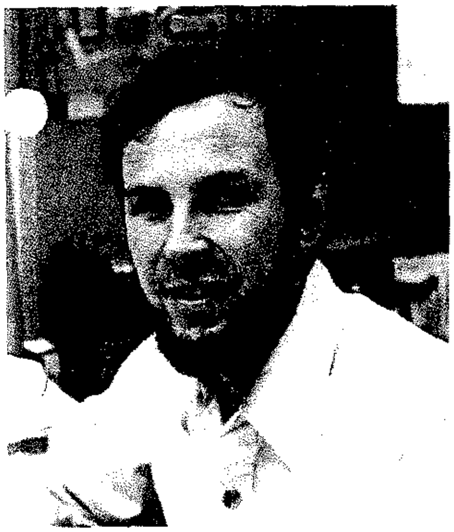
To better serve customers who maintain their TEKTRONIX instruments, the service information formerly appearing in Tekscope will be expanded and published in a publication dedicated to the service function.

COVER

The three-sphere YIG preselector in the 7L18 provides spurious-free performance from 1.5 to 18 GHz and allows accurate amplitude measurements while still in the signal path.

Tektronix®
COMMITTED TO EXCELLENCE

Microwave Technology at Tektronix



Some thirty years ago, when Tektronix started in the instrument business, most oscilloscopes were indicating devices. With the development of regulated power supplies, triggered calibrated time bases, and integral calibrated signal sources, the oscilloscope was transformed from an indicating device into a measurement device.

Standard components were used to build the unique circuits designed by the engineers, and about the only parts fabricated by Tektronix were the chassis, cabinets, and front panels.

It soon became evident that if oscilloscope performance was to continue to advance, improvement in the components available was essential. And so we set about designing and building better cathode ray tubes, developing more stable timing capacitors, winding highly reliable low- and high-voltage transformers, developing low reactance potentiometers for attenuators, and designing distributed terminations for wideband amplifiers. Special coaxial cable with a high resistance center conductor was conceived to stretch the bandpass of passive probes. And new devices and techniques for mounting components shortened manufacturing times and improved serviceability. Innovation continued until, today, the state-of-the-art oscilloscope is vastly different from that of thirty years ago.

Progress in spectrum analyzers and other microwave products at Tektronix is following much the same pattern. State-of-the-art performance is being achieved through innovative circuit design and the development of new and improved microwave components.

Working with frequencies in the microwave region requires special skills. Materials exhibit a different set of characteristics at gigahertz frequencies, and physical dimensions and surface conditions become important design considerations.

A very capable team possessing the unique skills needed, is involved in the development of new microwave devices at Tektronix, from the concept stage through manufacturing and evaluation of the finished product. Their design skills are augmented by modern computer technology employing programs such as COMPACT, SPICE, and GLUMP—a TEK-developed program.

Sophisticated processing facilities are required to implement the exotic designs of the microwave engineers. Precision machining, chemical milling and plating, advanced thin and thick film hybrid technology, and integrated circuit design and manufacturing all contribute to the success of the effort. Innovative people in each of these areas regularly respond with unique solutions to difficult problems.

Thin film technology at Tektronix is exemplified by the thin film assembly shown in figure 1. Resident on the 3" x 3" quartz substrate are fifty circuits, each containing three capacitors and two resistors. Metal conductors are laid down on the quartz substrate using a proprietary process which yields low-resistance, well-defined conductors that can be soldered, wire bonded, die attached, or gap welded. The deposited resistors are heat treated in a high-temperature bake to achieve the desired resistivity within ± 5%. Laser trimming is not used as it disturbs the pattern—an undesirable situation for geometry-sensitive microwave devices. Passivation is performed using a pinhole-free organic material that provides a high voltage dielectric for the capacitors deposited on the substrate. Breakdown voltage is in excess of 500 volts, and dielectric losses at microwave frequencies are substantially less than can be achieved with silicon passivation.

New techniques for mounting microwave substrates have also

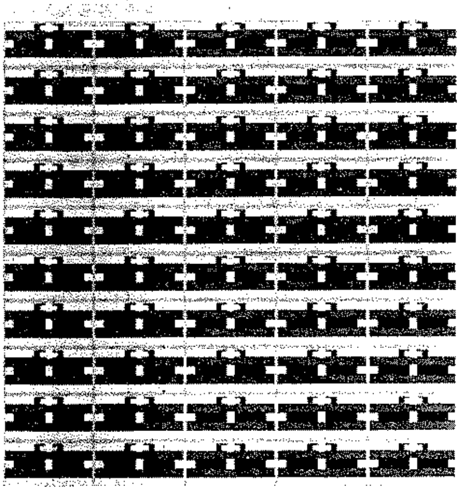


Fig. 1. Thin film technology at Tektronix is exemplified by this 3" by 3" quartz substrate which contains fifty circuits, each consisting of three capacitors and two resistors. Resistors are brought to the desired value by high-temperature bake rather than by laser trimming.

been developed. Microstrip (conductor above ground plane) becomes very lossy above about 8 GHz. A suspended substrate technique is used that completely encloses the substrate with ground, thereby greatly reducing rf losses. This technique is merged with stripline to produce a balanced distributed transmission medium that can be designed to create complex microwave assemblies such as mixers, amplifiers, oscillators, etc.

Augmenting the device development and processing areas is a well equipped and competently staffed microwave component assembly area. Electrical performance is directly related to tolerances on most mechanical parts used in microwave assemblies. An excellent example of this is the three-sphere YIG-tuned preselector that gives the 7L18 its excellent wide-band spurious-free calibrated performance. YIG-tuned filters are not new; what is unique is the precision with which the elements of the filter are assembled, and processing of some of the materials.

Optimizing frequency tracking between the three filter sections requires extreme care to ensure that the pole pieces are parallel and the YIG spheres are equidistant from the axial centerline of the pole pieces. Another important consideration is the orientation of the YIG spheres to minimize the effects of temperature and magnetic field variations. A mechanically complex fixture is required to attach a YIG sphere to a beryllia rod so the sphere can be rotated about the 100 crystallographic axis. This allows the sphere to be rotated so the best possible axis, the 0, 8, 13, can be aligned parallel to the applied magnetic field.

Other considerations such as minimizing spurious modes and coupling variations call for special attention to the design and orientation of the coupling loops and cavities associated with each sphere.

The external waveguide mixers that allow 7L18 users to perform accurate measurements to 60 GHz

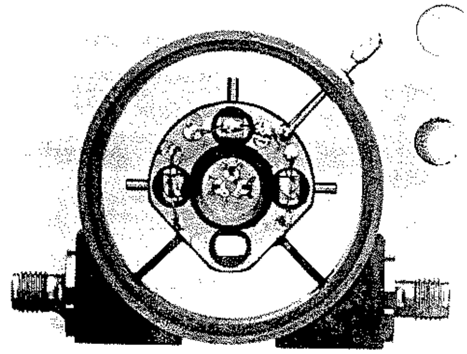


Fig. 3. Advanced YIG-tuned filter design yields wide-band spurious-free operation. Critical alignment and orientation of the YIG spheres and coupling loops are essential in achieving the desired performance.

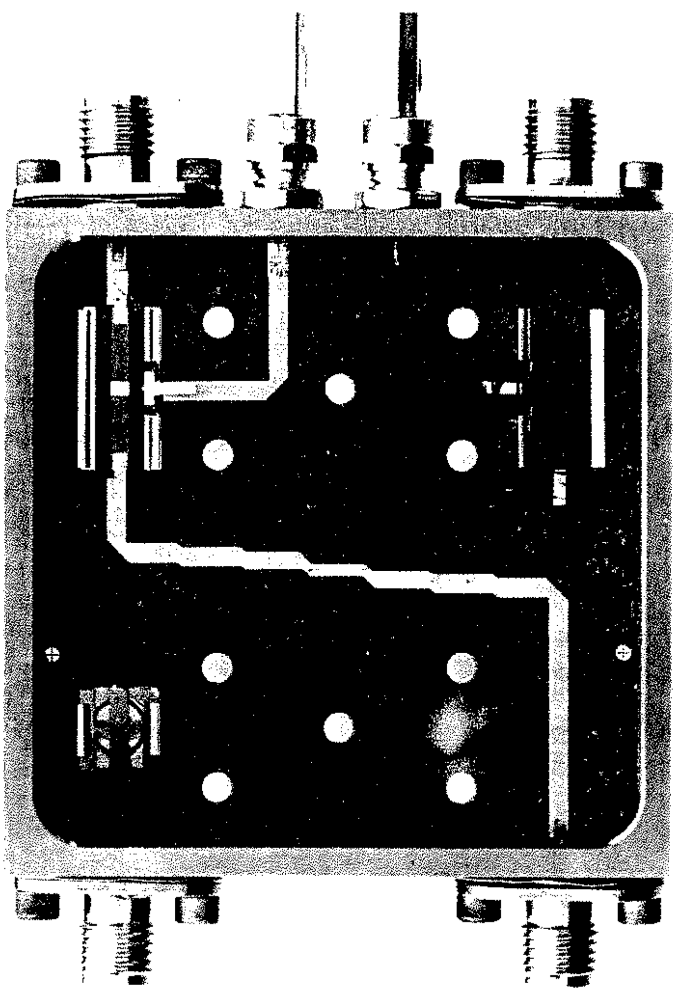


Fig. 2. This stripline directional coupler couples the 2.4 GHz first L.O. signal to both internal and external mixers. The coupler uses a suspended substrate completely surrounded by ground which greatly reduces rf losses. Visible in upper left corner is thin film circuitry pictured in Figure 1.

a— excellent examples of the value of highly integrated electrical and mechanical design.

The basic approach to the design of a high-performance broadband harmonic mixer is to minimize the unwanted parasitic inductances and capacitances associated with the mixer diode mounting system, and to provide as much rf energy as possible to the mixer diode. Achieving these two goals will result in optimum broadband flatness and conversion efficiency.

The 7L18's external mixers use a very small Schottky-barrier diode and tungsten "cat's-whisker" type probe mounted directly across the high-fields region of a ridged waveguide. Mixers of this type are not new. They were built twenty years ago using standard waveguide and older style silicon point-contact diodes. The use of a tungsten "cat's-whisker" probe dates back even further, finding wide use in devices during World War II.

New technology in the fabrication of silicon wafers is the primary factor contributing to the high performance of the 7L18 waveguide mixers. An array of hundreds of 4.7 μm diameter Schottky-barrier diodes on a 0.010" X 0.010" silicon wafer was developed by Tektronix specifically for use in these mixers (figure 5). Newly-developed metallurgical processes are used to produce a diode which can survive in an unpackaged environment and withstand the pressure of the tungsten probe. These extremely small diodes and the smaller still (0.001" diameter) probe provide minimal junction capacitance and probe inductance, thus eliminating in-band parasitic resonances and minimizing reflections. The tip of the tungsten probe is etched by an electrochemical process to produce a sharp but rounded tip. This is important in maintaining ohmic contact against oxidation of the tungsten, without damaging the metallization and destroying the diode.

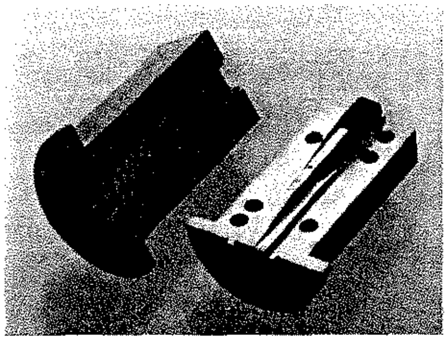


Fig. 4. An internal view of the 40-60.5 GHz mixer showing the ridged waveguide construction. The diode matrix is mounted on the small disc in the left portion and the tungsten "cat's whisker" protrudes through the small hole in the ridged portion. The black wedge is a carbon block termination.

In addition to the careful design of the special mixer diode assembly, refinements in the mixer housing further improve broadband flatness and conversion efficiency. Conversion loss is minimized by using ridged waveguide. This type of structure concentrates the rf energy in the gap between the top of the ridge and the adjacent waveguide wall, where the mixer diode assembly is located. Therefore, the diode can become saturated with rf energy at power levels as low as −30 dBm, but can easily withstand up to 10 mW without damage.

Further improvements in flatness are achieved by designing a standard-to-ridged waveguide broadband transition into the mixer body preceding the mixer diode, and a tapered waveguide load beyond the diode to terminate the rf line.

Summary

This has been just a brief glimpse into the microwave capability at Tektronix. The key element, of course, is people. Dedicated, innovative people not content with the current state-of-the-art. Supporting the innovators are craftsmen operating in many disciplines, and extensive research and manufacturing facilities to transform their "dreams" into realities. Realities in the form of instruments like the 7L18 that help you make microwave measurements with greater ease and convenience, and confidence in the accuracy of the end result.

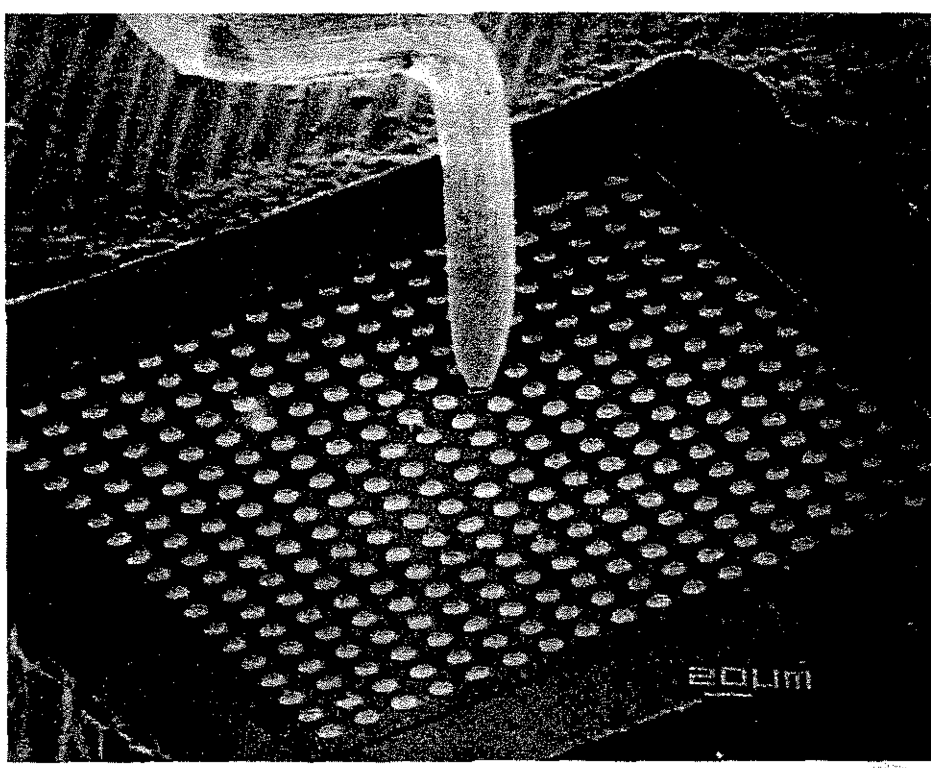
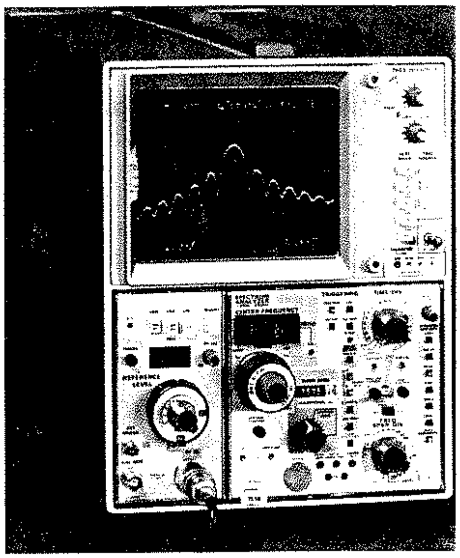


Fig. 5. External mixer diode consists of a silicon wafer containing an array of hundreds of 4.7μm Schottky-barrier diodes. Tungsten "cat's whisker" probe is 0.001 inch in diameter.

A High Performance Transportable Microwave Spectrum Analyzer



Precision microwave measurements typically are difficult and time consuming to make and usually limited to a laboratory setting. Now a new microwave spectrum analyzer, the 7L18, offers substantial improvement in the speed and convenience of making such measurements, and can be hand-carried to the site.

Covering the spectrum from 1.5 GHz to 60 GHz, the 7L18 extends the 7000-Series user's choice of high performance analyzers over the range of 20 Hz to 60 GHz. The 7L18 can be used with any 3- or 4-wide mainframe including the militarized USM-281C.

Several technological innovations contribute to the ease and accuracy with which measurements are made. Advanced YIG-tuned filter design gives spurious-free displays from 1.5 GHz to 18 GHz. External millimeter-wave harmonic mixers of improved design provide specified calibrated flatness from 18 GHz to 60 MHz. Advanced phase lock techniques yield a usable resolution capability of 30 Hz through X-band (12 GHz) and 300 Hz resolution to 60 GHz. Custom LSI signal processing chips provide split-memory storage, computation of average value, display of maximum signal level, and comparison of reference and incoming signal levels for rapid analysis of differences. We will discuss some of these innovations, with others covered in detail elsewhere in this issue.

Microprocessor based control system

One of the major design goals for the 7L18 was to achieve a quality we call "transparent." Transparent means the controls have been human engineered so the operator can use the instrument without conscious effort, and the instrument gives accurate, unambiguous results. This goal was realized by implementing a microprocessor-based control system.

The microprocessor has changed the basic concept of how test instruments are organized. Before, instruments were organized much like a spoked wheel, with the front panel being the wheel's hub. The spokes were the various assemblies directly controlled by front-panel knobs and switches. The rim of the wheel was the various assembly interconnection of both signals and interacting controls. Now, the microprocessor is the wheel's hub, the front panel is relegated to being one of the spokes, and only signals travel the rim of the wheel.

Before, instrument designers were forced to compromise many aspects of their design because of the difficulties of controlling a complicated system with a limited amount of logic. Now, this barrier has been removed. The designer is free to optimize his design, knowing that with a microprocessor he can devise a control system.

The span attenuator circuit in the 7L18 is an example of this process (see figure 1). Previous microwave analyzer designs required two, and sometimes three, attenuators: one for the span knob, and one for the band switch, to attenuate the sweep for harmonic conversions, all in cascade. Some phase lock techniques require another that is proportional to the first local oscillator frequency. This multitude of attenuators caused signal-to-noise degradation of the sweep signal but made it possible to control the oscillator sweep width with a series of user-operated switches.

Only one span attenuator is used in the 7L18. The microprocessor sets it to the proper value which is computed from the span per division knob setting, the band switch setting, and the local oscillator frequency (in the phase locked setting only). A complex algorithm chooses the attenuator setting and determines when to go into phase lock. The result is simplified design and improved signal-to-noise ratio.

Other functions performed by the microprocessor include: computation of center frequency from a digital voltmeter reading that is proportional to the oscillator frequency and band switch setting; reading the IF gain switch, RF attenuator, and band switch settings and computing the proper IF control settings and the reference level; reading the time per division, span per division, and resolution bandwidth settings and performing the appropriate control functions when automatic time and resolution bandwidth functions are selected; and sending information to the crt readout for Center Frequency, Reference Level, Resolution Bandwidth, and Span per Division.

The microprocessor used in the 7L18 is the Intel 4004, a 4-bit processor well suited to this use. The control bus consists of four address lines, four data lines, a data input strobe line, and a data output strobe line. This bus is carried throughout the 7L18, touching on most of the major circuit board assemblies.

To get an overall picture of how the 7L18 functions let's consider the simplified block diagram

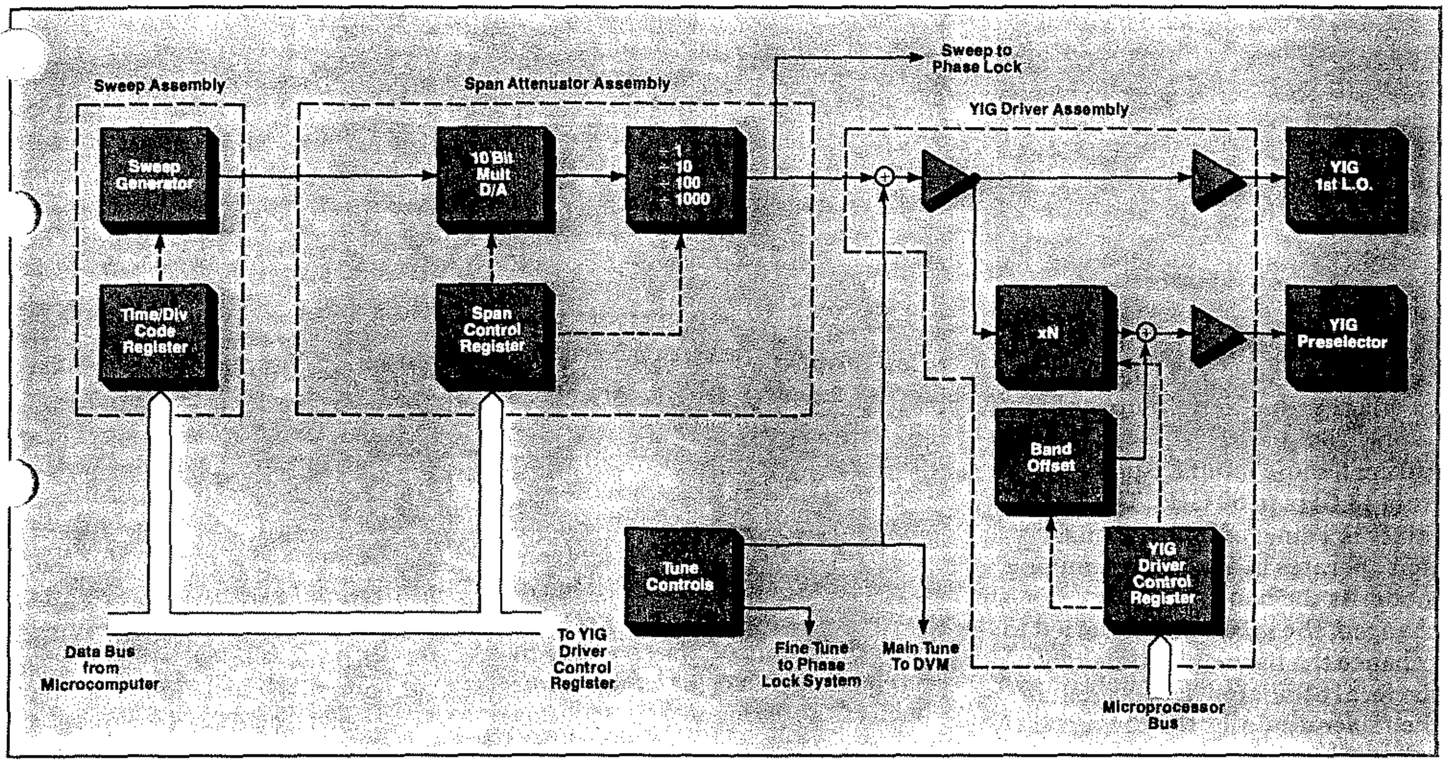
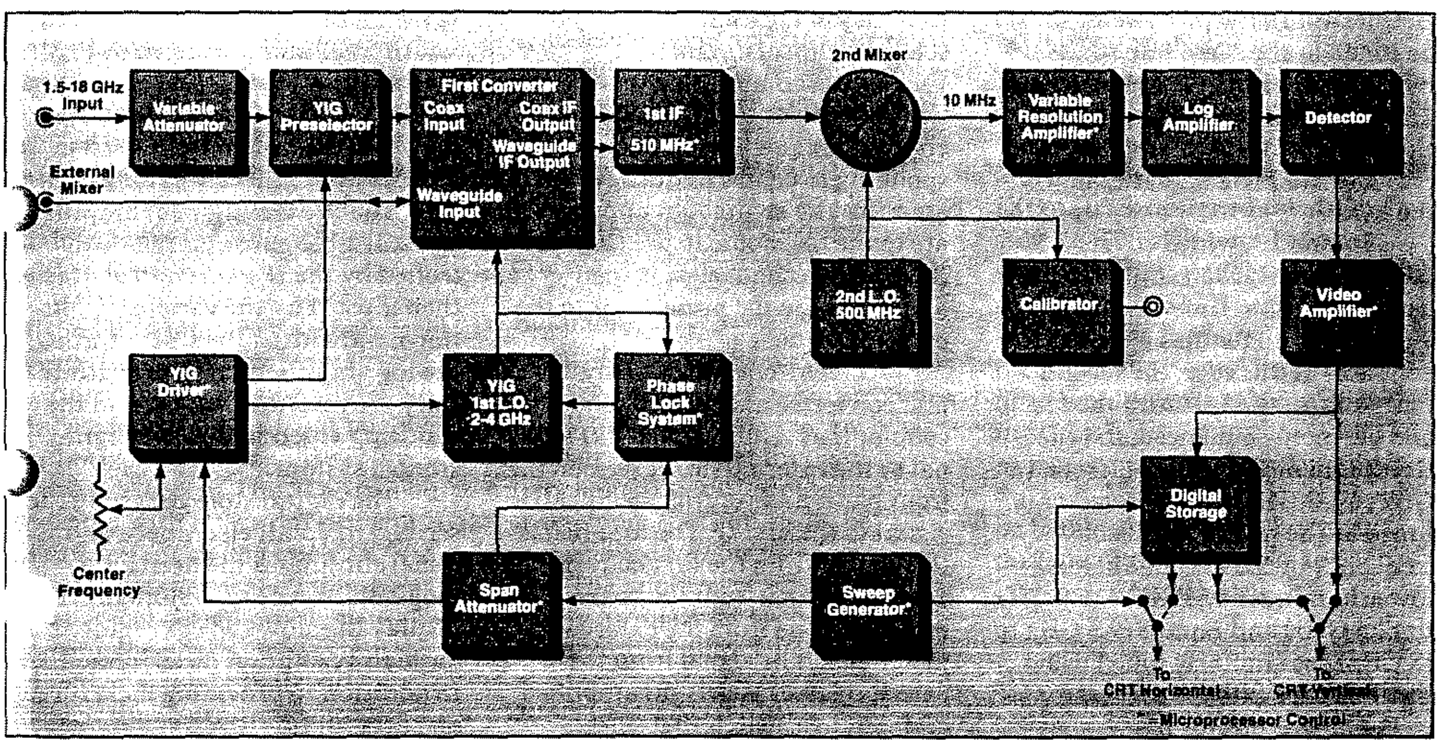


Fig. 1. Special attention was given to minimizing the number of connections between assemblies as evidenced in the block diagram of the 7L18 span control system.

Fig. 2. Simplified block diagram of the 7L18. Note the elements that are affected by microprocessor control.



shown in figure 2. A signal entering through the coaxial input filter first passes through the RF attenuator and is then sent to the YIG-tuned preselector. The 3-sphere YIG filter (described elsewhere in this issue) provides a voltage-tuneable band-pass filter that selects which signal is to be applied to the first converter.

The first converter assembly contains the first mixer and a coupler for the external mixer input on the front panel. (Three external mixers handle input frequencies from 18 GHz to 60 GHz. The first mixer is a singly-balanced mixer that operates in a harmonic mixing mode. As the band switch is changed, the mixer bias is varied to enhance the harmonic content of the local oscillator (LO) current in the mixer diode for the conversion in use. This optimizes mixer performance for each band.

The first LO operates in a frequency band of 2.0 to 4.0 GHz. The first IF frequency is 510 MHz. To pass a signal from the input to the first IF, the preselector must be tuned to an appropriate frequency with respect to the first LO. For instance, if it is desired to pass a signal in the range of 1.5 GHz to 3.5 GHz (Band 1), the preselector must be tuned at the same rate as the LO but 510 MHz lower. Band 2 covers 2.5 GHz to 4.5 GHz. On this band the preselector tunes at the same rate and 510 MHz higher than the LO.

In Band 3, which covers 3.5 GHz to 7.5 GHz, harmonic mixing is used for the first time. As noted previously, the mixer bias is varied to enhance, in this case, the second harmonic of the LO. With the second harmonic enhanced, the effective frequency of the LO is from 4.0 GHz to 8.0 GHz. The preselector is tuned at the rate of the effective frequency of the LO but 510 MHz lower in frequency. Band 4 (6.5 GHz to 12.5 GHz) and Band 5 (9.5 GHz to 18 GHz) are similarly tuned using the third and fifth harmonics.

The preselector has a bandwidth of about 50 MHz but significant unflatness will result unless the preselector is tuned to within about 2 MHz of the correct frequency. Special attention was given to temperature and drift compensation to maintain the accuracy of the oscillator and preselector control circuitry.

The oscillator tune voltage, which includes both the sweeping component and an offset corresponding to center frequency, is amplified by an amount appropriate to the harmonic in use (X1, X2, X3, X5). A second offset is then added to tune the preselector to the correct frequency.

As mentioned previously, the first converter assembly includes a coupler that sends the first LO signal to the external mixer jack on the front panel and returns the 510 MHz signal to the first IF. The first IF has two inputs from the first converter assembly—one from the coaxial mixer and one from the external mixer jack. The signal from the external mixer jack is preamplified and sent to a switch that selects between this signal and the coaxial mixer input signal. The amplifier following the switch is variable gain to compensate for the wide range of conversion losses caused by the use of harmonic mixing.

The amplified 510 MHz signal is then filtered with a 3 MHz band width filter and converted to 10 MHz by the second mixer and the second LO at 500 MHz. The second LO is amplitude regulated and the harmonics used as a calibrator signal.

The 10 MHz signal is amplified by a variable gain amplifier controlled by the IF gain control. It is then filtered by the various resolution bandwidth filters, sent through the log amplifiers to be logarithmically converted, detected, and the resulting video sent to the digital storage system.

The digital storage system (described in detail else-where in this issue) eliminates the need for a long-persistence type storage crt to display the slow sweeps required for high-resolution measurements. In addition to providing flicker-free displays, the digitized video signal is processed further to provide sev-

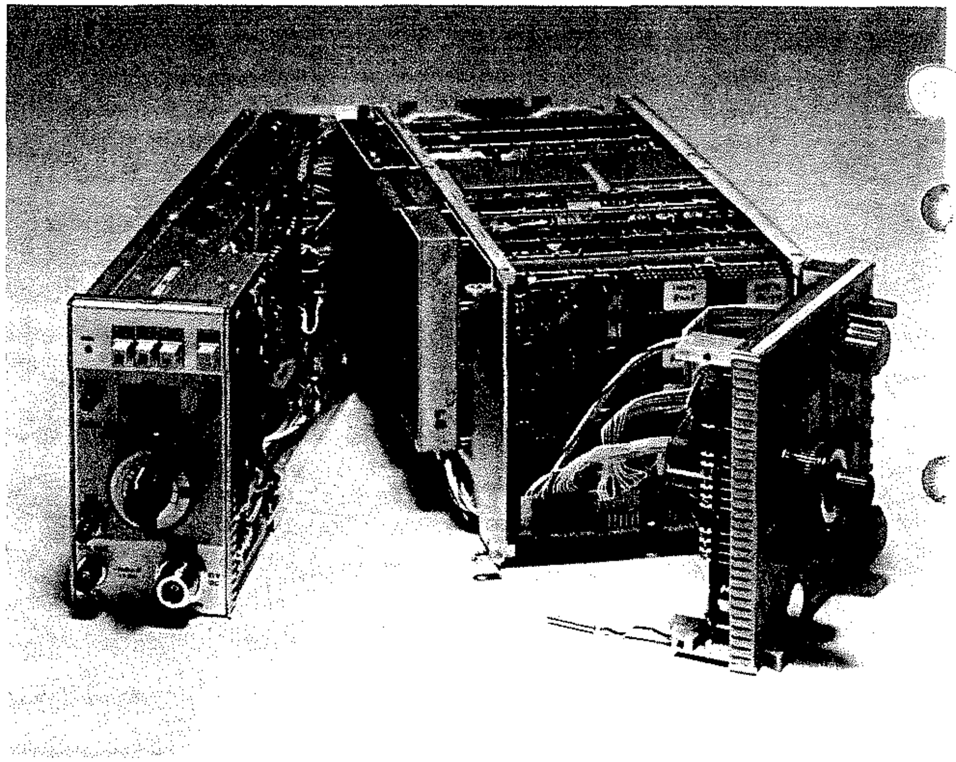


Fig. 3. The vertical section and front panel module are hinged for easy access to circuitry. An extender extrusion gives access to individual circuit boards. The 7L18 can be operated outside the mainframe in this configuration by means of a flexible extender cable.

eral computed signal parameters such as average value—ideal for eliminating the effects of noise, comparison of a reference signal and an incoming signal and display of only the differences between the two, and the display of maximum incoming signal level over an extended period of time.

Mechanical design

In microwave design, mechanical innovation is often as significant as circuit innovation. This is particularly true in the 7L18 where the goal was to package the electronics for a state-of-the-art microwave spectrum analyzer in a 3-wide 7000-Series Plug-In. Easy access to internal modules to facilitate adjustments, maintenance, and occasional repair was a must—all to be accomplished without compromising RF performance.

After extensive consultation with the electrical design team, precise space allocations were agreed upon for each of the circuit functions. The bulk of the circuitry resides on 4" by 5" printed circuit boards fitted into U-shaped extrusions. These extrusions interlock with extrusions on either side of the unit providing mechanical stability and a means of shielding between adjacent modules. Any module can be removed without disturbing the structural or functional integrity of the other modules. An extender extrusion is available to give access to individual circuit boards while the 7L18 is operating outside of the mainframe using a flexible extender cable.

Further access is accomplished by a hinge between vertical (signal input) and horizontal sections, and the front-panel module (see figure 3). The front panel of the horizontal section also is hinged to provide access. The 7L18 can be operated with either or both of these sections swung open.

One of the most challenging mechanical design problems was housing the phase-lock system which gives the 7L18 its outstanding stability. Several assemblies had to be well isolated to ensure spurious free response, yet located in close proximity.

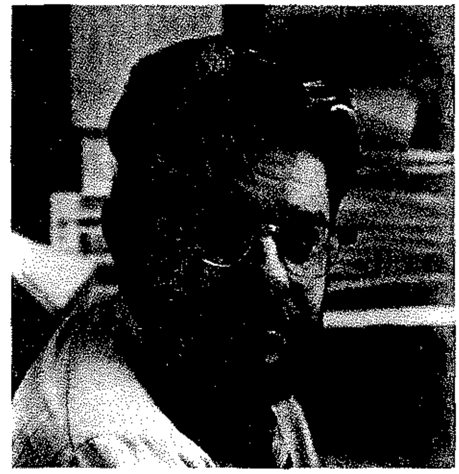
The needed isolation was achieved by housing the critical phase-lock circuitry in an aluminum milling. The milling utilizes solid bottom wells into which the individual circuit boards are mounted. Compartment to compartment interconnections are made by jumpers that pass through slots cut in the top of the side wall. To enhance the isolation further, each circuit board has an individual cover that fits under the outer cover.

To reduce incidental hum modulation by stray line related magnetic fields, the master sweeping oscillator is shielded in two layers of magnetic shielding. The resonator itself is shielded in a small mu-metal enclosure and the entire oscillator circuit is shielded within another mu-metal can. This reduces hum modulation to a very low level.

Numerous other mechanical design innovations in the 7L18 include direct input to the front-end attenuator; a 40:1, two-position, center-frequency control with a proprietary detent system that locks it firmly into the selected position; and a compact front-panel-readout drum that indicates both the selected band and its associated harmonic. Precision bending of semi-rigid coax to eliminate reflection and minimize transmission losses was achieved with special tooling that controls bend curvature within 0.5° and assures accurate plane relationships.

Summary

State-of-the-art performance and state-of-the-art packaging are combined in the 7L18 to give you new measurement capability and unparalled operating ease in an instrument that can easily be transported to your measurement site. The addition of this microwave spectrum analyzer to the 7000-Series family allows you to make measurements over the spectrum of 20 Hz to 60 GHz with a high degree of confidence in the results.



…nley Gumm is Project Leader for the 7L18 program. He designed trigger circuits for the 454, 7B50/51 and 7B70/71 time bases before joining the spectrum analyzer group. He has a B.S.E.E. '64 from Washington State and M.S.E.E. '[illegible] from the Univ. of Washington.

Acknowledgements

As Project Manager for the 7L18 I would like to express my thanks to those who contributed so much to the success of the project. Bob Bales worked on the sweep, span attenuator, YIG driver, and instrument-interconnect; Russell Brown and George Maney did the microprocessor programming; Carlos Beeck and James Wolf mechanical design of the microwave assemblies, with Dave Shores and Philip Snow providing the electrical design; IF design was done by Wesley Hayward; Jack Reynolds was involved in the early design of the phase lock circuitry with Steve Morton completing the work; Don Kirkpatrick designed the digital storage IC's with Dennis Smith doing the front panel and digital storage board; Al Huegli was responsible for the outstanding job of mechanical design. Virginia Morehead was indispensable in providing prototype support, as were the plant support people during introduction. Many other names should be included in this list but space doesn't allow. My thanks to each of you for a job well done.

The 7L18 will be introduced outside the United States during the first quarter of 1978. For further information, please contact the nearest Tektronix Field Office, Distributor, or Representative.

Digital Storage For A Microwave Spectrum Analyzer

Dennis Smith, at left, did the readout board design for the 7L18 and assisted with the storage board and front-panel design. He has his B.S.E.E. '74 and M.S.E.E. '75 from Montana State. Don Kirkpatrick, at right, designed the storage circuitry for the 7L5, reducing most of it to two ICs for the 7L18. Before joining the spectrum analyzer group he worked on the 4012 and 4014 Graphic Display Terminals. He has his B.S.E.E. '69 and M.S.E.E. '75 from Oregon State.

Digital storage is a relatively recent innovation in spectrum analyzers and is usually found only in those covering the frequency spectrum below 100 MHz. Why, then, digital storage in a microwave spectrum analyzer?

The excellent stability made possible by state-of-the-art circuits and components permits resolution measurements of 30 Hz at frequencies up to 12 GHz and 300 Hz up to 60 GHz. To scan through and fully display a 10 kHz spectrum at 30 Hz resolution requires scanning at more than 20 seconds per sweep. The usefulness of storage at these sweep speeds is obvious—it lets you view such slow moving displays flicker free. A storage crt could accomplish much the same thing. But, in addition to simplified operation, digital storage offers other advantages; for example, signal averaging to reduce the effects of noise, capturing the peak level of a signal, displaying drift in a signal, and comparing an incoming signal to a previously stored reference signal.

In this article we will discuss some of the problems, and solutions, involved in developing a digital storage system for the TEKTRONIX 7L18 Microwave Spectrum Analyzer.

The average calculation

The first problem considered was the necessity of performing an averaging function for smoothing of the waveform. This is usually done in an analog manner using a low pass filter called a video filter. The major problem encountered in smoothing digitally is the wide range of sweep speeds over which the 7L18 operates (20 sec/div to 1 ms/div). This is a large dynamic range over which to do digital averaging.

The solution to this problem involved finding a practical method of performing division rapidly. After considerable research, we adapted a technique employed in an early hand-operated mechanical calculator—that of using a series of subtract and shifts to effect division. The numerator and denominator are justified left and subtractions are performed until the denominator is larger than the numerator. The denominator is then shifted one place to the right and subtraction continued until the division is completed. Using this technique allows us to perform a division of a 17-bit denominator into a 25-bit numerator and arrive at an 8-bit quotient in 18 microseconds—a speed adequate for our needs.

The technique was first implemented in the TEKTRONIX 7L5 Spectrum Analyzer. The circuitry occupied two printed circuit boards totalling about 60 square inches, used 60 integrated circuits, and consumed a moderately large amount of power. When the 7L18 was conceived, it was evident we would not have nearly the same space and power available so we set about making the necessary reductions.

Nearly all of the digital circuitry was put into two custom LSI circuits—one for the horizontal function, the other for the vertical. These two ICs, along with external D/A converters, operational amplifiers, switches and switch debounce circuitry, and connectors are contained on a circuit board of less than 20 square inches (see figure 2).

The two chips are tied together into one coherent unit by a major synchronizing pulse which occurs every 9 μs. Data is stored serially in the 8k X 1 random access memory. This simplifies some of the other chores to be performed and provides some unique operating features. For example, you may want to read out the memory contents into an external device. This is accomplished through the use of an external "handshake". When a BUS REQUEST signal is received, the address bus on the memory goes tristate once every 40 microseconds and gives an external device access to the memory for one 9 μs cycle. The external device must provide the addresses and whether the information is to be read or written. The entire memory contents can be read out in about two milliseconds.

Memory with a difference

The digital storage memory in the 7L18 is functionally (but not physically) divided into two sections—A and B. Several modes of operation are available to you. You can store data in A or B, or in both. There are 512 A values and 512 B values. When both are displayed, the origin of B is shifted such that the A and B coordinates are interlaced giving you a display of about 1024 increments.

When the SAVE A function is activated the data in A memory is held, and only that in B memory is updated. In this mode, all of A is drawn and all of B is drawn, each in a separate trace.

A third display mode is available, called B-SAVE A. (B minus SAVE A). In this mode the displayed values are the differences between the B and A values for the same X coordinate. This is a very convenient mode to use in aligning filters and other devices where you can tune for a null. However, an interesting problem arises if the device you are testing is active. The reference waveform is stored in A memory and the unknown is stored in B memory. If the device is active, the B waveform may be larger than A resulting in a shift in the zero reference line. Then, for a particular application, where should the reference line be positioned—center-screen, at the top, or at the bottom? (It is set near top-screen at the factory.) We resolved this problem by allowing you to select the position of zero reference through the choice of a digital word. We created the mathematical expression B-A+K, with the value of K set by the selected digital word, which you can program.

Now let's take a closer look at the two LSI chips developed for the digital storage system. As we pointed out earlier, the storage display system is partitioned into two sections—the Vertical Control Circuit and the Horizontal Control Circuit. The vertical chip contains circuits for vertical acquisition, vertical display, peak detection, signal averaging, Z-axis blanking, and special Y-value processing. The horizontal chip contains the horizontal acquisition address counter, horizontal display counter, ten-bit RAM address multiplexer and a program logic array system control matrix. External to the two chips are two 8-bit digital-to-analog converters, two 10-bit digital-to-analog converters, one 10-bit latch, 8k bits of random access memory, and all required analog functions.

The vertical control circuit

A simplified block diagram of the vertical chip is shown in figure 3. The vertical analog voltage is converted to a Y-value binary number using an 8-bit successive approximation register. Eight clock cycles are required to perform the analog to digital conversion. For one clock period between each conversion the successive approximation register produces a low-going pulse called $\overline{\text{SYNC}}$. This is the synchronizing pulse mentioned earlier that ties the two chips together into one coherent unit. Nearly all functions of both chips are related to this pulse.

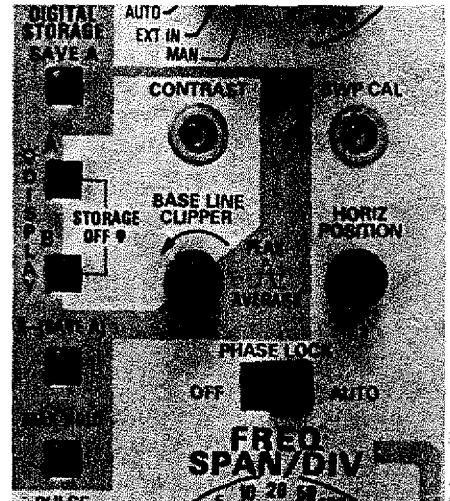
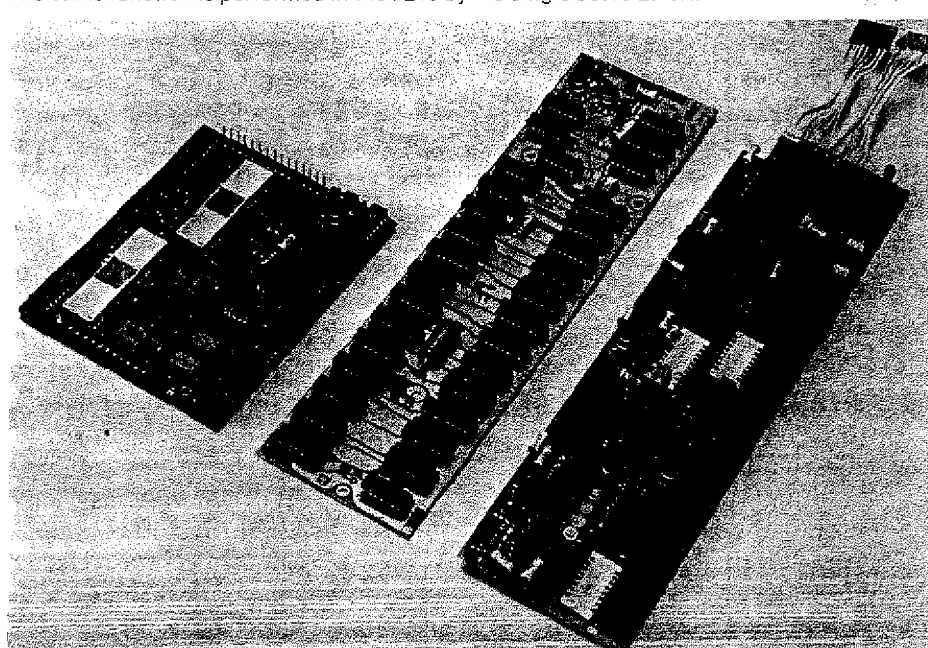


Fig. 1. Front-panel storage controls permit you to store one or two traces, or display the difference between the two.

The averaging circuit has three distinct parts: the grand total of all the Y values (for a given X coordinate), called the numerator; the number of samples comprising the numerator, called the denominator; and the subtract and shift circuit which performs the division. As each new Y value is converted, it is added to the eight least significant bits of the numerator. Each carry from the most significant bit of this addition is simply counted by a 17-stage ripple

Fig. 2. The digital storage circuitry in the 7L5 occupies the two boards at right. The same function is performed in the 7L18 by the single board at left.



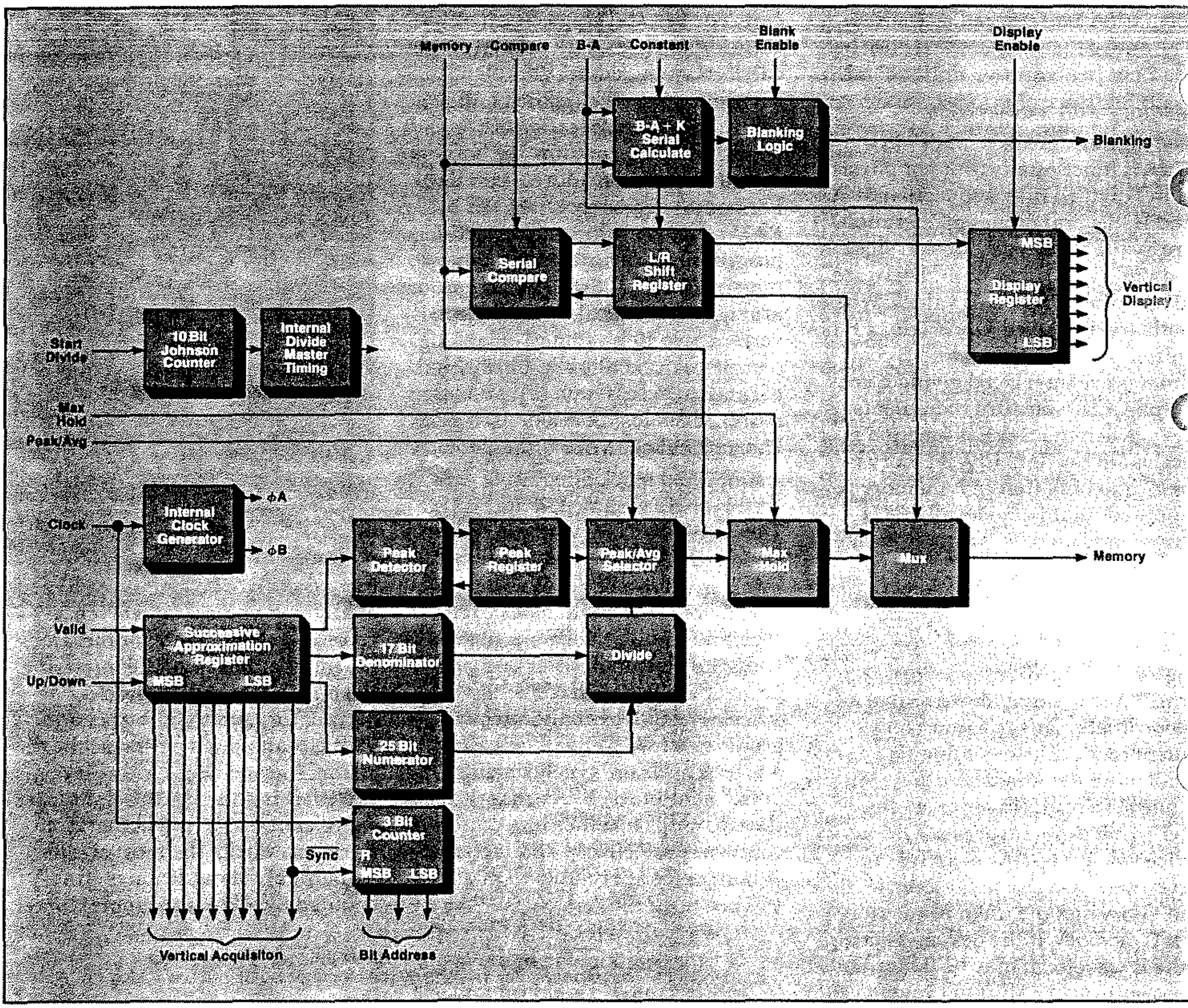


Fig. 3. Simplified block diagrams of the integrated circuit containing the vertical portion of the storage circuitry.

counter. This counter and the eight-bit sum are cascaded to form the 25-bit grand total. Each time a new sample is added to the numerator, a second 17-bit ripple counter is incremented, generating the 17-bit denominator.

A division cycle is started when the horizontal chip detects a change in the X coordinate. It sends a logic START DIVIDE signal to the vertical chip. Ten clock periods are required to load the divide circuit with the numerator and the denominator, with the actual divide taking an additional eight periods. The cycle starts on a $\overline{\text{SYNC}}$ pulse and the first bit of the quotient is available shortly after the positive edge of the first clock pulse following the next $\overline{\text{SYNC}}$. As we discussed previously, division is performed by repeated subtract and shift. The quotient is created serially with the most significant bit first. Since only eight-bit accuracy is required, the divide circuit is loaded with the eight most significant bits of the denominator and the sixteen most significant bits of the numerator.

The peak Y value reached during the last set of samples has been stored in an eight-bit shift register. At the start of a conversion cycle, a serial compare circuit is set to the state "don't know if the old or new number is larger". Each bit of the new and old value is then compared, most significant bit first, and when one number is found to be larger, a flip-flop is set and the larger number is stored in the shift register. A multiplexer circuit selects either the peak or average value to be routed to the memory, based on the setting of the front panel PEAK/AVERAGE control.

One of the special features of the 7L18 is MAX Hold. When this function is selected (by pressing a front-panel pushbutton), the larger of two values—the current memory value at this X coordinate, or the previously selected peak/average value—is stored in memory. Because the memory cannot read and write simultaneously, the current memory value was read at the same time the divide circuit was being prepared, and was temporarily stored in the vertical display serial-to-parallel shift register. The circuit which selects the larger of peak/average or memory value is functionally identical to the peak detector.

Timing for setting up the divide and clearing the numerator, denominator, and peak circuit is controlled by a ten-stage Johnson counter. Nor gate taps are taken from appropriate stages to develop the necessary clear and latch timing pulses.

As we discussed earlier, all data enters and leaves the memory serially. Data read from the memory enters an eight-bit shift register and, timed by $\overline{\text{SYNC}}$, is transferred to the vertical display latch. This shift register is used for other purposes, so the DISPLAY ENABLE signal allows only display information to be transferred to the display latch. One example of data moving through this shift register is during a B-A display. The A value is first read from memory and stored in the shift register. As the B value is read, the subtraction is done serially and the answer is fed to the shift register. The subtraction must be performed least significant bit first so a set of exclusive OR gates change the order of extracting B from memory. The direction of shift for the shift register is reversed also to present the most significant bit to the proper display latch. The answer is transferred from the shift register to the display latch by the DISPLAY ENABLE signal.

The subtract network does more than just B-A. The actual expression is B-A+K where K is a serial input external constant specified by the user. This permits you to place zero reference at any point on the display. To avoid possible confusion, when B-A+K is off-screen the subtractor blanks the display.

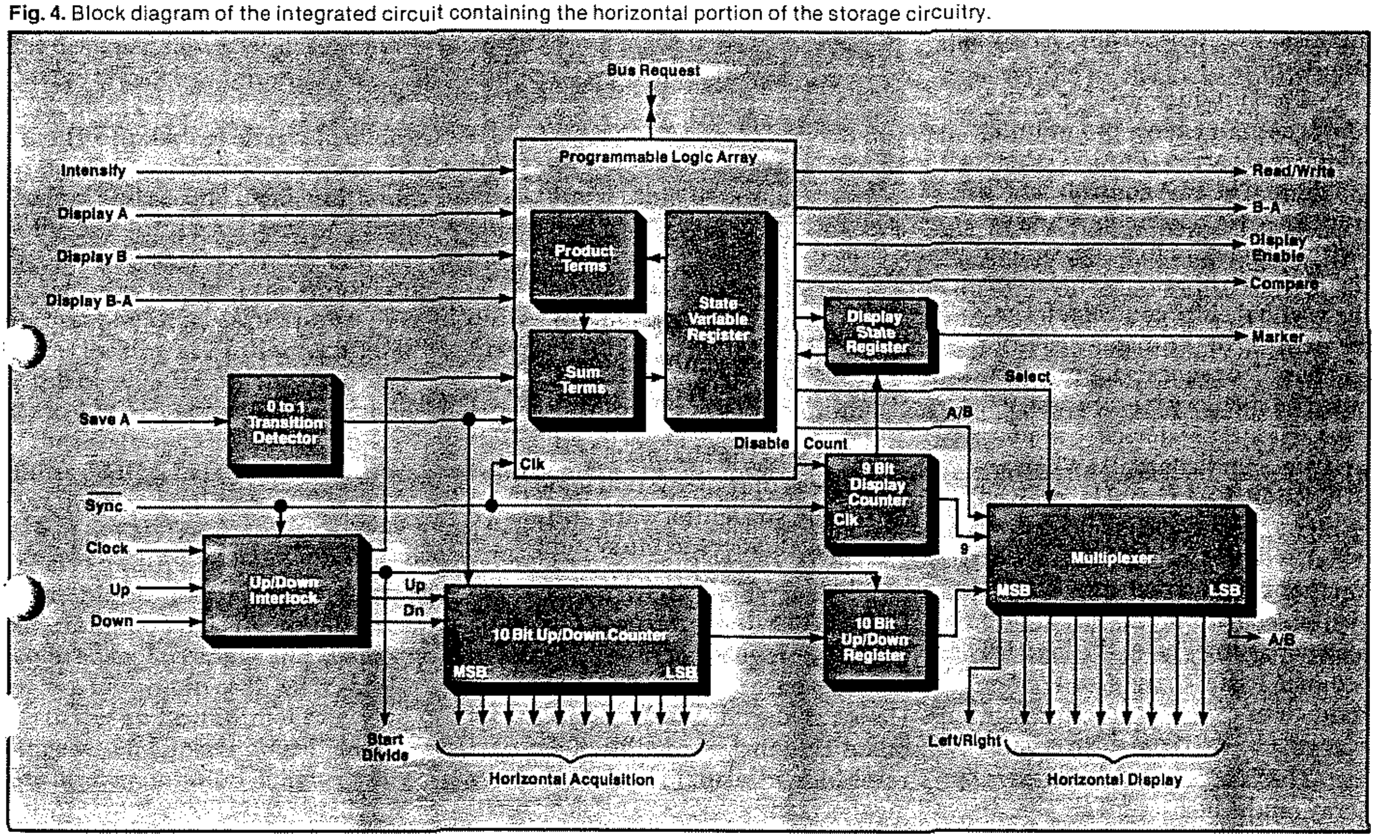
When SAVE A is disabled and both A and B are being displayed, maximum resolution of 1024 elements is displayed. If this display shows a very narrow pulse on the screen, it is possible that the top of the pulse is a single X coordinate wide. If this maximum value were in B memory, and SAVE A turned on then display B turned off, there would be an apparent drop in amplitude on the screen. For this reason, when SAVE A is turned on, a special circuit on the vertical chip compares all A and B values with the same X coordinate and stores the larger in the A memory.

The vertical chip also contains a three-bit synchronous counter which identifies which bit of the eight-bit vertical value is to be read or written by the memory. This is the only memory addressing done by the vertical chip; all other addressing is under the control of the horizontal chip.

The horizontal chip

The horizontal chip is considerably

Fig. 4. Block diagram of the integrated circuit containing the horizontal portion of the storage circuitry.



less complex than the vertical chip. A simplified block diagram is shown in figure 4.

The X analog voltage is converted to a horizontal address for memory by the use of a ten-bit tracking analog-to-digital converter. As the sweep moves to the right, the counter increments. As the sweep retraces, the counter decrements. Each time the counter is incremented, there is a new X coordinate, and a START DIVIDE is generated to start the storage cycle. When the counter decrements, no START DIVIDE is generated. The increment clock is $\overline{\text{SYNC}}$ and the decrement clock is the basic 1 MHz system clock. When SAVE A is activated, the counter skips every other binary number, thus only B coordinates appear as addresses.

The stored waveforms are recreated by reading from memory the Y value and converting this value and its X location to analog voltages. The counter which cycles through all the X locations is located on the horizontal chip. By the use of a multiplexer, the memory address is switched from display to acquisition.

The "intelligence" for the system is contained in a programmable logic array (PLA) ROM-state machine. The PLA controls which trace is going on-screen, when to switch from read to write, generates the B-A coordination signals with the vertical chip, controls the incrementing of the display counter, and handles requests for memory bus. The memory bus request allows an external device to read or write memory contents. When a BUS REQUEST signal is received, an eight-clock cycle is selected which will not interfere with other functions. When that time becomes available, all address lines and the read/write lines go to the high impedance tristate mode for the next eight clock cycles. It can then be accessed by external devices.

The Programmable Logic Array on the horizontal chip is

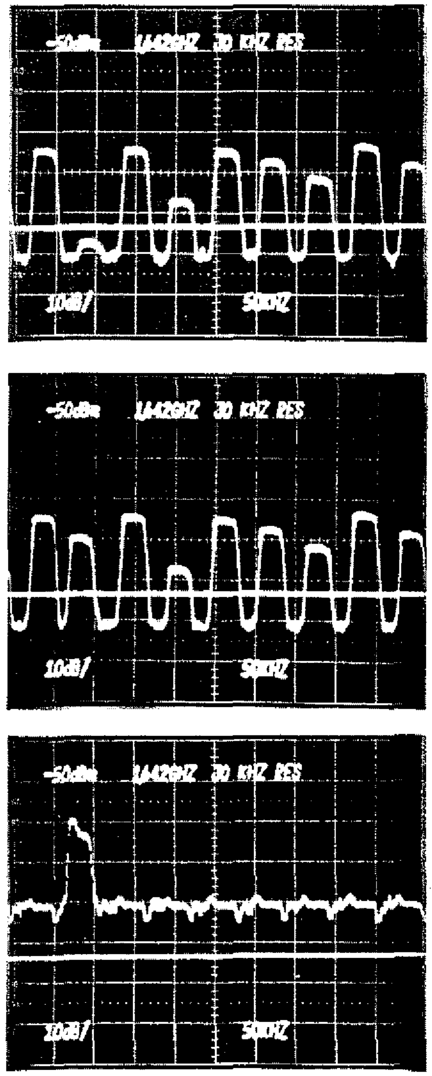


Fig. 5. This series of photos shows (top) display in SAVE A mode, (center) display in B mode, (bottom) display in B-SAVE A mode.

modeled after the classic Huffman/Moore finite state machine with the PLA performing the combinational logic. The advantage to a PLA and the Huffman-Moore machine is that the system logic is extremely straightforward and easy to follow. Changes to the system become very easy to effect.

Conclusion

Digital storage is not usually found in microwave spectrum analyzers. However, the outstanding stability of the 7L18 makes possible 30 Hz resolution measurements at gigahertz frequencies. The slow sweeps necessary for such measurements make storage a valuable adjunct.

The power and space available for the storage circuitry in the 7L18 provided an engineering challenge that was successfully met, with new time-saving operating features added as a bonus.

A Phase Lock Stabilization System For 30 Hz Resolution At 12 Ghz

The first question when engineering was confronted with the 7L18 Spectrum Analyzer stability requirements was "is it possible?" Today we can easily say "yes". For a while, though, we were not at all certain that the 7L18 stability goals were attainable. Consider the fact that 30 Hz resolution at 12 Ghz is a ratio of 1 10[8]. Consider further that this had to be attained in a sweeping system, with over 80 dB of display dynamic range, without introducing spurious responses. The implications of such specifications can be quite frightening. What follows is a discussion of some of these implications and the implemented solutions.

A balance of compromises

All frequency stabilization phase lock systems comprise certain basic elements such as a sampler, reference oscillator, error amplifier, etc. The designer, however, has many choices of block diagram implementation.

The first block diagram choice on the 7L18 was whether to sweep the first and second local oscillators or the first local oscillator only. Figures 1A and 1B show the two choices. Assume that the stability of the first (2-4 GHz) oscillator requires locking at a full screen span width of 500 kHz. By the time we get to 40 GHz, at the 10th harmonic of the oscillator, the 500 kHz becomes 5 MHz. Let us assume also that the first oscillator will be locked in 1 MHz steps. These steps are also multiplied by the operating harmonic number, assumed ten for our example. Thus, the total range required for sweeping and centering is a minimum of 15 MHz. Adding to this some minimal safety range we end up at about 17 MHz. The implementation of figure 1A requires that the 500 MHz oscillator sweep 17 MHz.

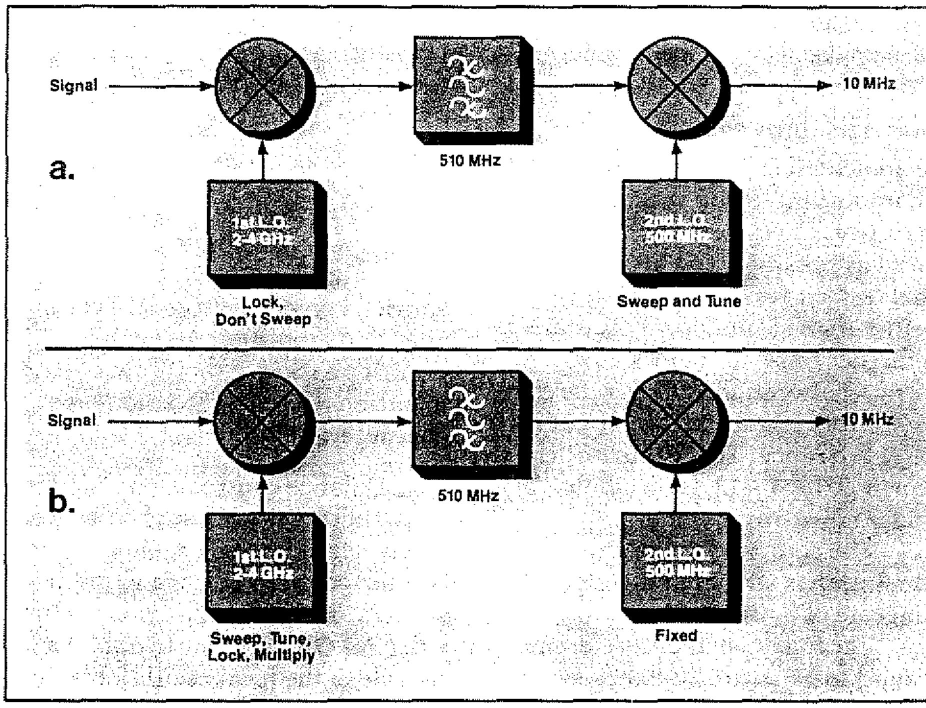


Fig. 1. (a) During phase lock operation, the First L.O. is locked and the Second L.O. is swept and tuned. In Fig. 1(b), the First L.O. is swept, tuned, phase locked, and multiplied, while the Second L.O. is fixed.

This system has the advantage that stability is virtually independent of operating harmonic number so that the same specifications apply at all input frequencies, and it avoids such complicating features as a conversion harmonic attenuator. The difficulty is that 17 MHz is a very large percentage of 500 MHz resulting in a loss in stability. Furthermore, this requires a nearly-impossible-to-design sharp cutoff, flat, 17 MHz-wide filter in the first IF.

One way of reducing the required tuning range is to lock the first oscillator in smaller increments, for instance 500 kHz. However the reference noise is multiplied by 20 log M, where M is the ratio of locked oscillator frequency to reference oscillator frequency. Therefore, a two to one reduction in reference frequency means a 6 dB degradation in sideband phase noise; not a very attractive prospect.

Another technique of reducing second local oscillator tuning range is to lock the first oscillator in small synthesizer tuning increments. But room and power constraints prohibited this.

The compromises implicit in figure 1B are different. Basic sweep width requirements are not multiplied at higher operating harmonics since this happens automatically in the mixing process. But other difficulties creep in. All instabilities experienced by the locked oscillator are multiplied by the conversion harmonic number. Thus, incidental fm is dependent on frequency with a ten times degradation, for example, at 40 GHz compared to 4 GHz. The input reference and sweep oscillator are used to lock a relatively wideband oscillator (2-4 GHz) as opposed to an essentially fixed frequency 500 MHz oscillator. As we tune the first local oscillator to change input frequency, the ratio of reference and locked oscillator frequency changes. This means that the ratio of any movement or sweeping of the reference oscillator also changes. To maintain a constant relationship it is necessary to normalize the reference sweep voltage through a conversion harmonic attenuator.

Clearly the implementation of figure 1B is much more complicated. But, barring the use of a reference synthesizer, it also gives better stability for the lower conversion bands. It is the technique, chosen for the 7L18.

Adding improvements

As indicated in the previous section, an important key in getting good stability is to sweep as narrow a band as possible. The first choice in this respect was to sweep the first rather than second local oscillator. A further improvement was to switch between four fixed reference oscillators to get 1 MHz steps at a 4 MHz reference. This is theoretically worth 20 log4 =12 dB in sideband phase noise improvement.

The complete basic implementation is shown in the block diagram of figure 2.

The four megahertz reference is used to generate 20-nanosecond wide, 4-volt strobe pulses which are further sharpened up to a 100 picosecond or less risetime in a snap diode circuit. This drives a sampling phase gate to generate the phase lock error signal. Phase gate characteristics are important in transferring the full cleanliness of the reference signal to the local oscillator. Precise balance between coupler arms, sampling diodes, and strobe pulse amplitude level has to be maintained to prevent reference strobe harmonics from getting into the local oscillator, thus creating spurious responses. Control of balance and amplitude level also permit phase lock loop gain optimization for best sideband noise characteristics.

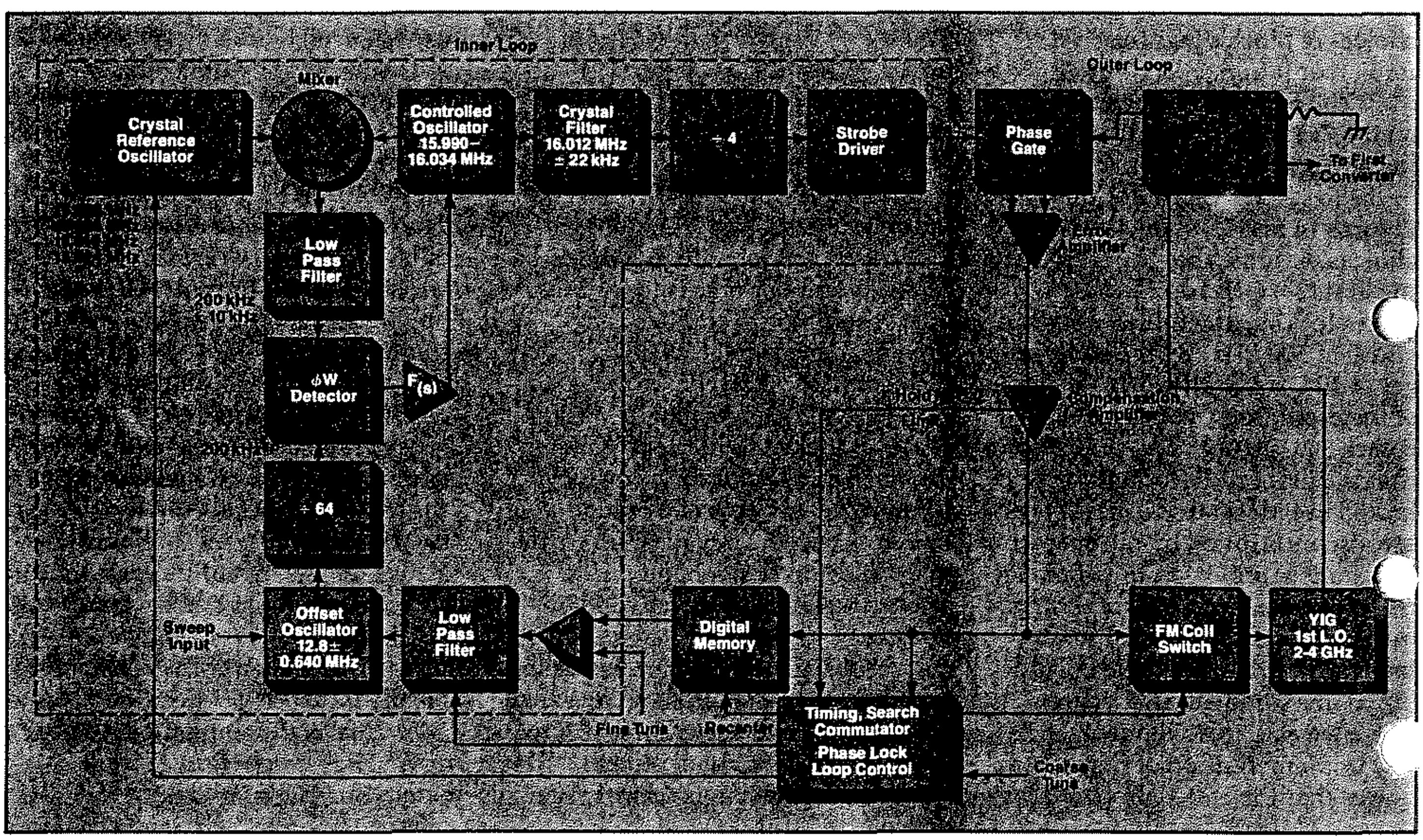
Balance control is obtained by constructing the phase gate, as well as associated circuitry, on an interconnected array of three alumina substrates. These substrates include a flat 2-4 GHz coupler to obtain a sample of the local oscillator, a resistive power divider to separate the local oscillator input into two channels, two terminated sampling diode chips, a combiner and integrator to drive the error amplifier, a balanced snap diode driver with snap diode, and two couplers for coupling the snap diode generated strobe pulses into the sampling diode lines.

Defining stability

With all this fuss about getting things stable it might be useful to explain what it is that we are after. Figure 4 shows an illustration of the three elements which are affected by phase lock stabilization.

Drift—a gradual shift in center frequency with time, temperature, line voltage, etc. is a relatively slow phenomenon. Incidental fm on the other hand is a fairly rapid random frequency shift or perturbation. It can be analyzed as a narrowband fm modulation process. When this is due to power supply line related ripple, we get coherent sidebands. These can be quite troublesome for a high resolution instrument like the 7L18. The sideband noise pedestal shows the "far down" stability performance of the oscillator.

Fig. 2. Block diagram of 7L18 phase lock system. The inner loop serves as the frequency reference for the outer loop.



Unfortunately, the stabilization circuitry affects the three stability elements differently. The choice of performance is, therefore, a matter of compromise.

Drift and incidental fm are closely related to sweep or tuning width and to the isolation of the oscillator from the environment. A wide tuning circuit must, by it's very nature, have elements which greatly affect frequency. If uncontrolled environmental factors such as voltage or temperature get into the frequency sensitive elements of the oscillator, then we have drift and incidental fm. The solution is two fold—reduction of frequency sensitivity and isolation from the environment.

Frequency sensitivity is reduced by locking the main oscillator to as narrow a tuning reference as feasible. Some of the efforts at reducing reference sweep and tuning range have already been discussed. In addition, many not so obvious steps have been incorporated. Observe from figure 2 that the basic crystal reference oscillators differ from each other by only 8 kHz, i.e., 15.800 MHz and 15.808 MHz. Eventually, of course, this small difference is multiplied to become 1 MHz steps (2 GHz/16 MHz=125, 8 kHz X 125=1 MHz). The offset oscillator moves 640 kHz/64=10 kHz. This gives extraordinarily little overlap when switching between the four reference crystals. Oversweep, false locks, failure to switch crystals, or failure to lock to the right crystal can all cause annoyances or worse. The usual procedure is to have plenty of oversweep range for safety. Not so in the 7L18. Here extra effort in the lock, search, and control circuitry was traded for a narrower sweep range.

Once the main oscillator is locked to a reference, the sideband phase noise characteristics are determined mainly by the reference oscillator and lock loop bandwidth. Obviously, great care must be taken to make the basic reference oscil-

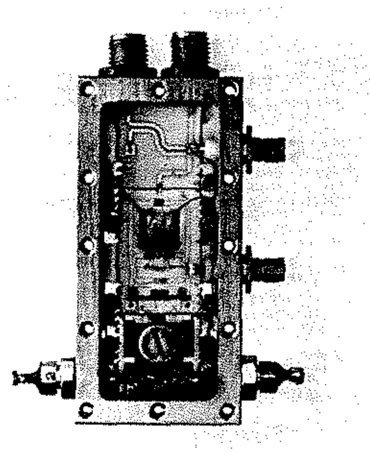
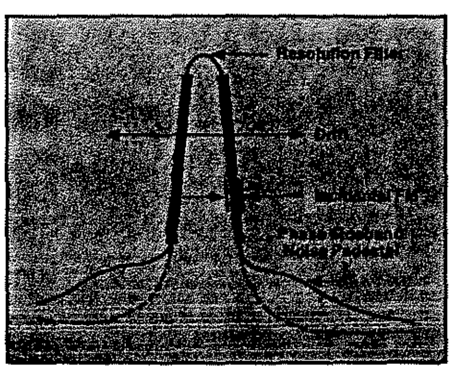


Fig. 3. Phase gate assembly includes a 2-4 GHz coupler, a resistive power divider, two terminated sampling diode chips, a combiner and integrator to drive the error amplifier, and two couplers to couple the strobe pulses into the sampling diode lines.

lator as clean as possible. This involves choice of crystals (type of cut, Q, mounting etc.), choice of circuit, and isolation from the outside environment. But even the best reference has a wideband noise floor and the sideband noise level comes up as 20 logM (M=multiplication ratio). Therefore, the higher the reference frequency the better. For the 7L18, the basic reference frequency is 4 MHz (16 MHz÷4). This is multiplied by 500 times to get to 2 GHz, producing a 54 dB increase in apparent reference sideband noise. Had we used a 1 MHz reference the increase would have been 12 dB worse.

Fig. 4. An illustration showing the three elements affected by phase lock stabilization — drift, incidental fm, and phase sideband noise.



This performance area is accentuated in the 7L18 because of the sharp 4:1 resolution shape factors. More gradual resolution bandwidth roll off permits use of a dirtier lock reference since the phase noise can not be resolved. As a consequence it was considered worth the complexity to go to a four crystal reference system in order to save up to 12 dB on phase noise.

Finally, it is essential that sensitive circuits be well isolated from undesirable outside influences. The crystal oscillators are separated from the offset VCO by a mu-metal housing. The reference oscillator system sits in a separate compartment of a multicompartment milling. Other elements of the phase lock system are mounted in the remaining compartments of the milling. As a final measure, all compartments are enclosed on both sides by mu-metal plates. Input and output connections are handled through special feedthrough capacitors to create the highly isolated compartment shown in figure 5.

A closer look

Now let's take a closer look at how the phase lock circuitry does its job. It is easier to understand if we discuss it in two parts. The first covers the generation of the strobe, or reference frequency, to which the YIG oscillator is locked. This is called the inner loop. The second part discusses the circuitry necessary to lock the YIG oscillator to the strobe; we call this the outer loop (see figure 2).

The inner loop

As you can see from the block diagram in figure 2, the inner loop consists of three oscillators: a stable crystal reference oscillator (referred to as the reference oscillator), a moveable reference oscillator (referred to as the offset oscillator), and the controlled oscillator, which is phase locked to the sum of the reference and offset oscillators. The controlled oscillator frequency is divided by four and used as the source for the strobe driver. This strobe is used as the reference to which the YIG tuned (2-4 GHz) first LO of the 7L18 is phase locked.

The reference oscillator is comprised of four crystal resonators at 15.800, 15.808, 15.816, and 15.824 MHz. A 1 Hz change in this oscillator moves the strobe 125 Hz at 2 GHz and about 250 Hz at 4 GHz when the offset oscillator is centered at 12.8 MHz. Therefore, the 8 kHz spacing between crystal frequencies moves the strobe lines in increments of 1 MHz at 2 GHz. Both the positive and negative supplies of the reference oscillator are zener referenced to reduce the affects of power supply variations and coherent side bands from other circuits in the 7L18.

We use the offset oscillator to sweep the controlled oscillator for interpolating between lock points, and to provide fine tuning. The offset oscillator frequency is divided by 64, then added to the reference oscillator frequency, and again divided by 4 for a total division ratio of 256. When locking the YIG oscillator at 2 GHz, the strobe signal is multiplied up about 500 times, depending on the reference oscillator frequency. This means that a 1 Hz change in the offset oscillator will move the YIG oscillator frequency about 2 Hz (500/256) when the strobe line is at 2 GHz. You will recall that the multiplication ratio depends on the YIG oscillator frequency, thus a 1 Hz change in the offset oscillator will cause a 4 Hz change in the strobe line at 4 GHz.

Because of noise consideration, limitations on the linear sweeping range of the offset oscillator, and the bandwidth of the 16.012 MHz crystal filter, the recentering range of the offset oscillator is only 1.2 MHz on-screen at 2 GHz. Consider that at 2 GHz, the strobe must also move 500 kHz (±250 kHz) to give a fine tuning range of one screen diameter in the widest phase lock position, plus provide a sweep of 500 kHz. This means that the strobe must move another 1 MHz. The total range of the YIG oscillator, therefore, must be 2.2 MHz at 2 GHz. Hence, the offset oscillator must move 1.1 MHz because of the 2:1 multiplication ratio discussed previously. In the offset oscillator circuitry, the varactor, zener diode and operational amplifiers must be carefully selected for noise to give good performance at an equivalent YIG oscillator frequency of 12 GHz. This is equivalent to looking at the 12th harmonic of the offset oscillator.

A mixer combines the reference oscillator, at about 15.8 MHz, with the controlled oscillator, at about 16 MHz. The difference frequency of 200 kHz is applied to the phase/frequency detector through a low pass filter which prevents the 15.8 MHz and 16 MHz signals from getting into the phase detector. These frequencies combine with harmonics of the 200 kHz to produce a family of crossover spurious responses which must be down 150 dB– no small task. Careful shielding is a must at this point.

A phase/frequency detector and compensation amplifier (Fs) lock the output from the mixer, to the offset oscillator. This lock loop has a bandwidth of about 10 kHz because it must be swept.

The output signal from the controlled oscillator is filtered by a 6-pole monolithic filter to remove the residual 200 kHz sideband (200 kHz being the update rate of the phase/frequency detector) before going to the strobe driver.

One final comment on the inner loop function. Since the strobe rate is about 4 MHz, there will be a strobe frequency line approximately every 4 MHz to some frequency greater than 4 GHz, (the upper end being determined by the bandwidth of the phase gate sampler). At 2 GHz, the strobe frequency increments in 1 MHz steps when a crystal in the reference oscillator is replaced by an adjacent crystal. The range allowed in the offset oscillator moves the strobe 1.2 MHz at 2 GHz to give a 20% overlap

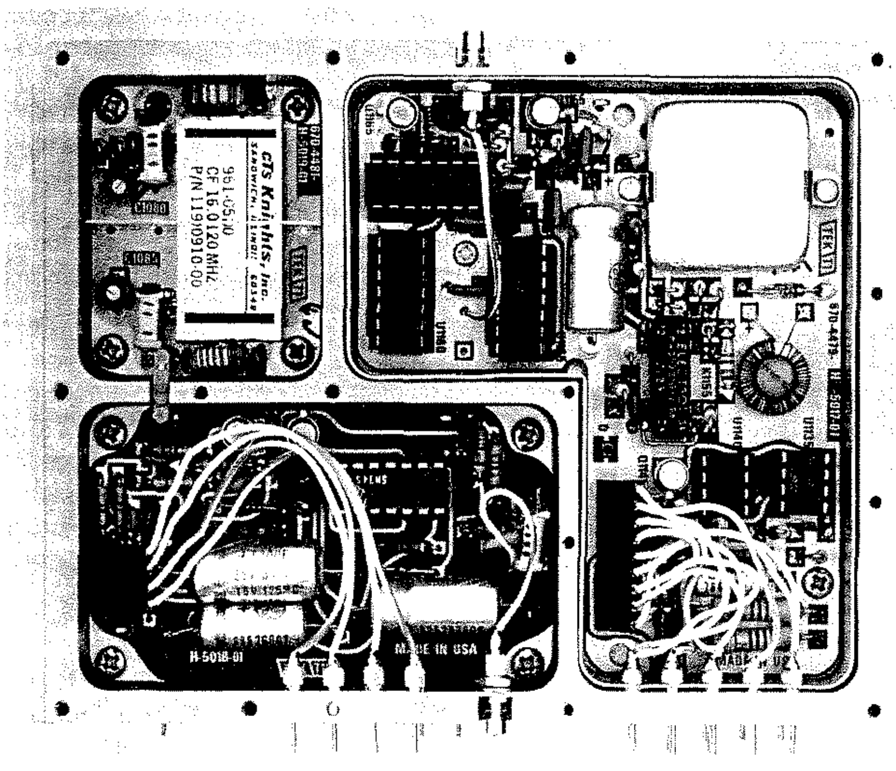


Fig. 5. Milled housing contains phase lock system. Mu-metal shielding is used extensively to create highly isolated compartments.

(see figure 6). At 4 GHz, the minimum spacing due to incrementing a crystal is 2 MHz. However, the strobe harmonic at 4 GHz now moves twice as far, or 2.4 MHz, when the offset oscillator is varied before, thus no additional range is required from the offset oscillator.

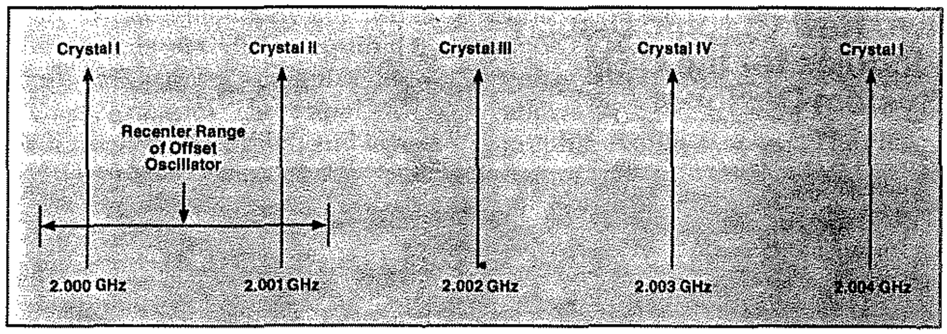


Fig. 6. The recenter range of the offset oscillator is ±20% to provide adequate overlap between adjacent crystals.

The outer loop

The discussion thus far has been concerned with the generation of the strobe reference. Now let's consider the loop that locks the YIG oscillator to this reference. The outer loop portion of the block diagram is shown in figure 2.

The outer loop performs a host of functions as follows:

- Connects the compensation amplifier to the YIG oscillator when in phase lock positions
- Provides search when not locked
- Delays connecting the error amplifier after the strobe is turned on
- Varies lock-in range as a function of tune voltage
- Commutates between crystals in the reference oscillator
- Locks the YIG oscillator to the strobe
- Senses when lock is achieved
- Moves the strobe reference to recenter the YIG oscillator
- Connects the sweep and offset oscillator filter after lock occurs
- Limits hold-in range

The compensation amplifier and search oscillator form a conditionally stable amplifier that requires the phase lock loop to have acquired, to become stable. When the loop is not locked, the compensation amplifier oscillates at about a 3 Hz rate. As the amplifier oscillates, the YIG oscillator searches an amount somewhat greater than MHz.

The search voltage moves the oscillator more than the distance between strobe lines to ensure that neither temperature effects nor dc balance errors from the phase gate will change the lock-in range. As we discussed earlier, the lock-in range when the YIG oscillator is at 2 GHz must be greater than 1 MHz, the spacing between crystals, and less than 1.2 MHz. the maximum recenter range of the offset oscillator. At 4 GHz these numbers are 2 MHz and 2.4 MHz respectively.

The output voltage of the search oscillator is monitored, and when this voltage exceeds an absolute value determined by the tune voltage, a lock inhibit command is given. In this manner, the allowable lock-in range is varied a factor of two as the oscillator is moved from 2 to 4 GHz.

When the allowable lock-in range is exceeded, it means the oscillator was not able to acquire lock with the crystal in use, and a new crystal is selected. The inner loop has time to settle before the search oscillator comes back into lock-in range and the new crystal is tried.

Eventually the YIG oscillator locks to the strobe reference and the search oscillator stops oscillating. When this happens, lock is sensed after a fixed period of time has elapsed to ensure that the lock is real. The crystals are then no longer allowed to change.

The next step is to recenter the YIG oscillator so that a signal on-screen will be in the same place as before the lock was initiated. This is done by applying a correction voltage to the offset oscillator from an 8-bit digital-to-analog converter, until the error voltage from the phase gate is zero. This D/A must be

Morris Engelson, at left, is the dean of spectrum analyzers at Tek having been with the analyzer program since its inception. He has a B.S.E.E. '57 and M.S.E.E. '64 from CCNY. Steve Morton, at right, has worked on the 7L5, 7L12, and 7L18 programs. He earned his B.S.E.E. '70 at Oregon State and M.S.E.E. '73 at the Univ. of Portland.

very stable to ensure low drift of the offset oscillator. If, for some reason, the D/A doesn't have enough range to recenter the oscillator, the lock sequence is started again, with provisions to ensure that the next crystal in the sequence is the first tried.

After the YIG oscillator is locked to the strobe reference and returned to the frequency it was before lock was initiated, the sweep voltage is connected to the offset oscillator to sweep the reference. The bandwidth of the outer loop must be wide enough to ensure that the loop remains locked during sweep and retrace. This bandwidth is about 10 kHz for the 7L18. The hold-in range of the loop is about 4 MHz to allow for the sweep, fine tune range, and drift of the oscillator.

Two New Graphic Display Modules for the OEM System Designer

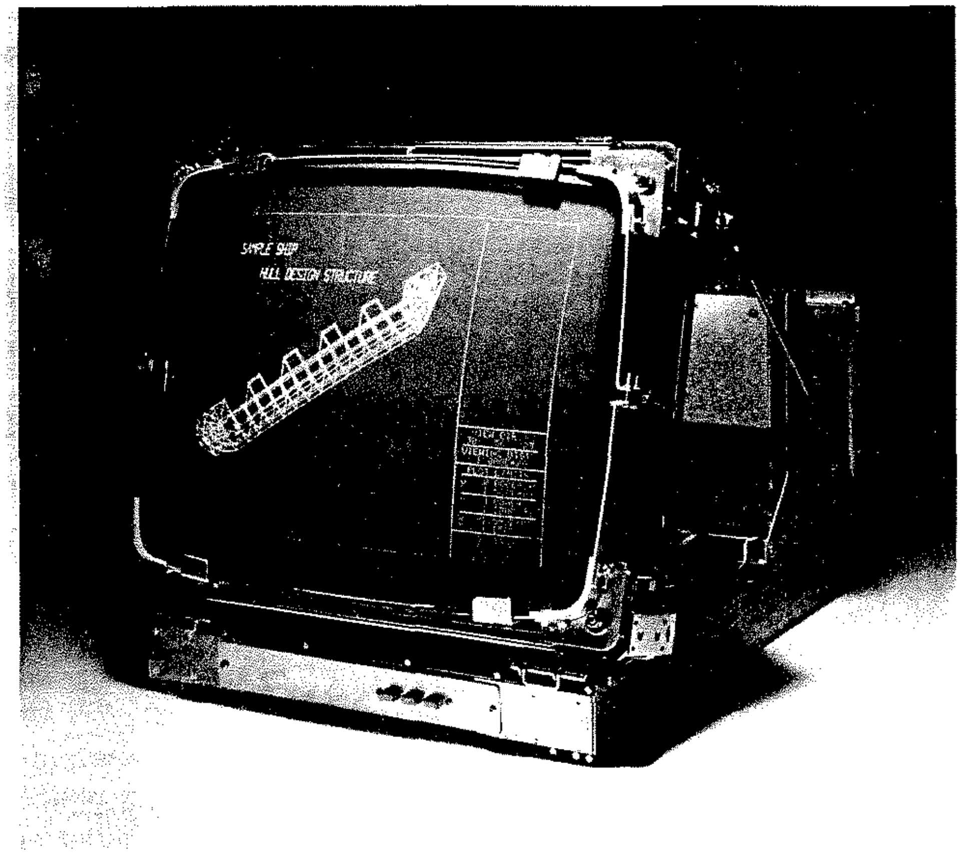


Fig. 1. The GMA101A Graphic Display Module designed specifically for the OEM market.

Business, engineering, science and education are all looking more and more to the computer to solve specialized problems. In the publishing field, large word processing systems with graphic display modules are used to layout and edit newspapers. Computerized circuit board layout systems are in use throughout the electronics industry. Programmed instruction systems can be found in elementary and secondary schools as well as in universities.

All these applications require the ability to interact with the system and graphically display words, images, or complex phenomena. Graphic displays are thus in increasing demand by system designers to help make these new, specialized computer systems more compatible with non-programmers and other "non-computer types," who will be using them.

To meet this demand, two new graphic displays, the TEKTRONIX GMA101A and the GMA102A, have been designed specifically for the OEM market.

Using its direct view storage tube (DVST) technology, Tektronix has for many years been a leader in the design and manufacture of high resolution, low cost graphic display modules and terminals. With this new OEM configuration, system designers can now tailor the DVST display to their specific system needs. In addition, the GMA series for the first time offers fully developed store-refresh capability, the ability to display stored and refreshed graphics on the DVST screen at the same time.

Lots of options

In designing the GMA series of graphic display modules for the OEM market, many packaging and performance options have been made available. Both the GMA101A and the GMA102A feature modular construction within a sturdy, wireform chassis. The 19-inch display screen can be oriented either horizontally (tv format) or vertically (page format), with a viewing angle of either 90° vertical or tilted back 15°. Each unit includes a power-supply, a vertical and horizontal amplifier circuit board, a high voltage and Z-axis board and a storage board. Space is available for three additional circuit boards, which can be selected from Tektronix' list of performance options or built by the OEM buyer. The list of performance options offered by Tektronix includes vector and character generator boards and extra current capacity for use by OEM-designed circuits. A hard copy interface is included as part of the standard display package. It can be removed, as an option, for OEMs who will never need hard copies directly from the display. Both basic display modules are all digital except for the X and Y inputs which are analog. With the interface options for both displays, the user also can drive the X and Y inputs digitally through use of a 16-bit, fully parallel, TTL-compatible format.

Low cost graphics

The GMA101A has the highest resolution for its price of any graphic display on the market. Since the image is stored on the phosphor of a DVST screen instead of in memory, is required with a refreshed display system, DVST displays allow high resolution, high density graphics to be displayed at a relatively low computer overhead. Over 3200 inches of vector or over 8500 alphanumeric characters can be stored on the 19-inch GMA101A display screen.

The many peformance and packaging options available with the GMA101A make it usable in a wide variety of applications including word processing, graphic display terminals, and graphic work stations for computer aided design systems.

The best of both worlds

The GMA102A offers the same precision graphic displays offered by the GMA101A, with the addition of store-refresh. Along with stored graphics, up to 1500 inches of refreshed vector can be displayed with the GMA102A.

Combined storage-refresh displays have been made possible by the development of a DVST technique called write-through. Using write-through, intensity of the electron beam is slightly reduced to just below the storage threshold level. The beam then writes on the phosphor, but the image is not stored. By varying the beam intensity, information can be displayed in a combination of storage and refresh.

In the past, the chief disadvantage of DVST displays has been the inability to selectively edit the display without erasing the whole screen. With the development of store-refresh, the GMA102A offers the best of both worlds: the low cost, high resolution graphic displays obtained with DVST storage and the selective erase obtained with refresh.

This combined storage-refresh display will be useful in applications where a moderate amount of display interactivity is required in the creation of very complex, high density graphics. These applications include the design and layout of IC masks and printed circuit boards, newspaper page composition, and map making.

Costs versus refresh

Designers of graphic display systems have traditionally made heavy demands on display technology. Computer aided design systems like those used in map making, for example, require precise, high resolution, high vector density displays. Of the four presently available display technologies—DVST, plasma, video (raster) and directed beam—only DVST and directed beam have been able to meet these demands. Both DVST and direct beam provide high resolution (60 to 110 addressable points per linear inch) and high density (from 3,000 to 10,000 inches of displayed vector). Directed beam displays are by nature refreshed systems and thus also provide selective erase capability. DVST displays have traditionally been pure storage devices, with no refresh capability. The ability to store a display on the screen phosphor, eliminating the need for costly refresh memory, however, allows the design of very low cost graphic display systems. The choice between DVST and directed beam has thus always been one of cost versus refresh.

A new question

With the recent reductions in the price of refresh memory, it appeared that directed beam displays were gaining on DVST in this competition. Now that store-refresh has been added to the picture, DVST displays should continue to offer the most favorable cost/performance combination for many years to come. System designers no longer will ask, "Do I need refresh?" The question is now, "How much refresh do I need?"

A good example of an application of the combined storage-refresh capability of the GMA102A is its use in a computer aided circuit board design system. Displaying all the runs and pads of a six layer circuit board with a refresh display requires a considerable amount of refresh memory. Using the

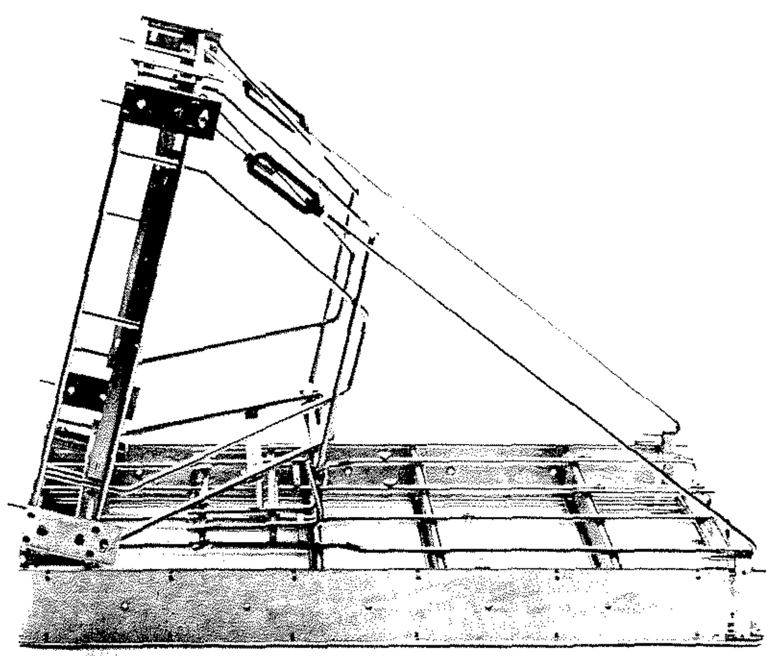


Fig. 2. The sturdy waveform chassis permits the 19-inch screen to be oriented vertically or horizontally with a viewing angle of 90 degrees vertically or tilted back 15 degrees.

High speed vector generation

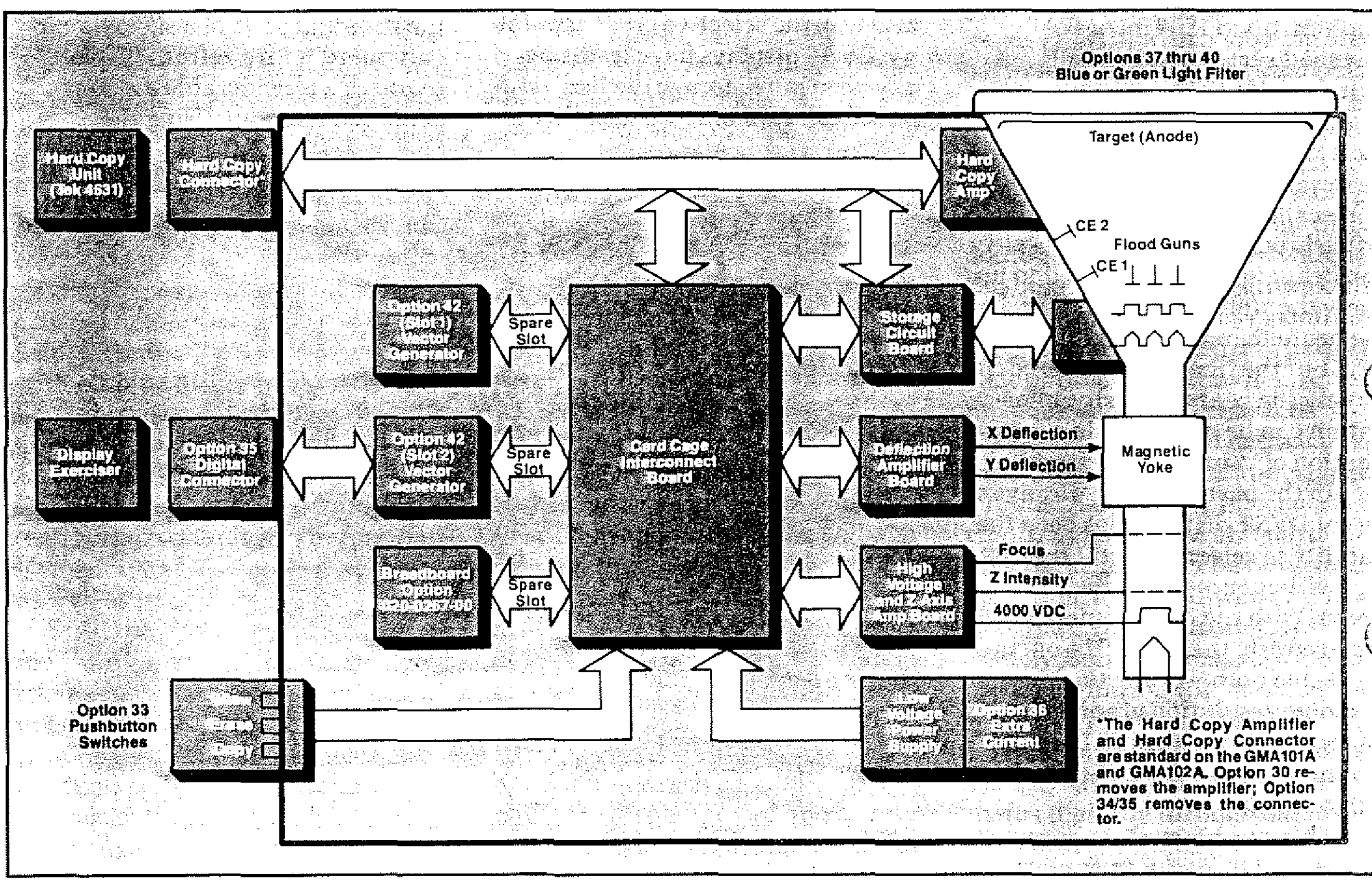
GMA102A, the circuit board layers can be designed and displayed one layer at a time in refresh. Once a layer has been brought-up and edited in refresh, it is stored on the display, and the next layer is started in refresh. This use of refresh and storage to build a circuit board allows selective editing of each layer, but requires only one-sixth the refresh memory (for a six layer board) of a directed beam display. To augment the write-through capability of the GMA102A, a high speed vector generator, option 42, and a high speed character generator, option 43, have been developed. These two options are available on separate circuit boards that plug into the spare circuit board connectors in the GMA102A. Complete digital interfacing to both these circuit boards eliminates the need for the OEM to design complex analog circuitry.

Option 42 utilizes a digitally based hardware vector generator algorithm and an active deglitching circuit to provide clear, high speed, repeatable graphic displays. With a writing rate of 90,000 cm per second, up to 1180 inches (3000 cm) of graphics refreshed at a 30 Hz rate can be displayed on the GMA102A using Option 42. Stored vectors can be drawn at up to 4000 inches per second.

This hardware vector generator provides theoretically 100% repeatability for each refresh cycle, with less than 0.05% of a full line length non-linearity. Fifteen different dash patterns and two line widths are provided. 12-bit positional resolution is used to achieve high precision positioning (absolute or relative) in 3.5 mil steps. The active deglitch circuit filters out noise at the digital-to-analog converter output to provide glitch free vectors. Besides drawing vectors to drafting-like standards, Option 42 draws vectors that are smooth. This is achieved by illuminated spot overlap—an outgrowth of the high addressability feature coupled with the essentially continuous nature of the GMA102A phosphor surface. Spot overlaps of 55%, worse case, are achieved on vectors written at even a 45 degree angle.

Option 43 provides four character fonts and the ability to create a display of over 400 refresh characters at a 30 Hz refresh rate. Both Opton 43 and Option 32 (a combined vector/character generator) feature interchangeable ROMs for alphabets and type faces. Made by Motorola, these ROMs can be purchased for different alphabets and type styles. The characters are created in a 7 x 9 dot matrix. In the

Fig. 3. Simplified block diagram of the GMA102A.



storage mode, Option 43 can generate up to 7000 small characters (90 x 110 mil) and 2000 large characters (160 x 195 mil) per second.

Option 32 is a storage-only vector/character generator circuit board for use with the GMA101A. It can draw stored vectors (absolute addressing only) at up to 3940 inches per second with 3.5 mil steps. It can generate 1000 large (160 x 195 mil) and 2000 small (90 x 100 mil) characters per second. A refreshed display cursor is also provided. As with Options 42 and 43, Option 32 features completely digital interfacing.

A practical, low cost, display exerciser is available as one of the support options. For OEMs, this exerciser is especially useful by their engineering group in verifying the display specifications and interfacing requirements. It is also useful by the OEM's manufacturing group in incoming inspection and quality control. In addition, a variety of other service devices and design aids, such as a breadboarding kit, are available for use by OEMs in making it easy for them to integrate the GMA displays into their systems.

Plenty of room for added value

The all-modular construction of the GMA series should be a welcome feature to OEM buyers. The wireform chassis construction method was selected because of its high strength-to-weight ratio, its openness, and the ease with which it can be modified. Cables can easily be threaded throughout the unit and card cage; additional modules can be added with little trouble.

The choice of vertical or horizontal display orientation is offered at no additional cost. Rackmounting is easily achieved.

The low voltage power supply module includes easy line voltage selection, fusing, appropriate heat sinks and a cable to distribute power to the circuit module. However, a line cord is not provided as

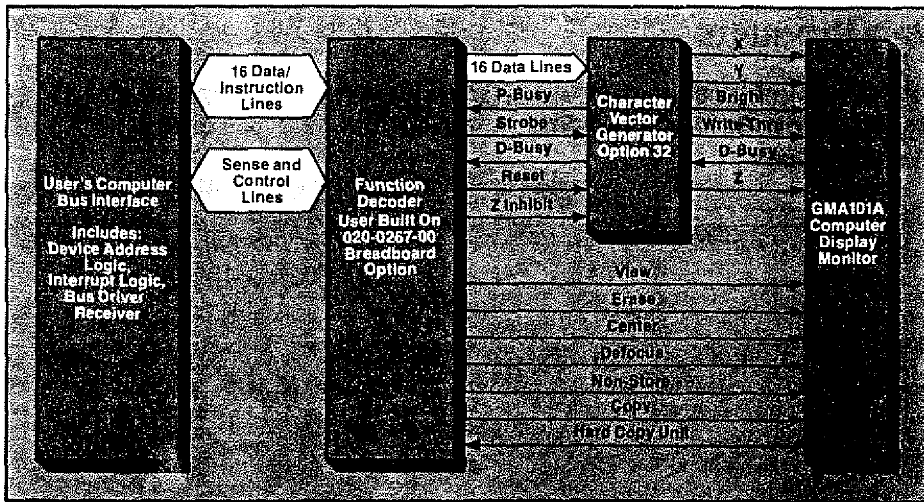


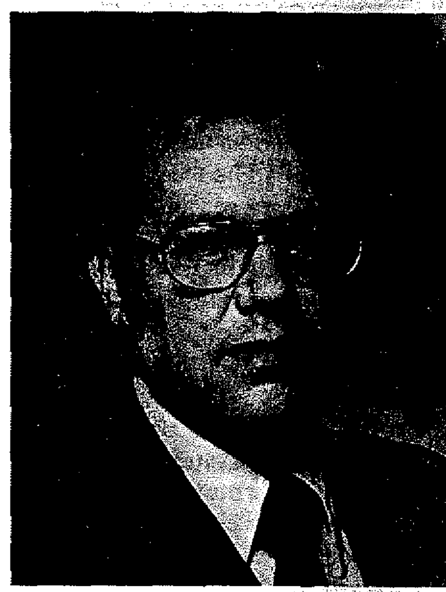
Fig. 4. Example of the GMA101A interfacing for use as a Graphic Work Station. Function Decoder is built by the user.

OEMs desire the flexibility of connecting the unit directly into their console power distribution units.

The circuit module provides an interconnect board with room for six plug-in circuit boards. Enclosed in a card cage, it offers easy performance modification and convenient access to components for service. The additional plug-in slots provide space for further product development by either the OEM or Tektronix. Besides the performance options already mentioned, this space could be used for a serial ASCII interface board, a keyboard interface, a microprocessor controller with local refresh memory, or a custom vector generator.

Graphics solutions for today and tomorrow

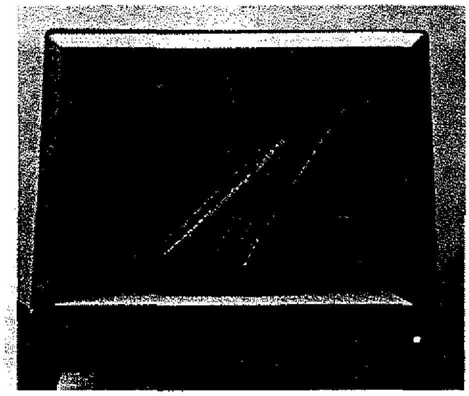
Tektronix has led the graphics display market for almost ten years in the development of low cost, high performance graphic display systems. With the development of store-refresh in the GMA series and a solid commitment to the OEM buyer, we believe that DVST technology will have a growing impact on the graphics display market for many years to come.



Dick Epler has been working in Marketing Product Development since coming with Tek in early '76. He has several years of marketing and sales experience in the computer field and five years as Instrument Research Engineer with Batelle Northwest. He received his B.S.E.E. '63 from Washington State University.

New Products

Finite Element Modeling System Reduces Model Building Time and Cost

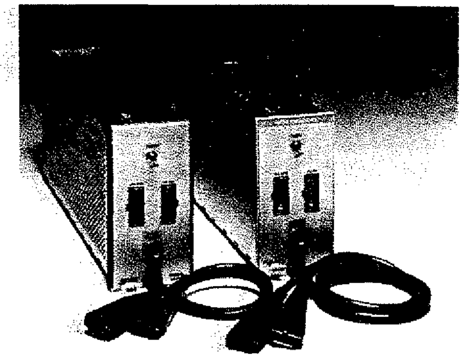


The TEKTRONIX FEM181 Finite Element Modeling System is designed to reduce the time it takes to build models and eliminate the time-share costs usually incurred by this activity. The FEM181 operates independent of the host computer. It allows the structural analyst to create models, for example, of a wheel or motor mount, wing or turbine blade, verify its accuracy, and format the model data into a form compatible with the input requirements of the host finite element analysis system. Once the data has been formatted, it is transferred to the host computer.

The basic system consists of a 19-inch storage-refresh cathode ray tube display, a terminal keyboard, a 10 megabyte disc memory, hard copy unit, and the flexible, finite element modeling software package. The software package is designed to speed model building, provide the analyst with a variety of modeling options, and make the system easy to learn.

For further information on the FEM181, use the inquiry card accompanying this issue.

DL2 and DL 502 Digital Latches

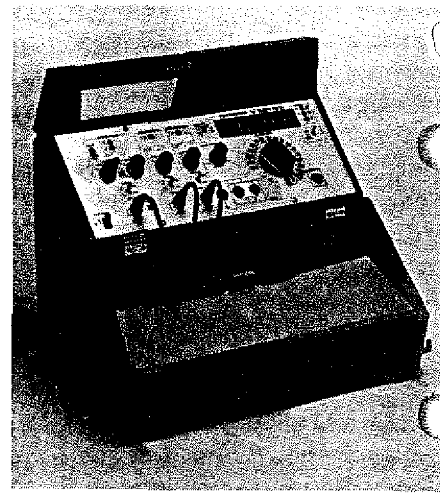


Digital latching capability is now available for the 7D01 and LA 501W Logic Analyzers. The TEKTRONIX DL2 and DL 502 Logic Analyzer Digital Latches are designed to detect glitches in data that cannot be captured by the logic analyzer alone. Glitches as narrow as 5 ns can be latched and expanded for easy detection.

The DL2 is designed to plug into the 7000-Series Oscilloscopes and the DL 502 plugs into a TM 500 Mainframe. The latches enable the user to asynchronously capture pulses shorter than one sample interval, and both feature 16 channel latching capability.

A Versatile, New Digital Tester

The new TEKTRONIX 851 Digital Tester is a portable, easy-to-use digital tester ideal for field service and production testing. The 851 combines many of the functions of a DMM, counter, timer, logic probe, thermometer, and an oscilloscope in a single package weighing only 13 pounds/16 kg. One knob allows you to dial 22 different functions.



Eleven functions measure timing, two register plus and minus peak voltages, three carry out DMM measurements through separate leads, and one reads line voltage at the outlet. Another function allows you to take temperature measurements with an optional temperature probe. The 851 also makes four self-measurements to correctly adjust each of its four input thresholds to the logic levels of the equipment under examination.

Altogether these functions allow you to:

- Measure system parameters.
- Check for signal activity.
- Correct synchronization problems in electro-mechanical subsystems through adjustment or repair.
- Identify boards or component parts of the system in need of replacement.

The measurement capabilities of the 851 make it particularly suitable for servicing computer peripherals, small business systems, and industrial control equipment.

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

BULK RATE
U.S. POSTAGE PAID
TEKTRONIX, INC

1195114 2545
MR F CAPELLUPO ENGR
NEW YORK TELEPHONE CO
8858 75 AVE
GLENDALE NY 11227

A Multi-Function Digital Service Instrument.

A New Concept in Data Representation: The Complete Integration of Graphics and Alphanumerics.

The Virtual Bit Map Brings High Resolution Graphics to the Alphanumerics Terminal User.

Evaluating Test Data with Computer Graphics.

Volume 10
Number 1

1978

Tekscope

Tektronix®
COMMITTED TO EXCELLENCE

Contents

Tekscope

Customer information from
Tektronix, Inc.
Beaverton, Oregon 97007

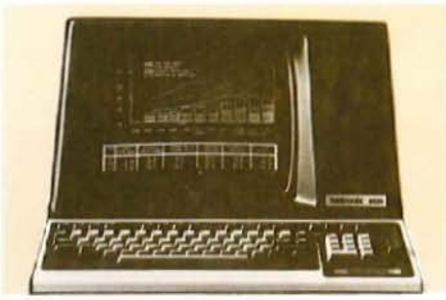
Editor: Gordon Allison

A Multi-Function Digital Service Instrument

The 851 Digital Tester, a new concept in service instruments, combines the functions of several different test instruments in one small, portable, easy-to-use package.

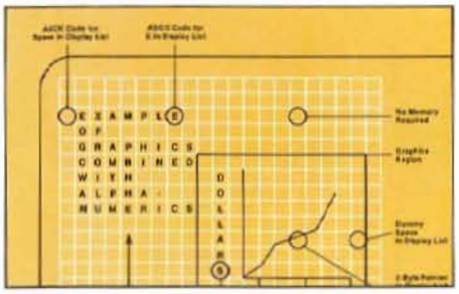
A New Concept in Data Representation: The Complete Integration of Graphics and Alphanumerics

The 4025 Computer Display Terminal brings versatile, easy-to-use graphics to the alphanumerics terminal user. From a basic alphanumerics terminal, the 4025 can be expanded to include forms ruling and extensive graphics capability.



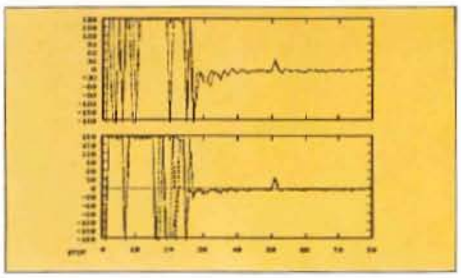
The Virtual Bit Map Brings High Resolution Graphics to the Alphanumerics Terminal User

An interesting variation in the traditional method of storing graphics data makes it possible to scroll graphics and alphanumerics together, and reduces the memory required for graphics.



Evaluating Test Data with Computer Graphics

Use of a graphic computer terminal for data previewing saves time and expense in solid-propellant rocket fuel research at Georgia Tech.

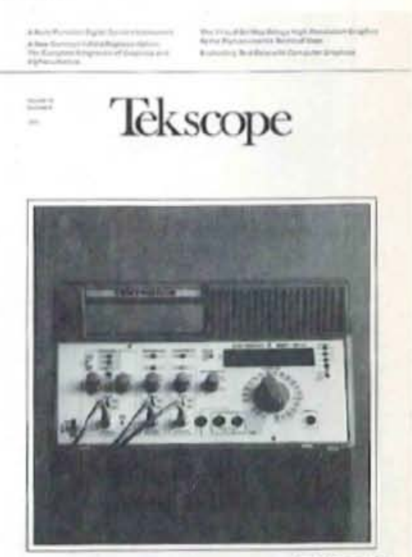


Tekscope is a bimonthly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique. A new products section gives a brief description of products recently introduced and provides an opportunity to request further information.

To better serve customers who maintain their TEKTRONIX instruments, the service information formerly appearing in Tekscope will be expanded and published in a publication dedicated to the service function.

Cover

The simple, uncluttered front panel of the 851 Digital Tester belies the wide-ranging measurement capability contained in this small, portable package.



A Multi-Function Digital Service Instrument

Dave Allen started his career with Tek in 1968 after completing his B.S.E.E. at Brigham Young University. He has been project leader for all of the 200-Series hand-held miniscopes which include single and dual trace instruments, bandwidths from 500 kHz to 5 MHz, bistable storage, and one which contains both a DMM and miniscope in one unit. All operate from internal batteries.

Dave was project manager for the 851 Digital Tester program.

The digital products population is exploding. And how to effectively service these products is of prime concern to both suppliers and users.

A substantial share of service activity in digital systems is devoted to maintaining and adjusting electromechanical devices as well as troubleshooting computer peripherals, point-of-sale terminals, microprocessor systems, and other subsystems. This calls for the use of several types of instruments — oscilloscopes, counters, digital multimeters, logic probes, and usually some specialized instruments.

The TEKTRONIX 851 Digital Tester, a new concept in service instruments, was developed to meet such a need — increasing the customer service engineer's effectiveness and efficiency in performing routine preventative maintenance, non-routine alignment and adjustment, and troubleshooting.

The major design goal was to incorporate the needed measurement capability in a lightweight portable package that would be easy to carry, easy to use, and highly reliable. Easy to use dictated that front panel controls be kept to a minimum, and that they be easy to understand and operate. It was decided that every measurement should be converted to an unambiguous numerical readout that would enable the operator to quickly determine normal or faulty operation right down to the component level.

Considerable effort was put into human engineering to tailor the 851 to the varied work environments encountered by the customer service engineer. The sloped-front-panel design was chosen to yield a large front-panel area providing an uncluttered appearance and easy access to controls. It makes the unit convenient to use whether it's sitting on the floor, the workbench, or atop a computer cabinet. A further advantage is that storage space can be provided for probes and accessories without adding to the overall dimensions of the unit.

There are very few controls on the front panel, the most prominent being the FUNCTION switch. With this single control, twenty-two functions can be selected — eleven measure timing, two measure plus and minus peak voltages, three perform DMM measurements, and one reads line voltage supplied to the 851. Four positions measure threshold voltages on the three counter probes, and the final position measures temperature using an optional temperature probe. There are three sets of probes that are used with the 851 — three counter probes for channels A, B, and C, two DMM probes, and the optional temperature probe. Except for the DMM and temperature measurements, most measurements are made using Channel A. Channels B and C are used for some timing functions, and the gating of Channel A signals.

Operation is greatly simplified by the color coded FUNCTION switch, channel control areas, and probes. The colored bands on the FUNCTION switch correspond to the colored bands on the probe, or probes, to be used for a particular function. You will note that for some of the timing functions all three probes are used.

There is a minimum number of controls for each channel — just a SLOPE switch and THRESHOLD control. There are no attenuator, gain, or coupling controls to worry about. Since some measurements require sensing both HI and LO levels, Channel A is provided with two THRESHOLD controls. The two

Fig. 1 The sloping front panel of the 851 provides good visibility and easy access to controls whether the unit is sitting on the floor, the workbench, or atop a computer cabinet as in this photo.

thresholds can be made to track by setting the LO threshold above the HI threshold. A front-panel light indicates when you are in this mode. The threshold levels may be set over a range of −30 to +30 volts with a resolution of 10 millivolts, by setting the FUNCTION switch to the appropriate position and reading the threshold voltage on the display. Each THRESHOLD control has a detent position present for TTL trigger levels.

Logic state indicators for each channel provide a logic probe capability for the 851. Channel A has three indicators — HI, LO, and X for signal activity in the in-between state. Channels B and C have only HI and LO indicators. Either of these two channels can serve as a logic probe while Channel A is being used for another measurement.

There is one other variable control on the front panel — the INPUT FILTER. Digital signals often contain noise generated by race conditions, ripple counters, etc. While these signals are not large enough to affect circuit operation, they could be sensed by the wideband amplifiers in the 851 and cause erroneous measurements. To prevent this, the input filter can be set to reject signals having a duration of less than 50 nanoseconds, up to as much as 300 nanoseconds. It can also be turned off to accept all signals above 14 nanoseconds. The filter operates on Channels A, B, and C.

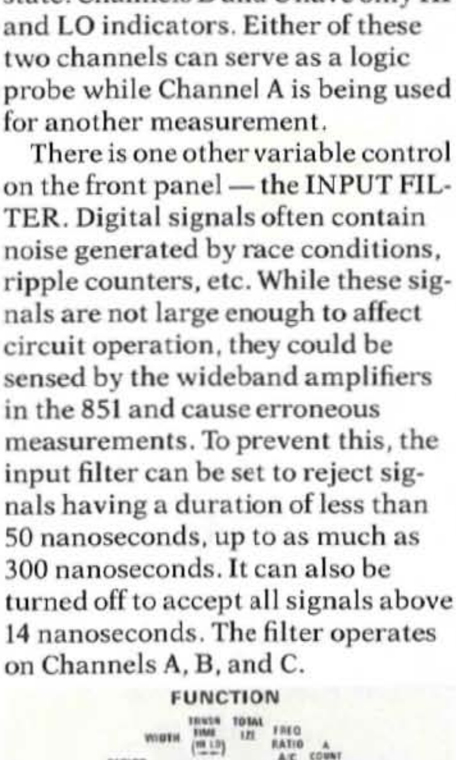


Fig. 2 The function switch allows the operator to select which one of twenty-two functions will be performed and arranges the internal circuitry to accomplish it.

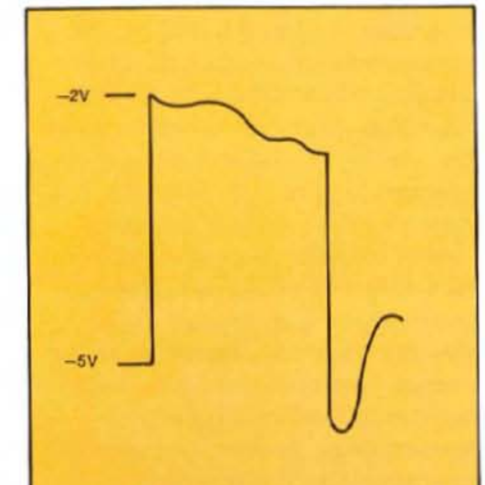


Fig. 3 The + PEAK function measures the most positive peak of the input signal. The display will show a negative number if the most positive peak happens to be a negative voltage as in this example.

In keeping with the goal of providing an unambiguous readout for all measurements, the 851 is completely autoranging. The FUNCTION switch is color coded to indicate the proper probes for the measurement and brings the necessary circuitry into play to convert the input signal to an appropriate display. The readout is a large, bright, five-digit LED display. Timing measurements use all five digits, while the DMM provides 4½ digits. The display is updated three times a second for most functions. For timing or gated functions, the display is held until a new measurement occurs; the display for any measurement may be saved indefinitely by putting the DISPLAY switch in SAVE. A CLEAR TEST position clears the display, resets the counters to zero, and gives a test reading of ±8.8.8.8.8 to verify proper operation of the readout. The autoranging function can be deactivated by placing the RANGE switch in the MNL mode. This is sometimes desirable to prevent the readout from changing ranges while making adjustments to equipment.

Self test an important feature.

The ability to quickly determine the operating condition of your test instrument can often save many wasted hours of troubleshooting. The CAL OUT signal provides such a capability for the 851. When all of the probes (except temperature) are attached to this signal, you can step through all the functions and get a unique reading for each function that assures you the the instrument is operating properly. The CAL OUT signal is dependent on the setting of the FUNCTION switch. In the + and − Peak V positions the output remains at + 8 volts for two seconds, then alternates between +8 and −4 volts at a 5 kHz rate for eight seconds. This special feature is used to compensate channel A input for accurate measurements. For the other functions the output alternates at a 5 kHz rate continuously.

A look at the functions.

With this brief overview let's take a look at the functions performed by the 851. Specifications for the 851 are shown at the close of this article so they will not be discussed in detail as we consider the individual functions.

The digital multimeter functions: dc volts, ac volts, and resistance are performed by the DMM section of the 851. The DMM inputs are fully floating and rated at ±500 volts peak. Considerable effort was expended to ensure the 851 would maintain measurement accuracy and safety specifications over the wide range of humidity and temperature expected to be encountered by a service-type instrument. Components such as precision thin film attenuators for the front end, relays for the autoranging circuitry, and Teflon IC sockets, wires, and solder cups for making connection to the circuit board were all selected to ensure conformance to the rigid specifications.

Several functions use the dual slope analog-to-digital converter in the DMM to measure the signal but do not use the DMM input probes. These include plus and minus peak voltage, percent duty factor, threshold levels, line voltage, and temperature. The + and −Peak V functions provide a direct readout of the most positive or negative peak of a repetitive signal applied to Channel A input. The positive peak does not have to be a positive voltage. For example, −3 volts may be the positive peak of a signal whose average level is −5 volts dc. The converse is true for negative peaks.

The measurement is accomplished by comparing the input signal to a dc voltage from the peak detector circuit, instead of to the voltage from the THRESHOLD control. If the input signal peak exceeds this dc level, the peak detector increases the dc voltage. Conversely, if the input peaks do not reach this dc level for a set period, the voltage is decreased. The resulting dc voltage is measured by the analog-to-digital converter portion of the DMM.

The Percent Duty Factor function averages the time the input signal is above or below the Channel A threshold setting and displays it as a percentage on the digital readout. The slope switch setting determines whether the measurement is the percentage of the time the signal is HI or the percentage of the time it is LO. Duty factor from 0 to 100% can be measured at dc and over a range from 40 Hz to 10 Mhz.

Frequency measurements are also made using Channel A. Frequencies up to 35 MHz can be measured to an accuracy of ± 0.005% of reading ±1 count.

The next three functions — Period, Width, and Transition Time are timing measurements which involve the counting of an internal 100 MHz clock. These measurements are made using Channel A only and in much the same manner as using a counter. The slope switch setting determines whether the positive or negative pulse width, or the rise or fall time is measured. Minimum measurable pulse width and transition time is 20 nanoseconds.

The Totalize function is similar to that found on other counters and is performed using Channel A. The DISPLAY switch is used to start and stop the count. The CLEAR TEST position of this switch serves as a reset, and as a test function for the display. The readout is updated 100 times a second for this function.

The functions we have discussed thus far require only the use of Channel A. The next five functions use two, and sometimes all three, channels to make the measurement.

Frequency Ratio A/C uses Channel A and C inputs. This measurement, basically, counts the number of events on Channel A that occur during the period of one event on Channel C. A typical application for this function is checking a divide-by-N counter. The measurement can be made even when a random clock is used.

The A Count (B→C) and A Transitions (B→C) functions use all three inputs, with Channels B and C used to gate the measurement of a signal on Channel A. The threshold and slope settings on Channel B define the start of the gate while those on Channel C define the termination.

The two measurements are simi-

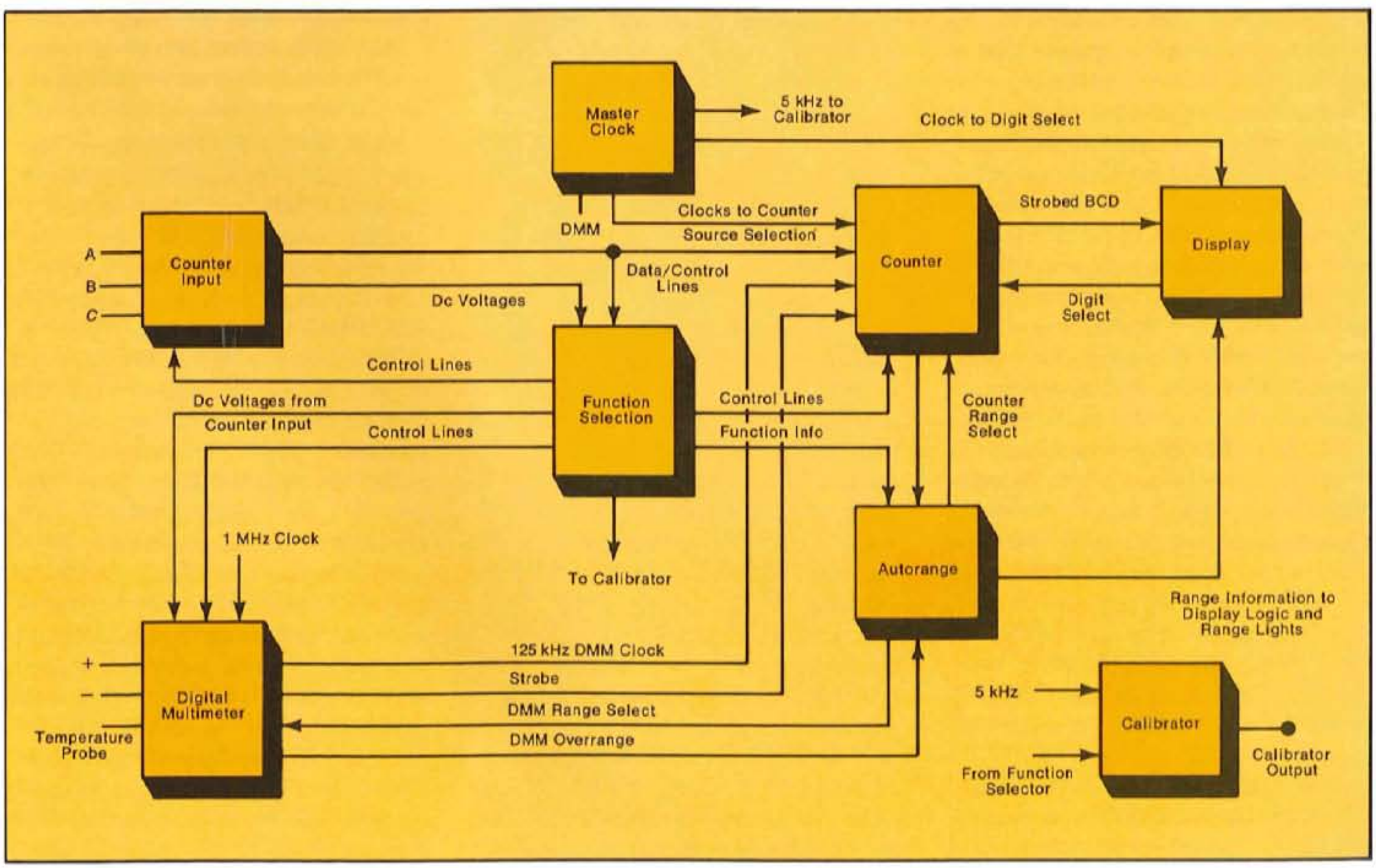


Fig. 4. A simplified block diagram of the 851.

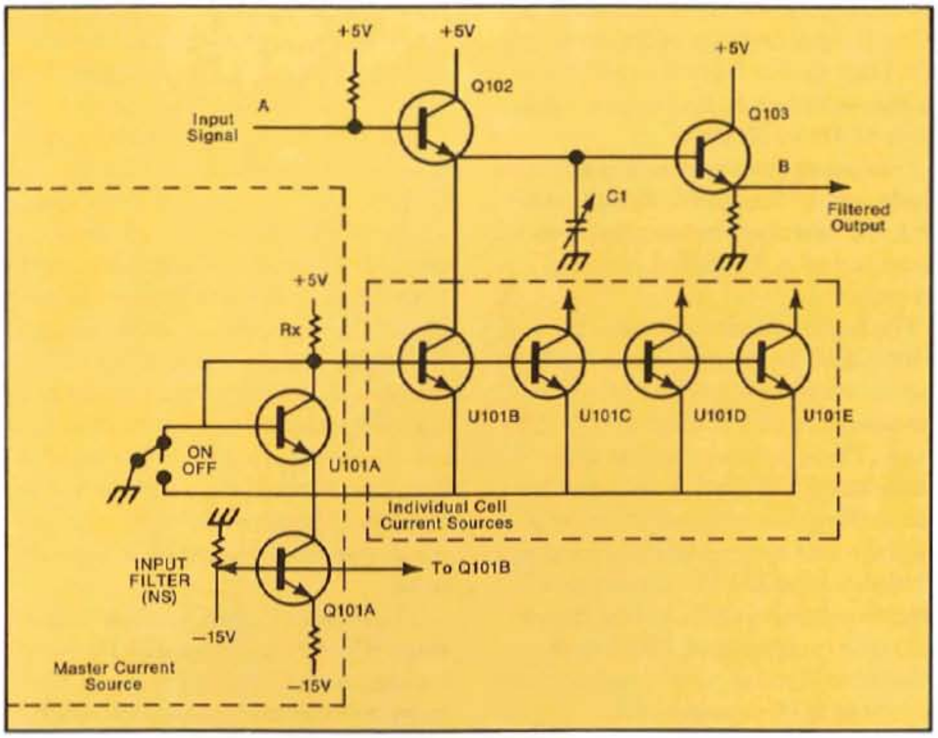


Fig. 5. Tracking of the eight filter cells is enhanced by placing individual cell current sources on a common substrate. Source current establishes discharge rate of C1 determining pulse width that is passed to point B.

lar with the exception that the transition function counts each time the A input signal traverses from LO to HI and each time it traverses from HI TO LO as determined by the Channel A threshold settings.

The transition counter can be a powerful digital troubleshooting aid with a little advance preparation. Transition counts can be taken on a known good instrument and recorded on the logic diagram. The gating points for Channels B and C are also noted. When a problem occurs, verifying the transition counts can often lead quickly to the problem area or faulty component.

The final two timing functions, Time (B→C) and Time (B•C) use Channels B and C to gate an internal clock which is counted and displayed. Time (B→C) measures the time between two events, while Time (B•C) measures the time two signals are in coincidence. Coincidence provides a quick means of making measurements of four different logic combinations: B and C, $\bar{B}$ and C, B and $\bar{C}$, and $\bar{B}$ and $\bar{C}$, simply by the appropriate choice of Channel B and C slope switch settings.

The four Threshold functions provide a convenient means of setting the individual threshold controls without the need for applying the input probes to a reference source. Each control has a detent position preset to a TTL level (0.7v for A LO, 2.1 V for A HI, and 1.4 V for B and C). The threshold voltages can be set over a range of −30 to +30 volts with a resolution of ±10 millivolts.

Line voltage fluctuations and low line voltage often cause equipment malfunctions. With the 851 powered from the same outlet as the equipment under test, the Line V function provides a quick, safe means of measuring the line voltage. An internal connection applies line voltage to the DMM circuitry for direct readout; there is no need for an external probe.

Temperature is an optional measurement capability available on the 851. This is often the fastest technique to use in locating a faulty component. It is usually a comparison type test — looking for a component that is considerably hotter than its neighbor. Surface temperatures can be measured over a range of −55° to +150°C.

The block diagram.

A simplified block diagram of the 851 is shown in Figure 4. All of the measurements made by the 851 are converted to digital information and displayed on the 5-digit readout.

The Counter Input accepts signals from the Channel A, B, and C inputs. Depending on the function selected, the Counter Input supplies pulses to the Counter, gates the Counter while it counts internal clock pulses, or supplies dc voltages to the digital multimeter (DMM) for conversion to digital information. The DMM uses a conventional dual slope conversion technique.

Autoranging, an important feature of the 851, operates on all of the functions. It automatically selects one of eight possible operating ranges. Not all ranges are permitted for each function. Maximum and minimum range logic prevents automatic change to an illegal range. When switching from one function to another the range selected for the previous function may be illegal for the new function. An illegal state logic circuit senses this condition and presets the range to one suitable for the selected function.

The Counter is a 100-MHz counter. The signal to be supplied to this counter is selected by the counter source selector logic. It may be the signal from Channel A input, the DMM clock, or some frequency up to 100 MHz from the master clock. In all functions except DMM, the maximum count displayed is 99999. In DMM functions, the count is restricted to 19999. The binary-coded-decimal (BCD) output of the counter is strobed into storage registers and thence to the display.

The display consists of five seven-segment, half-inch, LED displays and four LED range lights. A BCD to seven-segment decoder driver converts the BCD information from the storage registers to signals which drive the seven-segment display. A digit-select logic signal gates one storage register and one seven-segment display at a time so only one BCD to seven-segment decoder driver is needed. Leading zero suppression blanks leading zeros in the three left positions except for the first zero to the left of a decimal point. The display is updated three times a second for most functions and 100 times a second in Totalize.

The Master Clock oscillator is a crystal-controlled oscillator with 100 MHz output. The output is buffered and passed through a differential amplifier to shift the output from ECL to TTL levels and provide some waveshaping. One output of the differential amplifier is applied to a frequency divider string for division as needed to operate the various 851 circuits. The other output is applied to the counter source selection logic where it can pass directly to the decade counters for the timing functions.

Some unique circuitry

While many of the circuits in the 851 are typical of technology in common use today, there were some unique problems to be solved. The input filter is a good example.

Each input channel requires two input filter cells — one for positive going pulses and one for negative-going. (Channel A has an extra set of filter cells to accommodate the additional logic light function.) This means we need eight individual filter cells, all controlled from one front-panel control. The problem was how to get all eight filter cells to track.

The filter is a pulse-width, not a bandpass type filter. Basically, all eight individual cells are controlled by two adjustable current sources (one for each group of four cells). A current source and typical filter cell are shown in Figure 5. When the filter is turned on, current is supplied by Q101A, U101A, and U101B to Q102, establishing a charge on C1 that sets the output level at point B. Point B drives an output flip-flop. When the input signal at point A goes HI, Q102 turns on harder rapidly charging C1. The output at point B naturally follows. When input A steps LO, C1 starts to discharge at a rate established by the current supplied by the current source. Now if input A steps HI again before point B goes low enough to trigger the output flip-flop, the negative going pulse appearing at the input will be ignored.

Since the current source is the key to determining the pulse width to be passed, the solution to getting the filter cells to track lay in supplying equal currents to each cell. This is achieved by placing the two master current source transistors, Q101A and Q101B, on a common substrate. The individual cell current sources are placed on two substrates containing five transistors each. The current in U101A will be mirrored in U101B, C, D, and E providing the same current to each of four cells. The capacitor, C1, is variable to compensate for small differences in currents and stray capacitances.

With the filter on and maximum "on" current being supplied from the master current source, the filter will pass pulses 50 ns or longer in duration, shorter duration pulses are filtered out. With the filter turned off, the emitters of the matched current sources U101A, B, C, D, and E are grounded and the source current is determined by the value of Rx. This current is much larger than was supplied by Q101A and enables C1 to discharge fast enough to pass all pulses delivered to the filter. With the filter off, at high current, the stored charge of Q102's, base-to-emmiter junction helps speed up the discharge of C1 enabling very short pulses to be passed to point B.

The Peak Voltage detector circuitry in the 851 is of interest in that it does not use the conventional sample and hold approach; it requires a repetitive signal of 40 Hz or more. The circuit will respond to peak signals of 25 nanoseconds or longer. This requires the detector to respond rapidly to changes, and yet maintain the input level if no changes are occurring.

In Peak functions, the output of the input comparator goes to a Tek-developed hybrid circuit that stretches the input signal to about 50 microseconds. The output of the stretcher charges a capacitor in small steps each time a signal is sensed, with the resultant dc voltage fed back to the inverting input of the input comparator. The feedback voltage will increase until it is higher than the peak of the signal, then no further increase will occur.

If the comparator input signal does not cross the inverted input level within 25 milliseconds, the capacitor is discharged rapidly via a timing circuit, pulling down the feedback voltage until the hybrid stretching circuit receives a signal. The feedback voltage will then be equal to the input voltage peaks. The dc level fed to the inverting input is filtered and routed to the DMM for conversion to a digital readout of the peak measurement.

Safety and reliability.

Much of the 851 design effort revolved around keeping power usage low to eliminate the need for a fan, and keeping reliability high. The majority of integrated circuits in the 851 are pretested and then soldered in. Extra space is provided for the DMM positions of the FUNCTION switch to prevent arc-over from high voltage inputs to sensitive circuitry. We have already discussed some of the steps taken to ensure meeting specifications over a wide range of temperature and humidity.

The DMM input and probe connectors are designed for maximum operator safety. Extra protection has been employed to prevent coming in contact with the signal voltage even when the probe is removed from the instrument while still attached to the circuit under test. The unique connectors for the counter probes also assure the probes will remain with the 851 instead of being borrowed for another instrument.

Summary

The 851 was designed to provide the customer engineer with a multi-function test instrument that would be easy to use, highly portable, highly reliable, and enable him to complete his service function on the first call in most instances. That's a big order. We're confident the 851 is equal to the task.

851 Specifications

Electrical

Inputs
(ACV, DCV, Ω)

Resistance and Capacitance — 10 MΩ ±1% and approx 100 pF. Red to black terminal. (Volts only)

Max Safe Input Voltage (≤1 kHz) —

±500 V (peak) red terminal to ground.

±500 V (peak) black terminal to ground.

±500 V (peak) red to black terminal.

±250 V (peak) red to black terminal in Ω function.

Resistance
Ranges — 200 Ω, 2 kΩ, 20 kΩ, 200 kΩ, 2 MΩ, 20 MΩ, and 50 MΩ.

Accuracy —
200 Ω, 2 kΩ, 20 kΩ, 200 kΩ: ±0.3% of reading ±4 counts (plus probe resistance).

2 MΩ: ±0.5% of reading ±4 counts.

20 MΩ: ±5% of reading ±10 counts.

50 MΩ: ±10% of reading ±20 counts.

Extended temperature range: add 0.2% on 200 Ω through 2 MΩ and 5% on 20 MΩ and 50 MΩ ranges.

AC Volts
(Average responding RMS calibrated for sine wave.)

Ranges — 2 V, 20 V, 200 V, and 350 V.

Accuracy —
2 V and 20 V:
±0.5% or reading ±4 counts, 40 Hz to 1 kHz.
±2% of reading ±4 counts, 1 kHz to 25 kHz.
>9% full scale.

200 V and 350 V:
±0.5% of reading ±4 counts, 40 Hz to 1 kHz.
Extended temperature range: add ±0.2%.

DC Volts
Ranges — 2 V, 20 V, 200 V, and 500 V.

Accuracy —
2 V, 20 V and 200 V: ±0.1% of reading ±3 counts.
500 V: ±0.15% of reading ±3 counts.
Extended temperature range: add ±0.05%.

Normal-Mode Rejection Ratio
(Dc volts) — ≥60 dB at 50 to 60 Hz. For peak amplitude ≤5X full scale.

Common-Mode Rejection Ratio
(Ac and Dc volts) — ≥80 dB at dc; ≥60 dB at 50 to 60 Hz; ≥52 dB on 350 V.

Line Voltage
Range — 90 to 132 V and 180 to 250 V.

Accuracy — ±3% of reading.

Temperature
Range — −55° to +150°C.

Accuracy — ±2°C (0.01° resolution). Extended temperature range: add ±1°C.

Inputs
(3 probes; one for each channel A, B, C.)

Resistance and Capacitance — 10 MΩ and approx 12 pF.

Max safe input voltage — ±500 V at probe tip (≤50 kHz)

Threshold Levels
Variable (4 controls) range: ±30 V; settability ±10 mV.

Threshold Error — (Max difference between a displayed threshold voltage or TTL threshold voltage and the actual signal voltage at threshold crossing.) A Input (HI and LO THRESHOLDS): ±100 mV ±2% of threshold voltage ±3% of the signal voltage (p-p) for pulses at least 14 ns wide at the threshold. B and C inputs: ±100 mV ±2% of threshold voltage ±8% of the signal voltage (p-p) for pulses at least 14 ns wide at the threshold.

Extended temperature ranges: add ±20 mV ±2% of signal voltage (p-p).

TTL (nominal, in detent position) — Input A LO + 0.7 V; HI + 2.1 V; Input B and C + 1.4 V.

Input Filter
(Narrow pulse rejection) max input rep rate for pulse rejection = 20 MHz.

Range — off and 50 ns ±20% to >300 ns.
Channel to channel delay mismatch: <100% of setting.

+, − Peak Volts
Range — ±30 V.

Accuracy — ±2% of reading ±3% of p-p signal ±90 mV. Max time between recurrent peaks, 25 ms. Peak amplitude must be maintained for at least 25 ns. Extended temperature range: add ±1% of reading ±1% of p-p signal ±10 mV.

Frequency
Ranges — 100 kHz (1 Hz resolution), 1 MHz, 10 MHz, and 35 MHz.

Accuracy — ±0.005% of reading ±1 count.

Time Measurements
(Period, pulse width, transition time, time interval, and coincidence time.)

Ranges — 1 ms (10 ns resolution), 10 ms, 100 ms, 1 s, and 10 s.

Minimum Time Interval — 20 ns.

Accuracy — ±0.005% of reading ±1 count ± Trigger Error.

Trigger Error —

$$\pm\frac{\text{Threshold Error}_1}{dv/dt \text{ of signal}_2 \text{ at time start threshold}}$$

$$\pm\frac{\text{Threshold Error}_1}{dv/dt \text{ of signal}_2 \text{ at time stop threshold}}$$

± Input filter setting

Counting
(Totalize, frequency ratio, events count, and transitions count.)

Range — 0 to 99,999

Max Input Frequency — 35 MHz (except 17.5 MHz for transition counting).

Accuracy — ±1 count, ±A Input event or transition frequency multiplied by the Time Interval Trigger Error3.

Duty Factor
Range — 0 to 100%

Input Freq Range — 40 Hz to 10 MHz.

Min pulse width (HI and LO portions) — 50 ns.

Accuracy —

$$\pm 3\% \pm \frac{\text{Trigger Error}_3 \times 100}{\text{Pulse Period}}\%$$

$$\pm\frac{300 \text{ ns}}{\text{Pulse Width}}\%$$

Mechanical

Dimensions (approx)	cm	in
Width	33	13
Height	31	12
Depth	18	7
Weight	**kg**	**lb**
Net	6	13

Power Requirements

Line Voltage Range — 90 to 132 V or 180 to 250 V.

Frequency — 48 Hz to 440 Hz.

Power Consumption — 57 watts max.

Environmental Capabilities

Ambient Temperature — Operating: +15°C to +40°C. Nonoperating: −40°C to +75°C. Extended operating range: +5°C to +50°C.

Altitude — Operating: to 10,000 ft. Nonoperating: to 35,000 ft.

Vibration — Operating: 15 minutes along each of the 3 major axes, .06 cm (0.025 in) p-p displacement (4 g's at 55 Hz) 10 to 55 to 10 Hz in 1 minute cycles. After cycle vibration in each axis, hold frequency steady at 55 Hz for 10 minutes. All major resonances must be above 55 Hz.

Humidity — To 90% at 30°C Tektronix Test Method #1 90% relative humidity at 30°C for 4 hours.

Shock — Two shocks at 30 g's, ½ sine, 11 ms duration, each direction along each major axis. Total of 12 shocks.

EMI — Reference Mil Standard 461A-462 susceptibility as specified. Conducted emission, relax 10 dB. Radiated emission, relax 15 dB <100 MHz and relax 25 dB ≥100 MHz.

1See Threshold Error under Threshold Levels.

2Refer to the appropriate input (CH A, CH B, or CH C) for the measurement being made.

3See Trigger Error under Time Measurements.

Display

Readout
Type — 5 digits, fully buffered, 7 segment, 0.5" LEDs.

Polarity Indication — + for positive readings, − for negative readings.

Overrange Indication — Display flashes.

UP Ranging — Up ranging occurs at 100% of display range.

Down Ranging — Down ranging occurs at 9% of volts and ohms ranges, and 8% of time and frequency.

Range Indicators — LEDs show function ranges in Ω, kΩ, MΩ, MHz, kHz, ms, μs and V.

Logic State Indicators — Red, yellow, and green LEDs show valid and invalid logic state inputs for CH A. Red and green LEDs show logic states above or below the threshold set for CH B and C. Any state change indication is sustained long enough to be visible.

Threshold Lock Indicator (LO > HI) — Red LED indicates when CH A LO and HI thresholds are locked together (LO threshold setting is higher than the HI setting).

INCLUDED ACCESSORIES

Three signal probes (010-0280-00), two DMM probes (012-0732-00).

A New Concept in Data Representation: The Complete Integration of Graphics and Alphanumerics

Jack Liskear is Product Marketing Manager for the 4020 Series. During most of his ten years at Tek he served in various sales and service capacities with Tektronix, Ltd. in Australia. Returning to the U.S. he spent a year in the International Sales Office before joining the Information Display Group in his present capacity.

The use of computer graphics is nothing new to engineers, scientists and educators. For years they have been using graphics display terminals and computer controlled plotters for such applications as displaying three-dimensional structural models, drawing graphs of statistical functions, or illustrating the various concentrations of minerals in a soil sample.

Now with the increasing emphasis on analysis, planning, and data display in all corners of the business, educational, and governmental community, a whole new group of computer graphics users is emerging.

A new way of selling a concept

A few years ago, for example, the president of a large national bank came up with an innovative application for computer graphics. One of his responsibilities was to meet with prospective clients — people who were thinking of using the investment and trust services of the bank. After a few minutes of bantering dollar amounts and percentages about with these potential customers, however, he noticed that their interest would often begin to wain. He considered this problem and decided that the bank must find a more dramatic, easy-to-understand manner of presenting their banking and investment concepts.

On the advice of the head systems analyst at the bank, he authorized the purchase of a TEKTRONIX graphics display terminal and put a programmer to work writing a set of programs to display investment data.

A few days after the system was complete, the bank president was again asked to meet with a potential investor. This time instead of telling the bank's story, he and the prospective client sat down at the terminal together and he showed him the story. He first drew graphs on the display screen of various national financial statistics such as the GNP, inflation rate, and Dow Jones averages over the past 10 years. Then he displayed graphs of the financial activity of his bank over this same time period — assets, sales, earnings per share.

Next he turned the keyboard over to one of the bank's investment counselors. He showed the potential customer a variety of investment plans that the bank could undertake for him, and graphs of the probable rate of return on his investment for each. At the same time, the investment counselor made copies of the graphs of each of these plans with a TEKTRONIX hard copy unit.

The result? The investor was delighted with the presentation and the bank got a new customer.

A picture makes all the numbers clear

Tektronix' graphic display terminal solved this bank president's problem for one basic reason. Graphic displays are much easier to interpret than lists of numbers. They show us immediately the trends, cycles, peaks and valleys. They allow us to quickly comprehend the situation, project into the future, and make decisions with confidence. They help us illustrate to others what we are doing, what we can do for them, or why a particular course of action is the best one.

Though the power of a graph or chart to quickly and clearly communicate information is well recognized, computer users in the past have shown more interest in the output of alphanumeric data from a computer, than in the computer's ability to create a graph of that data. When a graph was needed, they generally resorted to a pencil and a pad of graph paper.

But now, as the sizes of data bases and models are increasing, and the time frames for decision making are decreasing, financial analysts, business operations managers, and economists, as well as engineers and scientists, are beginning to look for quicker, more efficient tools for representing data.

An alphanumerics terminal or a graphics terminal?

To satisfy this growing demand for a

fast, cost-effective method of producing graphs and charts of data, Tektronix developed the 4025 Computer Display Terminal — a completely new concept in data representation. The 4025 is a raster scan (video) display terminal that provides all the features of a high performance alphanumerics terminal such as data entry, editing, and forms fillout, and also provides the ability to translate data quickly and clearly into graph or chart form. It is really two terminals — a graphics and an alphanumeric terminal — in one. It's a gralpha terminal.

The 4025 is the first terminal with graphing capability designed specifically for the alphanumerics terminal user. It gives terminal users who are primarily interested in entering and manipulating words and numbers the added capability of displaying that information in easy-to-interpret graphs and charts. It answers the question, "How do I justify the expense of a graphics terminal that gives me graphs quickly and efficiently, but that I'll use only 20% of the time?" The answer is that the other 80% of the time the terminal can be used for data entry, editing, forms fill out, or on-line inquiry, just as is done with the strictly alphanumerics terminals available today.

The cost effectiveness of the gralpha terminal concept is further enhanced by making the 4025 upwards expandable. Form fill out and graphing are offered as options to the 4025. They can be added to the basic terminal at any time.

Part of a growing family

The 4025 Computer Display Terminal is part of the new 4020-Series of raster scan terminals developed by Tektronix. The series also includes the 4024, an alphanumerics-only version of the 4025. The 4024 is provided for use in multiple terminal configurations, where graphics is not required at each work station.

Both of these terminals are microprocessor based systems, intended for use as an interface between a user and a computer. The keyboard is connected to the display unit by a thin flexible cable. The display unit contains the communications interface and possibly one or more optional peripheral interfaces, as well as the display electronics. Both the 4024 and 4025 provide full alphanumeric capability.

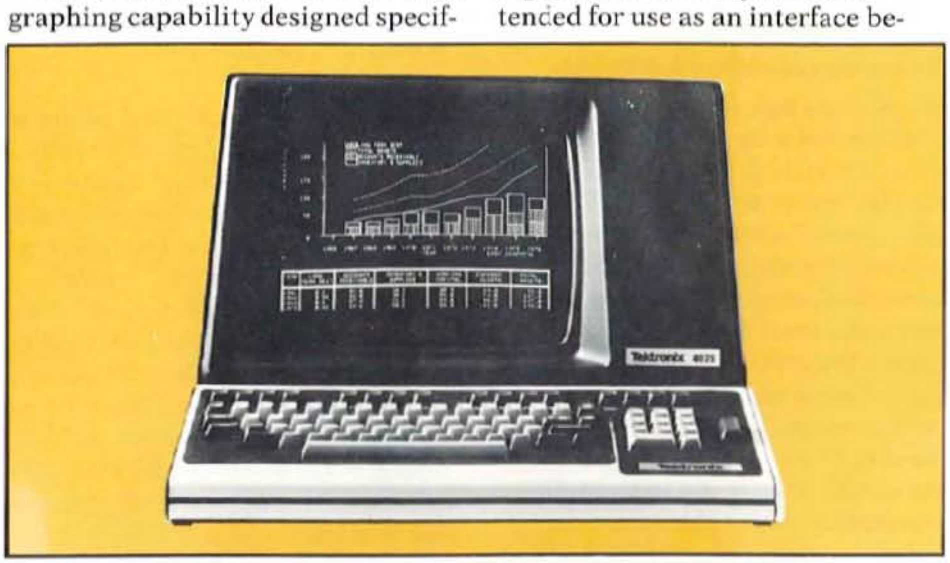


Fig. 1. The 4025 provides scrolling of both graphics and alphanumerics at the same time. Here both data and a graph of the data are viewed at the same time.

The bright, 11-inch diagonal video display provides the standard 80 characters across and an unmatched 34 lines deep, instead of the more common 24 lines. The 3 to 4, vertical to horizontal, ratio of the display area of the screen provides the ideal proportion for creating useful, attractive displays of any combination of graphics and alphanumerics. A P39 phosphor is used on the display screen. Its green shade reduces fatigue from many hours of viewing. Its relatively long persistence reduces flicker.

The keyboard features a standard office typewriter layout rather than the ASCII configuration. This layout was selected because it is more familiar to typists and other nonprogrammers. Also included on the keyboard is a numeric pad and 16 user definable keys. Four of these user definable keys are preprogrammed to provide the standard keyboard editing features — line delete, character delete, line insert, and character insert — at the touch of a finger.

Forms fillout for fast, accurate data entry

Forms fillout can be added to either the 4024 or the 4025 with the forms ruling option. Forms fillout is a feature found on alphanumeric terminals (see Fig. 3), which allows the user to divide the display screen into specific areas called fields. A field is described by its location, length, visual attributes, and logical attributes, and may consist of at most one line. The fields are set off with ruling lines and alphanumeric labels. A programmer generally constructs a form locally and stores it in the host. The terminal operator then recalls the form from the computer with a command typed on the keyboard. With the form displayed, the operator can enter data or tables quickly and efficiently merely by tabbing through the form. Virtually any source document can be recreated with this forms ruling package.

A complete selection of visual and logical attributes is included in the forms ruling package to allow portions of the screen to be highlighted or protected. The visual attributes include enhanced, blank, and blinking fields on the 4024, and on the 4025, inverted and underlined fields. Logical attributes include protected, modified, alphanumeric, and numeric only.

Easy graphing

The central theme in the design of the 4025 is to make it easy for the user to display graphics and alphanumerics. All the hardware and software has been designed with this concept in mind. To fully understand how this concept has been implemented, the performance of the 4025 can be divided into three functions: basic graphics, report generation, and hard copy.

For graphing purposes, the 4025 display screen is divided into 640 by 480 addressable points, providing a resolution of 71 addressable points per linear inch (28 points per centimeter). This resolution is more than sufficient for creating clear, precise line graphs, bar graphs, and pie charts.

To aid in making graphs, Tektronix provides its PLOT 10 Easy Graphing software package. This interactive package is highly user oriented, allowing even a novice terminal operator to generate complex graphs and charts with a minimum amount of training. Given a set of data, it is possible with this software package to generate a graph in a few seconds after answering only a few simple questions. Axes can be scaled in any units and increments. Graphs can be made up of solid and a variety of weighted and textured lines. Variable shading and textures are also available for bar charts. Pie charts can be drawn with one section of the chart pulled out.

A versatile report generation terminal

The 4025 is the first computer display terminal to truly integrate graphics and alphanumeric capability into one mainframe. It provides the ability to create a display that combines graphs and charts with alphanumeric text and tables, and further, to scroll the graphics and alphanumerics together.[1]

The concept of scrolling is probably more familiar to users of alphanumerics terminals. It is the ability to review page after page of alphanumeric information as if it were on a scroll or roller. Most alphanumeric terminals that offer graphics can scroll alphanumerics only. When graphic information is

Fig. 2. The keyboard features a standard office typewriter layout plus a numeric pad and sixteen user-definable keys. In the LEARN mode, virtually every key can be programmed for another character or character string.

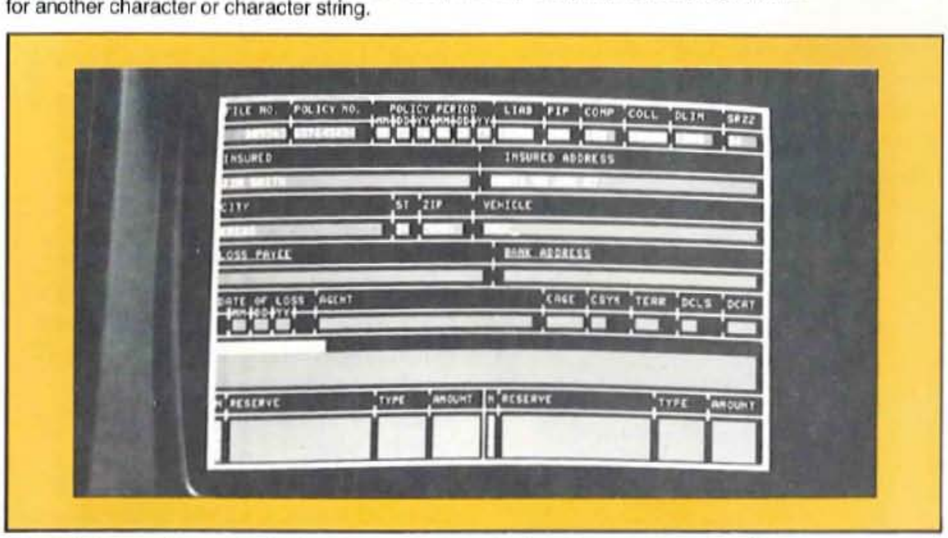


Fig. 3. A forms ruling option for the 4025 makes it a simple task to re-create virtually any source document.

displayed on such a system, it is on the screen in its set area all the time. If alphanumeric information is scrolled while graphic information is on the screen, the characters are written over the graph. The 4025 is the only terminal on the market to offer scrolling of both alphanumeric and graphics.

An example of the convenience of being able to scroll both alphanumerics and graphics is in the display of financial data. The graph of a particular function can be kept off screen and continually updated, while the user is filling out forms on the top part of the screen. When the user wishes to look at the graph, he merely scrolls it onto the screen.

Two or more graphs can be displayed on the 4025 screen at the same time, or a report can be created that provides a number of pages of text and graphs combined. This feature is ideal for working with large bodies of text and graphics together. In this case the terminal user can define a different alphanumerics and graphics area for each page, fill in the words and graphs, then scroll through the various pages of data. Such reports are not only informative but also very attractive.

The size of the 4025 memory is the only limit to the number of graphs, charts, or text characters that can be displayed on the screen and stored in memory for later scrolling on screen. Both the 4024 and the 4025 offer a minimum of 4k of memory, expandable to 32k. With an average of 20 characters per line, up to 30 pages of alphanumerics and graphs can be stored in the full 32k memory.

Permanent hard copies

When its time to save or distribute a graph or report, a number of Tek-developed copy and graphic display peripherals, which can be connected to the 4025 through the peripheral interface, are available.

The 4631 Hard Copy Unit, for example, duplicates on-screen and buffered displays of alphanumerics and graphics — up to 53 lines by 80 characters on an 8½ by 11 inch piece of paper. TEKTRONIX Hard Copy Units are dry copiers, as opposed to a line printer or plotter. The 4631 produces a clear, sharp copy of the 4024 or 4025 screen in a matter of seconds. The ability to copy both alphanumerics and graphics makes these copies very useful for distribution to customers and management or to keep for records.

For detailed camera-ready graphics and alphanumeric output — in 9 colors — the 4662 Interactive Digital Plotter can be selected. It produces ink copies of both graphics and alphanumerics. Copies up to 11 by 17 inches can be made on paper or film for use in an overhead projector. You can view and edit information with the 4025, then when it is corrected, plot it with the 4662.

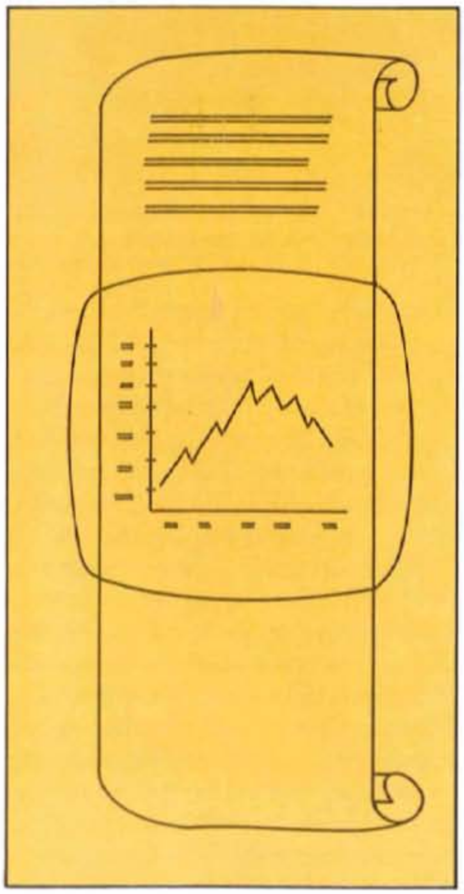


Fig. 4. The concept of scrolling is presented in this artist's sketch showing graphics on-screen with data off-screen available for instant viewing.

The 4642 Printer is also available for copying alphanumerics output only. It is designed for use with either the 4024 or the 4025.

For large presentations, the 4024 and 4025 can be connected directly to a video monitor or large screen video projector.

Direct interfacing

All the standard type of interfacing, such as RS-232C and current loop, are available for the 4020-Series terminals. Both the 4024 and the 4025 are easy to interface to any computer, because they use English-formatted command sequences. In an effort to get away from escape sequences, which are not recognized by all host computers, each command is represented by an English-language ASCII string.

A polling interface and polling controller are also available that allows one 4025 and up to seven additional 4024s and 4025s in any combination to be polled by the host computer. The polling controller is housed in the first 4025, so at least one 4025, is required to operate the polling network.

The first polling controller offered for use with the 4020-Series terminals provides an interface to an IBM 370 computer. It causes the 4024s and 4025s to emulate an IBM 3270 terminal. The polling controller also includes an RS-232C peripheral interface. With this interface, a single hard copy unit or plotter can be used to copy data from any of the terminals connected to the polling controller.

Customizing the 4020-Series

A number of other features are provided that allow the 4020-Series terminals to be used for specialized applications. Using the LEARN mode, virtually every key on the keyboard — 81 keys all together — can be programmed for another character or character string, which is then inserted whenever the key is struck. This allows commonly used character strings, words, or commands to be invoked with a single key stroke.

Another useful feature is the ability to divide the display screen into two areas: the workspace and the monitor. The operator controls the total number of lines assigned to each area. 30 lines may be assigned to the workspace area, for instance, and 4 lines to the monitor area. The workspace is generally used for forms fillout, graphics, or for entering and examining alphanumeric data. The monitor space is used for special communications between the computer and the operator. It may not contain forms or graphics. When a user is entering data into a form in the workspace, for example, and the computer wishes to send the user a message, the message is sent to the monitor area. The monitor area provides a convenient method of communicating with the computer without interfering with a form or graph on the screen.

Gralpha: a concept for today and the future

Whether its business or financial management, government agencies, or the more traditional users of computer graphics — engineers, scientists, and educators — the demand for fast, efficient methods of turning alphanumeric data into easy-to-interpret graphic displays is growing at a rapid pace. With its upward expandable packaging and full performance alphanumerics and graphics, the 4020-series has met this demand and will continue to meet it well into the future.

The gralpha terminal is a cost effective concept; a cost effective solution to the problem of data representation.

[1] See the article on page 13 of this issue of Tekscope for more information on the ability of the 4025 to scroll graphics.

The Virtual Bit Map Brings High Resolution Graphics To the Alphanumerics Terminal User

Stan Davis has been involved with computer terminal design since coming with Tektronix in 1968. He worked on the keyboard and other circuits for the T4002, was project engineer on the 4023, assisted on the 4081 program, and was project leader for the 4025 program. He gave a paper on the virtual bit memory map at MiniMicro in Anaheim in December. Stan received his BSEE and BA from Rutgers University in 1964 and an MBA from University of Portland in 1975.

In the past, computer display terminals have, in general, been designed either for graphics — graphs, charts, three-dimensional models, maps, etc. — or alphanumerics — data entry, text editing, forms fill-out and on-line inquiry. Now with low cost video chips, microprocessors, and the declining cost of memory, it is possible to produce a low-cost, raster-scan (video) terminal that combines the two functions in one low cost package. This new category of terminal is called a gralpha terminal.[1]

In designing Tektronix' version of the gralpha terminal — the 4025 Computer Display Terminal — we had two design criteria. We wanted to offer the user as much flexibility as possible in creating combined displays of graphics and alphanumerics. For example, we wanted to be able to place graphics anywhere on the display screen and to be able to scroll both graphics and alphanumerics. The second criteria was to be able to handle almost all conceivable graphing needs with a moderate amount of graphics memory. These needs included both the ability to create complex graphs, and the ability to store a number of graphs in the graphics memory at one time. Such a terminal could be used for graphic analysis and data display as well as for generating reports that combine alphanumeric text and graphics.

Bit map graphics

Meeting these criteria called for an interesting variation in the traditional method of storing graphics. Most raster-scan terminals that offer graphing capability use a bit map for storing the graphics data. With a bit map, one bit in the graphics memory is assigned to each addressable point on the display screen — one bit for each dot. The graphics memory is then scanned one row of dots at a time to create the graphics display. The scanning is done with a simple counter. No display list or pointers are used.

To combine alphanumerics with the graphics display, a separate alphanumerics generation system is provided. Some sort of mixing technique is then used to combine the graphics with the alphanumerics. A video mixer is one example.

The most significant drawback of the bit map method of storing graphics is that the graphics can not be scrolled. The display window of the bit map is defined as the boundaries of the display screen, and can not be moved. Another limitation is that a bit map memory is a very inefficient way of storing graphics. A large percent of the memory is used to store spaces or voids in the graphics area.

Displaying words and numbers

In order to make more efficient use of graphics memory and to allow scrolling of graphics on a raster scan terminal, a new technique for storing graphics data called a virtual bit map was developed.

To better understand the virtual bit mapping technique, it is helpful to understand how a raster scan terminal generates alphanumeric characters (see Fig. 2). The display screen is divided into alphanumeric cells which are 14 dots high by 8 dots wide. 80 of these alphanumeric cells fit together side by side to form a row of characters. With the 4025, up to 34 rows of alphanumeric cells can be displayed at one time on the display screen. A dot is equivalent to the width of one raster line, so that it takes 14 raster scans to create one row of characters.

The 4025 uses an interlaced raster scan system. Every other row of dots is thus scanned with each complete scan of the display screen.

The alphanumeric data to be displayed comes from the host computer, a mass storage device, or the terminal keyboard. A microprocessor in the terminal uses this data to create a display list, which combines ASCII character codes, character set attribute codes (upper or lower case), and field attribute codes (blinking field, enhanced field, etc.).

The display controller scans the display list one row of characters at a time and uses each ASCII code for fetching a dot matrix character from a character generation ROM, which is then displayed on the crt screen.

The virtual bit map technique

Creating a display of alphanumerics and graphics with the TEKTRONIX 4025 is somewhat like putting together a jigsaw puzzle with the help of a computer. Using a software program such as the PLOT 10 Easy Graphing software package, the 4025 user initially establishes a graphics region on the display screen. The rectangular graphics region can be placed anywhere in the display area. The remainder of the display area is then considered alphanumerics region.

The microprocessor then further divides the graphics region into graphics cells. A graphics cell is the same size as an alphanumerics cell — 14 dots high by 8 dots wide. When the microprocessor receives information from the host computer telling it the size and location of the graphics region, it uses a firmware program to create a uniform array of dummy address pointers in the display list. Each of these dummy addresses potentially points to one graphics cell of information stored in the graphics memory.

Next the 4025 operator defines the graph parameters and inputs the data to be graphed. Using an incremental plotting algorithm, the microprocessor writes the dot pattern for the desired graph in the graphics memory. A writable RAM is used for the graphic memory. It has been designed to be written into by the microprocessor as an I/O device. Its output is designed to look like that of the character generation ROM.

The addresses for each of the graphics cells that contain graphics information are then exchanged for dummy addresses in the display list. Those graphics cells that do not contain graphics information appear in the display list as spaces.

Alphanumeric codes are also written in the display list just as with an alphanumerics only terminal. The resulting display list is made up of codes to generate specific characters with the character generation ROM and addresses in the graphics memory for the dot pattern to fill up specific graphics cells.

Using the display list as a guide, the display controller puts together the alphanumeric-graphics puzzle from the top of the display to the bottom. When the display controller scans the display list and comes to a part of the list that has been designated as graphics, it goes to the graphics RAM. The pointer in the display list points to a group of bytes that designates the dot pattern for the part of the graph that is contained in that particular graphics cell.

This technique of allocating graphics memory is called a virtual bit map, because it appears to the terminal user that every addressable dot location in the graphics area is assigned a bit in the graphics memory. In reality, only those graphics cells in the display area that actually contain graphics information are assigned bits in graphics memory.

A virtual bit map thus makes more efficient use of memory than the traditional bit map technique, where each addressable dot location in the display area is allocated a place in the graphics memory, even if the actual graph takes up only a small amount of display area. A complex graph, for example, taking up the entire display screen can be stored in 16 kilobytes of graphics memory using the virtual bit map technique of storage. With the traditional bit map technique, this graph requires twice as much memory. The

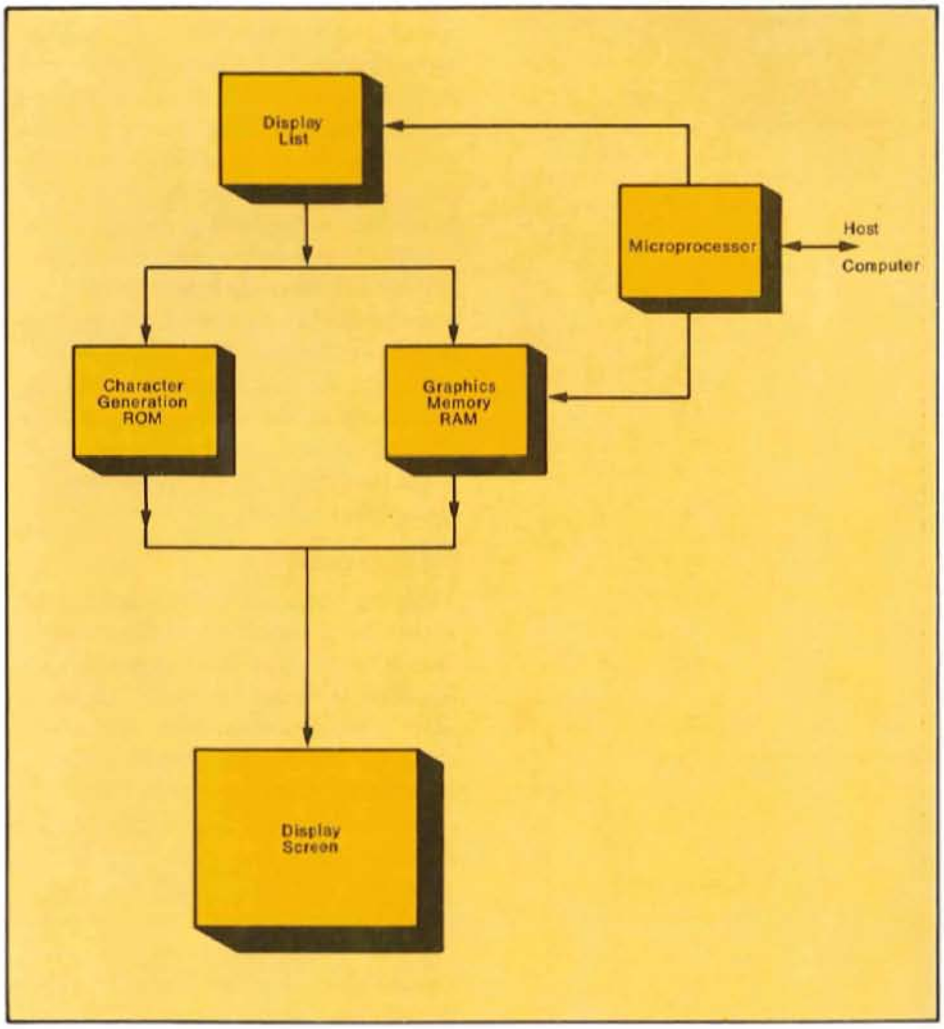


Fig. 1. Simplified block diagram of the 4025. The Display List contains alphanumeric codes for the character-generation ROM and addresses in the graphics memory for the dot pattern in specific graphics cells. Using the Display List as a guide, the Display Controller assembles the display a line at a time. The display is interlaced.

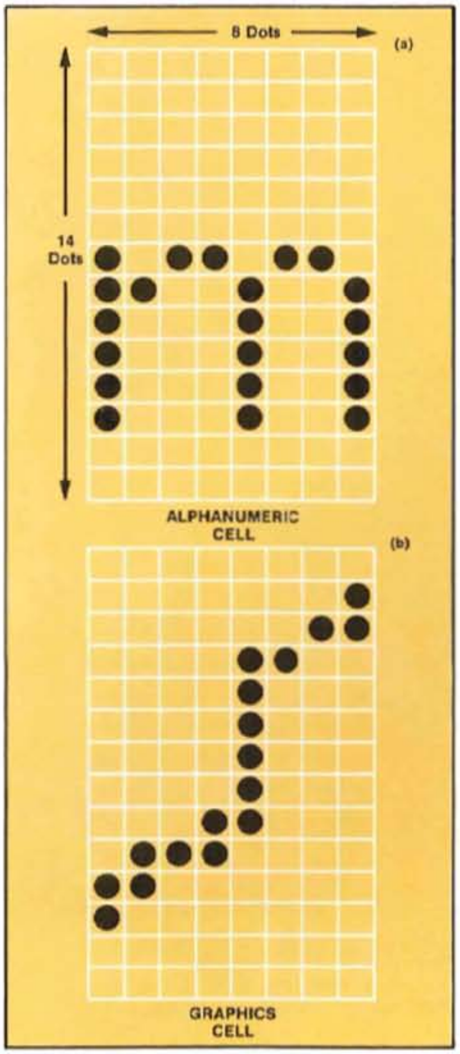


Fig. 2. In the 4025, graphic data is stored in graphic cells (b) containing the same number of elements as alphanumeric cells (a). Graphic memory is required only for those cells containing graphic data; empty graphic cells are treated as spaces. This greatly reduces the memory required for graphics.

savings in memory is the greatest for small, simple graphs.

Report generation

The virtual bit map graphing technique also solves the problem of being able to scroll graphics. The display list can hold more information than can be displayed on the screen at one time. Scrolling and paging are used to make it all visible. Scrolling is accomplished by starting the field at a point in the display list that is designated as being a fixed memory location — the beginning of a line. To scroll the display, the display controller sequences through fixed memory locations — line by line — or jumps 34 lines at a time — paging. The graphics scroll with the alphanumerics, since the graphics information is contained in the list the same as the alphanumerics.

Store two or more graphs

More than one graph can be displayed on the screen at one time. The microprocessor merely designates a new section of the graphics memory for each additional graph. The amount of graphics and alphanumerics that can be stored in the 4025 at one time is determined by the size of the display list memory and the graphics RAM. 4 kilobytes is the standard size for each of these memories in the 4025, but each can be expanded to 32 kilobytes. It is thus quite possible to create a graph that extends vertically off the page and can only be viewed in its entirety through scrolling or hard copy (if it is 53 rows or less).

Create special characters

Besides containing graphs, the graphic memory can also be used to store user-defined characters, character sets, or symbols not found in the character ROM. Under the direction of user software, the character or symbol is merely written in one of the graphics cells. It can then be inserted anywhere in the display list by specifying the addresses of the graphics cell.

Summary

The demand for an easy-to-use gralpha terminal that can display graphs, charts, and alphanumeric text in an attractive format is on the increase. It is the virtual bit map method of storing graphics that makes this kind of a terminal possible.

The ability to store a number of graphs in the graphics memory and to construct a multi-page report that combines text and graphs on each page gives the 4025 considerable flexibility for use in data analysis, report generation, and data display. Scrolling both graphics and alphanumerics makes the 4025 extremely convenient to use, allowing both text and graphics to be quickly reviewed and edited.

[1] See the article on page 9 of this issue of Tekscope for a discussion of the gralpha concept.

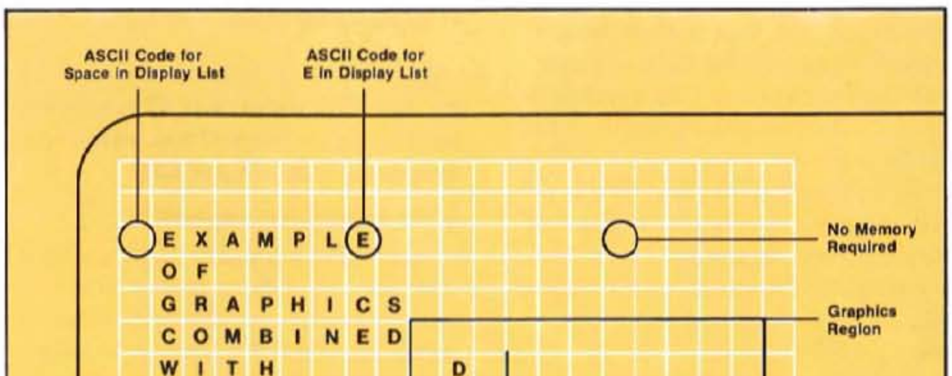


Fig. 3. Drawing depicting a portion of the 4025 display area containing both graphics and alphanumerics. The screen is divided into 34 rows of 80 cells each. Data for the graphic cells are stored in RAM. Alphanumeric data are stored in a character-generation ROM.

Evaluating Test Data with Computer Graphics

Computer display terminals have a versatility that extends far beyond final-data presentation. One of the more effective applications of the terminal is to use it for a preliminary view of raw data and any intermediate stage of data reduction. This previewing technique can be an impressive diagnostic indicator, time saver, and data compactor.

Data previewing at Georgia Tech.

Data previewing is being utilized at the Georgia Institute of Technology, where the Aerospace Engineering Department is using a TEKTRONIX 4012 Computer Display Terminal to make a preliminary analysis of the data acquired from impedance tube measurements during the burning of solid-propellant rocket fuel. This previewing is done before investing time in extensive data reduction and data presentation.

Aerospace scientists at the Institute are processing information with a minicomputer-based data acquisition system. The computer program is divided into two sections (overlays) that, due to their length, must be placed into the computer memory separately. One overlay is used for data acquisition, the other for data presentation.

By concluding the first overlay — data acquisition — with a graphed data preview on the 4012 terminal, the research team can quickly ascertain if the desired test conditions were established.

If valid test data is not attained, then the research team can repeat the experiment without a software delay, because the data-acquisition overlay is still in computer memory. If necessary, preliminary runs to verify proper instrumentation function and test conditions can be made rapidly and easily with the 4012 preview-display format. After a test series, the scientists can load the long, more extensive data presentation overlay into the computer, confident that the desired test conditions were obtained and that only significant raw data will be used for further data reduction. This preview technique can save the scientists as much as 1½ hours per test.

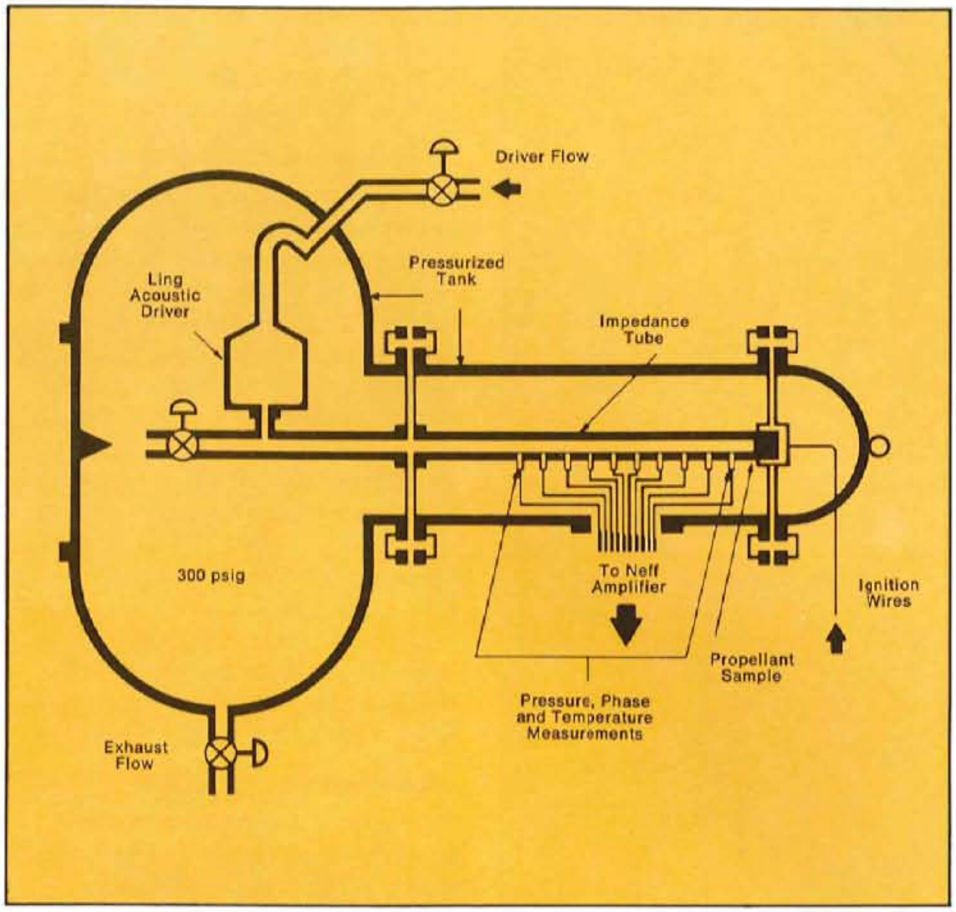


Fig. 1. To minimize pressure differences across the delicate transducer diaphrams, the impedance tube is enclosed in a pressurized tank or shell. A sound source of known frequency and the propellant sample are placed at opposite ends of the tube. After propellant ignition, the amplitude and phase of the resultant pressure oscillations and the temperature in the tube are monitored.

Solid-fuel rocket research

For the last two years, Georgia Tech scientists have been conducting basic research on solid fuel rocket propellants for the Air Force Office of Scientific Research. Primarily, they are investigating the phenomenon of combustion instability in solid-fuel rocket motors by studying the interaction between sound waves and the combustion process. When a solid propellant burns, it produces turbulent conditions in the combustion chamber of the rocket motor. This turbulence is perceived as noise. The noise or pressure fluctuations produce fluctuations in the combustion process. If the interaction between the pressure and combustion oscillations are in phase, the pressure waves tend to amplify the combustion oscillations, which in turn, amplify the pressure fluctuations. Undamped, this disturbance can seriously impair the effectiveness of the rocket engine performance and even cause failure of the combustion chamber, usually between 10 to 10,000 Hz.

At Georgia Tech, Dr. Ben T. Zinn, the principal investigator; two research engineers, Dr. William Bell and Mr. Bob Daniel; and a graduate student, Mr. Mohammed Salikuddin have spent three years exploring some of the important parameters of this problem and creating a viable testing procedure.

Testing fuels in an impedance tube

The experiments are centered around the study of the combustion process using an impedance tube at pressures from 15 to 350 psig. The tube is a 6-foot-long stainless steel pipe capable of testing propellant samples two inches in diameter. Although solid-fuel rocket chambers are often designed in gargantuan sizes (10 to 15 feet in diameter), the diminutive impedance tube provides an effective testing apparatus that can be used at minimum cost and maximum safety.

At the beginning of a test, a solid propellant — portioned to burn for approximately 4 seconds — is placed on a steel plate that is secured inside one end of the impedance tube. At the other end, an electropneumatic acoustic driver introduces sound into the tube at a controlled frequency (Figure 1).

The fuel sample is ignited at the initiation of the testing procedure. The sound from the acoustic driver sends incident waves traveling down the impedance tube to the combustion area. There, the wave interacts with the combustion process and is reflected back towards the driver. The reflected and incident waves combine to form a standing wave along the length of the tube (Figure 2). The amplitude and shape of this standing wave is dependent upon the amount of sound absorbed or amplified by the combustion process and upon the phase relationship of the incident and reflected waves.

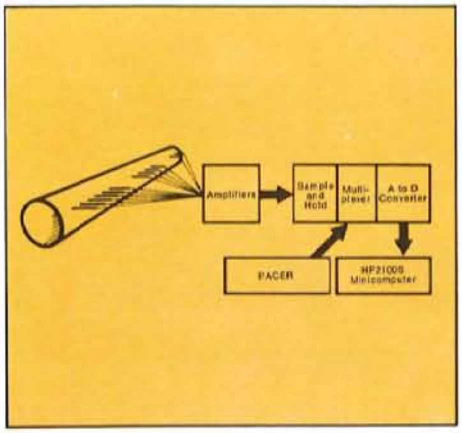


Fig. 3. The signals from the pressure transducers and thermocouples are amplified and simultaneously sampled and held. A multiplexer samples each data channel, and the voltages are converted to digitized form. The sampling rate is controlled by the pacer. The raw signals are recorded on a disc, using the computer as a buffer.

Measuring the standing wave

The scientists use transducers (condenser microphones) to measure the amplitude and phase of the standing wave at different tube locations. They can then determine the ratio of the incident to the reflected wave. Fourier analysis is applied to filter the pressure signal at the test frequency from harmonics and noise.

Testing restrictions caused by temperature changes

The amplitude of the sound in the impedance tube is fluctuating wildly because there is approximately a 3,000° increase in temperature from ignition until steady burning is achieved. Once the temperature stabilizes, there is only one or two seconds where reliable, steady standing-wave readings can be obtained.

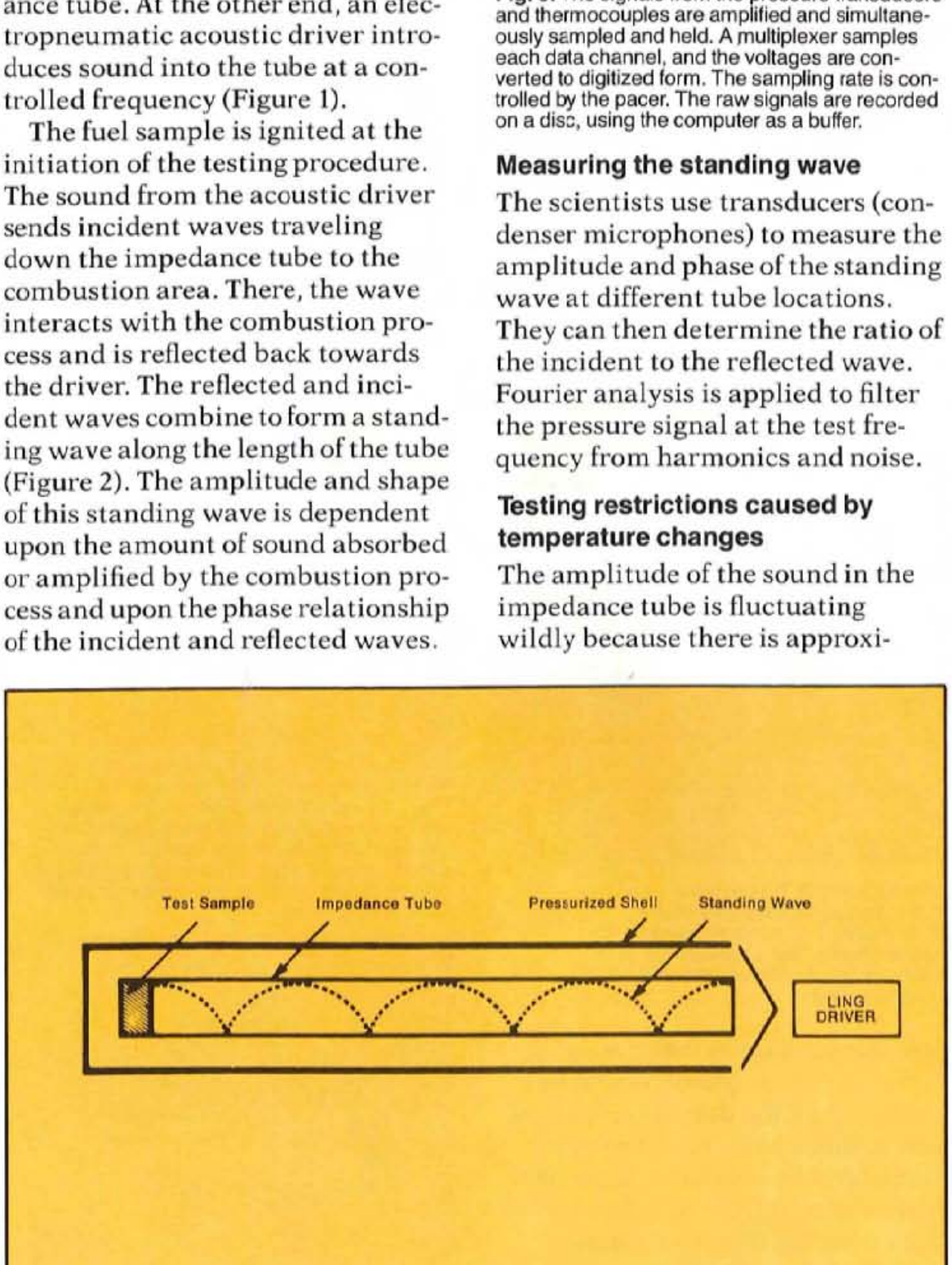


Fig. 2. The shape of the standing wave can be reconstructed by analyzing the amplitude, phase, and temperature measurements taken along the impedance tube. The standing wave shape makes it possible to determine how much the combustion process amplified or attenuated the acoustical oscillations.

Test equipment

The Aerospace Engineering Department's data acquisition equipment consists of a...

Neff amplifier;

Preston GMAD-11 twelve-channel analog to digital converter with multiplexer;

Hewlett-Packard 3320-A frequency sythesizer;

TEKTRONIX 4012 Computer Display Terminal;

and a Hewlett-Packard 2100S 24K memory computer with two direct memory access channels, disc storage with a capacity of 2.5 million words, and a transfer rate of 128,000 words per second.

Data acquisition

Data from up to ten transducers and two thermocouples are taken during an experiment. After being amplified by the Neff amplifier, the transducer signals appear at the input of the A to D converter in a ±2½ volt range (Figure 3).

Data Anaylsis

The research team previews the experimental data with two displays on the 4012 terminal to determine the valid data ranges (Figures 4 and 5). The displays plot the standing wave's amplitude and phase relationship versus time as recorded by each transducer. The time period of steady combustion can be determined by a visual inspection of the display. The terminal keyboard is used to communicate the valid beginning and ending test parameters to the computer; subsequent data presentation and analysis is restricted to this data segment (Figure 6).

There, the analog signals are converted into digital data that are stored in 8-bit bytes (1 bit to indicate the polarity and 7 bits for voltage). The A to D converter compacts two

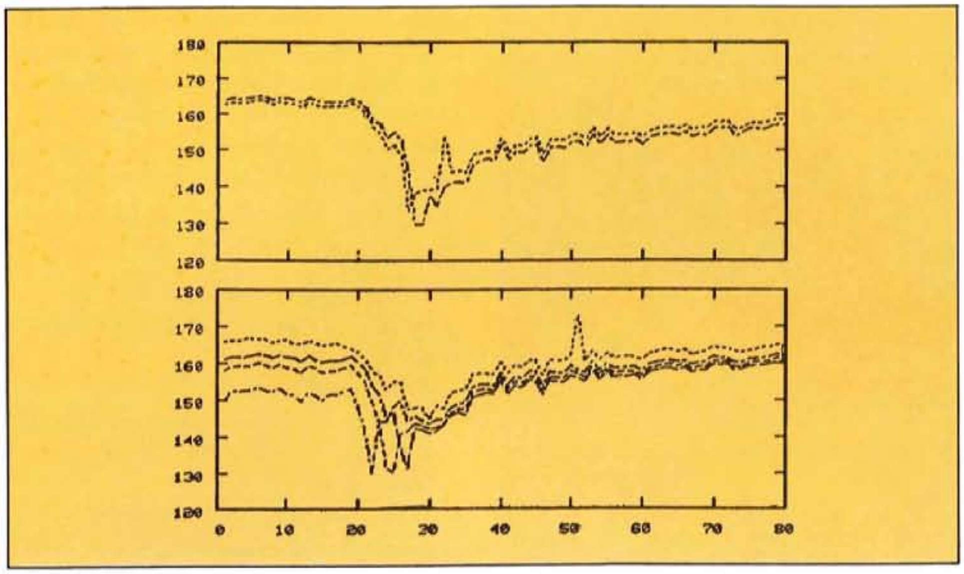


Fig. 4. These graphs displayed on the 4012 terminal and copied on a TEKTRONIX 4631 Hard Copy Unit show the oscillating pressure amplitude in decibels versus nondimensional time at six axial stations along the impedance tube. The propellant is ignited at time T=20; the increase in temperature causes fluctuations in the amplitude until time T=40. After this point, the temperature reaches a constant level, the amplitude variation diminishes, and desirable test contitions are achieved from T=40 to T=80.

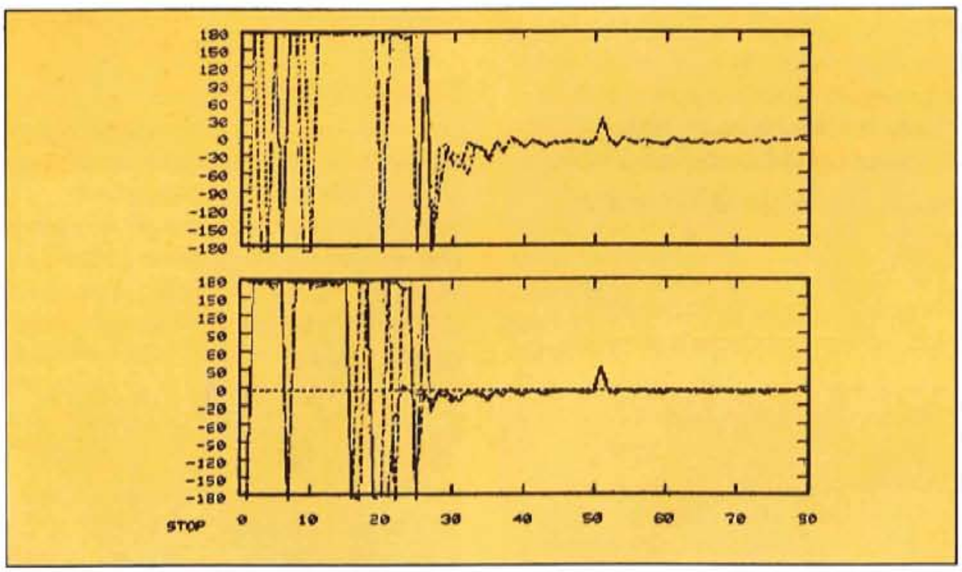


Fig. 5. These plots show the corresponding phase differences between the pressure oscillations at the six axial stations along the impedance tube. The phases are referenced to one of the transducer signals. Before ignition, the oscillations are ± 180 degrees out of phase with the reference signal. After ignition, the pressure oscillations are almost in phase. By measuring these phase differences, it is possible to determine the capabiltiy of the propellant to drive unacceptably large oscillations in a rocket motor.

8-bit bytes into a 16-bit word. Six words then, represent one measurement sample.

The frequency synthesizer acts as a pacer and controls the rate at which the A and D converter digitizes and stores the data. This rate can be set to optimize the accuracy of the amplitude and phase data for a given frequency. The multiplexer sequentially stores the digitized data from the pressure transducers and thermocouples into a memory buffer in the computer. When the buffer is full, the data is stored on a disc to allow more readings to be taken into the computer. Upon completion of a test, the raw data is read back from the disc into computer memory as required.

Data presentation

After 4012 terminal previewing has isolated valid raw-data parameters, the long data-presentation overlay is loaded into the department's minicomputer (Figure 7). The output of this program is steady-state amplitude, phase, and temperature information from the experiment. This data is graphed on a plotter and listed on a teletype. Selected data are taken and transmitted to the university's CYBER 70 computer system for final analysis and presentation. Essentially, the CYBER 70 analyzes the amplitude, temperature, and phase data; performs a least squares curve fit; and indicates on a line printer how much the sound is increased by the tested propellant.

Summary

Data previewing is an important time and cost saving technique for this and many other applications. This particular application calls for a terminal that is reliable, versatile, and reasonably priced. The 4012 meets all of these requirements.

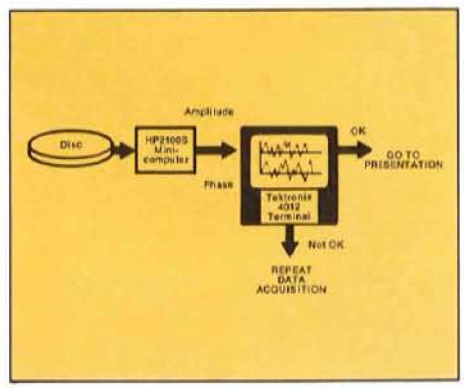


Fig. 6. The raw digitized data are converted to amplitude and phase data and displayed on the Tektronix computer display terminal. If proper test conditions were not established during the 4 second propellant burn, the test can be rerun with minimal time delay.

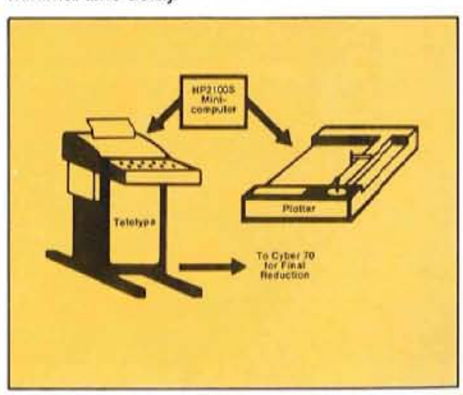
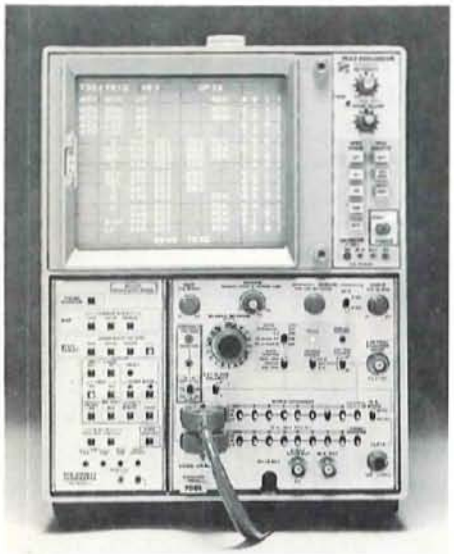


Fig. 7. Amplitude, phase, and temperature data versus time are plotted and printed. Final data analysis to reconstruct the standing wave is performed on a CYBER 70 computer.

New Products

The DF2 Display Formatter with 7D01 and 7603



P6303 Dc Current Probe with AM 503 Amplifier

The New C-28 Crt Camera

New Display Formatter Offers GPIB ASCII Capability

Digital designers can now look at disassembled GPIB (IEEE Standard 488-1975) activity with the TEKTRONIX DF2 Display Formatter. The DF2 also formats data stored in the 7D01 memory in ASCII format with further decode in hexadecimal, binary, or octal notation on the same display.

The DF2 works as a companion to the 7D01 Logic Analyzer. Additional display formatting capabilities include: timing, mapping, hexadecimal, octal, and binary. An automatic data comparison feature enables the user to catch intermittent faults.

Synchronous operation enables the user to view blocks of the 256 GPIB instructions stored in the 7D01 memory, 17 instructions at a time. Disassembled instructions of activity on the data bus, transfer bus (handshake lines), and management bus (control lines), are displayed in IEEE 488 mnemonics. Asynchronous GPIB measurements can be displayed in a timing diagram when monitoring handshake line activity. The DF2's GPIB capability enables digital designers to design, troubleshoot and integrate GPIB systems easier and simpler.

GPIB or ASCII modes are selected from the DF2 front panel by pressing a MENU button.

Included with the DF2 is a GPIB probe adapter with standard IEEE 488 connector and quick connection to the P6451 Probe head.

Dc Current Measurement To 100 Amps

The P6303 is a new current probe designed to make ac and dc current measurements to 100A, 500A peak.

The current measurement system consists of the P6303, the AM 503 Current Probe amplifier, a TM 500 Power Module and any oscilloscope with at least a 50-MHz bandwidth and 10 mV/div vertical sensitivity.

With its large 1 x 0.83 inch (2.54 x 2.11 cm) jaw opening, the P6303 can make accurate dc coupled current measurements of large conductors which previously were not possible. The spring-loaded jaw slides open for placement around the conductor. There's no need to break the circuit under test. For differential or sum measurements, merely place the conductors in the probe jaw in the proper phase.

The P6303 is highly recommended for measuring current in X-ray tubes, SCR motor controls, industrial controls and power supplies. It is especially useful when making measurements at high impedance points or with current dependent devices.

C-28 Camera Features Electric Shutter

The new C-28 Crt Camera features an electric shutter, changeable magnification, a quality lens, and mechanical rigidity.

The electric shutter allows remote operation for operator convenience or system control of the camera, and provides accurate, repeatable exposure times. The shutters' input trigger is TTL-compatible to simplify interfacing to the user's system. Reliability of the electric shutter is far superior to that of mechanical shutters.

Magnification can be changed from 0.67 to 0.85 to permit full-frame photographs of both 8 x 10 cm and 10 x 12 cm displays. This is accomplished by changing spacing rings on the easily disassembled lens barrel. The economical f2.8 lens provides the performance needed in general crt photography.

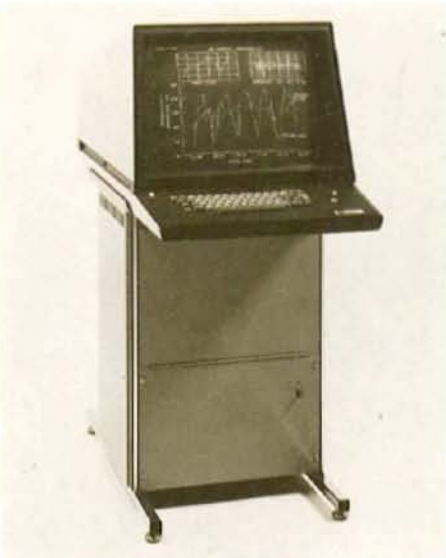
The C-28 offers outstanding strength in its frame and crt bezel attachment mechanism.

Two film backs are included with the C-28 — a Graflok 4" x 5" roll film back and a Polaroid Type 405 back modified to fit directly onto the Graflok back. This special interface allows the user to quickly switch from negative film to Polaroid.

Medical diagnostic applications

New Products

8001 Microprocessor Lab with Optional CT8100 Crt Terminal



including ultrasound, nuclear medicine, and computerized tomography are excellent examples of applications for the C-28. It is also well suited to general purpose trace recording.

8000-Series Microprocessor Labs Add 8085 Support

With complete 8085 software and hardware emulation, software development support, and hardware debug capability, the 8085 option for the TEKTRONIX 8000-Series Microprocessor Labs extends the coverage of this multiple-approach development aid to still another popular microprocessor. Previously announced options include support packages for the 8080, 6800, Z-80 and 9900.

Like the other 8000-Series microprocessor support packages, the 8085 option package runs as a component of the total Tektronix' systems approach to easing microprocessor based designs. The 8002 Microprocessor Lab, with dual floppy discs, up to 64k bytes of user memory, separate 16k system memory, and optional terminal provides

The 4014-1 Computer Display Terminal

an operating system and text editor to facilitate program development. Then, the program can be gradually integrated with a prototype by using the 8002 emulation and debug capabilities. The 8001 Microprocessor Lab — which is intended for users with time-sharing or other software development facilities — provides emulation and debug facilities, and uses a ROM-based operating system.

Intelligent Graphic Enhancement for the 4014

Users of the large screen 4014 Computer Display Terminal now have the opportunity to combine the graphic display superiority of the 4014 with proven techniques of distributed processing. All are designed to reduce data transmission and online time, speed up applications and interactivity, and further increase the ease of use, interactivity, and productivity of the 4014.

Three new options allow you to select the degree of enhancement to suit your particular needs:

Option 40 provides programmable keyboard capability with storage of alphanumerics and graphics in local memory. Data may be entered from the keyboard or down loaded from the host or local peripheral devices. After loading, the data stored for any key may be displayed on the screen or transmitted to the host or local peripheral by simply depressing a key, or by the host transmitting the key value. The data stored under a key name could be an entire display, a graphic segment, a symbol, local commands, or the names of several other keys which also contain graphics.

For convenience a one line editor is included which maintains the most recent typed line in refresh. Graphic data may be displayed in the normal location or displayed in new locations by redefining the origin coordinates. In addition, Option 40 provides local clipping of any graphics outside the screen boundary and local buffering of all communications.

Option 41 adds local rotation and scaling (upwards and downwards) of graphics, use of any alternate down-loaded character set, and local circle and circular arc generation. To assist in development of an alternate character set, a local symbol design mode is provided in which symbols or characters may be defined using the crosshair cursor or graphics tablet, then saved on a local peripheral or host.

Option 42 adds an interactive buffer to the 4014 providing 1023 bytes of off-screen storage which can be used as a straight buffer capable of storing or refreshing alphanumeric or graphic displays, as a text editor, or in conjunction with thumbwheels or an optional joystick to provide moveable picture elements. The picture elements may be positioned anywhere on-screen, rotated, or scaled locally or under program control.

A-3843

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

0421867 MAR 9 1978 1339
MR THOMAS P DOWNEY LAB TECH
GEOLOGY DEPT EPS-J106
CITY COLLEGE OF NEW YORK
138TH ST. & CONVENT AVE.
NEW YORK CITY NY 10031

BULK RATE
U.S. POSTAGE PAID
TEKTRONIX, INC.

Unraveling the Mystery on the GPIB

IEEE 488 Bus — Going Your Way?

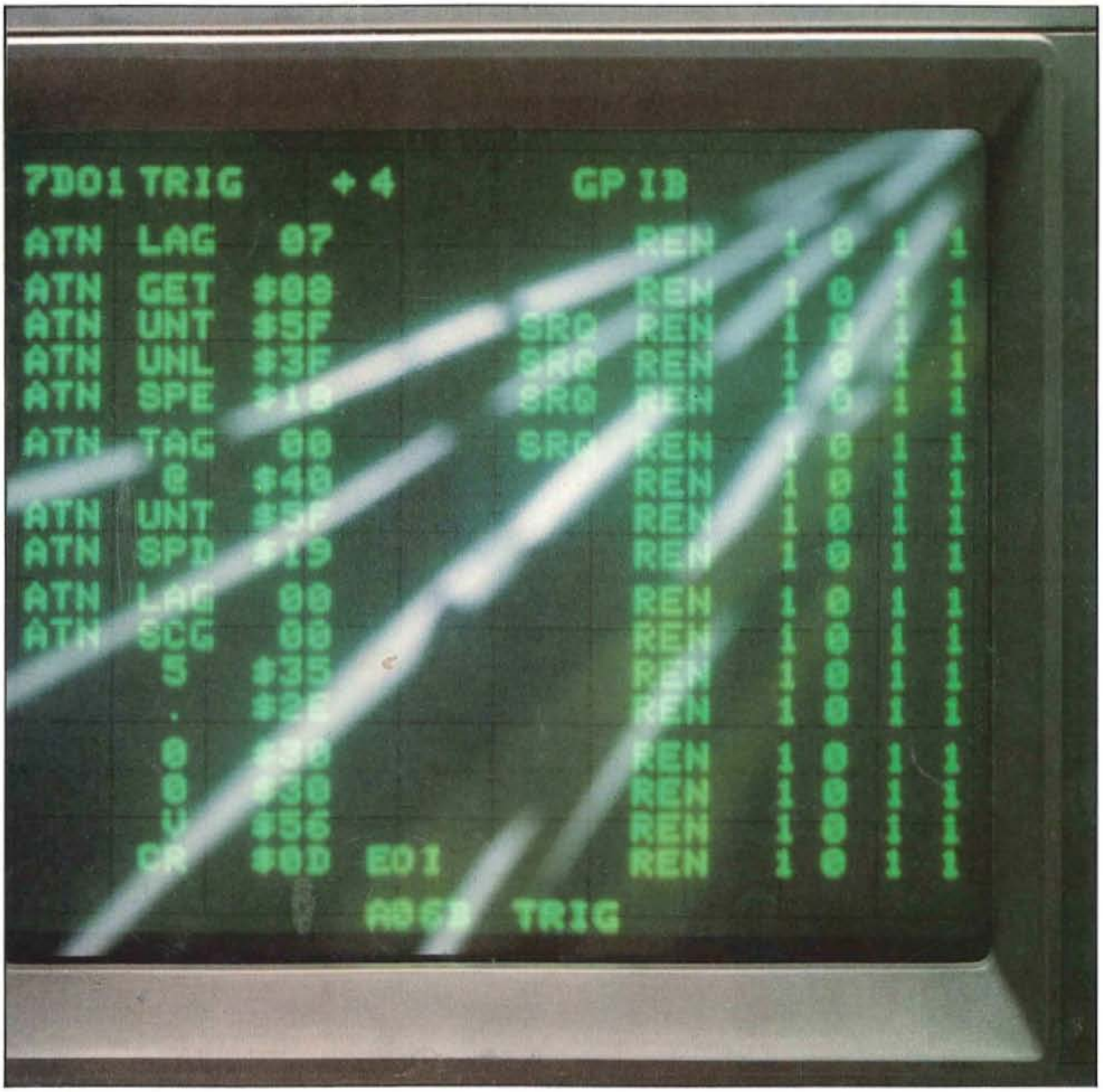
Pulse Generator or Function Generator? Making an Intelligent Choice

New Products

Volume 10
Number 2

1978

Tekscope



Tektronix®
COMMITTED TO EXCELLENCE

CONTENTS

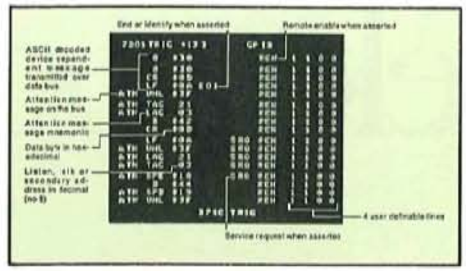
Tekscope

Customer information from
Tektronix, Inc.
Beaverton, Oregon 97077

Editor: Gordon Allison

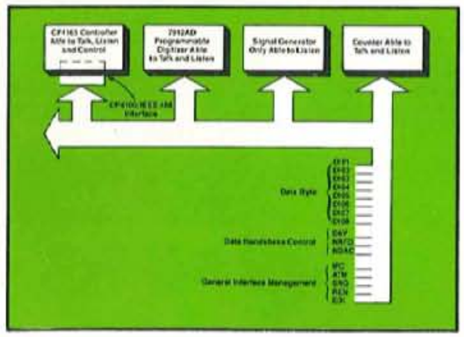
Unraveling the Mystery on the GPIB

The new DF2 Display Formatter, a companion plug-in for the 7D01 Logic Analyzer, lets you take a close-up view of action on the GPIB, displayed just the way it was programmed, in disassembled IEEE 488 mnemonic instructions.



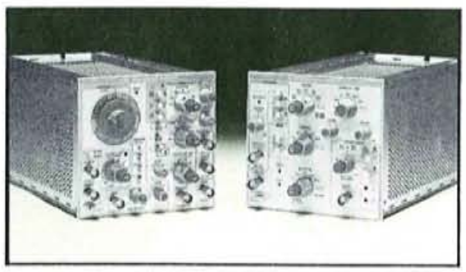
IEEE 488 Bus — Going Your Way?

Shedding a little more light on the IEEE Standard 488-1975, and discussing some pluses and minuses for the system designer.



Pulse Generator or Function Generator — Making an Intelligent Choice

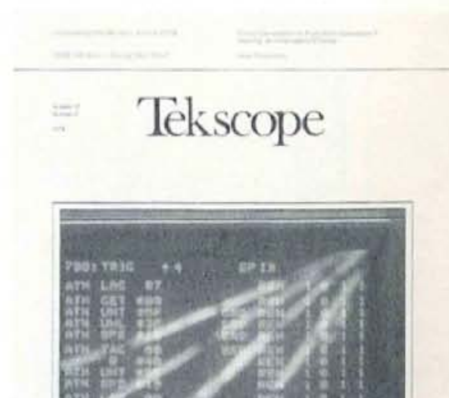
Function generators with pulse capabilities suitable for logic and other applications are supplanting pulse generators normally purchased for these functions. A careful look at their respective capabilities will help you make the best choice for your needs.



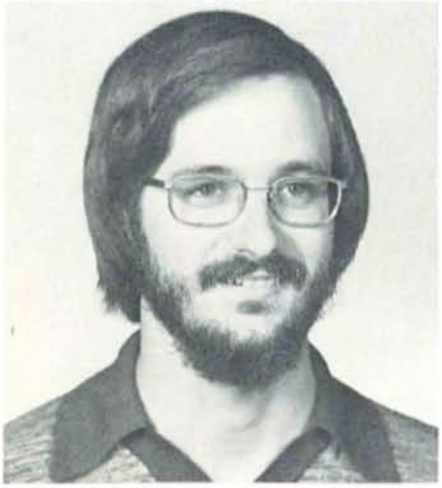
Tekscope is a bimonthly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique. A new products section gives a brief description of products recently introduced and provides an opportunity to request further information.

To better serve customers who maintain their TEKTRONIX instruments, the service information formerly appearing in Tekscope will be expanded and published in a publication dedicated to the service function.

Cover
The DF2 Display Formatter illuminates the activity taking place on the GPIB by disassembling the instructions and displaying them in familiar IEEE 488 message mnemonics.



Unraveling the Mystery on the GPIB



Bruce Ableidinger joined Tek 4 years ago upon completion of his BSEE at Washington State in '74. After six months in Component Evaluation he joined the TM 500 engineering group, working on digital products. His latest assignment has been Project Engineer on the DF2 Display Formatter for the Logic Development Products group.

When people try to communicate it helps if they all speak the same language. Even so, there are misunderstandings.

We now have a standard system for connecting instruments together so they can communicate. It's called the General Purpose Interface Bus (GPIB). The formal term is IEEE Standard 488-1975, "Digital Interface for Programmable Instrumentation." This standard specifies the mechanical, electrical, and functional elements of the digital interface system. One would suppose that with such a standard, a group of instruments could be connected together as a system and function perfectly. Not necessarily so, any more than people who speak the same language communicate perfectly.

When a group of instruments connected together fails to function properly, it is often difficult to determine the cause. Is it a defective instrument, faulty connection, timing problem, or programming error? How can one determine which?

One of the most useful instruments in working with digital systems is the logic analyzer. Early analyzers usually presented digital information in one of two formats — logic timing or logic state. The application dictated the type selected. Circuit designers preferred timing diagrams, while software designers chose state table displays. A third mode, mapping, appeared later on some logic state analyzers, providing the system designer a convenient means of monitoring program flow.

With the introduction of the TEKTRONIX 7D01 Logic Analyzer and DF1 Display Formatter[1], the user was given a choice of all three display modes in a single instrument.

Now, the increasing demand for programmable instrumentation using the GPIB has created a need to view data in still another format — IEEE 488 mnemonics. These mnemonics represent, or are the equivalent of, particular logic patterns occurring on the 8 data lines and 4 status lines of the GPIB, and are defined in the standard itself. The new DF2 Display Formatter with its companion 7D01 Logic Analyzer, converts the binary values appearing on the data and status lines into their equivalent mnemonics and displays the results on a crt.

How it works

Front panel pushbuttons on the DF2 give the user a choice of seven display modes: timing, map, binary, octal, hexadecimal, GPIB, and ASCII. In the GPIB and ASCII display modes, the user is given the further choice of displaying data in binary, octal, or hexadecimal.

In the GPIB mode, data is acquired from the GPIB by the 7D01

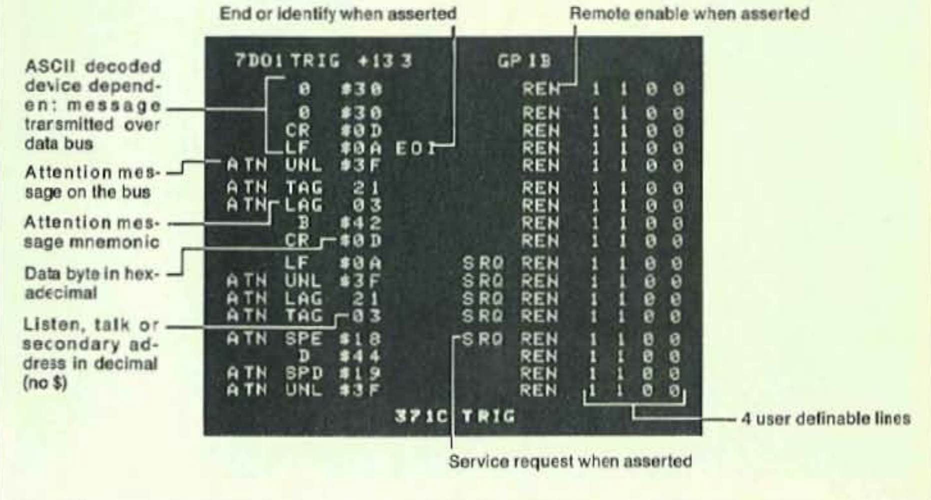


Fig. 1. GPIB display of activity on the data bus, transfer bus (handshake lines), and management bus (control lines). Disassembled instructions are displayed on the crt in IEEE 488 message mnemonics familiar to the GPIB user.

Logic Analyzer through an adapter that provides a convenient transition from the GPIB connector to the two P6451 Data Acquisition Probes used with the 7D01.
Note that specific assignments are given each probe input with the exception of channels 0-3 and the probe qualifier input.

Channels 0-3 and the qualifier input are user definable. They can be used to view signals from the user's circuitry or applied to the handshake lines available on the GPIB Adapter.

Data acquired by the 7D01 is transferred to the DF2 memory and processed for display under microprocessor control. A program ROM in the DF2 provides permanent storage for the microprocessor instructions.

Figure 1 is a GPIB display. Note that it is so labeled at the top of the right hand column. The GPIB transactions are displayed in hexadecimal, as indicated by a dollar sign ($) preceding the alphanumeric hex value. You will note a couple of exceptions — the listen, talk, and secondary address groups are displayed in decimal, and the four usable-definable lines are presented in binary. The number of clock cycles occurring between the trigger and the first line of the display (at top of screen) is also displayed in decimal, while the trigger word (at bottom of screen) is displayed in the previously selected format — in this instance, hexadecimal. This intermingling of formats on a single display lets you view each piece of data in its most useful form.

Seventeen GPIB events, plus the cursor position and trigger word, can be displayed on-screen at one time. As the data is "scrolled" manually using the 7D01 cursor control, all 254 events acquired by the 7D01 can be viewed. Each of the 17 lines (bus transactions) contains data information from the interface bus, displayed in IEEE 488 mnemonic message format.

Versatile triggering and storage

One of the keys to unraveling the mystery on the GPIB is the ability to capture the action occurring on the bus at any selected point in time, and examine events leading up to and following that action. The 7D01/DF2 provides that ability.

The user has a choice of synchronous or asynchronous triggering and synchronous or asynchronous data storage. This makes possible four combinations of triggering and storage to create a very versatile system. In synchronous operation, triggering and storage are related to an external clock, while asynchronous operation utilizes a very accurate internal clock. Let's consider where each of these triggering/storing modes might be used in a GPIB interface environment.

Synchronously triggering on an input value set by the word recognizer switches, and synchronously storing data into the logic analyzer clocked by the negative edge of data valid (DAV) is the most common mode for looking at data and control transactions across the GPIB. For example, one could look at device-dependent messages being transmitted to the controller from one particular device, by setting the word recognizer to trigger on the talk address of that device.

Triggering asynchronously on the input word equal to the word recog-

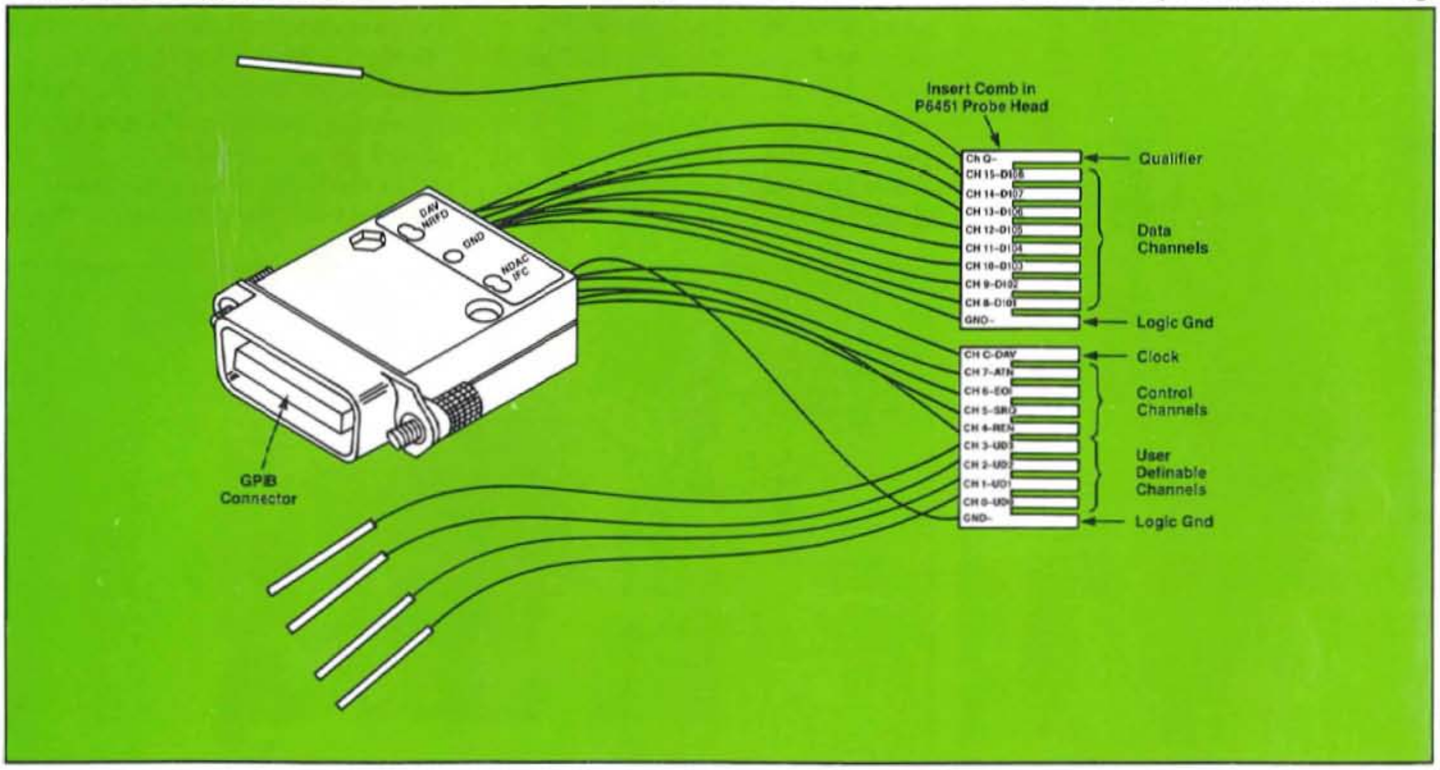


Fig. 2 The GPIB Probe Adapter provides a convenient means of interfacing the GPIB connector to the P6451 Probes used with the 7D01 Logic Analyzer. Note that four of the signal inputs and an external qualifier input are user-definable.

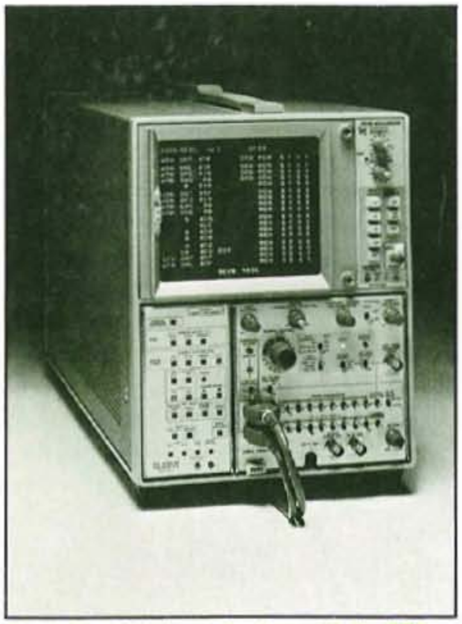


Fig. 3. The 7D01 Logic Analyzer with the DF2 Display Formatter converts any 7000-Series Mainframe to a Logic Analyzer with seven ways to look at logic.

nizer switch settings, and storing GPIB transactions synchronously clocked by DAV, is useful when the user wants to trigger on a single combinatorial event in the circuit and look at the GPIB transactions that led up to that event. The user-definable lines can be connected to the circuit, and the 7D01 can be triggered asynchronously relative to the data being stored. A typical example is triggering on the interface clear line (IFC) which occurs asynchronously to the handshake, and looking at the GPIB transactions before and after the IFC occurrence to discover why it was asserted and the effects it had on the system operation.

Triggering synchronously on a GPIB transaction and storing data asynchronously is generally used when timing information before, during, and/or after a GPIB transaction is desired. The most common example is studying the handshake cycle around a particular attention (ATN) message for correctness and speed. The user can also look at the effect a particular ATN message has on the circuit handling the interface.

Triggering the logic anaylzer on an asynchronous event and recording the timing information of the input lines is the normal operating mode of a timing logic analyzer. It is useful for studying the GPIB handshake and speed performance of the system. Typical examples would be examining the asynchronous parallel poll as the controller asserts ATN and End or Identify (EOI) to command those devices, with the capability, to put their status on the data lines; and looking at Service Request (SRQ), IFC, and Remote Enable (REN) for their time of assertion and relationship to other GPIB lines.

Design applications

The design, debug, and evaluation stages of a product containing a GPIB are all ideal application areas for the 7D01/DF2. Whether the design is accomplished using hardware techniques or with a microprocessor/peripheral implementation, the DF2 can save time in finding errors, validating the design, and measuring the performance of the interface.

Probably the most common design for the GPIB involves a subset of the total interface capability. The beauty of the IEEE 488 bus is that only a portion of its full capability need be implemented, depending on what the designer wants the interface to do. This allows the use of the GPIB while minimizing costs and design time.

For example, a designer may want to interface an existing line printer to the GPIB. This task involves implementing the Basic Listener function (and optionally Listen Only). The Basic Listener interface for the printer requires the receipt of the My Listen Address (MLA) attention command, before it prints device-dependent messages (those messages sent with attention false). Listen Only forces the printer to always listen and hence prints all device-dependent messages across the bus. These types of designs are best implemented in TTL hardware because of their simplicity.

After the design is finished and built, the DF2 can quickly check that the handshake cycle functions properly when attention is true and when it is false; that the interface handles My Listen Address correctly (if the Listen Only Mode switch is not set); and that the device-dependent messages are being printed correctly and no characters are lost or translated.

Microprocessor-based interface design

When designing a microprocessor-based GPIB interface, the DF2 can aid in the program development, debug, and performance measurement phase. A microprocessor-based GPIB interface presents more difficult design and evaluation problems than does a hardware-designed interface. Usually a more sophisticated portion of the total GPIB capability is to be implemented. For example, functions such as listening, talking, serial poll, remote-local, and even parallel poll may be included.

The IEEE 488 document needs to be understood very well in order to know all of the interdependencies and interactions of the state diagrams. To glean from the IEEE 488 standard the methods of implementing this sophisticated set of functions is far from a trivial task. Also, the firmware must implement these functions with the least amount of interaction. It is easy for subtle errors to crop up in such a complex system.

A microprocessor is inherently a sequential device which means it can handle only one task at a time; tasks such as reading from a port, analyzing the data, making a decision, and outputting an "answer" to another port. A strict hardware design can operate in a parallel mode, executing more than one function at a time.

While the IEEE 488 state diagrams show various events or messages occurring simultaneously when moving from one state to the next, the microprocessor must handle these messages sequentially. The designer must learn the legal order of occurrences and the maximum amount of delay permitted between them.

Finally, implementing the remote-local function and/or the interface clear function requires using interrupts. This adds complexity to the entire code because the interrupts occur asynchronously. The software designer must write programs with the knowledge that the microprocessor can be interrupted any time the interrupts are not masked. The designer must also consider how fast the interrupt has to be handled. The interrupts cannot be masked for too long because either Remote Enable (REN) going false or Interface Clear (IFC) going true must be recognized and handled within the GPIB specification of 100 microseconds.

The DF2 is useful in monitoring all of these design and debug tasks. For example, it can be used to measure the time the microprocessor takes to handle an interrupt, look for and illuminate implementation errors, and measure the speed performance of the bus to determine whether or not the design goals were met.

Controller functions analyzed

One of the functions of the GPIB standard is that of controller. Most controllers on the market today are calculator-based, or are an extension of a minicomputer. These devices control the bus through execution of program steps previously loaded into memory.

With another device on the bus, or perhaps a talker-listener simulator built up as a tool to handshake with the controller full speed, the controller can be checked out for correct "macro" instruction implementation. One program step in the controller memory can be translated into many GPIB attention commands to perform a specific function. For example, the TEKTRONIX 4051 GPIB controller has a poll statement in BASIC which handles service requests. The controller must Serial Poll Enable all devices on the bus (SPE is a universal attention command), then talk address each device sequentially to find out if that device was asserting Service Request (SRQ). The DF2 quickly and easily shows controller management of the SRQ function. It displays the sequence of attention messages that set up the serial poll, the status byte put out by the device that was talk addressed, and the sequence of attention messages to handle further device polling and serial poll disabling.

Other controller measurements the DF2 can perform include monitoring the asynchronous parallel poll for correct implementation and speed; verifying that one controller passes control to another correctly; and measuring the handshake speed of the controller for both attention messages and device-dependent messages into and out of the controller.

Summary

The adoption of IEEE Standard 488-1975 is a big step toward the goal of effective integration of a group of instruments and peripherals to form an automated instrumentation system.

The number of companies manufacturing GPIB-compatible instruments is growing rapidly, and it is becoming easier for the end user to find the particular devices needed for his or her application. If a system is being put together, it is very likely that more than one company's products will be represented in that system. Integrating these multiple-vendor purchases can be very difficult and frustrating because of the non-standard data transmission formats used and because of the less-than-adequate documentation supplied by some manufacturers. The 7D01 Logic Analyzer and DF2 Display Formatter can transform this normally time consuming and frustrating chore into a very short system-integration task.

1. A Display Formatter — the Indispensable Tool for the Data Domain — Tekscope Volume 8 Number 4 1976.

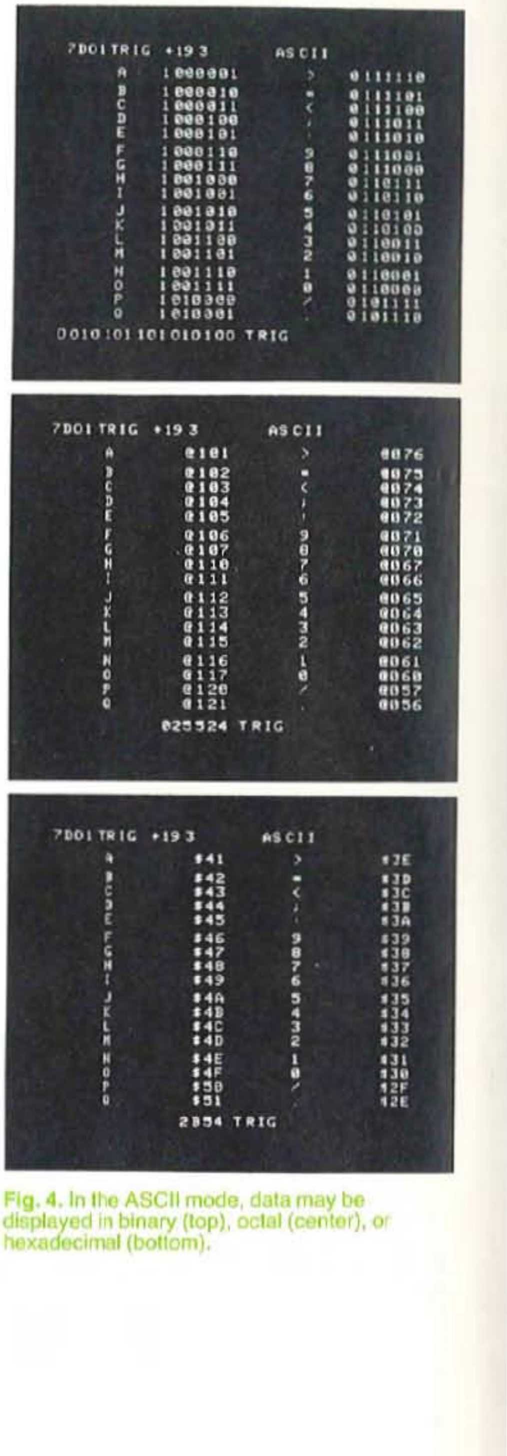


Fig. 4. In the ASCII mode, data may be displayed in binary (top), octal (center), or hexadecimal (bottom).

The IEEE 488 Bus — Going Your Way?

Jim Kimball has worked at Tek for four years as an electronics technician and engineering writer on digital instruments and systems. His interests in electronics include high-speed analog-to-digital conversion and data interfacing. He received an A.S. degree from Lane Community College and is presently working toward a BSEE degree at the University of Portland.

Many designers and electronic instrument manufacturers are getting on the IEEE 488 bus and many more are about to board. But as with any bus system, there are a few unhappy riders.

IEEE 488 critics are asking questions such as, "Sure, I won't get smoke if the instruments I connect are IEEE 488-compatible, but will they work?" And, "Even if I carefully select instruments for the capabilities I need, will they speak the same language?" And, "How can I be sure the instruments I choose for my system all implement the optional features in the standard that I need?"

A lot of confusion comes from too little understanding of the standard. So let's find out what the standard is and what it is not.

A closer look

The bus concept specified in IEEE Standard 488-1975* is partial to small automatic test systems. The IEEE 488 bus provides more flexiblity for such systems than other interface standards such as CAMAC (IEEE Standard 583-1975).

This flexibility is no accident. A primary IEEE 488 objective is to specify only those interface functions necessary for clear and orderly communication. Device-dependent functions — what the instruments do and how they do it — are specifically left up to the instrument designer.

The standard defines an interface system: first, the bus that connects the instruments, including the connectors, the signal lines, and the voltage levels on the lines; second, the functions used by the instrument interfaces to exchange data; and third, control messages and protocols.

Devices on the bus perform one of three roles: talker, listener, or controller. As in any good repertory theater company, each device may take more than one role as the occasion demands. As in a stage production, the parts are assigned by the director, called the controller-in-charge by IEEE 488. This role can be passed around, just as players in a repertory company may direct one production, but act in another. At any time, however, there can be only one director. Just as actors do not (or should not) step on each other's lines, only one device can talk at a time, though more than one can listen. The producer, called the system controller, retains ultimate authority and can double as director — that is, be both system controller and controller-in-charge.

To stage an IEEE 488 production, we must select the skills needed by the actors. These are the interface functions defined by the standard;

Source Handshake
Acceptor Handshake
Talker
Listener
Service Request
Remote Local
Parallel Poll
Device Clear
Device Trigger
Controller

The designer can choose from a list of subsets of these functions to put together the most cost-effective combination. A collection of subsets sounds strange until you understand that it's just a shorthand way of noting the device's interface functions. C0, for instance, states that a device has zero capability as a controller. DT1 means a device can be triggered to perform a designer-chosen function when it receives the device trigger interface message.

To see how these interface functions are used on the bus, let's take a look at the diagram of the bus signal lines shown in Figure 1. The 16 lines comprise three groups: data, handshake, and interface management.

The eight data lines are used together to transfer eight-bit bytes, hence the term "bit-parallel, byte-serial interface."

The handshake lines control an asynchronous, three wire handshake. DAV (Data Valid) is asserted by the transmitting device, and NRFD (Not Ready For Data) and NDAC (Not Data Accepted) are asserted by the receiving device to pace the dialogue on the bus.

The interface management lines have several uses. ATN (Attention) is like the director's megaphone: when the controller-in-charge asserts ATN, everyone pays attention. Two lines are reserved for the system controller: REN (Remote Enable) is asserted for remote control of devices on the bus, and IFC (Interface Clear) tells all devices to reset their interface functions. SRQ (Service Request) can be asserted by any device to interrupt the controller. EOI (End Or Identify) indicates the end of a data transfer, but can also be used with ATN in a special polling mode.

A byte at a time

How are these lines used by the interface functions? Let's take the source and acceptor handshakes first. Actually, they are two parts of the same handshake. Figure 2 shows the states of these lines as they are set by a talker using the source handshake and a listener using the acceptor handshake. Note that the timing diagram relates the electrical signals on the bus to the states of the source and acceptor handshakes. By looking at both, it may be easier to grasp the sequence of the interlocked handshakes than it is to absorb the infamous state diagrams in the standard.

1) To begin, the source (talker) goes to the Source Generate State (SGNS). In this state, the source is not asserting a data byte on the data lines or DAV. When no bus driver is asserting a line, it rises to the high level set by the bus terminating network. The acceptors (listeners) are in the Acceptor Not Ready State (ANRS), asserting both NRFD and NDAC. In this condition, NRFD and NDAC are low.

2) The source sets the data byte on the data lines and enters the Source Delay State (SDYS). If this is the last byte in the message, the source can assert EOI, as well. The source waits for the data to settle on the lines and for all acceptors to reach the Acceptor Ready State (ACRS).

3) Each acceptor says, "I'm ready" by releasing NRFD to move to ACRS. This is one of the points in the handshake designed to accommodate slow listeners. The NRFD line can be thought of as a wired-OR input to the source handshake logic. Any acceptor can delay the source handshake by asserting this line.

4) When the source sees NRFD high, it enters the Source Transfer State (STRS) by validating the data with DAV. The source then waits for the data to be accepted.

5) When the receiving devices see DAV asserted, they go to the Accept Data State (ACDS). Each device asserts NRFD because it is busy with the current data byte and is not ready for another.

6) As each device accepts the data, it releases NDAC to move from the ACDS to the Acceptor Wait for New cycle State (AWNS). Again, all receiving devices must release the NDAC line for the source to see a high level. When the source sees NDAC high (all have accepted the data), it enters the Source Wait for New cycle State (SWNS).

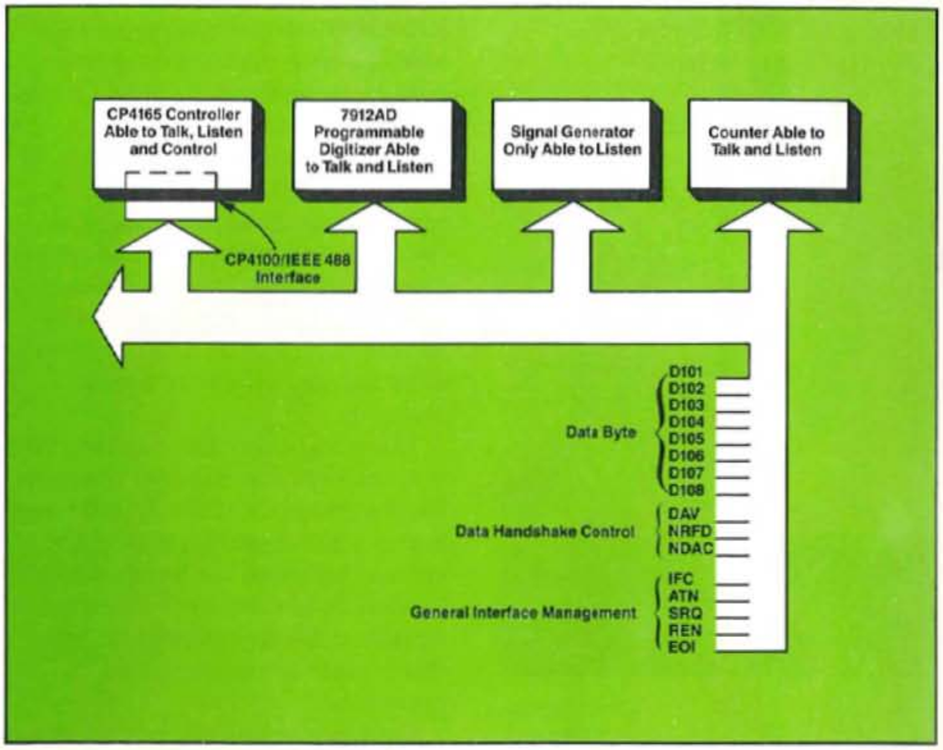


Fig. 1. IEEE 488 bus organization showing the bus signal lines and some typical bus instruments.

7) In the SWNS, the source can release DAV. This causes the acceptors to proceed to the ANRS, their intial state in the handshake. In ANRS, they assert NDAC.

8) The source continues to the SGNS, its intitial state in the handshake. In this state, it can change the data lines to prepare a new byte for transmission.

This is a typical sequence. The exact sequence is defined by the state diagrams in the standard. The only requirement is that if what happens on the signal lines differs from the above sequence, it must still conform to the state diagrams.

Who's in charge here?

We've just staged a dialogue between a talker and listener(s) using the source and acceptor handshakes, but they're not the only ones allowed to use the handshakes. The source handshake is also used by the controller-in-charge to send system control messages; these are called interface messages to distinguish them from device-dependent messages sent from talkers to listeners (see Fig. 3). Remember the director's megaphone — ATN? The controller asserts ATN to get the attention of all devices on the bus and then uses the source handshake to send interface messages on the data lines.

The interface messages that constitute the controller's vocabulary are defined by the standard. They can be thought of as ASCII codes given a new meaning when sent by the controller with ATN asserted.

Three groups of interface messages are reserved for the listen, talk, and secondary addresses. For instance, when a device sees its talk address (called My Talk Address) and ATN simultaneously, it must become a talker. When the controller removes ATN, the device begins the source handshake to transmit its data. Similarly, My Listen Address and ATN tell a device to listen to the data sent by the talker. Secondary addresses provide unique addresses for devices or functions that share a single listen or talk address. In the TEKTRONIX 7912AD Programmable Digitizer, for example, secondary addresses select among the mainframe and plug-ins, all of which share the same IEEE 488 bus interface.

The controller uses other kinds of interface messages for other tasks. One is the Serial Poll Enable command (SPE) used by the service request interface function. Suppose an instrument is designed to assert SRQ when it has acquired some data. The controller must poll the devices to find the interrupting device since any one (or more than one) can assert SRQ. To conduct the poll, the controller sends SPE, a universal command, and then addresses each device in turn and reads a status byte from each. If the device asserted SRQ, it can code the status byte to tell the controller why.

Parallel Poll Configure (PPC) is an example of an addressed command. It prepares addressed devices to indicate who is requesting service. When ready, the devices respond together; so a parallel poll is quicker than a serial poll, though more complicated.

Device trigger is another function that uses an addressed command: Group Execute Trigger (GET). It's up to the instrument designer to decide whether to use this function and for what purpose. This function is provided in the 7912AD to synchronize, when desired, a digitize operation with the GET command.

The controller issues the Device Clear message (DCL) to initialize internal functions of devices on the bus. A universal command, DCL, applies to all devices. Its effect on each instrument, however, is decided by the designer who can choose to initialize any device function to any state that suits the purpose of the instrument.

So far, in addition to reviewing some of the interface messages, we've used all the control lines except two, REN and IFC. These lines are reserved for the system controller. Just as the producer holds the ultimate authority in the theater, the system controller holds the ultimate authority on the bus with these two lines. Setting REN raises the curtain; that is, it enables remote operation of the devices on the bus. Releasing REN brings down the curtain; when REN goes false, all devices must return to local mode. IFC is used by the system controller to call a halt to action on the bus; talkers and listeners are reset to receive commands from the controller-in-charge, a role that automatically reverts to the system controller following an interface clear.

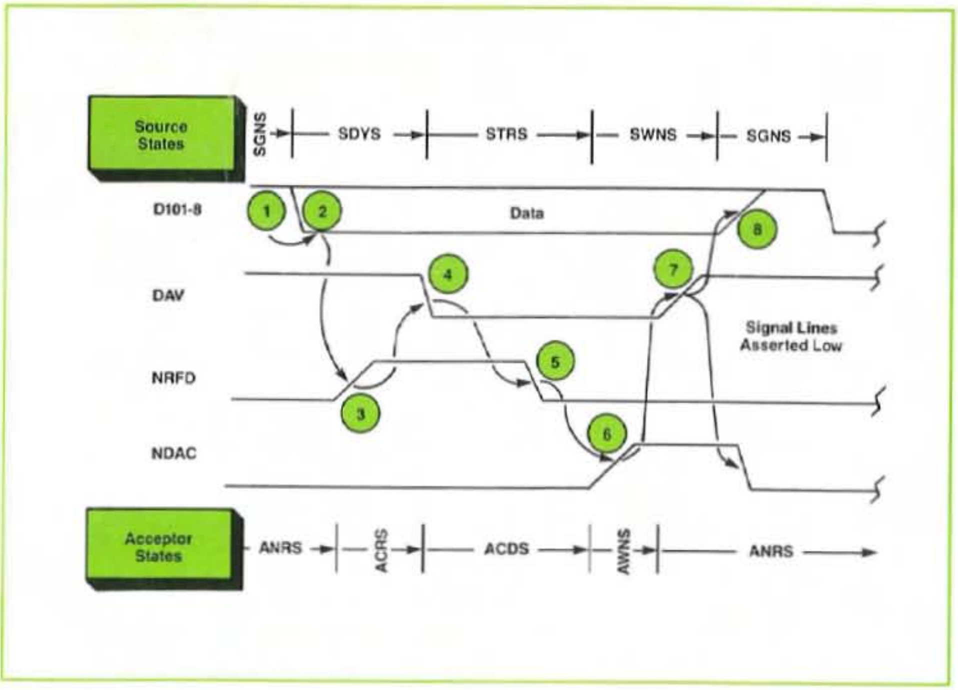


Fig. 2. Handshake sequence to move one byte from a talker to a listener. The numbers refer to steps described in text.

Adding it up

With this introduction to the IEEE 488 concept, let's add up the pluses and minuses for the system designer.

IEEE 488 is a parallel system. PLUS: Flexible configuration — it works, either in a star or linear configuration (Fig. 4). MINUS: Distance is limited in either configuration to 20 meters (about 65 feet). To maintain the bus electrical characteristics, a device load must be connected for each two meters of cable (no more than 15 devices connected). There's a fine point of etiquette here. Although you might expect devices to be spaced no more than two meters apart, they can be separated more if the required number of device loads are lumped at any point.

A variety of instruments can work together. PLUS: Both simple and complex instruments can be connected; they need only conform to the parts of the IEEE 488 standard they implement. You pay only for what you need. MINUS: Not all instruments include all functions. For example, not all instruments have the parallel poll function. The device trigger is another function that may be missing. At the end of a message, TEK instruments assert EOI when they finish talking; some others do not. They may send a special character or just quit talking, leaving it up to the controller to decide how long to wait before jumping in to take control.

Data freedom (or anarchy). PLUS: Designers are free to choose appropriate device-dependent messages. Even if instruments speak a different language, the standard allows them to be connected. MINUS: At least one of the instruments in a Talker/Listener pair must be smart enough to translate if the instru-

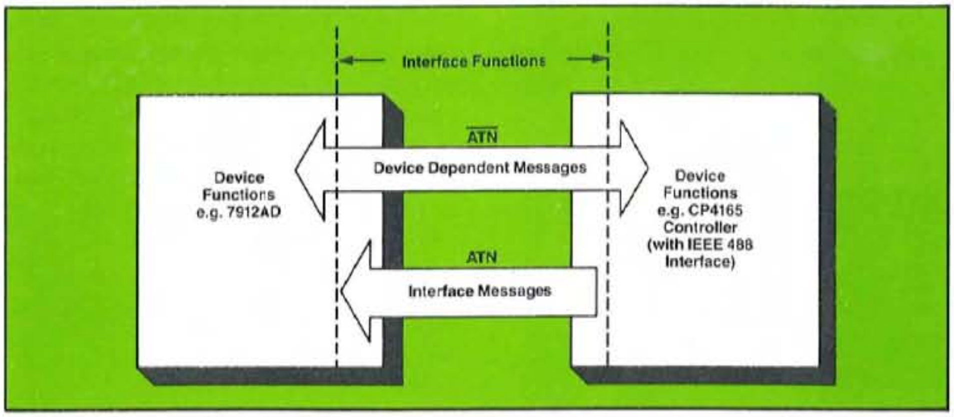


Fig. 3. The ATN line is used to distinguish between interface (system control) and device-dependent messages.

ments use different commands or formats. One voltmeter may switch to the 100 mV range when it receives a character string "VOL 100 E-3"; another may require, instead, a single ASCII character. The first instrument may send data in floating point decimal; the other in binary.

Asynchronous data transfer. PLUS: The handshake allows both slow and fast talkers to play together on the bus. MINUS: Everyone goes at the pace of the slowest device. As long as the race belongs not to the swift, but to the steady, that's all right. But that may mean a data rate of only 20 kilobytes per second, it may mean 10 kilobytes per second, or even less. Attention to design is required to get the device interfaces to go faster; it can be done, but it only takes one slowpoke to hold all devices back.

Common data byte size. PLUS: Eight bits is a useful size for data. It fits data processing that operates on words that are eight bits in length (or multiples of eight bits), as is often the case. MINUS: Eight-bit bytes are unhandy if your data happens to be nine bits wide, or your controller is a 12-bit machine.

Standard implementation. PLUS: The IEEE 488 electrical characteristics rely on the most common logic family — TTL. MINUS: The system is limited to medium speeds; ECL could go faster but doesn't fit the spec.

Making it play

There isn't room here to fit all the praise and blame heaped on the IEEE 488 standard to date. If you're trying to put together a system, you want to know if you can make it play. How can you select the right instruments and get them to speak to each other?

In many cases, the best answer is to let someone else do it for you. Buy the system, or at least the main components, from a single manufacturer who has already done the homework. For instance Tektronix offers the CP4165 Controller with an IEEE 488 interface and TEK SPS BASIC software to run an IEEE 488 system. Another all-in-one controller with an IEEE 488 port is the TEKTRONIX 4051 Graphic Computing System. Either way, you're off to a good start because the software that remains to be written amounts to filling in the blanks with commands and parameters specific to the instruments in the system. TEK SPS BASIC commands for TEKTRONIX acquisition instruments, such as the 7912AD, make it even easier with high-level software that needs no fill-ins.

Another advantage of buying from one manufacturer is that the system includes pieces that were meant to play together. Some of the minuses mentioned above are removed and some of the pluses enhanced.

But perhaps you want to put the system together yourself for any number of reasons. If doing it yourself includes designing an interface or writing extensive software, there's no way around reading the standard. Just as it's expected that a federal judge understands the Constitution, it's expected that an IEEE 488 designer understands the standard. It's dry reading, but it is thorough and complete. Be assured you'll eventually find the fine points. For instance, one more than half the number of instruments connected to the bus must be powered-up to maintain the bus termination. Some users found this out on their own when they discovered intermittents on the SRQ line, but they could have read it first in the standard.

The standard is thorough, but as designers continue to work with it, more questions are going to be raised. New design tools such as the 7D01 Logic Analyzer and DF2 Display Formatter, discussed elsewhere in this issue, will help answer some of these. Others may suggest topics for future articles on the standard.

*ANSI Standard *MC 1.1-1975* and proposed as an IEC standard. The interface system is often called the General Purpose Interface Bus (GPIB).

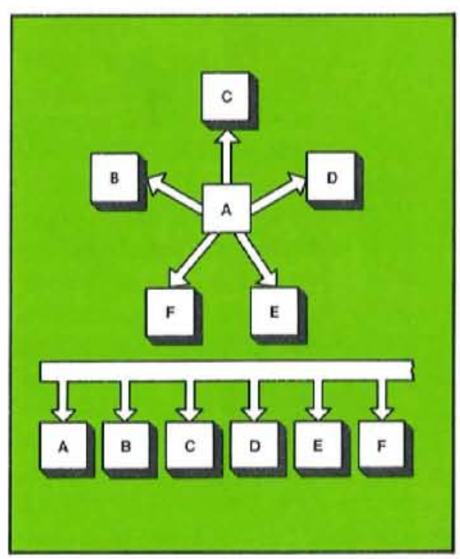
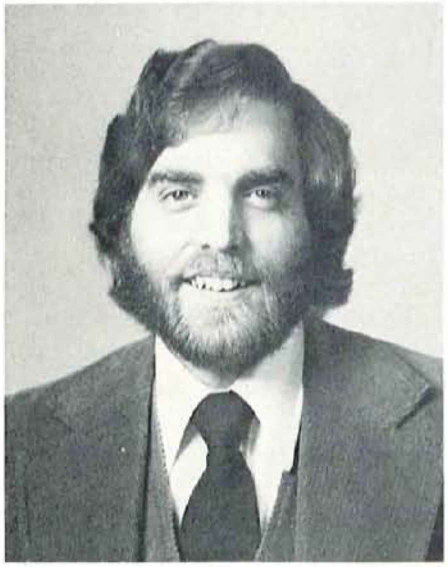


Fig. 4. An IEEE 488 system can be configured in either a star or a linear manner.

Pulse Generator or Function Generator? Making an Intelligent Choice



Bill Rasnake is well acquainted with customer needs, having served 4 years as a Tek field engineer. He continues to have frequent customer contact in his role in TM 500 Product Marketing. Bill has an Associate of Science degree from Victor Valley College in California, and served as an electronics instructor in the United States Air Force.

Versatility — the ability to do many things well — is basically a human characteristic. However, we often ascribe this virtue to instrumentation which can perform several functions or be used for many different jobs. When we consider buying a piece of test equipment and two instruments seem equally capable of doing our job, we usually choose the more versatile.

The 40-MHz TEKTRONIX FG 504 Function Generator and the 50-MHz PG 508 Pulse Generator often pose a dilemma for the potential pulse generator buyer. The comparison chart on page 14 gives a brief summary of the pulse generation characteristics of these two instruments. They are very similar in many respects and the difference in cost is small. The better choice might be obvious, but before deciding, let's consider some other factors:

What are the precise requirements for a pulse generator? Will these requirements change? Do we have other needs which the function generator would fulfill? What is the application for the instrument — production or engineering? Who will be using it — skilled or unskilled personnel?

The first question, of course, is the most important. While the pulse generation capabilities of the two instruments are similar, there are some important differences. We should examine these carefully to determine if both instruments can do our job, and what the tradeoffs may be.

Some important differences

Let's consider, first, how the two instruments generate pulses. The function generator produces a square wave which can be formed into a pulse by adjusting a front-panel symmetry control. The result is an output signal which maintains a relatively constant duty cycle with changing frequency. This is a very useful signal for checking the response of power amplifiers, pulse transformers, and other power sensitive devices without exceeding their dissipation limits.

The SYMMETRY control in the FG 504 varies the duty cycle of the square wave over a range of 7% to 93% for frequencies up to 4 MHz. Since the pulse width is a function of frequency, this imposes some operating constraints. For example, the narrower output pulses can be generated at an internally controlled repetition rate only at the higher frequencies. However, by triggering the FG 504 externally, pulse widths as narrow as 15 nanoseconds can be generated at repetition rates determined by the external trigger.

The pulse generator uses a different scheme for generating pulses. Separate circuits are used to determine period, or frequency, and pulse duration. This gives us the capability of generating constant width pulses independent of frequency — an important feature in working with logic and control circuits, and one usually preferred when working strictly with pulses.

The ability to complement the PG 508 output pulse makes it possible to achieve output duty cycles of 0%-100%, within 10 nanoseconds, the minimum pulse duration of the PG 508.

Figures 2 and 3 illustrate the change in pulse width and duty cycle with a change in frequency for both the function generator and pulse generator.

Delayed pulses

Another factor to be considered in choosing a pulse generator is pulse delay capability. Both the PG 508 and FG 504 have pulse delay capability but in quite a different sense. In the PG 508 you can select delays (65 ns to greater than 100 ms from an external signal) with a front-panel control, and operate the delay in any of three modes: pulse output delayed with respect to an external trigger input, pulse output delayed with respect to an internal trigger output, and a pulse output delayed with respect to an intitial pulse output. The latter is often referred to as double or paired pulse generation.

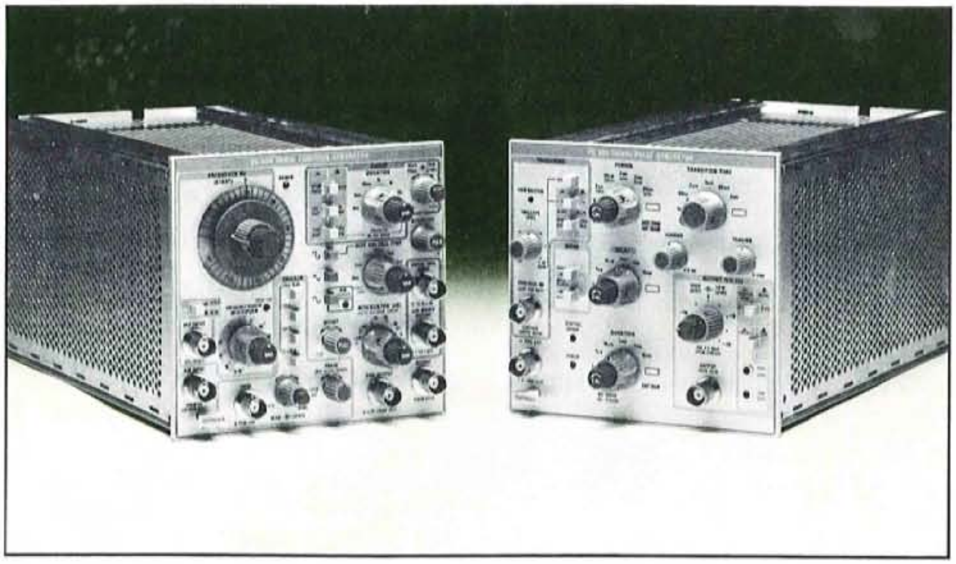


Fig. 1. Both the FG 504 Function Generator (left) and PG 508 Pulse Generator (right) offer a wide range of pulse capabilities. A thorough analysis of these capabilities may be necessary to detemine which instrument is best suited to your needs.

Paired pulses can be generated at selected repetition rates with the delay control determining the time between the two pulses.

Paired pulse operation is very convenient to use in evaluating a circuit's ability to differentiate between two closely spaced pulses.

In the FG 504, delay from an external signal can be achieved in several different ways. While not as convenient for pulse work as the delay capability in the PG 508, it has advantages for some applications. When the FG 504 main generator is operated in the triggered mode, the PHASE control can serve as a delay control covering a range equal to the pulse width being generated. The internal sweep generator also can serve as a source of delay. The sweep can be triggered externally and the sweep output connected via an external cable to the main generator trigger input. The LEVEL control then serves as the delay control. Delays from less than 10μs to greater than 100 s can be obtained at repetition rates to $\approx$ 5 kHz.

For many logic applications, the phase lock feature of the FG 504 also serves as a delay function. For example, the FG 504 can be triggered from, and locked to, the clock signal from a digital circuit. The PHASE control can then be used to control the start of the pulse output over a range of $\pm$90° with respect to the clock signal. This is a convenient means of generating a biphase clock.

Both the PG 508, with its delay capability, and the FG 504, with phase lock, are often used to generate muliphase clocks. The latter offers an advantage in operating convenience when used to generate the second, third, or fourth phase. The master clock frequency can be varied over a wide range and the phase-locked FG 504 will follow without major readjustment other than occasional range switching.

Pulse shaping capabilities

In many applications, the ability to adjust pulse rise and fall times is very important. For example, typical rise and fall times vary widely between logic families. If we are to accurately simulate logic circuit transactions, variable rise and fall times are a must.

Faster-than-specified drive signals can cause problems through capacitive coupling to adjacent circuitry. Conversely, slower-than-specified drive signals to a CMOS gate will cause its dissipation to increase greatly during each transition. Adjustable rise and fall times let us avoid these undesirable conditions.

Controllable rise and fall times are also useful in determining the characteristics of edge-triggered devices.

The fastest rise and fall times in the PG 508 and FG 504 are nearly the same — 5 ns and 6 ns, respectively. Both have adjustable rise and fall times, but with an important difference. In the PG 508, rise and fall time can be adjusted independently. In the FG 504, one control adjusts both at the same time. Each has advantages depending on the application. A single control is more convenient when simulating limited bandwidth. On the other hand, independent controls permit simulation of conditions where rise and fall times are unequal, such as in circuits having unequal slew rates or unequal

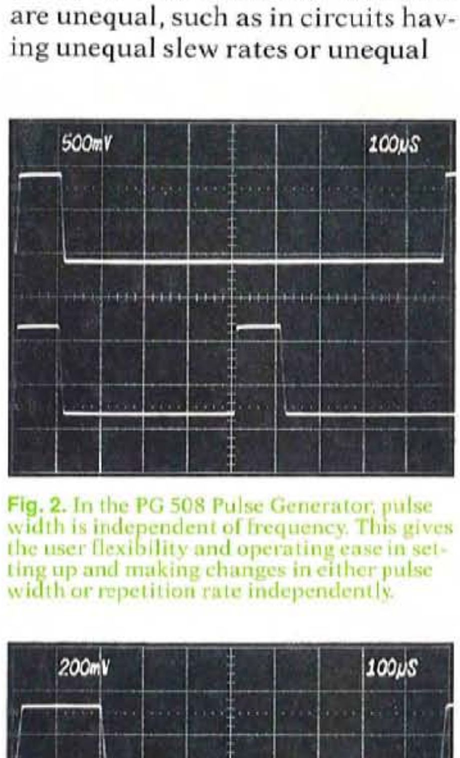


Fig. 2. In the PG 508 Pulse Generator, pulse width is independent of frequency. This gives the user flexibility and operating ease in setting up and making changes in either pulse width or repetition rate independently.

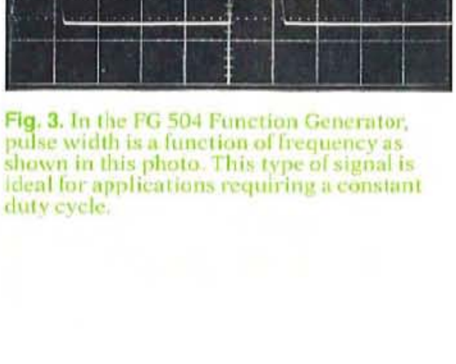


Fig. 3. In the FG 504 Function Generator, pulse width is a function of frequency as shown in this photo. This type of signal is ideal for applications requiring a constant duty cycle.

output impedances to rising and falling signals.

Pulse output voltage capability

One of the most important factors to be considered when purchasing a pulse generator is its output capability. It would appear from the comparison chart on page 14 that the FG 504 has a higher amplitude output capability than the PG 508. Let's take a closer look. Note the seeming contradiction between the peak-to-peak signal output capabilities and the unipolar output capabilities.

A unipolar pulse is one which does not cross ground. Both the PG 508 and FG 504 can generate unipolar pulses. But here again there are important differences in how they are achieved.

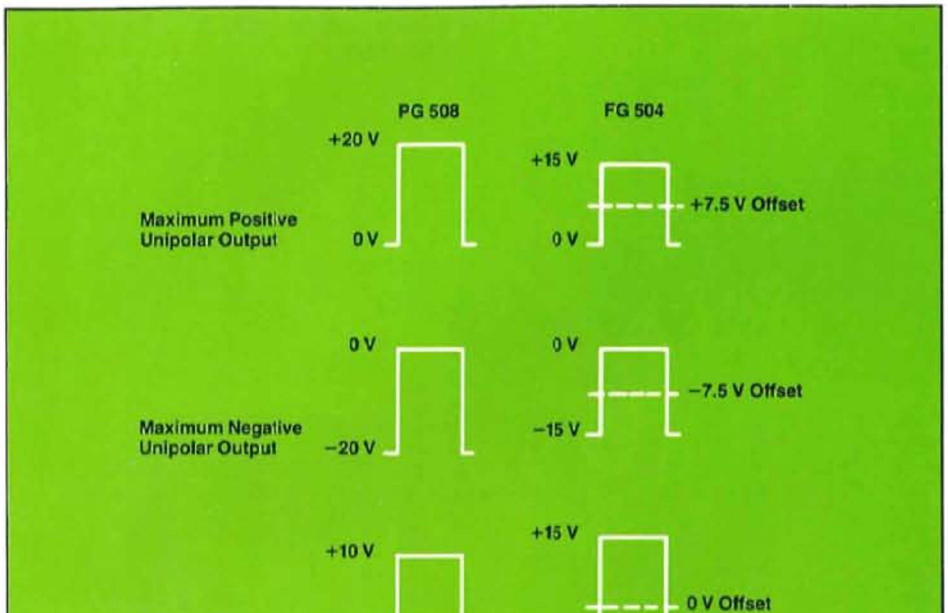


Fig. 4. Maximum unipolar and bipolar pulses obtainable with the PG 508 Pulse Generator and FG 504 Function Generator.

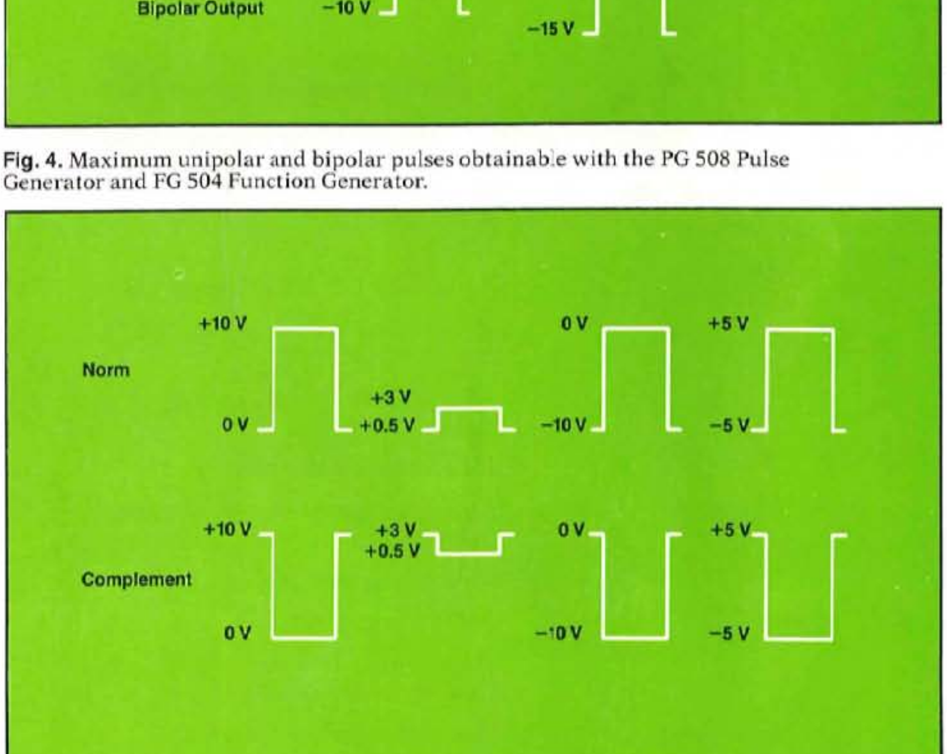


Fig. 5. Typical output pulse waveforms of the PG 508 Pulse Generator illustrating versatile output level control. Front-panel pushbutton complements the output pulse.

On the PG 508, independent HIGH LEVEL and LOW LEVEL controls allow you to precisely set the output pulse over a range of ±20 volts. Thus, it is a simple matter to set up either positive or negative unipolar pulses up to 20 volts in amplitude (see Figure 4). The ability to set the output levels precisely is a great convenience for many logic applications such as measuring noise immunity or rapidly setting the output to actual logic levels.

The output of the FG 504, on the other hand, normally swings ±15 volts around ground, and attenuator and offset controls are used to achieve the desired pulse amplitude and level. The OFFSET control range is ±7.5 volts which allows us to achieve a unipolar pulse 15 volts in amplitude.

The constant amplitude output with post-attenuator offset provides an ideal signal for determining comparator or logic thresholds, and also for determining optimum amplifier bias voltages.

The PG 508 has provision for presetting the output voltages, a time-saving convenience in many instances. For example, if you are working regularly with a particular logic family, the preset controls can be set for that logic family and be available simply by pressing a front-panel pushbutton. The output voltages can also be made to track an external voltage — a safety feature for some CMOS applications where the device can be damaged if the driving signal exceeds supply voltage.

Another convenience feature on the PG 508 is the ability to obtain the complement of the output pulse simply by pressing a front-panel pushbutton (see Figure 5). This is particularly useful in logic testing where a pulse going in the opposite direction is often needed.

Clean 50 Ω source.

An important specification to check when evaluating pulse output

A Comparison of the PG 508 Pulse Generator and the FG 504 Function Generator.

Similar Features

Similar Features	PG 508	FG 504
Output Frequency	50 MHz	40 MHz
Output Amplitude	1 V-20 V p-p from 50 Ω ±20 V Window	0.1 V-30 V p-p from 50 Ω ±20 V Window
Unipolar Output	20 V Max	15 V Max
Rise and Fall Time	5 ns	6 ns
Minimum Pulse Width	10 ns	15 ns
External Trigger/Gate	50 MHz	20 MHz
Output Source Impedance	Low Reactance 50 Ω	Low Reactance 50 Ω
Custom Timing Positions	Yes	Yes
Counted Burst Output (with DD 501 Digital Delay)	Yes	Yes

Unique Features

PG 508	FG 504
Constant pulse width with changes in frequency	Constant duty cycle with changes in frequency
Delay and double pulse	Phase lock to an external signal with phase control adjustment
High/Low level output voltage controls	Attenuator and offset controls
0% to 100% duty cycle (within 10 ns)	7% to 93% duty cycle (to 4 MHz)
Independent rise/fall time control with 100:1 range	Simultaneous rise/fall time control
External control of output voltage	Attenuator to 100 mV amplitude
Selectable 1 MΩ/50 Ω trigger/gate input impedance	10 kΩ trigger/gate/phaselock input impedance
±3 V, ± slope, trigger controls	−1 V to +10 V, + slope trigger control.
Complement pulse output	Haversine or $\sin^2$ pulses
3-state trigger light	Triangle/ramp output, Sinewave output
Control error light	Repetition rate to 0.001 Hz
Preset High/Low level output controls	AM/FM modulation
	Triggerable Lin/Log sweep with Linear Sweep output.
	Waveform hold below 400 Hz

amplitude is the load into which the output is specified. Both the PG 508 and FG 504 are designed to provide a clean 50 Ω source. Thus, it is not necessary to terminate the output cable into 50 ohms for many applications. This makes the full output voltage available to drive MOS, CMOS, and other high impedance devices that require larger amplitude signals.

Burst capability

Both the PG 508 and FG 504 can provide gated pulse bursts. This is a very useful feature for applications such as loading shift registers and counters, or simulating serial data.

For some operations, simply gating the generator on with an external pulse is adequate. For those applications where the number of bits (pulses) must be accurately controlled, the DD 501 Digital Delay unit may be used with the PG 508 or FG 504 to provide such a capability up to 100,000 pulses.

The number of pulses desired in the burst is dialed up on the DD 501, and the delayed trigger output from the DD 501 is used to gate the PG 508 or FG 504. A jumper inside the DD 501 converts the DELAYED TRIGGER OUT to a delay interval gate for this application.

Some unique capabilities

We have seen that both the PG 508 and FG 504 can perform similar pulse functions. There are, however, operating differences and functional differences that may make one or the other more suitable for your needs. Both have additional capabilities that you should consider before making a final decision.

The PG 508 triggering section has some features particularly well suited to logic applications. A 3-state trigger light tells you whether the input trigger signal is above or below the TRIGGER/GATE LEVEL control setting, and flashes when the PG 508 is being triggered. It, thus, can serve as a logic probe as well as being an operating convenience. The PG 508 can be triggered on either the plus or minus slope of the trigger signal. Trigger input impedances of 50 Ω and 1 MΩ are selectable by an internal switch.

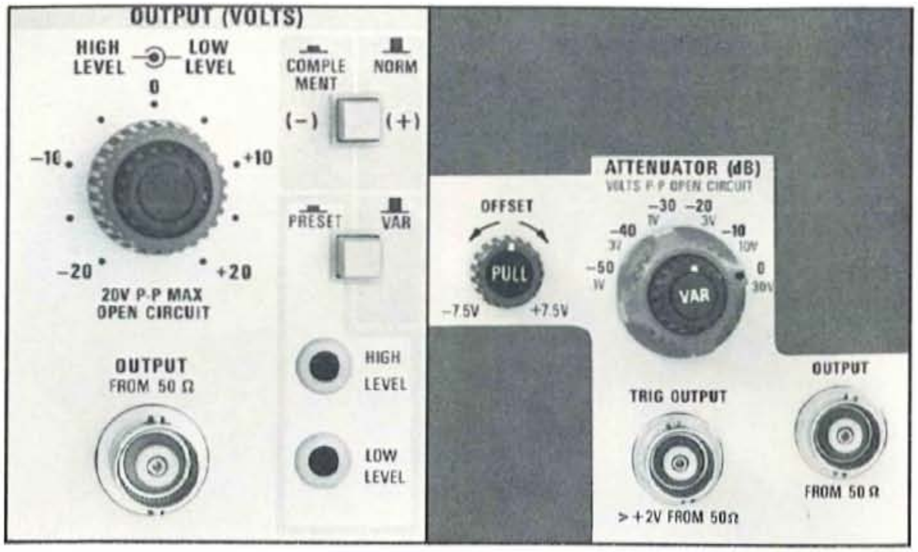


Fig. 6. A comparison of the output sections of the PG 508 Pulse Generator (left) and the FG 504 Function Generator (right) reveals some important differences in the output capabilities of the two instruments.

The FG 504 can only be triggered from a positive going signal, but the LEVEL control has an extended range of −1 V to +10 V, ideal for triggering from ramps. The VCF input on the FG 504 can be used to externally frequency modulate the generator providing pulse width modulation or jitter simulation capability.

There are two other features on the PG 508 which we should discuss. A CONTROL ERROR light indicates when the setting of any one of nine controls conflicts with the setting of another. If there is a timing conflict, for example, DURATION exceeds PERIOD, the light will flash. If there is a mode conflict, for example, SQ WAVE DURATION and DELAY pulse mode selected simultaneously, the light will come on steady.

The DURATION control on the PG 508 has an EXT DUR position. In this mode, the PG 508 serves as a pulse amplifier. The output signal will be of the same duration as the trigger input signal, with the output amplitude and levels determined by the output controls. This is a convenient mode to use in converting from one logic family to another. The rise and fall time controls remain operable in this mode allowing you to simulate precisely, or change, the rise and fall times of the incoming signal.

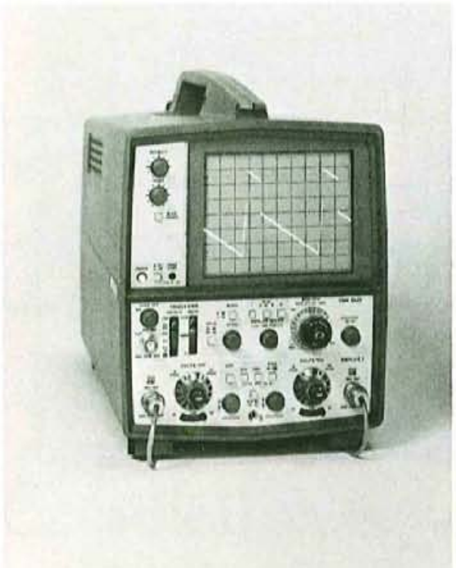
The FG 504, in addition to its pulse generation capabilities, offers all the versatility of a high performance function generator: a wide range sweep generator that provides logarithmic and linear sweeps; sine, haversine, $\sin^2$, square, and triangle waves; variable symmetry and rise time controls; amplitude and frequency modulation; phase lock operation; independent selection of start and stop frequencies for swept applications; and very low output frequencies to 0.001 Hz.

Conclusion

For the most part, pulse generators are the easiest to use when pulses are your only requirement. On the other hand, high quality function generators which include pulse capabilities suitable for digital logic and other applications offer greater versatility. One should carefully consider these and other differences before deciding which instrument is best suited to his or her needs.

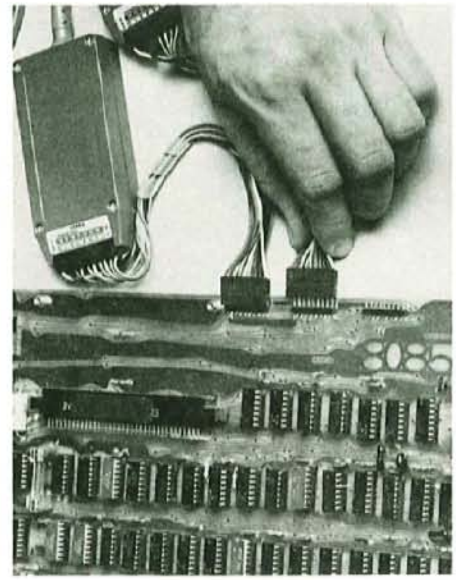
New Products

The T935A Portable Oscilloscope



The New C-5B Oscilloscope Camera

Harmonica Connector to Logic Probe Adapter



Two New T900-Series Oscilloscopes

The new T932A and T935A combine features previously not found together in low-cost instruments — including dual trace, differential display, versatile triggering capabilities, full sensitivity x-y and variable trigger holdoff.

The T932A boasts a 35-MHz bandwidth at 2 mV/div and 10 ns/div sweep rate with X10 magnification control. The T935A, identical in all these respects to the T932A also has delayed sweep capabilities.

Like the other T900 family members (with bandwidths starting at 10-MHz), the T932A and T935A are reliable, low-cost instruments well suited for education, consumer electronics repair, and other general service applications. Features like color-coded front panels, a beam finder, built-in delay lines, and a large 8 x 10 cm crt are designed to make accurate scope measurements easier than ever.

Low-cost Crt Camera Features Electric Shutter and Sharp Three-Element Lens.

The new C-5B Oscilloscope Camera is an improved version of our popular model C-5A. The camera now features a reliable electric shutter with speeds from 0.1 to 5 seconds and an improved fixed-focus, three-element, f16 lens.

The C-5B, with its interchangeable adapter hoods, mounts easily to the crt bezel of most TEKTRONIX oscilloscopes and small monitors. All adapter hoods have an opening in the top for a lift-up viewing door or a Xenon flash unit (to illuminate the crt on instruments without built-in graticule illumination). The flash unit has a flipdown viewing door.

The C-5B is the perfect camera for those requiring waveform photography on a limited budget and who don't need the more-sophisticated features of other TEKTRONIX cameras, such as single-sweep recording capability. It is especially recommended for use with the low-cost TEKTRONIX T900-Series Oscilloscopes.

New Logic Probe Adapter Speeds Multi-Pin Connection

Tektronix' new 10-Pin Harmonica Connector provides efficient, time saving plug-in capabilities for the P6451 Probe, used with the 7D01 and LA501 Logic Analyzers. The Harmonica Connector's circuitry terminal eliminates the time consuming mechanics of attaching connectors individually. This feature gives convenient access to data during development, manufacturing, and service of circuitry designed to accommodate the .025-inch square pins of the Harmonica Connector's plug. Also, the probe head terminal attaches quickly and easily to the P6451 Probe. The patented 10-pin Harmonica Connector contains one ground, one clock or qualifier, and eight data lines.

Prices of these products are shown on the inquiry card in the centerfold. Use the card to request further information or a demonstration.

4/78
A-3921

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

0421867 1339
MR THOMAS P DOWNEY LAB TECH
GEOLOGY DEPT EPS-J106
CITY COLLEGE OF NEW YORK
138TH ST. & CONVENT AVE.
NEW YORK CITY NY 10031

BULK RATE
U.S. POSTAGE PAID
TEKTRONIX, INC.

An Ultra-Stable Precision Demodulator for the Television Broadcaster

A 24 MHz Nyquist SAW Filter for the 1450 Demodulator

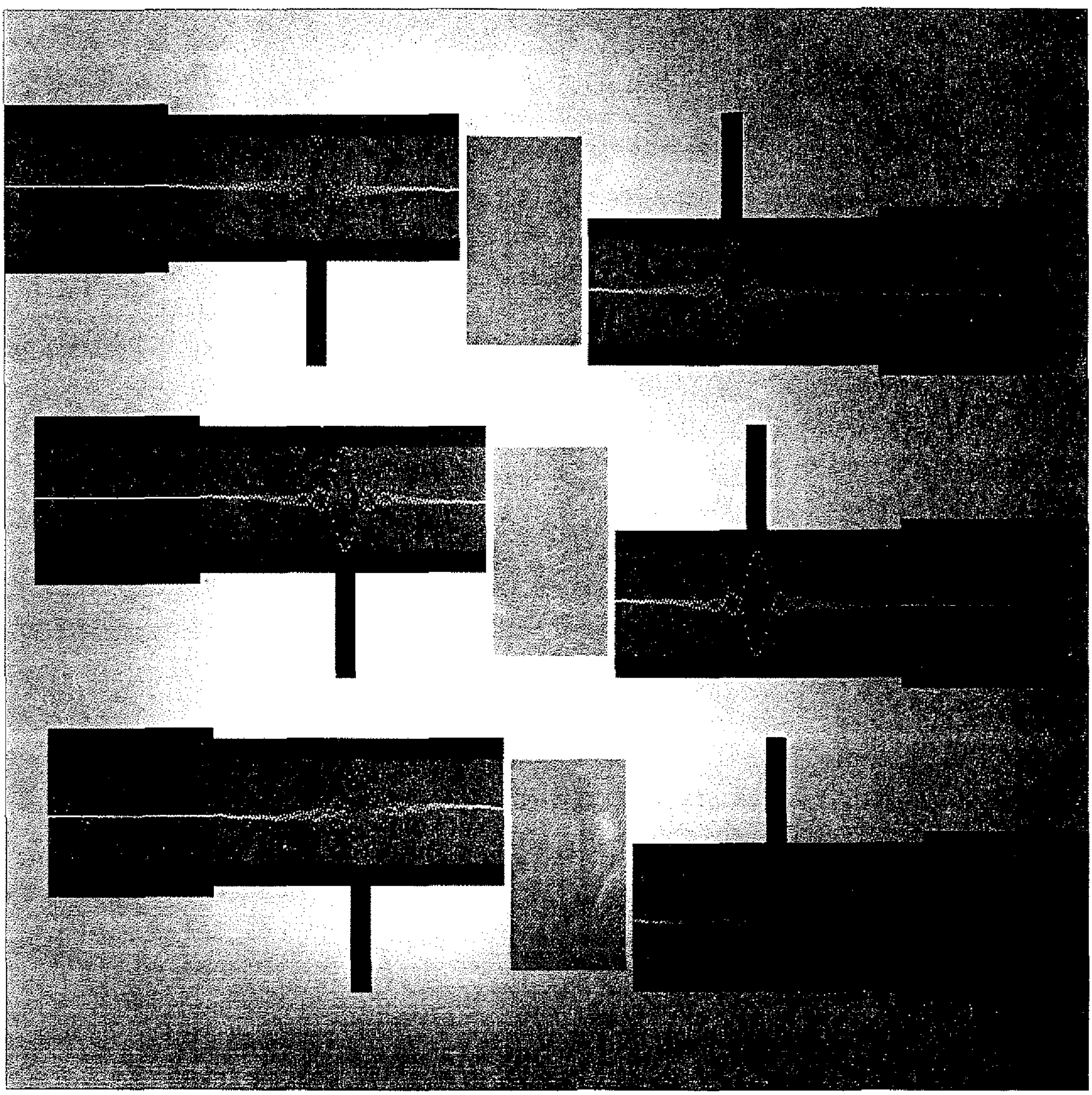
Spectrum Analyzer Applications in Baseband Measurements

New Products

Volume 10
Number 3

1978

Tekscope



Tektronix®
COMMITTED TO EXCELLENCE

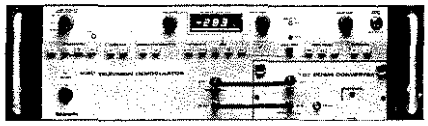
CONTENTS

Tekscope

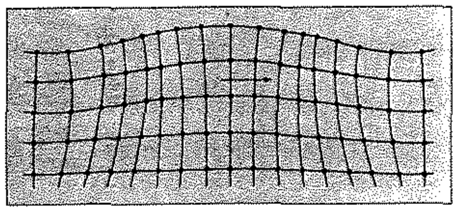
Customer information from
Tektronix, Inc.
Beaverton, Oregon 97077

Editor: Gordon Allison

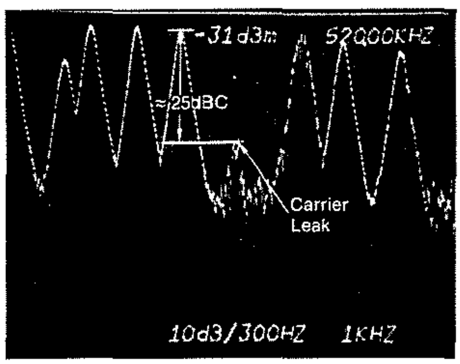
An Ultra-Stable Precision Demodulator for the Television Broadcaster
Innovative circuit and component design is focused on producing a "transparent" demodulator for measuring the true performance of the television transmitter.



Spectrum Analyzer Applications in Baseband Measurements
There are a host of baseband measurements the spectrum analyzer can make, in addition to the usual checks for spurious responses and intermodulation distortion.



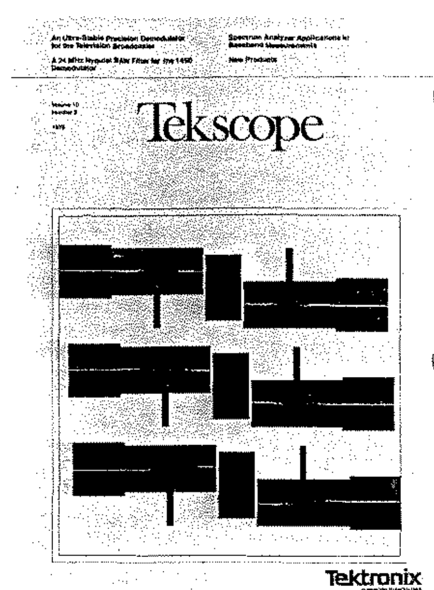
A 24 MHz Nyquist SAW Filter for the 1450 Demodulator
A brief overview of SAW devices, how they work, and how they are used in the 1450 Demodulator.



Tekscope is a bimonthly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique. A new products section gives a brief description of products recently introduced and provides an opportunity to request further information.

To better serve customers who maintain their TEKTRONIX instruments, the service information formerly appearing in Tekscope will be expanded and published in a publication dedicated to the service function.

Cover: The finger pattern on the SAW filter substrate is fine enough to serve as a diffraction grating as depicted in this photo of a photomask containing three SAW filter patterns.



An Ultra-Stable Precision Demodulator for the Television Broadcaster

Steve Roth has been with Tek since 1965 and has applied his talents to designing television products during this time. He participated in design of the 520 Vectorscope, the 140 Series generators, and the 650 Series color monitors; he is Project Leader for the 1450 Series. Steve has five patents on television circuitry. He received his BSEE in 1964 from Oregon State University.

The quality of the television picture we view in our homes is vastly improved over that of just a few years ago. Technical innovations in both broadcasting and receiving equipment have brought about this improvement.

In the forefront of these developments have been advances in our ability to measure and analyze the television broadcast signal. Precision demodulators play an important role in this measurement capability. As the major link between the transmitted television signal and the baseband (video) measuring equipment, it is essential that the demodulator itself not introduce distortion in the demodulation process. However, three serious problems occur in today's demodulators that make it difficult to achieve and maintain this level of performance—quadrature distortion caused by envelope detection; poor long- and short-term stability of tuned circuits caused by mechanical and thermal shock; and changes in bandwidth characteristics as a function of gain.

In the new TEKTRONIX 1450 Demodulator, these problems have been overcome with new technology and new components. The use of synchronous detectors resolves the quadrature distortion problem. Surface acoustic wave (SAW) filters and low-loss, temperature stable, discrete filter elements minimize the effects of mechanical and thermal shock. And constant gain amplifiers coupled with programmed PIN diode attenuators produce constant bandpass characteristics over a wide range of input signal levels.

Design goals

Versatility and high performance are often considered conflicting goals. Both were set for the 1450. Measurement of signals at the transmitter site and remotely off the air were to be made with no changes occurring in bandpass characteristics. Need for external attenuators was to be eliminated or minimized. Measurement of both visual and aural signals was to be provided for, and video and audio outputs suitable for rebroadcast were to be supplied. Ease of both initial calibration and field maintainability were to present a marked improvement over other available demodulators. These and other goals were coupled with a rigid set of specifications to define a demodulator that would set a new standard for the broadcast industry.

Plug-in down converters

The 1450 consists of two major assemblies—a mainframe containing the power supplies, IF, video, and audio circuitry; and a television down converter (TDC) which is a plug-in front end dedicated to the customer's channel frequency. The Standard Broadcast System M TDC converts the RF input signal to the 45.75 MHz visual IF. An optional System M TDC is also available for the 37 MHz IF, and customizing to other frequencies in that system is possible.

RF input signal levels from −69 dBm to −3 dBm can be fed directly to the input of the TDC. For stronger signals, an attenuator in the mainframe extends the maximum input range (in 10 db steps) to +27 dBm.

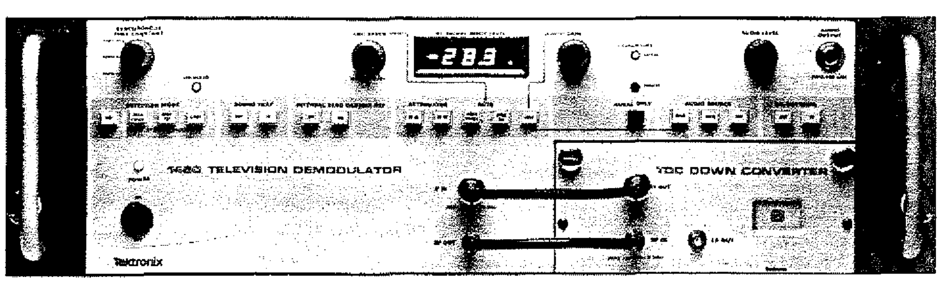


Fig. 1. The 1450 NTSC Television Demodulator. The plug-in down converter customizes the 1450 to any VHF or UHF channel frequency.

The attenuator is a slab-line, thick-film device which, in addition to attenuation, provides a clean 50 Ω load for the incoming signal and a 50 Ω source for the filter that follows.

From the input attenuator, the signal goes to a front-panel connector where it can be easily patched to the RF Input of the TDC. The TDC is housed in a milled aluminum housing with several compartments providing essential shielding between circuits.

A block diagram of the TDC is shown in Figure 2. In the TDC, the signal encounters the first of two ndpass filters tailored to the annel frequency for which the TDC is designed. Each filter consists of two helical resonators, with adjustable capacitive coupling (see Figure 3). The helical center conductor consists of a selected number of silver-plated tungsten turns which are applied to a ceramic core, using thick-film techniques. The result is a low-loss filter with excellent temperature stability.

The first of three PIN-diode attenuators that make up a calibrated AGC system is located in the TDC. Each attenuator is controlled by a PROM tailored to the particular attenuator and its operating environment. Each provides 21.7 dB of attenuation in 0.7 dB steps. With the 1.4 dB obtained in the analog AGC, a total of 66 dB of attenuation is realized.

Following the PIN attenuator, the signal gets a 16 dB boost from a wideband (50 MHz-900 MHz) amplifier and passes through the second filter to the first mixer. Eight Schottky diodes are used in the ring mixer which converts the RF signal to the IF signal. An 8-diode ring is used instead of the usual 4-diode ring to provide better intermodulation performance.

The first local oscillator (L.O.) is a voltage controlled oscillator (VCO) operating at a frequency equal to the RF input plus the IF. The VCO uses a quarter-wave helical resonator (with the same temperature-stable construction used in the bandpass filters) as the frequency determining element. The use of a VCO and a sampling phase lock loop yields the stability of a crystal oscillator, yet requires only seven crystals to cover all VHF and UHF channels. Transmitters using ±10 kHz offset frequencies are also easily accommodated. The 6-MHz crystals drive a snap-off diode frequency-comb generator which, in turn, drives the phase detector. The helical resonator in the VCO is tuned near the desired L.O. frequency and then locked to the appropriate 6 MHz spur. Pull-in range of the VCO is ≈ 1 MHz with a phase lock loop bandwidth of about 20 kHz.

As a result of the use of a single crystal to lock to more than one channel, the first IF may be off-frequency by as much as 100 kHz for some channels. The mainframe circuitry is designed to handle offsets of up to 250 kHz. (The converter L.O. is adjusted to compensate for such offsets before the SAW filter is encountered.)

The output of the first L.O. is amplified to about +20 dBm before being applied to the ring mixer, to assure good intermodulation performance. A variable attenuator at the output of the mixer provides an adjustment to normalize the TDC's gain for interchangeability.

The IF chain

In the basic 1450 System M configuration, the IF chain is designed to function at the 45.75 MHz visual IF, with 37 MHz being an option. It can also be custom-configured to other IFs for those who wish to measure and analyze the intermediate outputs of an IF-modulated transmitter.

The IF circuitry must handle a wide range of input signal levels (−20 dBm to −64 dBm) and yet maintain a constant bandpass. This is accomplished by operating the amplifiers at a constant gain and providing gain control with variable attenuation between stages. PIN diode attenuators similar to that used in the TDC are located ahead of the second and third IF amplifiers and provide up to 44 dB of AGC. (The attenuator in the TDC adds another 22 dB of attenuation for a total AGC range of 0 to 66 dB.)

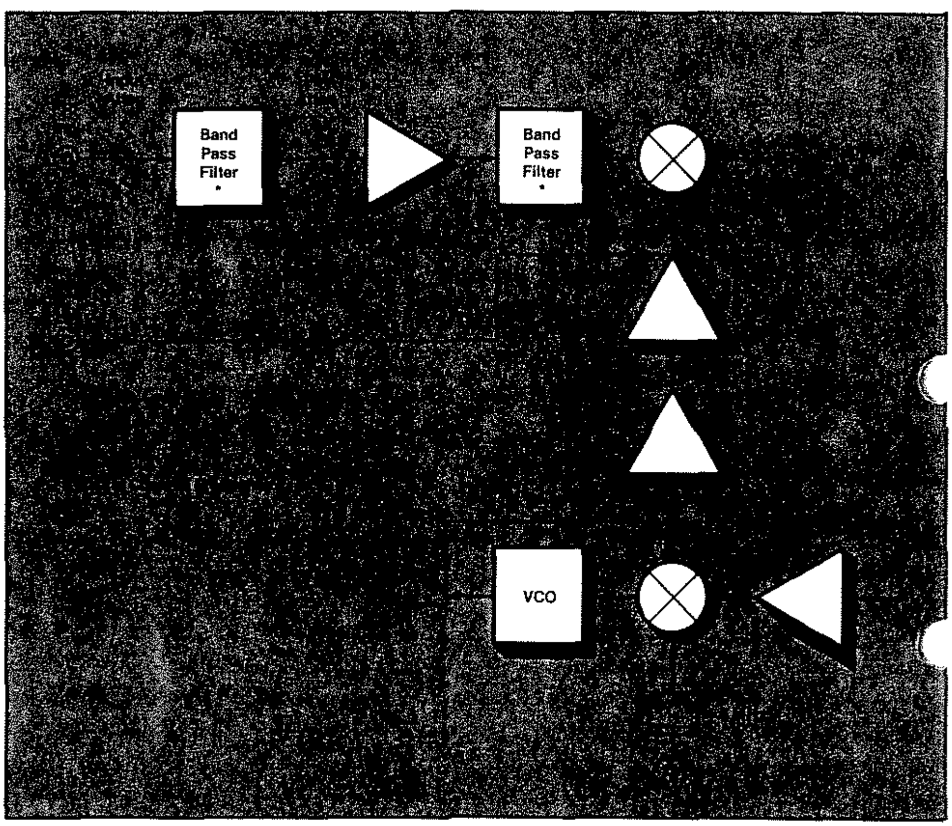


Fig. 2. Block diagram of the down converter. The use of a VCO permits all 83 channels to be converted using only seven crystals. The 0-30 dB input attenuators and AGC attenuators permit operating amplifiers at constant gain over a wide dynamic range of input signals.

The 1450 provides a calibrated digital readout of the input power level, permitting the instrument to serve as a field strength meter with an accuracy of ±1 dB and a resolution of ±0.1 dB. Accordingly, the currents in the attenuator diodes must be set precisely, and differences in diode characteristics must be compensated for. Adjustments are accomplished through digital control of the diode currents. During the calibration process, each attenuator is characterized and the respective values are digitized and burned into PROMs. The PROMs then control digital to analog converters that generate the required diode currents.

A simplified block diagram of the AGC circuitry is shown in Figure 5. Selection of AGC, and selection of back porch or sync tip as the AGC reference level are accomplished by means of front panel controls. For AGC, the video output level is sampled at the selected time and applied to a tracking analog-to-digital converter. The output of the converter drives the decoder which, in turn, controls the PIN diode drivers. Both the PROMs and the digital-to-analog converters are contained in the PIN diode drivers. Fine AGC is applied to the IF post amplifier to fill in between the 0.7 dB steps of the PIN diode attenuators.

The speed of the AGC loop can be set also by a front-panel control to allow the operator to either observe (SLOW mode), or eliminate (FAST mode), variations in input signal levels such as hum modulation or airplane flutter.

AGC circuitry also supplies control signals to actuate alarms in case of loss of the visual or aural carrier.

After the gain control section, the IF signal is converted to 24 MHz and filtered to remove extraneous mixer output signals. The IF converter mixer is a conventional ring diode mixer, with care taken to maintain a high degree of balance in the mixer.

The filtered 24 MHz signal goes to the SAW filter preamplifier, and to a pick-off amplifier having relatively high input impedance, to provide the Aural IF signal.

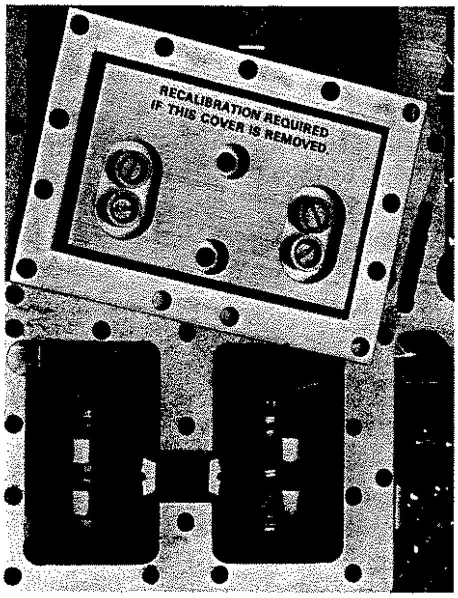


Fig. 3. The RF input bandpass filter consists of two helical resonators capacitively coupled. The helical center conductor is a series of silver-plated tungsten turns applied to a ceramic core using thick-film techniques. The result is a low-loss filter with excellent temperature stability.

The SAW filter

Some of the most significant improvements in performance achieved by the 1450 result from the use of SAW[1] filters to obtain the desired Nyquist slope characteristics. Conventional discrete-element Nyquist filters are complex devices difficult to adjust and maintain.

Two Tek-designed and manufactured SAW filters are used in the IF chain. A wideband unit is used for making out-of-service measurements with only the visual carrier on. A narrow band unit (which attenuates the aural carrier by greater than 50 dB) is used for making in-service measurements with the aural carrier on.

SAW filters offer several advantages over discrete-component designs: The desired bandpass characteristics are more easily achieved. For example, in the 1450, the Nyquist slope incorporates the S-shape characteristics which are in the new Demodulator Standards being prepared by the EIA. (see Figure 6). The filter requires much less space. There are no calibration adjustments. And the filters' characteristics do not change with mechanical or thermal shock.

However, along with the advantages, the SAW filter concept offers several design challenges. While relative response characteristics remain constant with changes in temperature, the absolute frequency does not. A SAW filter is also difficult to drive. It requires low driving and load impedances ($\approx 10\ \Omega$) and has an insertion loss of about 30 dB. This insertion loss, and the fact that the ultimate rejection desired is greater than 60 dB, means that greater than 90 dB of isolation between input and output is required to achieve the desired 1450 Demodulator performance. (This isolation is equivalent to putting in a megawatt of power and being able to receive only one milliwatt.)

The excellent performance of the SAW filter made the design challenges worth tackling. The temperature-induced change in operating point was resolved by placing a temperature sensor near the filter to generate a correcting signal for the converter L.O. And extensive shielding techniques at the input and output of the filter eliminated the undesired coupling.

The phase lock section

A simplified block diagram of the phase lock section is shown in Figure 7.

The VCOs for the converter L.O. and the reference L.O. have to meet two conflicting requirements—low phase noise generation and wide pull-in range capability. Phase noise must be low because any phase variations in these oscillators are added directly to the overall detected signals. This could obscure the phase measurements that the 1450 can provide. Wide pull-in range is needed to accommodate the ±100 kHz variation in the incoming IF, and also to thermally track the SAW filter.

The response time of the reference L.O. phase-control loop is made

[1]See article entitled "A 24 MHz Nyquist SAW Filter for the 1450 Demodulator" in this issue.

selectable so that phase errors in the incoming signal can be displayed and measured (SLOW mode) or tracked out and either eliminated or reduced (FAST mode).

The VCOs that comprise the converter L.O. and the reference L.O. are of similar design. Both are composite oscillators, combining the low phase noise of a crystal-controlled oscillator (XCO) with the wide pull-in range of an LC oscillator.

In both cases, the VCO output is compared to that of an XCO, and the resulting difference is converted to a correction signal by a pulse-count discriminator. The discriminator aids in achieving a rapid lock by supplying a large correction signal when the VCO is considerably off-frequency, and a progressively smaller correction signal as lock is achieved. This correction signal is used to balance out the voltage control signal.

The frequency lock circuitry of the reference VCO also accepts a correction signal from a temperature sensor to allow for temperature tracking of the SAW filter characteristics.

The reference L.O., through the temperature compensation, is kept at exactly the frequency to which the incoming IF signal must be converted, to pass through the SAW filter properly. The limiter output, because it is the same frequency as the converted IF signal, is then compared to the reference L.O. Any frequency difference between the two signals is representative of the frequency shift that must be obtained from the converter L.O. to bring the converted IF signal "on frequency".

The frequency lock system, however, does not have the capability of responding to fast phase disturbances in the incoming RF signal. The reference L.O./converter L.O. phase lock must work through the SAW filter which has about 7 microseconds of delay. This limits the rate at which corrections can be applied to that loop.

This difficulty is overcome by providing a method of shifting the phase of the reference L.O. so that it can track phase irregularities in the visual signal. Absence of delay or storage elements in this control loop allow the phase to be changed as rapidly as desired.

The correction signal for the phase shifter is derived by sampling the output of the quadrature detector during some "resting time", such as backporch or sync tip (front panel selectable). Since the output of the quadrature detector should be zero at those times, it can be used as the control signal for the phase shifter. (A continuous mode of correction is also available by front panel selection, if desired.) The control loop will adjust the phase of the reference L.O. to make the output voltage of the quadrature detector be zero at the selected time.

The limiter

The limiter plays an important role in the second L.O., video detector, and aural functions and has some stringent requirements. It must accommodate a wide range of signal levels (up to 40 dB with modulation), yet introduce less than one degree of phase shift, at frequencies approximating 24 MHz.

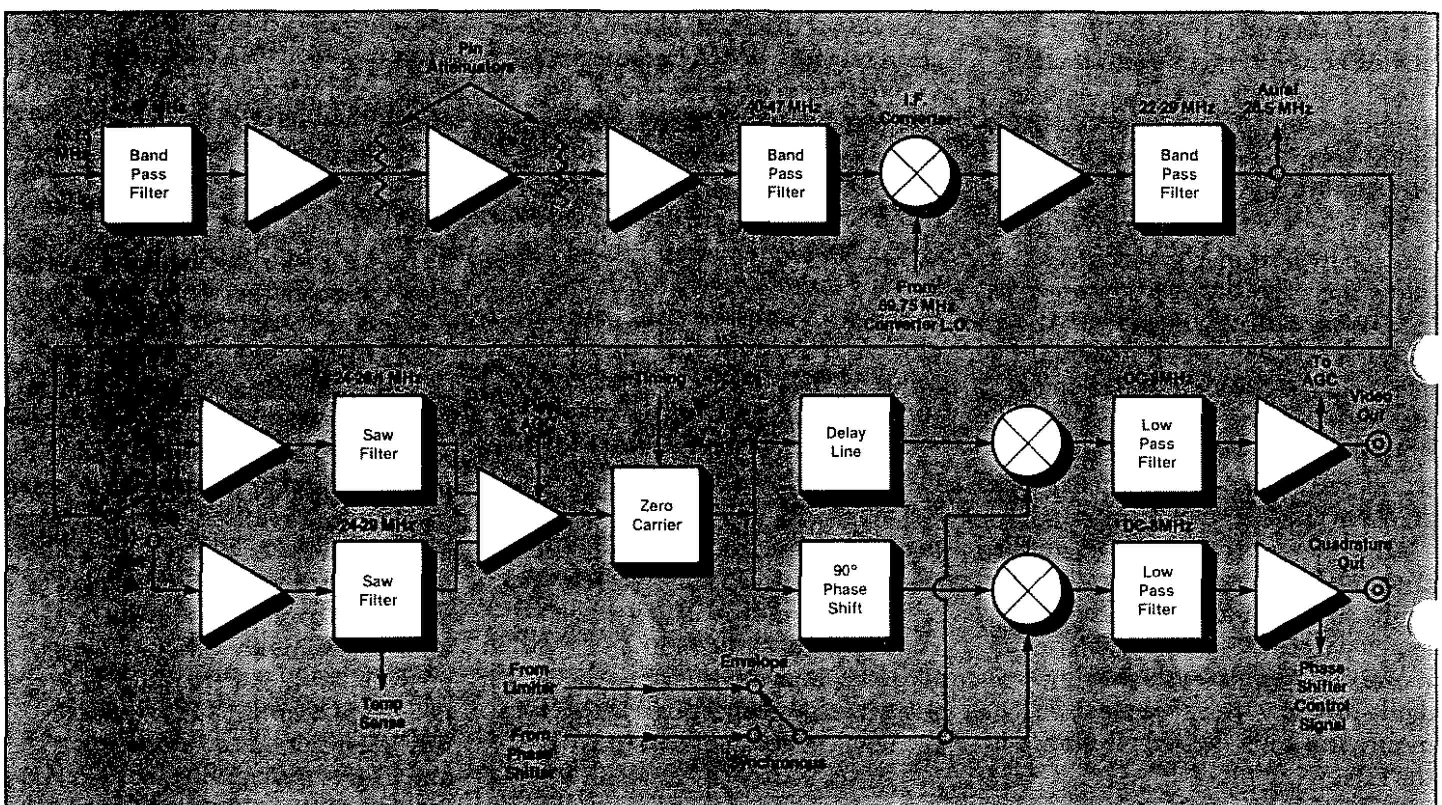


Fig. 4. Block diagram of IF and synchronous detector. Multiple amplifier stages are used to accommodate 0 to 66 dB range of AGC attenuation. Separate SAW filters are used for "visual only" or "visual plus aural" operations.

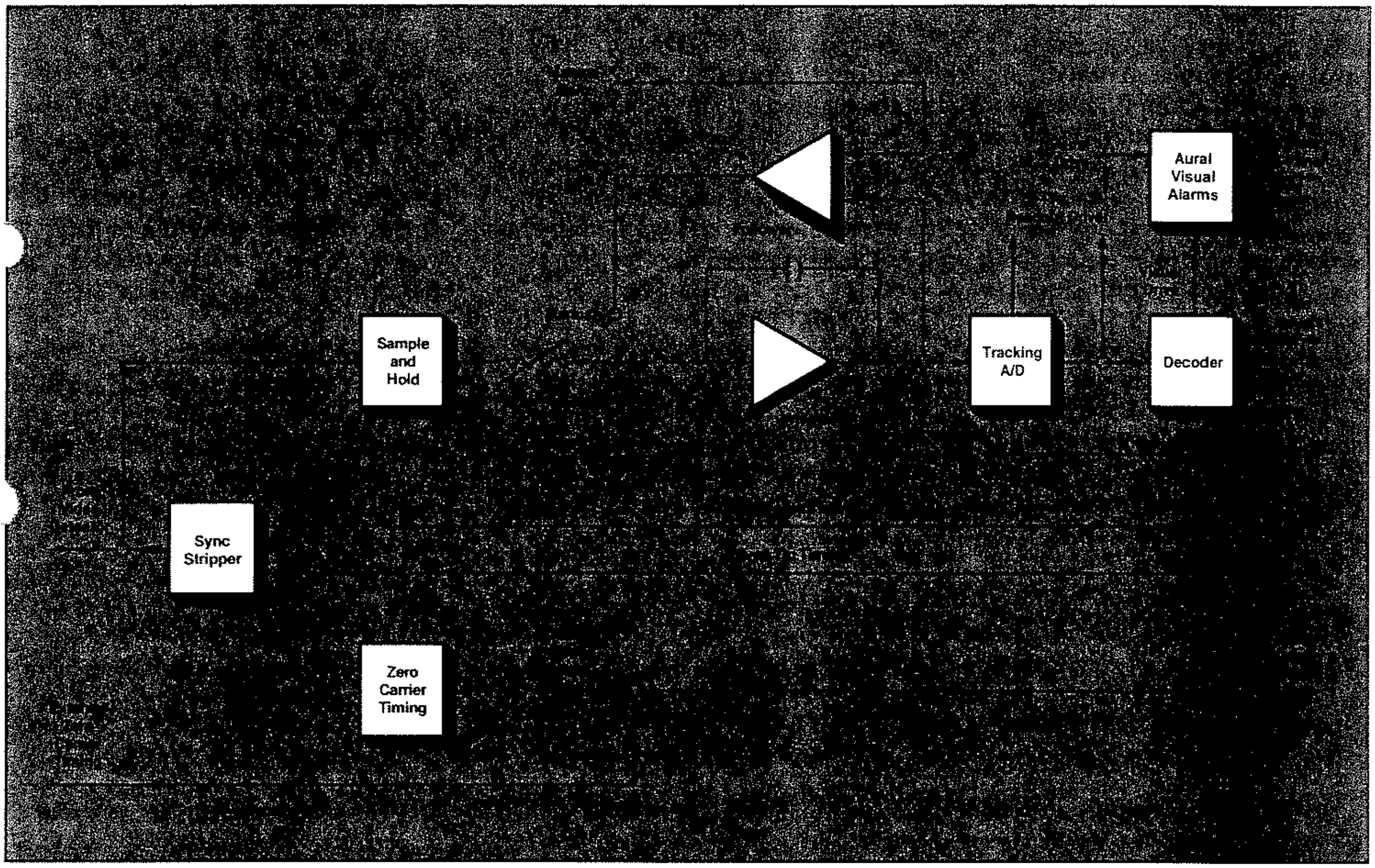


Fig. 5. AGC circuitry drives three PIN-diode attenuators for AGC range of 0 to 66 dB. PROM control of attenuator current yields readout accuracy of RF input within ±1 dB.

Four differential amplifier stages provide a total gain of 60 dB. Adjustable current sources for the amplifiers provide a delay adjustment mechanism for the limiter.

With amplitude variations removed, the limiter output can also serve as the local oscillator for the envelope detector. And since any transmitter phase noise is inherently present in the limiter output, the limiter output is used as the local oscillator for the first aural mixer when analyzing intercarrier IF performance.

The synchronous detector

The synchronous detector consists of two product detectors—one supplying the video output, the other the quadrature output. The IF signal to the video detector passes through a delay line of approximately 10.4 ns, which corresponds to 90 degrees of the 24 MHz IF frequency. The IF signal to the quadrature detector, on the other hand, passes through a bandpass filter

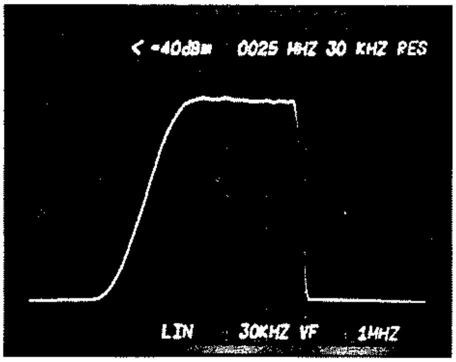


Fig. 6. A "textbook" Nyquist slope response is achieved by the SAW filters used in the 1450.

which has the same 10.4 ns of delay at 24 MHz, but introduces no phase shift of the IF carrier. Thus, two signals in time coherence but phase quadrature are produced to be detected by the product detectors.

The detector/amplifier combinations have a stringent stability requirement because the quadrature output is the control signal for the phase lock. Any errors in that signal, such as those caused by thermal drift, will cause the phase coherence between the IF signal and the reference L.O. to be in error. Since accurate phase measurements must be made and good transient response maintained, the phase error cannot be allowed to exceed 1 degree. This means the quiescent output of the quadrature detector/amplifier combination must not change by more than ±10 mV over the operating temperature range. This kind of performance is typically achieved only with chopper stabilization techniques.

In the 1450, the required stability was achieved with innovative circuit design. An integrated-circuit doubly-balanced mixer is used as a current mode switching detector. The bias current of the IC is set up to change with temperature, to maintain constant transductance. The transductance is stabilized if the dynamic emitter resistances

$(r_e = \dfrac{mk\,T/\alpha}{I_E})$

are held constant, which is done by allowing I_E to cancel out the effects of the T (temperature) term.

The output amplifier that follows the detector has been subjected to equally concentrated design. Since it is a feed-back amplifier, it is inherently more stable than the detector, which must exhibit "open loop" stability. The input offset voltage, however, is thermally tracked to compensate for amplifier output voltage changes caused by temperature variations.

Further, to insure that the potential stability is actually achieved, the instrument is subjected to environmental temperature cycling in the calibration process, during which a single compensating resistor is selected and installed.

The same detector/amplifier circuitry used in the quadrature channel is also used in the video channel. As noted earlier, the video output signal is sampled and used as the control signal for the AGC system. Any errors in its output will affect the gain stability of the instrument.

The end result of this attention to design in the detector/amplifier stages is a quadrature output well within the 1-degree specification and a video output level held within 1 percent by the AGC.

The correction voltage from the quadrature output is shaped by diode matrixes and applied to two mixers driven 90 degrees apart by the 24 MHz reference oscillator. The dc levels to the mixers are such that with zero output from the quadrature detector, the output of one mixer starts at full amplitude. As the correction voltage to the mixer increases, the output falls off in a sinusoidal manner until it reaches zero. As the correction voltage is decreased, the output falls off in the opposite direction until it reaches zero. These are the two limits of the control signal.

The correction voltage to the other mixer is such that its output starts out at zero amplitude and increases in amplitude as the correction voltage is increased, and vice versa.

The outputs of the two mixers are combined to give a constant amplitude sine wave whose phase can be shifted linearly with voltage. The bandwidth of this system is such that corrections can be made at a line rate, which is actually a limit imposed by the sampling of the reference time (sync tip or back porch).

The audio system

With an audio section bandwidth of 30 Hz to 20 kHz, one of the potential applications for the 1450 is as an off-the-air receiver for rebroadcast purposes.

The 28.5 MHz aural IF carrier is converted to 4.5 MHz using either the 24-MHz phase lock reference oscillator ("Split" mode), or the limiter output ("Intercarrier" mode), as the first L.O. Amplified and filtered, the 4.5 MHz signal is then converted to 1 MHz using a 5.5 MHz crystal oscillator for the second L.O. A limiter removes any amplitude varia-

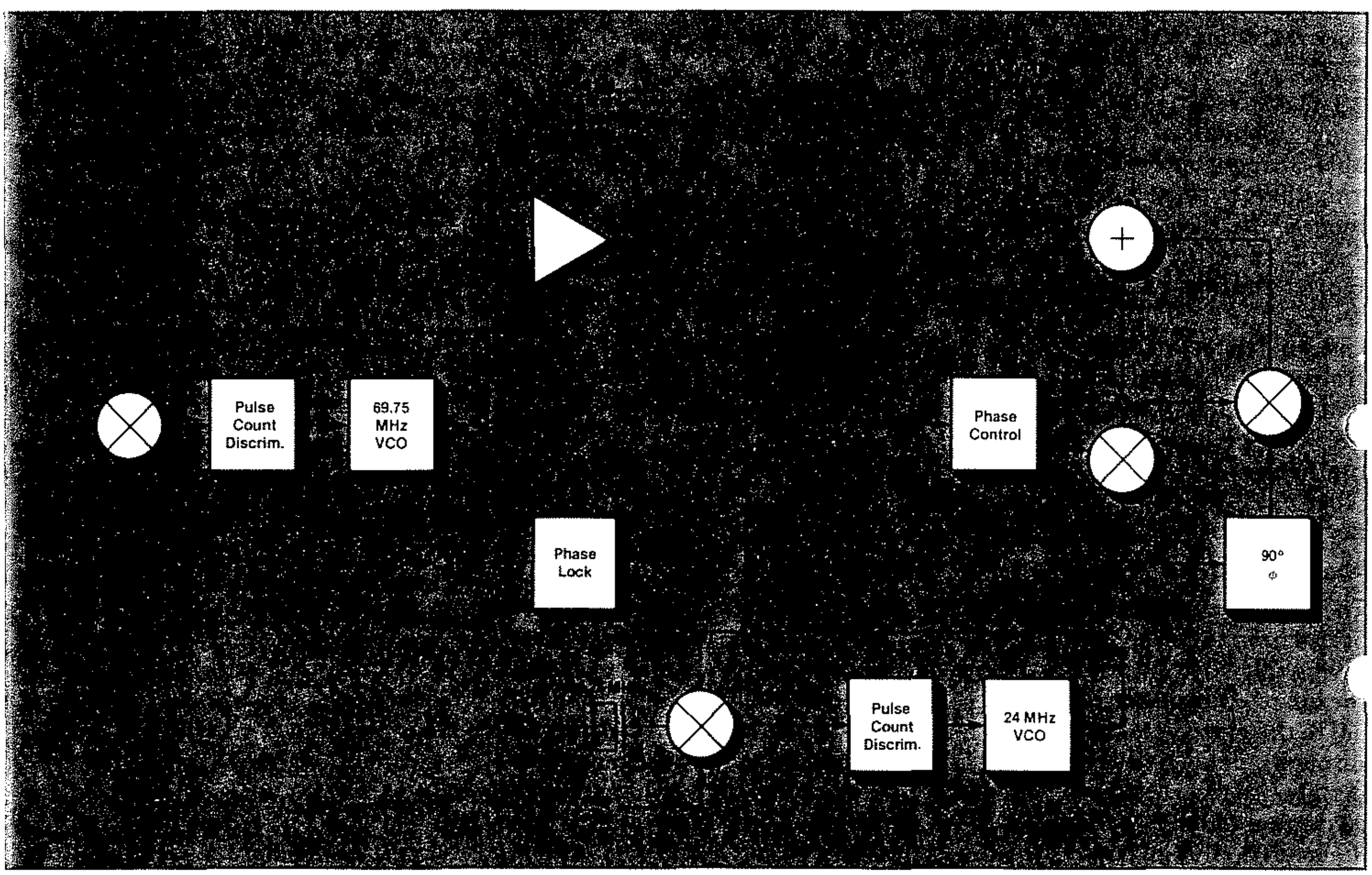


Fig. 7. Converter L.O. and phase lock circuitry. Two mode system uses a frequency control loop to give a wide pull-in range, and a phase control loop for fast phase correction.

tions, and the 1 MHz signal is then demodulated using a pulse count discriminator.

The pulse count discriminator is operated at 1 MHz to increase the available output signal, thereby improving the signal-to-noise ratio over the same circuit operating at 4.5 MHz. The discriminator puts out pulses of constant amplitude and duration, whose repetition rate varies at the modulating frequency. The discriminator is an FM detector which exhibits high linearity, and is the main factor in achieving the low 0.2% maximum harmonic distortion specification.

Multiple audio outputs are provided, including 600-ohm balanced line, 8-ohm speaker, and front-panel headphone jack. Bandwidth of the audio section is 30 Hz to 20 kHz. Other outputs include an aural alarm to indicate loss of the aural carrier, a calibrated deviation output, and a 4.5 MHz IF output.

Mechanical design

The 1450 interior is shown in Figure 8. Small circuit boards housed in extruded aluminum compartments comprise the major circuitry. The compartments provide essential shielding between the many oscillators and the sensitive circuitry. Individual covers for the compartments give maximum isolation. Interconnection between circuit boards is accomplished with interface boards and a few rigid coaxial lines. Easy access to components is provided by use of a circuit board extender.

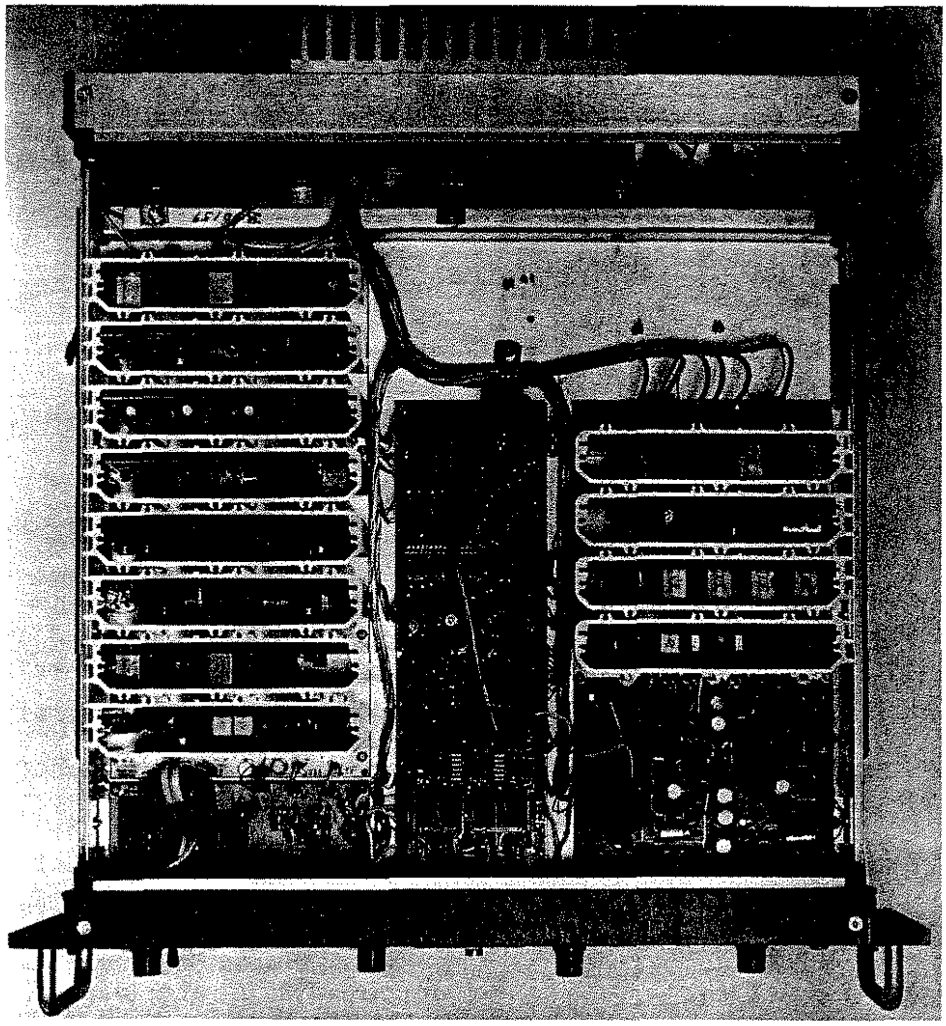


Fig. 8. The major part of the circuitry is mounted on small circuit boards housed in extruded aluminum compartments. Separate covers for each compartment enhance isolation.

Acknowledgements

Many people, in many departments, contributed to the successful completion of the 1450 project. Project Manager Chuck Barrows provided overall direction, with Charlie Rhodes challenging us with the seemingly impossible while providing many valuable inputs. Assisting in electrical design were Jim Zook, front-end design (including the ceramic core resonators); Keith Ericson, IF and synchronous detector; and Dan Nicholas, AGC and audio. Bill Drummond, Tek Labs, was responsible for the SAW filter designs; and Oscar Olson, Hybrid Circuits Engineering, worked with Jim Zook on the helical resonators. The front-end precision attenuators are the work of Jack Roberts, Frequency Domain Instrumentation. Paul Chadwick handled the mechanical design. Much credit is also due Ellis Workman for his circuit board layouts, and Bob Thacker in smoothing the transition to manufacturing. Prototype support technicians were Sherry Self and Kerry Montgomery.

A 24 MHz Nyquist SAW Filter for the 1450 Demodulator

[illegible] Drummond came to Tek from the [illegible] area in '73, starting in [illegible] group. In late '74, he joined [illegible] Research Group working on SAW filter [illegible]. Bill played a major role in [illegible] SAW filters used in the 1450. He received [illegible] BSEE from Healds Engineering College [illegible]

One of the major problems experienced by the users of precision broadcast demodulators is the change in the Nyquist filter's response caused by temperature change and mechanical shock. To achieve a reasonable Nyquist response requires a filter with many elements. Such filters are time-consuming to adjust and difficult to keep in adjustment. Yet, a proper Nyquist response is essential to the demodulator's function.

This presents an ideal application for a surface-acoustic-wave (SAW) device. These devices are usually small in size, highly reliable, and their phase response can be specified independently of their magnitude response, a distinct advantage in this application. They can produce a frequency response that is difficult, if not impractical, to achieve using discrete elements; and once designed, the devices are easily reproducible.

Perhaps a review of SAW filter basics would be useful at this point. Surface acoustic waves are essentially what the name implies. They are waves that travel along the surface of a polished substrate, penetrating only a very small distance into the surface of the material. Scientifically they are called Rayleigh waves, in honor of Lord Rayleigh who first described the acoustical waves that travel along the earth's surface after an earthquake.

Nearly any material with low mechanical losses such as glass, quartz, ceramics, and some types of metal will support the propagation of surface waves. The mechanism most often used to generate the surface wave is the piezoelectric effect. Accordingly, single crystal piezoelectric materials such as quartz and lithium niobate are generally used as the substrate for SAW devices.

The substrate is typically about two millimeters thick, with the length determined by the desired frequency response. Narrow filter bandwidths at low frequencies, or very steep skirts at any frequency, require long transducers and, thus, long substrates. Surface wave filters are currently in use from 10 MHz to 1.5 GHz. The lower limit is set by the practical size limits on the substrates, while the upper limit is set by the resolution of state-of-the-art lithography techniques and substrate velocities. One semiconductor manufacturer recently announced production of 3 GHz SAW units using two-stage electron-beam lithography.

The drawing in Figure 1 illustrates generally how the surface wave affects the substrate material and how its effect decreases as a function of depth into the material. Both longitudinal and transverse components are present in the surface acoustic waves. The velocity of the acoustic wave is typically five orders of magnitude slower than the velocity of light, which accounts for the frequent use of SAW devices as delay lines. For example, an electrical signal takes about three microseconds to traverse a cable one kilometer long. The acoustic wave travels about one centimeter in the same length of time. Hence, equivalent delays can be achieved with a substantial reduction in space and weight.

Excitation and detection of acoustic waves is accomplished by depositing an input and output transducer on the piezoelectric substrate using thin-film techniques. The transducers consist of two electrodes in the form of interdigital fingers. (See Figure 2). The spacing between the fingers determines the frequency of the acoustic wave that will be generated.

Applying a periodic voltage of the appropriate frequency to the input transducer causes a corresponding displacement to occur in the piezoelectric material. This periodic displacement propagates away from the input transducer in the form of surface waves in both directions normal to the fingers of the transducer. As the surface waves travel

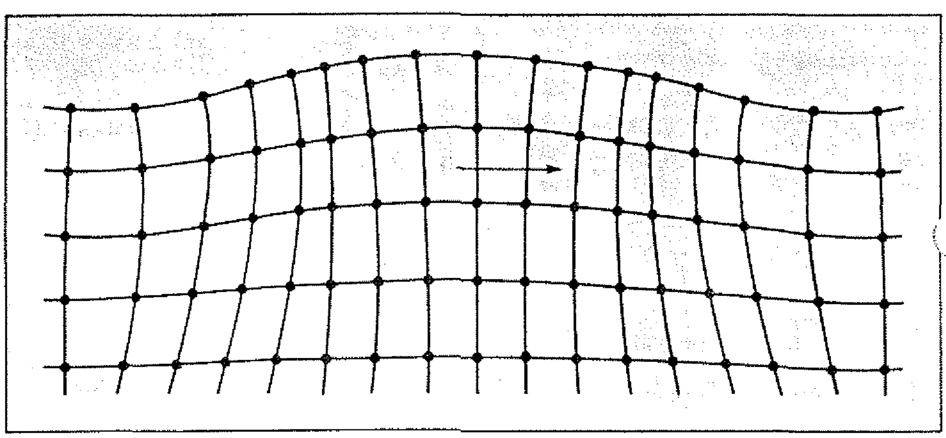


Fig. 1. A cross-section[illegible] view [illegible] the substrate [illegible] how the substrate material is affected by passage [illegible] acoustic [illegible]

down the substrate, they encounter the output transducer. If the periodicity of the surface wave and the fingers of the output transducer match, an output voltage is generated across the output transducer.

Any filter's frequency response is uniquely related to its impulse response through the Fourier transform. SAW filters are realized by arranging the filter transducers so that they produce the impulse response related to the desired frequency response. Transducers can be made to produce almost arbitrary, finite, impulse responses by varying finger lengths as a function of position along the transducer. For example, to produce a rectangular bandpass characteristic, its Fourier transform (*sin*x/x) is designed into the transducer pattern.

One of the important properties of SAW filters is the simple metal-on-insulator, one-mask fabrication process. Once the mask is defined, device reproducibility is a function of the substrate characteristics, metal quality, and metal thickness—all of which can be made highly consistent. This means devices having a precise frequency response are easily reproducible—a substantial improvement over complex discrete element filters with their inherent adjustment and stability problems.

There are, however, some tradeoffs involved in the use of SAW filters—one of the most serious being insertion loss. It was noted earlier that conventional biphase transducers radiate half the electrical-to-acoustical conversion in each direction; conversely, the output transducer can, at most, reconvert into an electrical signal only half the acoustic power incident on it, for a minimum insertion loss of 6dB.

Another consideration is the effect of triple-transit echoes caused by a part of the energy being reflected by the output transducer and re-reflected by the input transducer. This produces a periodic ripple in phase and amplitude in the passband of the filter. The triple-transit signal can be substantially reduced by electrical mismatching of the input and output transducers. However, this also reduces the level of the desired signal, which then must be amplified, with attendant deterioration in the signal-to-noise ratio.

A final consideration is the bulk wave effect caused by acoustic energy transmitted through the bulk of the substrate and reflected from the edge surfaces. This can be minimized by the use of damping material to mount the substrate, the use of a track changer, and other techniques, but it is difficult to eliminate completely.

Some Uses for SAW Devices

Before leaving the discussion of SAW filter basics we should mention some of the uses for SAW devices. Bandpass filters and delay lines are the two most common applications. Delay times from a few tenths to several tens of microseconds are eas-

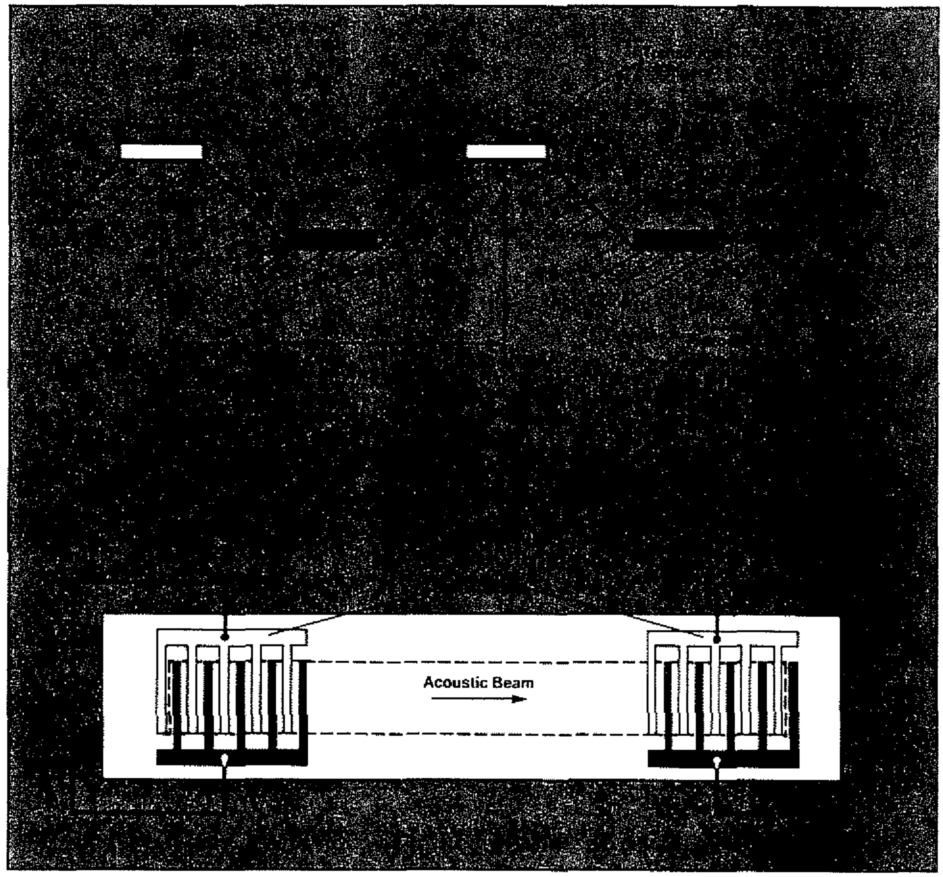


Fig. 2. An illustration of surface acoustic wave transducer operation. The spacing between pairs of fingers determines the frequency of the acoustic wave that will be generated. The input and output transducers are identical in design.

(A)

(B)

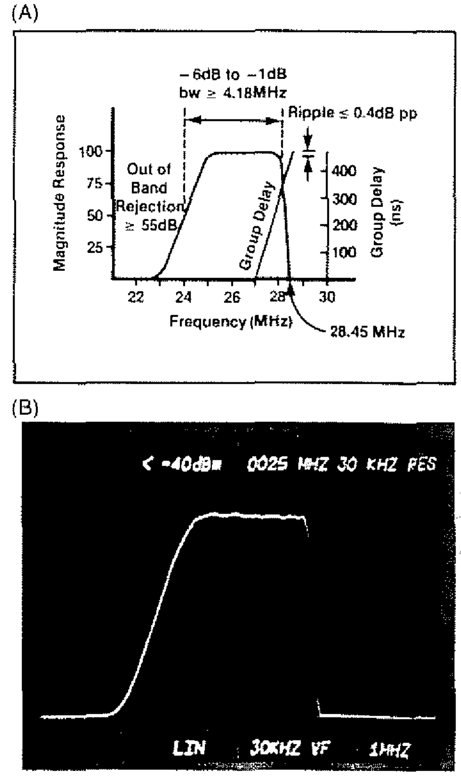


Fig. 3. (A) Desired, and (B) actual response of the 1450 narrow band filter. Both curves are in terms of a linear vertical scale.

ily obtainable. Delays up to 20 milliseconds have been achieved by passing a signal in a closed loop or helical path around the crystal.[1] However, these millisecond devices are still in the laboratory stage.

The most important uses of delay lines to date have been for demodulation functions for receivers—particularly, differential phase shift keying demodulation, frequency discrimination for FM receivers, and noncoherent moving-target-indicator radar receivers.

Recently-developed SAW resonators are finding increasing use as the frequency determining element in VHF and UHF oscillators. Their small size and high Q simplify amplifier design and provide better stability and immunity to external component variations.[2]

Other uses for SAW devices are still in the development stage—frequency synthesizers, matched filters for correlation applications, and electronically variable delay to name just a few.

The 1450 SAW Filters

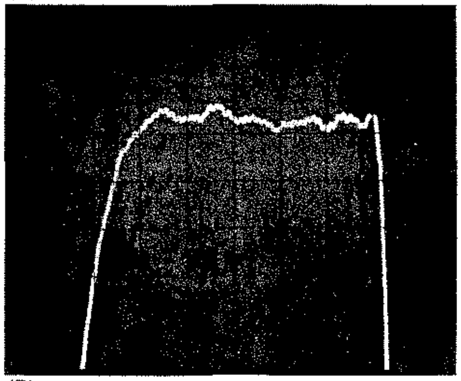
With this brief background, let's consider the SAW filters designed for the 1450. There are two of them—a wide-band unit with a passband of 24-29.5 MHz, and a narrow-band unit (24-28.1 MHz) which includes a sound trap to remove the aural carrier.

The narrow band filter has some unique characteristics as shown in the illustration of the desired response in Figure 3(A). The actual response achieved is shown in the photo in Figure 3(B). Both curves are in terms of a linear vertical scale. The actual response is also shown in Figure 4 with the vertical scale in terms of dB. The top photo shows the peak-to-peak ripple to be well within the 0.4 dB specification, while the bottom photo shows the filter out-of-band characteristics to be significantly better than the −55dB specification.

[1]Scientific American, October 1972, "Acoustic Surface Waves."

[2]Proceedings of the IEEE, Vol. 64, No. 5, May 1976. "Surface Acoustic Wave Devices for Communication."

(A)



(B)

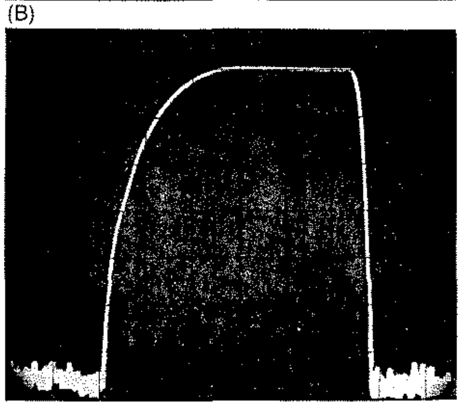


Fig. 4. The actual response with the vertical scale in terms of dB. (A) Top photo shows ripple to be well within 0.4 dB specification. Vertical sensitivity = 0.25 dB/div and span is 500 kHz/div. (B) Out-of-band characteristics are better than −55 dB specification. Vertical sensitivity = 10 dB/div and span = 1 MHz/div.

Both filters use a lithium niobate substrate. This material has a higher temperature coefficient than quartz but is much more efficient in coupling energy between the transducer and the substrate. With a change in temperature, the shape of the response curve remains the same but the center frequency shifts. This shift is compensated for in the 1450 by placing a temperature sensor near the SAW filter to generate a correcting signal for the IF converter oscillator.

By SAW filter standards, the physical size of the devices used in the 1450 is large. Packaged size is 1.4 x 2.3 inches. This is due to the relatively low frequency (24 MHz) and the steep skirt required for the sound trap. The cover photo shows the general layout of the SAW filter transducer patterns. The series of parallel unconnected fingers in the center of the device constitute a track changer called a multi-strip coupler. The track changer translates the acoustic energy from the input transducer acoustic track to that of the output transducer. Since the track changer is relatively insensitive to the bulk wave energy generated by the input transducer, little bulk wave signal is seen by the output transducer. To reduce bulk wave effects still further, the substrate is mounted in energy-absorbing material. The completed filter is then housed in a hermetically sealed package back filled with dry nitrogen to keep out dust and moisture.

In the circuitry surrounding the filter, both the input source and output load termination impedances are deliberately mismatched to the electrical impedances of the input and output filter transducers. Although the mismatch increases the overall insertion loss, it is required to minimize triple-transit-reflection effects. The losses involved in the track changer, losses due to bidirectionality, and losses due to mismatching add up to an insertion loss of about 30 dB for the SAW filters used in the 1450. This places some stringent requirements on the output amplifier of the SAW filter to maintain a favorable signal-to-noise ratio. The advantages realized by use of the SAW filter, however, far outweigh these considerations.

The SAW filters complement the precision and stability designed into the remainder of the 1450 circuitry, to create a demodulator which sets a new standard for the broadcast industry.

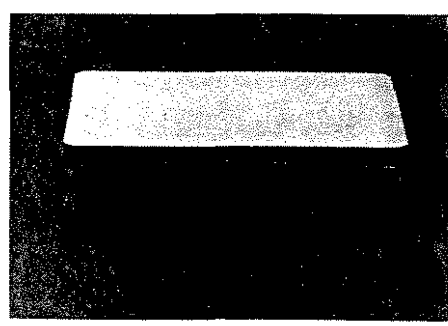
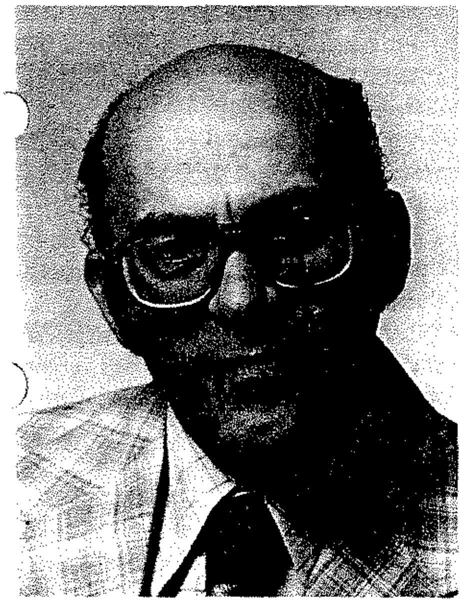


Fig. 5. Hermetically-sealed SAW filter package used in the 1450. Package is 3.6 cm by 5.8 cm.

Spectrum Analyzer Applications in Baseband Measurements



Morris Engelson has authored numerous articles on the design of spectrum analyzers and their application. He is well qualified to write on this subject having worked with spectrum analyzers for over 15 years. Morris received his BSEE in 1957 and MSEE in 1962, both from C.C.N.Y.

The modern spectrum analyzer has long been used for frequency division multiplex (FDM) baseband measurements such as hunting for spurious responses or checking intermodulation. This instrument can also be used for most of the measurements usually performed with a selective level meter.

The measurements that a modern spectrum analyzer such as the TEKTRONIX 7L5 can make include:

a. Amplitude levels of carriers, test tones, signal tones, data, etc.
b. Spurious signal levels and frequencies due to harmonics and intermodulation.
c. Leakage at channel carrier, group carrier, or other frequencies.
d. System noise levels.
e. Frequency shifts due to changes in degree of modulation or other causes.
f. Identification of random transient noise burst interference.
g. Determination of notch filter shape.
h. Checking for harmonic distortion.
i. Checking subsystem transmission characteristics by means of a tracking generator.
j. Noise measurements, including C-message and psophometric weighting.

The purpose of this article is to provide the reader with short illustrations of some of the above measurements. Detailed measurement techniques, interpretation of results, and a description of the instrumentation used are available in Tektronix applications literature referenced at the close of this article.

Wide span search measurements

Suppose one wishes to check or adjust the relative levels of the twelve carriers spaced at 4 kHz intervals bounded by 659 kHz and 615 kHz.

There might be other signals within the selected range, such as a pilot tone usually at 656.08 kHz. The simulated channel bank shown in Figure 1 displays only the unmodulated carriers.

With the measuring instrument operating normally with digital storage display, we can observe the twelve channels of interest. Note that the maximum amplitude variation is 2 dB.

Figure 2 shows a search of the full 5 MHz spectrum. A number of active channels below about 2 MHz are shown blending into each other. Two tones occur just above 2.5 MHz. The remainder of the spectrum display up to 5 MHz shows only system noise.

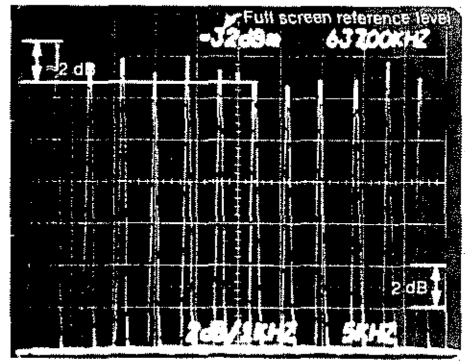


Fig. 1. Spectrum display of unmodulated carriers for 12 channel bank.

Figure 3 shows all baseband activity for the system of interest. One can observe at a glance which groups are occupied, which are missing, and whether anything is there that doesn't seem to belong, such as a suspicious tone at 1606.5 kHz, subsequently identified as spurious.

Harmonic distortion measurements

The 80 dB on-screen dynamic range of the TEKTRONIX 7L5 enables one to measure harmonic distortion down to 0.01%. When a single harmonic is involved, the measurement simply consists of determining the dB level with respect to the fundamental. This is also known as "dB down".

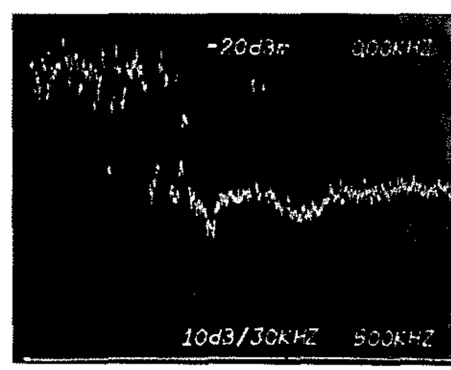


Fig. 2. Zero to 5 MHz display of baseband spectrum.

The dB down level is then converted to a voltage ratio which, when multiplied by 100, yields percent distortion. A simple rule to remember is that distortion changes by a factor of ten times for every 20 dB change in level. Thus, at 10 dB/div and the fundamental at full screen, distortion products 2 divisions down represent 10% distortion, those 4 divisions down represent 1%, and those 6 divisions down represent 0.1%.

Figure 4 shows a −10 dBm fundamental and over ten of its harmonics. This display was taken with a 7L5 Option 25 in a 7603 Mainframe. The instrument parameters are indicated on crt readout. The left upper position (set at 0 dBm) is tracking generator output—not used in this measurement.

We observe the following amplitude levels:

Fundamental	−10 dBm
2nd harmonic	−53 dBm
3rd harmonic	−64 dBm
4th harmonic	−60 dBm
5th harmonic	−71 dBm
6th harmonic	−65 dBm
7th harmonic	−76 dBm
8th harmonic	−68 dBm
9th harmonic	−78 dBm
10th harmonic	−71 dBm
11th harmonic	−85 dBm
12th harmonic	−72 dBm

Intermodulation distortion measurements

The ability to set frequency with a high degree of accuracy makes it easy to intercept intermodulation and other spurious signals whose frequency can be predicted. The high degree of accuracy also means that the frequency of unexpected spurious responses can be pinpointed and the source identified.

If three tones at 57 kHz, 2600 kHz, and 2714 kHz are fed to the system under test, the following second and third order intermodulation responses will occur:

a. $\begin{cases} 2(57) = 114 \text{ kHz} \\ 2714\text{-}2600 = 114 \text{ kHz} \end{cases}$

b. $\begin{cases} 2600 + 57 = 2657 \text{ kHz} \\ 2714 - 57 = 2657 \text{ kHz} \end{cases}$

c. $\begin{cases} 2714 + 2(57) = 2828 \text{ kHz} \\ 2(2714) - 2600 = 2828 \text{ kHz} \end{cases}$

Theoretically, the pairs of responses fall at precisely the same frequency, but the actual tones will be displayed as pairs due to slight input signal deviations in frequency. Figure 5 shows the two 2657 kHz components computed in (b), and Figure 6 shows the output at 2828 kHz.

Figure 6 also illustrates the usefulness of the 7L5's averaging functions to pick a low level signal out of the noise.

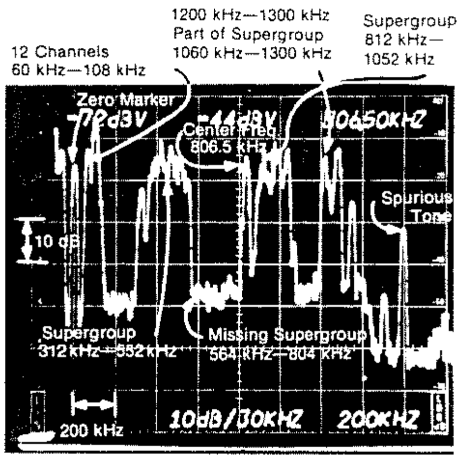


Fig. 3. Full baseband spectrum showing several supergroups.

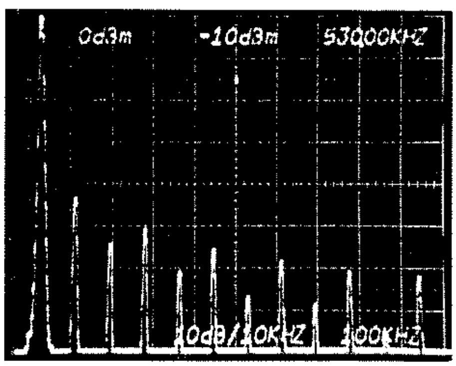


Fig. 4. Display of −10 dBm fundamental and harmonics.

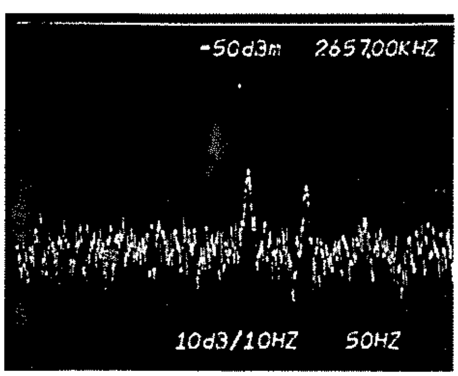


Fig. 5. Three tone intermodulation products

Detailed amplitude analysis

Figure 7 shows a carrier leak at 520 kHz. Carrier leak is the carrier signal that remains after suppression in a suppressed-carrier system. Leakage amplitude is −60 dBm. This is almost 25 dB below the level of the adjacent signals.

Figure 8 shows three channel carriers with the vertical scale expanded by a factor of ten to produce a display factor of 0.2 dB/div. The display was produced by connecting the detected vertical output at the 7L5 front panel to a 7A22 amplifier set at a sensitivity ten times the 50 mV/div output from the 7L5. Accurate vertical calibration is obtained by changing the 7L5 reference level by 1 dB and adjusting the 7A22 variable gain to get the desired vertical deflection (5 divisions in our example). Since the trace now occupies ten screen heights, it is necessary to use the 7A22 dc offset control to position the display on screen. Maximum amplitude difference is 0.6 dB and the minimum difference is 0.15 dB. Considering the close frequency spacing of the signals and the instrument flatness specifications, the measurement has an accuracy of better than 0.1 dB.

Detailed frequency analysis

For detailed frequency observation it is necessary to reduce the resolution bandwidth to the point where individual tones can be resolved. With 10 Hz resolution, the 7L5 can perform a detailed analysis even of frequency-shift-keyed (FSK) signals as illustrated in Figure 9.

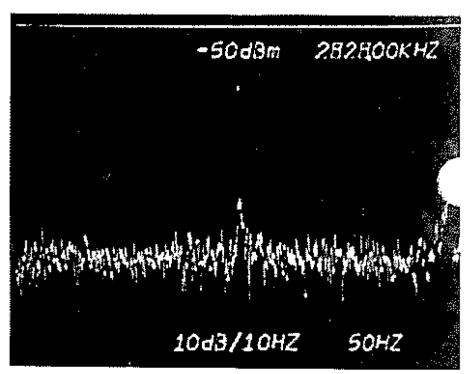


Fig. 6. Three tone intermodulation product at 2828 kHz.

Figure 9 shows the spectral characteristics of the first channel (409 kHz) in group three of the basic supergroup (312-552 kHz). At 50 Hz/div we are only observing 500 Hz of the 4 kHz channel. With individual components resolved, it is clear that this is an FSK signal. Tone amplitude level is −60 dBm (−69 + 9.1)*. At a vertical setting of 10 dB/div we can easily establish the level of the various tones, but the vertical resolution at this setting prevents high accuracy. For high accuracy, it is necessary to go to a vertical setting of 2 dB/div.

Looking at noise

The ability to save, and hence to freeze, a spectral display in the A digital storage section, while section B continues to update, permits some useful measurements. An illustration of the "Save A" feature is shown in Figure 10. The lower trace displays the shape of a notch filter at 2,057 kHz. There are also several spurious signals about 300 kHz below the notch frequency. The upper trace shows the update in Memory B with the MAX HOLD function activated. The MAX HOLD function will hold in memory and display the maximum amplitude level that occurs during observation time. Here a noise burst has increased the system noise by 10 dB while totally obliterating the effect of the notch filter.

Recommended equipment

All of the foregoing measurements can be made using the following equipment. Some of the basic features are listed. Complete specifications can be obtained from your Tektronix Field Engineer or Sales Representative.

7000 Series Oscilloscope: Any 7000 Series Oscilloscope with crt readout will accommodate the 7L5 Spectrum Analyzer Plug-in. The 7603 with its large 6½-inch crt makes an ideal choice.

7L5 Spectrum Analyzer: Plug-in spectrum analyzer with digital storage.

- Frequency range: 20 Hz to 5 MHz. Good for 600 channel systems.
- Resolution: Down to 10 Hz. Will resolve individual FSK tones.
- Sensitivity: Down to −135 dBm. Good for checking those hard to find leaks and spurious tones.
- Frequency accuracy: 5 Hz for accurate tuning to desired channels.

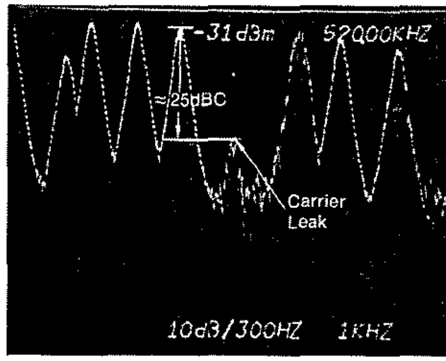


Fig. 7. Carrier leak measurement.

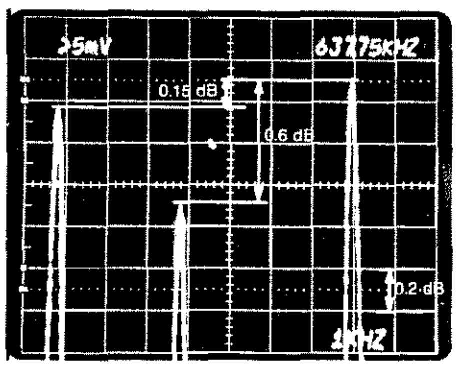


Fig. 8. Expanded amplitude measurement of three channel carriers at 0.2 dB/div.

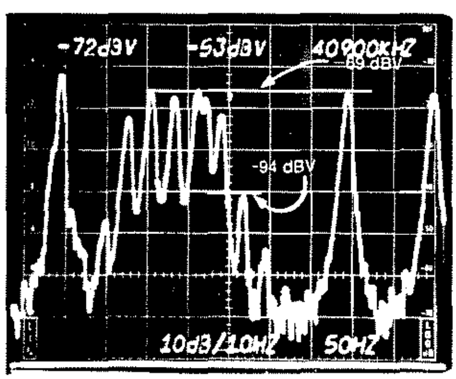


Fig. 9. Spectrum of FSK signal.

L3 Plug-IN Module Option 01: Plug-in front end for 7L5.

- Impedance levels: 1MΩ, 600Ω, 75Ω for bridging and single-ended measurements.

Option 25 Tracking Generator: Provides tracking output level over the full 5 MHz frequency range for checking component transmission characteristics.

013-0182-00 Balanced Input Transformer:

- Frequency range: 50 kHz to 3 MHz, usable from 10 kHz to 20 MHz.
- Built-in terminations: 124Ω, 135Ω and NONE for bridging.

Application notes describing in detail the measurement techniques used here are available on request. Customers in the U.S. and Canada may use the inquiry card in Tekscope. Overseas customers should contact their Tektronix Field Engineer or Sales Representative.

"Baseband Measurements Using the Spectrum Analyzer" Tektronix AX-3433

"The Spectrum Analyzer as a Frequency Selective Level Meter" Tektronix AX-3682

"Swept Selective Level Measurements" Tektronix AX-3861

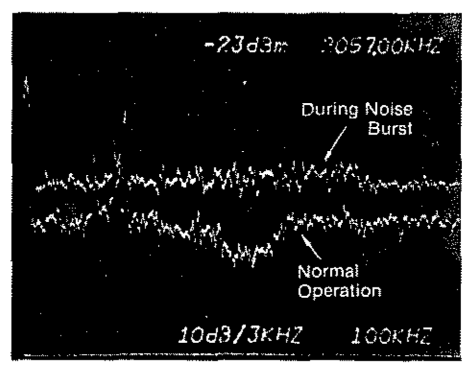
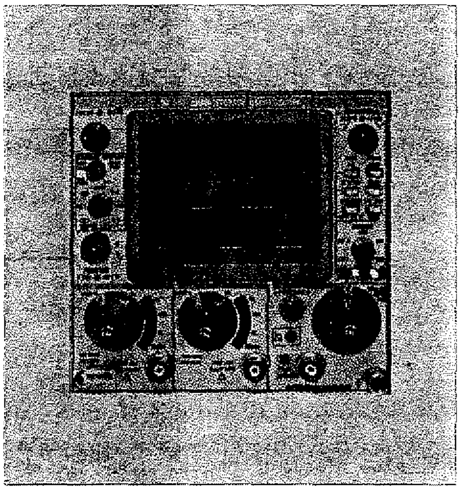


Fig. 10. The "SAVE A" feature allows comparison between normal operation and operation during noise burst.

*At 124Ω, dBm = dBv +9.07

New Products

SC 503 10 MHz Storage Oscilloscope



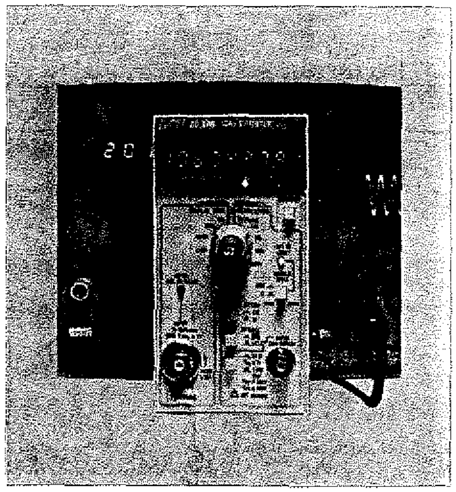
Bistable Storage for TM 500

A new 10 MHz storage oscilloscope is available for the versatile TM 500 Series. Bistable storage with auto erase provides a normal stored writing rate of 50 cm/ms (80 div/ms) which can be enhanced to 250 cm/ms (400 div/ms) by trading off storage time. Maximum storage time is about four hours. In auto erase mode, viewing time can be varied from 1 to 10 seconds. The SC 503 can also be operated in non-storage mode.

Versatile triggering — auto, normal, single-sweep — trigger view, and variable trigger holdoff add to the SC 503's ease of use. Other important features include 3% vertical deflection and time base accuracy. A full range of input modes, including X-Y, is provided.

The SC 503's storage capability makes it ideal for viewing the low repetition rate or low writing rate signals encountered in medical, biophysical, and electromechanical applications.

DC 508 1 GHz Frequency Counter



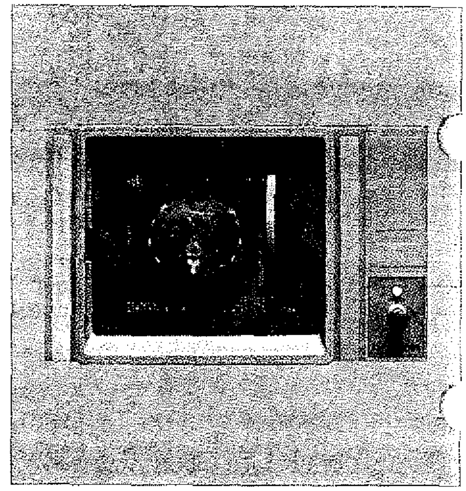
A Gigahertz Counter for TM 500

The DC 508 was designed to extend the TM 500 counter capabilities to include the critical frequency measurement problems that face the communications industry with the opening of the new 800 MHz to 1 GHz band.

The DC 508's 15 mV direct input sensitivity allows transmitter frequency measurements to be made by using a remote whip antenna or an inductive probe. Its X100 audio frequency resolution multiplier permits measuring resolution to 10 milli-Hertz in one second. This feature is particularly useful for communications systems involving frequency shift keying and tone squelch frequencies. For example, a counter without the resolution multiplier will take 100 seconds to get the same resolution.

The DC 508 features a 9-digit LED display which indicates frequencies and totalizes events from 0 to 999,999,999. Frequency range of the DC 508 is 10 Hz to 100 MHz (direct input) and 75 MHz to 1 GHz (prescaler input).

The 634 Video Display Monitor



Three New Monitors Broaden Your Price/Performance Choice

The new 634 Video Display Monitor offers superior resolution, brightness uniformity, and geometry for highest quality performance in medical-imaging applications. Worst-case resolution is 1100 lines (nominally 1400 lines) at a brightness of 100 cd/m² (30 fL). Geometric distortion is 0.5% or less over a 9 cm circle at the center of the screen.

The 624 Display Monitor features improved brightness in a moderately priced X-Y display. A brightness of 130 cd/m² (40 fL) and 12 mil spot size assure crisp, detailed displays even in normal room ambient light. The 10 x 12 cm viewing area permits more data to be displayed more clearly, including complex graphics and alphanumerics.

The new 620 Display Monitor is a very lowcost, electrostatically deflected display designed to accommodate OEM's who are now building their own displays. The 620's 10 x 12 cm viewing area, 5 MHz Z-axis bandwidth, 2 MHz vertical and horizontal bandwidth, and 12 kV accelerating potential make it an ideal choice for many price-sensitive, good-performance, OEM applications.

A-4022 7/78

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

1195114 2545
MR F CAPELLUPO ENGR
NEW YORK TELEPHONE CO
8858 75 AVE
GLENDALE NY 11227

BULK RATE
U.S. POSTAGE PAID
TEKTRONIX, INC.

The 4027 — Adding a Color Dimension to Graphics

An Easy Language for Talking with Color Machines

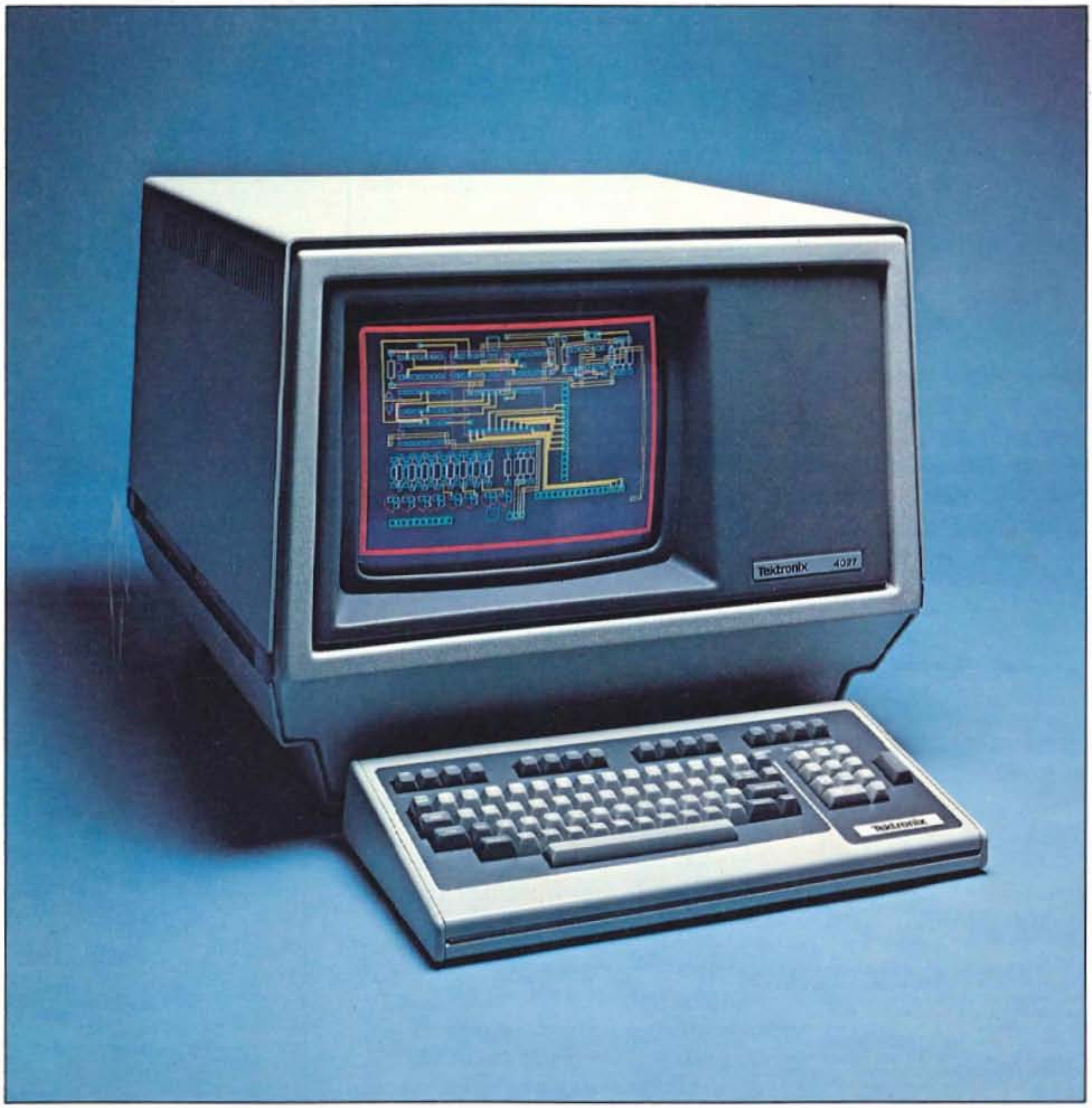
Reliability — the Continuing Challenge

New Products

Volume 10
Number 4

1978

Tekscope



Tektronix
COMMITTED TO EXCELLENCE

CONTENTS

Tekscope

Customer information from
Tektronix, Inc.
Beaverton, Oregon 97077

Editor: Gordon Allison

The 4027 — Adding a Color Dimension to Graphics

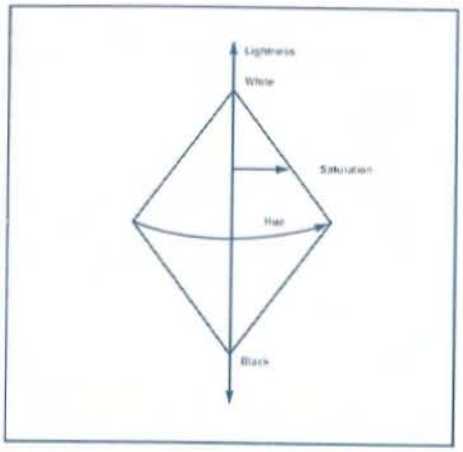
The 4027 Color Graphics Terminal is a compact, high performance computer terminal with a raster scan display. The memory required for both graphics and color is greatly reduced by using the virtual bit mapping technique developed for the TEKTRONIX 4025. Up to eight colors from a palette of 64 can be displayed simultaneously.

Tekscope is a bimonthly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique. A new products section gives a brief description of products recently introduced and provides an opportunity to request further information.

To better serve customers who maintain their TEKTRONIX instruments, the service information formerly appearing in Tekscope will be expanded and published in a publication dedicated to the service function.

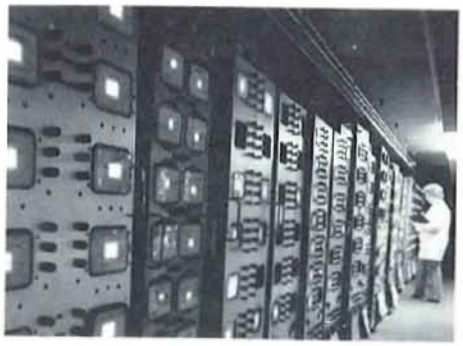
An Easy Language for Talking with Color Machines

A new color standard developed for the 4027 greatly facilitates selecting a color and getting it on-screen with the first attempt. It is easy to change color just a shade, or radically.



Reliability — the Continuing Challenge

Reliability doesn't just happen. You have to make it happen through people, programs, and perseverance. Here is just a brief overview of some of the activities dedicated to helping us meet this continuing challenge.



Cover: The use of color in developing a circuit board layout provides a convenient means of identifying select elements, as shown in this photo of the 4027 Color Graphics Terminal.

The 4027—Adding a Color Dimension to Graphics

Ken Willett came to Tek in October 1975 after receiving his BS in Physics and Mathematics from Whitman College and completing a year in the computer sciences graduate school at Washington State University. Since coming with Tek, Ken has worked on the 4020 Series Computer Terminals and PLOT 10 Easy Graphing Software.

Our everyday lives are greatly influenced by the use of color. Color movies, color television, and color printing carry much greater impact than their black and white counterparts.

Color has recently entered the world of computer graphics. And it offers much more than just the natural appeal of color. For example, it provides a means of separating information in multi-element charts and graphs. It can be used to call attention to a particular feature in the display. And it enhances human pattern recognition.

Color bit map displays have traditionally suffered from the high cost of memory involved (up to 120 kilobytes). Now, using the virtual bit map technique developed for the 4025 alphanumerics/graphics terminal,[1] memory required for color graphics is greatly reduced. In virtual bit mapping, the operator uses a software program to establish a graphics region on the display screen. The rectangular graphics region can be displayed anywhere in the display area, with the remainder of the area considered alphanumerics.

The graphics region is then further divided into graphics cells. A graphics cell is the same size as an alphanumerics cell — 14 dots high by 8 dots wide. A unique approach to graphics programming uses a display list and pointers to allocate graphics memory to only those cells containing graphics information. The remaining graphics cells appear in the display list as spaces. This greatly diminishes the memory required, especially for simpler graphs.

The addition of color to the graphics display requires a change from a single memory plane to three memory planes. Thus, a virtual bit map cell in the 4027 is a block of RAM which is 8 by 14 by 3 bits, rather than 8 by 14 by 1 as in the 4025. Each pixel (raster dot) within the cell may be displayed in any one of eight colors by properly setting the three RAM bits associated with that pixel. The basic 4027 contains 48 kilobytes of color graphics memory with options available to extend the total to 192 kilobytes.

While eight colors are enough for many applications, there was a problem in selecting which eight colors, in the spectrum of possible colors, were appropriate for a given application. It was clear that no one choice of eight colors was adequate for all applications, and that some method was needed for changing the selection under program control.

To provide this capability, a color map was included in the display hardware (See Fig. 2). The inputs to the mapping mechanism are the three bits in the virtual bit map for a particular point. The outputs of the map are two bits for each of the three guns in the color monitor. This allows the user, under program control or via keyboard commands, to set any one of the eight colors available, to one of 64 possible selections in the map. The Tektronix graphics terminal color standard (see page 7) was developed to allow easy control over selections from the 64-color palette.

Polygon concept saves memory

At this point in the design, the 4027 looked like a 4025 with color. However, there is a difference between adding color to a monochrome graphics terminal and building a good color terminal. This difference results from the fact that users demand different operations from a color display than the traditional selection of vectors and characters.

Most color pictures for which a color terminal is used contain solid-colored areas. This concept led to the development of the 4027 polygon feature. A polygon is a set of points describing the perimeter of an area. The interior of the polygon boundary is usually filled with a desired color or pattern. (See Fig. 3).

Here again the virtual bit mapping technique proved to be a major asset because most polygons contain entire cells of a fixed color. For these interior cells, it is not necessary to allocate graphics memory; a reference to a solid cell of the appropriate pattern or color is simply placed in the display list. In general, a solid area picture (such as a map), which is displayed on the 4027 as a set of polygons, will require significantly less graphics memory than the same picture drawn and cross-hatched on the 4025. Graphics memory in the 4027 is used only to draw the outline of the polygon. Firmware enables using another color to border the polygon if desired.

Fig. 1. The 4027 Color Graphics Terminal. A molecular modeling application is displayed.

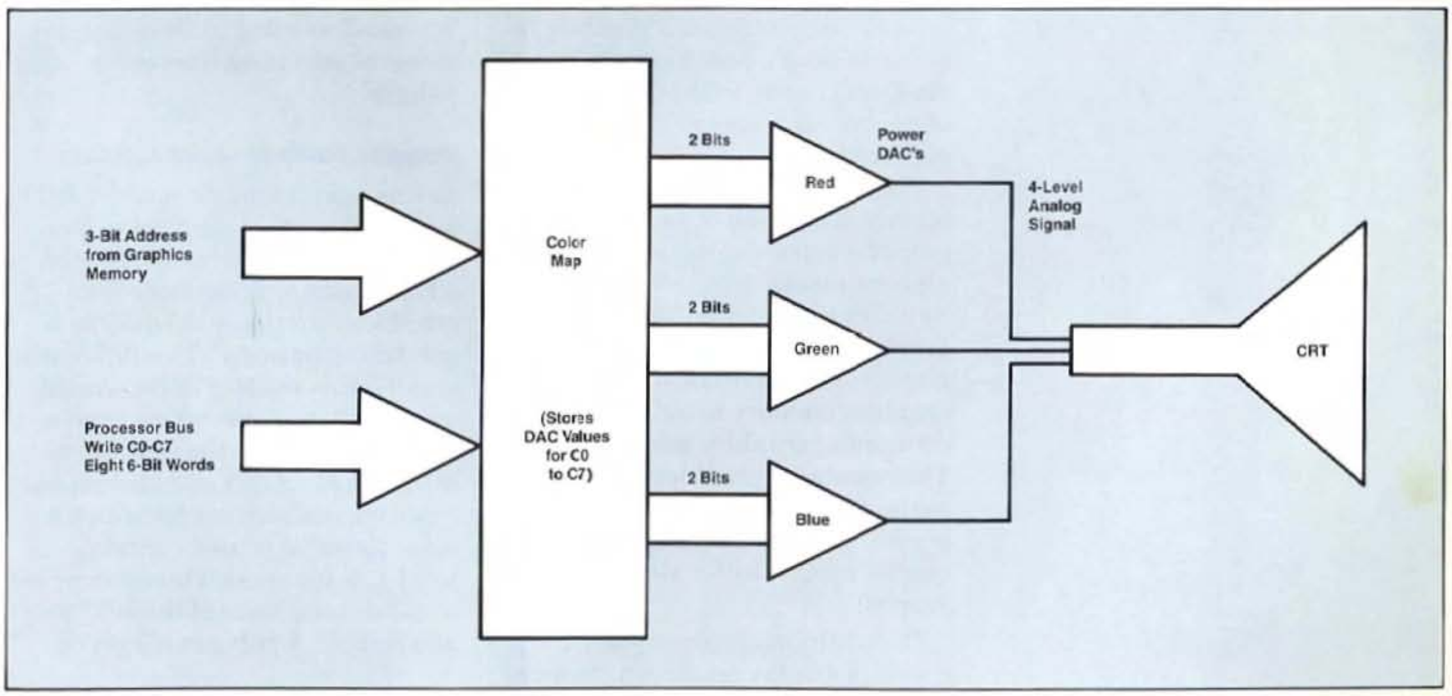


Fig. 2. Values of hue, light, and saturation for eight colors are stored in the color map in the form of eight 6-bit words. A 3-bit address from the graphics memory selects one of the 6-bit words as the output to the power DAC's driving the red, green, and blue guns of the color crt. Each gun is driven to one of four levels including off.

Patterns extend color choices

In some applications, eight distinguishable area types are not adequate. In order to increase the selection, the pattern concept evolved. Patterns are to polygons what dashed lines are to vectors. A pattern is a user-defined 8 by 14 grid, where each point in the grid may be one of the 8 colors. Once the pattern has been defined, it may be used to fill polygons. The pattern is simply repeated over the interior of the polygon.

There are two major uses for patterns. One is to generate additional colors by uniformly mixing dots of different colors.

Using this technique, pictures containing 125 distinct colors have been generated from patterned mixtures of the eight basic colors.

Let's consider an example of using a pattern to generate a desired color. Assume the color map for a 4027 has been set according to Figure 4. Note that the color map is coded such that Red = C4, Green = C2, and Blue = C1. If we add Red and Green (i.e., C4 + C2) we get Yellow (C6). We are now in a position to define color patterns.

A master pattern cell consisting of 8 by 14 raster dots, or pixels, is shown in Figure 5. The numbers in the master cell can be thought of as levels which correspond to the values of Red, Blue, and Green for the color we desire to generate. For example, assume we want to construct a color mixture of Red = 3, Green = 1, and Blue = 4. Each position in the master cell with numbers less than or equal to 4 (≤4) must get a Blue contribution, those with numbers less than or equal to 3 (≤3) must get a Red contribution, etc.

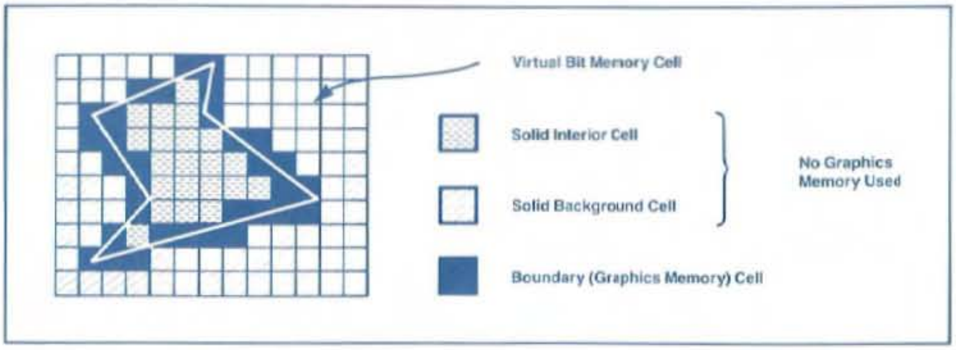


Fig. 3. The use of polygons makes efficient use of memory. Only the boundary cells require graphics memory. For the background and interior cells, a reference to a solid cell of the appropriate color is simply placed in the display list.

MAP #	HUE	LIGHTNESS	SATURATION	COLOR
C0	0	0	0	Black (K)
C1	0	50	100	Blue (B)
C2	240	50	100	Green (G)
C3	300	50	100	Cyan (C = B+G)
C4	120	50	100	Red (R)
C5	60	50	100	Magenta (M = R+B)
C6	180	50	100	Yellow (Y = R+G)
C7	0	100	0	White (W = R+G+B)

Fig. 4. Color map used for patterning. The colors selected provide the broadest range of discernible colors through patterning.

Note that the master cell is populated with a repeat of the pattern outlined in the upper left corner of the master cell. Let's focus our discussion on this sub-cell. (Fig. 6(a)). We start with a cell of all Black (K) as shown in Figure 6(b). Those elements with a value of ≤3 then receive a Red contribution as shown in Figure 6(c). Next, those elements with a value of 1 receive a Green contribution as shown in Figure 6(d). And, finally, those elements with a value of ≤4 receive a Blue contribution as shown in Figure 6(e). We then recode the RGB color codes to the appropriate color combinations from the color map in Figure 4; the result is shown in Figure 6(f).

By repopulating the master cell with this sub-pattern, we have a master pattern which exhibits the proportionate color properties of the desired color mixture. It is then a straightforward task to encode this pattern into the form needed by the 4027.

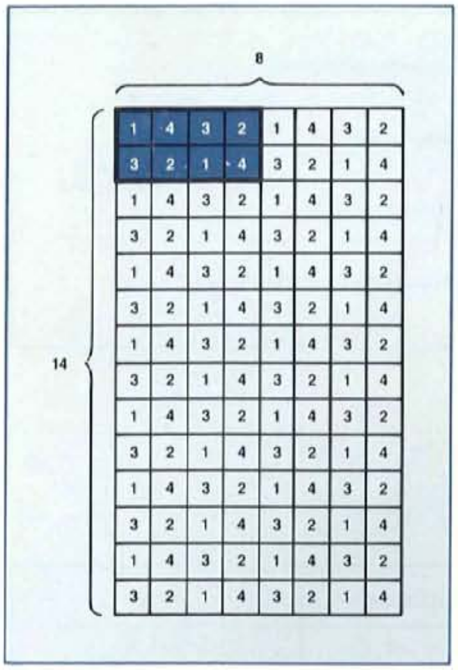


Fig. 5. A master pattern cell contains the same number of elements as alphanumeric cells. The numbers correspond to the values of red, blue, and green for a selected color. Note the two-row, four-column pattern is repeated throughout the cell.

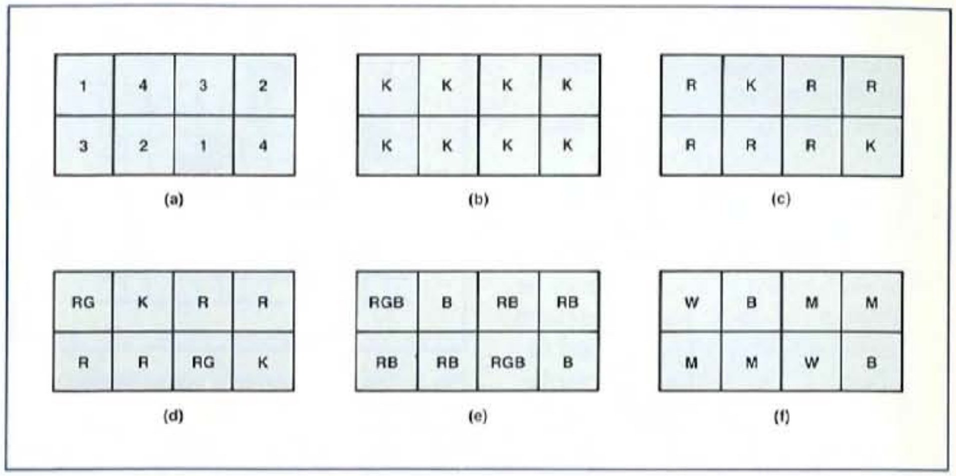


Fig. 6. (a) Basic pattern for the master pattern cell in Fig. 5. Numbers correspond to the values of red, blue, and green for a selected color. The desirec color is Red = 3, Green = 1, Blue = 4. Starting with an all Black cell (b), Red is added (c), then Green (d), and finally Blue (e). The resultant colors are White, Blue, and Magenta (f).

By repeating the foregoing process for all combinations of Red, Blue, and Green in the range of 0 to 4 we can construct a set of patterns to simulate the colors for a 5-step per gun color system—a total of 125 colors.

Patterns are also used to fill polygons with more traditional area coverings, such as crosshatch and stripes. These capabilities are available in firmware in the 4027, making much more efficient memory use than if they were a part of the host software.

More than just a color terminal

The 4027 is more than just another color terminal—it is a very versatile alphanumerics/graphics terminal. One of the important operating features made possible by virtual bit mapping is the unique ability to scroll color graphics and alphanumerics together. This same technique enables definition of multiple graphic regions for easy recall from local memory.

The 4027 uses the same functional PLOT 10 Easy Graphing host software as the 4025. Easy Graphing offers support for up to six curves or colored bar charts, line graphs with special symbols and dashed lines, legends, titles, grids, hard copy, and plotter control.

For more demanding color graphic applications, the PLOT 10 Interactive Graphics Library offers all the support commonly required in graphics applications.

A wide range of options allows one to extend the display and color graphics memories and connect to a variety of peripheral devices including the 4632 Hard Copy Unit (Option 06), 4642 Printer, or the 4660 Series of interactive digital plotters. Both RS-232-C and GPIB Interfaces are available. A polling interface permits multiple-terminal configurations on the host computer line. And a Forms Ruling Option lets you duplicate essentially any form.

Summary

The 4027 Color Graphics Terminal is a compact, high-performance terminal with a 13" raster-scan display.

The virtual bit map graphing technique allows one to perform many graphics functions with only a modest amount of memory. And a new color standard scheme provides a straight-forward, easy-to-learn method of specifying color. A wide range of options permits tailoring the 4027 to handle today's applications, and expand easily to meet tomorrow's.

In the 4027, alphanumerics, graphics, and color merge to provide a new and more versatile tool for information display.

1. See "The Virtual Bit Map Brings High Resolution Graphics to the Alphanumerics Terminal User." Tekscope Volume 10, November 1, 1978.

An Easy Language for Talking with Color Machines

Stan Davis has been involved with computer terminal design since coming with Tektronix in 1968. He worked on the keyboard and other circuits for the T4002, was project engineer on the 4023, assisted on the 4081 program, and was project leader on the 4025 and 4027 programs. Stan received his BSEE and BA from Rutgers University in 1964 and an MBA from University of Portland in 1975.

Lee Metrick developed the color standard for the 4027 and did a great deal of innovative computer work on the use of half tones in color graphics. Lee received his BSEE from Syracuse University in 1965 and a Masters in Science and Industrial Engineering from the University of Michigan in 1970. He is completing his dissertation for a doctorate in Industrial and Operations Engineering, also at Michigan. Lee taught Computer Science for three years at the University of Kentucky. A newcomer to the Northwest, he has been at Tek since September 1977.

The world of color is filled with unclear and ambiguous terms such as intensity, value, chromaticity. Many methods exist for specifying color, but most are "machine" oriented. Early in the development of the 4027 Color Graphics Terminal, it was apparent that a people-oriented method for communicating with the terminal about color was needed. But how does one go about selecting a color and describing it in meaningful, precise terms? Before proposing a solution to this problem let's review some methods now in use.

Television is a light generator and is referred to as an additive color system. When red, blue, and green are combined in proportionate amounts, they add up to a color perceived as white. Colors for television-based computer terminals are often described as mixtures of RGB, for example, red 3, green 2, and blue 0.

Printing pigments are light filters and are subtractive. When magenta, yellow, and cyan pigments are mixed together in equal amounts and illuminated, they subtract reflected light so that black is perceived. the printing industry deals with separations of magenta, yellow, cyan, and luminance (black and white). It describes colors, for example, as 75% magenta plus 25% cyan.

How do people like you and I specify colors? We use names and adjectives. Most have a clear idea what the following names represent; red, green, blue, black, white, orange, purple, grey, dark grey, brown, dark red, pink. But how about dark magenta, walnut brown, Aztec blue, or passionate pink?

Numerical descriptors are more nebulous still. What color is created with red = 3, green = 3, and blue = 2? Or how do you get flesh tone by mixing magenta, yellow, and cyan?

Describing and generating colors at the paint store is an activity with which we're all familiar. We decide to paint the bedroom walls with a shade like the drapes, only lighter. At the store we select the Aztec blue chip from the collection. The clerk then finds the numerical machine instructions for mixing pigments and mixes the paint. The room is painted and the color evaluated. It should be a little greener and a little lighter, but changing it will be time consuming and expensive so we decide to live with it.

Interactivity a necessity

We need a better approach for working with color terminals.

The special thing about a color terminal is displaying images in the desired colors. This is best accomplished by interactivity. The user specifies a color. The terminal displays it. The user evaluates it and corrects it if necessary. It is important, therefore, that the method of describing colors facilitates this interactivity.

To be valuable to Tektronix and the industry, the method must not only work with the 4027, but also accommodate future products. These may have many more colors than the 8 out of 64 used by the 4027.

The method used to specify colors should:

- Be easily learned and remembered.
- Provide for interactivity.
- Work for displays.
- Work for copying devices.
- Work for devices with thousands of colors.
- Work for computers, data bases, transmission lines.

Selecting a method

While the commercial availability of color graphics terminals is new, color scientists have been around for some time. Theories and models abound. One text alone shows over 30 approaches for thinking about color. From these, two were selected for further consideration—the double-ended cone and the cube. The color cube (Fig. 1) relates directly to the hardware, but is difficult for people to use because it is difficult to portray the colors inside the cube in an organized, meaningful way.

In the double-ended cone (Fig. 2), colors are selected by specifying hue, lightness, and saturation. (This is often referred to as the HLS method). These attributes relate to how colors are perceived rather than generated. Hue is the characteristic associated with a color name such as red, yellow, or green. Lightness is the characteristic that allows the color to be ranked on a scale from dark to light. And saturation is the extent to which the color differs from a gray of the same lightness. For example, fire-engine red is highly saturated.

Colors are arranged in the geometry of a double-ended cone (Fig. 2). Variations in lightness are represented along the vertical axis with black at the bottom apex and white at the top apex. On a plane which intersects the cone perpendicular to the lightness axis, all colors are of equal lightness. Variations in saturation are represented by a radial distance from the lightness axis. And hue is represented as an angular displacement around a circle intersecting the cone.

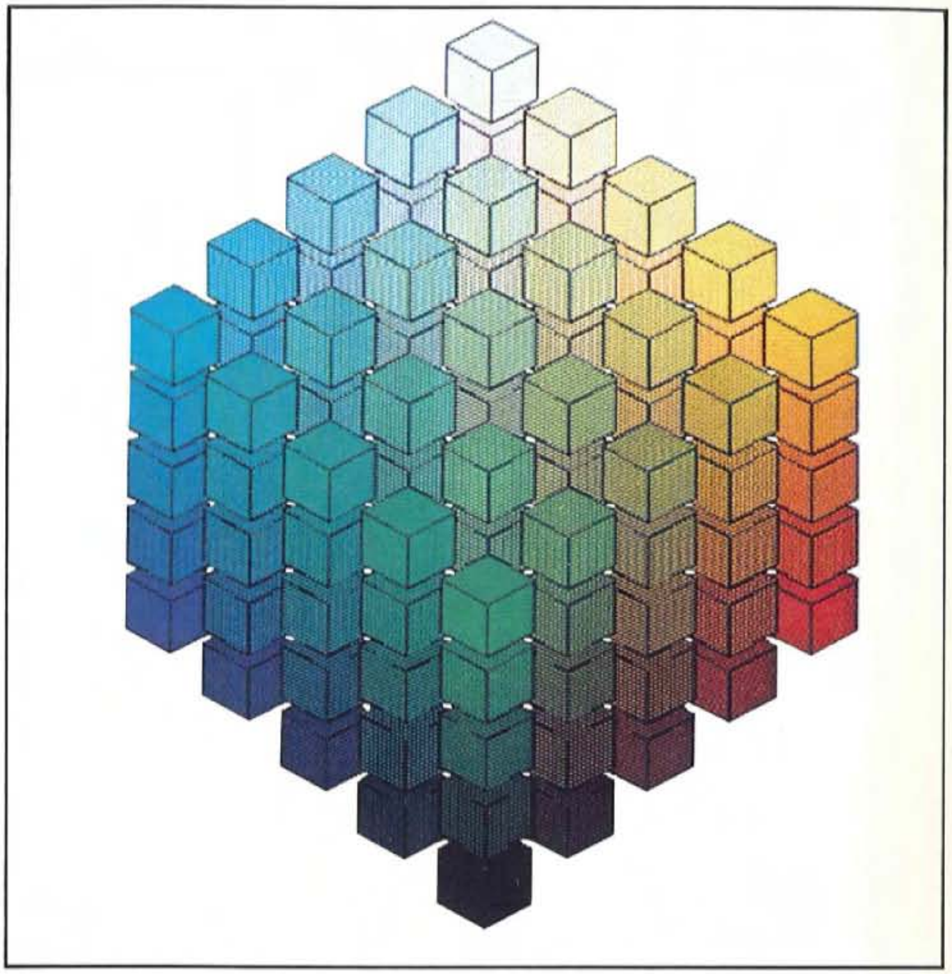


Fig. 1. The cube relates colors in a manner most comparable to the hardware, but it is difficult to visualize colors inside the cube. This photo was taken from the 4027.

Stated quantitively, hue is a variation of color advanced by degrees represented as an angle from 0 to 360 degrees from a reference where 0 degrees is blue.

Lightness ranges from 0%, which is black, to 100%, which is white.

And saturation is expressed as a percentage of the distance to the surface of the cone ranging from 0%, maximum white at that lightness level, to 100%, which is fully saturated.

The TEKTRONIX 4027 color standard (Fig. 3) illustrates one product implementation of the double-ended cone. The continuous and infinite theoretical cone has been approximated by the 64 regions of color that a 4027 can generate. The figure can be used to illus-

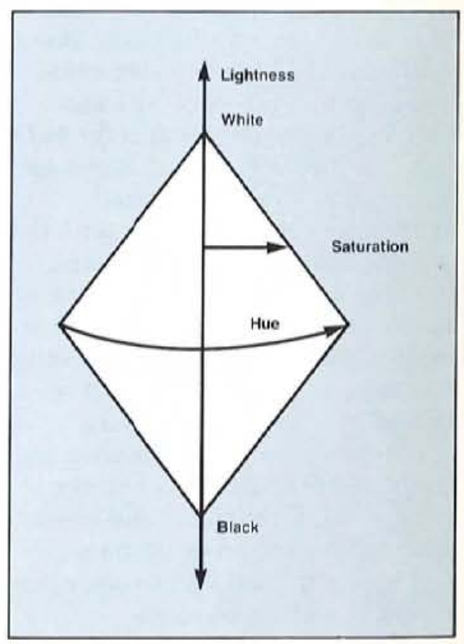


Fig. 2. The double-ended cone can be used to express colors in terms of hue, lightness, and saturation. Hue is expressed in degrees from 0 to 360, lightness from 0 to 100%, and saturation from 0 to 100%.

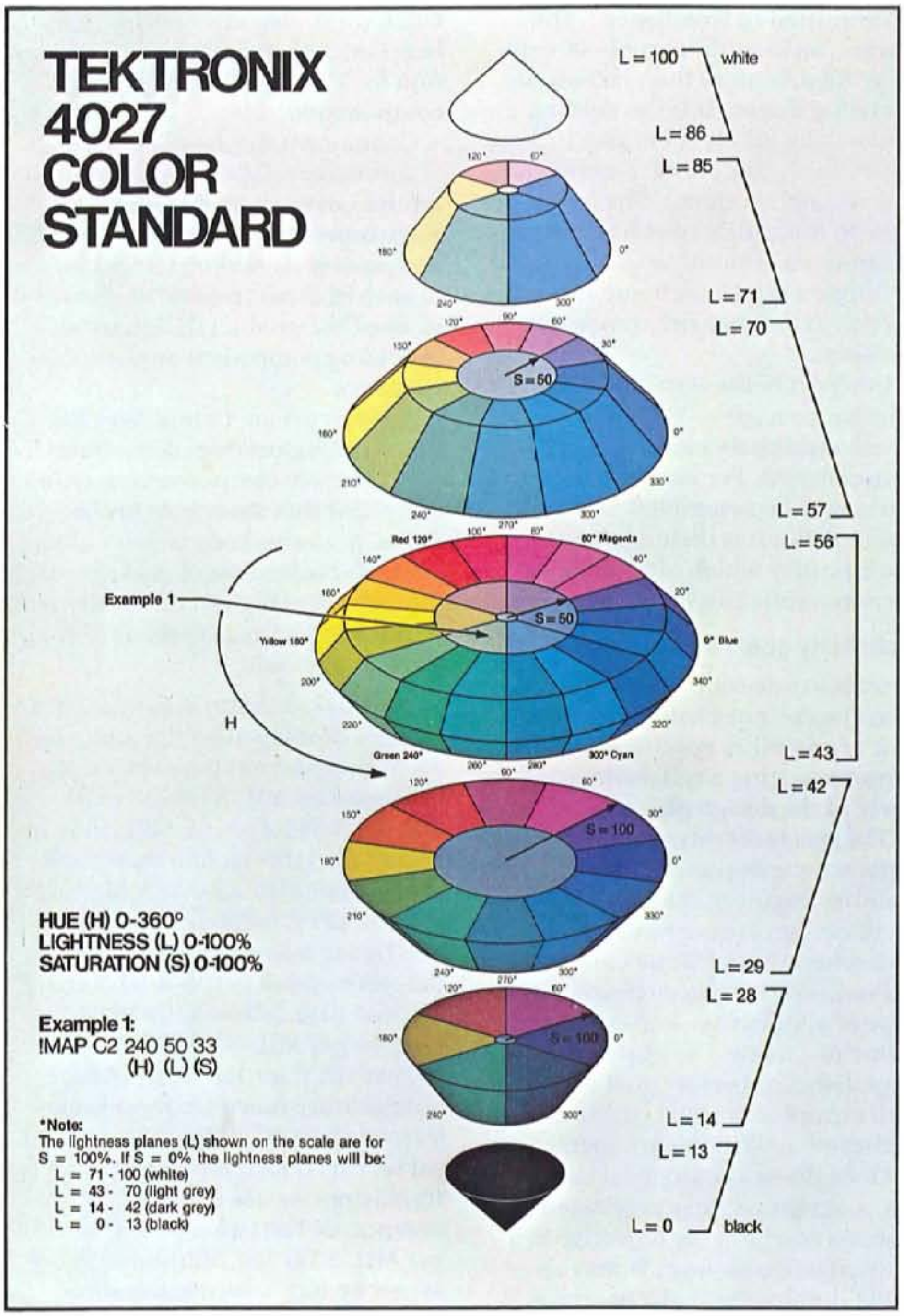


Fig. 3. The 4027 Color Standard is one implementation of the double-ended cone concept. It is relatively easy to specify a desired color in terms of hue, lightness, and saturation using such a standard.

trate the concept and assist a 4027 user in specifying color. It can be seen that fire-engine red can be obtained as follows: hue is red (120°), lightness is 50%, and saturation is full (100%). This would be specified as 120, 50, 100.

A look at the hardware

Having discussed the method for specifying color for the 4027, let's consider the hardware itself for a moment. The 4027 uses a delta gun, shadow mask, high resolution color tube. The user can select any 8 colors from a palette of 64, to display on-screen. A three-bit-deep, virtual bit map stores the information relating a color number, C0 through C7, to the color of a pixel (picture element or dot). The red, green, and blue guns of the cathode ray tube can each be driven in 4 levels, including off, creating up to 64 colors. A register arrangement in the display controller, called the color map, remembers which of the 64 colors to generate when, for example, C3 is called for.

Use of the virtual bit map graphics technique and other features such as polygons and patterns, gives the 4027 unusual capability with only a modest amount of graphics memory. The 4027 is discussed in greater detail in a companion article in this issue.

Summary

The HLS method of specifying color provides a terminology and conceptual framework for working with color. It is easily learned and remembered. Users are able to select a color from the color cone and get it on-screen. They also find it easy to memorize the cone and input numbers to the 4027 that get close to the desired color, on the first try. After judging it, they can easily change hue, lightness, and saturation as needed.

The HLS method was adopted and developed for the 4027. It could be used by other Tektronix terminal and peripheral products. Indeed, it could well serve the industry internationally as a method for people and machines to effectively interact with color.

Reliability—The Continuing Challenge

William Peek is manager of Test and Measurement Operations and chairs the Corporate Reliability Committee. During his 16 years with Tektronix, Bill has been heavily involved in the development and design of Tek products—working as a project engineer in the 7000 Series, managing several product lines, and most recently, managing the Laboratory Instrument Division. He holds a BSEE and MSEE from Oregon State University.

"Committed to Excellence." This phrase, an integral part of our company logo, is more than just an advertising slogan. It is the guiding philosophy for all of our day to day activities — designing, manufacturing, selling, servicing. Strict adherence to this philosophy has earned Tektronix a reputation as a manufacturer of quality test and measurement and information display products.

Inherent in the term "quality" is another concept —"reliability." These are closely related but separate concepts. For example, quality parts may be assembled in a skilled manner. But it is their application in the circuitry which ultimately determines reliability.

Reliability goals a necessity

Reliability doesn't "just happen." It must be designed into the product just as any other specification. This requires setting a reliability goal early in the design phase.

The goal is set through discussions between the design engineer, the reliability engineer, manufacturing engineering, product marketing, and others. Many factors are involved — operating environment, type of application, and cost, to name just a few. The objective is to establish a reliability goal which will ensure continued customer satisfaction with the product.

Once the reliability goal has been set, a design strategy is selected that assures reaching the objective in a cost-effective manner. It may require development of a new integrated circuit, use of a premium part, or special temperature control techniques, perhaps all three. The design engineer has extensive support in making these decisions.

Component support

With the rapid change taking place in solid state and other devices, it is a real challenge for the design engineer to be knowledgeable about every component. At Tektronix, the Component Engineering group assists designers in this task. Their primary function is to provide evaluation, characterization, specification, and application information for Tektronix purchased components.

Component Engineering consists of several specialized evaluation groups covering analog, digital, electromechanical, optoelectronic, and passive components. Specialists in each of these areas serve as extensions of the product design team, providing component applications guidance.

Another group, Component Reliability Engineering, determines cost-effective component screening and reliability assurance procedures, performs comparative evaluations for selections of package style and vendor of highest reliability, and performs electrical analysis of components that fail.

Typical reliability assurance procedures developed by the group for discrete devices and microcircuits are based on MIL-STD 750 and MIL-STD 883. For example, the procedure for MOS memories is 100% burn-in per MIL-STD 883, Method 1015, at 125°C for 96 hours. Digital and linear microcircuits are temperature cycled per MIL-STD 883, Method 1010, followed by 100% burn-in per MIL-STD 883, Method 1015 at 125°C for 160 hours. A high-temperature functional test is performed at 100°C, followed by electrical test at room temperature. For transistors we use a reliability lot acceptance test using power burn-in per MIL-STD 750, Method 1036, followed by 100% electrical testing.

Note that these are "typical" procedures, and are modified accordingly to meet specific reliability requirements.

Fig. 1. Tek uses it's own S-3200 Series Test Systems to perform incoming inspection on millions of parts annually.

Component Reliability Engineering plays a vital role in our long-term reliability program by performing failure analyses of parts removed by our field service centers. Returned parts undergo electrical tests, and those found to be defective are analyzed to determine the failure mode. Parts are filed to be available for further analysis at a later date if desired.

Component Reliability Engineering also performs special analyses on request. For example, an extensive study was performed to determine the reliability of plastic encapsulated semiconductor devices under various humidity conditions. In an evaluation of devices removed by our field service centers, it was found that humidity was not a significant contributor to field failures.

Tek made components

While most of the activities just discussed are devoted to ensuring the reliability of purchased parts, there is comparable activity taking place relative to Tek-manufactured components. In many instances, the desired performance cannot be achieved with purchased parts. Accordingly, Tektronix has developed a substantial in-house component capability. This includes resistors, capacitors, transformers, coils, switches, relays, cathode ray tubes, solid state devices, printed circuit boards, etc. Each of the major component groups has its own reliability personnel and programs.

The Integrated Circuit Manufacturing (ICM) group has developed programs and testing capabilities that are among the most comprehensive in the industry. Reliability programs for new devices are established at the beginning of the design phase. Drawing upon years of experience, a checklist of some 34 factors has been prepared, against which new designs must be evaluated before design acceptance. One of these factors is the setting of a reliability goal for the device and defining life-test conditions.

Reliability inspection parameters for each device are established using MIL-STD 883 as a basis. Both mechanical and electrical tests are included. A look at just a few of the tests performed will serve to illustrate the thoroughness of the program.

Thermal shock consists of 15 cycles of −55°C to +125°C, air-to-air, with a 4-5 second transfer time. Fine and gross leak checks (on cavity packages) follow the thermal shock tests. On some devices leak checks are performed both before and after thermal shock. Next comes 10 days of temperature and humidity cycling. Temperature is cycled once every 24 hours over a range of −10°C to +65°C at humidities of 90 to 98%. Power may be applied during all or part of this test. The high temperature operating life test then follows. Ambient conditions and electrical conditions are adjusted to yield junction temperatures from 125 to 200°C, depending on the design of the device. Typical test times are 1000 hours, or as the reliability goal dictates. These tests are performed in series to qualify a new product for certification.

Production run devices receive 100% burn-in and 100% testing in accordance with the reliability goals set for them. In addition, life tests are performed on a continuing basis.

The ICM group performs its own failure analysis. Their sophisticated test equipment includes a scanning electron microscope (SEM), optical microscopes, curve tracers, cameras, and an electron microprobe (EMP). The photo in Figure 3 shows a typical application of the SEM in determining the source of an intermittent open in an integrated circuit lead.

The cathode ray tube is another key component manufactured at Tektronix. Reliability programs for this device center on maintaining tight control of production processes, analysis of field returns, and continuous life testing. New materials and processes are thoroughly tested before release for use in production units.

Tek has one of the finest electrochem facilities on the West Coast. Reliability of etched circuit boards is primarily a function of attention to the materials and processes used. A well-equipped metallurgical laboratory exists to ensure continuing quality and reliability in the metals we use. Because complex multilayer circuit boards require precise process control, much of the lab's activity is devoted to microscopic analysis of these boards to assure electrical and metallurgical continuity of the contacts. Boards are examined for the quality of through-hole plating following the critical processes, and again after the holes have been soldered, as in the assembly process. Close attention is also given to handling and cleaning techniques to avoid the development of leakage paths.

The foregoing examples are typical of the attention given to reliability by all of the component groups at Tektronix.

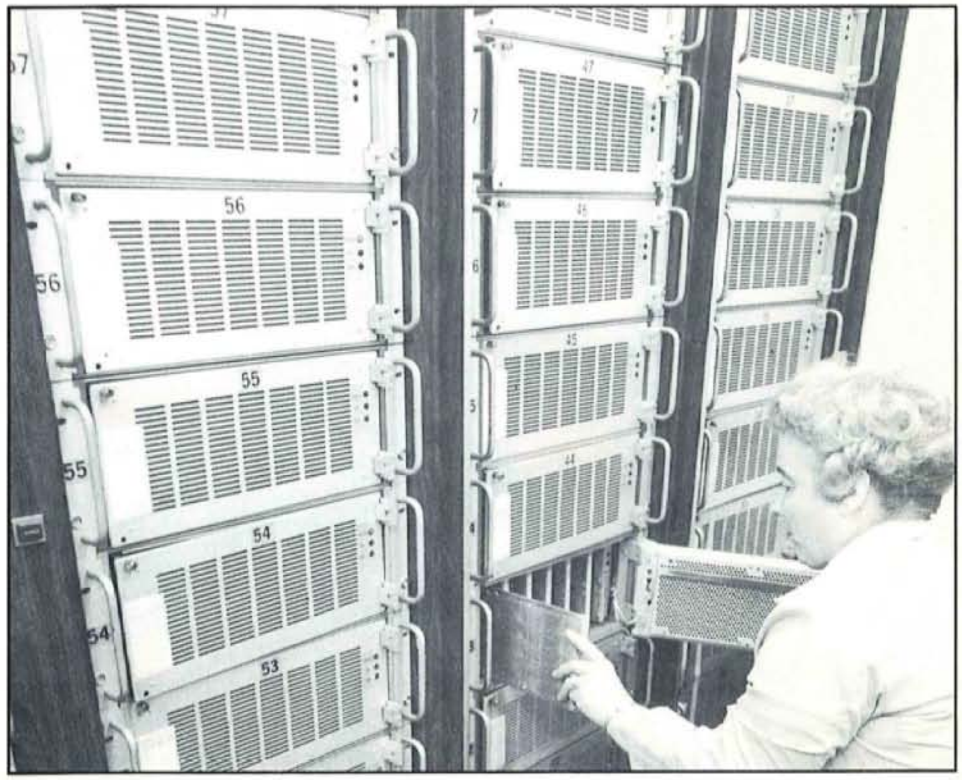


Fig. 2. One hundred percent burn-in of memories and other solid state components weeds out infant mortalities and marginal devices. Operator is loading components into the cycling rack.

Component reliability information

To realize maximum benefit from all of this component reliability activity, component information must be readily available to the design engineer and other interested parties. This is provided through personal consultation and by various internal publications.

A five-volume in-house parts catalog lists preferred parts, which have been determined to be acceptable for new design. Frequent updating keeps the catalog current. A companion publication, *Device Derating Guidelines*, provides further guidance in component selection. It includes stress and excursion limits, failure rate information, and derating notes. The information is derived from our own experience, manufacturers' notes and recommendations, and various reliability handbooks. MIL-HDBK-217B is referenced in much of the material.

A biweekly publication, *Component News*, keeps the engineering community up-to-date on new components, their application, and information on quality and reliability. *ManuFACTuring*, a monthly publication, facilitates communication among Tek manufacturing areas. It also serves as an informal liaison between engineering and manufacturing groups, with much of the content devoted to reliability. Other publications including application notes, designer's guides, and users' handbooks are published periodically. A selection of data books from outside vendors is also readily available.

Another source of information is a computer program called "RELY" available on our scientific computer.

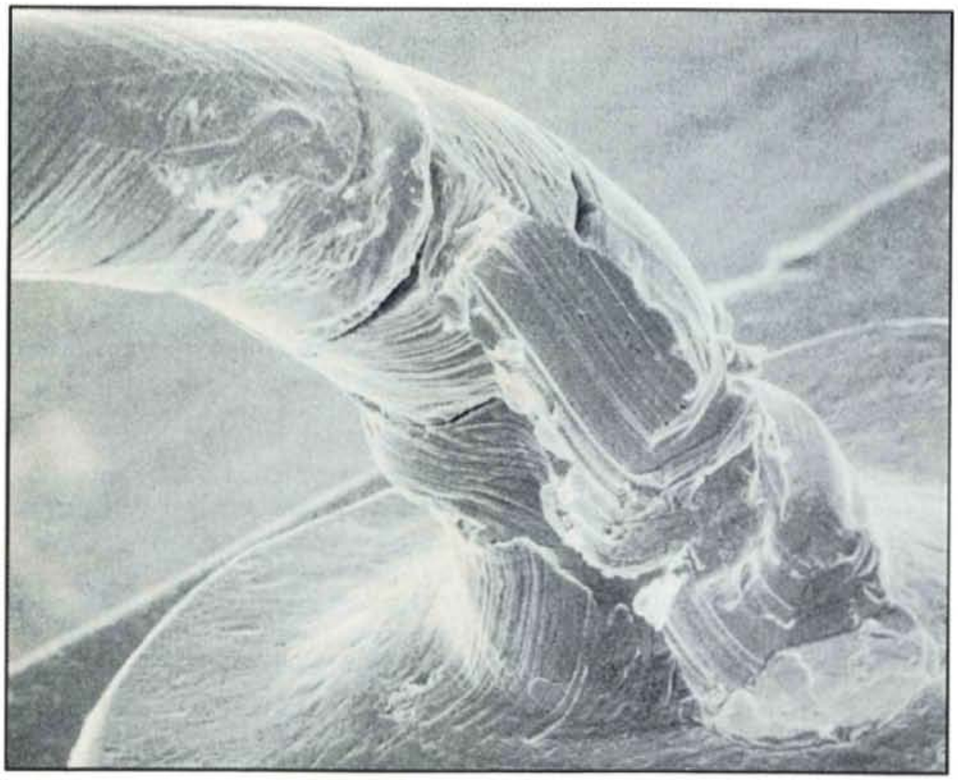


Fig. 3. The scanning electron microscope is a valuable tool for performing detailed analysis of semiconductor manufacturing processes. Source of a thermal intermittent is shown in this SEM photo revealing a cracked bond wire.

This program enables designers and evaluators to analyze the effect of parts population on reliability early in the design phase. The program, originally based on MIL-R-26474, has been updated to use MIL-HDBK-217B generic failure rates. It includes all applicable categories in 217B. Base failure rates for plastic encapsulated devices, which are not included in 217B, are derived from Tek field experience data. RELY is widely used to help us keep on target with respect to our reliability goals.

Product reliability engineering

Moving up from the component level, let's consider some of the programs and facilities devoted to product reliability. Tektronix uses a planned phase system of new product development and introduction.

By the time a design is completed, the reliability program for the new product must be established and a schedule for execution defined.

During prototype development, a number of units will be tested to ensure the reliability goal has been met. Once into production, routine reliability audit tests (usually 500 hours) are performed to verify the product meets expected quality and reliability levels.

Product reliability testing is the responsibility of the Product Reliability Engineering group. This group provides consultation in the setting of reliability goals and predictive analysis of reliability early in the design phase. It also establishes test procedures for verifying reliability. The procedures are designed around MIL-781 and are custom tailored to the product.

For example, a vibration test (usually 500 hours) is included for portables, to detect problems peculiar to their application. To accelerate life tests, instruments are cycled at elevated temperatures of 40° or 50°C. The group operates their own temperature-controlled test rooms and shake tables.

A well-equipped environmental laboratory and trained staff provide support to the engineering reliability group and others. Their capabilities and services are divided into three categories — the Dynamics Lab, Atmospherics Lab, and Electromagnetic Compatibility Lab.

As the name implies, the Dynamics Lab tests how well a product withstands physical abuse — shock, vibration, shipping, etc. Vibration tests are conducted over a range of 10 Hz to 55 Hz, or higher, with careful observation of components and mechanical structure. A "qualification shake" is included which consists of 75 minutes of swept and constant frequency vibration. This simulates operating and non-operating conditions experienced whenever the unit is wheeled on a cart or transported in a car trunk. A series of rotational drops simulate bench handling of the product. The product is then packaged for shipment and undergoes a vibration test simulating transit on a truck or cart. The packaging drop test calls for the product to be dropped on each corner, edge, and surface from a height of three feet for a total of 26 drops. Forces up to 60 "g's" are experienced in this test.

In the Atmospherics Lab the product is exposed to extremes of temperature, humidity, and other elements. Non-operating tests include exposure to a high of 125°C and a low of −65°C. Operating temperature tests are also conducted over a wide temperature range as called for

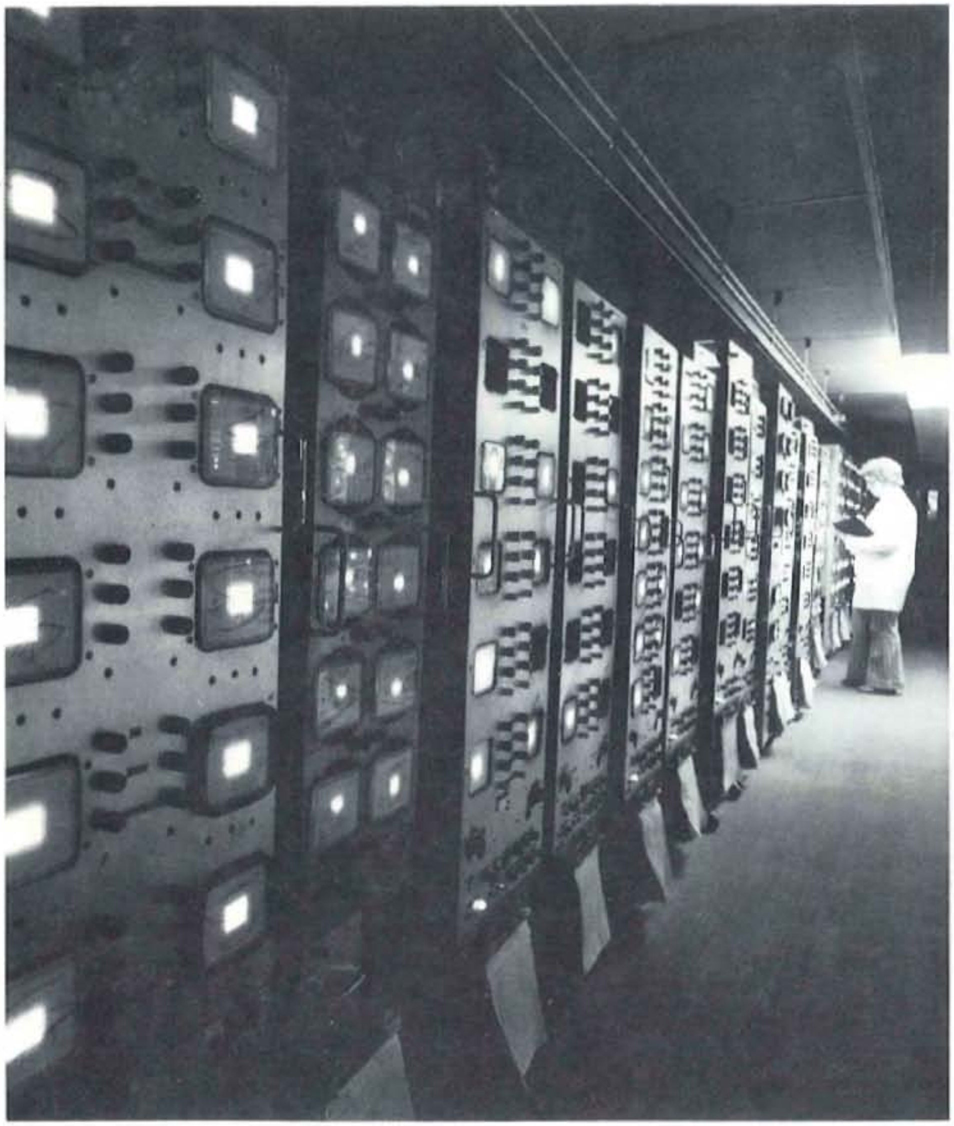


Fig. 4. Continuous life-cycle testing of cathode ray tubes ensures production units meet expected life times.

in the specification. Storage testing is performed at a 50,000 foot elevation to simulate transit in unpressurized aircraft freight compartments. The lab also performs salt spray, sulfide atmosphere, ultraviolet, flammability, and other tests.

In the Electromagnetics Lab the product is checked for electromagnetic emanations, either radiated or conducted, and for its susceptibility to such signals. Electrostatic discharge testing is also performed to measure both the charge build-up on the instrument and the effects of external discharges on its operation. The group also performs X-radiation tests.

Reliability feedback

With all of the foregoing materials, components, and finished goods tests, the ultimate test of reliability is the product's performance for the customer. How do we measure that performance?

A nationwide network of Tektronix service centers return all defective warranty parts with a report which gives the instrument type, serial number, circuit symbol, part number, and description of the part. The returned part is tested and then analyzed by the Component Reliability Engineering group discussed previously.

Failure data is recorded by the Reliability Information Services group. Failure information is gathered from many sources worldwide — Reliability Lab tests, manufacturing plants, Incoming Inspection, and manufacturing quality audits.

Warranty failure data, along with production data, is computerized and made available to top management and others on a routine basis. Data is supplied in several formats making it readily apparent when a problem exists with a particular production run, a part, or an application of a part.

A side benefit of this activity is the ability to determine parts inventories for field service centers. This improves the service centers' ability to stock the right parts for warranty repairs.

The reliability structure

Thus far we have discussed programs and facilities, but little about the people involved in reliability.

There is a high level of interest in reliability at the corporate level. A Corporate Reliability Committee provides visibility and coordination of quality and reliability activities across the entire product line.

Reports from the Reliability Information group showing the performance of each product line and a comparison of product lines are reviewed and discussed by the corporate group.

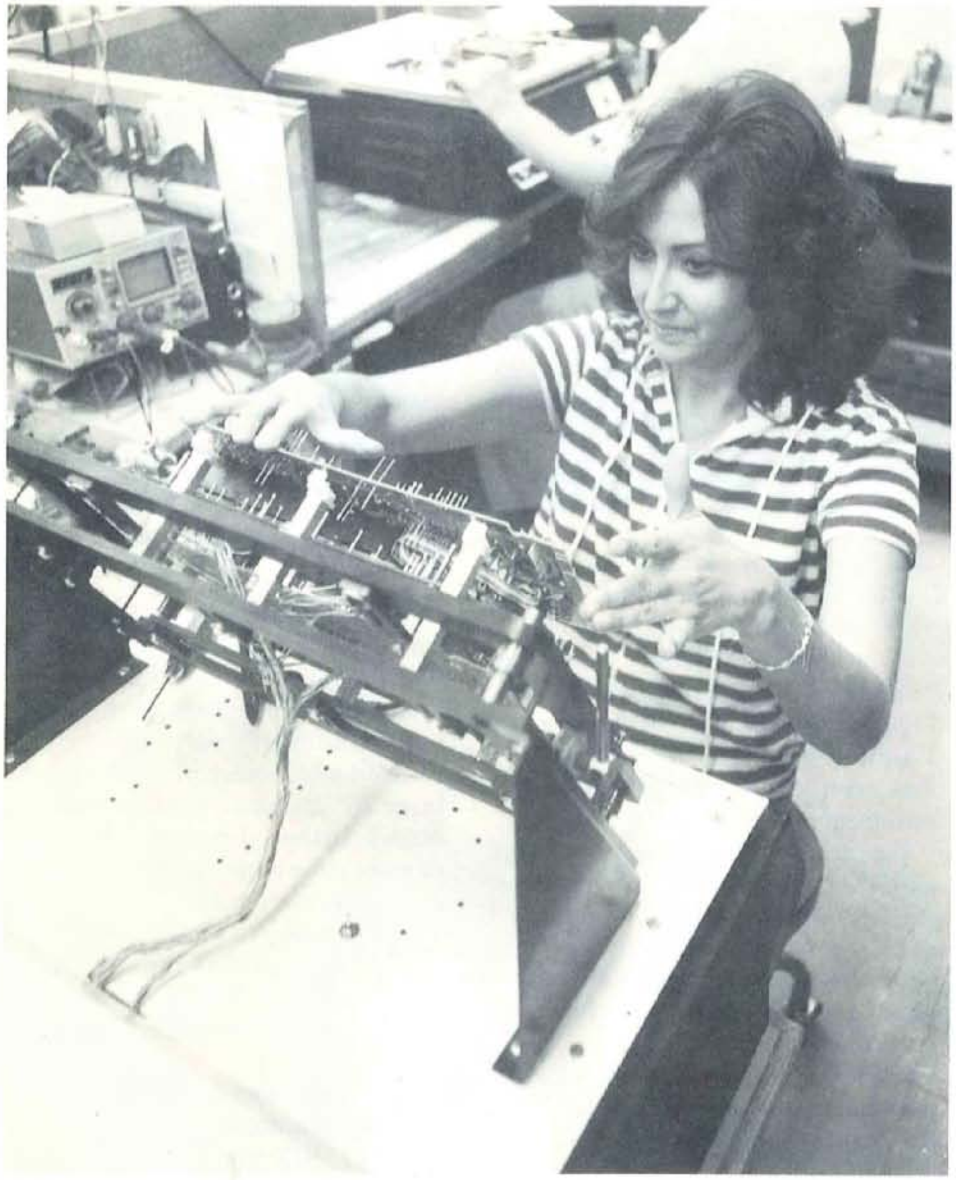


Fig. 5. Thorough testing of printed circuit boards before installation in final assembly is an important step in the reliability process.

Fig. 6. A unit undergoes drop test to ensure packaging will prevent damage to instrument during transit.

A subcommittee, Reliability Engineering Sub-Committee Unit (RESCU), consisting of reliability specialists from the business units, make up a smaller, working group which identifies and resolves interdivisional problems.

A corporate quality audit group also randomly selects products from finished goods inventory and performs critical examinations. Included is a 500-hour accelerated life test.

In general, the reliability engineer has the responsibility for the reliability program for a particular product line. These specialists help designers develop new products to meet desired reliability goals. They also can, and have, put a hold on production of a new product until the reliability goal set for that product has been met.

Summary

With all of the activity devoted to reliability, one would expect every instrument shipped by Tektronix to perform perfectly for the entire warranty period and well beyond. Most do. But there are exceptions. A host of people at Tektronix are dedicated to making those exceptions a rarity.

New Products

Two New Automated LSI Testers

The S-3270 20 MHz LSI Tester

Two new automated LSI Testers have been added to the TEKTRONIX S-3200 Series. The S-3270 represents the state-of-the-art in device characterization while the S-3250 makes the proven capabilities of the S-3200 Series available in a medium cost, high performance production and incoming inspection test system.

Both machines offer a number of high performance features. Twenty megahertz operation permits testing the newer LSI devices at their full operating speed. A local memory of 4K of RAM per pin (shift register) is standard, and an additional 4K of RAM is available as an option. A seven-phase clock is standard, with 14 phases optional. Return to inhibit (RI) driver format for high speed I/O bus testing is included. Other driver formats included are non-return to zero (NRZ), return to zero (RZ), return to one, and return to complement. Operating software language is the device-oriented TEKTEST III, field proven on the S-3260. An extensive library of routines for reducing test data is also available.

25" Storage/Refresh Graphics Display for OEM Market

GMA 125 Display Module

The GMA 125 is a high speed, 25-inch graphics display designed specifically for the OEM market. Featuring 70% more display area than 19 inch displays, the GMA 125 is ideal for computer-aided design and manufacturing, publishing, and automated cartography.

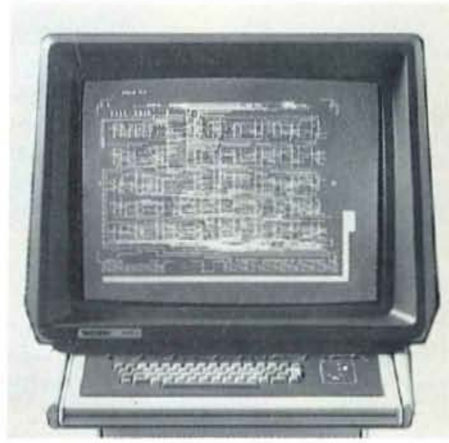
The direct-view-storage tube achieves high-quality, high-density graphics at low cost. And the substantial refresh (write-through) capability provides interactivity which greatly enhances the versatility of the system.

A full range of options, including analog and digital interfaces, minimizes the time needed for the OEM to electronically integrate the display into his product.

The high-efficiency, switching-type power supply reduces power consumption and weight. It also provides inherent compatibility with 220 volt, 50 hertz power source for international applications.

The GMA 125 chassis is a symmetrical structure so the entire unit can be rotated if a designer needs a long axis vertical format. It also can be mounted with any degree of tilt.

The 4010 Series Adds 25" Graphics Capability.



4016-1 Computer Display Terminal

The designers of electronic circuit boards, utility networks, schematic diagrams, street maps, and similar applications will welcome the increased work space provided by the large 25" diagonal screen of the 4016-1. Using a direct view bistable storage tube display, graphic lines are sharp, stable, and non-flickering making it easy to study the finer details of a design. The thumbwheel-controlled crosshair cursor makes it easy to interact precisely with this detail.

The 4016-1 was designed for complete compatibility with TEKTRONIX 4010-1 application software, communication support, and other Tektronix peripheral devices commonly used with the 4010 Series of terminals.

The 4016-1 includes a convenient detachable keyboard and detachable display.

A variety of hardware enhancements are also standard on the 4016-1. They include hardware generated solid, dashed, and dotted lines, point plotting with software-controllable point size, incremental "relative graphics" plotting, and four hardware character formats.

11/78 AX-4095

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

0421867 1339
MR THOMAS P DOWNEY LAB TECH
GEOLOGY DEPT EPS-J106
CITY COLLEGE OF NEW YORK
138TH ST. & CONVENT AVE.
NEW YORK CITY NY 10031

BULK RATE
U.S. POSTAGE PAID
TEKTRONIX, INC.

The 4663 — Large Plotter Capability with Small Plotter Convenience

Parameter Entry Device Simplifies Plotter Set-up and Servicing

Updating the Industry-Standard 100 MHz Portable Oscilloscope

New Products

Volume 11
Number 2
1979

Tekscope

Tektronix®
COMMITTED TO EXCELLENCE

CONTENTS

Tekscope

Customer information from
Tektronix, Inc.
Beaverton, Oregon 97077

Editor: Gordon Allison

Tekscope is a bimonthly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique. A new products section gives a brief description of products recently introduced and provides an opportunity to request further information.

The 4663 — Large Plotter Capability with Small Plotter Convenience

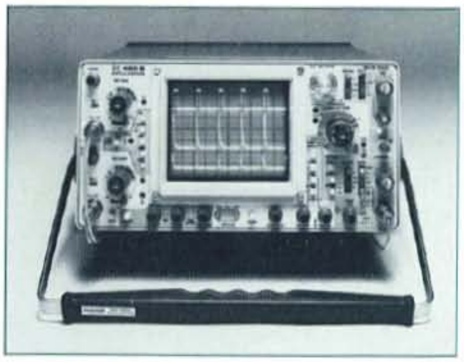
The 4663 is a C-size interactive digital plotter that features easy set-up, plotting on a variety of media, and fast dual-pen plotting. Extensive firmware provides unusual versatility even with a host computer of limited capability.

Parameter Entry Device Simplifies Plotter Set-up and Servicing

The parameter entry device replaces the usual profusion of rear-panel switches and jumpers, with just eight LED-lit pushbutton switches. The plotter can be put in a preselected operating configuration by pressing a single push-button switch.

Updating the Industry-Standard 100 MHz Portable Oscilloscope

The new 465B updates the industry standard with new display capability, faster sweeps, and even better reliability. Front-panel layout remains essentially the same as the 465 to eliminate the need for operator retraining.

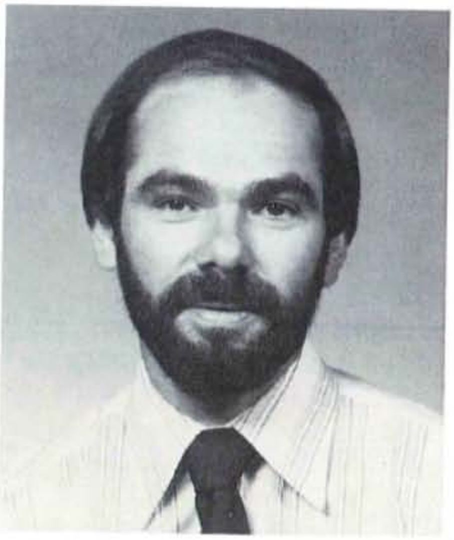


Cover: Setting up the 4663 Interactive Digital Plotter is greatly simplified through the use of the parameter entry device pictured here. The parameter entry card provides for step-by-step selection of the desired operating parameters.

The 4663 — Large Plotter Capability with Small Plotter Convenience

Douglas Bingham

Doug worked as a summer student at Tek while pursuing his B.S.E.E. at the University of Washington. He received his B.S.E.E. in 1965 and his M.S.E.E. in 1967. Following a stint with the military, Doug returned to Tek full time. He has worked on various microprocessor investigation projects, with his latest assignment as Firmware Project Engineer for the 4662 and 4663 Digital Plotters.



Guenther Wimmer

Guenther came to Tektronix in 1971 with an extensive background in the design of computerized numerical controls and precision large-scale photo plotters. He has been involved with Tek's digital plotter program since its beginning, serving as Project Engineer for the 4661, 4662, and 4663.

Most plotters are either too small or too large, too limited or too sophisticated, for many of today's applications.

The new TEKTRONIX 4663 C-size digital plotter is designed for those jobs requiring the versatility of a large plotter and the convenience and operating ease of a small plotter.

In applications like printed circuit board layout, numerical control, mapping, drafting, and report generation, most jobs fit easily on the 4663's 17 x 23.5 in plotting area.

The 4663 provides a choice of plotting media. Any media size up to U.S. C-size or European A2-size (420 x 594 mm) paper can be accommodated by the electrostatic hold-down platen. For automated production of multiple plots, an optional programmable paper advance for roll stock is available. Plotting can also be done on acetate film for preparing transparencies, etc.

The media choice is complemented by a choice of fiber tip, ball point, and wet ink multi-color pens. The 4663 features a dual pen carriage for fast two-color plotting. Pen selection is programmable, and optimum pen velocity and pen force for each pen station can be assigned by the operator.

Versatility with operating ease.

Versatility is often synonomous with complexity — but not in the 4663. A unique parameter entry device replaces the profusion of switches, jumper straps, and other rear panel arrangements common to most plotters, terminals, and similar peripheral equipment.

Some dozen system parameters and a like number of interface parameters can be preset using the parameter entry card. Eight LED-lit pushbuttons located just above the card indicate the status of each parameter, as the card is moved in or out one line at a time. All that is needed to change a parameter is to press the appropriate pushbutton.

The selections are stored in the battery-backed-up Parameter RAM which, in the standard instrument, will retain one complete user-environment specification for a minimum of 90 days, even with the instrument turned off for the entire period. Additional Parameter RAM is available, as an option, to store up to four user-environment specifications. A single keystroke will recall any one of the four and place the 4663 in the selected operating mode, ready for plotting. This ease of changing parameters makes it easy to change baud rate, parity, etc., when switching from one host computer to another. The parameter entry device is discussed in more detail on page 8 of this issue.

Simplified control panel

In addition to the parameter entry device, a series of front-panel controls provide manual selection of a variety of commands. Eight major control groups and two shift keys give you a choice of over 20 functions from an uncluttered, easy to understand front panel.

The selections and functions provided on the parameter entry device and the front panel provide great flexibility in how the plotter is to be used. Few, if any, selections are required to "get a plot." However, the operator can exercise considerable local control over the production of a plot without requiring extensive and cumbersome host computer support. For instance, graphics which have just been previewed at high speed on a graphics terminal can be replotted as a C-size drawing, at maximum speed, using a ball-point pen and coarse alpha characters (which are faster). They can then be plotted again as an A-size drawing (in vertical format as for a notebook) using a wet-ink pen and enhanced (high precision) alpha characters. Both plots can be drawn without making changes to the host program.

Such local configuration capability is ideal for applications where the plotter is used for output involving several media and pen types, several different presentations (standard drawings, text illustrations, overheads), or several different hosts or local storage devices. The 4663 is smart enough to provide the desired output under this wide range of conditions.

The initial set-up selections provided on the parameter entry card allow the 4663 to be quickly tailored to the type of pen to be used, the type of media, and the desired initial viewport size. The front-panel PAGE function can be used to locally calibrate the plotter to the absolute media dimensions, which will exhibit minute size variations as a function of humidity and printing variations.

In many instances it is desirable to use only a portion of the page for plotting. This is accomplished through the SET VIEWPORT function. A special often-used viewport, such as a mailing label, can be saved as a "user-defined" page via the parameter entry card. The viewport can also be set by the host computer via the VIEWPORT command.

In some applications you may want to digitize a drawing or plot and transmit the data to the host or a terminal. Digitizing commands, the front-panel POINT functions, and the joystick make this easy to do.

Other front-panel controls let you operate the plotter on- or off-line and in a local or remote mode. Pen force controls provide for fine-tuning the individual pen forces selected by the parameter entry device, for selecting a desired pen, and for raising or lowering the active pen.

Extensive firmware

Extensive firmware is an important key to the versatility and operating ease of the 4663.

Fig. 1. The 4663 Interactive Digital Plotter provides the versatility of a large plotter in a convenient and easy-to-use C-size configuration.

Operating commands for the 4663 can be divided into six major groups:

Interface commands
Plotter device commands
Graphic plot commands
Transformation commands
Alphanumeric commands
Graphic input commands

As a typical example of the firmware capability resident in the 4663, let's consider the transformation commands. These commands allow you to modify graphic or alpha commands from a host that may have a minimal graphics capability. For example, motion commands can be translated, scaled, rotated, and/or skewed before being plotted. All of these modifications can be accomplished by the control firmware in the plotter, without modifications to the host or its data.

Transformation is accomplished by multiplying each incoming command by a transform matrix containing the desired modification parameters (such as rotation, scaling, etc.).

Transform commands also allow you to change the viewport size and location, and to define window parameters. The window parameters are established in World Units, i.e., inches, pounds, angstroms, etc., and define the values of the edges of the viewport. Another command included in the transforms is the clipping control command. This command allows you to clip at either the viewport or the page boundary.

A comprehensive set of graphic plot commands allows flexibility in the choice of dimensional coordinate units, the type of line to be drawn (solid, dashed, etc.), the coordinate type (absolute or relative), and the choice of which pen will be drawing.

The choice of dimensional coordinate units, or graphic units, includes World Units and Device Units. (World Units are the units defined by the current window.) When Device Units are chosen you have a further selection of Addressable Device Units (ADUs), Graphic Device Units (GDUs), or millimeters.

ADUs provide device-dependent device addressing with a numeric addressable range of from 0 to 4096 on the longest axis of the viewport. The range of the shortest axis is determined by the current aspect ratio.

GDUs provide device-independent device addressing with a numeric addressable range of from 0 to 100 on the shortest axis of the viewport. Using GDUs ensures that any graphics containing only coordinates between 0 and 100 will be plotted without clipping, no matter what the current aspect ratio is. For millimeters, the numeric range is the actual axis length in millimeters. These units give a plot of the same physical size, regardless of the current viewport size.

Versatile alphanumerics

Graphics versatility in the 4663 is complemented by equal versatility in alphanumerics. Included are a self-contained character generator, provision for up to 15 character fonts (nine of which are resident in the 4663), and a host of commands to operate on the alphanumerics. One font can be designated as the standard font, and another as the alternate. The characters can be rotated, scaled up or down, or slanted, independent of the graphics and all under program control.

There are commands to set the character size and spacing, if you desire other than the default settings. You can also print centered characters for applications such as identifying a line on a graph. And the pen can be moved specified X and Y distances in fractions of the current character size, to facilitate drawing superscripts and subscripts.

It is sometimes desirable to draw alphanumerics in a paragraph format. A Set Margin Separation command activates the right margin and allows you to set the number of character spaces that separates the left and right alpha margins. Carriage Return and Line Feed functions will be automatically performed to draw a string of alphanumeric characters within the margins established.

The alphanumerics capability is enhanced with options that allow down-loadable character sets, programmable macros, and circular interpolation. The latter permits drawing circles or arcs with a single command. For circles, you need only to specify the radius, and the circle is drawn around the current pen location. Arcs are defined by specifying two points on the arc, which begins from its current pen location. You can choose the smoothness of the arc or circle, to meet the need for a quick overview or a high resolution finished plot.

Digitizing capabilities

For some applications it is desirable to digitize the plot on the 4663 and transmit the data to a host or terminal.

The joystick, the crosshair on the pen carriage, and the front-panel POINT switches, which allow the point to be designated as a DRAW, MOVE, or LAST point, are used in this function. Digitizing in one axis only is greatly simplified by using the Joystick Axis Disable command. This command allows you to disable either the X or Y axis, or both.

Block diagram discussion

A block diagram of the 4663 circuitry is shown in figure 3. The 4663 employs a functional bus, which is referred to as the product bus (PBUS). The product bus is a modular assembly consisting of a microprocessor, memory system, power supply, one or more communications interfaces, and several circuit board assemblies which interface and control the axis motors, pen activations, and media advances.

The circuit modules communicate through a standardized 80 lead interconnecting backplane. This functional bus hardware architecture promotes functional partitioning, which enhances product serviceability. It also allows updating the product through advances in technology, without disturbing those modules which are to remain unchanged.

Bus characteristics include non-multiplexed, 16 bit address and 8 or 16 bit data, asynchronous bus transactions of arbitrary length up to 3.8 μs (actual transaction time is defined by the addressed device's speed capability), and a master clock frequency of 14.7456 MHz. Up to eight prioritized DMA devices may be accommodated, with serial poll prioritization of either block mode or character bus DMA transactions. Eight hardware vectored maskable interrupts and one software interrupt are supported by the bus.

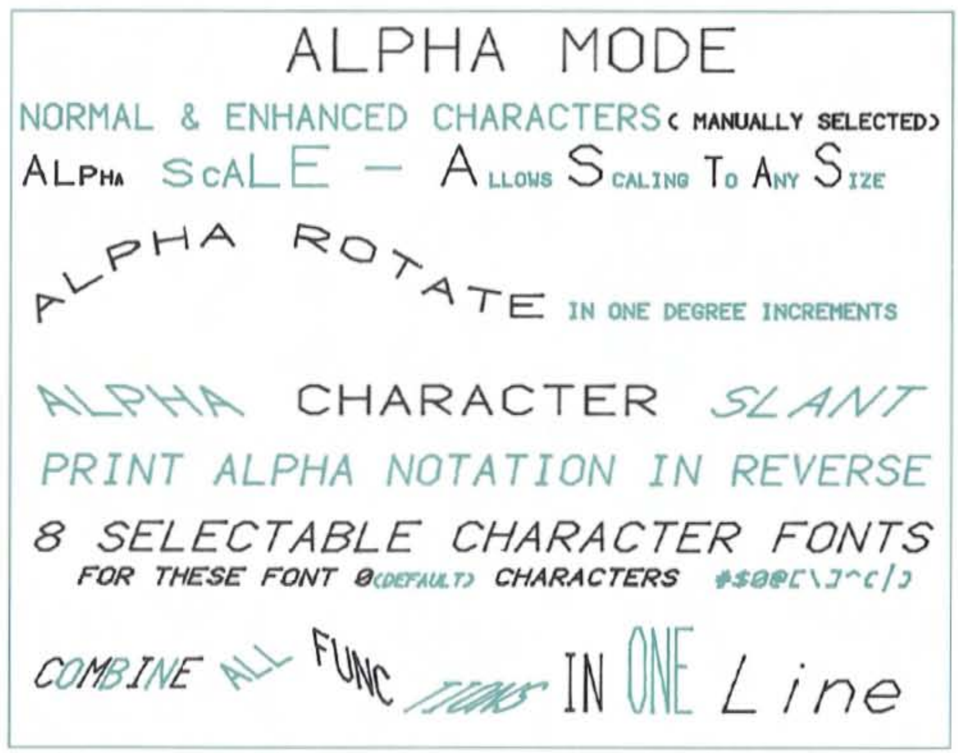


Fig. 2. Extensive firmware lets you draw alphanumerics in a manner that enhances the graphics portion of the plot. Characters can be rotated, scaled up or down, or slanted, independent of the graphics.

A single etched circuit board contains the MC6800 microprocessor, product bus interface, bus controller, RAM, ROM/PROM memories, processor enhancements, and the parameter entry interface.

The bus controller arbitrates interrupt requests to the processor and DMA activity on the bus (including debug system activity). Bus transactions for references to nonexistent or malfunctioning modules/memory are also monitored by the bus controller.

The standard memory system includes eight kilobytes of static RAM, with about 5.5 kilobytes available as a buffer pool which may be used for storing input commands, output data responses, programmable macros, nested transforms, or down-loaded character sets. The parameter entry device uses 128 bytes of battery-backed-up CMOS RAM for parameter storage. This can be expanded to 512 bytes to accommodate multi-user operating environments.

Up to 34 kilobytes of ROM and 6 kilobytes of PROM can be accommodated in the standard memory system. An additional 2 kilobytes of PROM, used for firmware patching, can reside in the parameter entry module.

The memory system is designed to provide wide latitude in ROM versus RAM allocation. (See figure 4). Mapping the I/O space for registers at the top of address space removes the restrictions of where ROM and RAM may extend in address space. The 6800 processor hardware vectors are placed down two kilobytes in the memory map. This isolates the peripheral circuit modules from alternative microprocessor implementations, and allows for flexible partitioning of ROMs, PROMs, and RAMs.

Multiple resident interfaces are accommodated on the bus without compromising available address space. This is done by bank switching the Interface Handler ROM, so that only the firmware of the active interface is mapped onto the bus.

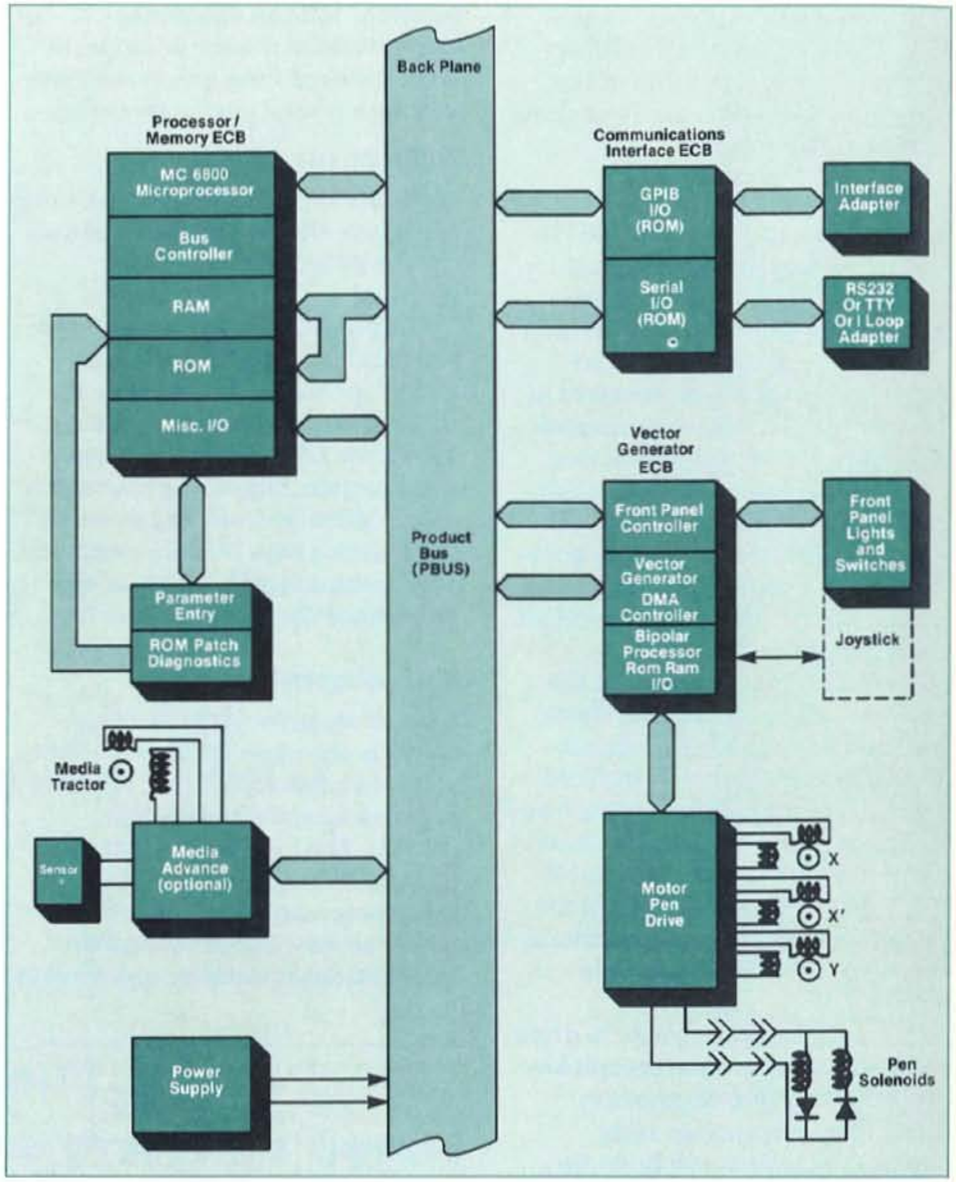


Fig. 3. Functional block diagram of the 4663. An 80 lead backplane provides interconnection for plug-in modules.

RAM address space is located at the bottom of memory address space and builds up from the bottom. Additional RAM in excess of the standard 8 kilobytes can be added in 1 kilobyte increments. However, it must physically reside on other than the processor/memory module.

The firmware patch

As the 4663 is applied to new applications it is sometimes necessary to modify or correct one or more of the mask programmed ROMs. This is accomplished in the 4663 through the use of a firmware patch module. The module, which plugs into a board slot in the parameter entry device, contains a field programmable logic array (FPLA) and a fusible-link PROM or EPROM. Interconnects and circuitry required to use the firmware patch reside on the processor/memory board.

The port through which the ROM patch communicates with the system is also used for installing diagnostic firmware for troubleshooting.

The FPLA may be regarded as a partially-populated PROM responding to any programmed address within a 16 bit field. The total capacity of the FPLA is 48 bytes. The device is applied in product maintenance by programming the address(es) of the ROM byte(s) which the firmware engineer identifies as requiring modification. Once these addresses have been identified, the firmware designer then defines the overlay bytes. The FPLA, once programmed with input and output terms, will respond to specific programmed addresses on the bus by disabling the main system memory and overlaying the new data byte. Patching ROM in this fashion imparts no extra time burden on the processor.

If the modification requires additional firmware bytes, one or two patch PROMs may be included on the ROM patch. The expansion bytes are accessed simply by overlaying three bytes in the original, to insert a jump instruction which will transfer control to the start of that particular code enlargement in the patch PROM. At the end of the extra code section, another jump instruction returns the processor to the original code.

4663 interface modules

One parallel and three serial interface conventions are supported by the 4663 through standard and optional interface modules. The 4663 will accommodate the GPIB (parallel) Interface Module and one of three serial Interface Modules, simultaneously resident on the bus. Only one of the interfaces, however, may be active at a given time. As the interface firmware ROM is resident on the particular interface, the 4663 is easily up-graded by simply installing an optional module in the bus.

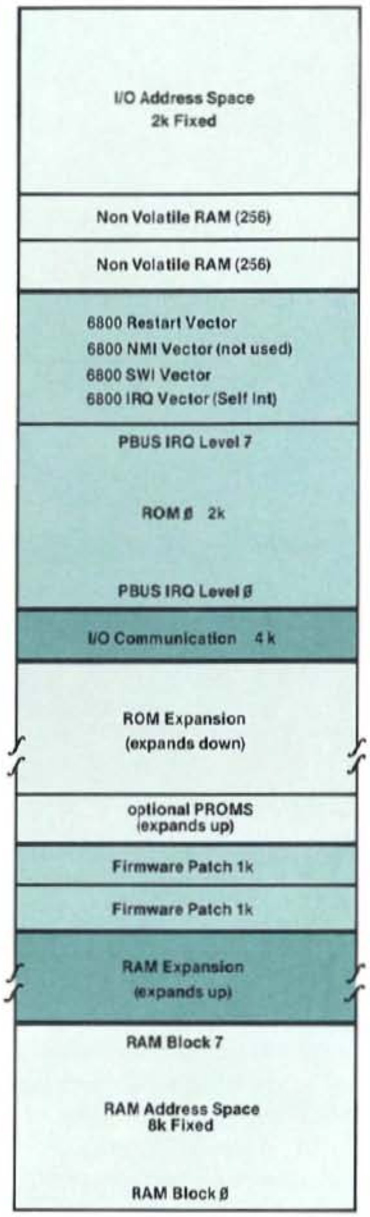


Fig. 4. Memory map for the 4663. Mapping I/O space for registers at top of address space removes restrictions on where ROM and RAM may extend in address space.

Serial interface conventions accommodated by the 4663 include:

1. RS 232 A/C at up to 9600 baud, full duplex, with selectable DC 1/DC 3 control and selectable hardware receive flagging for local host environments.
2. 20/60 mA Current Loop with external clock capability.
3. TEKTRONIX 4010 Series Terminal-compatible TTY interface which accommodates data communication rates up to 307 kilobaud.

Vector generation

The time-intensive tasks of vector generation and motor control are handled by a bipolar microcontroller (Signetics 8X300) in the 4663. By relieving the main system processor of these tasks, its intelligence is made available for product performance enhancements.

The microcontroller on the Vector Generator appears as a DMA device to the PBUS. Communication between the main system processor and the Vector Generator employs:

1. a circular queue in RAM which contains command/argument information,
2. references to ROM-based fixed constants, and
3. references to RAM-based operating environment variables.

Control of Vector Generator activity is exercised through hardware registers in I/O space. Flagging of the main system processor by the Vector Generator, of task status, employs the interrupt structure supported by the bus.

Non-functional bus oriented communication by the Vector Generator, with the Motor Drive Module, transports data representing the digital rotor position of the three motors driving the X and Y axes, pen selection, and pen force.

The vector generation process employs digital integrators implemented in the microcontroller, rather than conventional hardware rate multipliers. Digital integrators exhibit minimum frequency modulation (FM) at low axis drive rates, whereas rate multipliers will exhibit significant FM at these rates.

Minimizing FM of the axis drive rates results in reduced plotter line aberrations and measurable improvements in linearity.

Parameter Entry Device Simplifies Plotter Set-up and Servicing

One of the deterrents to using large, versatile plotters or other sophisticated peripherals is the set-up time required. The 4663 features a unique solution to this problem.

The parameter entry device provides a convenient means of identifying and selecting operating parameters without the use of conventional rear panel switches and jumpers, and volumes of user manuals.

The basic elements of the device include: the parameter entry card, which serves as a menu of the parameters and values available; eight LED-lit switches, which indicate the current selection and provide a means of changing the selection; the initialization LED, which indicates that the card should be placed in the "home" position to synchronize the system; three buffer registers, which provide temporary storage of the LED, switch, and interrupt status; and a small portion of battery-backed-up CMOS RAM (located on the processor board), which provides long-term parameter storage.

The parameter entry device is not product bus (PBUS) compatible as a stand-alone module, but communicates with the PBUS through an interface located on the processor board.

Fig. 1. Parameter entry device simplifies plotter set up and servicing.

How it works

When the 4663 is turned on, the parameter entry card is placed in the "home" position (fully inserted) to initialize the system. The set-up that was in use when the plotter was turned off is stored in CMOS RAM (Parameter RAM).

Parameter RAM serves as a condensed copy of all hardware and RAM based configuration registers. The hardware configuration registers are output ports for baud rate selection, interface enabling, etc. The RAM based configuration registers serve as common system variables which are referenced by the operating system.

The user may determine how the plotter is set up by withdrawing the parameter entry card one line at a time, noting the switch illumination. The movement and position of the card is sensed by three phototransistors. A quadrature detector (Motion Detector) detects the direction of card movement by comparing the order in which serrations along one edge of the card, cover, or uncover, two of the photo-transistors. The third photo-transistor senses when the card is moved to the home position.

Each time the card is moved in or out, an interrupt is generated that signals the processor to up-date a position register in main system RAM. The position register content is used as a pointer to address the Parameter RAM. With each card movement interrupt, the main system processor uses the position register to fetch current line status and store the information in the Parameter LED register, thereby illuminating the appropriate switch.

When one of the eight switches is pressed to change a parameter selection, an interrupt is generated that calls for the processor to read the switch register and up-date CMOS RAM and the Configuration and LED registers. Through this user-initiated action the operating characteristics of the 4663 are changed to the new selection. At the same time, the selection is recorded so that the 4663 will power up in the new configuration.

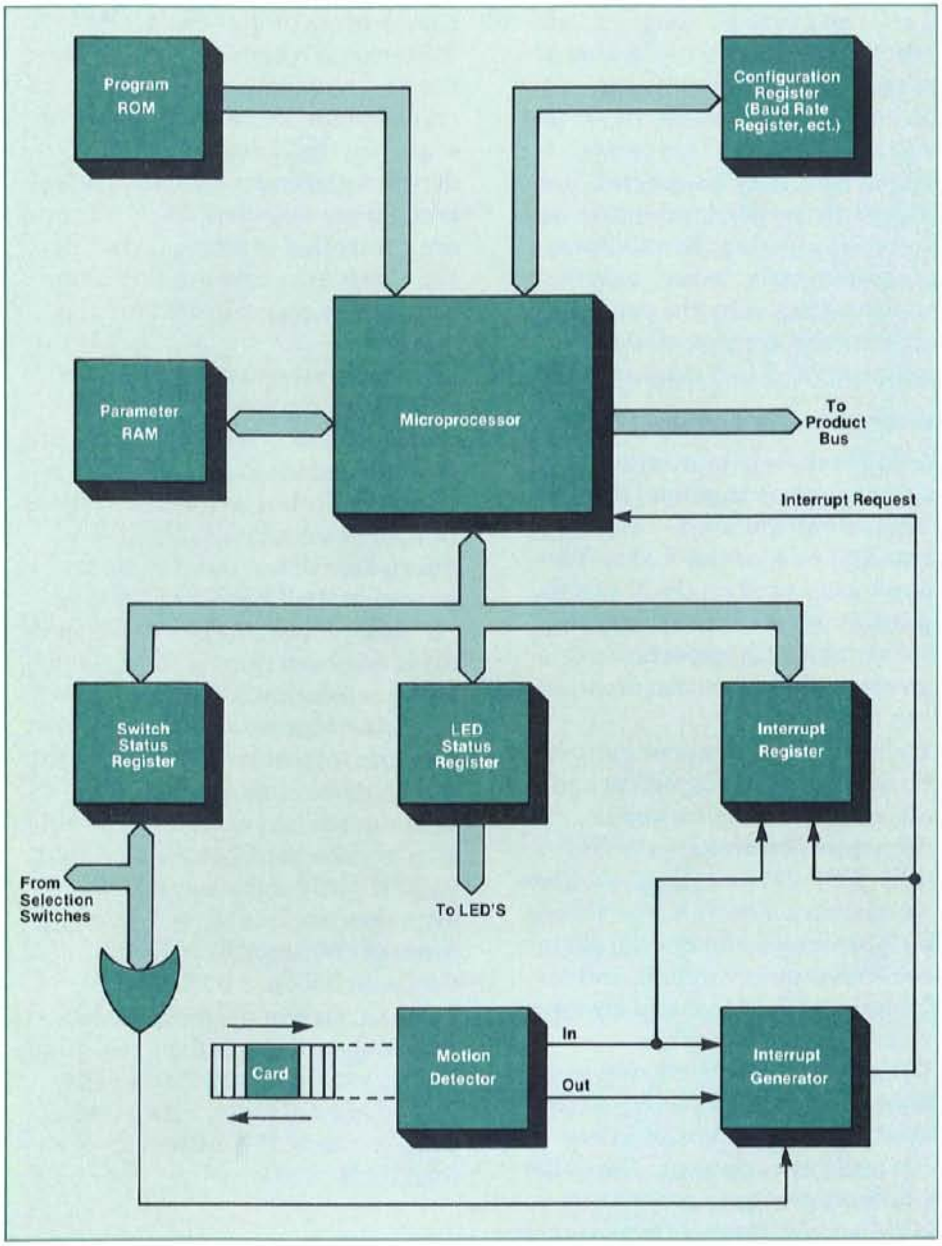


Fig. 2. Simplified block diagram of parameter entry device.

A servicing tool

The parameter entry device is also an important tool for servicing the 4663. Two positions on the parameter entry card are dedicated to this function. The EXECUTE SELF TEST position allows you to quickly check that all front-panel lights are working, and then to initiate a program to draw a test plot. The plot, properly executed, assures the mechanical portions of the plotter are working properly.

In the ERROR DATA position, the LED-lit switches serve as an error readout display. When the ERROR CODE switch is pressed, a code pattern indicating the type of error will be displayed. This may indicate system or operating errors such as insufficient RAM, a ROM check error, framing error, etc.

An optional diagnostics package consisting of a diagnostics card, a diagnostics printed circuit board module, and a manual, offers more extensive troubleshooting capability. The diagnostics card replaces the parameter entry card and directs the test technician through a logical series of tests of the plotter hardware.

The printed circuit board module contains sockets for three 16 kilobyte EPROMs, a RESTART switch to reset the whole system, and a multi-position rotary switch to select tests. Several test pins on the module provide convenient connection of a test oscilloscope.

The tests are run sequentially and are structured in ascending orders of complexity relying on hardware proven operational in previous tests.

Basic processor operation is verified, followed by tests of the Parameter Entry Device LED display and switch operation. Verification of Parameter LED and switch registers is essential as they will be used to display test results and enter test directives. Tests of the main system RAM, the interrupt functions, Parameter Card Position Encoder, CMOS RAM, and ROM checksum follow. Front panel controls are then checked. Both GPIB and Serial interfaces are checked, and then a series of tests are run on the vector generator functions. The motor and pen drives are exercised, and a calibration test is performed. A system test draws a plot which exercises both pens. The final test is a media advance test, if that option is installed in the 4663.

The parameter entry device LEDs indicate when a particular test is successfully completed or, in case of a failure, which type of failure occurred.

Integral with vector generation is the process of velocity profiling. If the plotter is to draw lines with a minimum of aberrations (wiggles, overshooting, etc.), the acceleration and deceleration of the axis must be tightly controlled.

In the 4663, velocity profiling is implemented by controlling the axis velocity as a function of position. The vector generator references a table stored in ROM, which contains the information of desired velocity versus position. The table has been optimized for the characteristics of the 4663 mechanism and drive system, resulting in 600 ips^2 rate of acceleration without adversely impacting the plot quality.

The seldom-specified "rate of acceleration" is a true indicator of a plotter's throughput capability. It is generally more significant than the plotter's maximum plotting speed, when one considers that often the bulk of an "average" plot is composed of short vectors (0.5 in).

Flexibility of the plotter, in its accommodation of a variety of pen types and enhanced line quality modes, is provided by allowing the user to specify one of four acceleration rates. The acceleration rates of 240, 300, 400, and 600 ips^2 are selectable on the parameter entry card and may be changed while the 4663 is plotting.

Pen speed is also controllable by the user and may be assigned independently to the two pen stations. Pen speed limits of 6 to 16 ips vector velocity, in 2 ips increments, or 16.5 ips axial velocity (23 ips vector velocity at 45°), may be selected and assigned to the pen stations while the 4663 is plotting. To maximize throughput, only "draw" axis motions are affected by the pen speed limits; moves are executed at maximum (16.5 ips) axial speed.

Axis drive motor and pen control

The 4663 employs conventional 1.8° stepping motors to propel the axes. Three motors are used — one for the Y axis and two for the X axis. Two motors were used on the X axis to minimize the drive cable lengths, which is of prime importance if high rates of aiceleration are to be supported.

By having independent motors, each driving their respective end of the Y axis assembly, torque requirements per motor were reduced. This allowed the use of identical devices for both X and Y axes, which promotes a better dynamic mechanism/motor match, and results in improved line quality for a given rate of acceleration.

Orthogonality of the Y axis arm with respect to the drawing surface is assured, irrespective of minor cable tension variations, due to the initialization sequence that the 4663 observes. During the power up sequence, the plotter establishes a mechanical reference for each axis. The X axis, however, has two reference sensors (one at each end of the Y axis arm) which are used to align the arm as well as establish the reference point. During the power up sequence the X axis motors are driven independently. Once the references are detected, the X motors are controlled in a fashion to align the Y axis arm, and are thereafter electrically phase locked to each other.

A micro-stepping technique is employed to control the motors. Conventional drive techniques, and their attendant drawbacks of resonance and relatively coarse resolution, are circumvented by the micro-step drive. Originally employed in the TEKTRONIX 4662 "B" size plotter, the micro-stepping drive has been refined for the 4663. Drive resolution is 6400 steps per motor revolution at a maximum of 42 oz.-in. of torque provided by the motor/drive combination. Conventional drives of full-step or half-step bipolar configurations would yield slightly more torque. However, they are limited to a maximum of 400 steps per revolution which would translate to 0.004 in./step in the 4663. Micro-stepping, which involves energizing the motors with quadrature sine and cosine currents, nets a linear translation of 250 millionths of an inch in the 4663.

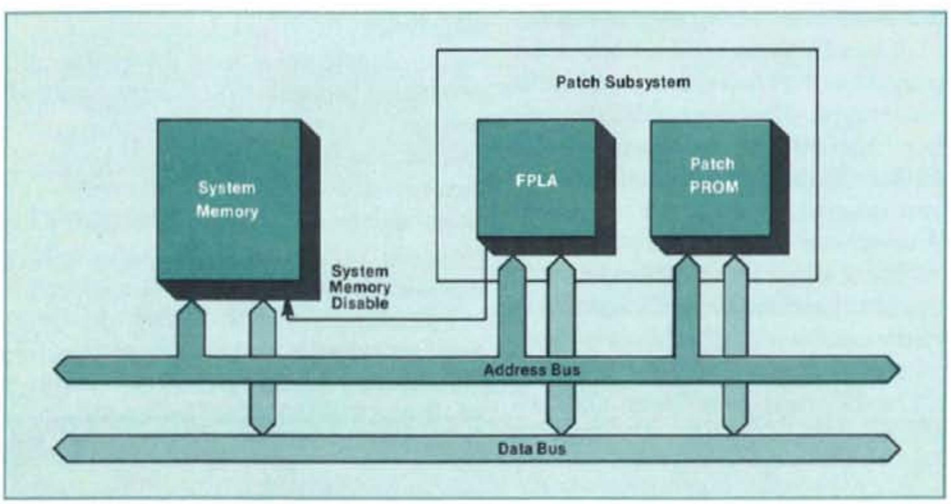


Fig. 5. Simplified block diagram of the firmware patch. When the FPLA receives an error address, it disables system memory and places corrected instructions from the patch PROM, on the data bus.

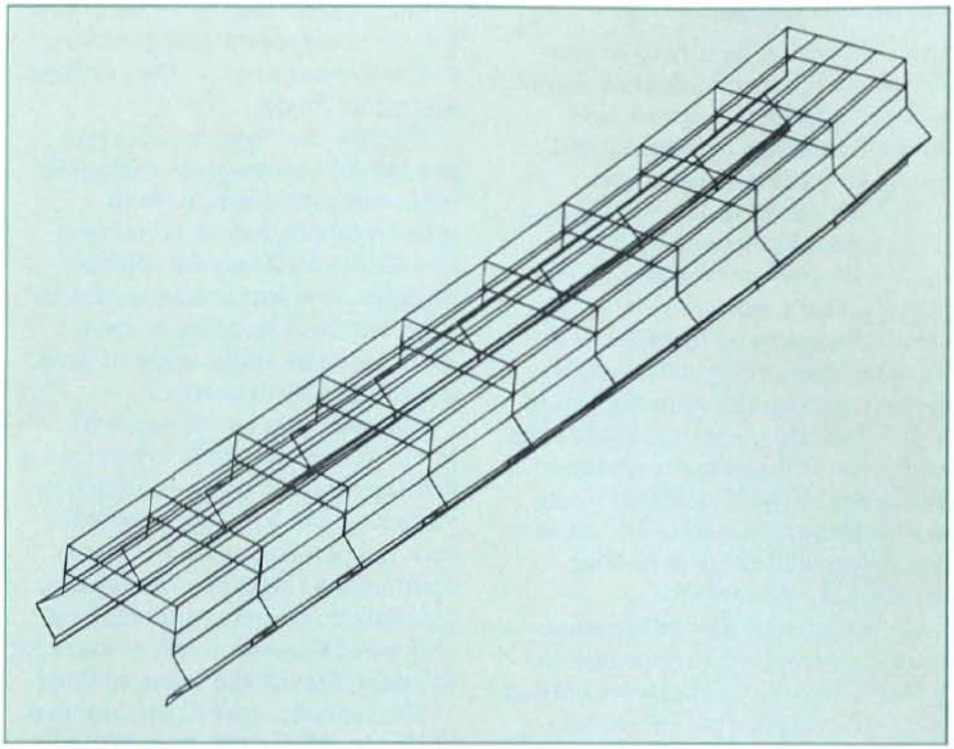


Fig. 6. Finite element analysis was used in designing Y axis arm. Box structure at top of arm provides rigidity with light weight.

Six transconductance-mode, high-efficiency, PWM (pulse width modulated) drive amplifiers power the three axes motors. References for the amplifiers are derived through a time-division-multiplexed D/A converter. The D/A converter operates at a 2.16 μs conversion cycle, with a total of seven conversions to be performed. Converted are the sine and cosine data for the three drive motors, and the pen force. Data from the vector generator, representing the digital motor position for the drive motors, is routed through a 256 x 8 ROM look-up table which provides sine ϕ and cosine ϕ data for each motor. The pen force data byte does not get translated by the ROM and is, instead, applied directly to the D/A. An analog de-multiplexer extracts the reference potentials and buffers them for use by the motor and pen amplifiers. Pen force data and pen selection are contained in an 8 bit data byte. A 7 bit field represents the pen force; the remaining bit selects which pen is active.

The pen drive circuit is configured as a bipolar, linear, transconductance amplifier. Commutating diodes mounted in the pen carriage steer the current to the selected pen, minimizing the number of electrical conductors needed. The pen force, either default for a specific pen type or user definable, is assigned by the main system processor when the pen station is characterized by the user through the parameter entry device. Whenever the pen station is activated, either under program control or from the front panel, the specific pen force is invoked. This allows the user to intermix fiber tip, wet ink, liquid ball, or special pens, and yet maintain optimum force characteristics for each type. Furthermore, each pen station has a vernier pen force control on the front panel which allows for fine adjustment while the 4663 is plotting. The range of adjustment is $\pm 25\%$ of the preselected pen force.

Front panel and joystick

Front Panel switches are polled by an on-board serial memory. Debouncing in both activation and deactivation is provided by votive logic. Once a valid state change has been decoded, the main system processor is interrupted by the Front Panel Controller which resides on the Vector Generator. The benefit to the user is a functional, live, front panel through which plotter functions may be manipulated. For example, the plotter may be placed in the "Pause" mode, which allows the user to annotate a plot and then resume plotting without data loss. Communication of the system processor with the front panel displays is through a serial data port, which minimizes electrical cabling requirements.

A two channel voltage-to-frequency converter interfaces user manipulation of the joystick with the vector generator.

The circuits sensitivity was made non-linear to maximize the human factors of cursor positioning. The joystick axis may be independently activated under program control to assist in digitizing graphic data which has Δ in one coordinate fixed. With suitable support software, the tedium of digitizing may be minimized by having the host increment one axis, following a graphic input command, and requiring the user to locate only the remaining axis before inputting the next point.

Mechanical design

There are many factors to be considered in the mechanical design of a plotter — plotting speed, line quality, accuracy, reliability, and quietness, to name just a few.

Plotting speed is determined to a large extent by the ability to move the Y axis arm and the pen carriage rapidly. The Y axis arm is the greatest mass to be moved and must be kept as light as possible, yet be rigid enough to resist bending and twisting during rapid starts and stops. If the natural vibration frequency of the Y axis arm is too low, vibrations which occur during operation of the plotter will adversely affect line quality.

The TEKTRONIX 4081 Interactive Graphics System was used in performing a finite element analysis of the pen rail design. The effects of doubling the side thicknesses, top thicknesses, both side and top thicknesses, or adding a box structure to the top of the arm, were explored. Different types of material were also evaluated.

The final design is that pictured in figure 6. The arm is an aluminum extrusion 22.77 inches in length, with a wall thickness of 0.062 inch. The top of the rail is an enclosed box.

Two separate cable, pulley, and stepping motor systems drive the Y axis arm, one at each end. This, in effect, cuts both the load and the length of the X axis cable in half, thus increasing the stiffness of the drive system significantly. This requires careful matching of the motor capstans to ensure proper tracking of both ends of the Y axis arm.

Alignment of the Y axis arm is done automatically by a routine employing photo-optic sensors each time the plotter is powered up. Although there is no mechanical connection between the two motors, external forces rarely cause a misalignment since the dc current levels in the motors produce a very high holding current.

The pen carriage drive uses only one stepping motor and a cable/pulley system to move the carriage along the Y axis.

The pen carriage includes two pen holder components with their respective solenoids, a small printed circuit board containing two diodes to direct the solenoid currents, and a crosshair useful for digitizing and locating purposes. The entire assembly, without pens, weighs about two ounces.

The solenoids are driven with selected current levels to produce a writing force on the pens which is variable from 5 to 40 g. Since the selected pen force should be constant over a range of solenoid displacement, the return spring system was designed to compensate for irregularities in the solenoid force.

The moving mass of pen and pen holder is about 15 g. To write consistently with a pen force as low as 5 grams required "fine tuning" the solenoid, return spring, and bearing friction design parameters.

The frame of the plotter consists mainly of aluminum extrusions, resulting in a lightweight, rugged, yet inexpensive structure. Front and rear panels are also aluminum extrusions. Structural foam, which combines good appearance with rigidity, light weight, and low sound transmission, is used for the side panels.

Other steps taken to ensure operating quietness include isolating the X and Y axis drive motors and the bottom pan, from the plotter mainframe.

Serviceability is always a concern in mechanical design. In the 4663, the plotting surface is hinged at the rear. Lifting the front of the plotting surface gives easy access to the electronic circuitry. A support rod keeps the plotter open, freeing both hands for servicing. Printed circuit boards and the entire power supply unit can be easily removed and replaced.

Summary

The 4663 Interactive Digital Plotter combines the versatility of a large plotter with the convenience and operating ease of a small plotter. Programming ease enhanced by extensive firmware minimizes set-up time and makes the 4663 ideal for the multi-user environment.

Acknowledgements

The 4663 is the culmination of the combined efforts of many people. Not all can be mentioned here, but a special note of thanks is due Bill Yoresen, Project Manager, for his capable direction of the program; Dick Duggan, assisted by Dave Hoskins and Dick Sollars, for the mechanical design; Kathy Eastman, for her contribution to software; and Byron Fisher, for his valuable marketing input.

Updating the Industry-Standard 100 MHz Portable Oscilloscope

Harold Busch

Hal, a long-term Tek employee, began his career in the test department in 1955. He has a broad range of experience in the various areas of manufacturing, and currently is Production Manager for the 460 and 470 Series Oscilloscopes. Hal was Project Manager for the 465B.

Standards change very slowly, sometimes never. And that is as it should be, for standards form our basis for comparison. Soon after its introduction, the TEKTRONIX 465 became the recognized industry-standard for portable oscilloscopes. In the mark of a good standard, it has changed little since its introduction.

Now, the new 465B updates the industry-standard with new display capability, faster sweeps, and even better reliability.

Front-panel layout is essentially the same as the 465 so operator retraining is unnecessary. The major change that will be noted is the restyled pushbuttons. They are smaller, giving the front panel a more open appearance and providing easier function selection.

Display improvements

The vertical mode selection pushbuttons are changed from the self-cancelling type to the push-push type allowing you to display any combination of vertical signals and external trigger you desire. For example, you can look at either or both vertical channels, their sum or difference, and the external trigger, simultaneously.

The trigger view function is designed to provide zero-delay between the vertical channels and the trigger view, enabling you to make accurate time comparisons between the signal and the trigger, even at the faster sweep speeds. The quality of the external trigger view channel makes it useful as a third input channel with a sensitivity of about 100 mV per division.

Improved vertical preamplifier performance permits replacing gain switching with up-front attenuation, and yields a finer trace width at the maximum sensitivities.

Horizontal versatility is expanded to complement the vertical improvements. Top sweep speed is increased to 2 ns per division for greater resolution in examining fast rise time signals. And alternate sweep switching lets you look at both A and B delayed sweeps simultaneously, at full screen width. A separate intensity control for B sweep lets you set the contrast between A and B sweeps, with vertical separation between sweeps provided by the trace separation control.

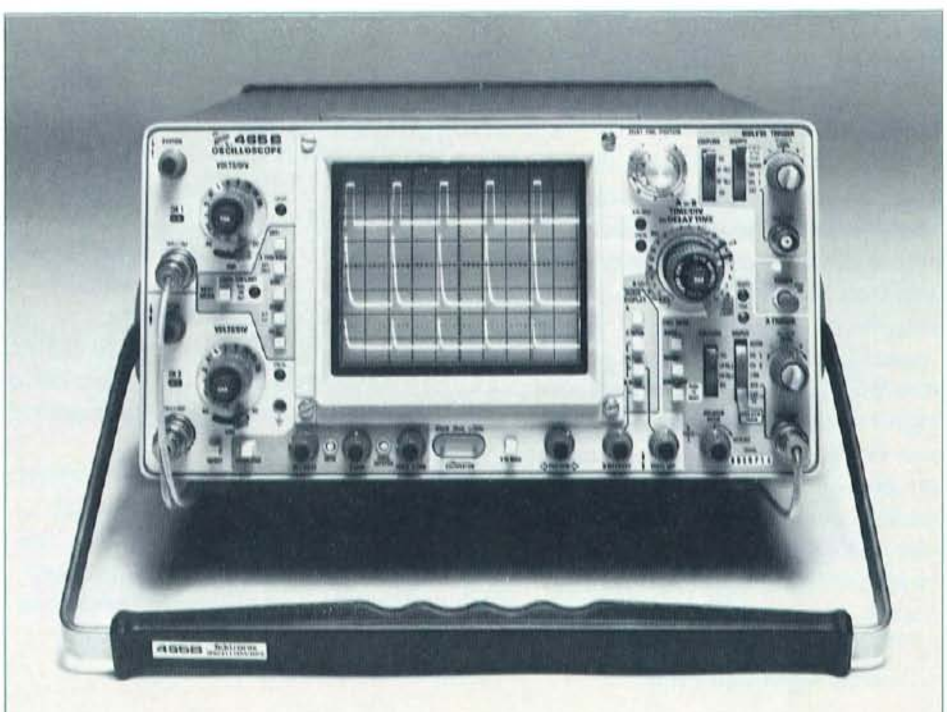


Fig. 1. The new 465B. Front-panel layout is almost identical to the 465. New features include a wider choice of displays and zero-delay external trigger view.

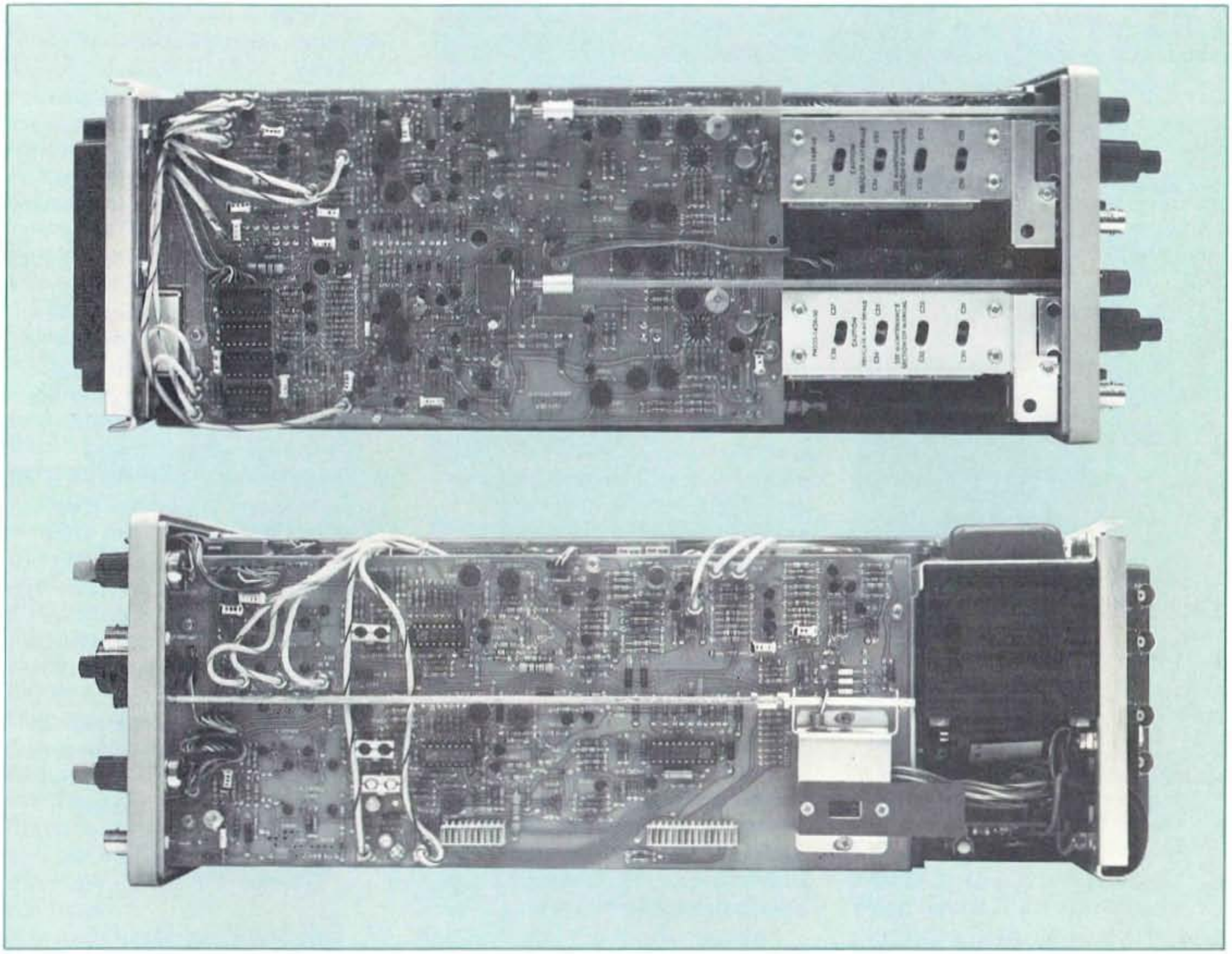


Fig. 2. Internal views of vertical (top) and horizontal (bottom) circuitry show reduced component count through the use of integrated circuits. Layout symmetry makes 465B easier to build and maintain.

Servicing improvements

A glance inside the 465B cabinet reveals even more extensive change. An all-new vertical amplifier replaces discrete components with integrated circuits. Operational amplifiers replace vertical "tweaks." And new switch assemblies provide easy access and high reliability. Soldered-in leads now have connectors, and jumpers are placed at strategic points to facilitate troubleshooting. Transistors and integrated circuits are mounted in sockets for the same reason. Front panel indicators use LEDs instead of incandescent bulbs for longer operating life.

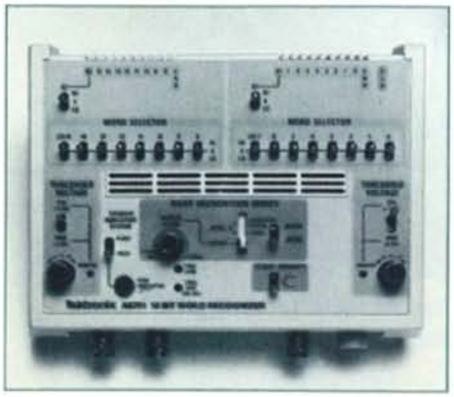
While the improvements in performance and serviceability were being considered, the buildability of the 465B was receiving equal attention. Printed circuit board layouts allow maximum use of automatic component insertion; the newly-designed switches are easier to build; and the reduced number of adjustments minimizes calibration time.

The end result is a new standard for portable oscilloscopes which offers new display capabilities, improved serviceability, still greater reliability, and all at no increase in catalog price.

Acknowledgements.

Many people are involved in the design of a new product. Special recognition is due Wayne Kelso for the sweeps, Jim Kuhns for the vertical, Ron Roberts for the alternate sweep switching, and Doug Stroberger for the zero-delay trigger view. Walt Neff and Merle Elkins provided valuable assistance in smoothing the path to production.

New 18 Bit Word Recognizer



The A6701 Word Recognizer

A new 18 bit word recognizer, the A6701, provides cost-effective, easy-to-use digital triggering for portable and laboratory oscilloscopes and other logic display products.

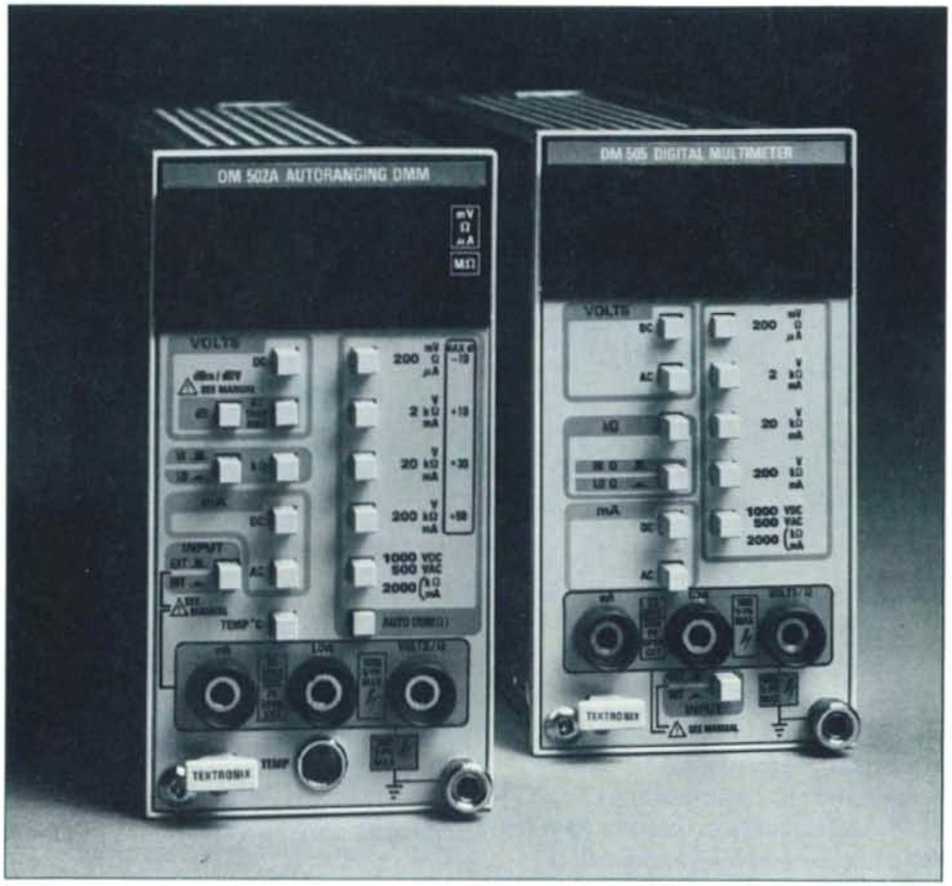
The A6701 consists of a control pod, separate power supply capable of powering two control pods, and a set of accessories. Up to four word recognizer pods can be linked together to provide 72 bit capability.

The unit can be operated in either synchronous or asynchronous mode with a choice of level or qualified clock output in synchronous operation.

Preset TTL or variable threshold voltage selection, and variable-width glitch filter add further versatility. The clock rate is 50 MHz at 18 bits.

Connection to the trigger inputs is via two 10-wide lead sets. An optional adapter accommodates the P6451 logic analyzer probe.

Two New Digital Multimeters for TM 500



The DM 502A and DM 505 Digital Multimeters

Two new 3½-digit multimeters, the DM 502A and DM 505, bring new measurement capability and operating ease to the TM 500 digital multimeter family. Seven measurement functions make the DM 502A the most complete 3½-digit DMM available. The DM 505 is a five-function DMM (dc and ac volts, dc and ac current, and high/low resistance), ideal for applications where low cost is paramount.

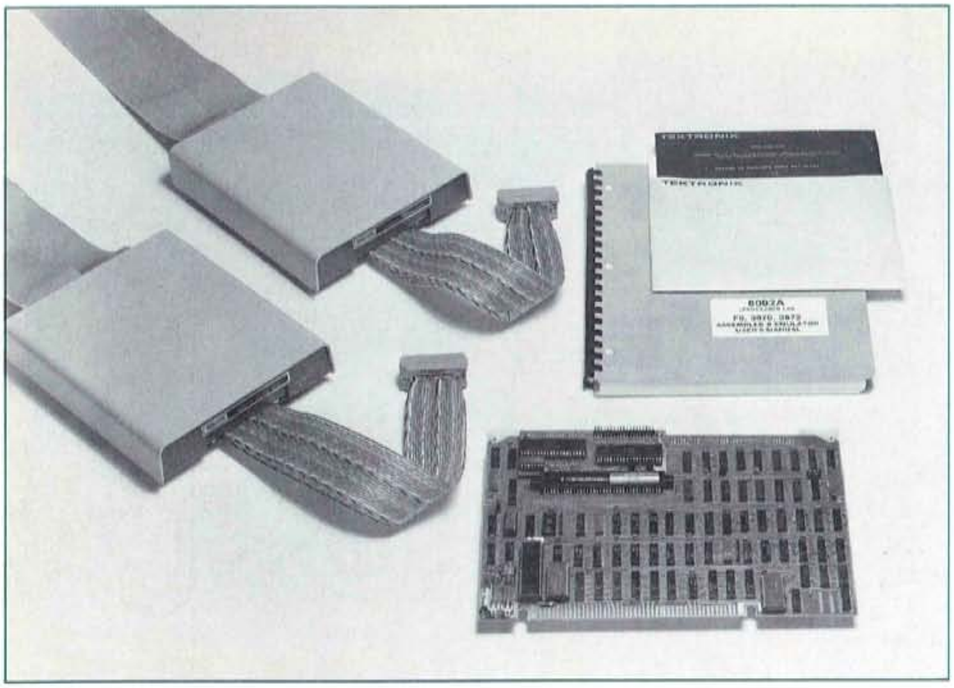
In addition to the basic DMM functions (dc and ac volts, dc and ac current, and high/low resistance), the DM 502A offers dBV and dBm measurements, temperature measurement, true rms readings, and autoranging for volts, ohms, and dB measurements.

The DM 502A's unique combination of autoranging and dB measurements makes it an excellent choice for communications applications.

Probe temperature measurement, pioneered by Tektronix, has been enhanced in the DM 502A. Temperature measurement range at the probe tip is −55°C to +200°C, and the entire P6601 probe tip and cable are specified for immersion to 140°C.

Pushbutton selection of all functions and ranges, plus easy-to-read 0.5 inch LED display digits, make the DM 502A and DM 505 fast and easy to use. A choice of front panel or rear connector inputs is pushbutton selectable.

8001/8002A Microprocessor Labs Add Support for F8, 3870, 3872, and 1802.



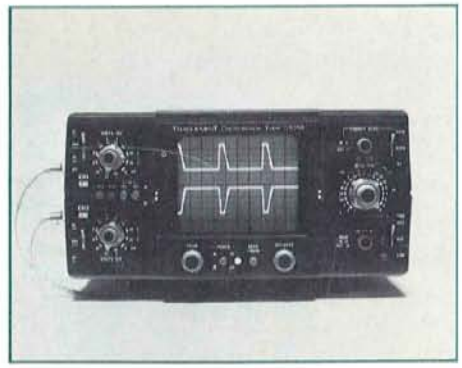
The F8, 3870, 3872 Emulator Processor and Prototype Control Probes.

Two new emulator processors extend the TEKTRONIX 8001/8002A Microprocessor Development Labs (MDL) capabilities to include the 1802 microprocessor, the F8 microprocessor, and the 3870 and 3872 microcomputers. This expanded capability is in addition to the present support for the 8080A, 8085A, 6800, TMS9900, and Z80A.

TEKTRONIX MDLs offer the 3870 designer greater design-environment support than previously available for these chips. The 8002A's assembler/linker features provide efficient program coding to make use of the limited amount of memory contained in these chips.

The 1802 and F8/3870/3872 emulators are similar to other currently available TEKTRONIX emulators — for each, a complete software debugging system, in-prototype emulation, and real time prototype analysis are available.

Low Cost 15 MHz Scopes Excellent Value



The Telequipment D1016 Oscilloscope

Two new 15 MHz dual trace models have been added to Tektronix' Telequipment line. The new Telequipment D1015 and D1016 Oscilloscopes feature dual trace operation; automatic, normal, and TV triggering; volts/division ranges from 5 mV to 20 V; and sweep speeds from 0.2 microseconds to 200 milliseconds/division. A X5 magnifier increases maximum sweep speed to 40 ns/division.

In addition, the D1016 is equipped with these features:

- X5 magnifiers for each vertical channel to extend sensitivity to 1mV/division. Bandwidth is reduced to 4 MHz at this particular setting.
- Separate pushbuttons to invert channel 2, and to add channels 1 and 2, permitting balanced differential input measurement.
- Direct X-Y displays using channel 1 and channel 2.
- Variable uncalibrated sweep control permitting continuously variable sweep rates.

Telequipment products are sold and serviced in the U.S. by selected stocking distributors. For additional information please use the reply card accompanying Tekscope.

7/79 AX-4268

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

Merging High Performance Alphanumerics and Graphics with Fast Computation

Dynamic Graphics Gives Best of Both Stored and Refreshed Display Techniques

A New Cost-Effective Highly Portable Data Comm Tester

A New DMM Family for the TM 500 Series

Simultaneous X-Y, Y-T Displays Using a 5100 Series Oscilloscope

11/14/79

Volume 11
Number 3

1979

Tekscope

Tektronix®
COMMITTED TO EXCELLENCE

CONTENTS

Tekscope

Customer information from
Tektronix, Inc.
Beaverton, Oregon 97077

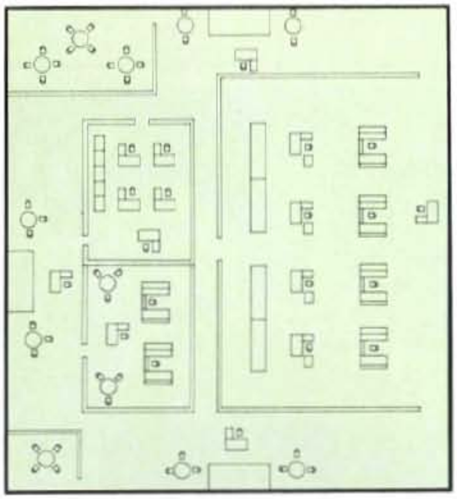
Editor: Gordon Allison

Merging High Performance Alphanumerics and Graphics with Fast Computation

The state of desktop computing is advanced to a new level by two new graphic computers using a bit-sliced architecture processor.

Dynamic Graphics Gives Best of Both Stored and Refreshed Display Techniques

The Dynamic Graphics option for the 4054 adds a high-speed processor and dynamic memory dedicated to the creation and display of refresh objects.

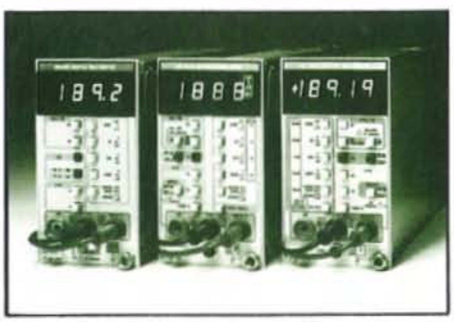


A New Cost-Effective Highly Portable Data Comm Tester

The 833 can monitor or apply test signals to and from data communication equipment and data terminal equipment. It can also perform BERT and BLERT testing. And all this performance is contained in a package weighing less than 12 pounds.

A New DMM Family for the TM 500 Series

Three new DMMs bring true rms ac measurements, autoranging for dB and other measurements, and the widest temperature measurement range available in a DMM today, to the TM 500 user.

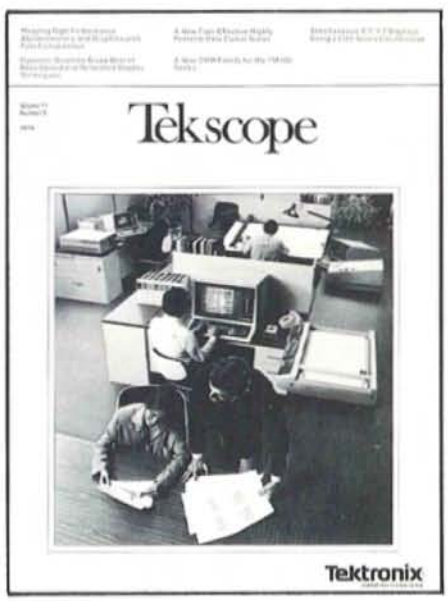


Simultaneous X-Y, Y-T Displays Using a 5100-Series Oscilloscope

The relationship between physical forces is often most easily analyzed when the forces are plotted against each other as in an X-Y display. An amplitude versus time display often adds valuable information. Both can be displayed simultaneously on a 5100-Series single beam oscilloscope.

Tekscope is a bimonthly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique. A new products section gives a brief description of products recently introduced and provides an opportunity to request further information.

COVER: The 4050 Series of desktop graphic computers are equally at home in architectural, electronic, geophysical, or business environments, providing unique solutions to every-day problems.



Merging High Performance Alphanumerics and Graphics with Fast Computation

Dave Barnard joined Tektronix in November of 1976 bringing with him an extensive background in computer and peripheral design. He has been involved in new product introduction and training programs for the 4052, 4054 and 4050 Series ROM Packs. He received a B.S.E.E. from the University of Minnesota in 1965 and an M.B.A. from Claremont Graduate School in 1976. He is currently a 4050 Series Product Specialist. A member of I.E.E.E. and Toastmasters International, he devotes his spare time working with a Boy Scout Troop and to amateur radio satellite communications.

A high rate of market acceptance and need for productivity improvements in the office, laboratory, and in the educational environment for teaching and research, point to one thing: desktop computers are growing in importance and application.

When Tektronix announced the 4051 in 1975, exciting new levels of computing power were available, either in small packages called desktop calculators or in the form of microcomputers whose language and operation required more extensive computer knowledge than was desirable for a user who wanted merely to get his analysis done.

The 4051, with graphically enhanced BASIC, brought problem solving to the desktop in the office or laboratory, with easy operation and graphics to make the results of analysis very visible.

The new 4052 and 4054 provide multi-dimensional enhancements to the features found in the 4051. These new members of the family enhance graphics, alphanumerics, and computing capabilities, by advancing the state of desktop computing to a new level.

Compatibility provides upward mobility

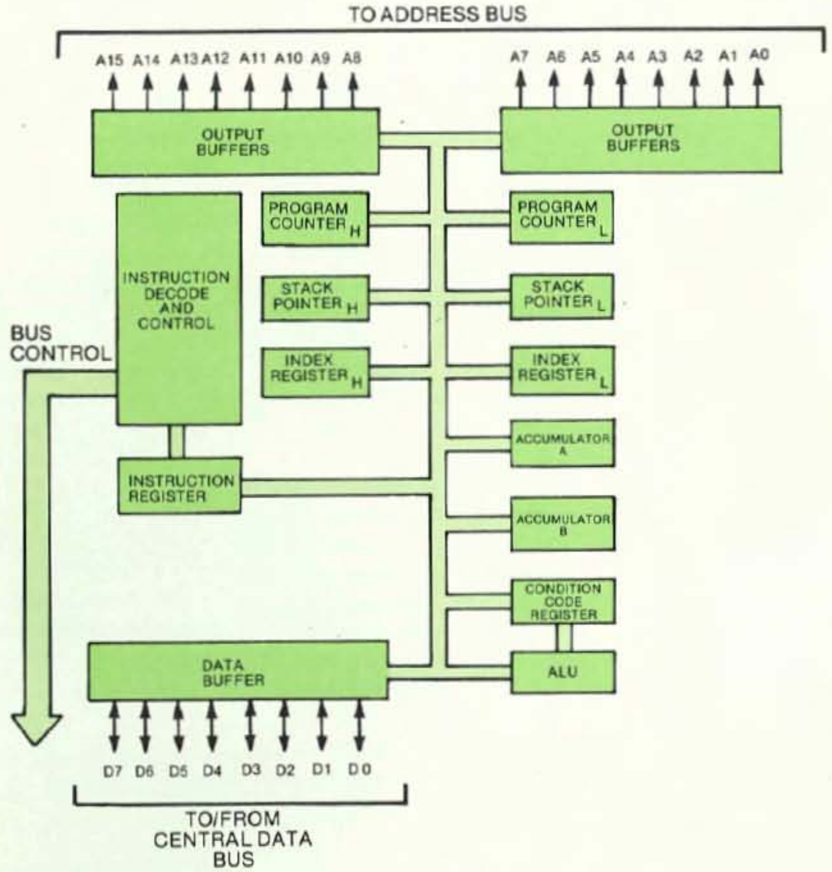
The primary goal in developing the new products was to enlarge the 4050 Series making it a family permitting both existing and new customers a greater choice of capability. Thus, the 4052 and 4054 were designed with compatibility as a major requirement. All three members of the family are completely software, data tape-, and disc-compatible. A customer having a 4051 can move up to a 4052 or 4054 without having to convert programs or data to a new format. Similarly, TEKTRONIX Plot 50 Software products and Application programs will operate on any of the 4050 Series desktop computers.

Performance enhancements

Compared with the 4051, the 4052 and 4054 provide:

- An order of magnitude faster (10X average) computation.
- Larger memory (32k bytes standard) expandable to 64k bytes (56k bytes usable).
- Speed enhancements to graphing using MOVE, DRAW extensions to 4050 BASIC.

Fig. 1. The 4052 desktop graphic computer provides a new dimension in speed, memory capacity and simple utility.



The 8-bit microprocessor shown is compacted on to a single chip of silicon. Instruction decoding (not shown in detail) is fixed in by chip designers and is unchangeable except by choosing another device of different design. All the main computational ingredients are present: working registers, arithmetic unit, control, and input and output. For a number of reasons, storage registers (A and B) are only 8 bits wide. The stack pointer (for subroutine return address handling), index register (for address modification) and Program Counter are 16 bits wide but are split into single byte halves to match the data path width. Having only two 8-bit registers (A and B) requires saving intermediate calculation results in main memory. This, plus the 8-bit-wide path, makes working on 4050 Series floating point numbers (8 bytes each) time consuming.

Fig. 2. Block diagram of the 6800 type microprocessor used in the 4051 desktop graphic computer.

- Faster transfer of data via the option 1 (RS232) and GPIB (IEEE-488 Std. 1975) standard bus.

In addition, the 4054 provides still greater capability:

- Large screen — 19" display with 13 million addressable points (16 times the 4051 or 4052 display).
- Improved alphanumerics — four character sizes and stroke generated characters.
- Faster, constant rate, vector generator.
- Ability to include Dynamic Graphics — non-stored displays of objects and alphanumerics.

A new multi-chip bit-sliced architecture processor

Achieving the design goals of compatibility with 4051 programs and data structures while enhancing performance was a challenge met by engineering an all new processor.

The most important choice in the new design was the choice of technology for the heart of the processor. The choice — a bit-sliced architecture of bipolar Shottky devices — offers several advantages:

- Modularity, allowing construction of processor word lengths in multiples of 4 bits (e.g., 4, 8, 12, 16 bits). This technique provides improvements in speed and accuracy.
- High density of functions without speed/performance sacrifices, leading to a simpler and faster design than would otherwise have been possible. Simplified design also enhances reliability.
- Microprogrammed design instruction set flexibility that allowed Tektronix to custom tailor the processor and its repertoire of actions (instructions) to suit problem solving with 4050 BASIC and graphics. In other words, the flexibility permitted an efficient processor (does things fast and well) to be made *effective* (does only the things needed and desired) from a user's point of view.

A tailored instruction set

To facilitate compatibility, the new processor's instructions are a hybrid of 16-bit minicomputer and "typical" one-chip microprocessor types.

The 8-bit-wide data path of the 4051 processor is a natural consequence of implementing a very compact and functional design. The new 4052 and 4054 had to appear to be equally comfortable with either 8-bit byte (character) operations or with 16-bit (two characters worth) operations. The character orientation of memory is apparent to a 4050 Series user when working with alphanumeric strings or when saving or reviewing program or data files.

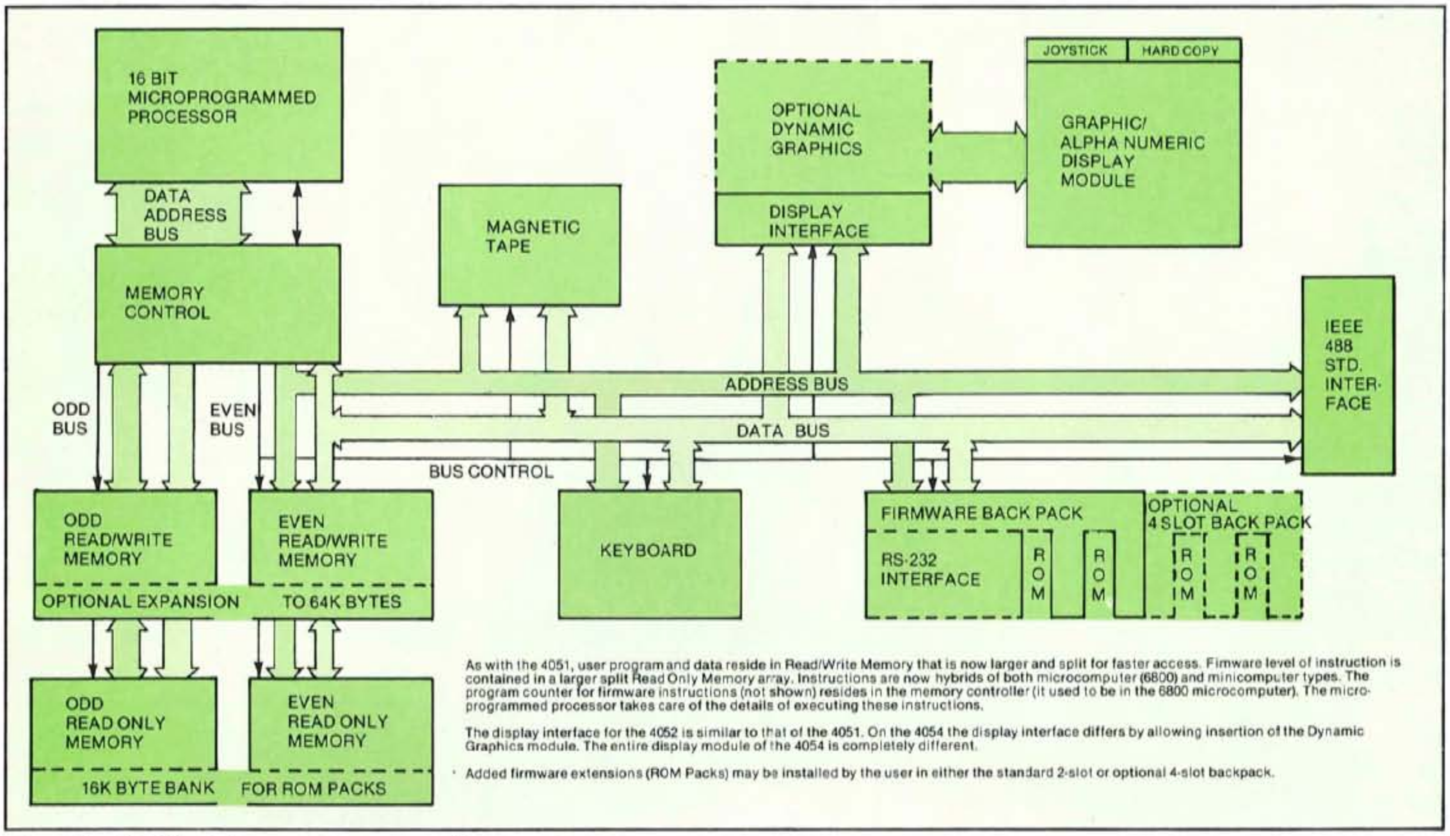


Fig. 3. Simplifed block diagram of the 4052 graphic computer system.

Compatible operations are provided by a new memory design for the 4052 and 4054. Memory is split into even and odd address sections with each on its own data bus. This may seem to be an insignificant detail. However, from the point of view of someone writing or running a program, splitting the memory into even and odd halves allows it to look like 4051 memory. The MEM and SPA commands return quantities of bytes just as with the 4051. Data is READ, INPUT, PRINTed; programs are OLDed, APPENDed, and SAVEd in 8-bit bytes compatible with 4051 operations. But the result of the split memory and faster odd/even busses is to present to the processor the ability to gather twice the number of bits simultaneously. The memory and bus organization are designed to match the 16-bit processor. Thus, compatible operation is provided without compromising performance enhancement.

Added instructions were developed for highly accurate floating point arithmetic operations. These new instructions (coupled with the memory design and faster processor) make complex calculations, such as sine, cosine, and tangent, thirty to forty times faster than with the 4051. The microprocessor of the 4051 has no floating point instructions to help with such complex calculations.

The results of the new processor and the technology choice are faster processing as calculations grow more burdening, simplicity for reliability, and complete compatibility to enable use with existing user and Tektronix written software.

Graphing improvements

Improvements in graphing also are realized. Graphic enhancements to BASIC — the MOVE, DRAW, RMOVE, RDRAW and AXES commands — allow graphics in the user's units, not machine or raster units. The arithmetic of converting user-familiar units to screen units is done by the processor with its own floating point arithmetic commands. This makes graphics, using the 4050 BASIC commands, five to six times faster on the 4052, even though the 4052 uses the same display module as the 4051.

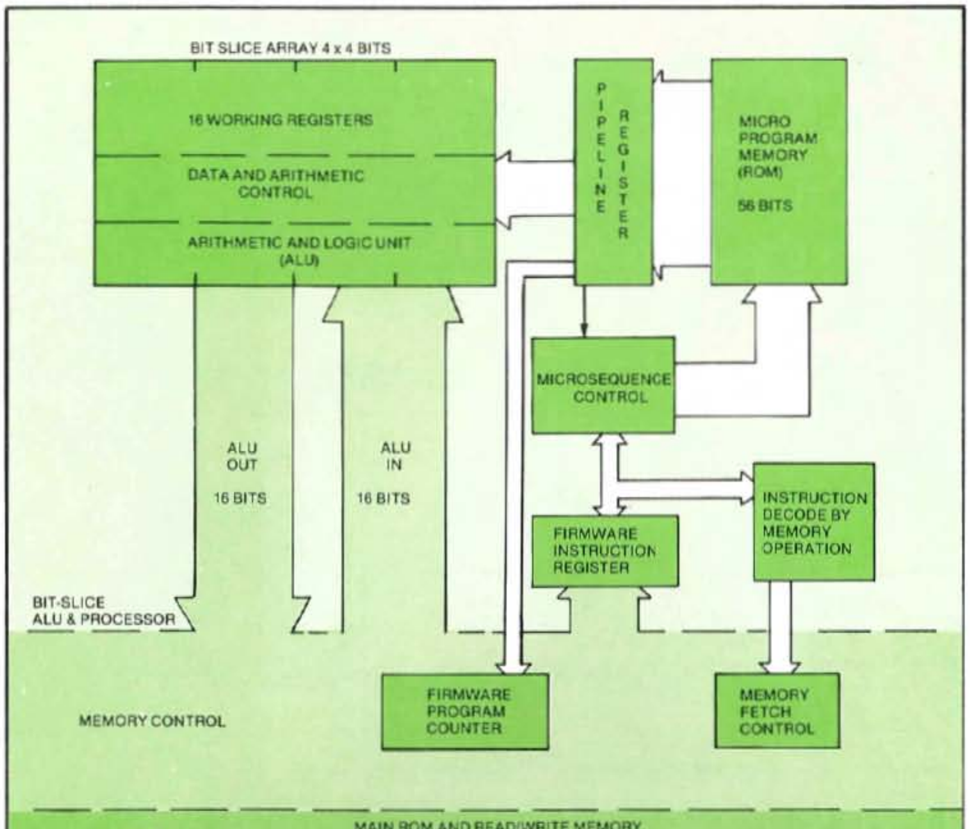
4054 provides enhanced graphics and alphanumerics

The 4054 has greater graphics capability than any other desktop computer. Its larger screen, with 4096 x 4096 addressable points, allows displaying many sets of curves, objects, maps, or business data in great detail.

However, more than just screen size and addressable points have been increased. The display electronics supports the larger viewing area by providing a faster writing rate at a constant 15,000 centimeters per second.

Unlike the display portions of the 4052 and 4051, which use a constant time (4-6 ms) per vector, the new 4054 display draws at a fast, but constant, rate. The maximum length vector, a diagonal 48.2 centimeters long, is drawn in under 4 milliseconds. This is faster than the 4052 and 4051 with either their longest or shortest vector.

Without a faster writing rate, the large screen display would have become a system bottleneck while drawing complex schematics, maps, or mechanical or structural designs. In the 4054, high density graphics is provided



The combination of four 4-bit processor slices receives its instruction information from a 56-bit pipeline register. While the current instruction is held during execution on the processor side of the register, the next instruction is being found and placed in line. The remaining bits (of the 56 bits) not used by the bit slices go to other portions of the processor system to direct operations concurrent with bit sliced processor operation. For each firmware instruction (obtained from ROM) one or more bit-slice instructions stream through the pipeline system. The firmware instruction location is determined by the program counter now located on the memory control section of the processor system. In addition, other devices perform partial decoding of firmware instructions to anticipate memory needs during execution. Thus the fast bit slices quickly handle only the details of program execution.

The bit slices provide sixteen (16-bit registers rather than two 8-bit registers) temporary storage for arithmetic calculations. Thus the registers can be loaded with a complete pair of 4050 BASIC floating point variables. Once in working registers they may be operated on using floating point instructions at top speed.

Fig. 4. The bit-sized architecture of the processor used in the 4052 and 4054 provides improvements in speed and accuracy.

with the support it needs to make it truly useful.

An optional feature, Dynamic Graphics, adds refresh capability to the 4054 for even greater flexibility and interactivity. This option is discussed in detail elsewhere in this issue.

Enhanced alphanumerics

The enhancement of alphanumeric displays is equally significant in the 4054. All characters are stroke generated for crisper hard copies. The 4051 and 4052 offer one character size — the 4054 has four. Labeling graphs or large amounts of columnar data is improved, with larger character sizes for labels. The smallest character size on the 4054 is approximately the same as the size of 4052 or 4051 characters. With this character size an entire 64 lines of 132 column print-out can be placed on the screen. When using the 4054 as a terminal (with Option 1) it provides a split screen view of 128 lines of program listing.

When different sets of data are combined on a single graph, as in graphs of actual versus forecasted sales, the hardware dash-dot vectors (36 of them visibly unique) allow distinguishing one set of data from another. Mechanical engineering applications can use the dashes for hidden lines, and different character sizes for title blocks.

The 4054 can help automate the drawing process. Like all other 4050 Series graphics systems, it allows easy mixing of alphanumerics and graphics in the same natural way that hand drawing presents information.

The 4052 and 4051 have a cursor (blinking arrow) which can be moved around the screen to select from a menu or pick a data point on a curve. Moving the cursor requires an optional joystick (or defining the User Definable Keys as "direction keys"). The 4054 has built-in thumbwheels for cursor positioning. The cursor is a full-screen crosshair cursor more useful in some mechanical and other engineering design applications because it is easier to line up objects along rectangular grid lines.

Summary

The new features and enhancements added to the 4050 Series by the 4052 and 4054 are intended to serve a simple but useful purpose — to provide Tektronix customers a wider performance choice of easy-to-use desktop graphic computers which will enrich their productivity by providing timely, easy-to-perceive solutions.

Dynamic Graphics Gives Best of Both Stored and Refreshed Display Techniques

Miki Tokola joined Tektronix in April of 1978 and has been heavily involved in U.S. and International new product introduction programs and training for the 4052 and 4054 Graphic Computing Systems. He has a B.S.E.E. and B.S. in Psychology, both received from the University of Washington in 1973. After three years as a scientific programmer/analyst, he returned to the University of Washington and received his M.B.A. in 1978. He is currently the 4050 Series Product Line Manager. Miki built his own house last summer and devotes his spare time to reading, guitar playing and family activities.

The bistable direct view storage cathode ray tube (DVST) permits the storing and display of complex mixed graphics and alphanumeric images at low cost. By storing high density graphics and alphanumerics on its specially processed screen, the DVST circumvents the need for and cost of the memory system required for refreshed displays.

Without the need for large amounts of memory, meaningful displays of information, interactive complex designs of objects in mechanical design, and building layouts are all possible at lower cost. The stored display technique is used on the 4051, 4052, and 4054 Graphic Desktop Computers.

Standard on all three product displays is a single character of non-stored display. The page full blinking "F" indicator, the cursor, and the blinking "?" that appear in response to a 4050 BASIC program request for keyboard input are all non-stored, single-object displays. These single objects are provided to prompt the programmer or user of the products, via the screen, without cluttering the screen. The Dynamic Graphics option for the 4054 makes these and many other non-storable objects programmable. In fact it does much more.

Dynamic Graphics expands 4054 flexibility and interactivity

The Dynamic Graphics option (4054 Option 30) adds new BASIC commands, and object storage memory to hold objects created with its new 4050 BASIC commands.

Objects, user-defined collections of vectors and/or alphanumerics can be created, displayed, and moved to any position on the screen without being stored, unless or until storage is desired. It's almost like having a superimposed second screen. Use the storage mode as a usual screen display. Use Dynamic Graphics for creating and moving objects without affecting the stored display.

When developing a schematic office layout, architectural, or other drawing, the portions that are completed can be stored on the 19" diagonal screen. By using the Dynamic Graphics option, symbols and lines can be drawn interactively, without storage, superimposed on the same screen. Objects can be selected from a menu (also displayed non-stored), moved around, tried in various positions, and then fixed (stored) when it's desirable to add them to the completed portion of the display.

Objects may also consist of alphanumeric lines to allow placing operating instructions on the screen without cluttering the display. When an operator prompt message is no longer needed, it is deleted from the screen without having to erase and redraw the entire display.

An interactive example

Let's examine an office layout application closely and see how the 4054 with Dynamic Graphics provides an efficient solution to the design problem. To begin, a menu in refresh is displayed in the upper left corner of the screen, explaining the functions of the User Definable keys.

First, the designer draws the exterior walls of the office. Pressing one of the User Definable keys brings up the cross-hair cursor. Using the cursor and the thumbwheels, the designer defines the corner points of the walls and doors. Once the walls are placed, the menu is returned by pressing a User Definable key. Notice that the menu can be recalled and erased independently with Dynamic Graphics. It is no longer necessary to erase the entire screen to eliminate the menu.

Next, desks are arranged. A User Definable key brings up a menu of desks and other office furniture at the bottom of the screen. After the appropriate object (in this instance a desk) is chosen, it is moved around the screen using the thumbwheels. The desk can be tried in different places in the office; when the deisred location is found, an image of the desk is stored on the office display with a single keystroke. Successive replicas of the desk can be positioned around the office by moving the object with the thumbwheels and storing copies as the design continues. Similarly, wall partitions, plants, file cabinets, and conference tables are quickly picked from menus, positioned and stored. Once the plan is completed, a 4662 or 4663 Digital Plotter plots the office layout. The procedure is quick, easy, and highly interactive.

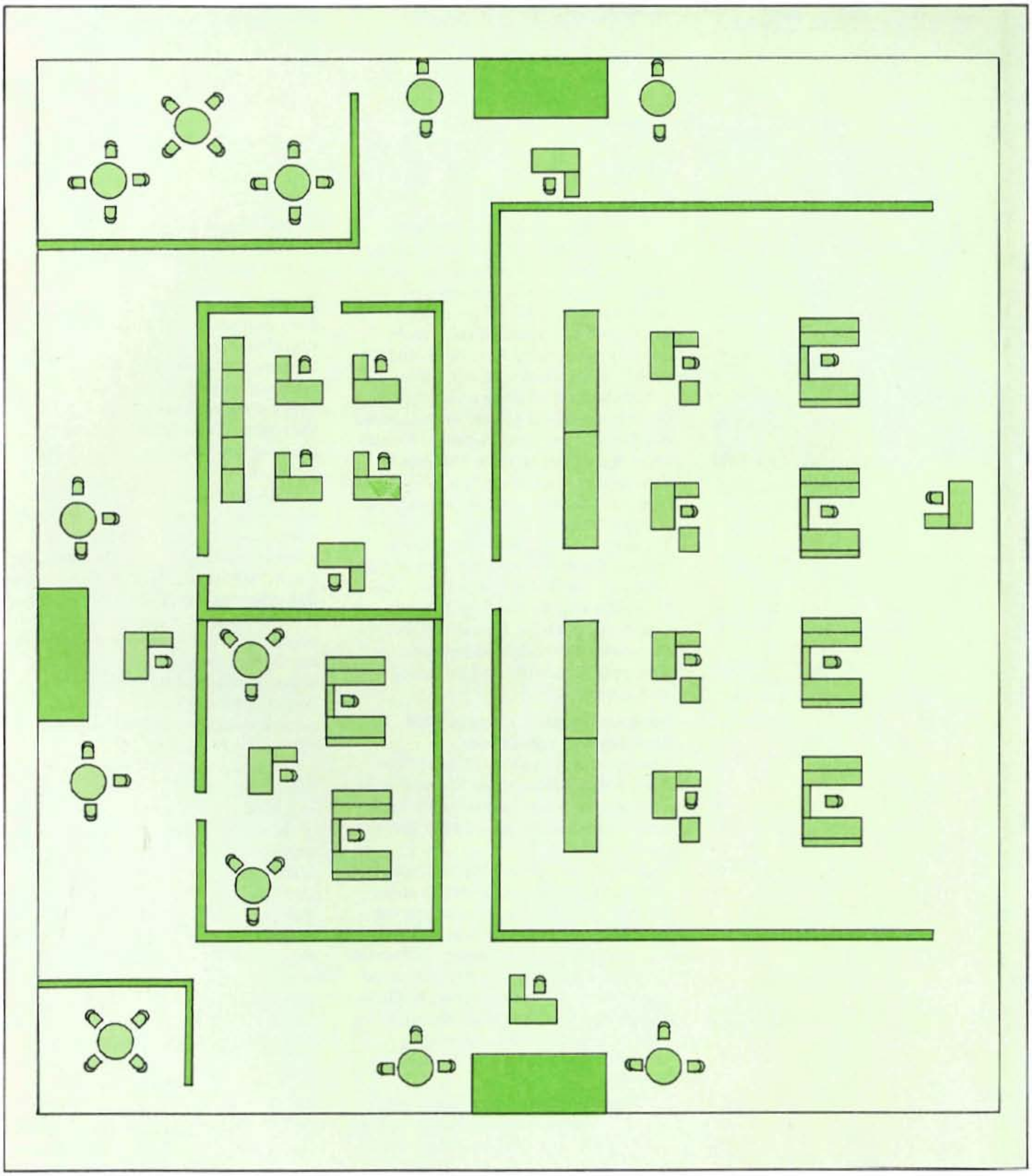


Fig. 1. Dynamic Graphics offers a great speed advantage in applications such as designing office layouts, as illustrated here, where objects stored in dynamic memory are called up and displayed in refresh mode.

Dedicated graphics option adds a dedicated microprocessor

By now you can appreciate not only the power of Dynamic Graphics but also the computing power and memory required to provide this capability.

Dynamic Graphics is a single circuit board installed in the 4054. A high-speed microprocessor and 32 kilobytes of dynamic memory are dedicated to the creation and display of refresh objects, completely independent of the 4054's processor. When Dynamic Graphics commands are received, the microprocessor stores the objects created in its own memory. Timing circuits prompt the Dynamic Graphics option to retrace its display memory, producing non-stored images on the screen.

The number of vectors displayed without flicker depends on the length of the vectors. Up to 1,000 vectors averaging one-half centimeter in length may be displayed without flicker. The amount of displayable text is related to the number of strokes in each character. At least one full line of text, or several shorter lines, can be displayed in refresh mode.

New commands

New language commands facilitate writing BASIC language programs to create objects. The object can be any meaningful unit: a simple line or word, a complex 1,000 vector object, or a program menu. An ROPEN statement begins the construction process; subsequent vectors and text strings define the object. The definition continues until an RCLOSE statement is encountered. An RAPPEND command will expand the definition. The specified object is reopened to add additional vectors and/or text. Object definitions can also be deleted or replaced.

The object definitions, along with some display information automatically provided by the 4054, are stored in the Dynamic Graphics memory. This separate memory permits efficient object storage which doesn't subtract from the 4054's read/write memory. It's easy to build a large set of objects.

An object appears on the 4054 screen through the VISIBILITY command. This command causes the object's definition to be repeatedly retraced (refreshed), producing a non-stored image on the screen. The displayed image of the object can just as easily be deleted; the image no longer refreshed vanishes from the screen. However, the definition remains in dynamic memory. This allows interactive prompts and program responses without cluttering the screen with unneccessary text.

A BLINK command alternates an object between visible and invisible modes according to user-specified on and off times. It can be used to draw the operator's attention to a prompt or indicate an object needing some user action.

Motion is another major graphic enhancement. The refreshed image of the object can be moved around the screen either under program control interactively with the thumbwheels, or by using an optional graphic input device such as a graphic tablet or joystick. The CURSOR command replaces the standard cross-hair cursor with a specified object and places it under direct control of the thumbwheels.

The FIX command copies the object onto the screen in storage mode. You can quickly place multiple images of an object by repeatedly positioning and fixing the object. There is a great speed advantage with Dynamic Graphics. An object stored in the dynamic memory can be displayed on the screen up to 100 times faster than by drawing it directly from a program onto the screen.

No compromise in compatibility

Language compatibility, a major feature of the 4050 Series, is maintained. The new commands are ignored by the 4052, and by 4054s without the option. Special provisions to interact with optional graphic input devices, such as the joystick or graphics tablet, have been incorporated.

New application for graphics

This refresh capability also provides real-time simulations. With the CURSOR command, it is possible to replace the cross-hair cursor with any refreshed object and place the object under the control of the thumbwheels. Imagine a 4054 with Dynamic Graphics as a tactical decision aid. A submarine is created and becomes the cursor. A second object, a destroyer, can be displayed in refresh and its position determined by the location of the submarine. It is now possible to simulate evasive maneuvers by allowing the operator to move the submarine around the screen, trying to avoid detection by the destroyer.

To be useful — tools must fit their uses

In designing, you often think in terms of standard graphic components, such as a desk in facilities layout, or a transistor symbol in a circuit diagram. Dynamic Graphics provides the graphic power to work directly with these graphic elements, not just points or lines.

The examples we've chosen can only hint at the power of 4054 Option 30 Dynamic Graphics. We know that users will apply this increased graphic interactivity in many creative ways.

The 4054 has the most powerful graphics feature available in a desktop computer. With the addition of Dynamic Graphics, the potential application areas are greatly expanded.

A New Cost-Effective Highly Portable Data Comm Tester

Art Yerkes is a relative newcomer to Tek having started with the Digital Service Instruments Group in 1978. After receiving his B.S. in Electronics Physics from LaSalle College in 1974, he worked for Datapro Research, an organization that provides a computer product reference service, a type of consumer's guide of the computer industry. Much of Art's digital communications background involved working with stock market information systems. He is presently engaged in marketing activities for Digital Service Instruments.

When problems strike a data communications system, fast, effective service is a must. For example, there are networks in existence where cost for down time extends into tens of thousands of dollars per hour. The TEKTRONIX 833 Data Comm Tester is designed for just such a function. Typically, a service technician, using the 833, should be able to locate and correct over eighty percent of the troubles on first call. The remaining ten to twenty percent will probably require an expert on the data comm system, and more sophisticated, expensive test equipment.

The 833 is a "friendly" instrument — easy to learn, easy to operate, and easy to carry. It weighs just twelve pounds. Applicable to any RS232-C, C.C.I.T.T. V.24, or current loop interface, the 833 can monitor or apply test signals to and from the modem (DCE) or the data terminal equipment (DTE). It can also be used to evaluate the quality of the data link. Microprocessor control gives the 833 unusual versatility and, at the same time, reduces the number of front panel controls needed to effectively use that versatility.

A perusal of the front panel shown in figure 2 provides an overview of the many operating configurations available with the 833. Note that in addition to working with synchronous and asynchronous systems, the 833 accommodates systems using the HDLC protocol and employing standard or NRZI data encoding schemes.

A wide choice of data rates is provided. Baud rates from 50 to 9600 bits per second are available from an internal clock, or you can select a supplied clock from the host computer, data terminal, or communications equipment. Provision is also made to derive the clock from the data stream.

The 833 can operate in full duplex or half duplex mode with turn-around delay in half duplex selectable from the keypad. The keypad plays an important role in 833 operations. It allows you to program the instrument specifically for the network under test, e.g., selecting character length, synchronizing signals, etc. The keypad also serves as mode and buffer selector.

Operating modes

The versatility of the 833 is evidenced by the wide choice of operating modes provided. In the MONITOR mode, data transmissions in both directions are displayed in real time and recorded. The portion recorded is determined by the START, STOP, and MEMORY CONTROL controls. You can choose to display DCE or DTE data, or both. Both are recorded and maintained irrespective of which is selected for display. The source of the displayed data, and the status of the interface lines are also recorded and displayed along with the data and its location in memory.

In testing data terminals and DCEs, the SIMULATE, ECHO and REPEAT modes are used. Regular SIMULATE

Fig. 1. The highly portable 833 Data Comm Tester

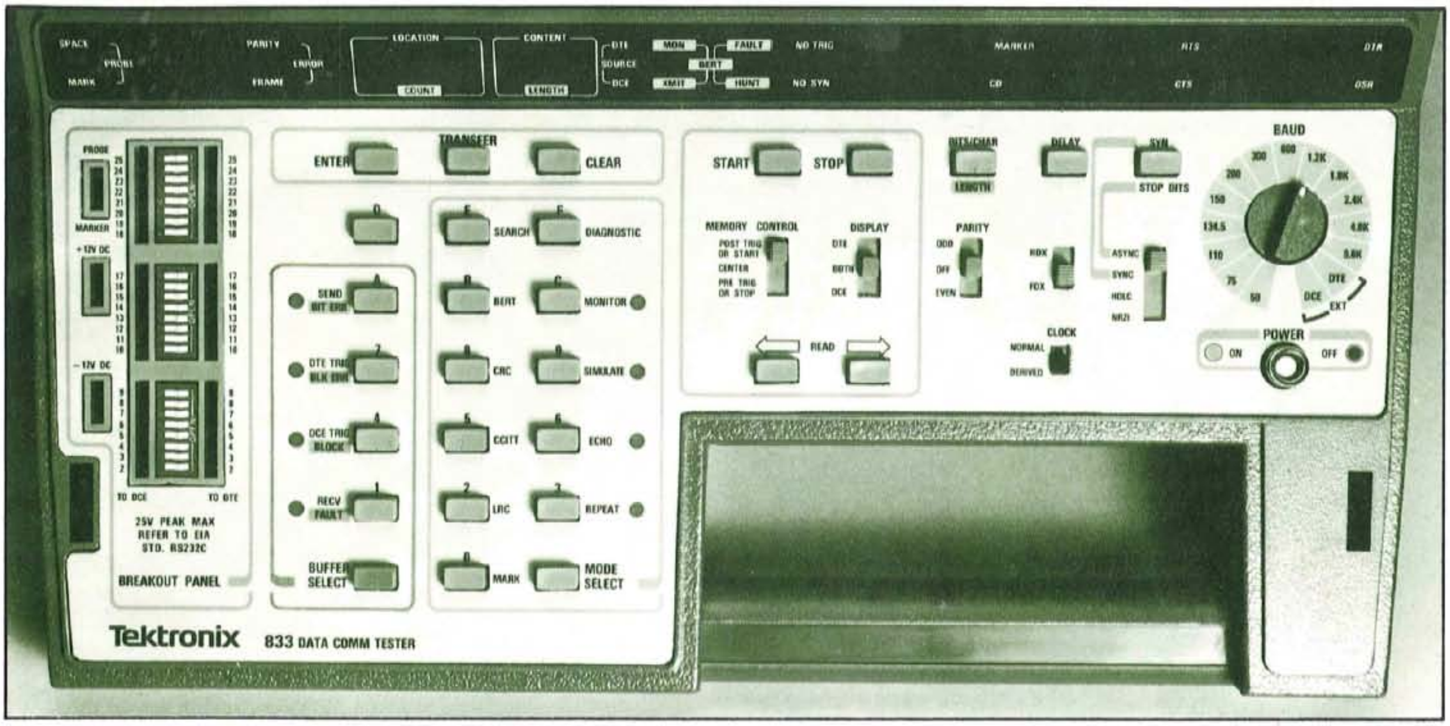


Fig. 2. The many operating configurations available to the 833 user are easily discerned from the functional front-panel layout.

mode transmits a message once and records the response. REPEAT mode transmits a message repeatedly, recording any interleaved responses. And ECHO mode performs as the regular simulate mode but, in addition, echos received characters back to the transmitting device. Trigger sequences may be used with any of the simulation or monitoring modes to achieve a variety of specialized tests.

A message can be entered from the keypad, or you can select one from several stored in ROM. Messages in ROM include an ASCII fox test, upper case ASCII characters, a full ASCII character set, a set of 132 upper case ASCII characters, an EBCDIC fox test, and upper case EBCDIC characters. There is also provision for a user-defined message PROM with a capacity of 2048 bytes.

The SEARCH mode provides a convenient means of searching both the send and receive buffers for the presence of data sequences of from one to three characters. The trigger buffer is used to hold the specified characters.

Extensive self test

As you work with communications systems it is important to know that your test instrument is working properly. The 833 performs a self-test on power up. A RAM march test, RAM bit independent check, and a ROM check sum test are performed, and all of the LED readouts are energized.

In addition to the start-up tests, the 833 can be put in the DIAGNOSTIC mode and a number of extensive test routines called up from the keypad. These include a more thorough test of memory, the display elements, slide switches, pushbuttons, baud switch, CPU, and other elements.

CRC calculation

Communication systems differ in the scheme used to detect errors in data handling. The 833 calculates three kinds of message check bytes: CRC-16, CRC-CCITT, and LRC-8. CRC, or cyclic redundancy check, is most commonly performed on bisynchronous messages that use EBCDIC code. CRC-CCITT is another form of CRC that is commonly used on systems with HDLC protocol. LRC-8, or longitudinal redundancy check, is still another form of check character in which a parity check across the whole message is performed. It is commonly encountered in bisynchronous systems that use ASCII code.

CRC characters are numbers generated by using message data as a very long binary number and performing a mathematical operation on it. The MARK key is used to select the character marking the start of each CRC calculation. The user selects the end character for the calculation by stepping through the buffer until the desired character appears in the readout. The CRC calculation is then initiated by pressing the appropriate CRC key, followed by MODE. Results of the tests are displayed in the LOCATION and CONTENTS section of the display.

BERT testing

It is sometimes useful to check the quality of the data line itself, and the most common method of doing that is to perform bit error rate testing, or BERT. The 833 provides this capability. The CCITT BERT pattern is a 511-bit message sent and read on a looped-back line, or sent to a receiving BERT tester on the other end, so that errors may be counted. The 833 will perform three different test lengths — 100,000 bits, 1,000,000 bits, or continuous. In the continuous mode, the test is run until 999 bit errors are counted or until the STOP key is pressed. The results of the test reside in several registers. You can choose to read the bit error rate (which is displayed real time during the test), the number of 1000-bit blocks received, the block error rate, or the number of faults. A fault is recorded each time the error rate exceeds twenty five percent over a span of sixty-four characters. Errors may be injected into a transmitted bit stream, and you may clear all registers during the test, if desired.

Buffer selection should be an integral part of the operating mode discussion. There are four selectable buffers: SEND, DTE TRIG, DCE TRIG, and RECV. These also serve an alternate function in BERT operation. The send and receive buffers will hold 255 and 256 characters, respectively. The trigger buffers hold three characters.

Messages can be entered into the SEND, DCE, or DTE buffers from the keypad. Messages stored in any buffer, including the receive buffer, stored message buffers, or user-defined message buffers (EPROM) can be transferred to the SEND buffer. The transfer action does not destroy the contents of the buffer transferred. The receiver buffer is automatically cleared when the START button is pressed, and records whenever a trigger occurs or the STOP button is pressed.

The EPROM capabilities provide users the ability to construct a fairly large set of messages specific to their needs, and use them in a manner which makes it appear as if they were factory installed, e.g., with no complication of the user interface.

The interface breakout panel

The interface breakout panel on the front panel of the 833 is an important troubleshooting aid. It provides direct access to the interface lines. Twenty-four line disconnect switches are used to control throughput to and from the data terminal or data communication equipment. Patch pins, electrically connected to each side of the disconnect switches, provide easy access to any line.

Also included in the breakout panel are jumper pins for the probe and marker LEDs, and for the −12 volt and +12 volt reference supplies. You can open any line using the breakout switch, or cross-connect lines using supplied jumper wires between the patch pins. The probe LED circuit can also be patched to any line; or, if you want the signal recorded, you can patch to the marker LED circuit. Any of the lines can be forced HI or LO by patching to one of the reference supplies.

A simplified display

In selecting the type of display to be used in the 833 many factors were considered — the kind of information to be viewed, the space required, weight, and cost being the major factors. Digital information is presented by two 7-segment LED readouts — one a three digit and the other a two digit. The two digit display presents data in hexadecimal format. This simplifies the display and eliminates the need for memory space for special ROMs for the different code sets. The three digit display is used to show the location of the data in memory, and for other functions. Other LEDs are used to indicate the source of data, parity and framing errors, trigger and sync status, and the status of the interface lines. Two LEDs provide a built-in logic probe function that can be connected to any interface line (at the breakout panel) to show its logic level in real time. The MARKER LED serves a similar function but differs from the PROBE LEDs in that the status is recorded along with each character.

Summary

The 833 is designed to provide a cost-effective solution to the problem of servicing data communication systems in a fast, efficient manner. It can monitor data flow in both directions and allow you to analyze that data; simulate the modem, poll multi-terminal systems, and perform BERT testing to check the quality of the data link. These and many other tasks can be performed on an instrument which is easy to learn, easy to operate, and easy to carry to the site of the next problem.

A New DMM Family for the TM 500 Series

Bill Mark joined Tek in 1968 after completing his B.S. in Electrical Engineering Technology at Weber State College in Utah. He received his B.S.E.E. from the University of Portland in 1978. Bill worked with the Product Evaluation group doing electrical evaluation on accessories and general purpose instruments. He also did high-impedance attenuator design for some of the 400 Series Oscilloscopes. He is responsible for the electrical design of the DM 501A.

Bill is an amateur mycologist (one who can discern between palatable and poisonous mushrooms) and enjoys gardening, hunting, and fishing.

The capability to assemble an instrumentation system tailored to your application is one of the major benefits offered by the TEKTRONIX TM 500 Series. Now, three new digital multimeters — the DM 501A, DM 502A, and DM 505 expand this capability substantially.

In designing these additions to the TM 500 family, the major goals were to improve reliability, increase display size, expand measurement ranges, improve accuracy, enhance operating ease, and provide a wider choice of measurement capability. All of these goals have been achieved.

The DM 501A and DM 502A replace their earlier counterparts, the DM 501 and DM 502, respectively, while the DM 505 is a new addition to the family.

The DM 501A and DM 502A are seven-function multimeters, including dc and true rms ac voltage and current measurement, HI-LO resistance, decibels (dBm and dBV), and temperature. The DM 501A features 4 ½ digit readout with 10 μV resolution and 0.05% dc voltage accuracy.

The DM 502A adds the convenience of autoranging for all but current measurements and provides 3 ½ digit readout with 100 μV resolution and 0.1% accuracy for dc voltage.

True rms measurements

True rms ac measurement is a new capability for the TM 500 Series DMMs. Both the DM 501A and DM 502A use the technique of rectifying the input waveform, squaring it, filtering it over several cycles, and then taking the square root of it. This approach results in a true rms reading for any input waveform within the bandwidth and crest factor limitation of the DMM. The DM 501A and DM 502A have a crest factor of 4.

Many applications, such as measurements on regulators, power control circuitry, etc., involve signals other than sinewaves which can only be measured accurately with a true rms meter. White noise, two-tone intermodulation test signals, and other communications signal measurements also require true rms for accuracy.

The DM 502A couples true rms dB measurement with autoranging capability to provide unprecedented operating ease for communication and audio measurements. Autoranging eliminates the traditional need for range changing and addition of the display reading to the range setting for computing the final value. If the test signal source is a TM 500 plug-in, the ability to switch between rear and front panel inputs speeds up gain measurements still further.

Unexcelled temperature measurement

A new temperature probe, the P6601, provides the DM 501A with the widest temperature measurement range of any DMM available today (−62° to +240°C). Temperature measurement with the DM 502A is −55° to +200°C.

The P6601 uses a thin-film platinum resistor mounted on a silicon substrate, as the sensing element. This is bonded to a hemispherical beryllium oxide tip for contact with the outside world.

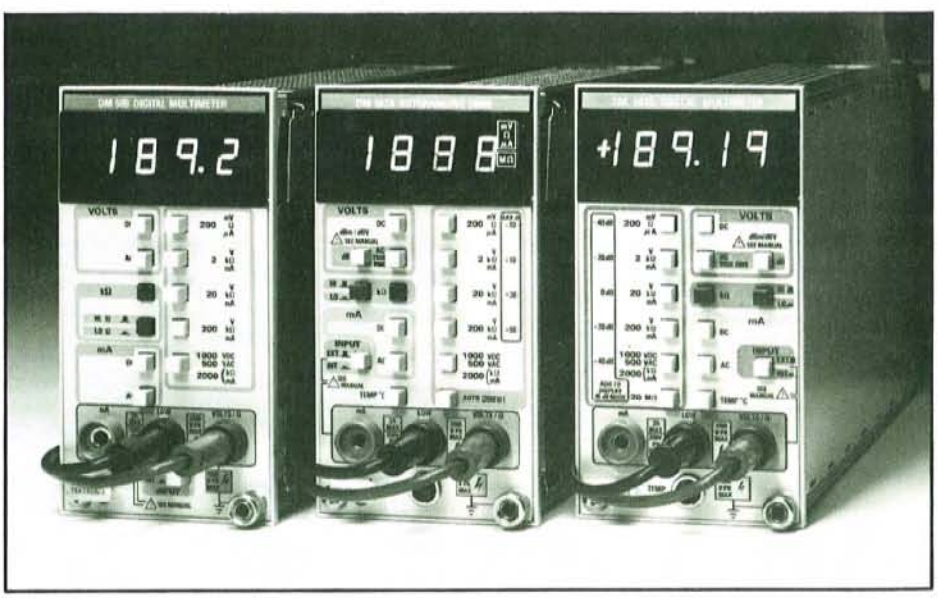


Fig. 1. Three new digital multimeters greatly expand the range of measurement capability available to TM 500 users.

Electrical contact with the sensor is via fine wire bonding leads. The entire mass is very small which results in minimum heat sinking of the object to be measured, and a rapid response time (0.5 seconds ±0.2 seconds). The dome-shaped tip reduces the amount of surface contact and eliminates the need for a thermal compound (silicon grease) and precise probe positioning. Combined heat sinking and thermal gradient errors for common transistor cases is shown in figure 2. The high temperature probe body and cable design of the P6601 permits immersion in liquids or use in temperature chambers at temperatures up to +140°C.

There are no calibration ajustments on the probe assembly. Any necessary adjustment is done in the DM 501A and DM 502A which contain the probe amplifier and linearization circuitry.

A new low cost member

The DM 505 is a 5-function DMM designed for the many applications best met by an inexpensive, easy-to-operate dependable digital multimeter. Education and production uses are typical examples. Functions include dc and ac voltage and current, and HI-LO resistance measurements. The ac voltage function is average responding, rms calibrated, which is a convenience when comparing results with earlier readings taken by average responding meters.

A family resemblance

The DM 501A, DM 502A and DM 505 have much in common. Each features a large, bright, seven-segment LED display, pushbutton range and function selection, floating inputs, and selection of rear and front-panel inputs. Measurement ranges are the same with a few exceptions. The chart in figure 3 provides a quick comparison of characteristics.

Some special considerations

Several areas required intensive effort to meet design goals for performance, buildability, maintainability, and reliability.

Making accurate ac voltage measurements will serve as a typical example. Many printed-circuit boards exhibit a characteristic we call "hook". Hook may be defined as the effect on a signal's voltage amplitude caused by a change in pc-board capacitance with a change in frequency. This capacitance varies inversely with frequency and is most dominant below 1 to 20 kHz.[1]. In addition to pc board material, dielectrics used in capacitors, switches, and other components were evaluated for hook.

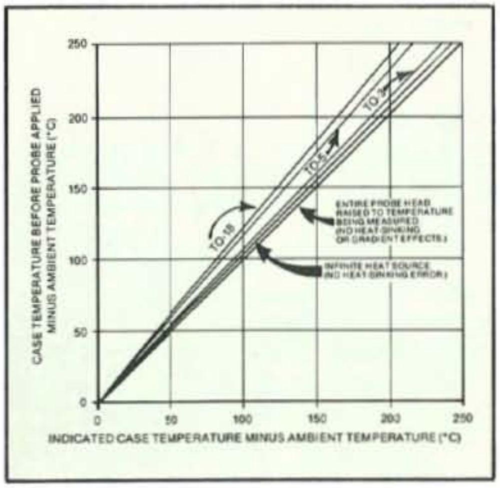


Fig. 2. Combined heat sinking and thermal gradient error introduced by the P6601 when measuring different sized transistor packages.

The effect of hook is most troublesome in DMMs in the attenuators used for the ac converter circuitry, where it can introduce measurement errors of 1% or greater. The effect is aggravated in high-humidity environments. Working with our pc-board suppliers we have established standard tests for measuring board capacitance and determining which boards are acceptably hook free. This allows us to use conventional manufacturing techniques and yet hold tight specifications over the entire operating range of 20 Hz to 20 kHz.

Floating input ac measurement is another area which received special attention. The metal plug-in enclosure used for the plug-in modules provides good shielding from external signals but requires the use of guarded shields to eliminate the effects of stray capacitance on floating ac measurements. Both the ac attenuators and input circuitry have guarded shields.

To eliminate undesired coupling between digital and sensitive analog circuitry, a star grounding system was adopted. The star grounding scheme keeps pc board costs low by not requiring the use of multi-layer boards. Ground currents for these different circuits flow through separate ground paths and meet at a common point at the power supply. The points at which various ground currents enter a particular ground return are also carefully selected to prevent generating undesired offset voltages.

Summary

The new family of DMMs for the TM 500 Series is designed to give you a wide choice of measurement capability for your TM 500 measurement system. Extended capability, operating ease, large LED displays, specified accuracies over the entire operating range, and other features allow you to make DMM measurements with greater ease and confidence in the the results.

1 "Getting rid of hook: the hidden pc-board capacitance", Electronics, October 12, 1978.

MODEL NUMBER	NUMBER OF DIGITS	NUMBER OF FUNCTIONS	DC VOLTS			AC VOLTS			AC + DC CURRENT	dB	OHMS (HI-LO)	TEMP	TRUE RMS	AUTO RANGE
			RANGES	ACCURACY	BEST RESOLUTION	RANGES	ACCURACY	BEST RESOLUTION	RANGES	RANGES	RANGES	RANGE		
DM 501A	4½	7	200 mV to 1000V	±0.05%	10 μV	200 mV to 500 V	±0.6%	10 μV	200 μA to 2 A	+54 dB to -60 dB	200 Ω to 20 MΩ	-62 C to +240 C	X	
DM 502A	3½	7	200 mV to 1000 V	±0.1%	100 μV	200 mV to 500 V	±0.6%	100 μV	200 μA to 2 A	+50 dB to -60 dB	200 Ω to 20 MΩ	-55 C to +200 C	X	X
DM 505	3½	5	200 mV to 1000V	±0.1%	100 μV	200 mV to 500 V	±0.5%	100 μV	200 μA to 2 A		200 Ω to 2 MΩ			

Fig. 3. Chart providing rapid comparison of major characteristics of the DM 501A, DM 502A and DM 505.

Simultaneous X-Y, Y-T Displays Using a 5100 Series Oscilloscope

Les Hurlock joined Tek in 1958 and spent several years as Service Center Supervisor in mid-west and West Coast Field Offices. Returning to Portland, he served in Engineering and Training, where he authored several technical publications. Currently, Les is Marketing Product Specialist for 5000 Series products. He is heavily involved in applications for the life sciences market and has authored a number of biomedically-oriented application notes.

Medicine and other scientific fields often call for measuring the relationship between physical forces. By using transducers to convert such forces into electrical signals, an oscilloscope can be used as a convenient and accurate measurement tool.

Many physical measurements made with an oscilloscope involve the relationship between two separate forces, one placed on the vertical (Y) axis and the other on the horizontal (X) axis of the display. Applications occur where one of these forces must also be measured as it progresses through time (T). TEKTRONIX 5100-Series Plug-in Oscilloscopes are ideal for such applications, providing simultaneous X-Y and Y-T displays on a single instrument.

Any single-beam 5100-Series mainframe can be used for such displays. A 5100-Series dual beam mainframe can also be used but will require modification. The set-up uses two single-channel amplifier plug-ins (or two multi-channel plug-ins in the single-channel mode) in the left and center compartments, and a 5B12N Dual Time Base Plug-in in the right hand compartment.

The 5B12N controls are set for dual sweep operation with automatic triggering. The A Time/Div control is set to one of the amplifier positions (50 mV or .5 V/div), and the B Time/Div control to the desired sweep speed. The B sweep is triggered internally from the center plug-in.

With the 5B12N operating in the CHOP mode, time base A (now serving as an 'X' amplifier) is paired with the left hand plug-in to produce an X-Y display (top trace of Fig. 1). Time base B is paired with the center plug-in to present a Y-T display (bottom trace of Fig. 1).

The 'X' bandwidth (through the 5B12N) is dc to 1 MHz, while the 'Y' bandwidth depends on the vertical plug-in used. Typically it is 1 or 2 MHz. The X-Y phase shift is not specified when using time bases in the "amplifier" mode; however, it typically will be $\leq 2°$ dc to 100 kHz.

A typical application

As an example of the value of simultaneous X-Y, Y-T displays let's consider a fairly common medical application.

One way to measure human respiratory performance is through the use of an oscilloscope and a wedge spirometer with transducer outputs. Typical measurements include Vital Capacity, Forced Expiratory and Inspiratory Volume and related parameters. Usually, each measurement requires a separate effort on the part of both the patient and the test attendant. The 5100-Series simultaneous X-Y, Y-T capability allows two measurements to be made at once, saving both patient effort and lab time.

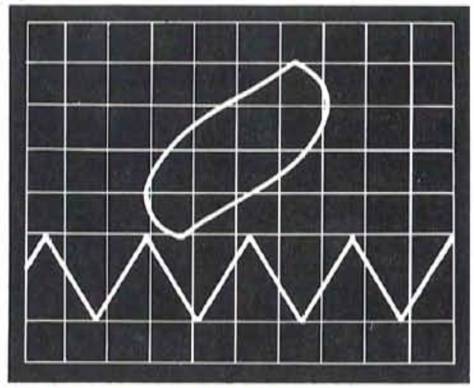


Fig. 1. Combination X-Y, Y-T display.

Since this application requires a permanent record of real-time activity, it is convenient to use a storage oscilloscope and then photograph the resultant display. In this instance, a 5111 Storage Oscilloscope with two 5A15N Amplifier Plug-ins, a 5B12N Dual Time Base, and a C-5B Camera are used.

The wedge spirometer has two outputs — "volume" and "flow" (see Fig. 2). The "volume" output serves as the 'Y' signal and is applied to the inputs of both 5A15 Amplifiers. The "flow" output represents the 'X' signal and is applied to the A Ext. Input connector of the 5B12N.

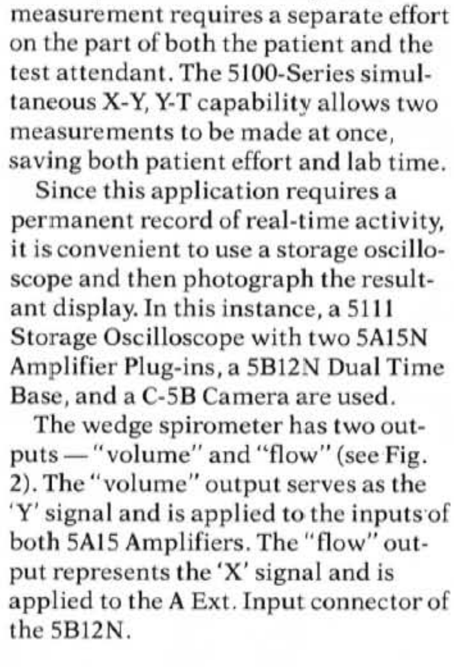


Fig. 2. Diagram of setup which routes the "volume" signal through both left and center amplifiers and represents the "Y" part of both X-Y and Y-T displays.

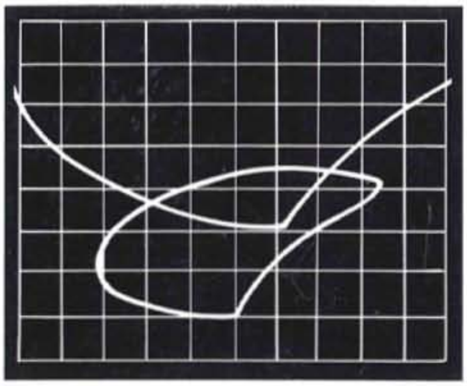


Fig. 3. X-Y display showing flow/volume loop (lower), and Y-T display of volume/time spirogram (upper).

The precise test sequence is determined by qualified medical personnel. Briefly, the patient is instructed to inspire to total lung capacity, blow out forcibly to residual volume, and then inspire rapidly to total lung capacity before taking the mouthpiece out of his mouth.

The resultant scope image will show two displays (Fig. 3). The flow-volume loop is the X-Y display produced by time base channel A (X = flow), and the left amplifier (Y_2 = volume). The volume-time spirogram is the Y-T display produced by the center amplifier (Y_1 = volume) and channel B time base (T).

Summary

TEKTRONIX 5000-Series Plug-in Oscilloscopes provide a wide range of measurement capability with a broad selection of mainframes and plug-ins available. They can operate as general purpose instruments, yet fulfill special measurement needs as in this instance of providing simultaneous X-Y, Y-T displays. Application notes covering this and other applications are available from your Tektronix Field Office or Representative.

AX-4269

10/79

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

0421867 1339
MR THOMAS P DOWNEY LAB TECH
GEOLOGY DEPT EPS-J106
CITY UNIVERSITY OF NEW YORK
138TH ST AT CONVENT AVE
NEW YORK NY 10031 11/14/79

A Portable High-Performance Microwave Spectrum Analyzer

The Tektronix 492 Is A New-Generation Spectrum Analyzer

Making Measurements With The 492

Packaging A Spectrum Analyzer For Performance, Maintainability And Survival

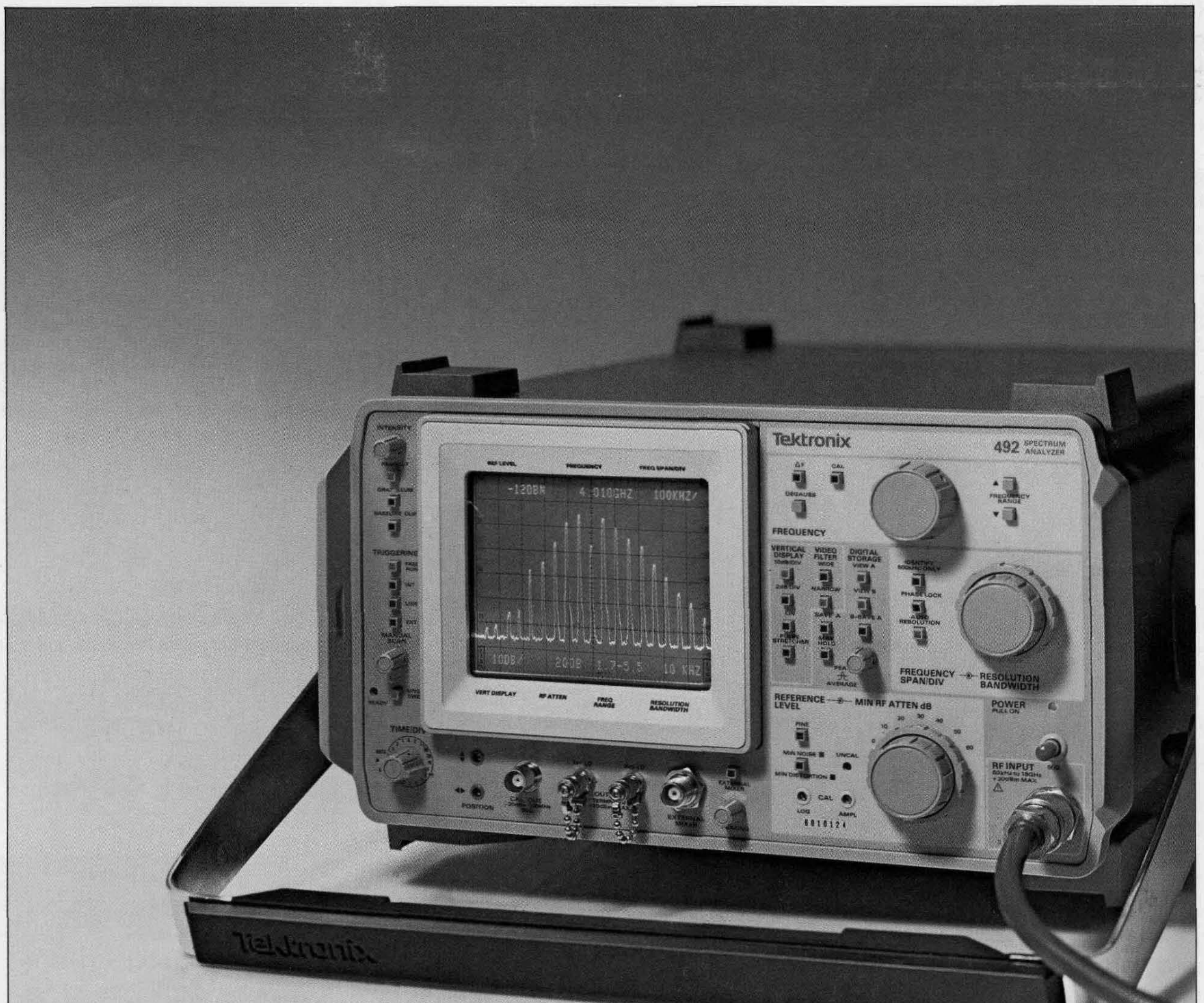
A First Converter With Field Replaceable Diodes

A Switching Power Supply For The 492 Spectrum Analyzer

Volume 12
Number 1

1980

Tekscope



Tektronix®
COMMITTED TO EXCELLENCE

CONTENTS

Tekscope

Customer information from
Tektronix, Inc.
Beaverton, Oregon 97077

Editor: Gordon Allison
Acting Editor: Art Andersen

Tekscope is a bimonthly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique. A new products section gives a brief description of products recently introduced and provides an opportunity to request further information.

A Portable High-Performance Microwave Spectrum Analyzer
The Tektronix 492 will make state-of-the-art measurements over the range of 50 kHz to 220 GHz, both in the laboratory and under severe environmental conditions.

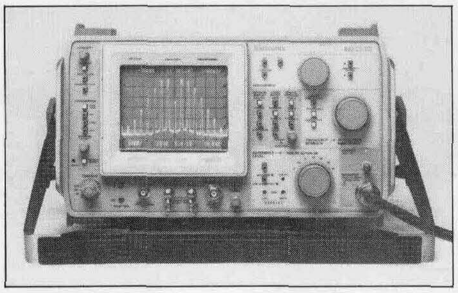
The Tektronix 492 Is A New-Generation Spectrum Analyzer
A few years from now, someone will undoubtedly introduce a new spectrum analyzer that improves on the 492. But that is in the future. The 492 is here today.

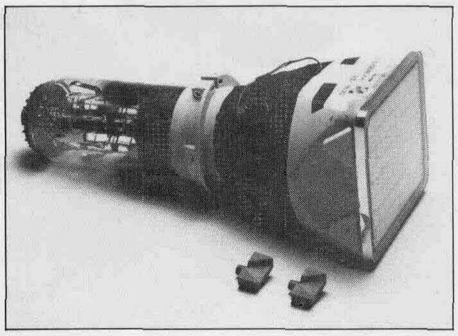
Making Measurements with the 492
Some measurements showing the high stability and signal purity capabilities of the 492.

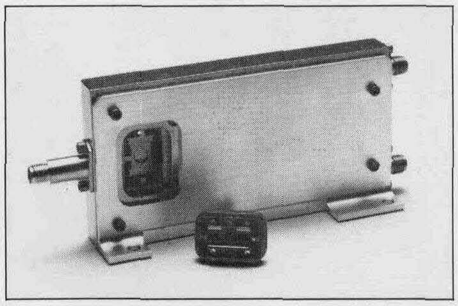
Packaging A Spectrum Analyzer for Performance, Maintainability And Survival
Designing and producing a portable package which would enable the 492 to meet MIL-T-28800B was a challenging experience. The key to success was the design of a crt capable of withstanding severe vibrations and shock.

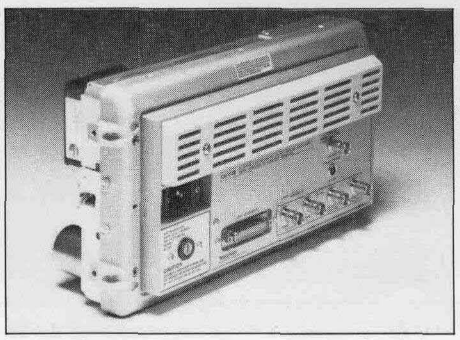
A First Converter With Field Replaceable Diodes
Field replacement of mixer diodes exposed to excessive voltage is easy in the 492, but that is just one benefit.

A Switching Power Supply For The 492 Spectrum Analyzer
The weight of conventional supplies have made the high-performance portable spectrum analyzer a rarity until now.



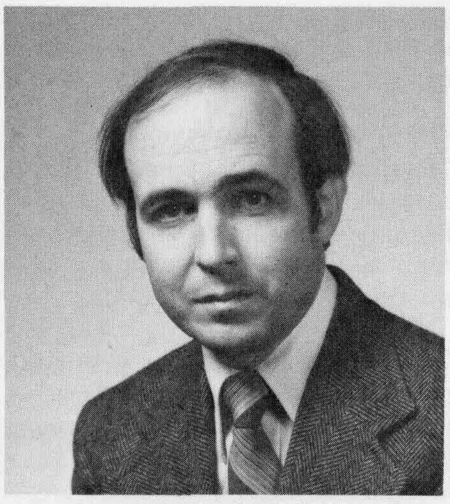






Cover: The 492 Spectrum Analyzer, equally at home in the field as it is in the laboratory.

A Portable High-Performance Microwave Spectrum Analyzer.



Dave Morton received his Ph.D. from Iowa State University. Dave joined Tektronix in 1971 as a Project Engineer and has been associated with microwave circuit design and measurement. He currently manages the Tektronix Spectrum Analyzer Electrical Engineering Group and is a member of the IEEE and its Microwave Theory and Techniques Group. He and his wife and two daughters particularly enjoy the Oregon Coast in spite of the rain. Woodworking and photography are among his spare time interests.

It is often impractical to transport laboratory instruments to remote places and highly unlikely that, once transported, they will function properly under the environmental extremes encountered. Yet there is a growing need for laboratory spectrum-analyzer measurement capability at remote sites.

The Tektronix 492 meets this need for making state-of-the-art measurements over the range of 50 kHz to 220 GHz, both in the laboratory and under severe environmental conditions. This portable analyzer qualifies under the MIL-T-28800B, Type III, Class 3, Style C specification, a very rigid specification.

Much has been done in the 492 to make it easier to get the desired display on screen and make measurements precisely.

A simplified front panel

The uncluttered appearance of the front panel is achieved by removing the scales for the frequency, span, resolution bandwidth, and reference-level controls from the front panel. These parameters are displayed on the cathode-ray tube along with the signal. Thus, all the parameters required to properly characterize the display are available in one place.

The three main elements in a spectral display — frequency, frequency span, and amplitude reference — are controlled by three large knobs. Other controls are located where they are readily available.

In the 492 automatic coupling between primary controls is usually used to insure display calibration for virtually all selections. If the parameters manually selected are such that amplitude calibration is not maintained, a warning light indicates the *uncalibrated condition* and a "less than" symbol precedes the reference-level readout to indicate *uncalibrated value.*

The frequency-span control is concentric with the resolution-bandwidth selector and the switches that control span-related functions such as signal identification, phase-lock stabilization, and automatic resolution selection are situated nearby.

Concentric with the reference-level control is the minimum rf-attenuation selector. Vertical display factors, video filters, digital storage, and other signal processing function controls are also appropriately grouped for easier use.

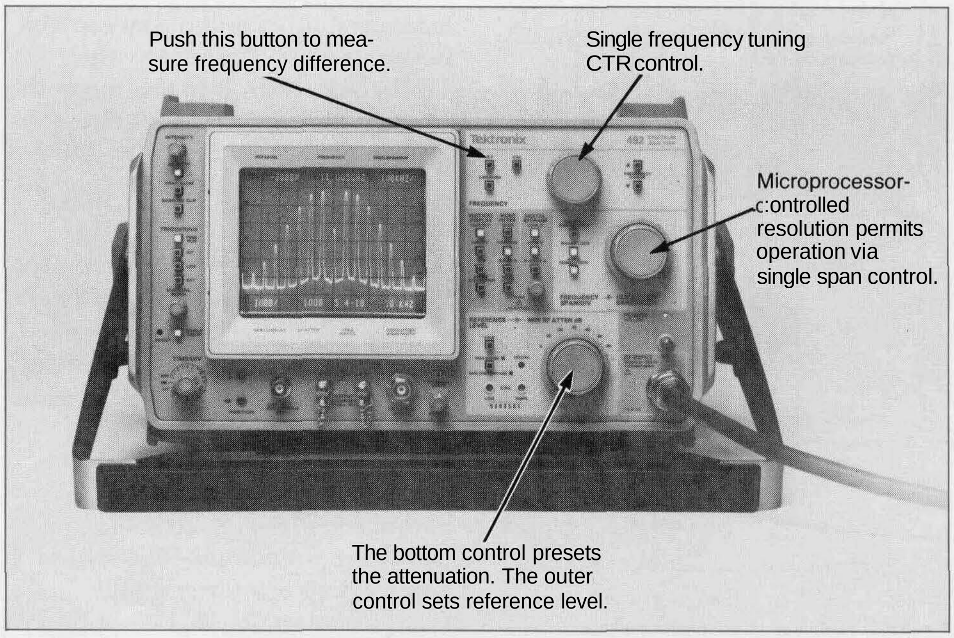


Figure 1. The three main elements, frequency, frequency span and amplitude reference, are controlled by three knobs.

Digital storage

The digital storage option provides flicker-free displays at the low sweep rates required for high-resolution measurements.

Two displays can be stored separately and displayed simultaneously for comparison, or the difference between the two signals can be displayed. In addition maximum signal levels can be captured and displayed.

The 492 with digital storage also provides an adjustable noise-averaging threshold to store and display signals that would otherwise be buried in the noise.

Single-knob wideband tuning

A most important spectrum analyzer function, tuning, is *digitally* controlled in the 492 by a Tektronix-designed optical switch.

Spectrum analyzers "tune" by varying the voltage applied to a voltage-controlled oscillator (vco). This is conventionally accomplished with a low-noise potentiometer and precise frequency selection is difficult.

With a resolution of about one part in two million, the tuning control of the 492 can set an oscillator with a 4 GHz range to within 2 kHz.

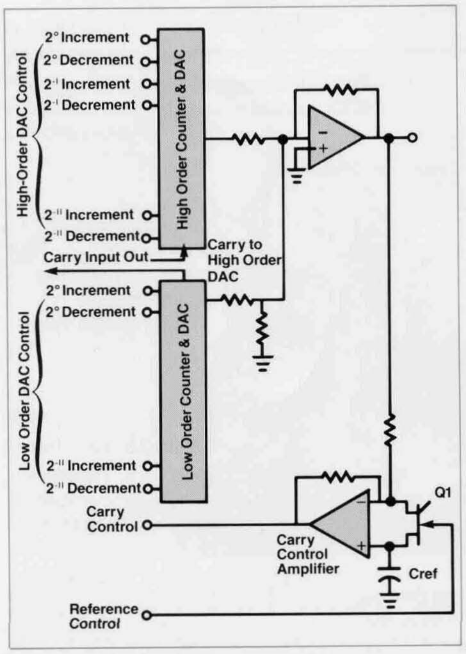


Figure 2. Timing is accomplished with a Tektronix-designed optical switch and two counter/digital-to-analog converter circuits.

Even finer tuning increments are effected in the 492, however, through the use of two separate digital-tuning systems. One controls the frequency of the YIG-tuned first local oscillator through its main, or coarse, tuning coil. The second controls the second local oscillator. The tuning rate, referred to the frequency span displayed, is essentially constant for all frequencies and is set with a single control knob.

Coupled-control operation

In the 492 the resolution bandwidth is normally operated in the automatic mode. In AUTO RESOLUTION the bandwidth is 1 MHz for the wider spans. It is reduced automatically in decade steps as the span is decreased to maintain a convenient span-to-resolution bandwidth ratio. The TIME/DIV control is usually set to automatically select the fastest sweep speed compatible with resolution. This assures proper amplitude calibration.

Thus when the span-control setting is changed, resolution bandwidth and time per division are set automatically to provide a calibrated display. Either control function can be manually operated.

Zero span is a mode in which no sweep is applied to the internal local oscillators and the sweep displayed is a *time base* set by the TIME/DIV control. In this mode the 492 may be used as a modulation waveform display device with the time-per-division value displayed on the crt.

Single knob reference level control

Reference level setting in the 492 is greatly simplified by using a single control and by microprocessor control of intermediate-frequency gain to *automatically compensate* for the rf attenuation selected. When the 492 is turned on, rf attenuation is automatically set to 60 dB to protect the input against inadvertent applications of a large signal.

Attenuator changes are prohibited in the differential amplitude measurement mode in order that highly accurate intermediate-frequency substitution-type measurements can be made. An example of this substitution technique is described in the article " The 492 Is A New Generation Spectrum Analyzer" in this issue.

The internal control system

The simplified front panel and the ease with which measurements can be made with the 492 are benefits realized largely by firmware microprocessor control.

Interconnection of the many circuit functions to the control microprocessor is by means of static address and data buses. A static-bus system prevents control-signal interference with sensitive rf and analog circuitry.

Each of the controlled modules latches its own control status instructions until change is necessary. To maximize communications efficiency, controlled modules are designed to operate without the burden of scanning the front-panel settings continuously. When a front-panel control is changed, the new setting is encoded and a processor interrupt is generated. The processor then initiates the necessary actions.

The system firmware that administers the control is modular. This simplifies maintenance and repair.

After the power is turned on the processor reads headers in the control-system roms. As each required module is found, its corresponding starting address is read from the header and stored in a table in system ram. The table can be filled in any order, thus the modules may exist in the rom in any convenient order. The rom is searched from low-to high-order address. Since only the first header reference to a given module is recorded in the ram table, repairs are made by simply placing a desired routine at a lower address location.

The run-time linker just described is quite circumspect. A run-time linker allows repair of routines in production, as well as facilitating firmware configuring for the version of the 492 ordered (a number of options are offered.) If, for example, the digital-storage hardware module is not installed, the run-time linker will not attempt to load the digital-storage module starting address, and the 492 will operate as a non-digital-storage instrument. Such a design enhances the ability to keep the 492 in service should a failure occur. Further, since one set of roms contain the firmware modules for all instrument configurations, firmware can be replaced easily and unambiguously.

Signal handling and processing

A high-performance spectrum analyzer must have a superb signal-handling system to make state-of-the-art measurements. In the 492 state-of-the-art rf subsystems include a 60 dB step attenuator, a three-stage tuned yig preselector, and a 50 kHz to 21 GHz input mixer. (See "First Converter" With Field Replaceable Diodes in this issue.)

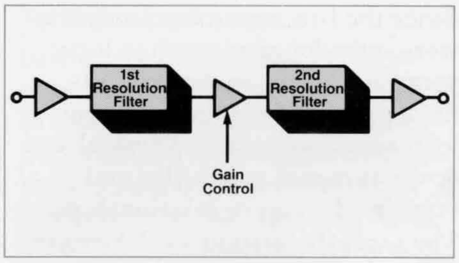


Figure 3. The distributed filter configuration eliminates the need for a wide-dynamic-range, low-noise, controlled-gain amplifier.

The first local oscillator is tunable over a greater than 4 GHz range, covering the 50 kHz to 21 GHz basic frequency range of the 492 in only five bands, while avoiding spurious-signal displays (undesired mixer conversion products.)

Depending on the frequency band selected one of two first intermediate frequencies (829 MHz or 2.072 GHz) is used. The 2.072 GHz first i-f is used with external mixers to cover the 18 to 220 GHz bands to minimize the display of image frequencies. With two first intermediate frequencies two second local oscillators are required to convert to the 110 MHz second i-f. A 100 MHz crystal-based oscillator provides conversion to the 10 MHz third i-f.

The variable-resolution filters in the 492 have a shape factor of 7.5 to 1. This is achieved by using a distributed filter configuration as shown in figure 4. This eliminates the need for a wide-dynamic-range, low-noise, controlled-gain amplifier at the output of the variable resolution section. Bandwidths of 1 MHz to 100 Hz are selectable in decade steps.

The logarithmic amplifier is similar to that used in other Tektronix spectrum analyzers. The pulse stretcher function and fine reference-level adjustments also occur here.

Finally, after detection, the signal is routed through the video filters (if selected) and to the digital-storage circuitry. Instrument-parameter information for the crt readout is multiplexed with the video information in the deflection amplifier circuitry.

Programmability

The programmable version of the 492 is designated 492P. This version of the 492 is fully programmable by means of the IEEE 488-1975 (GPIB) standard. The 492P retains all of the front-panel controls of the nonprogrammable instrument. Since these controls are digitally interfaced, an instrument "status profile" is available upon request by a controller such as the Tektronix 4051 Graphic Computer System.

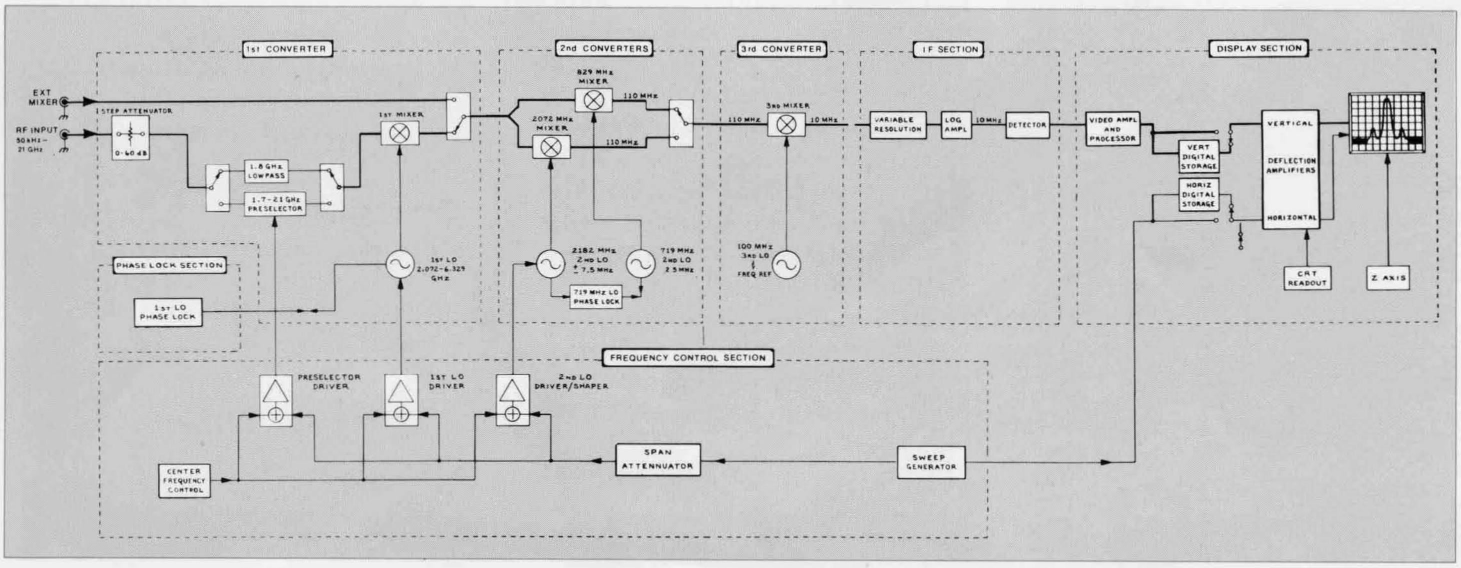


Figure 4. Simplified block diagram of the 492 Spectrum Analyzer.

The Tektronix 492 is a New-Generation Spectrum Analyzer

Morris Engelson, Marketing Manager of Frequency Domain Instruments, has written three books and between 30 to 40 papers ("depends on how you count" says Morris.) He helped Tektronix enter the spectrum analyzer field fifteen years ago. He holds a BEE and a MEE from C. C.N. Y. An ex-New Yorker, Morris likes the Northwest and is active in school board activities. His concern for his family and others is evident from his efforts in keeping alive the lessons of the Holocaust by talking to people in schools and other organizations.

Since the first spectrum analyzers were introduced more than forty years ago, many improvements have been made in technical performance, ease of use, physical and environmental capability, and price/performance relationships. The recently introduced Tektronix 492 Spectrum Analyzer provides advances in all these areas, and its wide range of options permits the user to select the optimum price/performance combination for his application.

Frequency range

The top frequency setting on commercially available spectrum analyzers has been 60 GHz. The options available on the 492 extend this upper frequency limit to 220 GHz, while maintaining a lowest characterized frequency of 50 kHz.

Two technological factors contributed to this high-frequency-end breakthrough of the 492. The first was the development by Tektronix several years ago of the first broadband, fully-amplitude-calibrated waveguide mixers to 60 GHz for use with the 7L18 spectrum analyzer. Operating on the fifteenth harmonic of the 7L18's 4-GHz local oscillator, these mixers exhibit only 30 dB of conversion loss. The 492 is designed to use the same mixers.

The second factor is the use in the 492 of a 2-to-6.3 GHz local oscillator rather than the traditional octave-range 2-to-4-GHz local oscillator. The new local oscillator makes possible higher operating frequencies at lower harmonic conversion numbers. As a result, the 492 has full frequency and amplitude calibration to 60 GHz using Tektronix broadband waveguide mixers. In addition, full frequency span and input-frequency calibration are provided to take advantage of commercially-available mixers to 220 GHz. Thus, millimeter-wave spectrum analysis is extended by 160 GHz!

Resolution

The resolution bandwidth of the 492 is from 100 Hz to 1 MHz. Combined with less than 50-Hz incidental fm and the wide operating range of the first local oscillator, the 100-Hz resolution bandwidth setting is perfectly usable over the full coaxial input-frequency range of 21 GHz. Indeed, respectable measurements at 100-Hz resolution setting are possible even at 60 GHz. In addition, sideband noise is sufficiently low to permit easy observation of 70-dB-down signals only 3 kHz removed from a carrier in fundamental mixing mode.

Stability

Drift, incidental fm, and phase noise sidebands are some of the considerations involved in stability. An area that is not usually discussed is how easily the instrument can be stabilized and how well it will stay stabilized.

Although automatic phaselock is no longer special, the 492 has the advantage of staying phaselocked no matter what external temperature change or other adverse frequency-destabilizing conditions are experienced. This performance is a result of routine monitoring of various internal spectrum-analyzer functions by a microprocessor.

Whenever frequency drift threatens to disturb phase lock, the microprocessor readjusts the local-oscillator tuning voltage to maintain balance. The advantage of this system is that continuous frequency restabilization is not necessary, and ease of measurement is improved.

Dynamic range

A preselector-equipped 492 provides a full 80-dB on-screen display with 100-dBc harmonic measurements.

Sensitivity

Sensitivity for the 492 is −123 dBm at 100-Hz resolution setting for fundamental conversion in a non-preselected instrument. Because of the wide frequency range of the first local oscillator, fundamental conversion extends to over 7 GHz.

Amplitude accuracy

Besides a typical absolute amplitude measurement accuracy of 3.3 dB, the 492 introduces amplitude comparison in 0.25-dB steps by means of its differential amplitude (delta A) function. This variation of the i-f substitution technique provides 200 quarter-dB steps for precision amplitude comparison over a 50-dB range. The result is improved ease and accuracy whenever relative amplitudes have to be determined, such as in AM, FM, or pulse signal measurements.

Programmability

All front-panel measurement settings are fully programmable via the IEEE-488 General Purpose Interface Bus in the programmable 492P. Control settings and signal display information can be manipulated by a controller such as a Tektronix 4050 Series Graphic Computing System intelligent terminal.

Technical performance

In the area of technical performance, the 492 introduces advances in three of the seven most-quoted performance specifications (highest input frequency, microprocessor phaselock control, and quarter-dB amplitude comparison) without sacrificing the high standards of performance that users have come to expect from modern spectrum analyzers. The result is an instrument that covers the full radio-frequency spectrum (including much of the millimeter-wave area), that stays phaselocked, and that provides a new standard in relative amplitude measurements. Some of these capabilities are illustrated in the accompanying photographs.

Figure 1 shows a 104-GHz signal displayed on the 492. The internal noise level is 40 dB below full screen, providing 40-dB measurement range at 1-MHz resolution setting.

Figure 2(a) shows two signals of slightly differing amplitude level. The vertical display has been set to 2 dB/div, and the reference level in the upper left corner is set for 0-dB reference in preparation for amplitude-difference measurements. Figure 2(b) shows the same signals after the smaller signal has been set to full screen. The change in level setting shows as 3.25 dB. ■

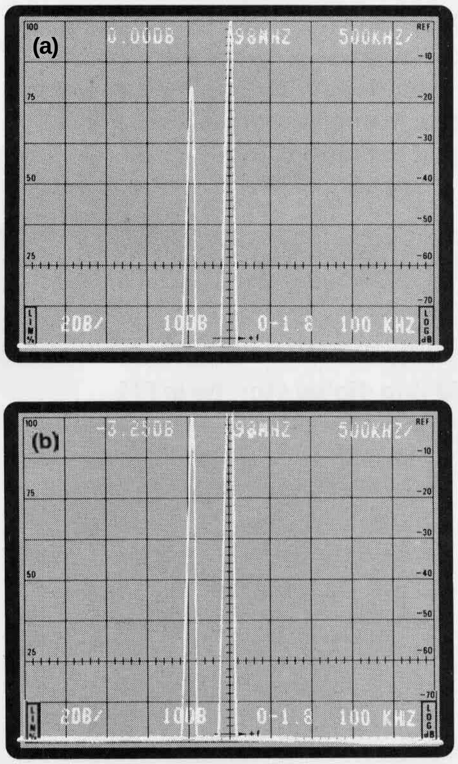


Figure 2. Amplitude comparison measurements can be made within 0.25 dB as illustrated in these two photos.

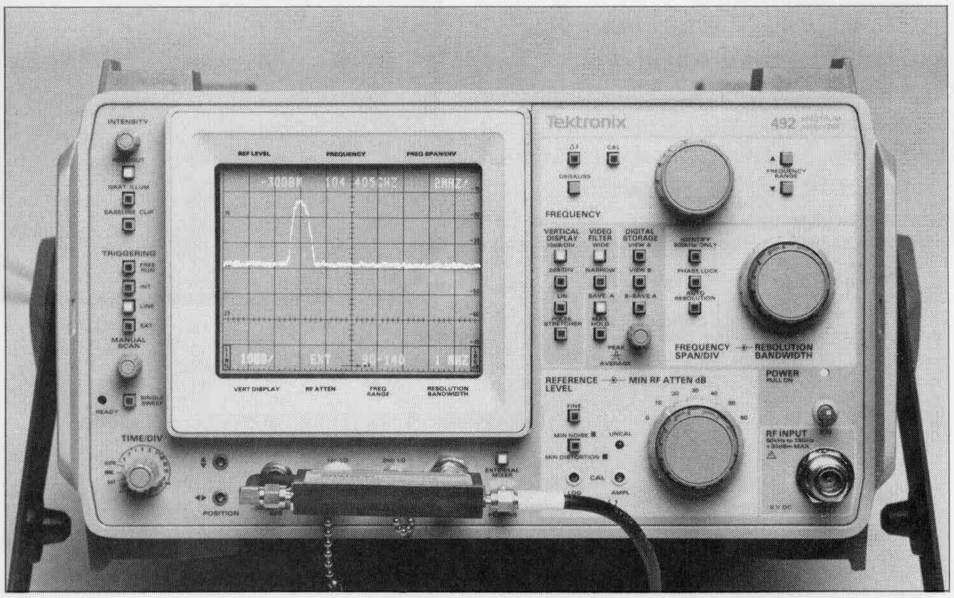


Figure 1. High frequency performance of the 492 is demonstrated in this photo of a 104 GHz signal displayed with 1 MHz resolution.

Making Measurements with the 492

By Morris Engelson,

Spectrum Analyzers are used for a large variety of measurements in applications ranging from EMC to doppler radar, and from FM broadcasting to oscillator purity determination. Whatever the application the primary emphasis is on checking the amplitude and determining frequency spectrum distribution of a signal. The following applications illustrate some conventional and some not so conventional capabilities of the TEKTRONIX 492 Spectrum Analyzer.

Using digital storage in FM measurements

A common spectrum analyzer application in FM is establishing deviation by the bessell-null technique. The usual procedure is to change the deviation setting which produced the display (shown in figure 1) until a carrier null is obtained as illustrated in figure 2. In figure 2 we observe the first carrier null at a modulation index of 2.4. Since the modulation frequency is 10 kHz peak deviation is calculated to be 24 kHz (2.4 x 10 = 24 kHz).

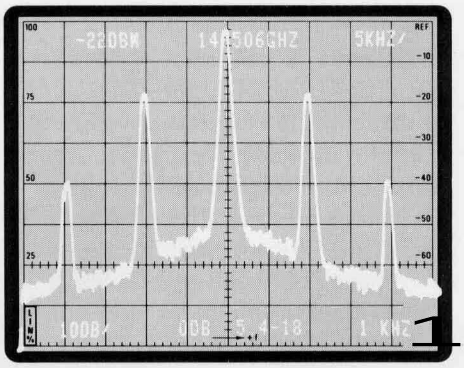


Figure 1

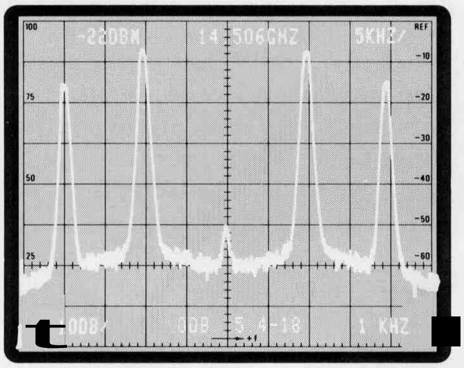


Figure 2

After establishing deviation it is sometimes difficult to get back to the original setting. Use of the *SAVE* feature of digital storage makes reproduction of original settings easier. This is illustrated in figure 3 where the original spectrum is saved in one memory while the bessell-null condition is displayed by the second memory. After the measurement is completed the original spectrum display, held in the first memory, is available as a guide for re-establishing the original equipment set up. These measurements were performed at 14.5 GHz. Yet the display is clean and your ability to resolve the FM sidebands is unimpaired.

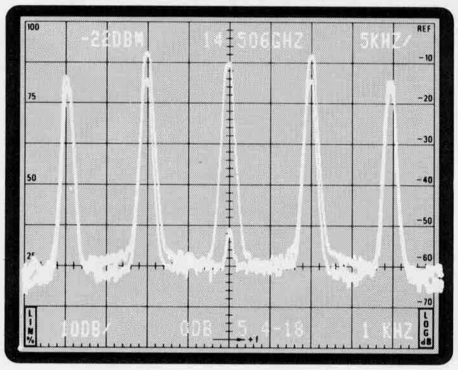


Figure 3

Signal purity and stability measurements

The high stability and signal purity capabilities of the 492 have already been shown in the previous photos at 14.5 GHz.

The 492 is excellent for measuring close-in sideband noise because of its high stability and purity of signal reproduction. In figure 4 the noise level is almost 60 dB down at a point only 500 Hz away from the 6 GHz carrier, improving to 70 dBc at 2 kHz offset from the carrier. These measurements were made using a resolution setting of 100 Hz. The exceptional capability for clean displays designed into the 492 is illustrated in figure 5 which shows the resolution of 500 Hz sidebands at an input frequency of 21 GHz.

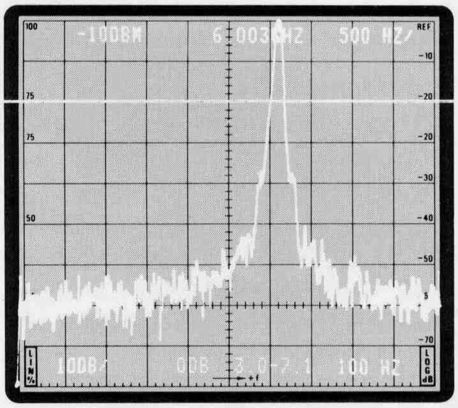


Figure 4

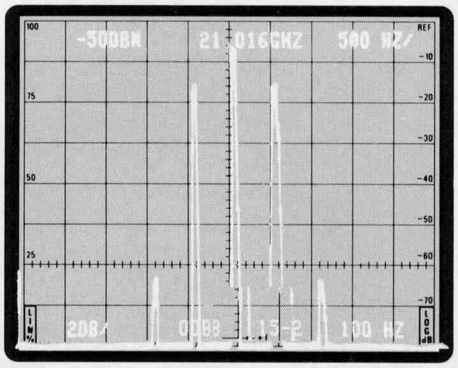


Figure 5

Using the delta modes

The 492 features differential amplitude and differential frequency modes that provide easier means for you to make these measurements. The delta A mode increments in 0.25 dB steps, greatly improving measurement accuracy over other techniques.

After the carrier peak is set to the full-screen reference the differential amplitude mode is activated setting the reference level to 0.00 dB (upper left corner of figure 6). The first sideband on the left is then positioned to the top of the display with the reference level control and is determined to be at 3.00 dB below carrier (figure 7). The right sideband is at -3.50 dBc (figure 8) and the next set of sidebands are 16.25 dB down from carrier (figure 9). The 492 provides over 50 dB of measurement range in the delta amplitude mode in increments of 0.25 dB.

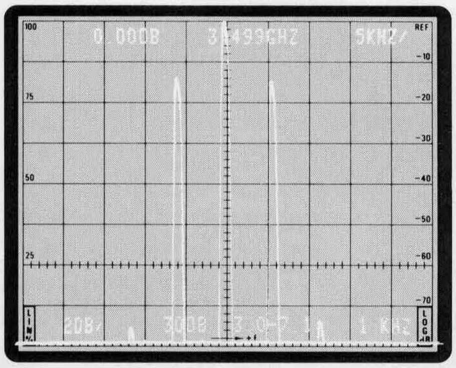


Figure 6

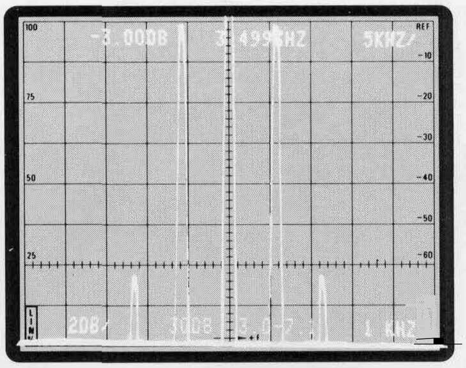


Figure 7

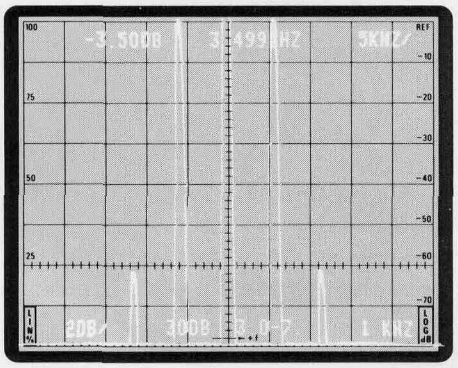


Figure 8

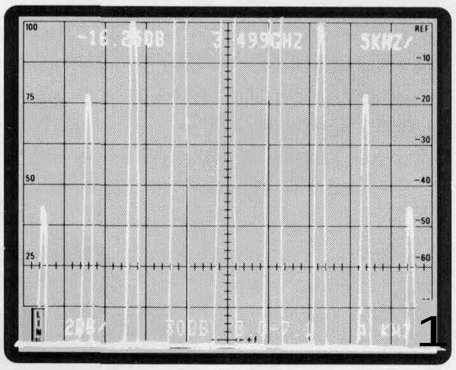


Figure 9

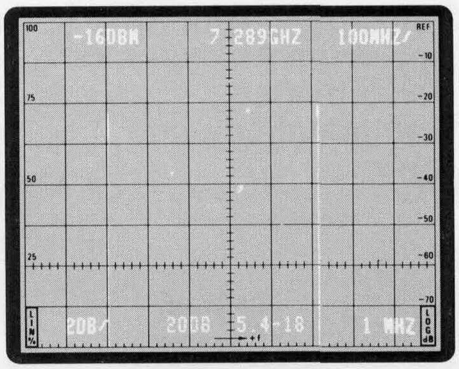


Figure 10

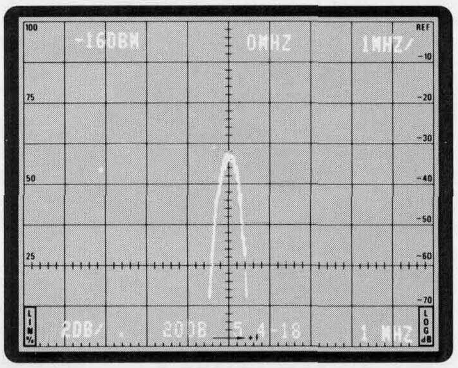


Figure 11

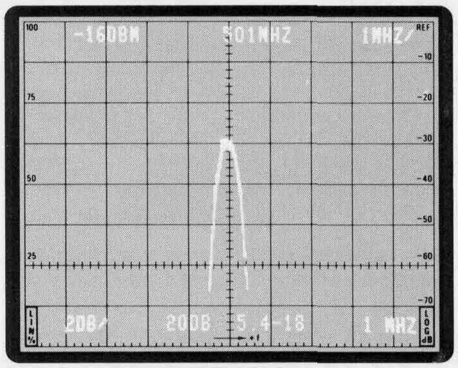


Figure 12

The frequency difference (AF) mode enhances the measurement accuracy when determining frequency differences between widely spaced signals. In figure 10 two signal components appear to be 500 MHz apart. But, is the separation precisely 500 MHz or 510 MHz, or 493 MHz, or what? By reducing the span to 1 MHz/div. and activating the frequency difference mode, the frequency readout is set to 0 MHz reference (upper center of figure 11). Tuning the next signal to center screen we note that the frequency spacing is 501 MHz (shown in figure 12).

Packaging a Portable Spectrum Analyzer for Performance, Maintainability, and Survival.

Carlos Beeck was born in Lima, Peru. He came to the United States as an Air Force Cadet for engineering training. Carlos has a BSME from the California Institute of Technology and received an aeronautical engineering degree from Cal-Aero. At Tektronix since 1968, Carlos has participated in component and advanced mechanical engineering projects including work on the 7L5, TR 501, TR 502, 7L13, 7L18, and 492. He holds patents for the opto-switch and the rf hybrid package. Outside interests include wood working, inventing and painting.

The design goals for the 492 spectrum analyzer package included meeting the standards of the rigid military specification MIL-T-28800B, Type III, Class 3, Style C. In addition, the 492 had to be suitable for laboratory environments. The instrument also had to be readily maintained.

A rugged frame

Aluminum castings, combining strength with lightness, are used for the basic frame structure of the 492. There are a front and rear casting, and two identical side-rail castings. The rf deck spans the bottom portion of the frame tying the structure together.

A longitudinal member from the front casting to a transverse member adds further strength and provides support for plug-in circuit modules.

These modules plug into a mother board and are secured with screws. Any module can be readily removed for repair or be serviced on an extender board. The front-panel assembly and low-voltage power supply also plug-in and are easily removed for servicing.

Crt considerations

The best shock survival for a crt of the size available for the 492 was about 40 g's. Testing to MIL-T-28800B indicated that the crt should withstand accelerations of at least 100 g's.

Using computer analysis it was determined that the vibration dampers, which maintain the position of the electron gun in the crt neck, should be enlarged to produce a tube capable of withstanding in excess of 120 g's.

This rugged crt was then uniquely cantilevered from the front casting in a system of glass-filled nylon mounting wedges. These wedges hold the crt securely and tighten their grip as the crt encounters shock.

Improved cabinet feet and top stacking guides of vinyl rubber were developed to absorb shock and thereby limit the shock forces applied to the crt and other components and structures. Maximum shock applied to the crt with this system was 80 g's, well within the 100 g target.

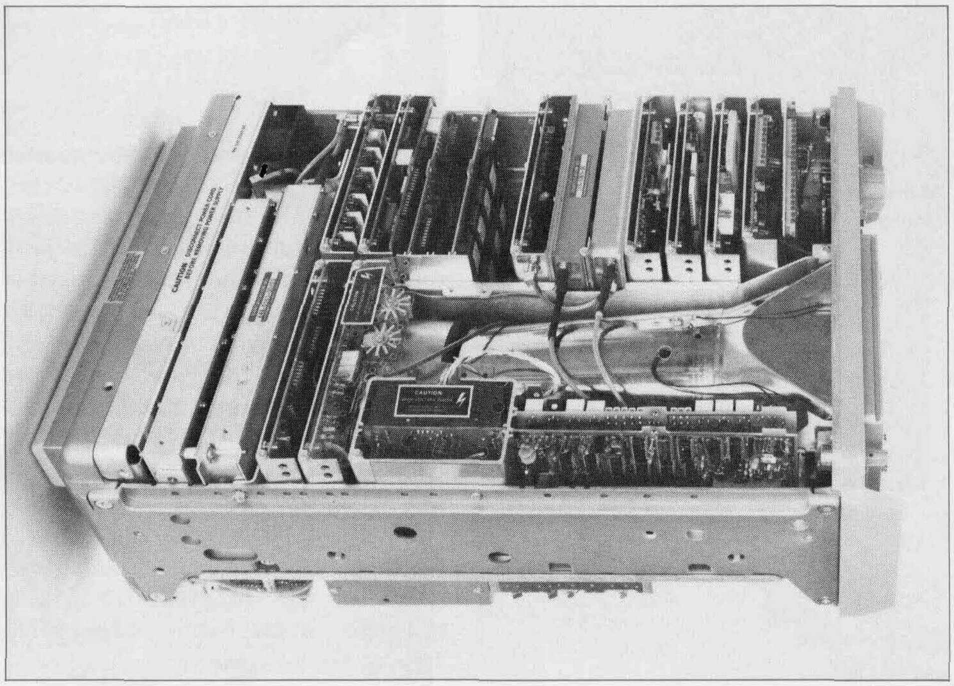


Figure 1. The 492 without covers.

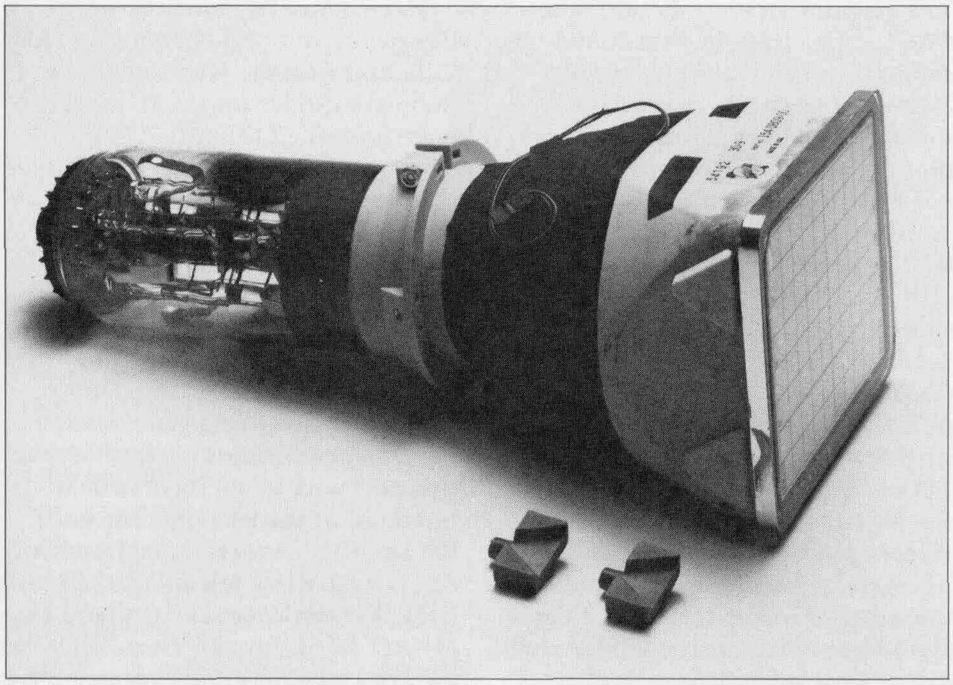


Figure 2. The ruggedized crt and crt mounting wedges.

Mechanical innovations enhance maintainability and performance

Many other innovations, while not major in themselves, enhance the buildability, maintainability, usability, and appearance of the 492 instrument.

Several options allow the user to order the 492 configured for a particular application. To simplify the production changes required by these options the traditional anodized-aluminum front panel has been replaced by a clear polycarbonate-plastic front panel laminated to an aluminum back plate. The panel nomenclature and colors are silk-screened on the back of the polycarbonate. Thus panel nomenclature resists deterioration and the front panel becomes highly scratch resistant.

The rf deck is also designed to facilitate the addition or deletion of components and contributes to the design goal of maintainability. Any rf component can be removed or installed in less than ten minutes.

A new method of making semi-rigid coaxial-cable connections, used in the 492, contributes to a very low voltage standing wave ratio (between 1.01 to 1.02:1.00). The outer conductor of the coax is flared to receive a ferrule and nut which screws on the female portion of the connector. This replaces the traditional soldered connection.

492 Specifications

FREQUENCY RELATED

Frequency Range — 50 kHz to 21 GHz with internal mixer, to 220 GHz with external mixers. Option 08 deletes coverage above 21 GHz (calibrated mixers to 60 GHz available from Tektronix).

Frequency Accuracy — ±0.2% or 5 MHz, whichever is greater, +20% of span/div.

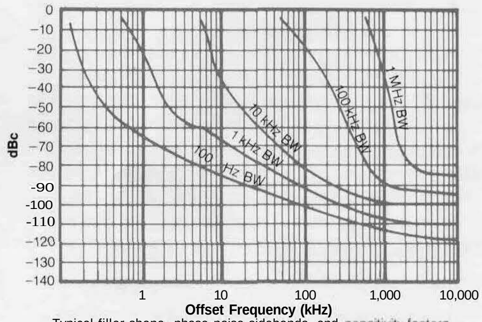
Frequency Readout Resolution — Within 1 MHz.

Frequency Span per Division — 10 kHz to 200 MHz plus zero and full band max span, down to 500 Hz with Option 03 in 1-2-5 sequence.

Frequency Span Accuracy — ±5% of span/div, measured over center eight divisions.

Resolution Bandwidth @ 6 dB Points — 1 MHz to 1 kHz (100 Hz for Option 03) in decade steps within ±20%.. manually or automatically selected.

Resolution Shape Factor (60/6 dB) — 7.5; maximum.



Typical filler shape, phase noise sidebands, and sensitivity factors for fundamental mixing on a preselected 492 (Option 01).

SPURIOUS RESPONSES

Residual (no input signal) — -100 dBm or less referenced to input mixer for fundamental conversion.

Harmonics — At least -60 dBc for full screen signal in the Min Distortion mode to 21 GHz. At least −100 dBc for preselected Option 01. 1.7 to 21 GHz.

Intermodulation — 3rd order products at least -70 dB down from two full screen signals within any frequency span in the Min Distortion mode. At least -100 dB down for two signals spaced more than 100 MHz apart from 1.7 to 21 GHz for preselected Option 01.

STABILITY (after 2 hour warm-up)

Residual FM — (1 kHz p-p) x n (mixing number) for 2 ms time duration, improves to (50 Hz) x n for 20 ms with phaselock Option 03.

Long Term Drift: 200 kHz/hour unphaselocked, 25 kHz/hour phaselocked for fundamental mixing.

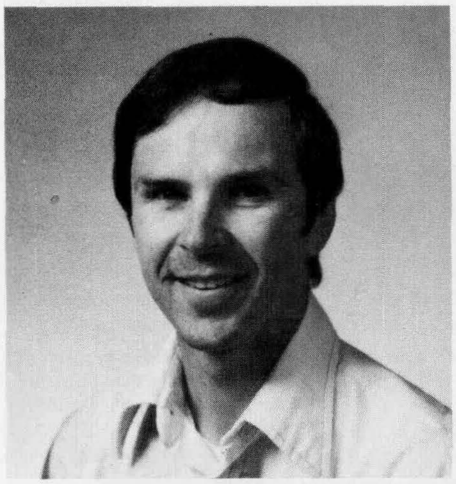
Noise Sidebands — At least 75 dBc @ 30X resolution offset (70 dBc for 100 Hz resolution) for fundamental mixing.

AMPLITUDE RELATED

Reference Level Range — -123 dBm to +40 dBm (+30 dBm maximum safe input) for 10 dB/div and 2 dB/div log modes. 20 nV/div to 2 V/div (1 W maximum safe input) in the linear mode.

Continue to page number 13

A First Converter with Field Replaceable Diodes



Phil Snow received his BSEE from California State University, LA. in 1962. Prior to coming to Tektronix in 1974 he designed radar receivers and radar receiver components and was a microwave hybrid processing services consultant. Phil is presently manager of the Microwave Technology Group in Tektronix Labs. He is the author of papers on surface acoustic wave filters and fabrication. His inventions include the "Resistive Weighted Transducer." and a "Microwave Integrated Circuit Package." Phil and his family live in the Beaverton, Oregon area.

The instrument architecture of the 492 requires that the first converter, or input mixer, operate from 50 KHz to 21 GHz. This wide range of input frequencies precludes using a double-balanced mixer since it is not presently possible to build an appropriately coupled input-signal feed-structure that will function over such a broad frequency spectrum.

Since the first local oscillator (LO) of the 492 tunes over a frequency range from 2 to 6 GHz, a *single-balanced mixer,* in which the LO and RF/IF ports are isolated, is the best choice. Single-balanced mixers generate just one-half the intermodulation (IM) products of an unbalanced mixer and reduce the signal level of the LO at the RF port, an important factor for a 492 when operated without a preselector.

A stripline 3 dB quadrature coupler cascaded with a 90 degree phase shifter is chosen as "nearly optimum" for the first converter. This configuration provides broadband microwave performance in a converter package that is easy to build, reliable, and reasonably priced. The diagram in figure 1 shows the concept of this four-port network.

A port-to-port analysis of the cascaded distributed circuits in figure 1 reveals that a voltage applied to port 1 produces equal voltages (reduced by a factor of 0.707) at ports 3 and 4, with a 180 degree phase difference. Equal in-phase voltages applied at ports 3 and 4 will add at port 2 and cancel at port 1.

Experience from lower-frequency, lumped-element designs indicates that the junction of two Schottky diodes makes an ideal RF port, with the LO applied to port 1. Since the impedances of the coupler and phase shifter affect the input match at the RF port, the distributed network is designed to operate from 2 to 21 GHz instead of just the 2 to 6.3 GHz range of the first LO.

Port 2 is selected as the IF port because IM products generated in the diodes are summed in-phase at this port and do not have to be filtered out at the RF port. Since the RF and IF ports are not isolated, a directional filter selects the 2.072 GHz IF. A diplexer selects the 829 MHz IF (see figure 2). These filtering structures are used because they provide a broadband match to the non-isolated RF and IF ports.

Due to the reflected resistance of the balanced feed (50 ohms at ports 3 and 4), the usual mixer conversion loss is increased by about 3 dB, because half of the RF power is lost in the resistive loads that appear in series with the Schottky diodes. Another 3 dB is lost in the power split between RF and IF ports since converted power is removed from only *one* port.

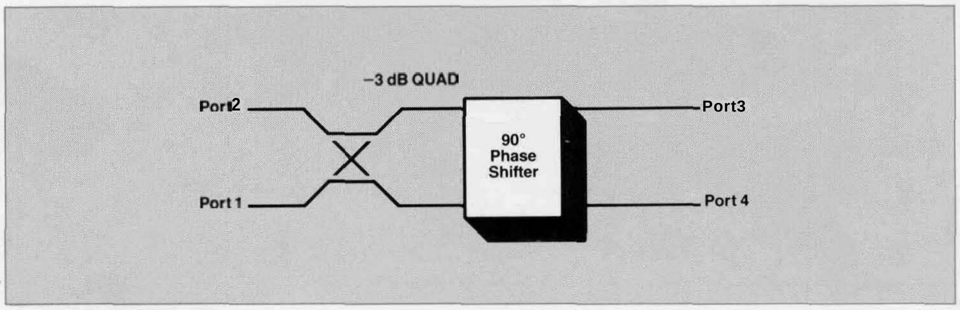


Figure 1. A stripline quadrature coupler cascaded with a 90-degree phase shifter provides broadband microwave performance in a converter package that is easy to build, reliable, and reasonably priced.

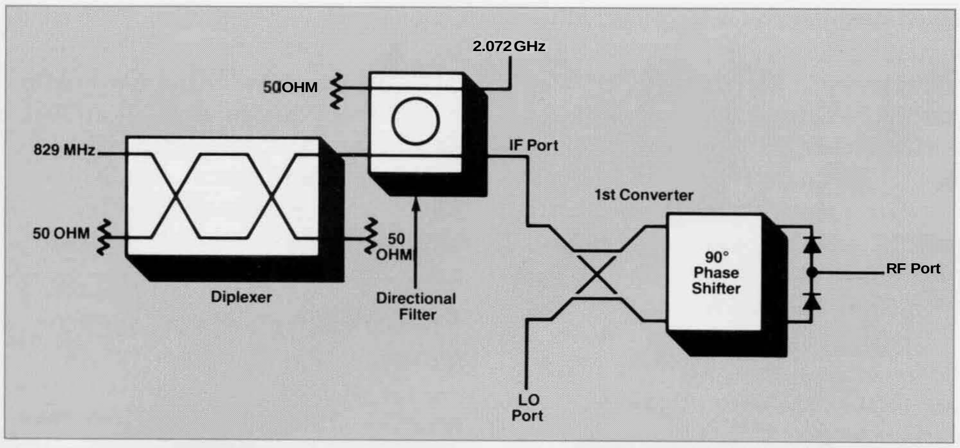


Figure 2. Simplified block diag ram showing first converter inputs and output, and selection of the 829 MHz and 2.072 GHz IFs.

Thus, the first converter has an intrinsic loss of about 12 dB compared to the usual 6 dB. However, a very-flat (±1 dB typical) fundamental is achieved.

Low capacity (0.1 pF) and low-inductance (0.1 nH) beam-lead Schottky diodes are used as switching devices in the first converter to achieve wide-band performance to 21 GHz. The Schottky diodes are mounted on a quartz thin-film suspended substrate. The substrate is mounted directly into the stripline feed-structure of the converter (see figure 3.)

The mixer housing need not be opened to replace the Schottky diodes; only a small, easily removable "dual diode assembly" is involved. This simplifies field replacement of diodes exposed to excessive input power.

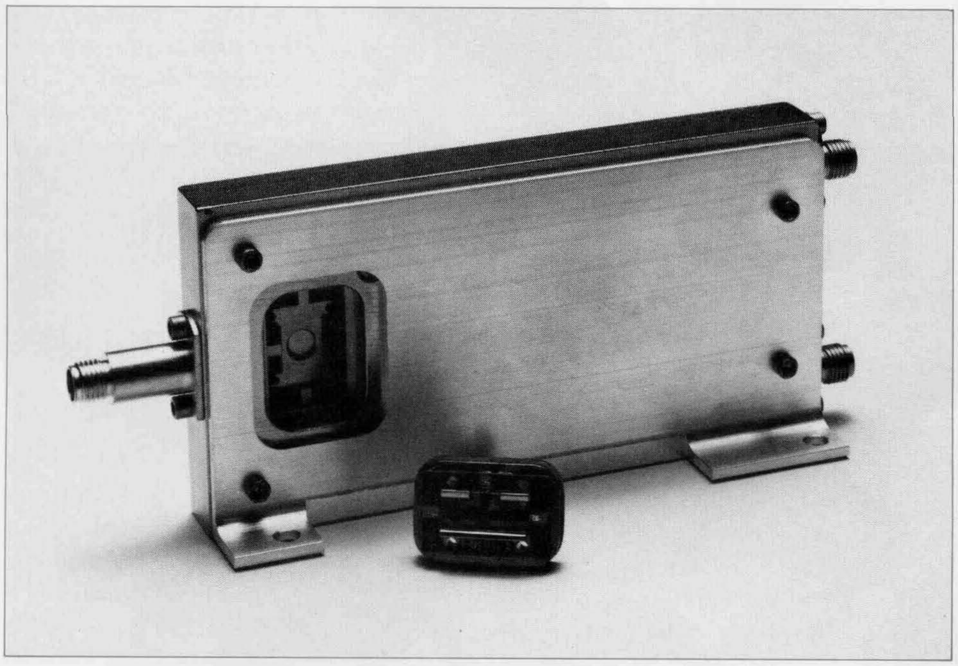


Figure 3. The first converter with the easily- replaceable input-diode assembly.

Additional 492 Specifications

Reference Level Steps — **10 dB, 1 dB,** and 0.25 dB for relative level (A) measurements in log mode. 1-2-5 sequence and 1 dB equivalent increments in LIN mode.

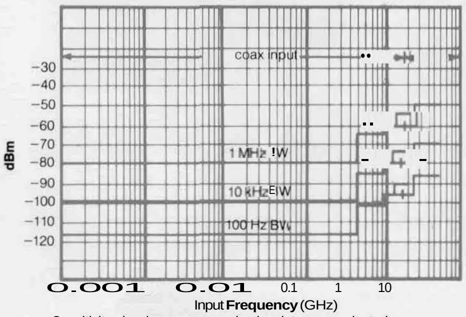
Reference Level Accuracy — Amplitude change of 0.25 dB ±0.05, 1 dB ±0.2 dB, 10 dB ±0.5 dB; to a maximum of ±1.4 dB for 60 dB and ±2 dB for 90 dB reference level change when gain change and attenuation do not offset each other.

Display Dynamic Range — 80 dB @ 10 dB/div, 16 dB @ 2 dB/div and 8 divisions linear.

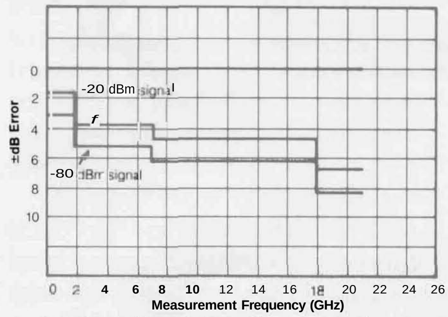
Display Amplitude Accuracy — ±1 dB/10 dB to maximum of ±2 dB/80 dB; ±0.4 dB/2 dB to maximum of ±1 dB/16 dB; ±5% of full screen in LIN mode.*

Resolution Bandwidth Gain Variation — **±0.5** dB.

*Flatness and accuracy specifications do not apply to the 30, 40, 50, and 60 dB rf attenuator positions between 18 and 20 GHz.



Sensitivity showing average noise level for a preselected 492 (Option 01).



Cumulative maximum absolute amplitude measurement error as a function of amplitude and frequency for a preselected 492 (Option 01)

INPUT CHARACTERISTICS

Internal Mixer — Type N female connector, VSWR 1.45 to 18 GHz, and 3.5 to 21 GHz; with 10 dB or more attenuation.

Optimum Level for Linear Operation — -30 dBm referenced to mixer.

1 dB Compression Point — −28 dBm from 1.7 to 2 GHz for Option 01; otherwise -10 dBm.

Maximum Safe Input Level — +13 dBm without Option 01, +30 dBm (1 W) with Option 01, zero rf attenuation.

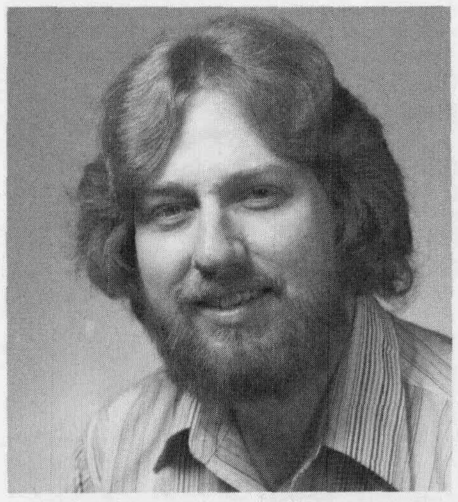
Attenuator Power Limit — +30 dBm (1 W) continuous, 75 W peak for 1 μs or less pulse width and 0.001 maximum duty factor.

PHYSICAL

Environmental Characteristics — Per MIL-T-28800B type III, class 3, style C.

Configuration — Portable, 20 kg (44 lb) (all options), 12 x 32.7 x 49.9 cm (6.9 x 12.9 x 19.7 in) without handle or cover.

A Switching Power Supply for the 492 Portable Spectrum Analyzer



David Leatherwood joined Tektronix in 1976 bringing with him experience in miniaturized and militarized power supplies. He has been in power conversion since he received his B.S.E.E.T. from University of Houston in 1974. He is currently a project engineer with the Power Supply Design Group. A native of Texas, David and his wife and three children live in Portland, Oregon. A member of the Sierra Club, he collects wine and repairs TVs (for neighbors and acquaintances who discover his occupation.)

Until recently the weight and power consumption of conventional supplies have made the high-performance *portable analyzer* a rarity. Therefore, the power-supply design group for the 492 needed to develop a compact, high-efficiency supply. One that was compatible with the noise-sensitive circuitry of the proposed analyzer.

The 492 Spectrum Analyzer's high accuracy called for extensive use of power-consuming linear circuits. The portability objective placed stringent limits on weight and size. The instrument would also have to meet the requirements of MIL-T-28800 general specifications, as well as the specifications for electromagnetic interference of MIL-STD-462. High performance and reliability were major design criteria. And UL and IEC safety requirements were additional design goals. Added to the challenge was the noise-sensitive nature of spectrum analyzer circuits.

A pulse-width modulated supply

A pulse-width modulated (PWM) circuit topology offered the way to greatly reduce weight and increase the efficiency of the 492 power supply.

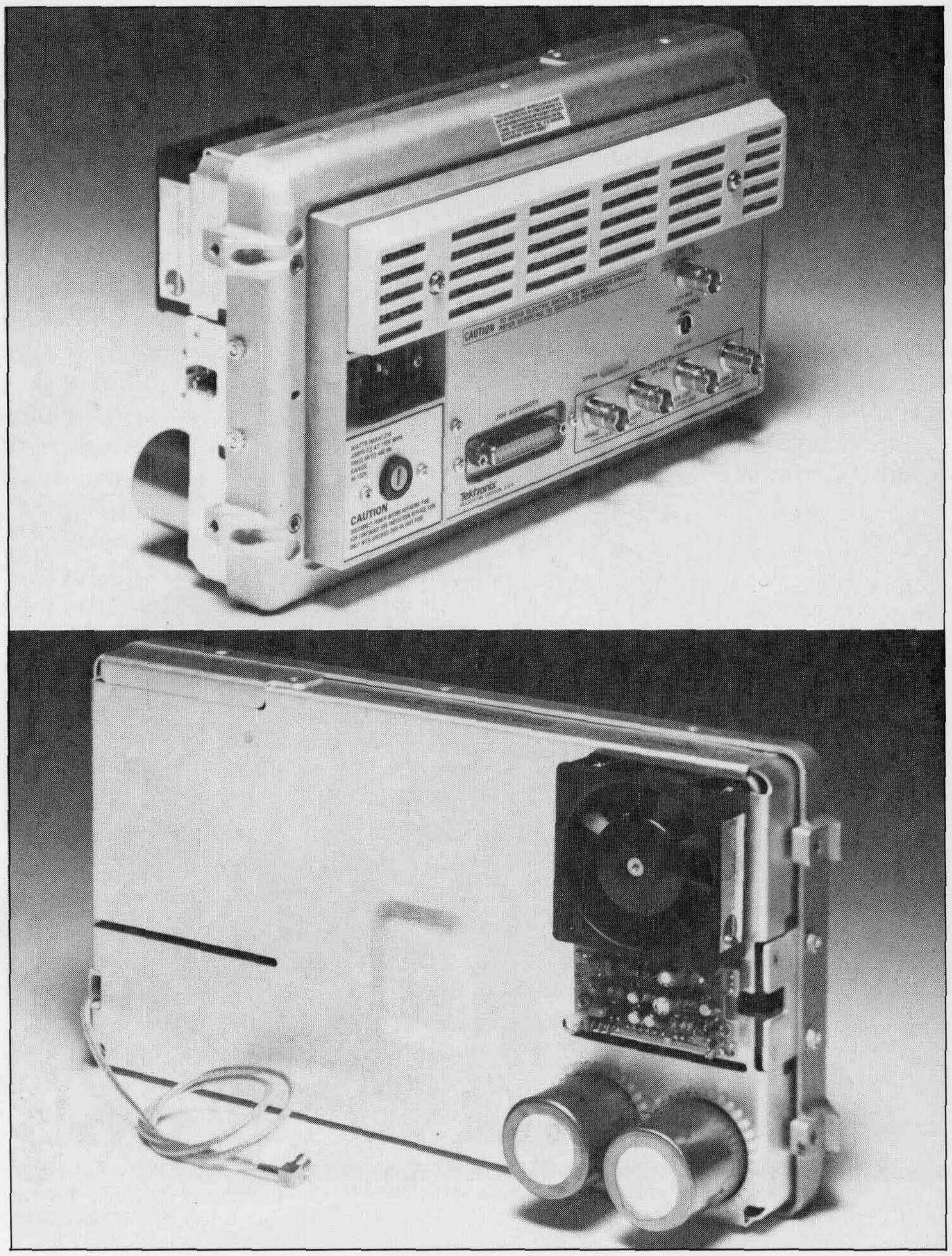


Figure 1. The plug-in power supply is easily replaced.

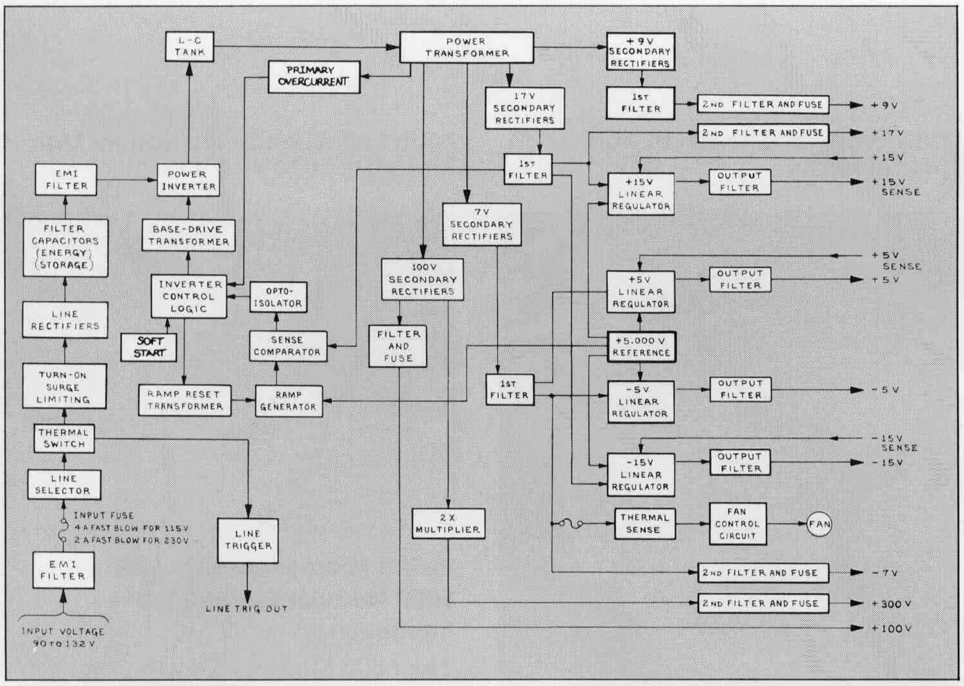


Figure 2. 492 Power supply block diagram.

The pulse-width modulator is a high-frequency, power-switching circuit. Output voltage is controlled by varying the duty cycle.

However, this approach required additional normal-mode and common-mode line filters that were low in radiating or receiving stray fields.

Design highlights

Fast recovery diodes with resistive/capacitive units (snubbers), which damp energy during diode turn-off, are used as the main line rectifiers. Bleeder resistors connected to the primary supply rectifiers eliminated the weight of a separate "housekeeping" supply for control logic.

The relatively-high switching frequency of 33 kHz used in the convertor simplifies filtering and improves regulator transient response. The output-sense feedback to the primary control circuits is quick acting, using a digital signal coupled via a high-speed opto-isolator (typical data-rate capability of 10 megabits per second.) Such speeds are necessary because propagation delay contributes to inadequate phase margin and poor loop stability.

The heart of the power supply is the main silicon switching transistors that convert dc voltage from the line-filter capacitors to ac square-wave power at the transformer primary. The transistors were selected for short storage time and isolated cases. Short storage time allows switching at the 33 kHz rate without damage and noise-generating cross conduction, while the isolated case prevents electrostatic coupling of collector-switching signals to chassis ground.

A PWM supply requires an averaging inductive filter on each of the nine outputs to dc average the switching waveform. Lumping nine secondary inductors in a single primary-tank choke reduced the space required for the required filtering in the 492 supply.

In a PWM power-supply tank circuit the peak-to-peak primary voltage can be regulated to any value up to the dc input voltage supplied to the switching transistors by simply varying the input pulse width. The switching waveform's fundamental component is passed through a series-resonant tank to the power transformer with little loss and the harmonic content is rejected by the reactance of the inductor.

When the duty cycle is reduced by increasing transistor hold-off time in response to load or line variations, the fundamental component decreases, causing a reduction in primary voltage. The filtering effect of the series L-C transforms an approximately 400 volt pulsating voltage into a symmetrical square-wave voltage and a sinewave current. With square-wave voltage and sinewave current in the secondary, output diodes switch at the zero crossing of current. This greatly reduces switching losses and electromagnetic interference (EMI) generation caused by diode "snap."

The many supply voltages required by the 492 are provided by three secondary windings on the 33 kHz power transformer. These *pre-regulated voltages* are used for on-site three-terminal regulators and for non-critical loads such as heaters, solenoids, and graticule illumination.

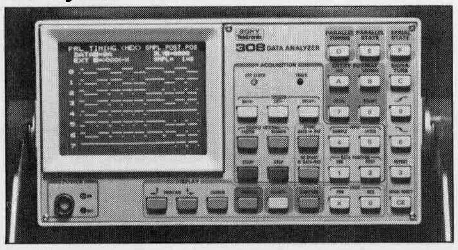
Circuits requiring tightly regulated voltages, (typically less than 0.5% over full line and load variations), are supplied by four linear series-pass regulators. These regulators, are fed by the preregulated voltages to greatly increase operating efficiency.

Most 492 circuits plug into a main mother board. Rather than have power distributed in a random manner to the various elements, a central power area was established on the mother board. The regulated outputs are remotely sensed in this area and radially distributed to the plug-in module circuits. In this way, circuit-run losses are compensated and circuit interaction is minimized.

The entire switching power supply can be easily replaced for field repair or operated on an extender *for ease in servicing.*

New Products

Data Analyzer Combines State, Timing, Serial, and Signature Analysis.



308 Data Analyzer

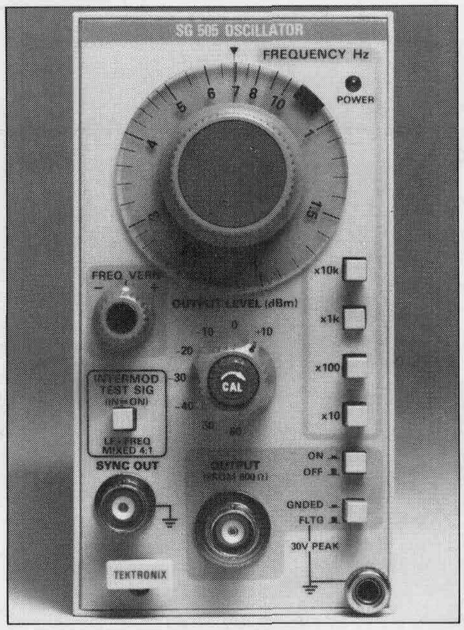
The 308 Data Analyzer is a keyboard controlled multi-functional, portable data analyzer. It can be operated as a parallel timing analyzer, a parallel state analyzer, a serial state analyzer, or a signature analyzer.

The parallel timing analyzer provides 8 channels at 20 MHz with 252 bits/channel memory size. The 8 channel parallel word recognizer provides internal triggering upon recognition of preset digital-system state; this capability is expandable to 24 channels with the optional P6406 Word Recognizer Probe. Digital delay counts up to 65,535 clocks; data can be stored at sample intervals of 50 ns to 200 ms.

Parallel state analyzer functions are similar to the parallel timing analyzer functions except that displays are in binary, octal, and hexadecimal format.

The serial state analyzer acquires 5, 6, 7, or 8 bits/character data synchronously or asynchronously. Two-character word recognition provides internal triggering upon recognition of present digital system state. Digital delay counts up to 65,535 words; data can be stored at baud rates of 50 baud to 9600 baud. The stored data is displayed on the crt screen in binary, hex, and ASCII format.

New State-Of-The-Art in Audio Signal Purity



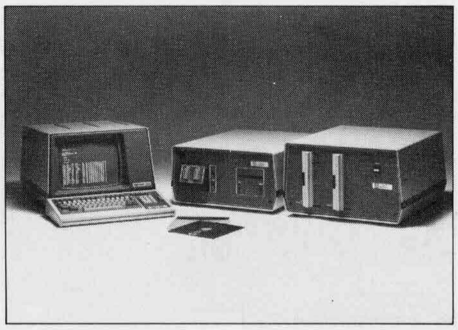
SG 505 Oscillator

The SG 505 establishes a new state-of-the-art in signal purity (0.0008% THD). This top-of-the-line sinewave oscillator, addresses the needs of professional audio measurement. The SG 505 is another in the growing line of TM 500 Modular Test and Measurement products.

FEATURES

Frequency Range: 10 Hz to 100 kHz
Harmonic Distortion: ⩾0.0008% THD (typically 0.0003%)
Calibrated Output: Yes
Step Attenuators Range: +10 to −60 dBM ±0.1 db.
Level Flatness (audio range): ±0.1 dB.
Maximum Output Voltage: 6 V rms.
Sync. Output: 200 mV rms sinewave.
Intermodulation Test Signal: Option 01.

High Level Language Support for Motorola 6800 And 6802



8002A Microprocessor Lab 6800 Modular Development Language

The 6800 Modular Development Language (MDL/6800) is an option for the 8002A Microprocessor Lab. This option broadens the high-level language support offered by Tektronix for the Motorola 6800 and 6802. The total MDL/μ offering now includes the 8080A, 8085A, the 8080A subset of the Z80A, 6800, and 6802.

MDL/6800 is a modified form of ANSI minimal BASIC. It supports modular programming and the use of specific 6800/6802 features and 8002A I/O resources. This allows program development to be divided among several engineers working in parallel. Software can then be developed in modular components and compiled separately. Subroutines and data defined in one module may be referenced by another. The 6800/6802 I/O and interrupt structures as well as 8002A peripherals and file I/O can be accessed with MDL/6800 constructs. The language provides data handling capabilities for integers, strings, and arrays of these types.

1/80 AX-4313

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

0853432 1481
MR DICK PATTERSON
20221 140TH SE
KENT WA 98031

BULK RATE
U.S. POSTAGE PAID
TEKTRONIX, INC.

Portable Analyzer Speeds Test and Service of Microprocessor-Based System

An Automatic Video Signal Parameter Measuring Instrument with Logging Capabilities

Developing a Practical Automatic Television Parameter Measuring and Logging System

New Products

Volume 12
Number 2

1980

Tekscope

Tektronix
COMMITTED TO EXCELLENCE

Tekscope

Customer information from
Tektronix, Inc.
Beaverton, Oregon 97077

Editor: Gordon Allison

CONTENTS

Portable Analyzer Speeds Test and Service of Microprocessor-Based System

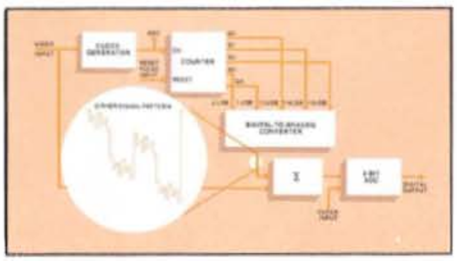
The Sony/Tektronix 308 Data Analyzer combines parallel timing analysis, parallel state analysis, serial state analysis, and signature analysis in a single, compact, lightweight instrument that is cutting dollars and hours from digital test and service functions.

An Automatic Video Signal Parameter Measuring Instrument with Logging Capabilities

Monitoring and logging television transmitter performance is a tedious, time consuming job. Now it can all be done, automatically and unattended, by the Tektronix 1980 ANSWER. This microprocessor-based instrument digitizes the video signal and uses unique signal-processing techniques to make measurements more quickly and accurately than is possible by conventional means.

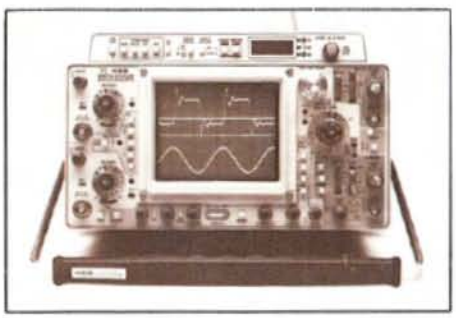
Developing a Practical Automatic Television Parameter Measuring and Logging System

Digitizing the broadcast video signal with sufficient accuracy to allow measurements to broadcast standards provided some interesting challenges. High speed A/D and D/A converters developed in-house are coupled with precision offset and dither signals to provide resolution and accuracies equivalent to 11-bit digitization.



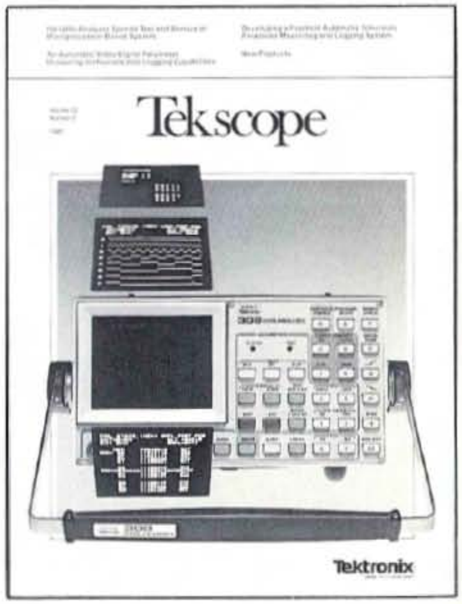
New Products

A host of new products including digital scopes, a digital television test signal generator, a state-of-the-art distortion analyzer, and a programmable oscilloscope calibrator apply the power of the microprocessor to meet your test and measurement needs for today, and tomorrow.

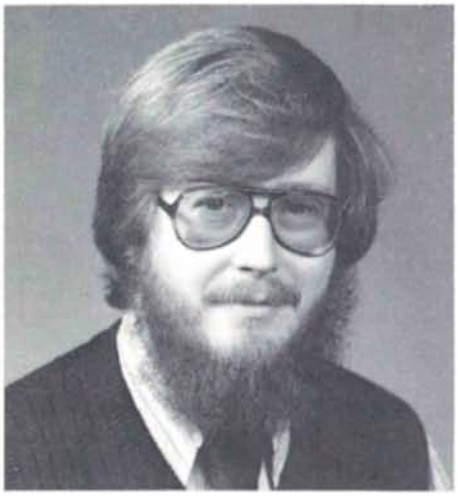


Tekscope is a bimonthly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique. A new products section gives a brief description of products recently introduced and provides an opportunity to request further information.

Cover: The four displays in this photo show only the basic capability of the Sony/Tektronix 308 Data Analyzer. This small, lightweight instrument packs more measurement power than you could normally carry using both hands.



Portable Data Analyzer Speeds Test and Service of Microprocessor-Based Systems



Ed Averill joined Tektronix three years ago after completing his BSEE and a year of post-graduate studies at the University of Nebraska. His work on the 308 included evaluation of both electrical and firmware design, which entailed spending three months in Japan. He is writing the thesis for his MSEE, and is studying to improve his Japanese. Ed enjoys camping, hiking, and outdoor photography. He processes both color and black and white in his own darkroom.

John Huber started his electronics career in the United States Navy as a Fire Control Technician. Since joining Tek in 1973, he has performed diverse functions from quality control of large-screen storage display monitors to on-site service of complex semiconductor test systems. Currently, he is an applications engineer for Logic Analyzer Marketing. John is completing work on his BSEE at the University of Portland. For recreation, he enjoys racquet ball, golf, and woodworking.

New microprocessor-based products are announced almost daily. Hundreds more are in the design stage. The circuit complexity and diversity of signals present in these products complicate their manufacture and maintainability. It is imperative, therefore, to have an effective, efficient means of testing and servicing such products.

Figure 1 depicts a typical microprocessor-based system. Three major categories of signal are present: input and output signals in serial logic, address and data bus signals in parallel logic, and timing and control signals such as CLOCK, READ, WRITE, RESET, etc.

To test such a system effectively, each type of signal must be monitored in an optimum manner and analyzed differently. For example, the relationship of the clock and control signals is best analyzed using a parallel timing display. Bus transactions are usually observed using parallel state analysis, and serial data through the communications port using serial state analysis. Signature analysis compresses sequential data into a four character alphanumeric code for quick GO/NO GO information. Modes that can be observed as clocked data can be tested using signature analysis.

Usually several different instruments would be needed to acquire and display the varied signals in the desired format. Now, all of these capabilities — parallel timing, parallel state, serial state, and signature analysis — are combined in one lightweight, portable instrument, the Sony/Tektronix 308 Data Analyzer.

The operation of the 308 is controlled from a front-panel keyboard, which greatly simplifies mode and parameter selection. Within the four basic operating modes, there are several subfunctions available. For example, in the parallel timing mode you can select the menu timing display, timing cursor display, or timing window display. In the parallel and serial state modes there is a choice of four displays: menu, cursor,

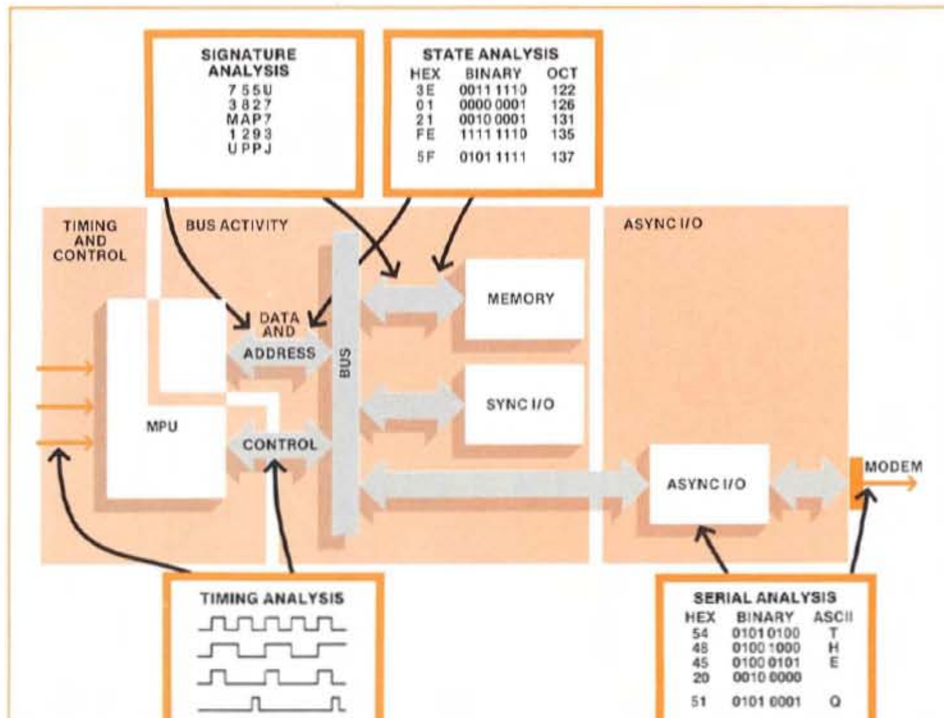


Fig. 1. Typical microprocessor-based system requires varied data acquisition techniques for thorough analysis of its activities.

search, and compare. In the signature mode you can select either hold or repeat modes. In addition, there are several diagnostic displays available for self-checking the 308's operation.

A menu displayed in the upper portion of the screen lists the operating mode selected and the operating parameters to be set from the keyboard. The data entry format selected (hexadecimal, octal, binary, or decimal), sample or latch mode, pre or post-trigger display, trigger word, source, and delay, and other pertinent parameters are included in the menu. It serves to direct the operator in setting up the 308 and lets one know, at all times, the current setup.

Acquiring data

Data and trigger inputs are located at the side of the 308 to keep the front panel clear for operating ease. An eight channel data probe provides inputs for acquiring parallel data at rates up to 20 MHz. Serial data and signature inputs are via a single, high-impedance probe. Serial word lengths of 5, 6, 7 or 8 bits can be selected and data acquired at rates from 50 to 9600 baud.

Acquired data is stored in an 8 x 252 bit Data Memory. Stored data can then be copied into a Reference Memory and be available for a Compare function. However, only the contents of Data Memory can be displayed. In the Compare mode, differences in the two memories are highlighted by display in inverse video. If the two memories match, the 308 can automatically restart data acquisition and continue until a difference in data is detected. The restart feature allows an automatic search for an intermittent problem. A count of the number of times the memories match is displayed at the bottom of the screen.

Trigger versatility

Quick, easy selection of a variety of trigger modes is in keeping with the other attributes of the 308. The trigger word is defined from the keyboard and can be programmed in hexadecimal or other of the data entry modes. Eight inputs to the trigger are provided by the Data Acquisition probe. These can be augmented by an optional 16-bit Word Recognizer probe. An external trigger qualifier input adds a bit for a total trigger word length of 25 bits. A word recognizer trigger output is provided for triggering an oscilloscope or other external equipment.

When triggering internally from the serial probe input, the menu calls for defining two consecutive data bytes as the trigger word (figure 3). External triggering can be accomplished by a single bit via channel 0 of the Data Acquisition probe. A programmable trigger delay of up to 65,535 counts or words is available in parallel and serial operating modes. Data displays can be either pre or post delayed trigger. In the pre mode the delayed trigger is positioned at the 240th position in the 252 byte data memory; in the post mode it is positioned at the 13th position. Data acquisition can be stopped manually at any time by pressing a STOP key. The last 239 bytes acquired are then displayed.

Fig. 2. Versatility, operating ease, and small size make the 308 useful in a wide range of applications. Here the 308 is being used to analyze graphic terminal operation.

Data display

Once the data is acquired and stored, it can be displayed in one of several formats. In the parallel timing format up to 168 eight-bit words can be viewed simultaneously. A window mode provides a magnifying effect for close analysis of timing relationships, by displaying only 84 or 42 words. The window can be positioned anywhere in the 252-byte memory by the horizontal position control.

For parallel state display, data is conveniently displayed in three formats simultaneously — hexadecimal, octal, and binary. The same applies to serial state displays except that octal is replaced by ASCII. Up to twelve lines of data are displayed at one time. The vertical position control allows the operator to step forward and backward through memory.

In addition to the usual menu display modes, several special displays are available. These include cursor modes, window, compare, search, and extended serial displays. Each display meets a specific need, enabling the operator to view the desired data in an optimum manner.

In signature analysis mode, the 16-bit words are converted to a four-character alphanumeric signature and displayed

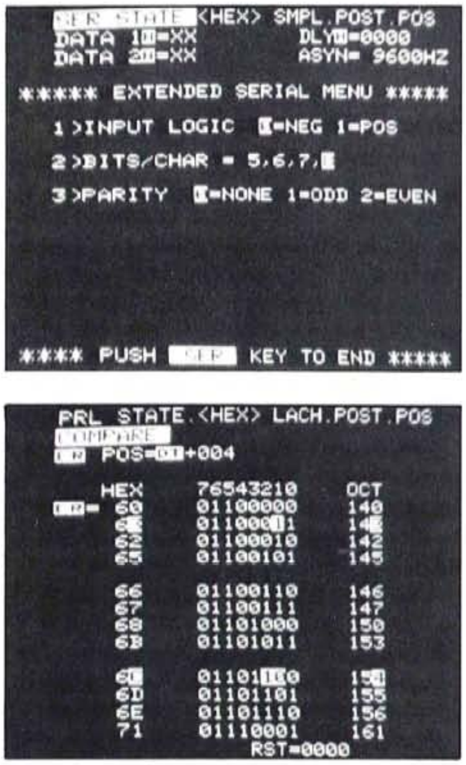


Fig. 3. Some of the many displays available on the 308. Changing from one display to another is accomplished by one or two keystrokes.

in one of two formats. In the hold mode, a signature is acquired and displayed each time the HOLD/RESET key is pressed. Up to eight signatures can be displayed at one time, with a < symbol indicating a change in signature.

In the repeat mode, signatures are repeatedly acquired. If a change in signature is detected, a FAULT sign is flashed momentarily and the new signature is displayed. This is a very useful mode for isolating intermittent malfunctions.

Acquisition and display synergism

One of the many unique functions in the 308 allows data acquired in one mode to be displayed in another. For example, when using parallel acquisition, the display can be done with serial displays that will analyze parity and decode ASCII.

When using serial acquisition, the parallel displays can be used to show octal information, and the parallel timing displays can show a summary of trends over long sequences of data. An example of the latter would be analysis of the parity bit. The activity of bit 7 can be shown along one line in the timing display with up to 168 bytes in the display at one time.

In performing signature analysis, correct information depends on both the gate formation signals and the data they frame for the signature. A faulty signature can be caused by a faulty signal on any of the lines — START, STOP, CLOCK, or DATA. The clock-sampled START and STOP lines can be observed using parallel display modes, without changing any probe connections (just press the appropriate keys). Parallel modes are useful in identifying a stuck START line, an unstable START/STOP line, etc. By applying one of the parallel data input probes to the signature analyzer data point, the data pattern can be observed relative to the gating information.

As the serial and signature data memories are identical, a comparison can be made between data acquired in each mode. Thus, a reference memory can be obtained from a data bus, and compared to test points on the other side of a USART (communications interface) and its line drivers.

A microprocessor-based system

The versatile acquisition and display capability of the 308 is accomplished through use of a microprocessor controller. Some features are the result of firmware residing in ROM, while others are highly dependent on groups of hardware components. The simplified block diagram in figure 4 shows some of the details. The key factor in determining which features require additional hardware is the speed with which each function must be performed. This differs for each of the subinstruments.

The powerful displays, and their ability to help the user understand the data, are the result of firmware. Over 18,000 bytes of program are used. The basic instrument control is designed as a state machine, with transactions between states controlled by keystrokes. Each

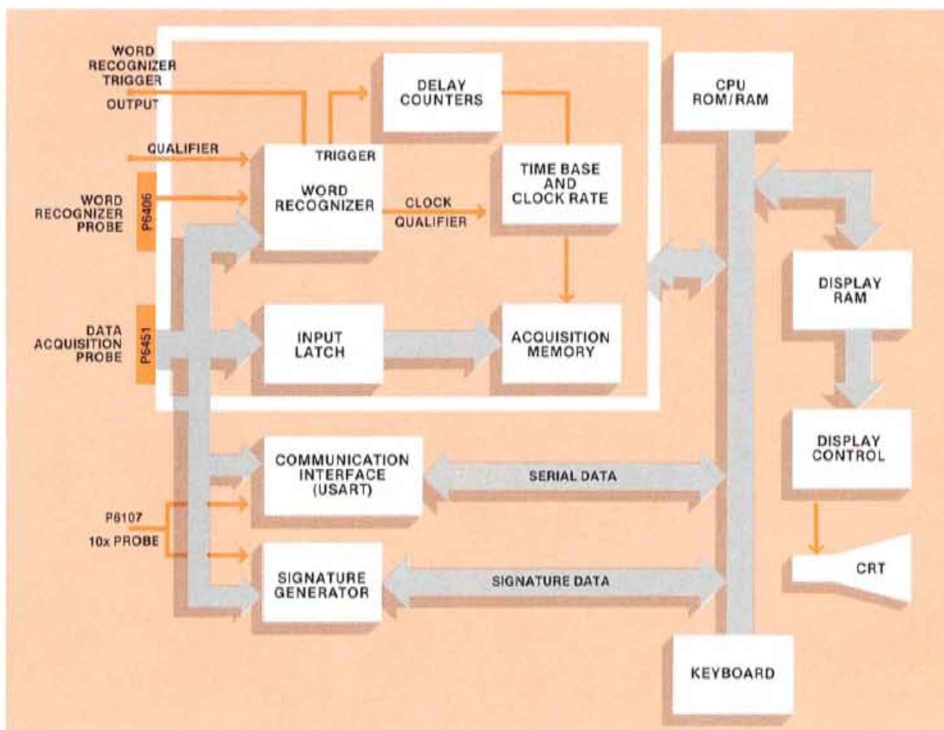


Fig. 4. Simplified block diagram of the 308. The data paths for the three subinstruments start at the probes, pass through separate high-speed circuits, then merge at the microprocessor controller for processing and display.

state has its unique display form. Within each display state, fields of the display can be controlled with different keystrokes. For example, positioning of the cursor or window. The three acquisition systems can be invoked from any of their associated display states simply by pressing the START key.

The parallel logic functions are required to work at speeds up to 20 MHz. Thus, all of the decisions needed to store a full acquisition have to be made at hardware speeds; decisions like do I have a trigger, have I delayed to the delayed trigger point, was the acquisition terminated with a full data memory, etc.

An interesting part of the parallel acquisition circuitry is data latching. In SAMPLE mode, data is accepted by normal setup and hold rules. In the latch mode, however, each sample period records any change from the previous sample period's recorded value without regard to when the change occurred. This is important when trying to observe changes in data that are not occurring near clock edges. Examples are glitches in the middle of sample intervals and other nonsynchronous activity, such as observing patterns with periods much longer than could be recorded synchronously.

In the serial data acquisition system, data speeds are much slower. The hardware is used to interpret the bit-to-byte transformation protocol. After that, the bytes of information are completely handled by firmware. The firmware determines if a trigger has been received, counts the delay to the delay trigger, senses protocol errors, reorients the acquired data into the main data memory, etc. Finally, the displays are formed by the firmware in a way similar to those of the parallel logic analyzer.

In the signature analyzer, the data input rates are, again, 20 MHz. Thus, the signature gate formation and data manipulation must be done with hardware up to the point where a signature is formed. Signatures are then moved into the microprocessor control system where they are processed for fault information and displayed.

The input circuitry is chosen to make a few probes serve many purposes. Where several signals are going to be used together, a multiple input probe is used. Where changing from one test point to another is important, a single input probe is used.

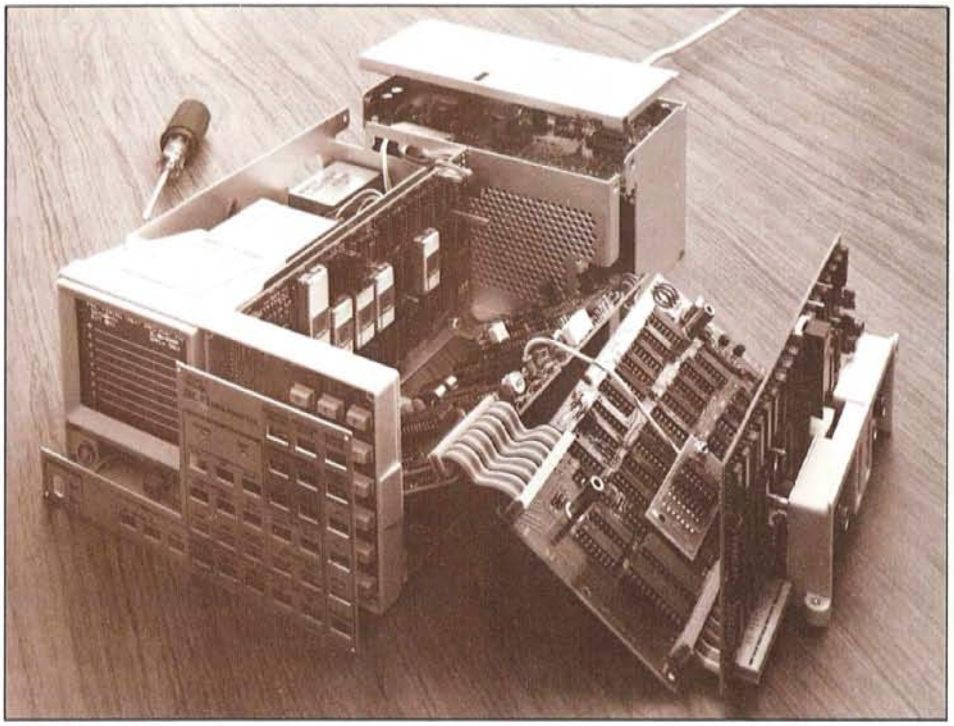


Fig. 5. Easy access to circuitry even with the 308 powered up facilitates calibration and servicing.

The data paths for the three subinstruments start at the probes, pass through separate high-speed acquisition circuits, and then merge at the microprocessor controller for processing and display. Note the parallel acquisition circuit contains delay counters, and a word recognizer. The serial acquisition has the same functions, but they do not appear in circuitry. Instead, the microprocessor controller performs the serial word recognition and delay counting functions.

Self-test diagnostics

In many instances, valuable time is lost trying to fix defective equipment with a test instrument which is, itself, faulty. A set of diagnostic routines resident in the 308 precludes the probability of this happening to a 308 user.

A self-test procedure is invoked each time the instrument is powered up. The display informs the operator that a self-test is in progress and then indicates OK if no errors are formed. If an error is detected, a code denoting the type of error detected is displayed. A series of six user-initiated diagnostics can then be called up to help in locating the source of the problem. A seventh routine designed specifically for the service technician is also resident.

The 308 is mechanically designed for easy access to components, and can be operated and fully calibrated while spread open (figure 5). Modularity and the use of ribbon cable connections allow quick, easy replacement of subassemblies or component parts.

Summary

The task of testing and servicing the myriad of microprocessor-based products entering the marketplace is of increasing importance. The Sony/Tektronix 308 Data Analyzer combines in one compact, lightweight instrument the data acquisition and display capabilities needed to effectively test and service such products. Microprocessor-based, itself, the 308 provides a low-cost, yet versatile solution to many of today's digital instrument problems.

An Automatic Video Signal Parameter Measuring Instrument with Logging Capabilities

Jim Capps is a Program Manager in Television Products Marketing. During his six years at Tektronix, he has applied his programming skills to various areas including Manufacturing Planning, Manufacturing Engineering, and the Mechanical Products group. Jim is single and enjoys fly fishing, back-packing, and outdoor photography.

The "vital signs" of every television broadcasting system must be monitored and logged at frequent intervals. It is required by government regulations to ensure that equipment is set up and operating properly. Of equal importance, is the opportunity such monitoring affords for early detection of subtle changes in the transmission system which, if uncorrected, could eventually result in major failure.

The 1980 Automated Video Signal Measurement Set is a microprocessor-controlled digital instrument capable of making and recording, automatically, the majority of common video measurements. It has been designed to alleviate most of the problems associated with video measurement.

The standard video signal contains vertical synchronizing pulses, horizontal synchronizing pulses, and active picture elements. The time between synchronizing pulses, the shapes and risetimes of the pulses, and the peak-to-peak amplitude of the signal are relatively easy to measure while actual broadcasts are in progress. The problem is that there are many additional factors affecting picture quality that require special test signals to measure. These parameters include frequency response, delay of the chrominance with respect to the luminance, differential gain, differential phase, etc. Because these parameters affect the quality of the broadcast picture so dramatically, it is important that they be measured during the course of actual broadcasting, especially when it is considered that the broadcasting day may now be up to twenty-four hours long. In fact, the FCC requires that many of these parameters be measured during actual broadcasting.

Special test signals help

There are obvious disadvantages to broadcasting test signals, such as color bars, at frequent intervals during the day while long sequences of measurements are made. Therefore, there are special signals that are inserted in the video signal during the vertical interval, the time when the beam of a television receiver is "blanked" as it returns from the bottom of the picture tube to the top. These are called vertical interval test signals, or VITS. The vertical interval

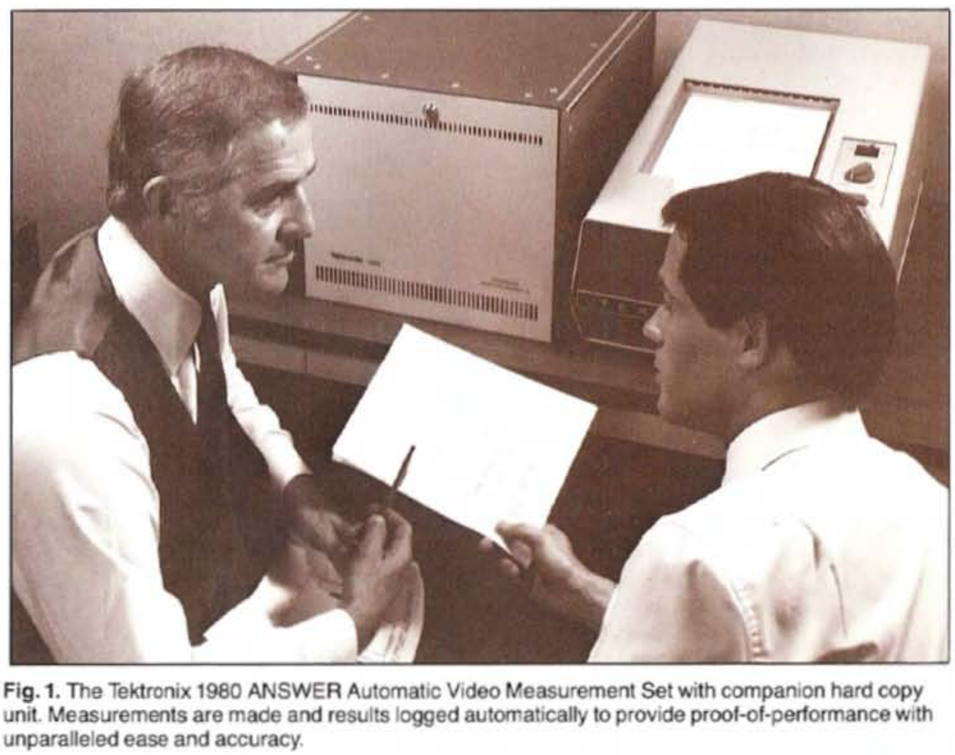


Fig. 1. The Tektronix 1980 ANSWER Automatic Video Measurement Set with companion hard copy unit. Measurements are made and results logged automatically to provide proof-of-performance with unparalleled ease and accuracy.

occurs sixty times a second and lasts for approximately 1.3 milliseconds, or about the same time as 21 scan lines of regular picture. This interval may also contain the VIR signal (Vertical Interval Reference) which can be used for automatic correction of certain signal parameters, as well as information such as the origin of the program material, the time of day, and captioning for the deaf. The VIT signals allow accurate determination of how the signal has been affected as it passed through distribution amplifiers, telephone lines, microwave links, switchers, and the transmitter. Generally, measurement of VIT signals is made using two special types of oscilloscope: a waveform monitor, and a vectorscope.

Signal measurement using these two special instruments involves certain difficulties, however. Accuracy and repeatability of these measurements are limited by factors such as operator interpretation and the presence of noise on the signal. It is difficult to record the results, as this requires photographing the signal and recording the settings of the measuring equipment. Instrument controls must be changed several times during the course of a set of measurements and highly trained personnel must make the measurements.

In contrast, the 1980 automatic video measurement set makes a complete set of standard operating video measurements in just a few minutes. Results of these measurements are printed on a terminal or printer that may be located many miles from the site of the measurement taking. Because the measurement results are simply printed numbers, there is no operator interpretation of waveforms, and because the 1980 is almost all digital, the results are accurate and repeatable. Since the results of the measurements can be logged on a printer, there is no need to record the measurements, or waveforms, with a camera. Best of all, the 1980 can be run totally unattended so there is no need for a skilled operator to spend many hours at a repetitive task.

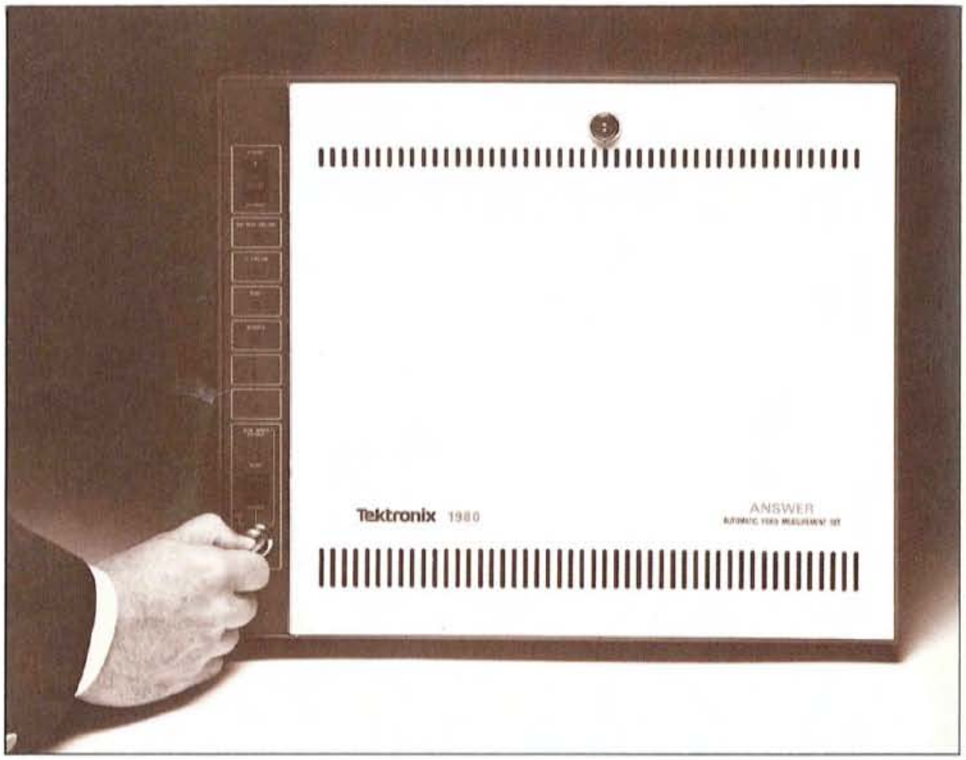


Fig. 2. A front-panel keylock switch controls what happens when power is applied to the 1980. In one position, the 1980 will start itself, run a set of diagnostic programs, and enter its normal monitoring mode. Other positions allow programming the instrument and changing configuration parameters.

These features make the 1980 ideally suited for use as an off-air transmitter monitoring device. When combined with the Tektronix 1450 precision demodulator, the 1980 can be used to monitor both the output of the transmitter and the video signal arriving at the transmitter via the STL (studio transmitter link). Two video inputs, automatically switchable, are provided. The 1980 can be set up to make its measurements continually and only report the results when a set of limits are exceeded, or at fixed times of day, or both. In a typical transmitter application, the 1980 would be set up to report on the broadcast signal every three hours, continuously monitor both the incoming and outgoing video, and generate an alarm signal when either of these exceeded predetermined limits.

The limits are set up for each video source that the 1980 is monitoring, and there are two pairs of limits associated with each measurement parameter. The first pair, the broader of the two, are called alarm limits and are usually set so that they correspond to what is legally prescribed. The other pair, tighter in their tolerance, are called caution limits and signify that the signal is not of the quality that is should be although it is still within legal limits. Usually the 1980 would be set up so that it would print a measurement report when the inner or caution limits are exceeded, and to generate an alarm signal at the studio when the outer, or alarm, limits were exceeded. The 1980 can be set up to monitor and compare a full set of measurements against these limits, or make partial sets of measurements; for instance, to monitor the blanking intervals (the timing of the signal).

Microprocessor-based versatility

The great versatility of the 1980 is achieved by digitizing the video signal and using a microprocessor to measure it. The 1980 is programmed in TEK ANSWER BASIC, a programming language very similar to TEK SPS BASIC. TEK ANSWER BASIC has a set of measurement commands added to it that reduces the complexity of programming video measurements. There are special commands to digitize the video signal and store the values in a waveform array. A waveform array is a collection of eight-bit numbers (ranging from 0 to 255) that can be interpolated by a program to find the original peak amplitude, phase, and other characteristics of a digitized signal. Measurement commands do things such as find the amplitude of a sine wave with a single BASIC statement. Many of the measurement commands are specifically designed around video measurements.

This programmed adaptability makes the 1980 suitable for use in almost any transmitter monitoring application. The VIT signals do not have to be in any specific location within the vertical interval, nor do all of the FCC and Network Transmission Committee Report 7 VIT signals have to be present. The 1980 will scan the entire vertical interval and locate the VIT signals that are there, then make the appropriate measurements for each of the signals it finds, including the VIR signal.

The remoteness of many transmitters from the studio makes it very desirable to be able to make video measurements from a distance. Sending the signal back to the studio for measurement may introduce distortions in the signal that are not present at the transmitter. In some cases, off-air reception of the broadcast signal at the studio is not possible, especially when one studio is broadcasting on several transmitters. The 1980 solves these problems by providing the capability of making the measurements at the transmitter and sending the results back to the studio by telephone. The 1980 has five RS-232-C interface ports that may be connected to modems to send measurement results in ASCII code, over a standard telephone line, to a terminal or printer located in the studio. An optional RS-366 interface will allow the 1980 to dial the phone and call the terminal or printer at the studio to report problems at the transmitter.

The key to assurance

The 1980 has a keylock switch on the front panel that controls what happens when power is applied to the instrument. With the keylock switch in one position, the 1980 will start itself when power is applied, run a complete set of diagnostic programs, and enter its normal monitoring mode of operation. Other positions of the switch allow programming the instrument and changing the configuration parameters — operations that are infrequent. The 1980 contains a battery that keeps the real-time clock operating for about one month without external power. Another preserves information stored in the nonvolatile memory. This is important because the memory contains relatively constant information about the configuration of a particular installation. It includes things such as the number and type of terminals, the limits files, the phone number of the studio, and possibly even small customer-written programs.

The 1980 also has a feature called ATR (Automatic Timeout Reset) that takes control of the processor whenever sixteen minutes have gone by without the execution of a BASIC command. This is in case of a failure in the instrument. ATR restarts the instrument and runs a complete set of diagnostic routines before re-entering the monitoring mode. The diagnostic programs in the 1980 run special test procedures to ensure that the instrument is operating correctly. The results of these diagnostics are printed on the master terminal, and in most cases it is possible to determine on which circuit board a failure has occurred, simply by looking at the diagnostic printout on the terminal.

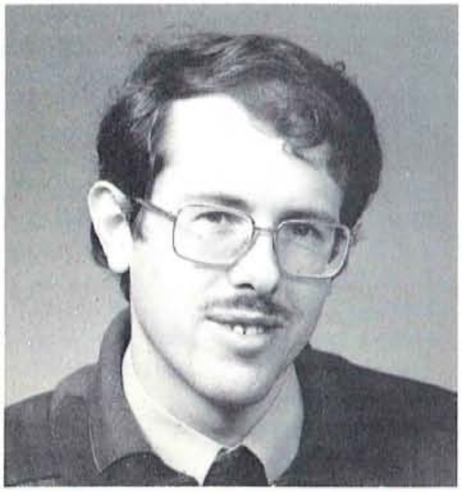
Broadcasting requires service from an instrument up to twenty-four hours a day, 365 days a year, so the 1980 has been designed with a long mean-time-between-failure (MTBF) and a short mean-time-to-repair (MTTR). Serviceability has been designed-in from the start with resident diagnostic programs that detect and isolate almost any fault. The instrument has been designed so that all of the circuit boards may be slipped out of their guides through the front of the instrument and replaced in a few seconds. The I/O board and power supply are the only exceptions. They are removed from the rear because of the cabling connections on them. All of the circuit boards in the 1980 may be removed without removing the instrument from its rack.

The 1980's digital design, customer-set limits, versatility, phone line compatibility, ATR, self-diagnosis, and other features have all been designed to make unmanned, remote, continuous transmitter monitoring a realistic, economical possibility.

Acknowledgements

Many people were involved in the development and completion of the 1980. Phil Crosby, Project Manager, also did much of the design work on the high-speed A/D and D/A converters. John Lewis was the Hardware Manager, with Dale Jordan performing a similar function for software. Earl Matney made substantial contributions in designing the digital feedback and memory controller circuitry. Jim Prouty did the applications software and Larry Morandi, the debug board, operating system, and diagnostics.

Developing a Practical Automatic Television Parameter Measuring and Logging System



John Lewis received his B.Sc(Eng.) from London University in England and upon graduation joined the British Broadcasting Corporation. Most of his ten years with BBC were spent in the TV Measurement Section of their Engineering Designs Department. He emigrated to the U.S. and joined Tektronix in 1976. John is married, has two young sons, and spends most of his leisure time with his family and in local church activities.

Earl Matney started his electronics career in the United States Navy. Electronics training was followed by submarine school and nuclear power school. Completing an extended tour of duty, Earl brought his family to the Portland area, joining Tek in 1974. His off-work hours are devoted to family activities, hunting, fishing, and studying.

Automatic measurement and logging of the television broadcast signal has been a long-sought-after goal. Prior to the introduction of large-scale integration and the microprocessor, however, attempts to automate the measurement process encountered serious drawbacks: such systems had limited capability, required frequent calibration, occupied a lot of space, and were very expensive. Now, with the availability of new components, the long-sought-after goal has become a reality in the new Tektronix 1980 ANSWER Automatic Video Measurement Set.

Typically, television signal measurements are made manually using analog instruments such as waveform monitors, vectorscopes, etc. The process requires highly skilled personnel and is time-consuming. Design goals for the 1980 were to make these same measurements automatically, with greater speed and accuracy, and at reasonable cost. Measurement results were to be logged automatically, on site or remotely. The instrument was to allow easy selection of individual tests, or series of tests, and provide for adding new tests. Reliability, of course, was essential.

Digitizing the signal

The key to developing an automatic video test set lay in finding a suitable high-speed analog-to-digital converter (ADC) for digitizing the video signals. With the video signal digitized, a microprocessor could be used to make almost any measurement desired.

Sampling theorem implies that if a bandlimited signal, such as broadcast video, is sampled at a frequency greater than twice the highest frequency component of the sampled signal, the original signal waveform can be accurately reconstructed by mathematical manipulation of the sampled values.

Investigation revealed a sampling frequency of four times the color subcarrier (14.32 MHz for NTSC, 17.72 MHz for PAL) affords some very significant performance advantages for the particular measurements to be made. Reviewing the commercially available ADCs it became apparent that to achieve our performance and cost goals we would have to develop the ADC in-house.

A simplified block diagram of the Tek-developed 8-bit, 20-MHz ADC is shown in figure 1. The converter uses a two-stage parallel conversion technique

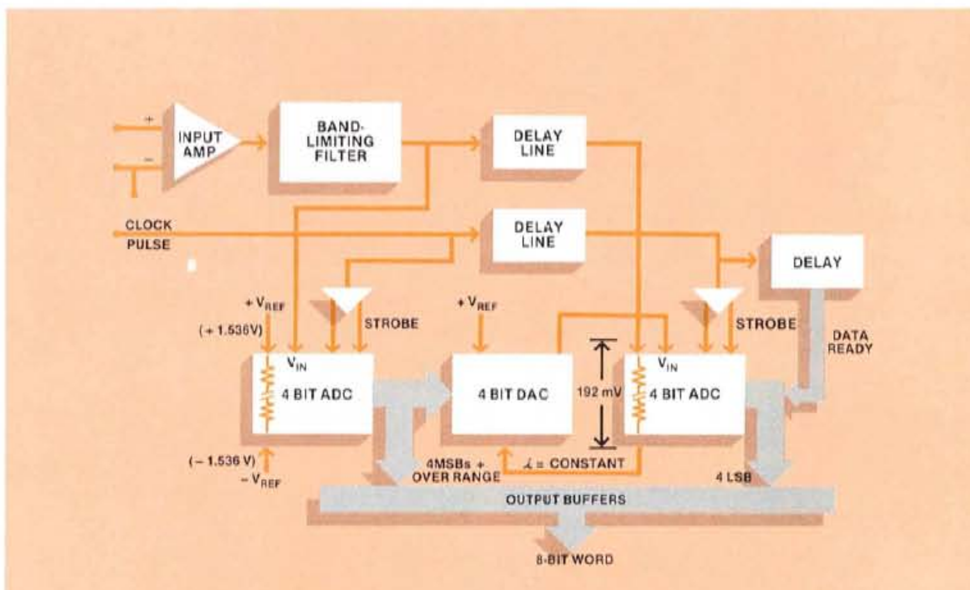


Fig. 1. The 8-bit, 20-MHz analog-to-digital converter uses two-stage parallel conversion, substantially reducing the number of comparators required.

which affords significant economies over the full parallel approach. For example, the number of comparators required is reduced from 255 to only 30. In two-stage parallel conversion, the first 4-bit ADC is biased so that it converts the four most significant bits.

The output of the first ADC drives a very fast digital-to-analog converter (DAC), also Tek designed. The analog output of this DAC is subtracted from the input video signal, and the difference signal is applied to the second 4-bit ADC to produce the four least significant bits (LSB).

In conventional two-stage parallel ADCs, a sample-and-hold circuit usually precedes the conversion process to ensure that the signal level does not change during the time between the two conversions. Because sample-and-hold circuitry is not readily integrated onto an IC chip, an alternate approach was developed. The input analog signal is delayed by 32 nanoseconds before being applied to the second 4-bit ADC. The strobe pulse is also delayed by precisely the same amount. As the ADC process occurs in each converter at the instant the strobe pulse is applied, both converters convert at the same point on the input signal waveform.

Development of both a 4-bit ADC and DAC as integrated circuits makes possible the high-speed conversion needed and provides other benefits. Linearity is improved by integrating the tapped voltage divider into the IC device containing the comparators, and laser trimming each resistor to optimally bias each comparator. Having all 15 comparators in a common thermal environment also improves the linearity of the conversion process over a range of temperatures. All of these factors result in an 8-bit, 20-MHz analog-to-digital converter with an accuracy of ±0.25 LSB.

Improving the resolution

To take full advantage of the dynamic range and inherent accuracy of the ADC, three significant elements are added during input signal processing — dynamic offset, dynamic gain, and dither (see figure 2).

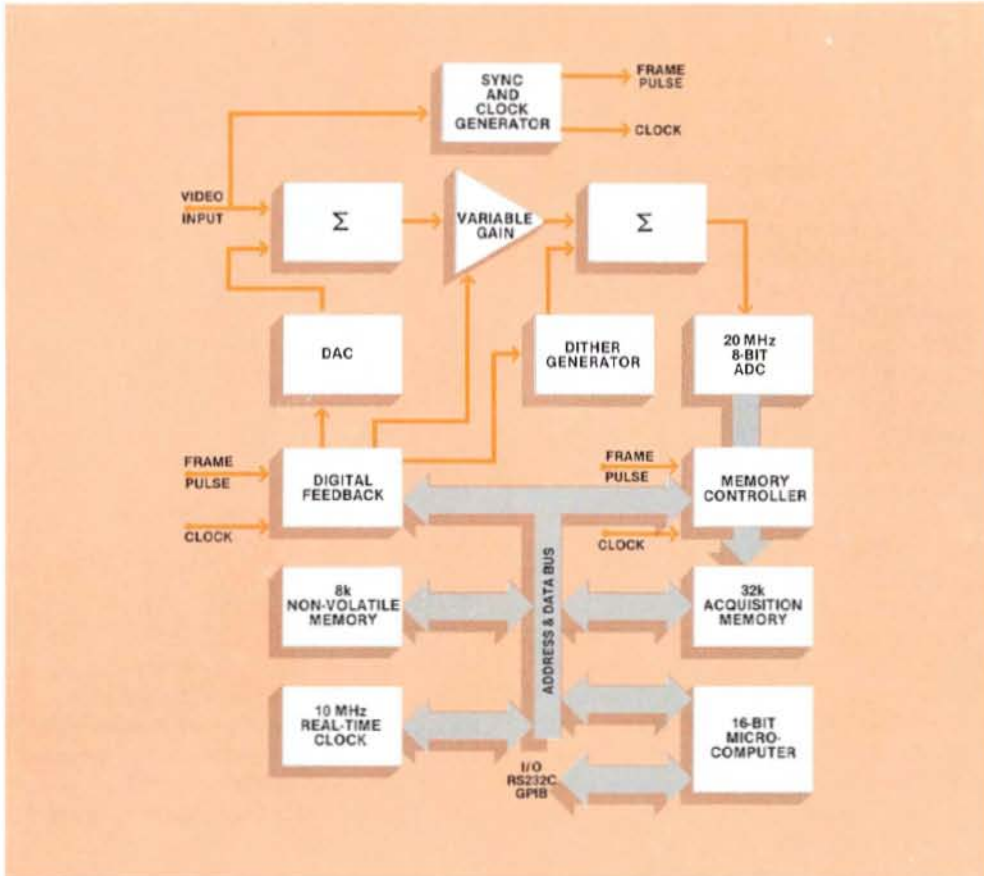


Fig. 2. Simplified block diagram of the 1980. Considerable signal processing is done to achieve maximum resolution and accuracy. Programmable memory controller provides great flexibility in selecting portion of video signal to be stored.

Dynamic offset is applied by summing a precision offset waveform with the input video signal. The offset pattern is digitally generated by the microcomputer and stored in the digital feedback memory. The contents of the memory are read out in sychronism with the video input signal, and applied to a precision (0.01% accuracy) DAC. The resultant analog output is then summed with the input video signal.

The output of the summing amplifier is applied to a digitally-programmable, variable-gain amplifier. This amplifier is controlled by the digital feedback memory which has been loaded with the appropriate gain pattern by the microcomputer. Figure 3 shows the effect of applying dynamic offset and gain to a linearity test signal. In this example, the resultant chroma portion of the input

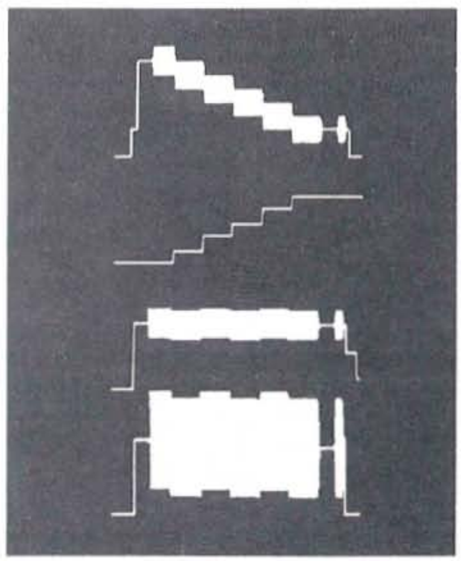


Fig. 3. Offset and variable gain applied to linearity test signal greatly enhances resolution and accuracy of measurement.

video signal is amplified by about three times to take full advantage of the dynamic range of the ADC.

Finally, a dither signal that causes successive waveform repetitions to have a slightly different dc term is combined with the video signal. The proprietary digital dither generator used in the 1980 provides a complex analog dither signal designed to improve both the accuracy and resolution of the quantization process.

A simplified block diagram of the dither system is shown in figure 4. The input video signal is coupled to a summing amplifier and to a clock generator which generates a clock pulse at the end of each repetition period of the input signal. The output of the clock generator, gated by an output of the feedback board, is connected to the input of a 5-bit counter. A reset pulse coupled to the reset input of the counter initializes the system. The counter outputs are coupled to the data inputs of a DAC whose output is then summed with the original input video signal. The resultant signal is then applied to the waveform digitizer. After 32 repetitions of the video input signal (32 television lines), the counter is reset and the process is repeated. Stepping the analog dither signal through 32 dc levels yields a resolution equivalent to that achieved if an 11-bit ADC were used.

The controller regulates the flow of sampled data to the acquisition memory. It can be programmed to sample any line or group of lines (up to 32) in the television field or frame; it can sample the same line in 32 successive frames; or, it can sample part of a line, skip several frames, and sample that part of the same line again. The latter capability is useful, for example, in conducting bounce tests or transmission links. Sampled data is stored sequentially, eight bytes at a time, in shift registers and then transferred in parallel to the acquisition memory. The acquisition memory has the capacity to store up to 32 lines.

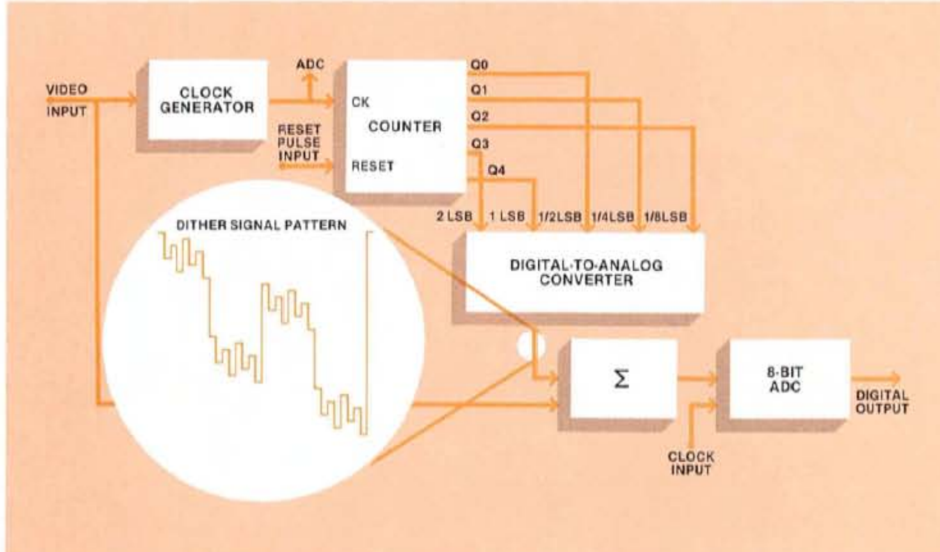


Fig. 4. Digital dither generator produces thirty-two precision levels which are summed with video input signal to enhance resolution and accuracy of digitizing process.

For many measurements, the test signal data is averaged over 32 successive frames (one line per frame) to reduce the masking effects of random noise. Averaging results in an apparent 15 dB enhancement in the video signal-to-noise ratio.

The microcomputer

The microcomputer in the 1980 is designed around the TMS 9900 16-bit microprocessor, with extended addressing capability. Several memories reside in the microcomputer section. The operating system occupies 44k words of ROM, an application memory has 40k of PROM, and there is 32k of RAM for the main memory. These are all 16-bit memories. In addition, there is 8k of non-volatile memory powered by stand-by batteries should power be interrupted. This non-volatile memory may be used to store the parameter limit files and other configuration information usually entered from the keyboard.

There are several clocks used in the 1980. The sync and clock generator associated with the input video signal basically controls the front-end circuitry — phase lock, digital feedback, etc. The realtime clock (4-MHz) provides time-of-day, date, and automatic timeout reset. A user can substitute an external 1 MHz clock to lock the time information to the station master clock if desired. The main clock controls the processor and associated computer circuits.

User interaction with the 1980 is provided by multiple RS-232, CCITT V.24 input/output ports, allowing connection to various types of terminals, printers, modems, etc. An extended form of BASIC was developed to efficiently handle input/output communications and deal with the special requirements of processing the video signal.

Designed for reliability

The 1980 is designed for remote or unattended operation as well as operation where the intended use is to relieve engineering personnel from time-consuming, routine testing. In both applications, reliability is of paramount importance. Accordingly, much effort was expended in both electrical and mechanical design to ensure reliability.

All critical semiconductors undergo a 96-hour burn-in at 125°C before use in the 1980. In addition, the entire instrument undergoes several hours of burn-in at elevated temperatures to weed out infant mortalities.

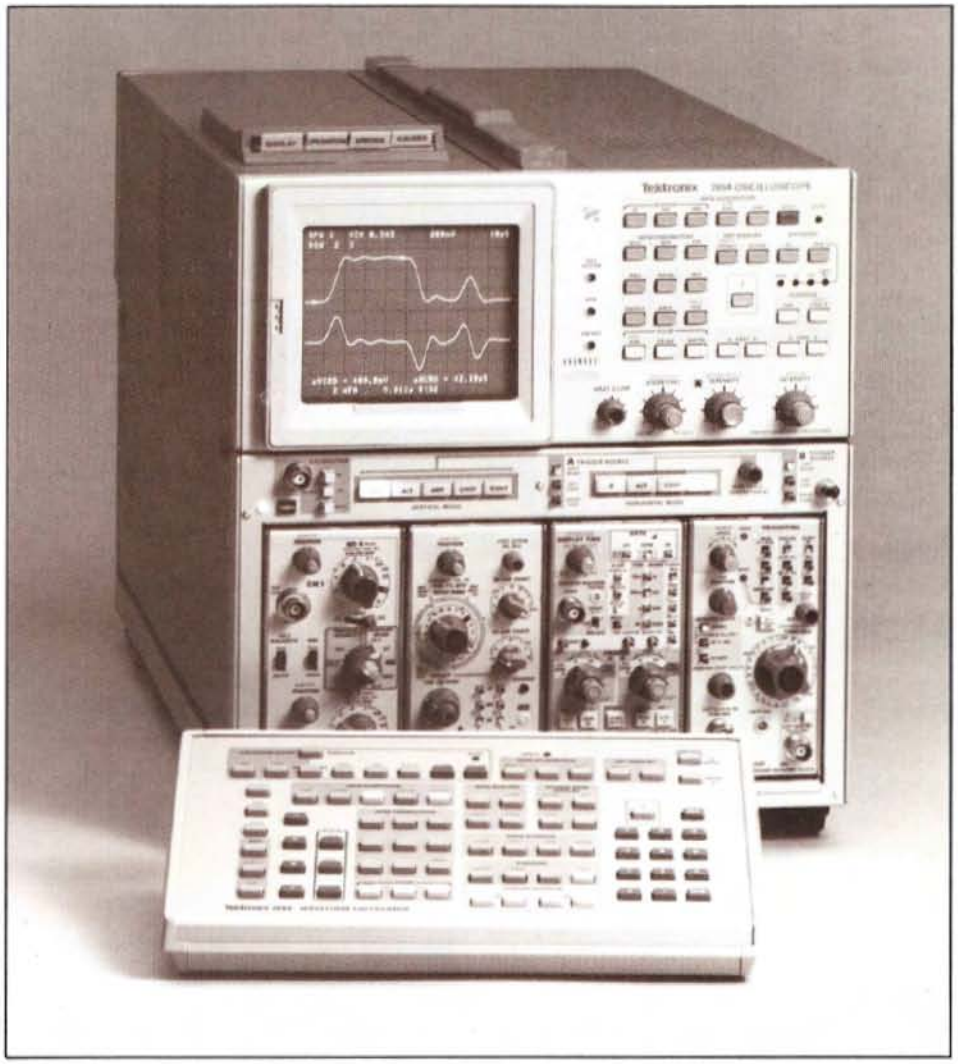
Digital Storage of Repetitive Signals to 400 MHz

To assure the operator that the 1980 is working properly, extensive self-check diagnostic routines are activated each time the instrument is powered up. Some of these routines are accessible by BASIC so the operator can program the 1980 to perform a self-check routine each time a measurement error is detected.

The instrument is mechanically and electrically configured for easy trouble-shooting. The design incorporates the ability to use signature analysis as an aid in quickly isolating faulty components or circuitry.

Summary

There is no longer any need to spend valuable engineering time making routine measurements and logging the results. The 1980 is designed to do this for you — to provide fast, accurate, automatic measurement of television signal amplitude, phase, and timing parameters. As an example, the 1980 can automatically run and log a complete in-service NTC No. 7 measurement routine in less than one minute, with worst-case accuracies of ±0.5%/0.5°C for most measurements. The instrument is easily programmed to meet special requirements and future needs.



The 7854 Oscilloscope

A new 7000-Series Oscilloscope combines 400 MHz analog performance with microprocessor-based waveform processing to greatly simplify waveform measurements and improve measurement quality.

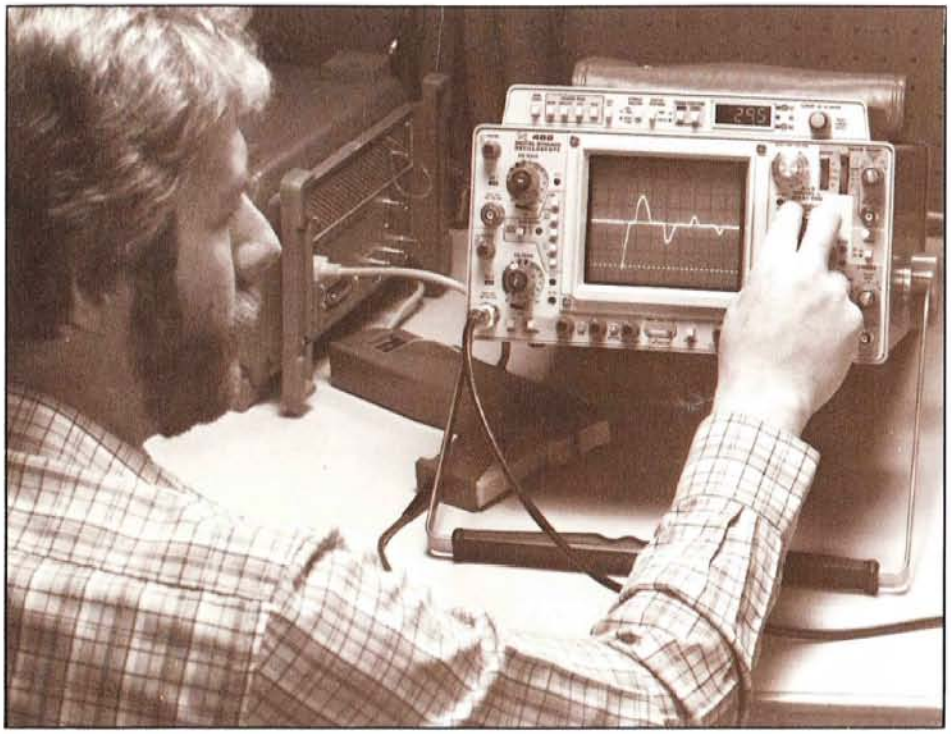
The 7854 is preprogrammed to make common measurements such as rise time, fall time, pulse width, peak-to-peak, RMS, and other measurements at the touch of a button. Through averaging, signals buried in noise can be recovered and measured with improved accuracy. Averaging also gives increased resolution, with differences as small as 0.01 division recorded in the digital storage process.

The 7854 can store repetitive waveforms up to 400 MHz and single-shot events at sweep speeds up to 50 μs/division. A choice of 128, 256, 512, or 1024 horizontal points is provided to allow storage of multiple waveforms. With optional memory, the 7854 can digitize and store up to 40 waveforms.

A GPIB interface is provided for customers requiring additional processing, data storage, or coordination of the oscilloscope with other instruments.

As a conventional oscilloscope, the 7854 operates like a 7904 or 7704A. The choice of more than 30 compatible plug-in units affords the same versatility enjoyed by users of other 7000-Series instruments.

A Digital Storage Scope with a Familiar Face



468 Digital Storage Oscilloscope ↑

The new Tektronix 468 Digital Storage Oscilloscope looks just like the industry-standard 465B, 100-MHz Portable Oscilloscope, and for good reason. The 468 "drives" just like the 465B, and in the non-storage mode has the same characteristics.

Switching to digital storage, the 468 uses state-of-the-art technology advances to extend digital storage bandwidths, simplify detection of aliased signals, and overcome envelope error and display jitter — all problems plaguing earlier digital storage efforts.

The 468 uses a 25-MHz, 8-bit digitizer and a unique display interpolation technique to achieve a 10 MHz "useful storage bandwidth." To accommodate a wide range of applications, both sine and pulse interpolation is included. An envelope mode provides dual digitizing rates useful in catching glitches and detecting aliasing.

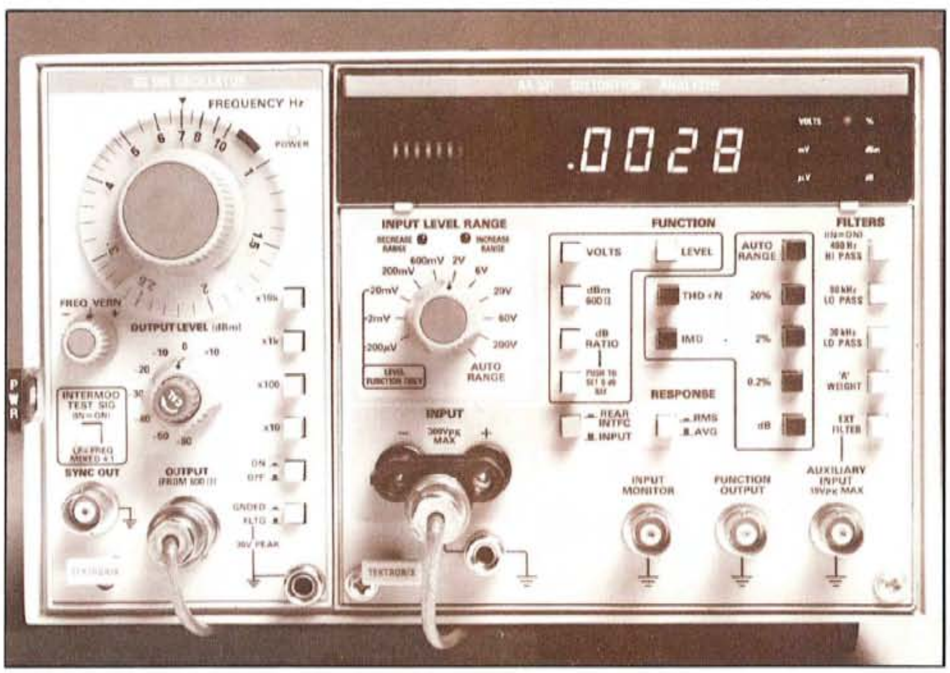
Operating ease and measurement resolution is enhanced by signal averaging, and cursors for measuring both time and amplitude differences. In addition to the signal averaging option, a GPIB option is available for waveform transmission.

Fully Automatic Distortion Analysis

With the introduction of the Tektronix AA 501 Distortion Analyzer and SG 505 Oscillator, complex distortion measurements become a totally automated process. Steps such as level setting, tuning, and nulling which previously required several minutes of skilled operator time, are now done quickly, precisely, and automatically by the AA 501's internal circuitry.

The AA 501 and SG 505 combination permits harmonic distortion, intermodulation distortion, frequency response, gain/loss, and signal-to-noise ratio measurements to be accomplished with minimal skill level. At the same time, both instruments feature state-of-the-art performance in residual noise and distortion. The system provides a total residual distortion of less than 0.0025% (−92 dB), residual noise of less than 3 microvolts, and fully differential input with a CMRR of 50 dB at 50 Hz. The SG 505 Oscillator gives a significant boost to measurement accuracy with ultra-low distortion, 0.0008% (20 Hz to 20 kHz). In addition, it features an extremely flat frequency response, within 0.1 dB from 10 Hz to 20 kHz, 0.2 dB from 20 kHz to 200 kHz.

↓ AA 501 Distortion Analyzer with SG 505



Automated Oscilloscope Test and Calibration

CG 551AP Programmable Calibration ↑ Generator

The Tektronix CG 551AP is a fully programmable, microprocessor-based oscilloscope calibration generator. It can be used as part of a computerized system for the calibration and verification of major oscilloscope parameters, including the following:

- Vertical gain
- Horizontal timing and gain
- Vertical bandwidth/pulse characteristics
- Probe accuracy and compensation
- Current probe accuracy
- Calibrator output accuracy

A diversity of functions, manually selectable from the front panel, are all programmable through a controller via the GPIB (General Purpose Interface Bus, IEEE-488). Many of the functions represent a new state-of-the-art in calibration performance.

The CG 551AP is compatible with any Tektronix 4050 Series or other controller operating on the GPIB. A typical system would include the CG 551AP, a Tektronix 4052 Graphics Computing Controller and a hard copy unit such as the Tektronix 4631 or a matrix printer such as the Tektronix 4642 for permanent documentation.

A Digital NTSC Television Test Signal Generator/VITS Inserter

The 1900 Digital Test Signal Generator and VITS Inserter is designed for state-of-the-art performance testing of NTSC television systems and equipment. Available in four different versions, the 1900 supports a wide range of transmitter, studio, common carrier, and equipment manufacturing applications.

Standard, full-field signals: modulated ramp, field square wave, window, convergence, and VIRS are included in each version. In addition, each version provides a special test signal complement tailored to the specific application.

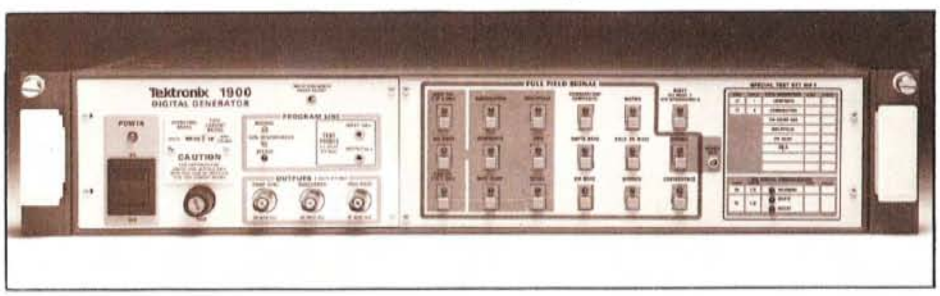
The generator's functions are controlled by an internal microprocessor and its associated PROM memory. Test signals are stored as 10-bit digital words and converted to analog form by a 10-bit precision DAC to ensure signal accuracy and long-term stability.

Since the 1900's signals are stored in PROM, test signal format changes are accomplished by replacing the appropriate test signal memory. No recalibration is required, and changing industry test signal standards will not cause obsolescence.

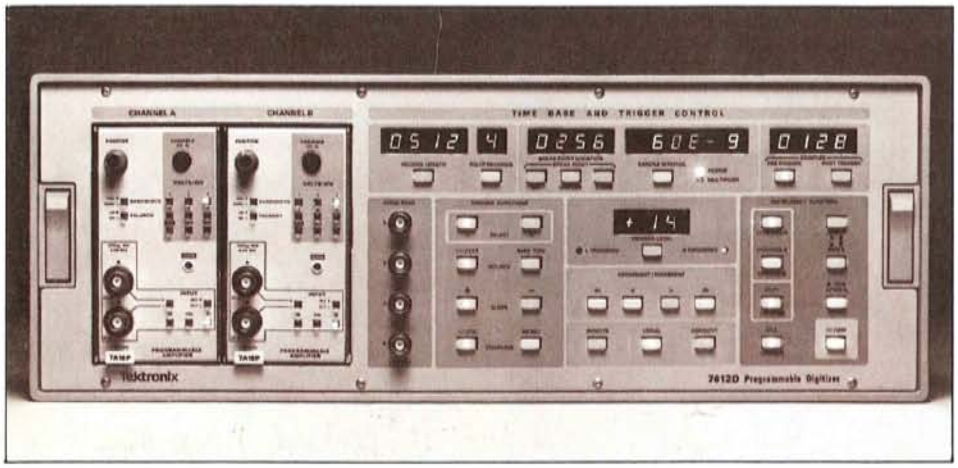
RS-232-C and ground closure interfaces allow wide-ranging remote control functions and applications versatility.

The 1900 is available for the NTSC television standard only.

↓ 1900 Digital Generator



A New Standard in Automatic Waveform Measurement



7612D Programmable Digitizer

The 7612D is a dual-channel/dual-time base programmable waveform digitizer. It is, essentially, two digitizers in one cabinet. Each channel accepts a 7000-Series vertical plug-in amplifier (fully programmable with two 7A16Ps), and each channel has its own built-in digital time base.

Sampling intervals, derived from an accurate, crystal-controlled clock, are selectable on each channel from five nanoseconds to one second. Analysis of single-shot signals shorter than one microsecond in duration is possible at the faster sampling rates. Samples are stored as 8-bit words in a 2,048 byte memory for each channel. Each memory may be partitioned into multiple sections of 1024, 512, or 256 words.

The 7612D features the ability to switch sample rates at specified time locations within a record. This allows increased resolution of fast waveform components, or skipping of unwanted waveform portions.

All the functions of the instrument are programmable over the GPIB bus through simple mnemonic commands. The 7612D is compatible with the 4050-Series and SPS PDP-11 based controllers.

4/80 AX-4399

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

0421867 1339
MR THOMAS P DOWNEY LAB TECH
GEOLOGY DEPT EPS-J106
CITY UNIVERSITY OF NEW YORK
138TH ST AT CONVENT AVE
NEW YORK NY 10031

MAY 27 1980

BULK RATE
U.S. POSTAGE PAID
TEKTRONIX, INC.

TECHNICAL INFORMATION
FOR TEKTRONIX CUSTOMERS

VOLUME 12 NUMBER 4
DECEMBER 1980

Tekscope

Tektronix®
COMMITTED TO EXCELLENCE

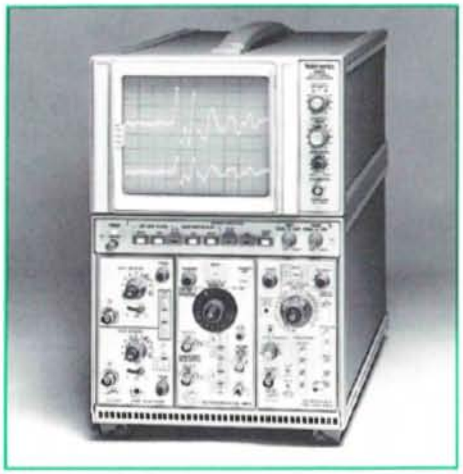
Tekscope CONTENTS

A User-Programmable Logic Analyzer for Microprocessor Design

The new Tektronix 7D02 Logic Analyzer is primarily a tool for designing, debugging, and troubleshooting microprocessor systems. It can support 8-bit and 16-bit microprocessors. The 7D02 can acquire up to 28 channels (44 optionally) of synchronous data. A timing option adds an additional eight channels of synchronous data or eight channels of asynchronous timing or state information.

Digital Storage and Plug-in Versatility Distinguish New 10-MHz 5000-Series Oscilloscope

The new 5223 Digitizer Oscilloscope offers some exciting new capabilities for making measurements in the areas of mechanical design, such as structural and engine performance testing; biomedical research, such as stimulus response and EMG studies; and similar types of applications.



A Programmable Data Communications Tester for First-Line Technicians

The 834 Data Communications Tester provides both monitoring and simulation of data terminal equipment and data communications equipment, such as modems. User-insertable ROM Packs provide extended programming capabilities and allow customers to design tests specifically for their systems. Highly portable, inexpensive, and easy to operate, the 834 is intended primarily for use by the first-line technician.

New Products

A host of new products, including a new microprocessor-development-laboratory family, a sophisticated semiconductor test system, high-resolution hard copy unit, and others are presented in this issue.

Customer information from Tektronix, Inc. Beaverton, Oregon 97077

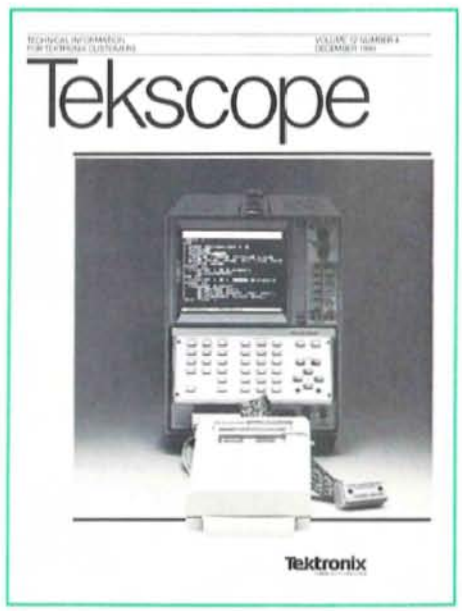
Tekscope is a quarterly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique.

Editor: Gordon Allison
Graphic Designer: Michael Satterwhite

Cover:

The 7D02 Logic Analyzer can be readily configured for a particular microprocessor by simply plugging in the appropriate personality module. The 6802 Personality Module is in use in this instance.

Cover photo by Steven Fish.



A User-Programmable Logic Analyzer for Microprocessor-Based Design

Mike Reiney, project manager for the 7D02, joined Tek in 1971 following receipt of his Bachelor's and Master's degrees in electrical engineering from Rice University. Mike was involved in the design of several TM 500 Series products before joining the Logic Analyzer design group. In his spare time Mike enjoys skiing, sailing, and motorcycling.

The logic analyzer is the basic tool for designing and debugging digital circuitry. The characteristics of a logic analyzer designed for working with random-logic systems differ considerably from those required for working with microprocessor-based systems. Random-logic analyzers usually emphasize sampling speed and depth of memory, while analyzers suitable for working with microprocessor systems feature a large number of input channels and extremely flexible triggering.

The new Tektronix 7D02 Logic Analyzer is primarily a tool for designing, debugging, and troubleshooting microprocessor systems. It can support both 8-bit and 16-bit microprocessors.

The 7D02 can acquire up to 28 channels (44 optionally) of synchronous data, and an additional eight channels of synchronous data or eight channels of asynchronous timing or state information are available through a timing option, for a total of 52 channels. With the timing option installed, the 7D02 is one of the most powerful, yet easy to use, tools available for working with microprocessor systems.

The 7D02 can be easily programmed (through a front-page keypad) to follow the complex sequences of events occurring in the system under test. Program displays are dynamic and interactive, with only necessary prompting on-screen at any given time.

As the programming cursor is moved, new prompting occurs. Menus default to reasonable values to simplify input, and the 7D02 assumes the most logical program and supplies intermediate program steps. Displayed data can be formatted in the basic radices and mnemonics pertinent to the microprocessor under test.

A series of personality modules adapt the 7D02 to the clock and bus characteristics of individual microprocessors. The basic 7D02 contains four word recognizers, two general-purpose counters, a user-configurable clock, data-qualification circuitry, programmable state machine, and three memories.

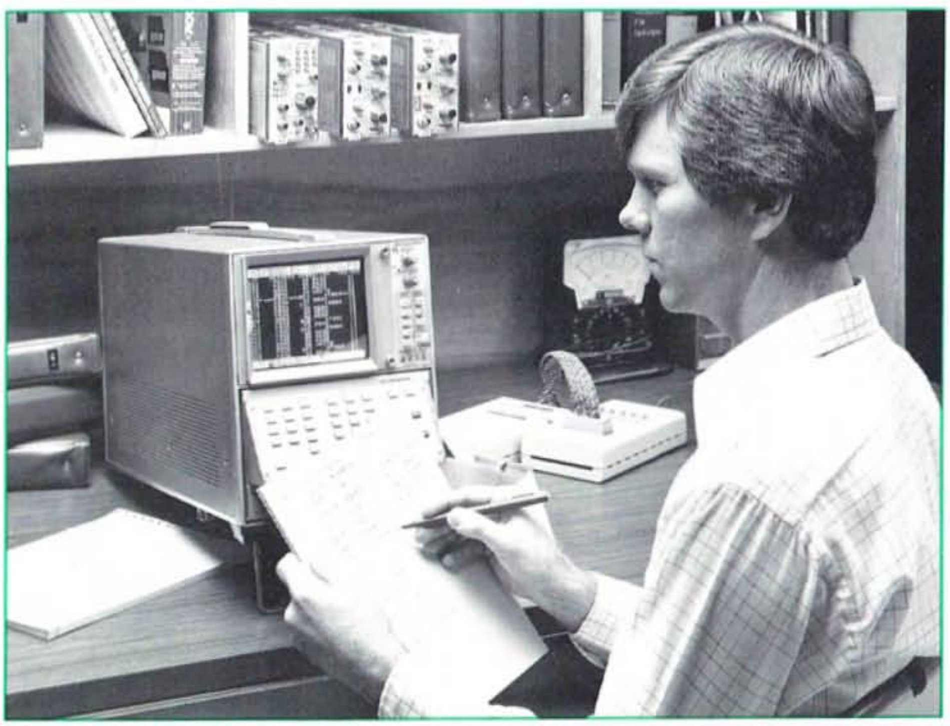


Fig. 1. The 7D02 Logic Analyzer is a versatile user-programmable tool for microprocessor-based design.

A programmable state machine

The programmable state machine is the key to the 7D02's flexibility. It provides two equally powerful capabilities — generation of a trigger algorithm that tracks the complex, convoluted program flow to trigger exactly where the user requires, and data qualification that determines precisely which data will be stored in the acquisition memory. In the 7D02, the qualify command works exactly like the trigger command. The user can employ these two commands to discard the bus transactions of no consequence and to store only that data which is of interest in solving the problem.

The user can program the 7D02's state machine for any one of four states, with each state representing a user-determined output that is the result of a user-determined input. The state-machine input consists of lines from the four word recognizers and two counters; the output consists of individual lines to the main trigger, timing option trigger, data qualifier, and four lines to control the two counters.

The inputs from the word recognizers and counters are called ***events***, and the outputs are called ***commands***. When programming the 7D02, the user can link any event or combination of events to any command or combination of commands. The state machine executes in real time with the system-under-test and can enter any of its states in any order, any number of times. These capabilities allow the user to program the 7D02 to follow the complex sequences encountered in microprocessor-based systems.

Block-structured programming language

The 7D02 programs with a block-structured language. The programming language uses four tests, each constructed using an IF-THEN-ELSE syntax. This syntax makes the execution of a command conditional on the occurrence of an event. Events are keyed in following an IF or an OR IF prompt, and commands are keyed in following a THEN DO or ELSE DO prompt. The user can have as many OR IF — THEN DO clause pairs as necessary (subject to memory limitations), but there can be only one ELSE clause in each test.

Only one test may be active at a time. The user moves from one test to another by executing a GO TO command. The following example shows a program containing two tests and illustrates moving from one test to another. This operation represents a two-level sequential trigger.

```
  TEST 1
1 IF
1  WORD RECOGNIZER #1
1  DATA = XX
1  ADDRESS = 4325
1  /NMI = X   /IRQ = X   FETCH = X   R/W = X
1  BA = X   INVAL OP = X   EXT TRIG IN = X
1  TIMING WR = X
1 THEN DO
1  GOTO 2
  END TEST1
  TEST 2
2 IF
2  WORD RECOGNIZER #2
2  DATA = XX
2  ADDRESS = 694F
2  /NMI = X   IRQ = X   FETCH = X   R/W = X
2  BA = X   INVAL OP = X   EXT TRIG IN = X
2  TIMING WR = X
2 THEN DO
2  TRIGGER 0-MAIN
2     0-BEFORE DATA
2     0-SYSTEM UNDER TEST CONT.
2     0-STANDARD CLOCK QUAL.
  END TEST 2
```

Pressing the 7D02 START button initiates TEST 1. When address 4325 is detected, the event in TEST 1 becomes TRUE and the GO TO (to TEST 2) is executed, deactivating TEST 1 and activating TEST 2. If address 694F is detected, the main acquisition memory will be triggered and data will be stored. Note that if address 4325 occurs again it will be ignored because TEST 1 is inactive. Entering this program required only three keystrokes plus filling in the field values.

Solving a practical problem

Now, let's consider a practical problem. Assume there is a location, OUTBUF, that is the character buffer for a computer line-printer. This location is only written-to from subroutine OUTCHAR. Unfortunately, data on the printer is not always what we expect. The problem is to determine whether location OUTBUF is being written-to from some other section of the code.

With a traditional logic analyzer, we could trigger on OUTBUF and examine the data result to see if the access was legitimate. We may have to examine many legitimate accesses before finding the problem access.

Using the 7D02 we can locate the illegitimate access quickly and easily. The program is shown in figure 2. The two events in TEST 1 are the detection of the addresses for OUTBUF and OUTCHAR. All events in a test are evaluated simultaneously. If the location OUTBUF is written to, the 7D02 will trigger. If the beginning of a subroutine OUTCHAR is detected, the 7D02 will progress to TEST 2. As there is no trigger in TEST 2, the 7D02 cannot trigger during TEST 2. When the end of subroutine OUTCHAR occurs, TEST 2 ends, and the 7D02 goes back to TEST 1. Thus, we see that the 7D02 will trigger and display data only when location OUTBUF is written to, and only if subroutine OUTCHAR is not running.

Now, let's assume that OUTBUF was never written-to from an improper location. If the error occurs at least once every several minutes (a reasonable time to wait for a trigger), the qualify command can be used to verify the accuracy of the data being written to OUTBUF. Figure 3 shows the addition to the program required to instruct the 7D02 to acquire only data written to OUTBUF. If the printer malfunctions, the user can manually stop this program. The contents of the trace memory can then be compared to the printed text by putting the 7D02 in the ASCII format mode.

If the error occurs very infrequently, or if the result of the previous exercise shows that correct data was being written to OUTBUF, we must employ a less direct means to solve the problem.

The two counters in the 7D02 can be used either to count discrete occurrences, or as timers. We can employ the counters to insert a fixed time period as a part of the trigger, a feature which can be very useful in some instances, as the following example shows.

Hypothesizing that there is a timing error in the printer, we set up an experiment to determine if the setup time specification on the print head is being met. We start a counter when the character is written to OUTBUF. If the print hammer is actuated within 10 milliseconds, the timing specification is being violated and the 7D02 will trigger. The 7D02 program is shown in figure 4.

```
  TEST 1
1 IF
1  WORD RECOGNIZER # 1
1  DATA=XX
1  ADDRESS=051B
1  IO/M=X   INRQ=X   FETCH=X   R/W=0
1  INACK=X   HOLD=X   EXT TRIG   IN=X
1  TIMING WR=X
1 THEN DO
1  TRIGGER 0-MAIN
1     0-BEFORE DATA
1     0-SYSTEM UNDER TEST CONT
1     0-STANDARD CLOCK QUAL
1 OR IF
1  WORD RECOGNIZER # 2
1  DATA=XX
1  ADDRESS=9721
1  IO/M=X   INRQ=X   FETCH=1   R/W=X
1  INACK=X   HOLD=X   EXT TRIG IN=X
1  TIMING WR=X
1 THEN DO
1  GO TO 2
  END TEST 1
  TEST 2
2 IF
2  WORD RECOGNIZER # 3
2  DATA=C9
2  ADDRESS=XXXX
2  IO/M=X   INRQ=X   FETCH=1   R/W=X
2  INACK=X   HOLD=X   EXT TRIG IN=X
2  TIMING WR=X
2 THEN DO
2  GO TO 1
  END TEST 2
```

Fig. 2. This 7D02 program will trigger when location OUTBUF is written to, unless subroutine OUTCHAR is running at the same time. The PM104 (8085) personality module is being used. Word recognizer 1 is TRUE when OUTBUF (015B) is written to. Word recognizer 2 is TRUE on the first instruction of OUTCHAR (9721). Word recognizer 3 is TRUE when a RET instruction is executed indicating the end of OUTCHAR. Entering this extensive program required only eight keystrokes plus filling in the field values.

```
  QUALIFY
Q  STORE ONLY ON
Q  WORD RECOGNIZER # 1
Q  DATA=XX
Q  ADDRESS=051B
Q  IO/M=XX   INRQ=X   FETCH=1   R/W=0
Q  INACK=X   HOLD=X   EXT TRIG IN=X
Q  TIMING WR=X
Q END QUALIFY
```

Fig. 3. Program additions required to qualify any write to 051B.

In this example, the external trigger line is connected to the hammer-driver signal and is defined in word recognizer 2 as a TRUE. Word recognizer 1 detects the write to OUTBUF.

TEST 1 waits for the write to OUTBUF. When this happens, the counter is started and TEST 2 is activated. In TEST 2 there is a race. If the hammer driver is actuated first, the 7D02 triggers. If the timer runs out, sufficient setup time has elapsed and TEST 1 is actuated again.

```
   TEST 1
1  IF
1   WORD RECOGNIZER # 1
1   DATA=XX
1   ADDRESS=051B
1   IO/M=X  INRQ=X  FETCH=X  R/W=0
1   INACK=X  HOLD=X  EXT TRIG IN=X
1   TIMING WR=X
1  THEN DO
1   COUNTER # 1 2 MS
1      2 RESET AND RUN
1   GO TO 2
   END TEST 1
   TEST 2
2  IF
2   WORD RECOGNIZER # 2
2   DATA=XX
2   ADDRESS=XXXX
2   IO/M=X  INRQ=X  FETCH=X  R/W=X
2   INACK=X  HOLD=X  EXT TRIG IN=1
2   TIMING WR=X
2  THEN DO
2   TRIGGER 0 MAIN
2   2 AFTER DATA
2   0 SYSTEM UNDER TEST CONT 1
2   0 STANDARD CLOCK QUAL
2  OR IF
2   COUNTER # 1=00010 2 MS
2  THEN DO
2   GO TO 1
   END TEST 2
```

Fig. 4. Program to check timing margins. If OUTBUF (051B) is written to and the hammer driver is actuated (as indicated by the TRUE and EXT TRIG IN) before COUNTER #2 reaches 10 milliseconds, we know the timing specification has been violated. This program can be set up using only seven keystrokes plus filling in the field values.

It is possible for the 7D02 to loop between TEST 1 and TEST 2 millions of times without triggering. The 7D02 will trigger only when the timing constraint has been violated.

The 7D02 also could be easily programmed to check that every write to OUTBUF is followed by only one actuation of the print hammer.

The timing option

The triggering capability of the 7D02 makes it an ideal tool for integrating the hardware and software in a microprocessor-based system. However, conditions often require us to analyze the random-logic circuits associated with the microprocessor. The timing option available for the 7D02 provides this capability. With the timing option installed, the 7D02 is essentially two logic analyzers in one — a 52-channel synchronous analyzer (with expansion option), or a 44-channel synchronous analyzer plus an 8-channel asynchronous logic analyzer.

The timing option uses the 8-channel P6451 Logic Probe to acquire data. The timing option has its own 255 x 8-bit acquisition memory, 255 x 8-bit glitch memory, 8-channel word recognizer (the external trigger input provides a ninth nonstored channel), and an internal clock. The sampling rate is programmable over a range of 20 nanoseconds to 5 milliseconds. A programmable 0 to 300 nanosecond filter is provided for the word recognizer output.

You can establish the trigger relationship of the main and timing option sections in any manner you choose. For example, either or both sections can be triggered or armed from either or both sections. This extreme trigger versatility is useful for debugging the interaction between a microprocessor and its peripheral hardware.

Some design considerations

A simplified block diagram of the 7D02 is shown in figure 5. The ability to completely program the triggering and qualification algorithms requires the decision blocks (such as word recognizers and the state machine) to be implemented in random-access-memory (RAM), which places considerable time constraints on the real-time acquisition system. At the maximum rate of 10 megahertz, the word-recognizer RAMs require almost a full clock cycle for storage. Likewise, the counter subsystem and state machine require another clock cycle. The 7D02 uses a pipeline decision process for delaying data flow to allow time for producing complex signals such as triggers and qualifiers. The pipeline consists of two sets of data latches and the 256 x 44-bit acquisition memory. Words are consecutively clocked into the pipeline latches by the state clock signal; the same clock edge writes data into the acquisition RAM. If the qualify signal from the state machine is TRUE, then the RAM address counter increments. Otherwise, the next state clock overwrites the same memory cell and the word is, effectively, not stored.

The state machine is RAM-based also. The state-machine latch stores the signals from the word recognizers, the state-feedback bits from the RAM, and the feedback bits from the two counters. The latched data (which represents events in the user language) addresses a location in RAM that contains the data appropriate for the next operation. The data outputs from the state machine are the logic analyzer control lines and represent the commands issued by the user language.

The dual-counter subsystem is implemented with direct-memory-access controller ICs to conserve space and power. Under state-machine control, the glitchless start/stop allows resolution to be increased using time-interval-averaging techniques. One counter may be used as the loop counter for the averaged measurement, which is accumulated in the second counter.

Designing plug-in personality modules — to allow the 7D02 to accommodate many different microprocessors without dismantling the instrument to change personalities — presented an interesting challenge. To achieve the necessary flexibility, a programmable clock synthesizer is used and appropriate firmware is included in the personality module.

The 7D02 clock synthesizer can shift or divide the input clock by up to four clock cycles or times to accommodate multiphase clocks. A programmable external synchronizer (Esync) locks the 7D02 to the system under test. A programmable wait-state generator tracks microprocessor wait states.

The programmable clock shifter is a universal shift register (see figure 6). It is loaded by the Esync signal. The wait signal asserts the hold line to suspend shifting. The clock divider adds feedback around the shifter. The Esync and wait signals are generated from the information provided by the hardware and by the firmware in the personality module.

The personality module

The personality module contains input buffers, bus demultiplexers, special control generators, and firmware. The personality module firmware provides information to program the 7D02 clock synthesizer and clock qualifier. It also provides information

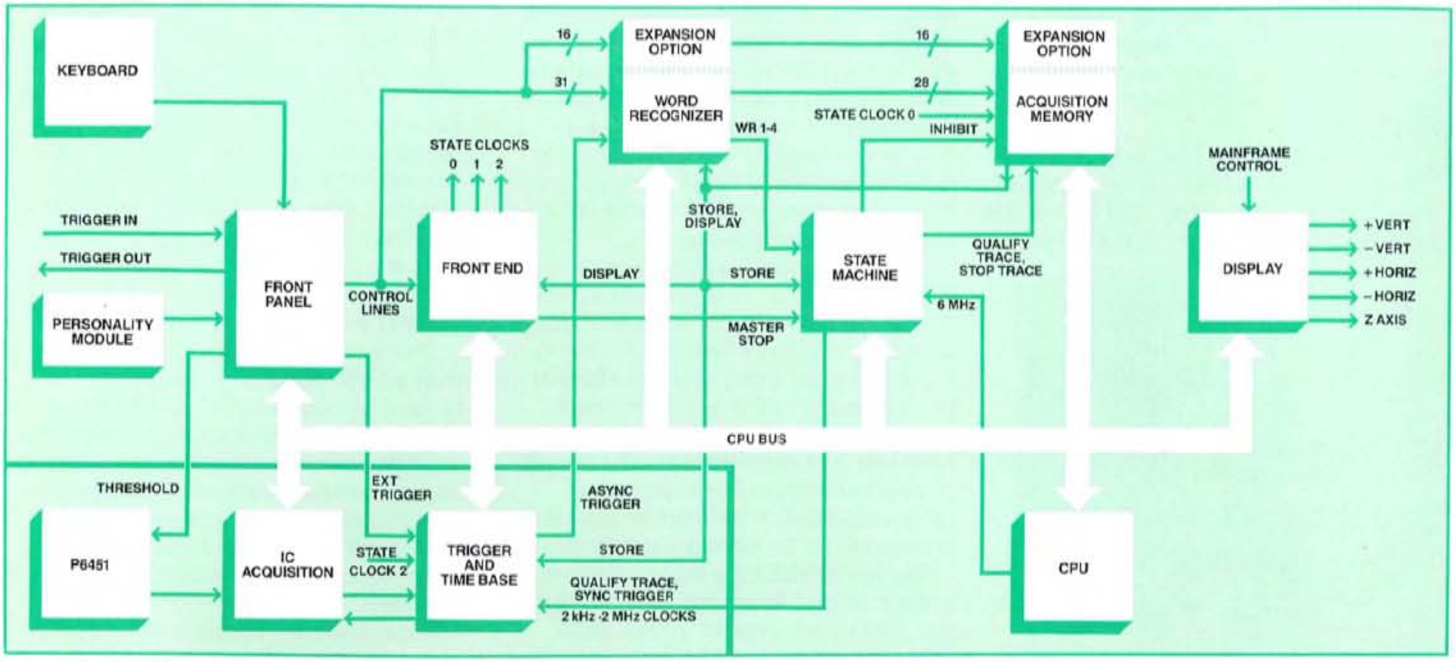


Fig. 5. Simplified block diagram of the 7D02 system. The expansion option allows the 7D02 to operate with 16-bit microprocessors and other systems, and extends the address lines to 24 and the data lines to 16. The timing option consists of the P6451, IC Acquisition, and Trigger and Time Base blocks.

to format the 7D02 input and output displays into the radices and mnemonics of the microprocessor under test.

To perform this format function, a special interpreter was developed. In display mode, data from the system is inhibited and the personality ROM is accessed via the acquisition bus. Commands are fetched from the personality module and executed by the interpreter. This approach allows extreme flexibility in designing future personality modules, saves coding space, and simplifies coding and debugging.

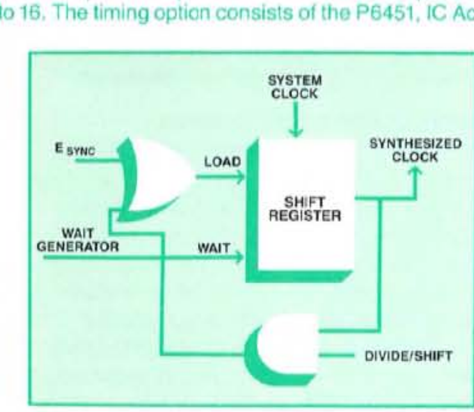


Fig. 6. Simplified block diagram of the 7D02's synthesized clock generator. Personality module firmware provides information to program the synthesizer and qualifier.

Self-test and diagnostic capabilities

An important consideration in using complex instrumentation is how to determine if it is working properly. The 7D02 has three levels of diagnostics to assist in this test.

At power-up, the 7D02 checks internal subsystems to the extent possible without having known data input. If problems exist, descriptive messages are displayed. These are keyed to troubleshooting trees in the 7D02 service manual.

The user can call up the Diagnostic Monitor — Module Test, which employs service test-generators contained in the personality modules. To verify all data paths through the system, the user plugs the acquisition probe into the service test socket, and the 7D02 acquires known input data and performs a checksum.

Suspect subsystems can be analyzed by using the Signature Exerciser Mode which generates test patterns that can be verified using a signature analyzer.

The diagnostic modes consume eight kilobytes of ROM (16% of the total firmware) and provide excellent diagnostic coverage of the 7D02 system.

Acknowledgements

Many people are involved in a project as extensive as the 7D02. While it isn't feasible to acknowledge each of them, I would like to express my thanks to all who worked so diligently on the project. Special thanks go to Dennis Glasby for the original 7D02 concept. Robin Teitzel was hardware project leader and Dave Moser performed a similar function for firmware. Paul Dittman, Steven Den Beste, Chris Benenati, and Bruce Ableidinger designed and implemented the firmware. The hardware team consisted of Vicky Tuite, Doug Boyce and Keith Taylor. Diagnostics are the work of Bob Heath, and the personality modules were the responsibility of Richard Jones. ■

Digital Storage and Plug-in Versatility Distinguish New 10-MHz 5000-Series Oscilloscope

Cliff Baker, project manager for the 5223, was educated in England and received his EE diploma from Oxford College of Technology. He has been involved with engineering 5000 Series products since coming to Tek six years ago. In his leisure time Cliff enjoys gardening and working with radio-controlled model airplanes.

Before the development of the storage oscilloscope, physical, mechanical, biomedical, and similar type measurements were difficult and time consuming to make. Direct-view-storage-tube oscilloscopes changed all of that. Now, a new storage instrument, the Tektronix 5223 Digitizer Oscilloscope, offers some exciting new capabilities.

In areas of biological research, such as stimulus-response and EMG studies, and in mechanical design applications, such as structural and engine-performance testing, the 5223 simplifies the data collection process. The 5223 takes the guesswork out of capturing single-shot waveforms by using two features — bislope triggering and pretrigger viewing. In addition to assured storage performance, the 5223 provides waveform retrieval via an X-Y output port to a chart recorder and waveform manipulation via the optional GPIB feature.

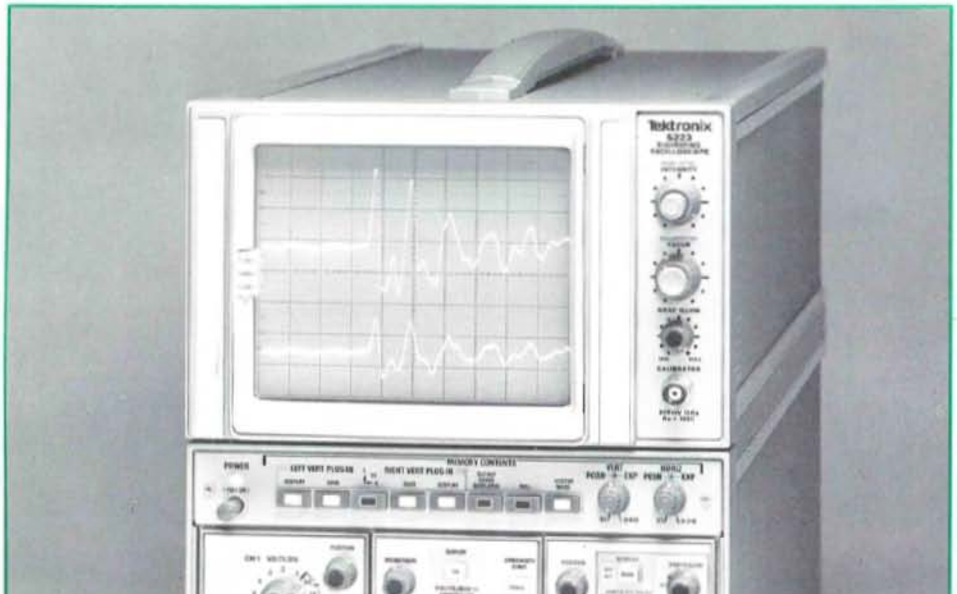


Fig. 1. The 5223 Digitizer Oscilloscope. With the 5B25N Time Base, the 5223 provides multitrace digital storage of repetitive events up to 10 MHz.

For display, the 5223 uses a high-resolution, 6½-inch cathode ray tube (CRT). Displayed waveforms are sharp and bright, and viewing time is unlimited. The large-screen CRT is ideal for viewing multi-trace displays. As an example, the 5223 can display up to four stored signals simultaneously, and you can view real-time signals and stored signals together. Waveform measurements and comparisons are facilitated because you can reposition and expand the stored waveforms on-screen.

For signal acquisition, the 5223 uses the 5000-Series of vertical amplifier plug-ins. These offer wide-ranging capabilities from differential, 10-microvolt/division sensitivity, to gigahertz bandwidth using sampling techniques.

For real-time operation, any of the 5000-Series time bases can be used. The new 5B25N Digitizer Time Base plug-in provides digital storage operation. It includes features of special interest to users making physical, mechanical, biomedical, and similar type measurements. For example, when viewing single-occurrence events, the user often misses the information of interest because of the uncertainty with which the trigger signal is generated. This uncertainty is overcome with the 5B25N by using the bislope triggering mode (see figure 2). In this mode, either a positive or negative-going signal will trigger the sweep. The trigger level control serves as a sensitivity control to prevent premature triggering on noise or other extraneous signals.

One of the unique features of digital storage is the ability to capture events occurring prior to the trigger event. The 5B25N, with continuously variable pretrigger control, lets you position the trigger point anywhere on-screen. The pretrigger portion of the display is intensified for easy identification.

Display format selection

One of the most useful features of digital storage is the capability to display digitized data in several formats. For example, in some applications it is desirable to continuously monitor changes in variably-shaped signals without the interruptions of sweep retrace and holdoff time. The roll mode of the 5223 provides this capability. In this mode, the memory contents are continually updated and displayed, with new data moving from right to left on-screen similar to a strip-chart recorder display (see figure 3). Should a point of particular interest appear on-screen, you can hold the display for further study by pressing the SAVE push button.

In many instances, it is helpful to display waveforms in other than the conventional Y-T format. With the waveforms in digital storage, you can elect to display them in an X-Y format. With two identical wide-bandwidth vertical amplifier plug-ins installed in the 5223, you can select the L VS R display mode and achieve 10-megahertz X-Y displays with less than five degrees of phase shift introduced by the instrument. When the real-time signal is displayed, you can view both the X-Y and Y-T information for a more comprehensive display.

The stored waveforms are available at rear-panel connectors for making hard copies on your analog X-Y plotter. A pen-lift signal and PLOTTER OUT speed adjustment are provided also.

Interpreting the display

Digital storage oscilloscopes usually display the digitized waveform as a series of dots. In some displays, perceptual aliasing (a type of optical illusion inherent in dot displays) occurs. The eye tends to visually connect adjacent points; however, the closest dots in screen position may not be the next in sequence. Perceptual aliasing is overcome in the 5223 by selecting the vector display mode. In this mode, the dots are connected by straight lines.

In addition to perceptual aliasing, dot displays can also show an "envelope error," which occurs when the dots do not fall on the peaks of the signal. The user may not be able to detect this condition even when using a vector display, as the actual signal could still be outside the waveform traced by the vectors. Switching to real-time operation quickly reveals if envelope error is occurring.

Another type of confusing display can occur when too few samples are taken to adequately reproduce the real-time signal. A POSSIBLE UNDERSAMPLING indicator on the 5B25N alerts the operator to this condition. The remedy is to choose a more appropriate TIME/DIV setting.

Digitizing the signal

The 5223 can capture repetitive events at speeds up to 10 megahertz, and single-occurrence events up to 100 kilohertz.

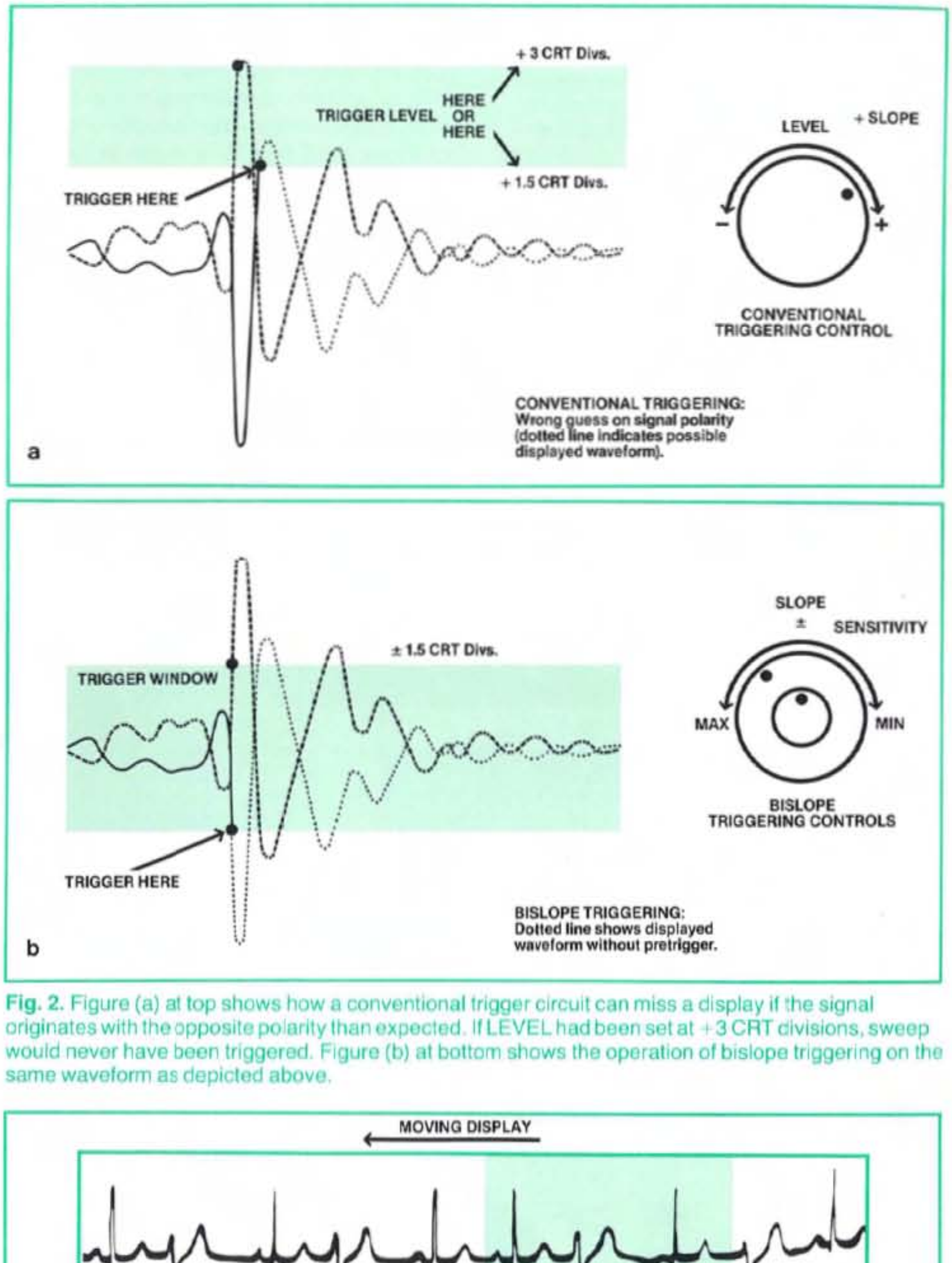


Fig. 2. Figure (a) at top shows how a conventional trigger circuit can miss a display if the signal originates with the opposite polarity than expected. If LEVEL had been set at +3 CRT divisions, sweep would never have been triggered. Figure (b) at bottom shows the operation of bislope triggering on the same waveform as depicted above.

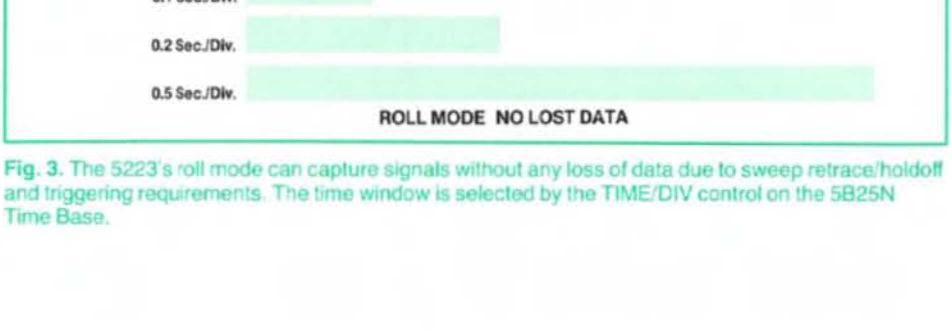


Fig. 3. The 5223's roll mode can capture signals without any loss of data due to sweep retrace/holdoff and triggering requirements. The time window is selected by the TIME/DIV control on the 5B25N Time Base.

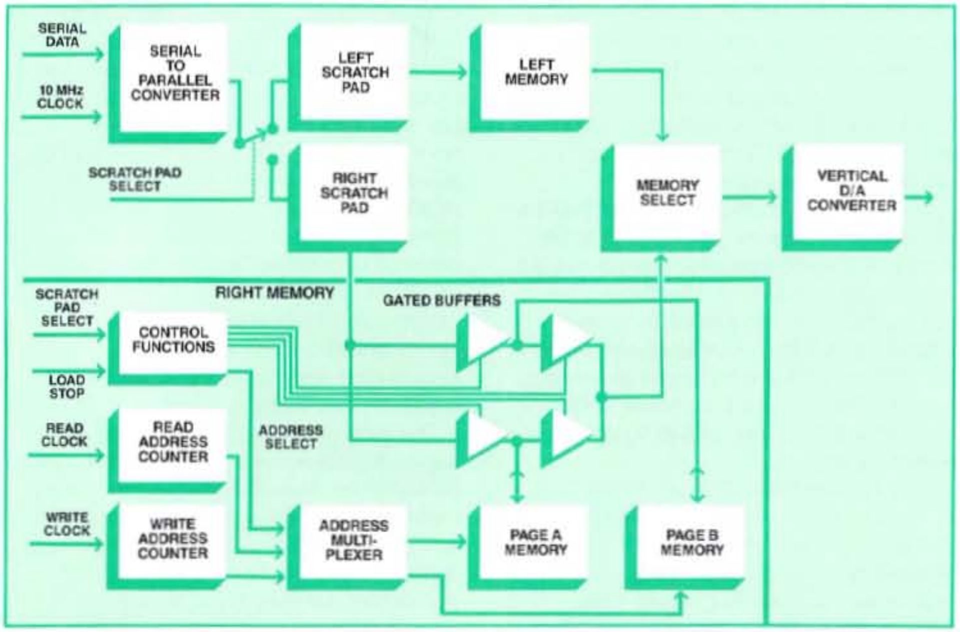


Fig. 4. Simplified block diagram of the 5223 memory system. The right memory is shown in detail to illustrate the two-page memory system that allows one page to be written while the other is being read, and vice versa. This scheme provides a flicker-free display.

Two types of sampling are used in the 5223. For sweep speeds of 0.1 milliseconds/division and slower, real-time sampling may be used. To store a complete waveform, 1024 samples are taken. The TIME/DIV control setting determines the sample rate. For sweep speeds of 50 microseconds division and faster, sequential-equivalent-time sampling is used, with one sample taken each sweep.

Both vertical channels of the 5223 are sampled simultaneously and then digitized sequentially. The analog-to-digital converter is a 10-bit successive approximation register that converts in one microsecond, allowing a maximum sampling rate of one megahertz.

The 1-megahertz clock from the digitizer enters serial data from the digitizer board into a serial-to-parallel converter. The 10-bit data bytes from the converter are temporarily stored in scratch-pad memories for later transfer to the left or right-compartment memory.

The memory system

The 5223 has two separate memory systems—one for each vertical compartment (see figure 4). Each memory system is, in turn, divided into two "pages" of 1024 words each. This arrangement allows the system to write data into one page, while reading data (for display purposes) from the other. Once a complete display cycle has occurred, the functions of the pages are interchanged (if the "acquisition" memory is fully loaded). This scheme ensures always having a full memory for display, and provides a flicker-free display. In the roll mode, page switching does not occur.

The memory output buffers are switched on, as appropriate, to apply the stored data to the vertical digital-to-analog converter. Conversion of the data from a full memory page takes about 4.5 milliseconds.

At sweep rates of 100 microseconds per division and slower, the display is chopped between the real-time signal and the stored signal. However, at faster sweep rates, the stored signal is displayed during the real-time sweep retrace, to reduce the likelihood of display flicker. This technique places some stringent requirements on the X and Y amplifiers as they have to switch to the "trace start" position and settle in less than the 0.25 microseconds provided by the delay line.

The optional GPIB

With the optional GPIB interface installed, the 5223's digital functions can be controlled via a controller such as the Tektronix 4052 Graphic Computing System. Because the 5223 is both a "talker" and a "listener," you can output waveforms for signal processing and data logging, or input externally recorded waveforms into the scope for comparison or reference purposes. Through software selection, the data can be output in binary or ASCII code.

Operating as a talker, the 5223 will output data continuously, a convenience for those applications requiring continuous data logging or real-time processing.

Summary

The 5223 combines digital storage, a real-time bandwidth of 10 megahertz, and plug-in versatility in an instrument designed to give you new measurement capability and operating ease. Multitrace storage, positioning and expansion of stored waveforms, X-Y plotter outputs, bislope triggering, pretrigger viewing, and other features provide important new measurement capability. The 5223 can be easily converted for rackmounting and occupies only seven inches of vertical rack space.

Acknowledgements

Many people are involved in the successful completion of a project like the 5223. My thanks to each one for their contribution. I would like to give special recognition to Mike Hurley for providing the original product definition; Gordon Meigs designed the memory system; Dave Dobak did the digitizer, power, and interface circuitry; the GPIB option is the work of Brian Rhodefer; and Roy Lewallen designed the 5B25N and X-Y circuitry. ■

A Programmable Data Communications Tester for First-Line Technicians

Pete Janowitz was project leader for the 834 electrical engineering team. He started with Tek in 1968 and worked with portable scope engineering before joining the data communications analyzer group. Pete received his B.S.E.E. from Oregon State in 1964. He enjoys hiking, camping, and performing with a popular singing group.

John Light was software project leader for the 834 project. He has been involved in programming since 1968. John has two degrees from Cal State at L.A. — a B.S. in Mathematics ('70) and a B.A. in Psychology ('73). He joined Tek in 1977. John's off-work hours are spent in maintaining his small acreage on which he raises milk goats, and working with his personal computer.

The data communications industry is expanding at a rapid pace, and so is the number of people involved in servicing data communications networks. Such rapid growth has made it impractical to hire and train enough technical specialists to satisfy each user installation.

An alternate approach is to train first-line technicians to a level adequate to solve most of the system problems encountered, and situate them in branch offices. They are on call by an installation in trouble. Highly-trained technical specialists, usually located at district or regional centers, back up the first-line technician, with experts at the factory providing top level support.

The Tektronix 834 Programmable Data Communications Tester is designed primarily for use by first-line technicians. Operating ease, portability, and cost are optimized for this service level. Programmability and multifunction capability make the 834 a valuable tool for the technical specialist as well.

Multifunction capability

Now let's look at some of the 834's capabilities. The instrument can perform several functions. It can monitor data flow on both sides of the communications network, that is, data from the host computer or data from a remote terminal. The 834 also enables the user to simulate data terminal equipment (DTE) or data communications equipment (DCE). Extremely flexible, the 834 can be used with asynchronous or bisynchronous byte-oriented protocols, or bit-oriented protocols such as HDLC (high-level data-link control). The 834 can confirm the condition of the carrier channel by performing bit or block error rate tests (BERT/BLERT), and can display or generate cyclical or longitudinal redundancy checks (CRC/LRC). All of these capabilities are contained in a package weighing just twelve pounds.

The technician's ability to exercise these capabilities is enhanced through the use of ROM Packs. The ROM Packs provide an extended programming set and specific and general routines, stored messages, and test patterns. Each ROM Pack has space for customer-designed routines based on the customer's application. The first-line technician can, thus, use custom programs without needing to know the details of the programming language or taking the time to enter programs via the keyboard.

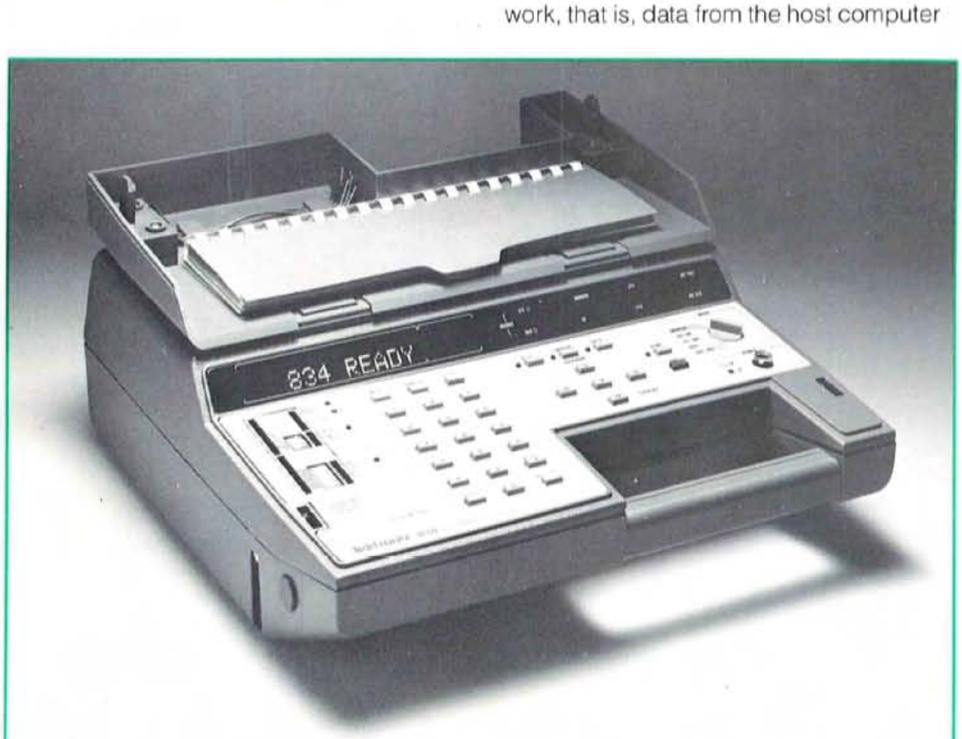


Fig. 1 The 834 Programmable Data Communications Tester.

Microprocessor control provides versatility

Microprocessor control makes the 834 extremely versatile, yet easy to operate. It also simplifies the front-panel controls. The front-panel contains four major sections: a five-position mode switch, seven-button display control, 21-button keypad, and interface access panel.

A bright, 16-character, fluorescent display is used for parameter and message display, with the four right-hand characters forming a scratch pad area for data entry and character translation. Additionally, eight individual LEDs serve as indicators for control-line status and operational references.

The 834 provides a menu to assist the user in setting up the instrument for a particular function. For example, suppose we select the MONITOR mode. In this mode, the 834 passively looks at data on the channel and can acquire up to 2699 characters from the data stream. Captured data can then be displayed on the 16-character readout.

To check the operating parameters for the selected mode, we press the SETUP button. The first setup parameter displayed is display coding. This item in the menu allows us to select how the data will be formatted for display. The default mode is EBCDIC. Pressing the ← and → buttons will display the other codes available; in this instance, EBCDIC$_{Hx}$, ASCII, ASCII$_{Hx}$, and HEX. A user-defined code can also be used. In EBCDIC and ASCII, the control characters will be decoded as 3-character mnemonics in the scratch pad area. Should we want to operate on the control character via the keypad, it would be convenient to have the character displayed in HEX. By selecting EBCDIC$_{Hx}$ or ASCII$_{Hx}$, the control characters will be decoded as hexadecimal pairs in the scratch pad area. In the HEX mode, all characters are displayed as hexadecimal pairs.

To go to the next, or the previous, setup parameter, we use the ↑ or ↓ buttons. In our example, the next parameter to be setup is baud rate. We can choose from baud rates of 50 to 19,200 bits per second. Continuing on through the setup, we can select full or half-duplex operation, half-duplex turnaround, delay, synchronous, HDLC, or asynchronous operation, bits/characters, parity and so forth.

Triggering capability

A key element in the setup procedure is defining the trigger. The precision with which we can define the trigger point often determines whether we capture the data of interest. With the 834, we can choose: to capture data preceding, following, or centered around the trigger event; whether triggering will occur on DCE or DTE data, or neither; whether to trigger on an error condition; or whether to trigger on the positive or negative transition of one of the EIA control lines. We can program a 0-to-5 character sequence or use a mask to set up a 0-to-25 character sequence (see figure 3). The ability to mask select bits when comparing the trigger character to acquired data is useful in working with bit-oriented protocols, and enables the 834 to trigger on a particular address and control-bit combination. Trigger sequences are entered from the decimal keypad which is part of the 21-button keypad.

Pressing the START button begins data acquisition. If a trigger has been programmed, the NO TRIGGER light remains on until the trigger is found. When triggering occurs, data is captured relative to the trigger event as we have programmed it. During data acquisition, data characters are displayed as they are received.

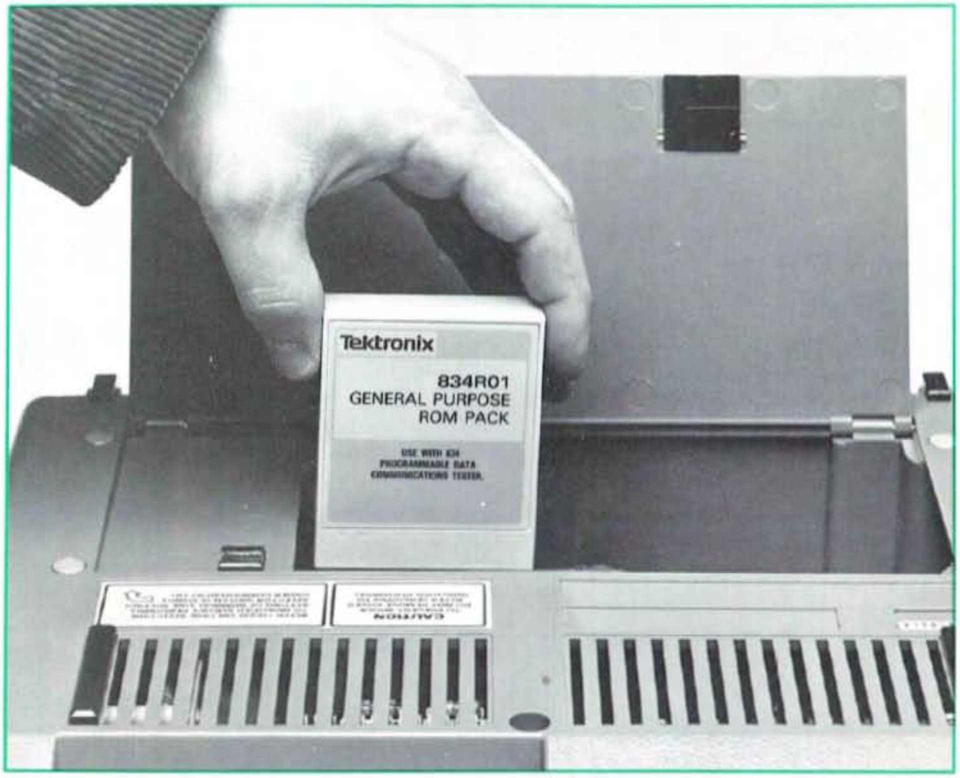


Fig. 2. Through the use of ROM Packs, the user can expand the capability of the 834 and employ programs customized for the system under test.

Source, error, and control line status also are displayed in real time.

After data acquisition, we can use the ← and → buttons to step through the capture-buffer contents. We can display any position in the buffer by entering (from the decimal keypad) the number of characters we want to shift and then pressing the ← or → button. The scratch pad area displays the hex equivalent of the right-most character in the display.

Normally, DTE and DCE characters are displayed in the order in which they are received. We can display only DCE or only DTE characters by pressing and holding the appropriate ↑ or ↓ button.

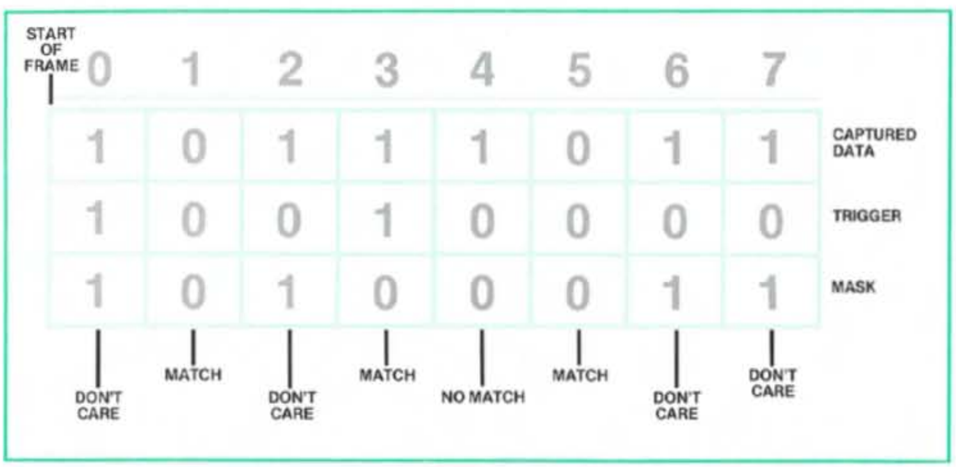


Fig. 3. A mask may be programmed to extend the 834's triggering capability. In this example, a match between data and trigger is attempted only where the mask contains a 0. There is no match, in this instance, because of the 1 in bit four.

Table 1. The basic 834 programming set includes 10 instructions. The ROM Packs provide a greatly extended set of instructions as shown here.

The programming instruction set resident in the basic 834 is as follows:

0	HALT:mm	Stop and display message MM
1	SEND:mm	Send contents of message buffer MM as a frame
2	RECEIVE	Obtain next complete data frame for processing
3	COMPARE:mm	Search frame for a match with message buffer MM
4	JUMP EQ→ss	Jump to step SS if a match is found
5	JUMP NE→ss	Jump to step SS if a match is not found
6	JUMP→ss	Jump to step SS
7	IF TIME→ss	Jump to step SS if the timer expires
8	TIMEOUT#pp	Start timer with value parameter PP
9	MASK:mm	Use message MM for mask during COMPARE operation
10	WAIT#pp	Start timer with value in parameter PP and do not proceed to following step until timer expires

The extended programming set contained in the ROM Packs consists of the following instructions:

			834R01 General Purpose ROM Pack	834R02 Bisync ROM Pack	834R03 Link Test ROM Pack
11	LOAD#pp	Load register with value in parameter PP	●	●	●
12	STORE#pp	Store register value in parameter PP	●	●	●
13	COMPARE#pp	Compare register value to value in parameter PP	●	●	●
14	INCRMNT#pp	Increment value in parameter PP by one	●	●	●
15	DECRMNT#pp	Decrement value in parameter PP by one	●	●	●
16	DISPLAY#pp	Display value in parameter PP	●	●	●
17	LOAD:mm	Load register with character from message MM	●	●	●
18	STORE:mm	Store register value in message MM	●	●	●
19	DISPLAY:mm	Display message MM	●	●	●
20	CLEAR:mm	Clear message MM	●	●	●
21	TRANSFR#pp	Invoke key sequence described by value in parameter PP	●	●	●
22	SETEIA=nn	Set EIA RS-232 control line specified by value NN	●	●	●
23	TESTEIA=nn	Test EIA RS-232 control line specified by value NN	●	●	●
24	TESTFRM=nn	Test for type of frame indicated by value NN	●	●	●
25	TESTKEY=nn	Test for keyboard input indicated by value NN	●	●	●
26	BREAK#pp	Send BREAK for length of time specified in parameter PP	●	●	
27	BCC:mm	Calculate and insert BCC for message MM	●		
28	NOP	Not available in present ROM Packs			
29	BLOCK:mm	Compare frame to message buffer MM and count bit errors			●

A colon (:) indicates that the argument to be specified is a message.

A pound sign (#) indicates that the argument to be specified is a parameter.

An equal sign (=) indicates that the value to be specified is to be used in the execution of the instruction.

An arrow (→) indicates transfer to another program step.

Simulation programming

When operating in either of the two simulation modes, the 834 provides the user a simple, data-communications-oriented programming language. This language is similar to the problem-oriented instruction sets of programmable calculators.

An 834 simulation program consists of from one to 99 program steps, one to 50 messages, and one to 50 parameters. Each program step performs a single function (send a message, search a received message, start a timer, etc.). The users must put these in proper order to solve their problem. Messages may be invoked by program steps to send, compare, display, and so forth. Parameters are numbers which may range from 0 to 9999. They are used as timer values (in milliseconds), counters, and intermediate storage for character manipulation.

The 834 firmware contains eleven instruction types which provide most of the features needed for simple simulations. Protocol ROM Packs provide additional instructions which allow more complex simulations and simplify dealing with some data simulation protocols. Table 1 provides a list of all of the available simulation instructions.

Self-test capabilities

The self-test and self-diagnostics features of the 834 greatly enhance its manufacturability and serviceability. Several levels of self-test are provided. When the instrument is turned on, the CPU, ROM, RAM and timers are tested while the front-panel lights are exercised to allow the operator to verify the functioning of the LEDs and fluorescent display. If either microprocessor finds a problem, the 834 displays a message which describes it. The power-up self-test does not test the interface circuits. An operator, suspecting that the 834 is not working properly, may turn the MODE switch to the SELF TEST position and quickly perform a series of tests that can find nearly any operational problem in the instrument. As these tests exercise nearly every instrument function, the operator can be confident that the instrument is working properly if it passes these tests.

If a problem is found in either power-up testing or confidence testing, the problem can be pinpointed easily. The service procedure defined in the Instruction Manual describes how to use a digital voltmeter

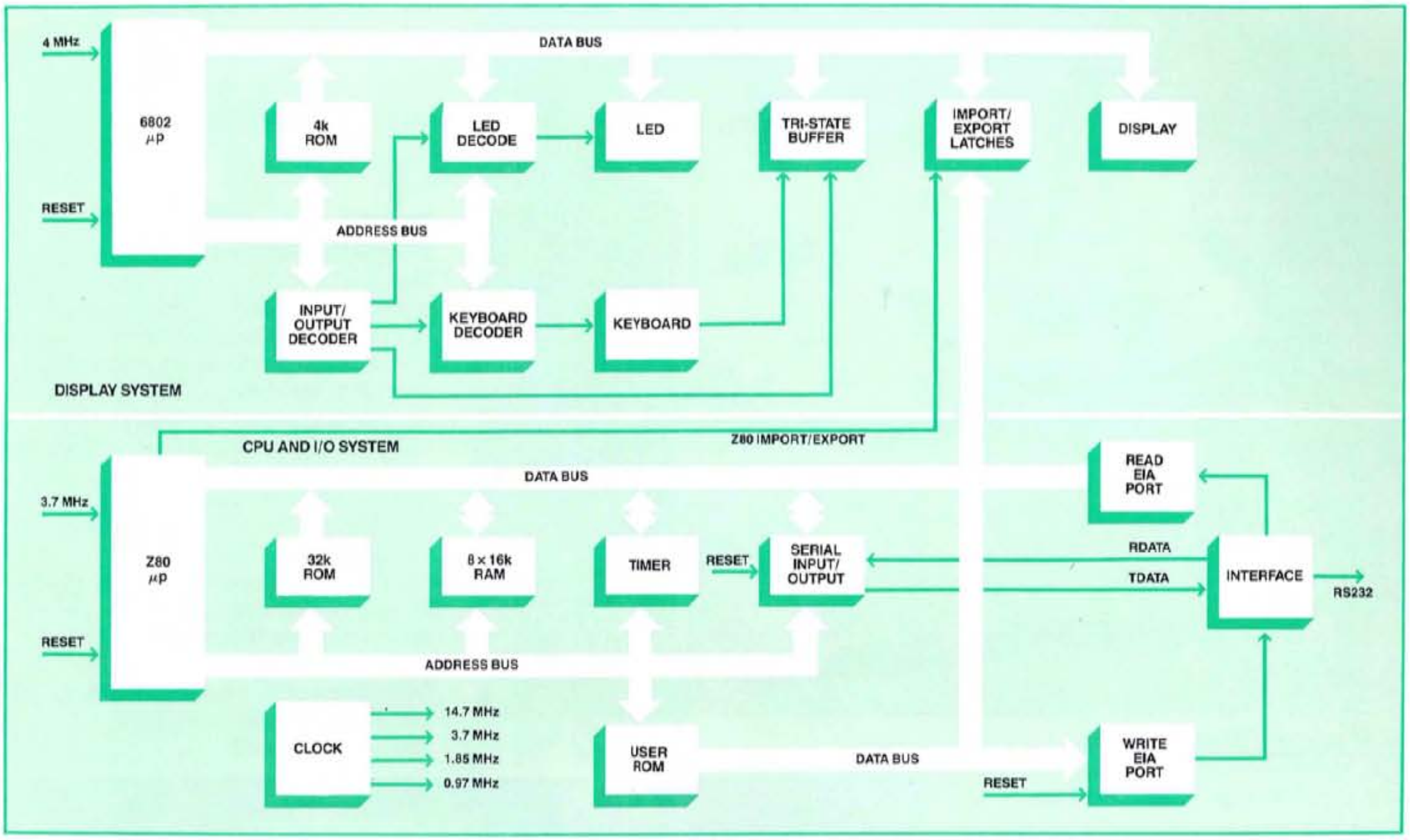


Fig. 4. Simplified block diagram of the 834. Separate microprocessors control the acquisition and display processes.

and frequency counter in conjunction with the Diagnostic ROM Pack to trace the problem to its source.

The system architecture

The 834 contains two microprocessor-controlled systems (see figure 4). A Z80 microprocessor runs the CPU and input/output system, while a 6802 (with self-contained RAM) handles the display processing.

The Z80 and 4 k of the 28 k bytes of ROM form the kernel of the CPU. The 4 k erasable ROM contains the initialization routines and power-up self-tests. Only power, a clock, and a reset pulse are needed for the kernel to function. If the kernel is functioning, the CPU can survey the rest of the 834 and identify system problems.

The 16 k bytes of RAM provide a space in which the CPU can store and retrieve data. Such data includes messages received from, or to be transmitted to, the RS-232 interface.

The serial input/output (SIO) chip plays a central role in the input/output function. It takes the 8-bit parallel data off the bus and then, under CPU control, serially transfers that data to the interface. Conversely, the SIO receives serial data from the interface and places it on the bus as parallel data.

The 834's internal timer is a programmable baud rate and interval generator which supplies transmit and receive clock signals. These signals are used in applications in which the 834 must provide its own clock or the system clock.

The interface does the signal conditioning between the RS-232 interface and the 834 I/O system. This includes shifting between RS-232 and TTL levels, decoding and encoding NRZI, selecting a timing source, and detecting transitions for the data-derived clock.

The display processor section of the 834 handles control and decoding for the keyboard, and for the LED and fluorescent displays. This section of the 834 is a complete microprocessor system containing its own 6802 microprocessor chip with on-board RAM, a 4-megahertz clock, 4 k ROM, LED drivers, and keyboard decoding.

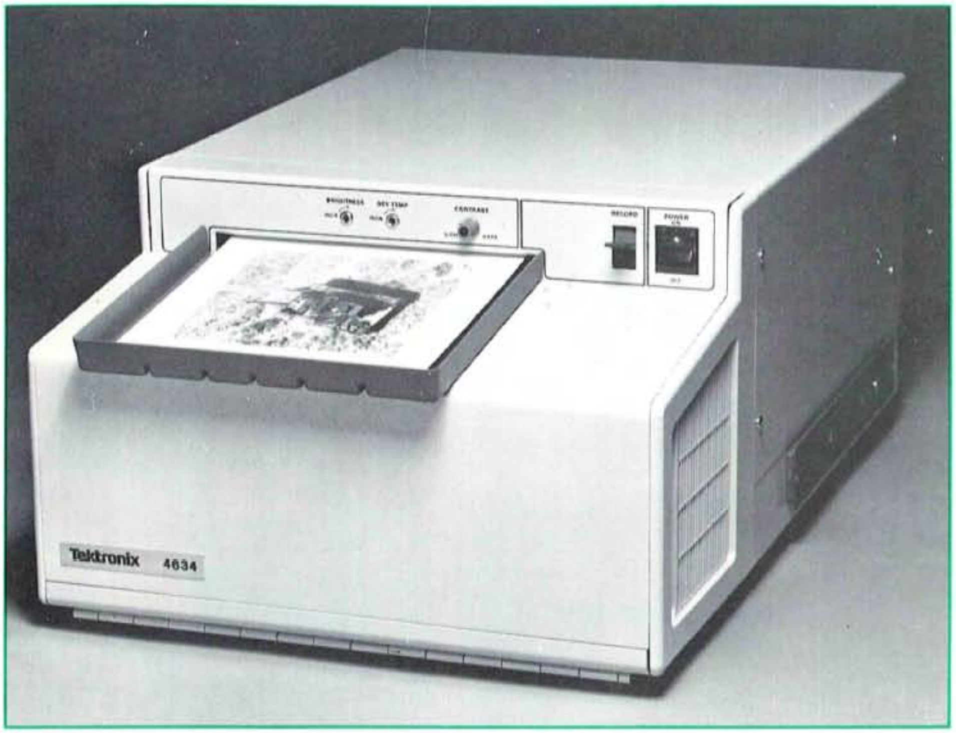
Summary

The 834 Programmable Data Communications Tester gives the user a wide range of capabilities in one compact, easy to use instrument. It is optimized for operation by the first-line technician. With the help of customized ROM Packs, the technician can perform sophisticated tests rapidly and accurately and should be able to solve most of the system problems encountered, on the first call.

Acknowledgements

We would like to express our appreciation to our cohorts in the hardware and software design teams for their individual contributions to the 834 project. Wendell Damm, project manager, provided overall direction and gave encouragement. Dave Thompson deserves special mention for his work on the service procedure, and Garth Eimers for his valuable marketing input.

High Resolution Hard Copier



4634 Imaging Hard Copy Unit

The Tektronix 4634 Imaging Hard Copy Unit produces high quality continuous tone copies from raster scan video sources in seconds. Designed to provide photographic quality images, the device is aimed primarily at digital image processing, pattern recognition, remote sensing, video disc and high resolution display environments.

The 4634 records on dry silver paper using a fiber-optic CRT. Clean and convenient, the dry copy process requires no toners or developers. The high resolution copies have a broad gray scale range (12 levels) that reveals fine image detail, and the large 6 x 8-inch image size on 8½ x 11-inch paper makes details easy to see.

The cost per copy is substantially lower than that for similar competitive units.

Front paper load and exit, and front-panel controls make it easy to integrate the 4634 into video system configurations. It is self-contained, usually requiring a single cable connection, and can be interfaced to most raster scan video sources, either analog or digital.

An automatic gain control circuit tracks the input signal, making the 4634 less sensitive to input signal variations. Image quality is thus more consistent over time, with minimum adjustment required.

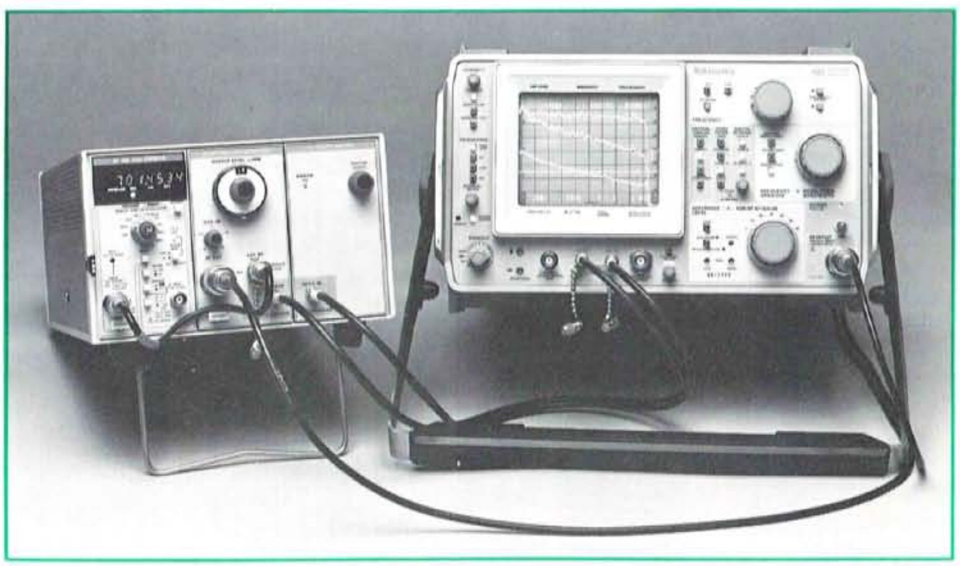
Tracking Generator for the 492-492P Spectrum Analyzers

TR 503 Tracking Generator with DC 508 Counter and 492.

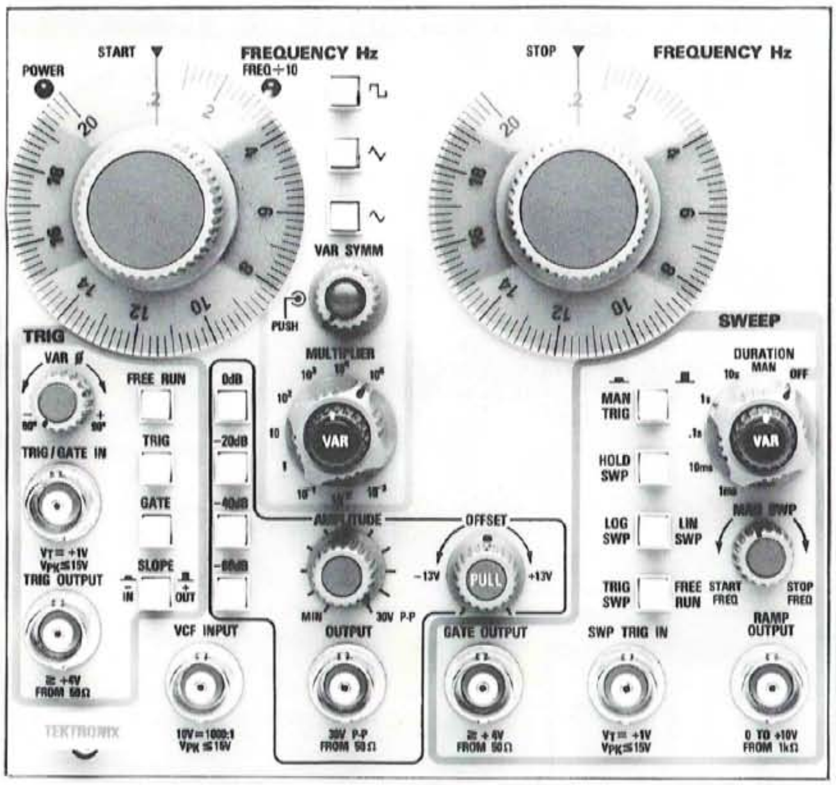
The new TR 503 Tracking Generator is designed to work with the 492 and 492P Spectrum Analyzers to provide state of the art performance in making frequency response measurements of passive and active devices, swept return loss measurements using an external passive bridge, and other applications.

The TR 503/492 has a frequency range of 100 kHz to 1.8 GHz with ±1.5 dB system flatness and 50 Hz stability.

The tracking generator is a two-wide unit compatible with the TM 500 Modular Instrument Series. When powered by a TM 503, there is room for a 1.3 GHz DC 508A or other counter for making frequency measurements with counter accuracy.



The New TM 500 Series Function Generators



FG 507 2-MHz Function Generator

Two new function generators broaden the signal generation capabilities of the versatile TM 500 Series instrumentation. The FG 501A provides low-distortion sine, square, triangle, ramp, and pulse waveforms from 0.002 Hz to 2 MHz in eight decade steps. Maximum output level is 30 V p-p into an open circuit, with up to ±13 V of dc offset from 50Ω. Waveform triggering, and gating are provided. A variable phase control permits phase shifts of up to ±90 degrees. Symmetry can be adjusted over a range of 5% to 95% to generate pulses and ramps. Pulse rise time is ≤25 ns. Pushbutton-selectable step attenuators provide 60 dB of attenuation in 20 dB steps, and a variable amplitude control provides an additional 20 dB of attenuation. A voltage-controlled-frequency input provides a 1000:1 ratio of swept frequency.

The FG 507 has all of the capabilities of the FG 501A, plus an internal sweep generator to internally sweep up to three decades of frequency with either a linear or logarithmic sweep. The log sweep allows accurate swept-frequency plots on log scales or paper. Separate start and stop frequency dials make swept-frequency measurements very easy. The FG 507 can sweep up or down in frequency, dependent on the setting of the two dials. A manual sweep capability is available also. The sweep can be free-run, or triggered either externally or manually. A sweep-hold mode allows the FG 507 to sweep to the stop frequency and remain there until released. ■

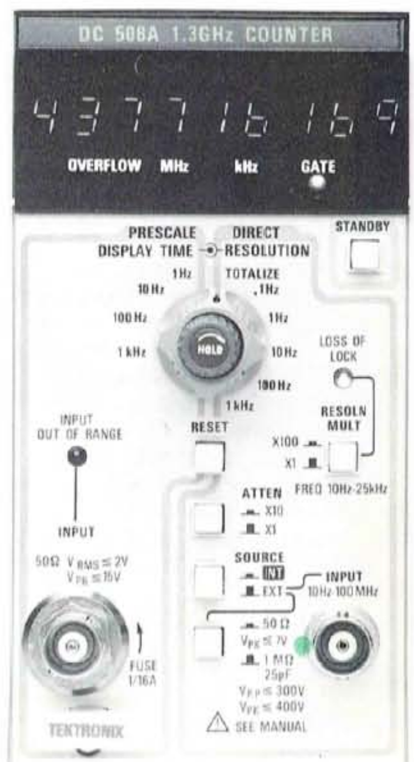
Counter Capability Extended to 1.3 GHz

DC 508A Frequency Counter

The DC 508A Counter, designed to operate in a TM 500 Series Power Module, measures frequency from 10 Hz to 1.3 GHz. The DC 508A provides a direct input for measuring frequencies from 10 Hz to 100 MHz and a prescaler input for frequencies from 100 MHz to 1.3 GHz. The DÇ 508A totalizes events from 0 to 999,999,999 over a frequency range of 10 Hz to 100 MHz.

A nine-digit display allows resolutions of 1 kHz to 1 Hz (0.1 Hz using direct input). An audio frequency resolution multiplier increases resolution by a factor of 100 times from 10 Hz to 25 kHz. This feature yields a resolution of 0.01 Hz in one second. Automatic decimal point positioning and blanking of leading zeros simplifies reading the display.

The direct input sensitivity is 15 mV RMS, and prescaler input sensitivity is 20 mV from 100 MHz to 1.1 GHz and 40 mV from 1.1 GHz to 1.3 GHz. The prescaler input has a VSWR of 2.2:1 or less and is protected by an easily-replaceable front-panel fuse. ■



A New Microprocessor Development Family

New 128-pin LSI/VLSI/Hybrid Semiconductor Test System

8550 Microcomputer Development Lab

The Tektronix 8550 Microcomputer Development Lab is the initial member of a new family of products (the 8500 Series) that will provide complete design, debugging, and integration tools for each of three major design environments: the single-user lab, multi-user lab, and host-computer operation.

The 8550 is a single-user lab and consists of two major components: the 8301 Microprocessor Development Unit and the 8501 Data Management Unit. The 8301 houses the operating system software, DOS/50, 32 kilobytes of static system memory, 32 kilobytes of static program memory, language processor, and emulator controller. Options include an additional 32 kilobytes of static program memory, the real-time prototype analyzer, and emulator processors. Optional systems software includes assemblers for all supported microprocessors, PASCAL and MDL/μ compilers for several supported microprocessors, and the Advanced CRT-oriented Editor.

The 8501 Data Management Unit handles files and auxiliary I/O for DOS/50 and manages the movement of user files between its dual-sided, double-density flexible discs and the Microprocessor Development Unit. Disc memory capacity is two megabytes.

The 8550 currently supports the following 8-bit chips: Intel 8085A, 8080A, 8048, 8049, 8041A, 8039, 8039-6, 8035, 8022, 8021; Motorola 6800, 6802, 6808; Fairchild F8; Mostek 3870, 3872, 3874, 3876; Zilog Z80A; Texas Instruments TMS9900, SBP9900; RCA 1802; and Rockwell 6500/A. Tektronix will soon offer full support, including emulation, for the Intel 8086/88, Zilog Z8001/2, the Motorola 68000 16-bit microcomputers, and the Motorola 6809 8-bit microcomputer.

The 8550 will be compatible with other members of the 8500 family. For example, the 8550 can be directly integrated into the 8560, which will be a complete microcomputer development system for up to eight work stations. Another member, the 8540 Advanced Integration Unit, will be a self-contained peripheral station that provides hardware/software integration in conjunction with a host computer. It also can be used to provide 16-bit emulation for a single-user system, like the existing 8002A.

S-3275 Semiconductor Test System

The introduction of the new S-3275 128-pin test system reaffirms Tektronix' commitment to provide test solutions in a changing and increasingly complex environment. It is consistent with our continuing support policy for our customer base.

The S-3275 features state of the art pattern generation and timing, and has an analog bandwidth unmatched in the industry. An expanded software system improves memory utilization, increases processing speed, and contains a networking option that permits the S-3275 to be interfaced to any large computer. The software enhancement is also downward compatible for all Tektronix S-3200 Series semiconductor test systems.

The S-3275 has 20-MHz functional capability and realtime error logging. The system's 128 data channels operate either as 64 input and 64 output channels, or as 64 input/output channels.

The pattern processor offers sophisticated pattern control and sequencing as well as algorithmic pattern generation. Four bits of pattern data (force, inhibit, compare, and mask) are sent by the processor to each pin electronics card at the 20-MHz rate. Force and compare pattern memories are 64 bits by 4k words deep; inhibit and mask pattern memories are 64 bits by 1k word deep.

In the algorithmic pattern generation mode, the pattern processor generates 12X, 12Y, 12Z, 16 force data, and 16 compare data bits on each cycle. The addresses can be scrambled by the topological memory (4k words by 12 bit), an integral part of the pattern processor.

The clock generator makes 16 clock phases available to the test station. Sixteen sets of timing data, including start, width, and cycle time can be programmed and selected on a cycle-by-cycle basis by the pattern processor, resulting in complex, split-cycle timing.

The networking option, an extension of the operating system software, provides the interface to user-defined mainframes. With the option, the user can interface the test system to any large computer to obtain central program management. ■

12/80 AX-4658

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

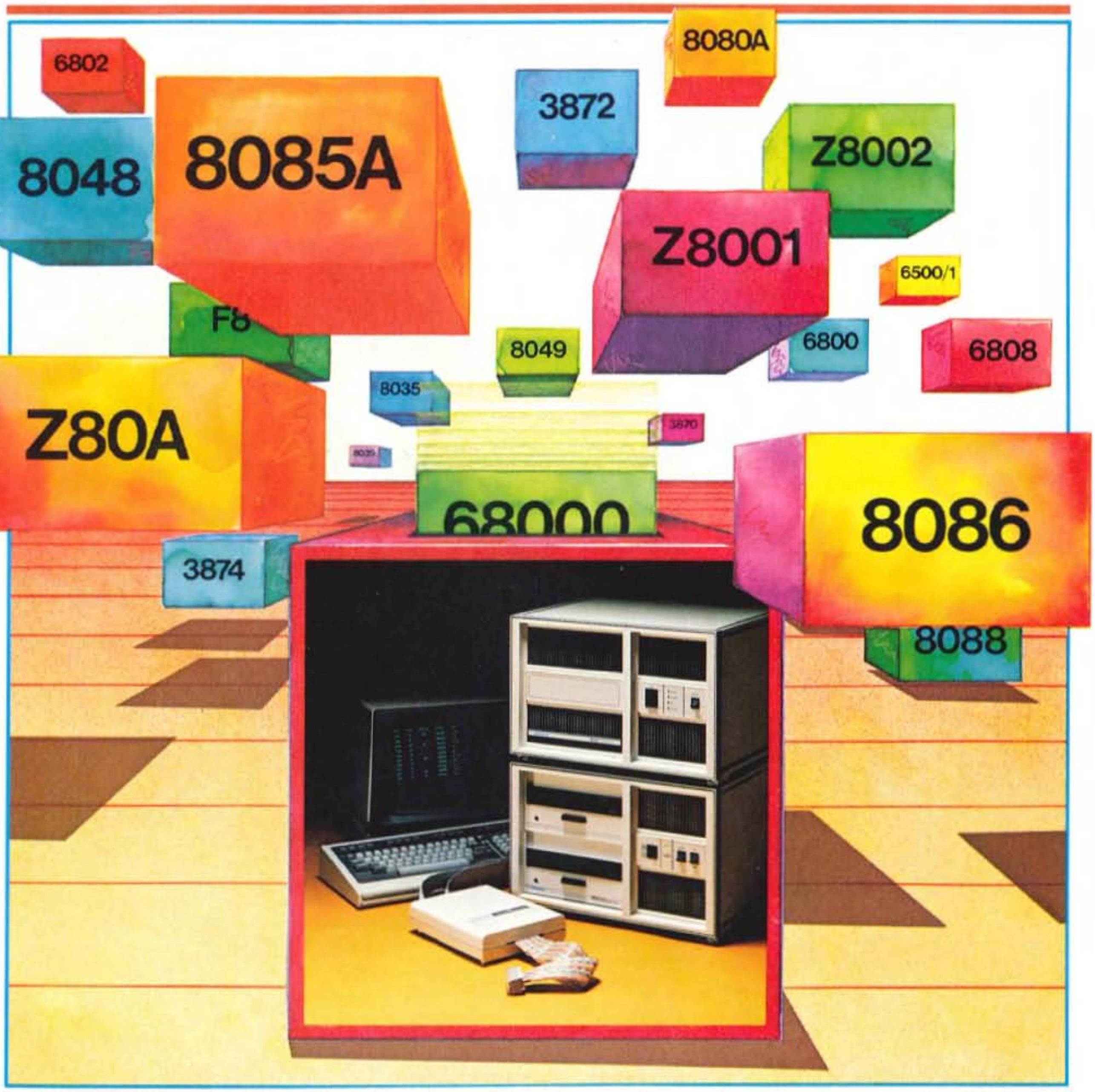
0421867 DEC 3 0 1980 1339
MR THOMAS P DOWNEY LAB TECH
GEOLOGY DEPT EPS-J106
CITY UNIVERSITY OF NEW YORK
138TH ST AT CONVENT AVE
NEW YORK NY 10031

BULK RATE
U.S. POSTAGE PAID
TEKTRONIX, INC.

TECHNICAL INFORMATION
FOR TEKTRONIX CUSTOMERS

VOLUME 13 NUMBER 1
MARCH 1981

Tekscope



Tektronix
COMMITTED TO EXCELLENCE

Tekscope CONTENTS

A Microprocessor Development Lab with an Expandable Future

The Tektronix 8550 Microcomputer Development Lab is the first member of a new family of advanced tools designed for developing microprocessor-based products. The 8550 is a self-contained single-user software development and hardware/software integration system that supports both 8- and 16-bit microprocessors.

Two New Hard Copy Units Feature Low-Cost, High-Contrast Copies

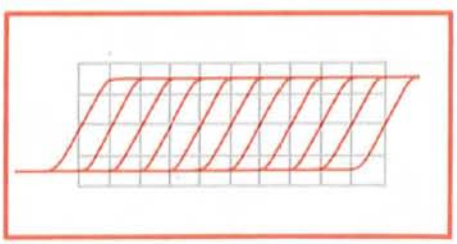
An innovative implementation of electrostatic technology uses moving-belt styli and a dry toner system to produce sharp, high-contrast copies inexpensively and with a new level of operating convenience.

Programmable Calibration Generator Speeds Instrument Checkout

Verification and calibration of complex test equipment is time consuming and requires skilled technicians. Automation of this function could save time and reduce the skill level needed. The new Tektronix CG 551AP Programmable Calibration Generator fills this role for oscilloscope users.

Slewed-Edge Signals Simplify Fast Sweep Timing

The use of high-frequency sine waves as timing signals for calibrating the fast sweeps on oscilloscopes has serious drawbacks. A new type of timing signal — the slewed-edge pulse — overcomes these drawbacks and offers a new level of accuracy and convenience.



Tektronix is an equal opportunity employer.

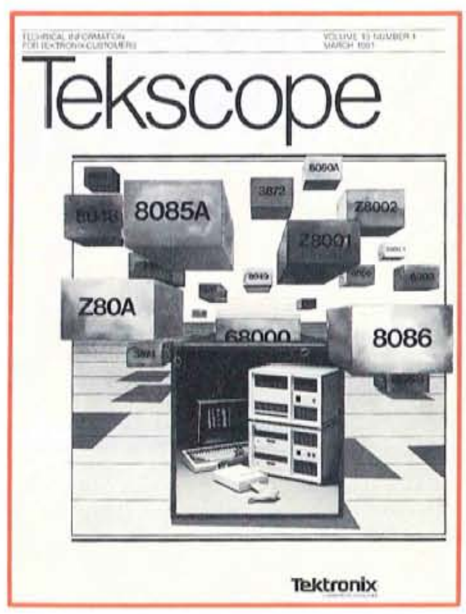
Customer information from Tektronix, Inc.
Beaverton, Oregon 97077

Tekscope is a quarterly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique.

Editor: Gordon Allison
Graphic Designer: Michael Satterwhite

Cover

The cover illustration conceptually demonstrates the multivendor capability of the new 8550 Microcomputer Lab. The 8550 supports a multiplicity of devices, 26 at present, and more in the near future. Illustration: Michael Satterwhite.



A Microprocessor Development Lab with an Expandable Future

Bob Hunter, Microprocessor Development Products Marketing manager, was educated in England, receiving his M.Sc. and Ph.D. in Digital Systems from Manchester University. He is a member of the Institute of Electrical Engineers. Bob gained extensive experience in development systems before joining Tek in 1977. After a time in Guernsey, he moved to EMC in Amsterdam as European marketing product manager for development systems, logic analyzers and communication testers. Bob moved to Beaverton and assumed his present position early in 1980. For recreation Bob enjoys racquetball and outdoor activities including hiking and camping.

Designing with microprocessors is a dynamic activity. New applications of the device appear daily. And tomorrow's processors will perform even more complex tasks. Microprocessor users must choose their design tools wisely to be able to take full advantage of the processors available today and those coming along.

As microprocessor capabilities increase, the size and make-up of design teams will change. More extensive programming will be needed to effectively put these new capabilities to work. It is important that the design tools you choose today be adaptable to your design needs well into the future. The new Tektronix 8500 Modular Microcomputer Development Lab Series is a design tool with such flexibility.

Right now, there are three major elements in the series:

- The 8550 Microcomputer Development Lab (MDL), a self-contained, single-user system that supports 26 different chips, including the more popular 16-bit processors such as the Z8001, Z8002, 68000, 8086, 8088, SBP9900, and TMS9900.
- The 8560 Multi-User Development Lab system, which contains a dedicated central computer and supports up to eight workstations.
- The 8540 Advanced Integration Unit for performing hardware/software integration in host computer environments.

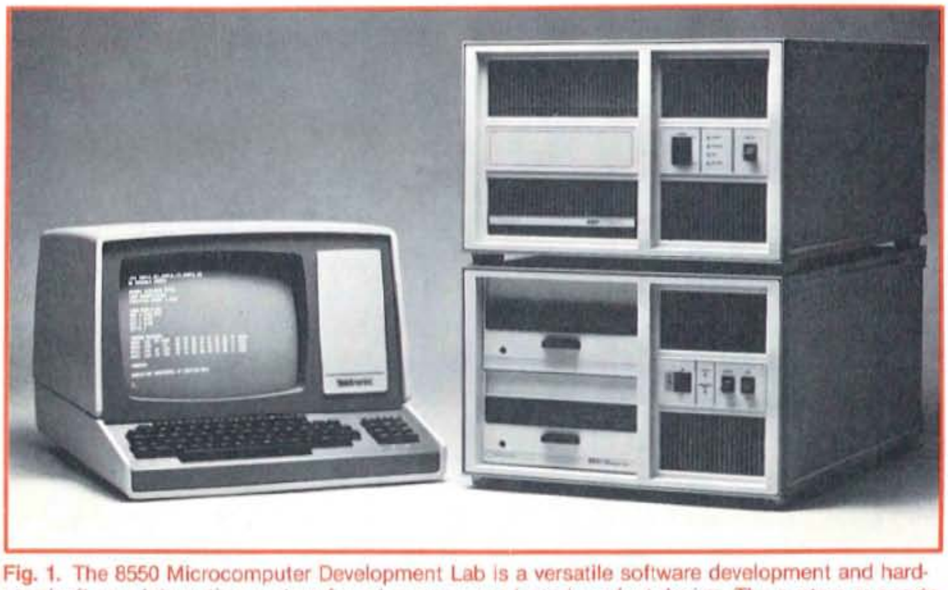


Fig. 1. The 8550 Microcomputer Development Lab is a versatile software development and hardware/software integration system for microprocessor-based product design. The system supports many popular 8- and 16-bit microprocessors.

The 8560 can accommodate up to eight users with any combination of 8550s, 8540s or any RS232C terminals. Enhanced performance is achieved with the Tektronix CT8500 Terminal.

The 8550 is available now, with the 8560 and 8540 to follow within the year.

The 8550 single-user system

The 8550 Microcomputer Development Lab (figure 1) consists of two basic units — the 8301 Microprocessor Development Unit and the 8501 Data Management Unit. Working together, these units support both software development and hardware/software integration.

The 8301 Microprocessor Development Unit houses a system processor with 32K bytes of static system memory, 32K bytes of static program memory, a language processor, and an emulator controller. There is room for plug-in hardware options such as emulator processors, an additional 32K bytes of static program memory, a real-time prototype analyzer (RTPA), and a PROM programmer. The 8301 accommodates up to 16 plug-in circuit boards.

Multiple processor architecture

The 8301 uses a multiple-processor architecture in a master-slave relationship (see figure 2). The system's controller board, serving as the master processor, runs the operating system, directs the input/output (I/O) activities for system peripherals, and directs all of the other system elements such as the emulator controller, language processor, PROM programmer, and emulator processors.

The language processor operates as a slave to the system processor and translates assembly language or high level language into machine language for the emulator processor. In addition, it runs the editors including the high-performance advanced CRT editor.

The emulator processor, which is the same type as that to be used in the prototype hardware under development, runs user programs and interfaces with the prototype hardware. Interaction between the system and emulator processors is controlled by the emulator controller under the direction of the system processor. The emulator controller ensures that only one processor has control of the system buses at any time.

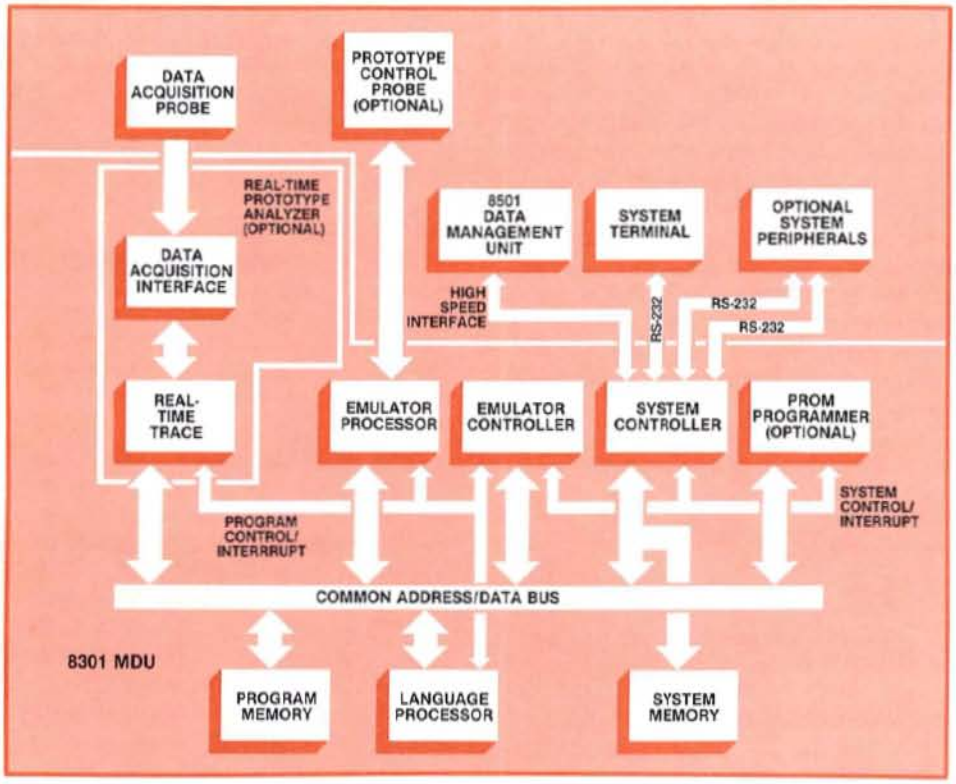


Fig. 2. Functional block diagram of the 8301 Microprocessor Development Unit. The system uses a multiprocessor architecture in a master/slave arrangement. The system processor (in the system controller) serves as the master, with the emulator and language processors serving as slaves. A high-speed interface provides rapid data transfer between the 8301 and 8501 Data Management Unit.

System bus structure

The system bus in the 8301 is a 100-line bus structure that is common to all 16 plug-in circuit boards. The bus is essentially universal in that data, address, and control lines are paralleled to all boards. The exceptions are the independent debug and interrupt lines and some control lines for the system and emulator processors (see figure 3). The separate lines result in a virtually uncrashable architecture.

The memory structure

In keeping with the multiprocessor concept of Tektronix systems, the 8301 memory is segmented. The system and program memories are identical 32K-byte static random-access memories (RAMs). The program memory is expandable to 64K bytes by adding a plug-in memory module.

The system memory is accessed only by the system processor and contains DOS/50, the operating system. The main resident part of DOS/50 is transferred into system memory at start-up, with subroutines loaded from the system disc in the 8501 Data Management Unit (DMU) as needed. The system memory also provides buffer space for I/O activities.

The primary purpose of the program memory is to store the user program during execution by the emulator processor. The program memory also provides working space for the system and assembler processors, but only during program assembly and editing activities. During emulation, all program memory is available for the target microprocessor.

The system processor has access to both system and program memories. Several operating features are available to speed up the transfer of data between memories, including direct memory access (DMA), memory-to-memory data transfer, and bank switching of 16K-byte blocks of data. A special high-speed interface port permits data transfer between the 8301 and 8501 at a 153.6 kilobaud rate.

Several emulation modes are available: mode 0, mode 1, and mode 2 (see section on emulation capabilities). When operating in emulation mode 1, a memory map function is available that allows the operator to assign 128-byte blocks of memory address space to either the program memory in the 8301 or the memory in the prototype hardware. Assignments can be made throughout a total address space of

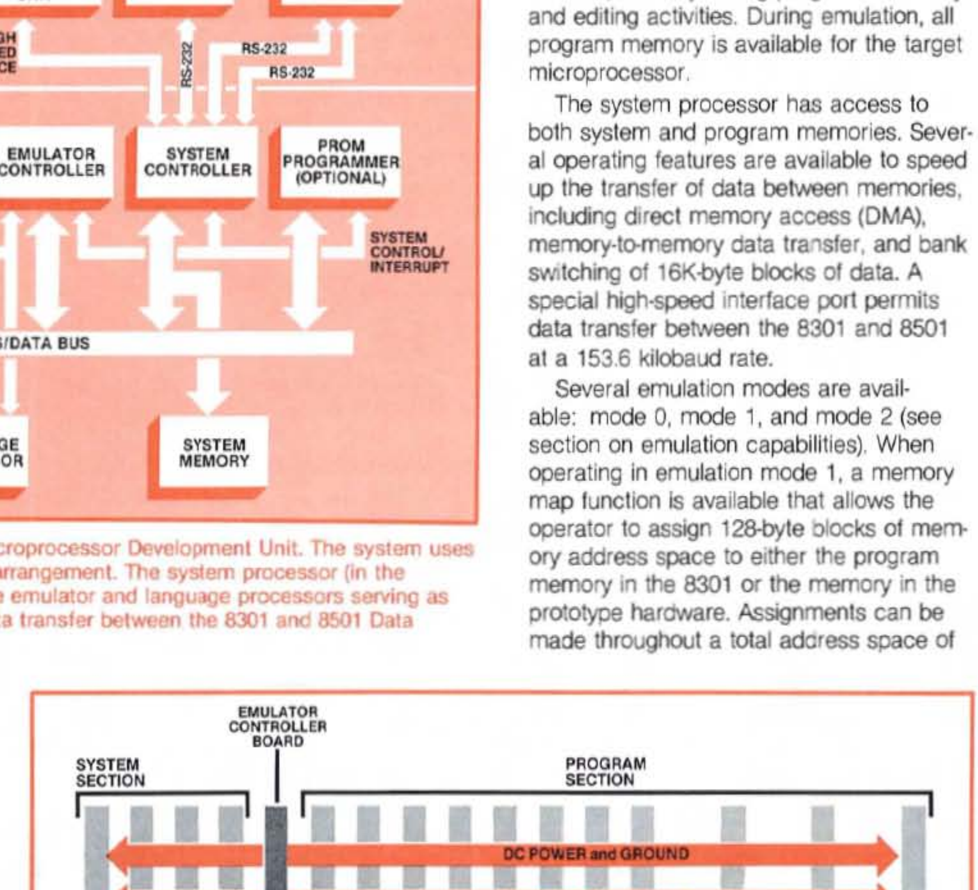


Fig. 3. The system bus consists of 100 lines that provide connection to the plug-in circuit boards in the 8301. The emulator controller board separates those control and signal lines that are dedicated either to the system section or to the program section.

64K bytes. This function also allows write protection to segments of program memory, as selected by the user.

The 8501 provides high-volume bulk storage up to two megabytes on two double-density, double-sided-disc compatible drives with DMA data transfers. A 32K by 16-bit dynamic RAM board provides temporary storage space for the file manager, device interrupts, and other functions.

The 8501 also contains two 1K-byte read-only memories (ROMs). These ROMs contain a boot-up program for loading the operating system into system memory, and a set of self-test routines that are performed at start-up to ensure the 8550 is ready for use.

The disc operating system

The 8550 uses a new operating system called DOS/50 (for Disc Operating System, 8550). While similar to TEKDOS (the operating system for Tektronix 8001 and 8002 MDLs) in many respects, DOS/50 provides several new options for arranging, manipulating, and protecting files and a number of enhanced debugging commands.

DOS/50 supervises general input and output, file creation and maintenance, program assembly and compilation, program execution, monitoring and debugging, PROM programming, and communication.

Optional software (such as assemblers) can be easily combined with DOS/50 on a master disc (which can store up to 1 megabyte) giving you the convenience of having all of the assemblers, emulators, and compilers you would normally use, on one system disc.

DOS/50 includes several other operating conveniences, such as *spooling*, which allows DOS/50 to send output to a line printer while performing other tasks; and *type-ahead*, which allows you to enter additional commands while the previous command is executing.

File management

The 8501 Data Management Unit handles files for DOS/50 and manages the movement of user files between its flexible discs and program memory in the 8301.

Data management is simplified by using a tree-like file structure (see figure 4), which allows the user to specify one main system directory, one root directory for each disc, and any number of subdirectories under the root directory. Data files may be created and entered directly into the root directory.

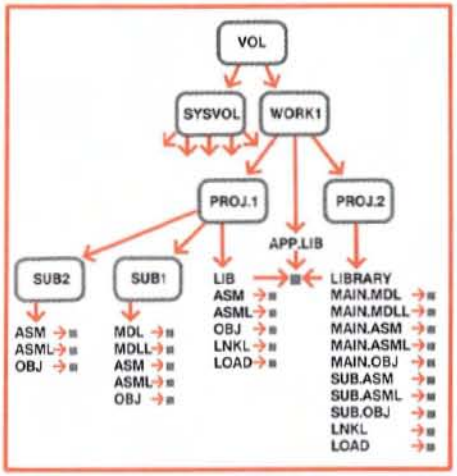


Fig. 4. An example of the DOS/50 tree-like file structure. The "root" of the tree is at the top. The rectangles represent directories, while the squares represent data files. Arrows indicate a logical connection, from which a path can be designated with a file specification.

As files are accumulated, the user may organize them into specific groups, each under its own specific directory. The user may create directories within directories to any level of nesting desired.

With extensive nesting, the file specification needed to access a specific file can be lengthy and cumbersome to use. DOS/50 includes a BRIEF command, which allows the user to specify a file by a single name. This greatly speeds up access to frequently used files.

DOS/50 also includes an extensive set of file attributes that allow the user to designate: the file owner, who can read from or write to that file, the date and time of file creation, when the file was last written to, when it was last accessed, and so forth. These attributes are especially helpful in keeping a file current when more than one user works with the file.

The assembler software packages for the 8550 offer powerful macros, library generators, linkers, and other capabilities designed to enhance the user's productivity.

Emulation capabilities

Integrating hardware and software is often the most time-consuming and frustrating task encountered in designing a microprocessor-based product. The 8550 emulator options allow integration in several stages, gradually transferring functions from the 8550 to the prototype.

Three levels of emulation are available:

- Mode 0, which uses the 8550's clock, program memory, and I/O signals to run the user's program. The prototype hardware is not needed in this mode, allowing software debugging to take place before the prototype is operational.
- Mode 1, (a partial emulation mode) uses the prototype's clock and I/O services. Some emulators also allow use of the 8550's I/O services in Mode 1. The program is run on the emulator, which may access both program memory and prototype memory. However, full control of the system is maintained by the system controller. A memory map function allows assignment of 128-byte blocks of memory address space as previously discussed in the memory structure section. The emulator can operate at full speed using either program or prototype memory.
- Mode 2, (the full emulation mode) uses only the prototype's memory, clock, and I/O facilities and runs the user program under the emulator processor's control. The user program can run at full speed, so any problems with functions involving critical timing relationships can be resolved.

In modes 1 and 2, the emulator takes the place of the microprocessor that eventually will reside in the prototype, using a prototype control probe to connect the prototype to the emulator.

The prototype control probe is a critical link in the emulation system. The ideal emulator would be transparent to the prototype hardware. That is, the prototype would function as though the microprocessor were plugged directly into its socket on the prototype hardware. In Tek emulators, the microprocessor is mounted in the prototype control probe pod, close to the prototype microprocessor socket, thus substantially reducing the loading and propagation-time effects normally associated with emulators.

The real-time prototype analyzer

The optional real-time prototype analyzer (RTPA) enables the designer to locate critical timing problems and hardware/software sequence problems in the prototype. The RTPA serves, in essence, as a logic analyzer for all data, addresses, and access control on the prototype's microprocessor socket. A logic probe provides an additional eight lines for viewing logic signals anywhere on the prototype board.

The RTPA uses a 43-bit buffer to store program information captured from the address, data, and control busses. The user has a high degree of flexibility in selecting the data to be stored. Every transaction can be stored and displayed, or a specific window can be stored and analyzed while program execution continues at full speed.

For working with 16-bit designs, a trigger trace analyzer (TTA) option will soon be available. With a 62-bit wide, high-speed buffer, it will be capable of working with bus cycle speeds up to 8 MHz, and storing up to 16 data bits, 24 address bits, 14 emulator-dependent bits, and 8 bits from external hardware. Up to four independent events can be combined in both logical and sequential combinations to form a breakpoint or data storage trigger.

The PROM programmer

The user's final step in integrating the hardware and software is committing the program to PROM and evaluating its performance in the prototype. A PROM programmer option for the 8550 will soon be available that provides the capability to burn a PROM with data from program or prototype memory, read data from a PROM into program or prototype memory, or compare the PROM's contents with the contents of memory. The 8550 PROM programmer will support the Intel and Texas Instruments 2716, 2732, and Intel 8741, 8748, 8749, and 8755 PROMs.

Conclusion

As microprocessors become more numerous and their capabilities expand, the number of people involved in putting microprocessors to work will increase drastically. Software development and hardware/software integration will become a larger part of total project design time and expense.

The microprocessor development tools you choose today should meet your design needs tomorrow. The Tektronix 8500 Modular Microcomputer Development Lab Series will give you the flexibility to expand your design system as your needs expand. ■

Two New Hard Copy Units Feature Low-Cost, High-Contrast Copies

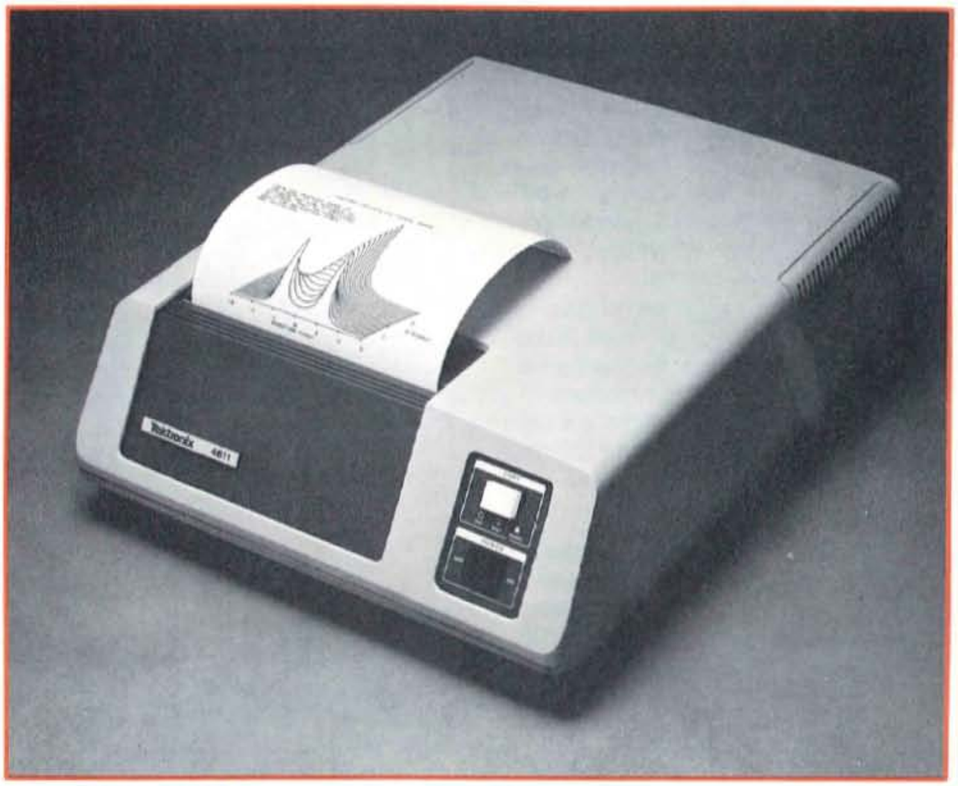


Fig. 1. The 4611 Hard Copy Unit provides fast, clean, low-cost copies of direct-view-storage tube displays. The companion 4612 provides copies from raster-scan displays or other video signal sources.

Very early in its experience with computer graphic displays, Tektronix recognized the need for what is now commonly known as a "hard copy unit" — a device that connects to a terminal or monitor and reproduces, on paper, all of the graphic and alphanumeric information that appears on the screen. The concept is to reproduce information quickly (in less than 30 seconds) and conveniently, so that the operator need only press a button to obtain a copy. This gives the operator the freedom to request copies as often as needed, with a minimum of interruption in the work flow.

Quick hard copies of this kind are excellent working documents to annotate and edit as an aid to program development and debugging. They also serve as permanent records for the file — documenting, for example, intermediate steps of an important work session with the computer terminal. High-quality hard copies are often incorporated into reports and presentations. And when you require extremely high-quality (camera-ready) output, hard copies provide a quick preview and a chance to screen information for errors before sending it to a plotter for final production. This capability becomes particularly important when the display is complex and final plotting can take several minutes.

A history of expertise in electrophotographics

Tektronix introduced its first hard copy unit in 1971, and has since developed a broad line of copiers (see figure 2). Prior to the introduction of the new 4611 and 4612, all of the Tektronix devices were based on electrophotographic technology. As the name implies, electrophotography is a photographic process, based on light-exposure techniques. Information to be copied from the display is brought into the hard copy unit and processed. Portions of the information are then displayed on a small cathode ray tube (CRT) located inside the hard copy unit. Light-sensitive paper containing a dry silver emulsion passes by the face of the hard-copy CRT, and thus is exposed to the same image as appears on the display to be copied. Bundles of tiny fiber-optic pipes keep the light from diffusing as it travels through the CRT faceplate to the paper. The paper is heat-developed, with the end result being a very crisp, clear image of the original display.

The electrophotographic technique has several advantages over other hard-copy techniques. The process uses no toner, and image quality is very high. But the technique's most important advantage is its ability to produce true continuous-tone gray shades. Most other technologies must simulate gray shading by using half-toning methods — that is, by varying the dot sizes or spacing between dots to represent different shades of gray.

The ability of electrophotography to produce true gray shading makes the Tektronix devices using this technique excel in providing working copies from sophisticated image-processing systems with twelve or more shades of gray (the 4634 Imaging Hard Copy Unit), and for providing black and white copies of raster-scan color terminal displays (the 4632 Video Hard Copy Unit).

The expansion into electrostatic technology

The new Tektronix 4611 and 4612 Hard Copy Units are based on electrostatic technology — a technique involving the transfer of an electrical charge to paper. Incoming information about the image to be copied is processed and sent to a printing mechanism which "deposits" the image in its preliminary form as tiny points of electrical charge. The charged points on the paper then attract particles of a black toner, making the image visible on the paper.

We have already discussed the advantages of electrophotographic light-exposure techniques. Why, then, expand into electrostatic technology and create the 4611 and 4612? Because electrostatic technology has some strong advantages of its own. The paper used in the process is excellent. Called "electrographic" or "dielectric," the paper has the look, feel, and handling characteristics of plain bond paper. The front side of the paper has an extremely thin plastic layer that aids in the charge-transfer process and is barely perceptible to the touch. Copies can be annotated with any kind of writing medium, including felt-tip and other liquid pens. Images are permanent with no tendency to age with exposure to heat or light.

Images made using electrostatic techniques are very high in contrast. That is, lines and characters are crisp and black on a very white background. And — perhaps the most significant advantage of electrostatics — the paper is very inexpensive, resulting in a copy cost less than one-third that of the dry silver paper used in electrophotographic copiers.

The 4611 and 4612 Hard Copy Units have all of these properties inherent to electrostatic technology. In addition, the 4611 and 4612 are based on an innovative implementation of the technology — one which brings advantages of its own. The implementation developed at Tektronix allows a lower base unit price than previously possible for an electrostatic hard-copy device. It also improves both image quality and operator convenience, and permits a very compact design. The 4611 and 4612 are only sixteen inches wide, seven inches high, and weigh just forty-five pounds.

A moving stylus for lower cost and better image

In most electrostatic copiers, charge transfer is achieved using a matrix of fixed-wire styli as wide as the paper being imaged. With up to 200 styli per inch, the manufacturing cost of this matrix and the electronics necessary to drive each stylus is high. The 4611 and 4612 use a novel approach — a moving stainless steel belt with raised styli in contact with the paper (see figure 3). This belt and the associated drive electronics are much less complex than the wire matrix and its drive circuitry, and thus less costly to manufacture. An added benefit of the moving styli is the ability to position adjacent dots with significant overlap to achieve smoother and darker lines and characters. This is illustrated in figure 4. As you can see, the line on the right is smoother and more easily integrated by the eye. This is due to high addressability (number of dots per inch) and significant dot overlap.

Dry toner for less mess and more consistent image density

Most electrostatic instruments use liquid-toning systems. Liquid toner consists of a suspension fluid (usually Isopar, a highly refined form of kerosene) containing suspended, black, charged particles that are attracted to imaged areas when this liquid is pumped against the paper. These systems have several disadvantages — the liquids are messy and inconvenient, and as copies are made, the black particles are used up resulting in a progressively lighter image. Copies can become faint and hard to read. Both concentrate and suspension fluid must be added periodically to maintain proper image density. Also, if the paper sits still for any length of time in contact with the liquid applicator, the toner seeps into the paper and leaves a gray smudge.

In contrast, the 4611 and 4612 are the first desktop terminal copiers to use dry, single-component, magnetic toner. This powder is inert and nontoxic and consists of particles that are a uniform mix of

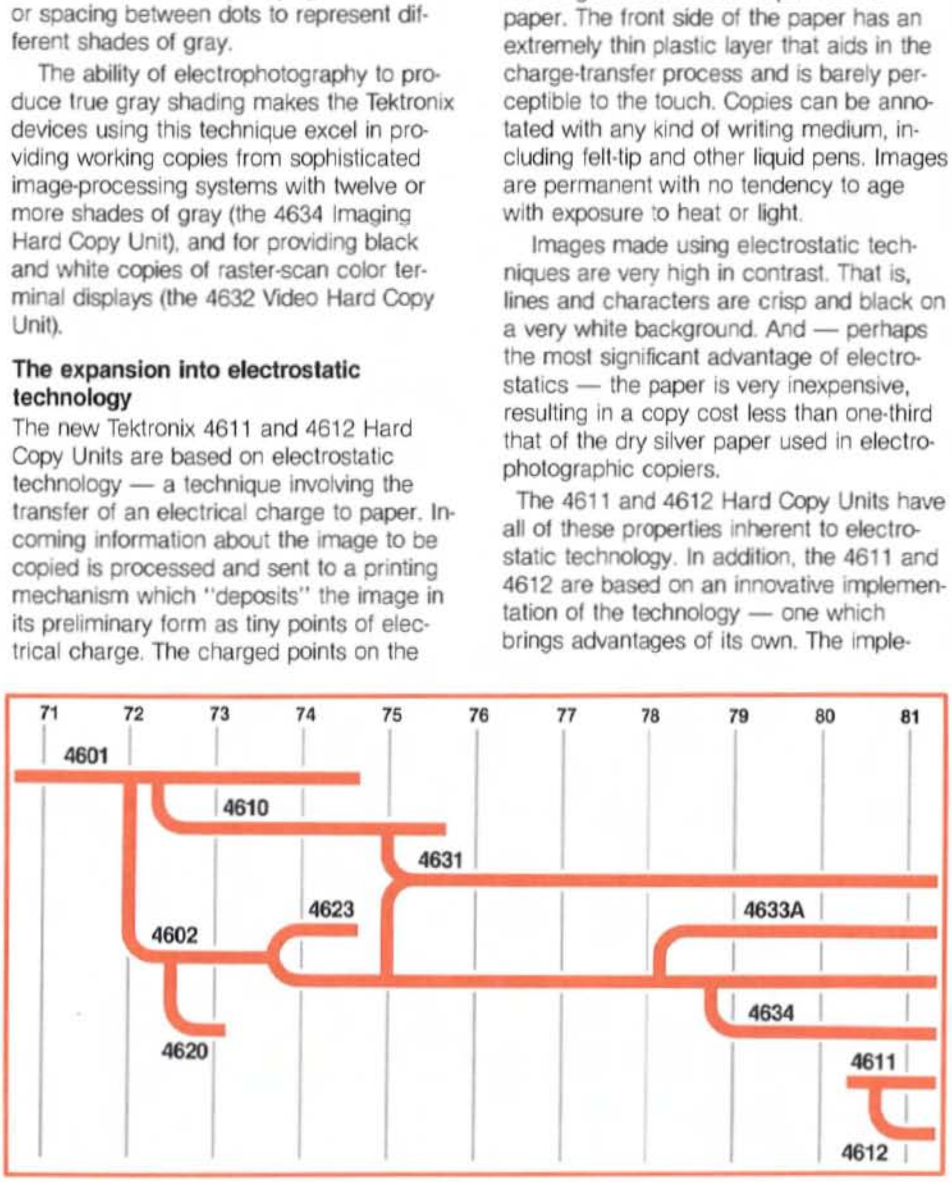


Fig. 2. The Tektronix family tree of copiers includes units that provide, in seconds, high image-quality copies of direct-view-storage tube and raster-scan displays. A line-scan recorder and a unit providing extensive gray scale (photographic) capabilities are also available. The 4611 and 4612 are the newest members of the family.

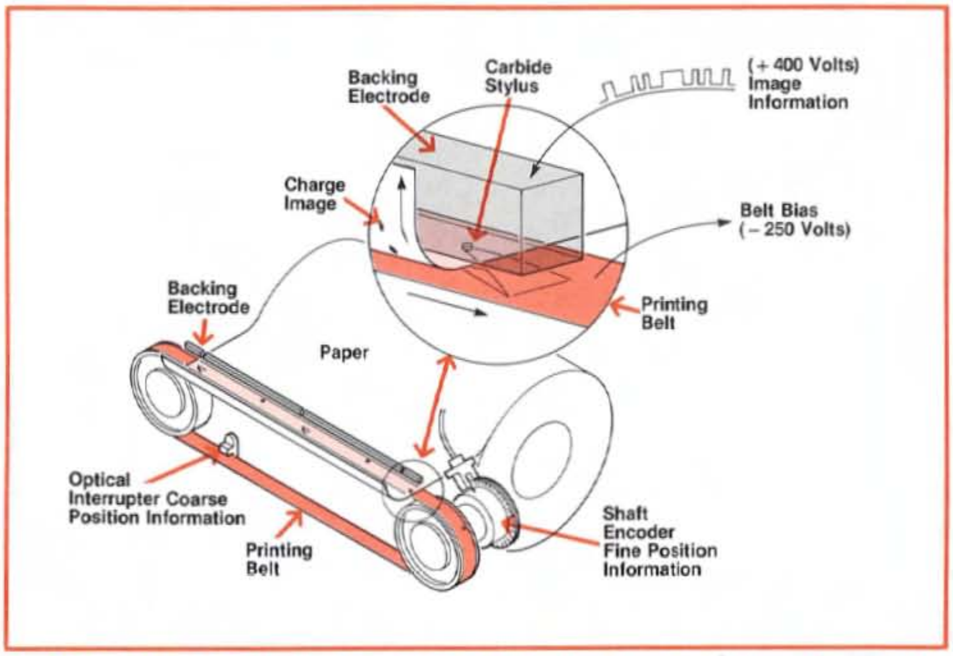


Fig. 3. The 4611 and 4612 employ a unique means of applying charge to the paper. A 0.001-inch thick stainless steel belt contains carbide styli attached to raised triangular portions of the belt. Two of the styli are in contact with the paper at any point in time.

carbon, wax, and magnetite. The most significant benefit of single-component toner is consistent image quality. As toner is used up in making copies, image density is consistent until the toner is almost completely gone. One loading of powder (about five ounces) will produce approximately 2,500 copies. Another important advantage is that there are no liquids or separate elements to mix, a major step in user convenience.

The inside story

A schematic of the 4611 and 4612 printing mechanism and charge-transfer process is shown in figure 3. A latent image is created on dielectric paper by charge transfer from a carbide stylus attached to a moving stainless steel belt. The belt scans across the paper as the paper is being pulled through the instrument, forming a raster-scan image. The 0.001-inch thick belt has raised triangular sections with a carbide writing stylus attached to the tip of each section. The belt also has square holes located in fixed relation to each stylus, to provide position-sensing by an optical detector. The belt runs on a set of 8-inch circumference crowned pulleys. One pulley is driven at approximately 2500 revolutions per minute by an induction motor, giving the belt a linear velocity of 330 inches per second. The total copy time for an 11-inch piece of paper is 24 seconds.

Two optical detectors provide position information to control image placement. One detector looks at holes in the belt, producing a signal each time a stylus starts at the left edge of the paper. The second detector looks at an encoder disc attached to the drive pulley. As the pulley rotates, output pulses from the detector provide belt linear motion and position information. The resolution of the encoder on the drive pulley gives 2048 imageable positions per eight inches of stylus travel (one revolution of the drive pulley). This arrangement is how the high addressability (256 points per inch) and dot overlap are obtained to give the line quality shown in figure 4.

Charge is deposited on the very thin non-conductive coating on the surface of the paper. Charge transfer occurs via air-gap breakdown when a potential difference of 650 volts exists between the writing stylus and a backing electrode in contact with the conductive backside of the paper. The air gap is caused by paper-surface roughness. The stainless steel belt is biased at −250 volts and the backing electrode is driven from zero to +400 volts when an image is desired on the paper. Negligible charge transfer occurs with a voltage differential of less than 300 volts.

Two styli are on the page at any one time. Using two styli requires a segmented backing electrode and slightly more complex electronics, but produces approximately twice the printing speed possible with a single stylus. The controlling circuitry monitors position signals from the two optical detectors and applies voltage to the appropriate backing electrode(s) when either stylus is in a position where image information is desired.

After receiving the charge image, the paper moves past an applicator, where single-component magnetic toner is transferred to the charged areas on the paper (figure 5). Because the toner particles are magnetic, they form chains along the lines of flux from the magnet. As the magnet rotates, these chains are brushed against the surface of the paper. Because the toner

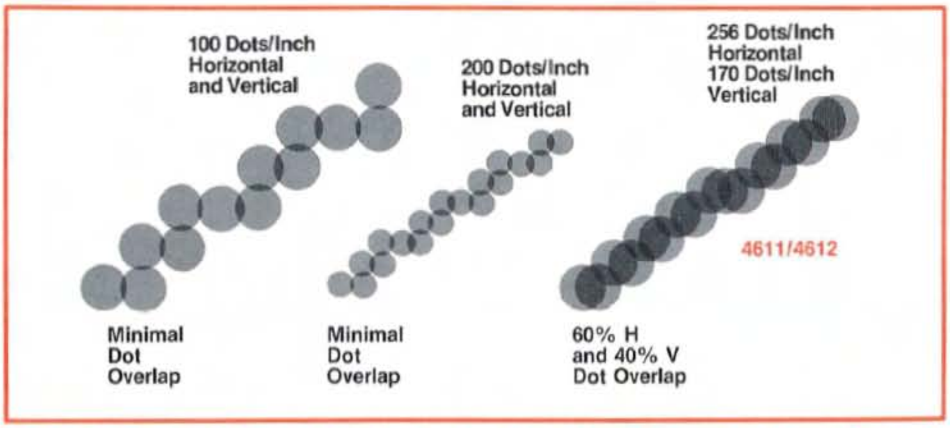


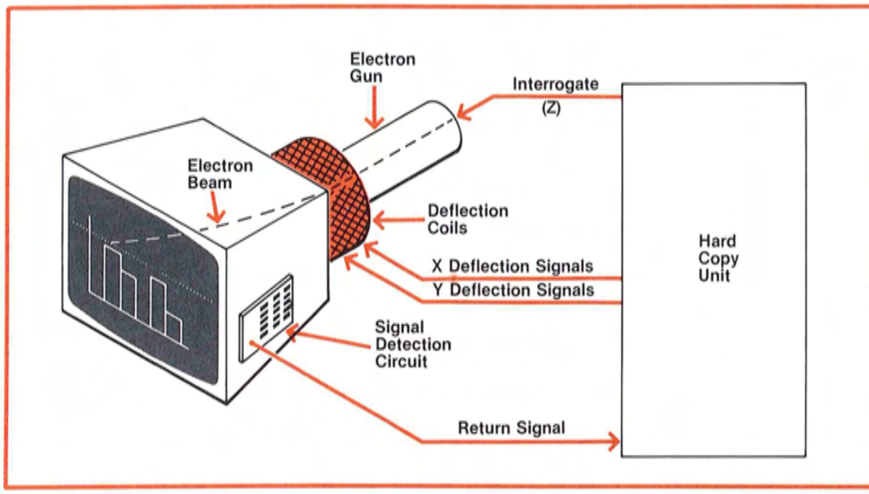
Fig. 4. Line quality is a function of dot overlap and the number of addressable points. The 4611 and 4612 have an addressability of 256 dots per inch horizontally and 170 dots per inch vertically. Dot overlap is greater than 60 percent in the horizontal direction and 40 percent in the vertical direction.

Obtaining a Hard Copy from a Cathode Ray Tube Display

It is often desirable to make a permanent copy of the information displayed on a cathode ray tube (CRT) screen. CRT hard copying is the process of transferring a temporary image from a CRT screen to a piece of paper. "Hard" refers to the ability to touch the results, and means that the image doesn't disappear when power is turned off. "Copy" means that what you see on the screen is what you want on the paper.

The first basic element of any hard-copy process is to acquire the image information.

In direct-view-storage tubes (DVSTs) the image is stored in the phosphor on the surface of the screen. This process means that we must scan the phosphor screen to obtain image information for making a copy. To determine whether any given point on the screen has stored information, we position the electron beam to that location and turn it on, but without the intensity required to store that point. A sense amplifier on the storage backplate can determine whether or not that point has stored information, because secondary emission is different for written and nonwritten areas of the phosphor. The image may be read by moving the electron beam from point to point in a raster-scan fashion until the entire screen has been covered.



In a raster-scan terminal, the image is stored in semiconductor memory and constantly refreshed on a CRT screen. The image is commonly available as a composite video signal. This signal consists of timing pulses and picture data, repeating at the refresh rate of the terminal. RS-170[1] is commonly used in the television industry for specifying format, timing, and voltage requirements of a monochrome composite video signal. The composite video provided by most CRT terminals follows the basic format of RS-170 but may vary somewhat in specific timing or voltage levels. Once you have a composite video signal and know its voltage and timing characteristics, it is fairly straightforward to sample the image information.

[1]EIA RS-170: Electrical Performance Standard — Monochrome Television Studio Facilities

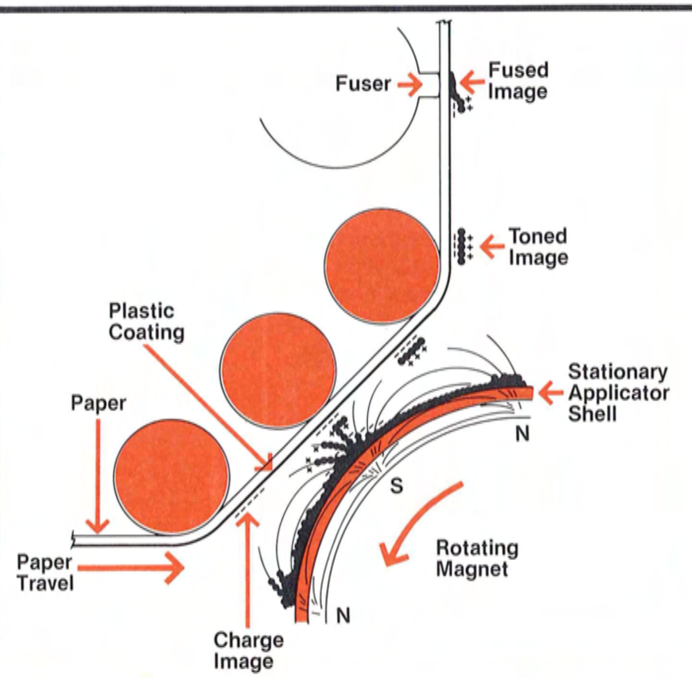


Fig. 5. A new dry toner overcomes the inconvenience and mess typical of liquid toners, and yields a uniform-density, high-contrast copy every time.

is also conductive, as the end of a chain approaches a charged area on the paper, like charges are repelled, giving the end of the chain an opposite charge that bonds toner to the charged areas. In nonimaged areas, magnetic force pulls the toner particles back to the applicator, leaving very little background. The toner particles are fused to the paper by heat from a metal fusing bar contacting the backside of the paper. This bar rotates downward when the copier is quiescent to prevent excessive heating of the paper. This action also prevents the operator from being able to accidentally touch the hot surface when loading paper.

The benefits of a modular design

An outline drawing of the assemblies in the 4611 and 4612 is shown in figure 6. All major sections of the instrument can be assembled and tested separately. This capability provides significant benefits for both field service and the manufacturing line. Repair time in the field is much shorter because almost any failure can be fixed by

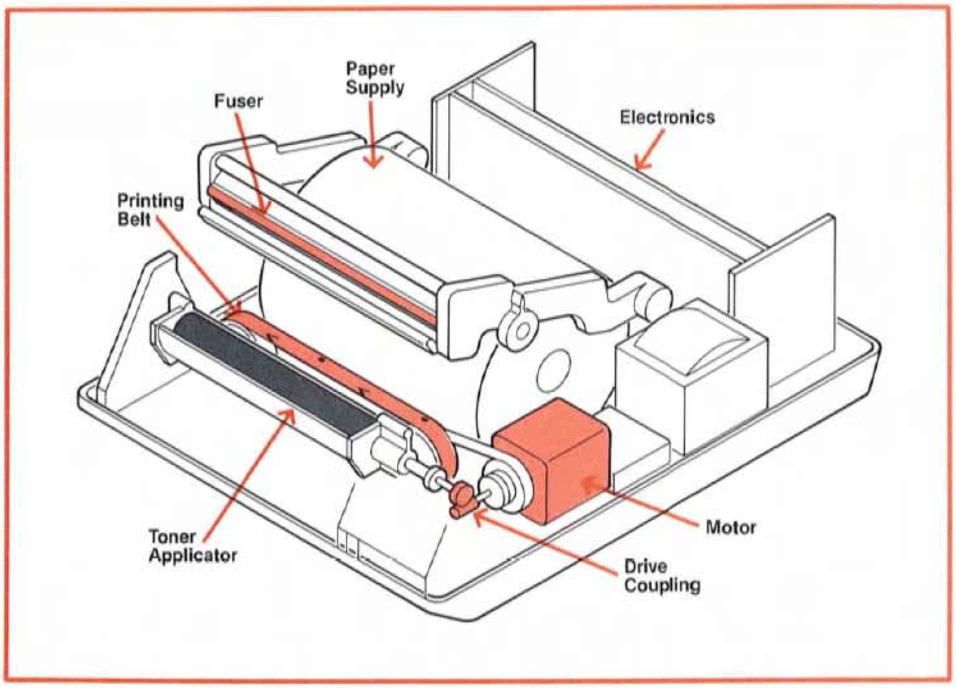


Fig. 6. The 4611 and 4612 consist of several subassemblies which are built and tested as individual modules. Modular design and construction simplifies both manufacture and service.

merely exchanging assemblies. On the manufacturing line, modularity allows for an efficient division of labor. Those items that require precision assembly are produced at the module level, independent of the flow of final instrument assembly. This technique simplifies final assembly to mainly coupling together completed subassemblies.

An emphasis on reliability

Attention was given to reliability at every design phase of the 4611 and 4612. Steps taken included subjecting critical mechanical components to extensive life-tests to detect possible failure modes and correct them, implementing well-established procedures for elevated-temperature life testing of the electronic circuitry, and putting early production instruments through environmental and life tests to ensure that the 4611 and 4612 would meet or exceed all design goals prior to start of product shipment.

The aluminum die-cast top and bottom instrument covers used on the 4611 and 4612 are examples of the commitment to product reliability. Although more expensive than plastic or structural foam, the die castings offer several advantages that offset the extra cost. Internal heat rise is an important reliability factor. The power-supply heat-producing elements in the instruments are tied directly to the bottom casting. Because of the excellent heat conduction and radiation properties of aluminum, and the large area of the top and bottom covers, no cooling fan is required. Good electrical shielding, greater structural strength, and smaller size are other benefits derived from using aluminum castings.

Summary

The 4611 and 4612 Hard Copy Units employ unique electrostatic technology to produce sharp, high-contrast, permanent images of direct-view-storage tube, raster-scan, and other video displays. With their ease of operation and low copy cost, the 4611 and 4612 are ideal complements to the Tektronix 4630 Series of high image quality copiers.

Acknowledgements

Pete Unger and Jon Mutton were responsible for developing the product concept. The mechanical design was the work of Larry Petersen, Eldon Hoffman, David Kreitlow, Jim Beehler, Tom Sjordal, Bob Neimeyer, and Maria Lochmann. The electrical engineering team included Sam Gordon, Larry Shorthill, Arthur Tobin, Willard Harrison, and Bruce Petrick. Others, too numerous to mention, also made valuable contributions to the project. ■

Cathy Cramer is the marketing product line manager for graphic hard-copy devices. She joined Tek following graduation from the University of California at Irvine with a B.A. in mathematics in 1975. Cathy wrote technical documentation for the 4051 Graphic System, then moved to graphic computing systems as a marketing product specialist working on the team that introduced the 4052 and 4054 Desktop Computers.

Tom Peekema is an engineering manager in the graphic hard-copy group and was project manager for the 4611 and 4612. He received his B.S.E.E. from Washington State University, joined Tek in 1974, and has worked in several areas of the Information Display Division. He leads a very busy personal life enjoying flying, soaring, puzzles, playing the piano, billiards, and racquetball.

Programmable Calibration Generator Speeds Instrument Checkout

Bob Oswald, project leader for the CG 551AP, joined Tek in 1974, feeling more at home with the lush greenery of western Oregon than with the desert beauty surrounding Scottsdale, Arizona. Bob received his B.S.E.E. from Michigan Technological University in 1964 and completed his M.S.E.E. in 1970 at Arizona State. He has worked on several TM 500 projects since joining Tek. In his leisure hours, Bob enjoys flying, woodworking, and silk-screen printing.

Electronic systems pervade our commercial, industrial and defense activities. Effective maintenance of these systems requires large numbers of skilled personnel and test equipment. However, the use of automated checkout procedures and equipment can substantially reduce the time required to maintain these electronic systems.

Programs are now underway in the armed services to extend automated checkout to maintenance of the test equipment, itself. The goal is to reduce the time and skill level required to verify calibration of test instruments used in large numbers.

The Tektronix CG 551AP Programmable Calibration Generator was developed to meet such a need. Designed primarily for oscilloscope calibration, it is also useful for checking other test instruments.

The CG 551AP packs all of the signals (except sine waves) needed to characterize oscilloscope performance, into one small, rugged package. Included are calibrated timing signals from five seconds to 0.4 nanoseconds, voltage amplitudes from 40 microvolts to 200 volts, current outputs from 1 milliamp to 100 milliamps, and fast, clean edges with risetimes of 200 picoseconds or less (using the Programmable Pulse Head accessory).

Fig. 1. The CG 551AP Programmable Calibration Generator provides six different types of signals useful in checking or calibrating oscilloscopes.

The CG 551AP is intended for use in a test system that uses the IEEE-488 General Purpose Interface Bus (GPIB) and a controller.

In a typical operation, the operator employs a program prepared for the particular oscilloscope under test. The program instructs the operator, via the controller display, how to set the oscilloscope controls. The controller then programs the CG 551AP (via the GPIB) to output the appropriate test signal to the oscilloscope. The CG 551AP display shows the parameters of the test signal selected. If the oscilloscope parameter being checked is not in perfect calibration, the operator manually adjusts a control on the CG 551AP's front panel so that the CG 551AP's output matches the oscilloscope's calibration. The percent of deviation from the standard, and whether the oscilloscope setting is slow, fast, low, or high, is displayed on the CG 551AP readout. The data from the CG 551AP's display and the CG 551AP's control settings can be sent (via the GPIB) to the controller and then to a hard copy unit to produce a permanent calibration record.

Microprocessor based control

The CG 551AP's system architecture is designed around the Motorola MC6800 microprocessor. The MC6800 was chosen because its capabilities best meet the requirements of the CG 551AP, and a family of support chips was available to handle the input/output, GPIB interface, and other elements of the design.

A block diagram of the central processing section of the CG 551AP is shown in figure 2. Firmware instructions for system operation occupy four kilobytes of read only memory (ROM). Eleven-bit addressability provides the capability of storing up to 8,192 instructions.

Temporary storage for programming operations is provided by one kilobyte of static random access memory (RAM). A smaller section of RAM (256 bytes) contains CG 551AP calibration constants, default values, and other data that need to be preserved when the instrument is powered down. A battery supplies power to this RAM during power down.

The microprocessor interfaces to the GPIB through an MC68488 general purpose interface adapter. Two kilobytes of ROM store instructions for the GPIB function.

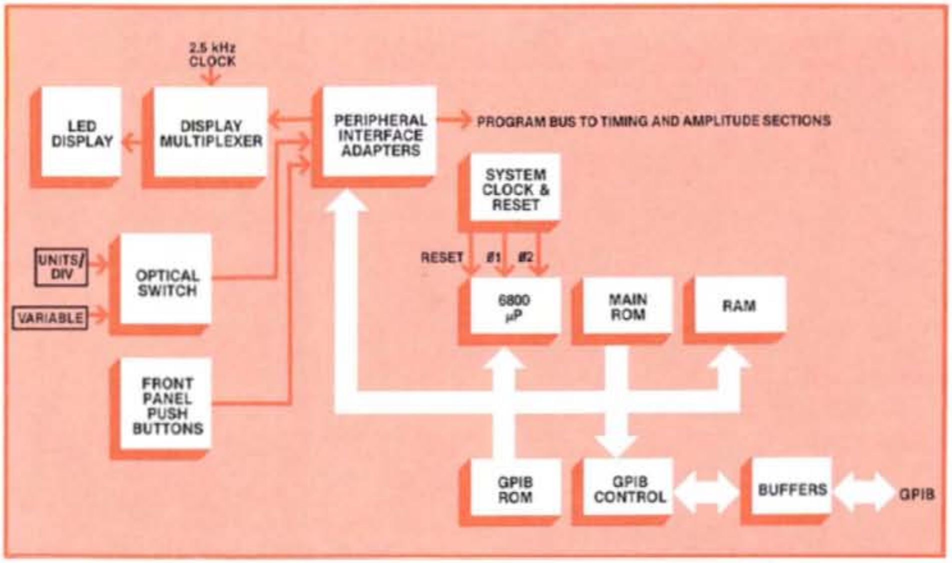


Fig. 2. Simplified block diagram of the central processor section of the CG 551AP. The CG 551AP is designed for use with a controller that communicates via the General Purpose Interface Bus.

Communication between the microprocessor and the CG 551AP front-panel controls is via an MC6821 peripheral interface adapter (PIA). Another MC6821 provides interface with the amplitude, edge, and timing circuits.

The front-panel TIME/DIV and VARIABLE controls use an optical switch to generate a Gray-code signal. (Gray-code is a binary code in which sequential numbers are represented by binary expressions, each of which differs from the preceding expression in one place only; for example, 0000, 0001, 0011, etc.). The optical switch contains two Gray-encoded discs. When the operator rotates either control, the slotted discs interrupt a light source that illuminates four photocells. Output from the photocells provide position information to the microprocessor, which thereby determines which control was turned and in which direction. As the control rotates, the microprocessor increments or decrements an internal firmware counter and programs the amplitude or timing section to produce the appropriate output.

When a front-panel control or push button is changed, or when a command is received via the GPIB to change the front-panel settings, the microprocessor responds by sending serial data from memory to control data registers in the timing and amplitude sections of the CG 551AP. The serial data in each data register is latched to parallel output stages by high-level strobe signals. The latched data determines the characteristics of the output waveform to be generated by the CG 551AP.

Low noise generation a must

To produce clean, low-level amplitude signals and jitter-free high-speed timing signals requires a design that limits the extraneous noise coupled into the analog circuitry. Several CG 551AP design elements reflect this concern, specifically the use of:

- serial data transfer in the analog sections,
- a separate power supply for the central processing unit,
- shielding of amplitude section power supplies, and
- shielded, multicompartment, aluminum castings for the timing circuitry.

Powering up only the circuitry needed to perform a given function reduces power consumption, limits internal temperature rise, and eliminates potential sources of noise.

The timing circuitry

A simplified block diagram of the timing and amplitude circuitry is shown in figure 3. The main timing generator provides the timing signals for all modes of operation. The 100 MHz main VCO output drives the time mark generator circuitry, while the 1-MHz reference oscillator serves the dual function of reference frequency for the main VCO and timing source for the chopping circuitry in the amplitude section.

The main VCO operates at a nominal center frequency of 100 MHz and is phase-locked to the 1-MHz reference oscillator. The frequency of the main VCO is changed in 100 kHz steps over a range of ±9.9 percent by the front-panel VARIABLE control. The purpose of the main VCO steering loop is to set the main VCO to the correct harmonic of 100 kHz; once this is accomplished, the steering loop disconnects and the sampling loop takes over to keep the main VCO on that harmonic.

Time markers covering the range from 10 ns to 5 seconds are derived from the 100 MHz main VCO frequency by using countdown circuits. The markers are shaped to provide optimum resolution, with equal rise and fall times and a base width of about four percent of the period. When operating in the MAG X10 mode, every tenth marker is increased in amplitude for convenience in checking the timing and linearity of magnified sweeps. For checking fast sweeps, a technique called "slewed-edge" timing is used to generate timing signals from 0.4 nanoseconds to 100 nanoseconds. The slewed-edge technique is discussed in an article on page 14.

The amplitude section

The standard amplitude calibrator (SAC) section of the CG 551AP provides voltage and current amplitude signals over a range of 40 microvolts to 200 volts and 1 milliamp to 100 milliamps, respectively. Pulses with clean, fast risetimes for checking oscilloscope vertical amplifier response also originate in the amplitude section.

Two floating power supplies — low voltage and high voltage — provide dc operating voltage for the SAC circuitry. Each supply can be enabled independently to power-up only those circuits needed for the function programmed.

A reference data register and floating data register accept and store serial data from the microprocessor, to set up the SAC circuits. A programmable voltage reference, which includes a multiplying digital-to-analog converter, converts a 10-bit digital signal to an equivalent dc analog voltage. This voltage is applied to a programmable precision resistive divider which provides a choice of eight voltage levels. The output of the divider goes to a level translator (not shown)

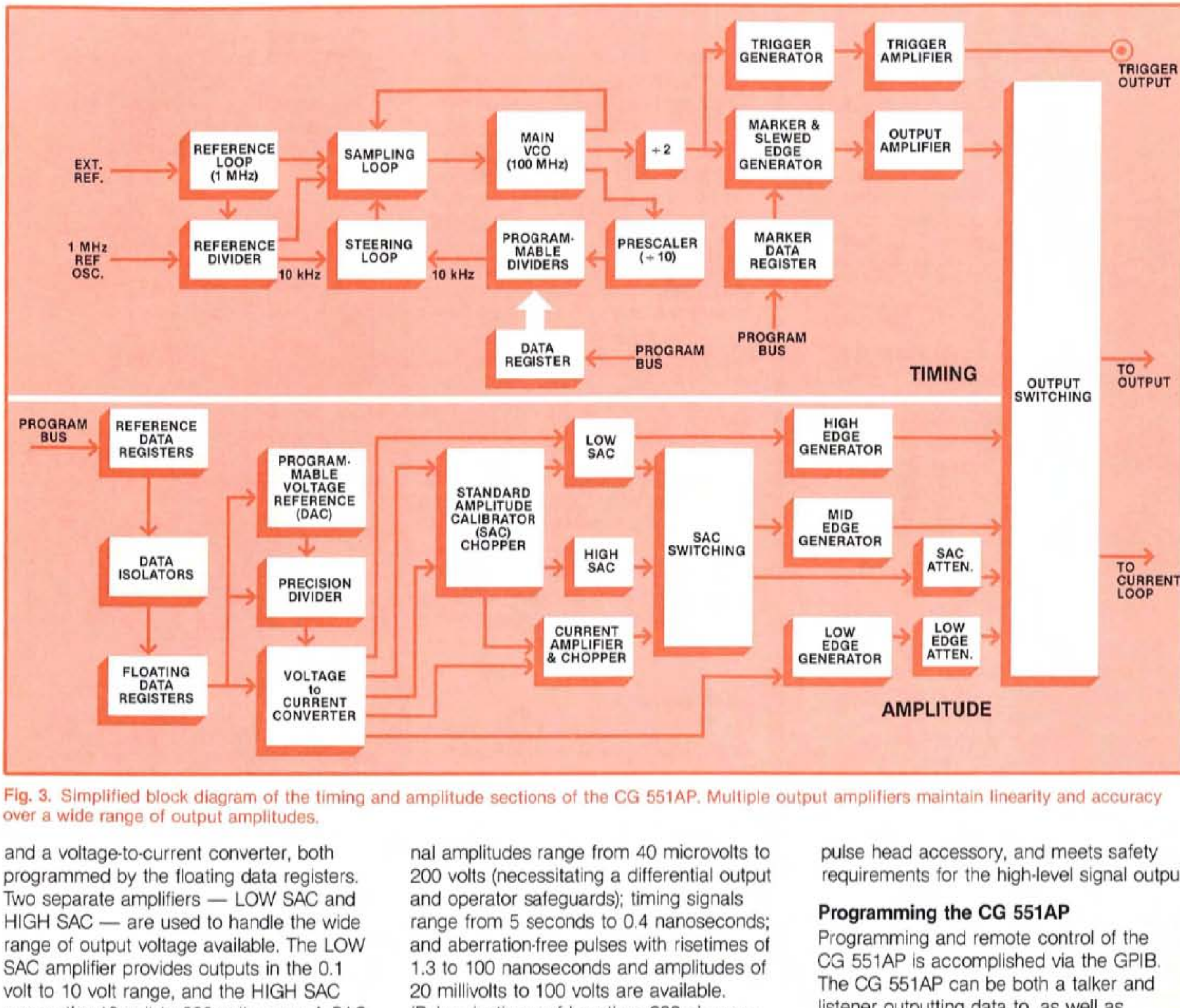


Fig. 3. Simplified block diagram of the timing and amplitude sections of the CG 551AP. Multiple output amplifiers maintain linearity and accuracy over a wide range of output amplitudes.

and a voltage-to-current converter, both programmed by the floating data registers. Two separate amplifiers — LOW SAC and HIGH SAC — are used to handle the wide range of output voltage available. The LOW SAC amplifier provides outputs in the 0.1 volt to 10 volt range, and the HIGH SAC covers the 10 volt to 200 volt range. A SAC attenuator provides precision attenuation of the signal to generate voltages from 80 millivolts to 40 microvolts.

Three separate amplifiers are used to cover the wide range of edge signals and maintain fast, clean outputs.

A single output connector

To make a programmable calibration system truly effective, all of the calibrated output signals from the calibration generator should be available at a single output connector. In the case of the CG 551AP, this task was no small undertaking. Output signal amplitudes range from 40 microvolts to 200 volts (necessitating a differential output and operator safeguards); timing signals range from 5 seconds to 0.4 nanoseconds; and aberration-free pulses with risetimes of 1.3 to 100 nanoseconds and amplitudes of 20 millivolts to 100 volts are available. (Pulse risetimes of less than 200 picoseconds are available using a programmable pulse head accessory that plugs into the output connector).

To handle this wide range of signals, a magnetic latching relay was designed which uses a contact structure similar to that developed for Tektronix cam switches. A matrix of these relays provide programmable switching of the various signals to the single output connector.

The output connector, itself, required considerable design effort. It provides a floating output for differential signals, supplies +10 volts and −10 volts for the pulse head accessory, and meets safety requirements for the high-level signal outputs.

Programming the CG 551AP

Programming and remote control of the CG 551AP is accomplished via the GPIB. The CG 551AP can be both a talker and listener outputting data to, as well as receiving set-up instructions from, the GPIB controller.

All of the CG 551AP output functions are programmable using either high-level or low-level remote control messages. High-level messages are sent in ASCII and the CG 551AP responds in ASCII. Low-level messages begin with an ASCII control character followed by data in 8-bit binary bytes. Low-level commands require much less space in the controller's memory than do high-level commands. However, only the functions of changing the 13 basic settings and the setting query (SET?) are implemented in low-level language.

Self test capabilities

To assure the operator that his calibration system is functioning properly, the CG 551AP performs extensive self-test routines. When power is applied, self-test routines check the internal memory, internal shift registers, conditions in the timing and amplitude sections, and calibration constants saved in the battery-maintained section of RAM. Almost eighty error codes are available for display on the CG 551AP's readout, to pinpoint circuit malfunctions or programming errors.

Summary

The CG 551AP can generate most of the signals needed to characterize an oscilloscope's performance. It is intended for use in a calibration system employing the IEEE-488 GPIB and a controller. The programmable signals are brought out to a single front-panel connector, greatly expediting the calibration function. The CG 551AP is designed to meet both commercial and military needs for a reliable, accurate, programmable calibration source for automated instrument checkout.

Acknowledgements

Many people made valuable contributions to the CG 551AP project. I would like to give special recognition to Mike Mihalik and Dave Hiltner for their work on the firmware; Ed Cleary, David Simmen, and Hakon Flogstad for the timing section; and Tim Flegal, Dave Hiltner, and John Bolonio for the amplitude section. Scott Hollister was responsible for the mechanical design. ■

Slewed-Edge Signals Simplify Fast-Sweep Timing

Most modern oscilloscopes are designed for pulse-type applications. They are optimized to provide a clean transient response, solid triggering on pulse-type signals, and fast sweeps for resolving pulse timing relationships.

Typically, it is difficult to accurately calibrate the faster sweeps on oscilloscopes because of limitations imposed by the calibration signals available. Many calibration generators use a 1-megahertz, crystal-controlled oscillator as a reference frequency source. Frequency multipliers are then used to generate the higher frequency time marks, which are output as sine waves. Usually, the higher the output frequency, the lower the signal amplitude, and the more predominate the subharmonic content in the signal.

The vertical amplifier bandwidth of the oscilloscope being calibrated often can't pass these high-frequency sine waves, resulting in a very limited display amplitude of the calibration signal. The subharmonic distortion present in the test signal is magnified under these conditions, making accurate calibration even more difficult.

A new approach

The Tektronix CG 551AP Programmable Calibration Generator uses a different technique to generate fast timing signals. This slewed-edge technique uses the leading edges of fast-rise pulses as time markers.

The slewed-edge circuitry generates a series of paired pulses. The first pulse in each pair is the trigger pulse — the second is the slewed-edge pulse. The trigger pulse starts the oscilloscope's horizontal sweep. The circuitry then generates the slewed-edge pulse so that the leading edge of the pulse is displayed on the first vertical graticule line on the cathode ray tube (CRT). The pulse length is such that only the leading edge appears on screen.

After a period of time sufficient to let the sweep run and be reset, the circuit generates another trigger pulse. The next slewed-edge pulse is delayed so that it is displayed at the second vertical graticule line (one sweep division) on the CRT. On each subsequent sweep, the delay between the trigger and slewed-edge pulse advances the displayed edge one sweep division. This procedure continues until a slewed edge is displayed for each sweep division (see figure 1). The slewed-edge pattern is repeated at a rate that produces a flicker-free display on the oscilloscope under test.

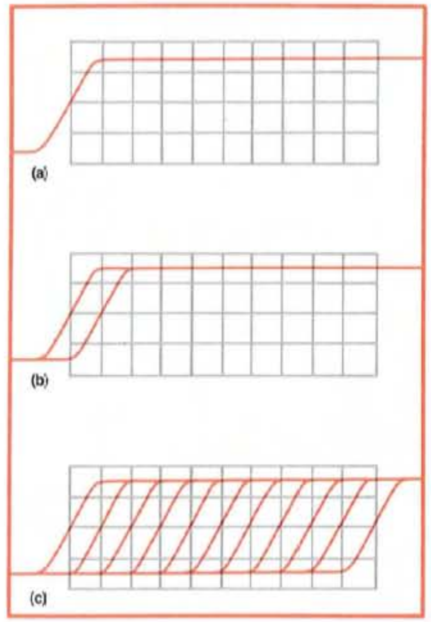


Fig. 1. A single slewed edge is displayed during each sweep. Subsequent slewed edges are delayed from the trigger pulse by linearly-increasing increments of time to produce a display similar to that shown in (c) above.

The slewed-edge circuits

A simplified block diagram of the slewed-edge circuit is shown at right. The generation of slewed edges requires two oscillators running at slightly different frequencies. A 100 MHz variable reference clock supplies timing for the circuit. The reference frequency is divided by two to obtain a trigger clock with a time period of 20 nanoseconds (50 MHz). An offset VCO, phase locked to the trigger clock timing source, generates a slewing clock with a time period of 20.5 nanoseconds (48.78 MHz).

The periods of both the trigger and slewing-edge clocks are divided further before the pulses are generated. The microprocessor calculates the divider values based on two requirements: the period between trigger pulses must be greater than the sum of the sweep run and holdoff times (in the CG 551AP, maximum holdoff time is arbitrarily selected as 3500 nanoseconds); and the incremental delay time between the trigger and slewed-edge pulses must provide a spacing of one sweep division between each pair of displayed pulses. The time base setting to be calibrated determines what the delay between the trigger and slewed edge pulses should be. The trigger and slewed-edge dividers each contain two sets of values (or counts), referred to as initial and offset counts. The initial counts are used to generate only the first pair of trigger and slewed-edge pulses, and are usually calculated so the trigger and slewed-edge pulses are generated simultaneously.

The offset counts are used to generate all subsequent pairs of trigger and slewed-edge pulses, and are calculated to allow a delay of one sweep division between the displayed edges.

With a trigger clock period of 20 nanoseconds and a slewed-edge clock period of 20.5 nanoseconds, we have a 0.5 nanosecond time difference between the leading edges of the two clocks. If we count multiple cycles of both clocks we can select any multiple of 0.5 nanoseconds we desire. For example, four counts of the trigger clock equals 80 nanoseconds and four counts of the slewing clock equals 82 nanoseconds, for a difference of two nanoseconds. In selecting the initial counts, we must calculate counts for the respective clocks that will result in a period of 3500 nanoseconds or longer and also result in time coincidence of the two clocks. Choosing an initial count of 205 for the trigger clock divider and 200 for the slewed clock divider results in coincident trigger and slewed pulses after 4100 nanoseconds (205×20 ns $= 200 \times 20.5$ ns $= 4100$ ns).

If we want to generate a delay of two nanoseconds between the trigger and the slewed-edge pulses, the microprocessor must select offset counts of 209 for the trigger clock divider and 204 for the slewed-edge clock divider.

After the microprocessor selects the counts for the dividers, the sync signal starts the counters in the trigger and slewed-edge dividers at the instant when the trigger clock and slewing edge clock pulses are coincident. With the initial trigger divider count set at 205 and the slewed-edge divider count set at 200, the first trigger and slewed-edge pulses are generated simultaneously. Without stopping the counters, the control logic switches the dividers to the offset counts (209 and 204), which causes the second slewed edge to occur two nanoseconds after the second trigger pulse. Retaining the same offset counts increases the delay between the trigger and slewed-edge pulses by two nanoseconds on each sweep. That is, the third slewed edge is delayed four nanoseconds after the third trigger pulse; the fourth slewed pulse is delayed six nanoseconds after the fourth trigger pulse, and so on.

The process continues until 15 slewed-edge markers have been generated. At this point, the edge counter directs the control logic to stop generating edges. When the control logic receives the next sync signal, the slewed-edge pattern is repeated, starting again with the initial counts of 205 and 200.

The shift feature

In an oscilloscope, there is an inherent delay between the trigger and the start of the sweep. A delay line is inserted in the vertical signal path to compensate for this delay. At the faster sweeps, the two delays usually do not match exactly. The result is that the slewed-edge pattern may appear to be shifted to the left or the right on the screen.

The CG 551AP has front-panel push buttons that allow you to shift the slewed-edge pattern to the left or right one sweep division at a time. Internally, the shift is accomplished by modifying the initial counts in the trigger and slewed-edge dividers to adjust the delay between the first trigger pulse and the first slewed-edge pulse. The shift capability is also useful when calibrating magnified sweeps.

Summary

The slewed-edge technique offers a convenient, precise method of calibrating the faster sweep speeds typical of today's oscilloscopes. The slewed-edge signal may well become a standard feature on calibration generators of the future. ■

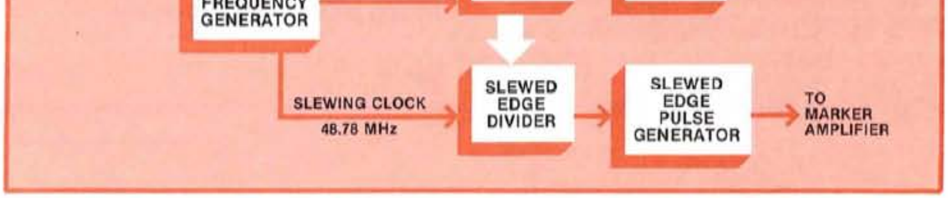
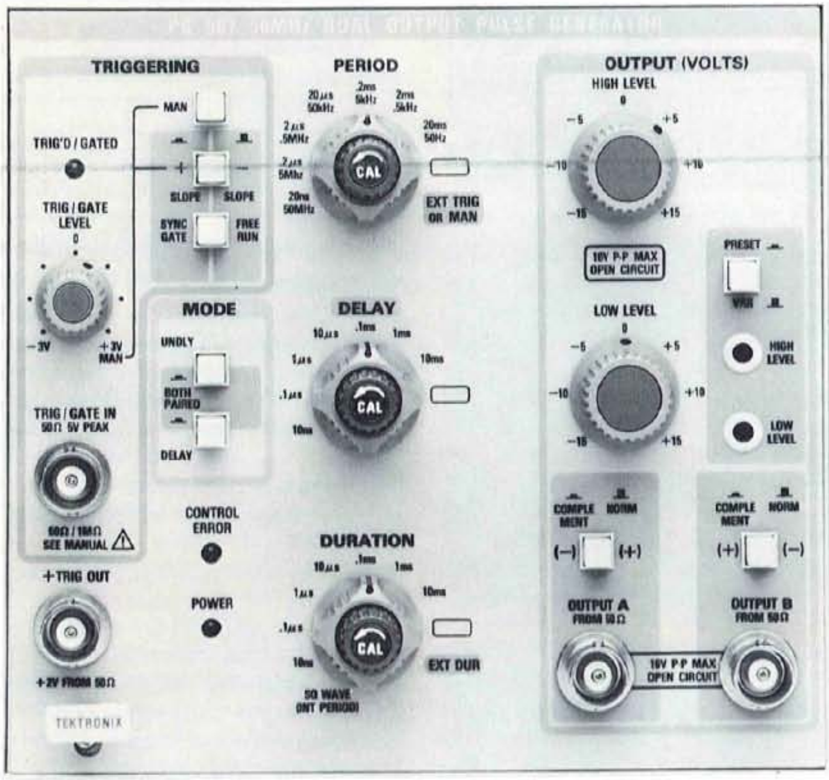


Fig. 2. Simplified block diagram of the slewed-edge circuitry. The outputs of two clocks running at slightly different frequencies are divided down to produce precise, short time intervals between the trigger and slewed-edge outputs.

New Products

A New Pulse Generator for the TM 500 Series



PG 507 50-MHz Dual Output Pulse Generator

The PG 507 adds new capability to Tektronix' pulse generator line — simultaneous, normal or complementary dual pulse output at frequencies up to 50 MHz. Dual pulse outputs are useful in many applications, such as digital line driver simulation, control circuit testing, differential amplifier testing, and multiplexer design.

The PG 507 uses the versatile input and timing circuitry of the PG 508, and adds a second output in place of the variable rise/fall time capability. Output amplitude is adjustable up to 7.5 V p-p into 50 ohms and 15 V into an open circuit. High and low level output controls allow you to position the output pulses in ±7.5 V and ±15 V windows, respectively. Pulse risetime is 3.5 ns into 50 ohms.

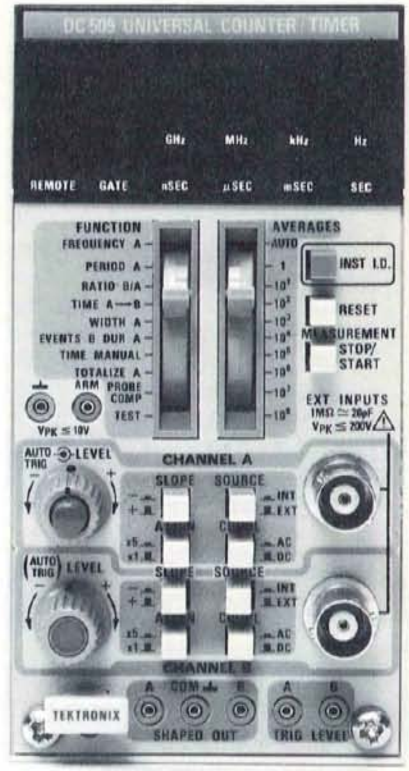
You can select pulse periods from 20 ns to 200 ms and pulse durations from 10 ns to 100 ms. Jitter is 0.1% + 50 ps. The PG 507 can be gated or triggered externally or manually, or be free run. A three-state trigger light tells you whether the input trigger level is above or below the TRIGGER/GATE LEVEL control setting, and flashes when the PG 507 is being triggered. It, thus, can serve as a logic probe as well as being an operating convenience. ■

New High Performance Universal Counter/Timer

The new DC 509 Universal Counter/Timer is a microprocessor-based, dual-channel instrument that can perform single-shot time-interval measurements with 10-ns resolution. With measurement averaging, you can achieve 1-ps resolution.

The DC 509 performs eight measurement functions including frequency, period, ratio, width, time A to B, events B during A, time manual, and totalize.

Frequency measurements to 135 MHz are made on channel A using the powerful reciprocal counting technique, which provides high resolution measurement of low-frequency signals much more quickly than do conventional counting techniques. ■



DC 509 Universal Counter/Timer

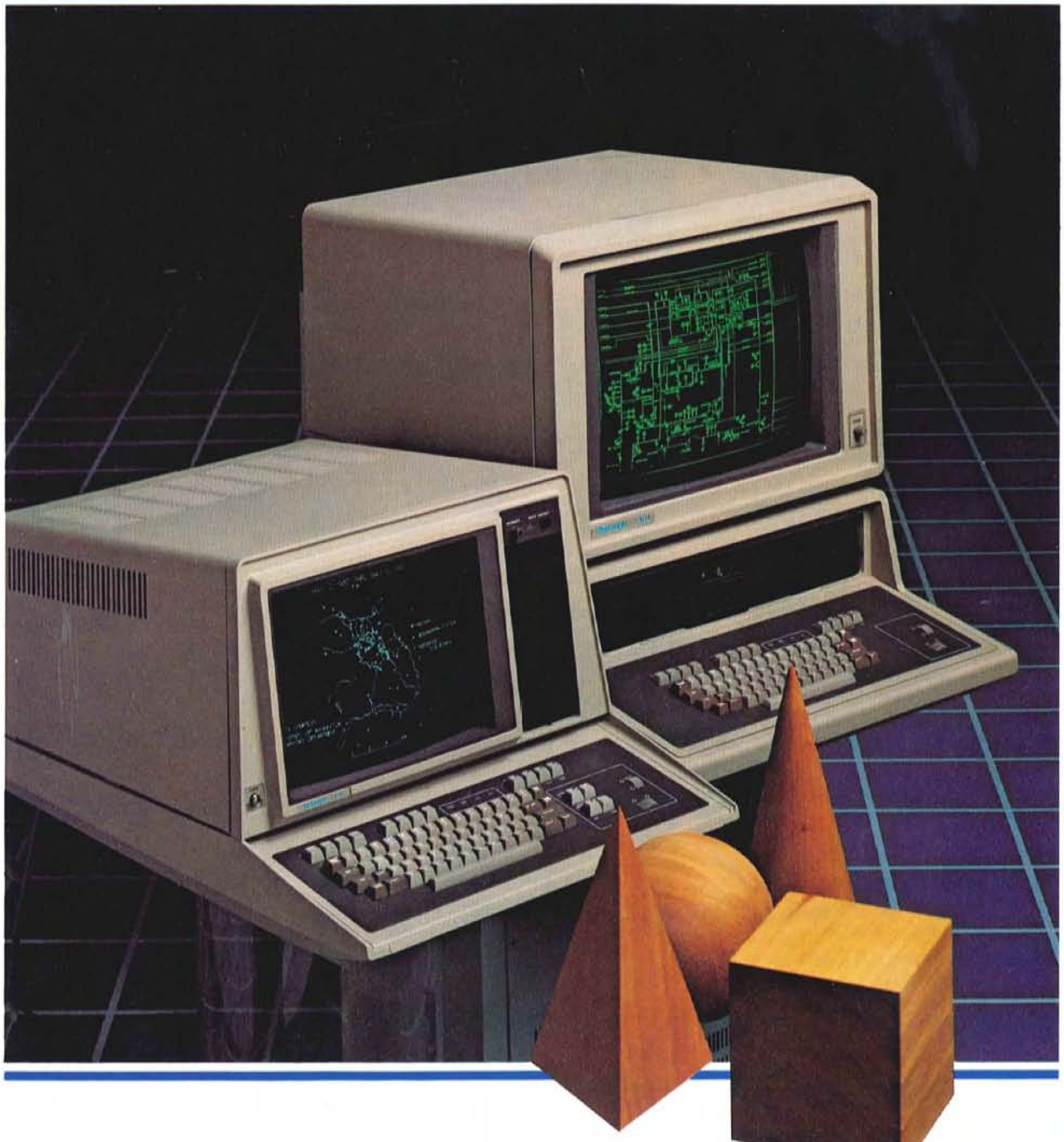
3/81 AX-4659

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

TECHNICAL INFORMATION
FOR TEKTRONIX CUSTOMERS

VOLUME 13 NUMBER 2
JUNE 1981

Tekscope



Tektronix®
COMMITTED TO EXCELLENCE

Tekscope CONTENTS

Two New Graphic Terminals Expand Graphic Capabilities

High resolution, color-enhanced refresh, and greater interactivity are combined in a new 19-inch DVST graphic terminal. A software-compatible 15-inch raster-scan terminal provides zoom and pan functions, multiple viewports, and multiple-bit planes for gray scale and overlays.

Software Innovations Increase Productivity of Desktop Computer Users

A new software library makes the graphic power of Tek's desktop computers available to users with little or no programming experience and enhances the productivity of skilled operators.

Three New Portable Oscilloscopes Designed for Field Service Use

Ruggedness, lightweight, and excellent EMI performance characterize the new 100-MHz 2300 Series Oscilloscopes designed expressly for field service applications.

A High Resolution Color Picture Monitor for Television and Laboratory Use

The 690SR is a precise, stable, color picture monitor with a unique color-convergence system that makes set-up a simplified, straightforward procedure. Plug-in interface modules and wide range scan circuitry make the 690SR easily adaptable to specialized applications.

Tektronix is an equal opportunity employer.

Customer information from Tektronix, Inc.
Beaverton, Oregon 97077

Tekscope is a quarterly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique.

Editor: Gordon Allison
Graphic Designer: Michael Satterwhite

Cover

The 4114, 19-inch DVST and 4112, 15-inch raster-scan computer display terminals increase user productivity through the use of segments — basic display elements that are used again and again in a display and can be called up with a single command.

Two New Graphic Terminals Expand Graphic Capabilities

Computer graphics users have varied requirements — so varied that no single display technology meets every need. The new Tektronix 4110 Series of graphic terminals offer users a choice of display technology: for high-density graphics, the high-resolution direct-view-storage-tube (DVST) display; and for dynamic graphics, the versatile raster-scan display.

Design goals for the 4110 Series were to expand on the capabilities of the current Tektronix 4010 Series, increase user productivity, decrease host communications traffic, and maintain compatibility with the 4010 Series and across the 4110 Series.

At introduction, two members of the 4110 Series were announced —the 4114 Computer Display Terminal, a 19-inch DVST terminal with refresh graphics and fast redraw capabilities, and the 4112 Computer Display Terminal, a 15-inch raster-scan terminal with zoom and pan functions, multiple-bit planes for gray scale and overlays, and multiple viewports (see Figure 1).

Compatibility maintained

The new capabilities of the 4110 Series were achieved without sacrificing compatibility with the 4010 Series. Host software designed for the 4010 can be used without modification with any 4110 Series terminal. As need for the expanded capabilities of the 4110 Series arises, the software can be modified accordingly.

Fig. 1. The new 4112 raster-scan terminal (left) and the 4114 DVST terminal (right) provide users a choice of graphics display capability with features designed to greatly increase the user's productivity. The 4112 and 4114 are software compatible with the 4010 Series terminals.

Even though the 4112 and 4114 use different display technologies, host software written for one terminal can be used without modification on the other. Compatibility also extends to the hardware — both terminals use an identical 16-bit microprocessor, a common bus structure, and identical mass storage. Each terminal includes firmware and 32K bytes of random access memory (RAM), and memory can be expanded up to 1M bytes of ROM/RAM. Optional flexible disk drives add a permanent storage capacity of up to 512K bytes per disk.

Both terminals work with a common set of peripherals, such as digital plotters, hardcopy units, printers, and graphic tablets. The 4110 Series are also supported by the Tektronix PLOT 10 Interactive Graphics Library.

The 4112 and 4114 allow the user a device coordinate space of 4096 by 4096 addressable points; however, the actual display resolution (the number of points that can be displayed on the screen) depends on the size and type of CRT. The 4112's 15-inch raster-scan tube provides a displayed resolution of 640 by 480 points, and the 19-inch DVST of the 4114 a displayed resolution of 4096 by 3131 points. The host can send an identical picture to both terminals in a coordinate space of 4096 by 4096 points, and each terminal will locally map the picture onto the actual coordinate space of its CRT.

Local picture segments

Both the 4112 and 4114 possess two of the most significant features of the 4110 Series terminals — local picture segments and a scrollable dialog area. A picture segment, as described in SIGGRAPH-ACM's proposed core system of computer graphics standards, is an ordered collection of output primitives (for example, vectors or text strings) defining an image which is part of the picture on a view surface. Let's illustrate the concept of the use of picture segments with an example.

An engineer is using a 4110 Series terminal to design an electronic circuit. The host computer sends the graphics data to display representations of components, such as transistors, resistors, and capacitors, on the terminal's screen. Each component is stored in the terminal's memory as a separate segment. The segment is numbered and therefore can be specified independently of the other segments. The designer uses the terminal keyboard controls or a peripheral graphics input device (such as a graphics tablet) to select the desired component and position it on-screen. The component remains displayed at that position, while the designer selects and positions other components.

The capability to store and manipulate segments locally provides several benefits. Host communications traffic is substantially reduced as it is no longer necessary to retransmit the entire sequence of graphics data to the terminal. The host need send only a command that says, in effect, display segment **n**.

There is a marked increase in repaint speed (the rate at which an erased display can be redrawn). This capability is particularly valuable when working with DVST displays containing large numbers of vectors or alphanumerics. For example, a diagram containing 25,000 short vectors, stored in RAM, can be redrawn and stored on the 4114 screen in less than half a second.

Refresh augments storage

The 4114 DVST terminal is given a substantial interactive capability by employing local refresh for up to 3000 short vectors. There is no limit to the number of vectors that can be displayed in the storage mode. In contrast, the entire 4112 raster-scan display is refreshed.

Both the 4112 and 4114 can perform local two-dimensional image transformations. A segment may be rotated, translated (shifted in position), and scaled (made larger or smaller). The user has the flexibility to define a picture segment of a standard size and shape, and after it is displayed, modify its image to fit the application. For example, consider an architectural application. The host sends a standard segment displayed as a square. The square can be modified locally to become the exterior outline of the building. The same standard square, transmitted again by the host, can be manipulated locally to become a window or a door.

A user-defined cursor

As a convenience in graphic input operations, the user can replace the cross-hair cursor with any picture segment. In the architectural application just discussed, the standard square could become the cursor, making it very convenient for positioning the square anywhere on the display.

Segments within segments

Another graphics convenience is the capability to include a copy of one or more segments within a segment. Consider, again, the architectural example. First, the host defines the exterior of the building as an individual picture segment and defines it as segment 1. The standard square displayed on-screen is defined as segment 2. Each time the architect positions and scales the square to create a door or window in the building, the host program commands the terminal to include a copy of segment 2 (as it appears on the screen) within segment 1. In this manner, segment 1 is progressively modified to contain the exterior of the building and all of its doors and windows. The host, then, with a single command to display segment 1, can redraw the exterior of the building with all of its openings.

Classes of segments

In some applications, it is desirable to modify related picture segments as a unit. This can be done by grouping several segments into a segment class. A segment may belong to one or more of a maximum of 64 classes.

To illustrate the utility of segment classes, consider an application that involves drawing a detailed block diagram of a complex instrument such as an oscilloscope. The block diagram could be constructed in modular form with separate modules for the trigger, timing, horizontal output, and so forth. The segments in each of the modules could be grouped into segment classes, one for each module. Using the host the user could then display or erase any module by sending a single command to the terminal.

A 4112 or 4114 equipped with the optional disk drive has the capacity to store locally-retained picture segments on the disk. The disk drive enables the host to load a segment from the disk into the terminal's memory directly. This is faster and less costly than retransmitting the data from the host.

The use of picture segments, segments within segments, local refresh and segment manipulation, and extensive local memory all serve to greatly reduce host communications traffic and increase the user's productivity.

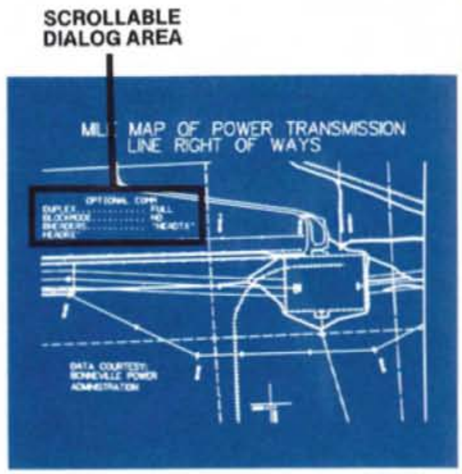


Fig. 2. Communications between the operator and the host computer are displayed in the dialog area. The size and location of the dialog area can be defined, to avoid interfering with displayed graphic information.

The dialog area

In addition to displaying picture information, a graphics terminal must provide a means for the operator at the keyboard to communicate with the host computer and, conversely, for the host to communicate with the operator. In some graphic terminals, the alphanumeric dialog between the operator and the host is sometimes written over the picture, necessitating redrawing of the picture. The 4112 and 4114 restrict the display of alphanumeric text to a defined dialog area (see figure 2). Communications between the host and the operator at the terminal are displayed in the dialog area; graphics information is displayed on the rest of the screen.

The dialog area on the 4112 and 4114 is scrollable. When filled with text, the top line is automatically moved up and out of view to make room for the next line of text at the bottom. Each line of alphanumeric text that is scrolled out of the dialog area is stored locally in RAM. This enables the operator to read previously displayed text by scrolling backwards with the keyboard thumbwheels.

The user can define the size of the memory buffer used to contain scrolled text, and can tailor the on-screen dialog area to the application by defining its size and position on the screen. The user can also choose to turn the dialog area on or off.

To provide for the scrolling capability, all text in the dialog area is displayed in refresh. In the 4112, the raster-scan tube pre-

A Direct-View Storage Tube With Color Refresh

The 4114 direct-view storage tube (DVST) terminal is given substantial refresh capability through the use of local random access memory. However, with flicker-free refresh it is sometimes difficult to distinguish between refreshed and stored images on the screen. The 4114 Color Enhanced Refresh option resolves that difficulty by displaying all refresh vectors in a second color. The color-refresh DVST displays stored information in the usual green color, while refreshed objects appear as a yellowish-orange hue easily distinguishable from the stored information.

Color refresh is accomplished by using a mixture of red and green phosphors for the DVST screen. In refresh mode, the writing beam excites both red and green phosphors, resulting in a yellowish-orange trace on the screen. The refreshed information, however, is displayed at a current density lower than that required to store a charge image.

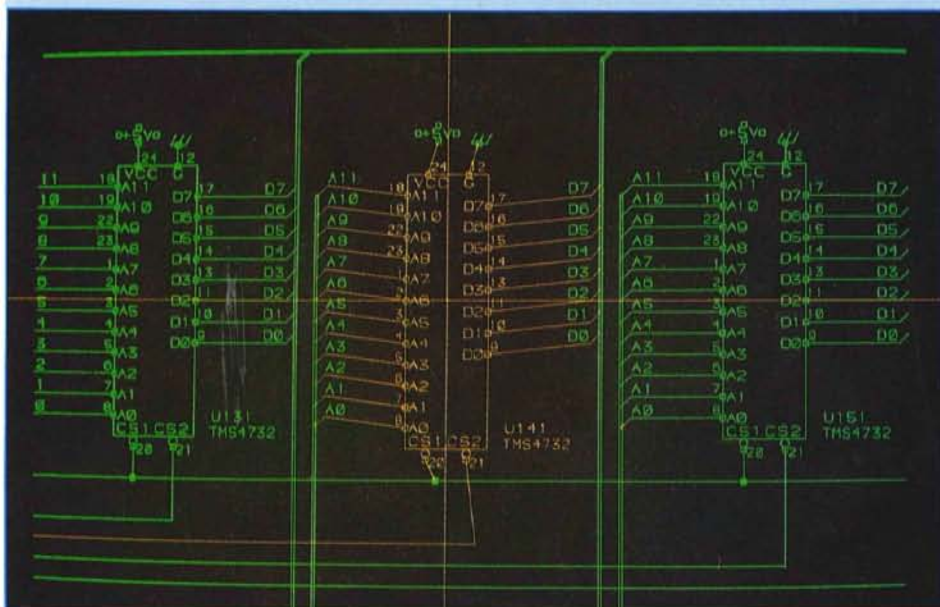


Fig. 1. A 4114 DVST display with color-enhanced refresh. The yellowish-orange hue of the refreshed information makes it easy to distinguish between stored and refreshed portions of the display.

To remain visible, the information must be continually refreshed.

In storage mode, the writing beam also excites both red and green phosphors causing a momentary yellowish-orange glow. In this case, the current density is high enough to store a charge image. After the writing beam draws the image, only the green phosphor continues to emit light. The red phosphor does not store because it requires a higher charge level to luminesce than does the green phosphor.

To achieve enough color shift to be easily discernible, the red phosphor must be 40 to 60 percent of the total by volume. However, this results in lowering the stored (green) luminance of the display. As luminance is also a function of power input to the screen, luminance can be restored by increasing this power. This is accomplished by processing the phosphor materials in such a way as to raise the nominal operating voltage level of the target, and changing the optics of the DVST funnel to increase the flood gun current density to the target. These changes result in a stored luminance 60 percent higher than that of conventional DVSTs.

Generally, an increase in the current density to the screen means a decrease in the life of the tube. In this instance, the use of rare-earth phosphors yields a 50 percent increase in tube life, even with the 60 percent increase in luminance.

An additional benefit of the new flood gun electron optics is improved hard copy capability. A primary factor in hard copy performance is the dispersion of flood-gun electrons in front of the tube target. The new design decreases the noise around the edges of the screen, resulting in consistently cleaner copies. ■

sents no limits to the size of the scrolling area; the 4114's DVST displays up to 300 characters in the dialog area.

Raster-scan graphics with the 4112

For applications that do not need the large screen and high resolution of the 4114, the raster-scan 4112 offers users some unique advantages: zoom and pan capability, multiple viewports, multiple-bit planes for gray-scale and overlays, a greater degree of operator interactivity, and lower cost.

The zoom and pan capabilities overcome the resolution limitations of the smaller CRT by allowing the user to isolate and magnify, on-screen, any section of the 4096 by 4096 point device coordinate space.

To understand how the zoom and pan features operate, it is necessary to understand the graphics concepts of window and viewport as they are used for the 4112. The window is any rectangular portion of the 4096 by 4096 point device coordinate space. The viewport is any rectangular portion of the display screen. The graphic contents of the window are mapped onto the viewport. The contents of the window determine the picture that will be displayed on the screen. The viewport determines the size and location, on-screen, of the displayed picture (see figure 3).

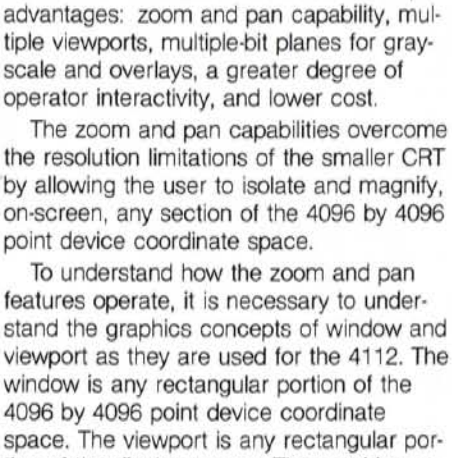


Fig. 3. Multiple viewports allow simultaneous display of an entire picture and enlarged views of selected portions of the picture.

Multiple viewports allow the user to display an entire picture on one portion of the screen, while detailed views of individual segments of the picture are displayed on other portions of the screen. The user can zoom and pan any viewport on-screen without affecting the images displayed on the other viewports. In addition, the user can specify which segments can be displayed in a viewport and which cannot. This feature allows the user to separately display pictures that might overlap in the device coordinate space, without the images overlapping on-screen.

Another powerful feature of the 4112 is the multi-bit plane capability that enables users to work with a maximum of three overlays, or up to eight shades of gray. Overlays are separately-addressable graphics surfaces. They can be compared to the transparent overlays commonly used in presentations made using an overhead projector. One of the more common applications for multi-bit planes is in the design of multi-layer printed circuit boards.

The gray-scale capability enables the user to "color" a picture with up to eight shades of gray to contrast various sections. Panels (polygonal areas of a picture) defined by the user can be filled with any of eight levels of gray scale, or with a user-defined pattern, or with one of 16 patterns available from the local intelligence of the 4112. A typical application would be the "coloring" of a map to mark differences in rainfall, temperature, population, and so forth.

Summary

The new 4112 15-inch raster-scan terminal and 4114 19-inch DVST terminal provide computer graphics users a choice of display technology, more versatile graphics capability, increased productivity through the use of picture segments and fast repaint, and lower cost through reduction of host communications traffic.

Compatibility with the 4010 Series of graphic terminals and between units of the 4110 Series allows users to expand their current 4010 software to incorporate the added capabilities of the 4112 and 4114, as the need arises.

Acknowledgements

We would like to express our appreciation to all who contributed to the 4112 and 4114 projects. Special thanks are due Lee Boekelheide and Ned Thanhouser for their outstanding work on the software. ■

Dean Bailey is manager of graphic terminal development at Tek. During his ten years at Tek, he has been manager of the Host Software group, had system responsibility for a major revision of the 4081, and currently is managing the 4100 Series program. Dean has a B.S. in Math from Portland State University (1965). The theater occupies much of his leisure time. He currently is rehearsing for a role in the Shakespeare-in-the-Park production of "As You Like It." Dean also enjoys astrophotography and has a 14-inch portable telescope.

Jack Sterett, project leader for the 4114, has been with Tek since 1960. His design projects include the 422 and 323 portable scopes, 4010 and 4014 computer display terminals, and several other display products. Jack received his B.S.E.E. from Portland State University and is a Master's candidate at Oregon State University. For recreation Jack enjoys water and snow skiing, hunting, and fishing.

Dave Squire is project leader for the 4112 project. He started with Tek in 1969, as a member of the Industrial Engineering group. During a stint with the Systems Division he designed the sector card logic for the 3260 Semiconductor Test System. He is currently with the Information Display Division. Dave received his B.S.E.E. and M.S.E.E. from Oregon State University. He enjoys mountain climbing, jogging, and playing guitar in a small "bluegrass" band.

Software Innovations Increase Productivity of Desktop Computer Users

Bruce Rodgers, software marketing manager for the Graphic Computing Systems business unit, is responsible for new software product planning, development, and promotion. He received his B.A. from Central Washington University in 1971 and his M.B.A. from the University of Washington in 1974, joining Tek shortly thereafter.

In 1975, Tektronix introduced its first desktop graphic computing system — the 4051. This was followed by the even more versatile 4052 and the graphically interactive, large-screen 4054. Now, with the introduction of New Generation PLOT 50 Software, we greatly enhance the usefulness of our entire 4050 Series family.

Since the introduction of the 4051, there have been major changes in what 4050 Series users want. There is a tremendous demand for more applications-oriented software to enable the user who has little, or no, programming experience, to take advantage of the graphic power of the 4050 desktop family.

In 1975, users had more time to incorporate new computing techniques into their problem-solving activities. For most users, this is not so today. Interest centers on productivity, not in the novelty of learning new technology. For example, in the past, a design engineer often spent considerable time creating, adapting, and programming statistical routines on the computer because such routines were not available from the vendor. Today, new statistics packages must be very easy to learn and incorporate into an application. Statistical tasks are a bottleneck in the design activity and need to be completed in an expeditious and reliable manner. Although the products must be simple to learn, they must also contain sufficient power to help solve the user's application problems.

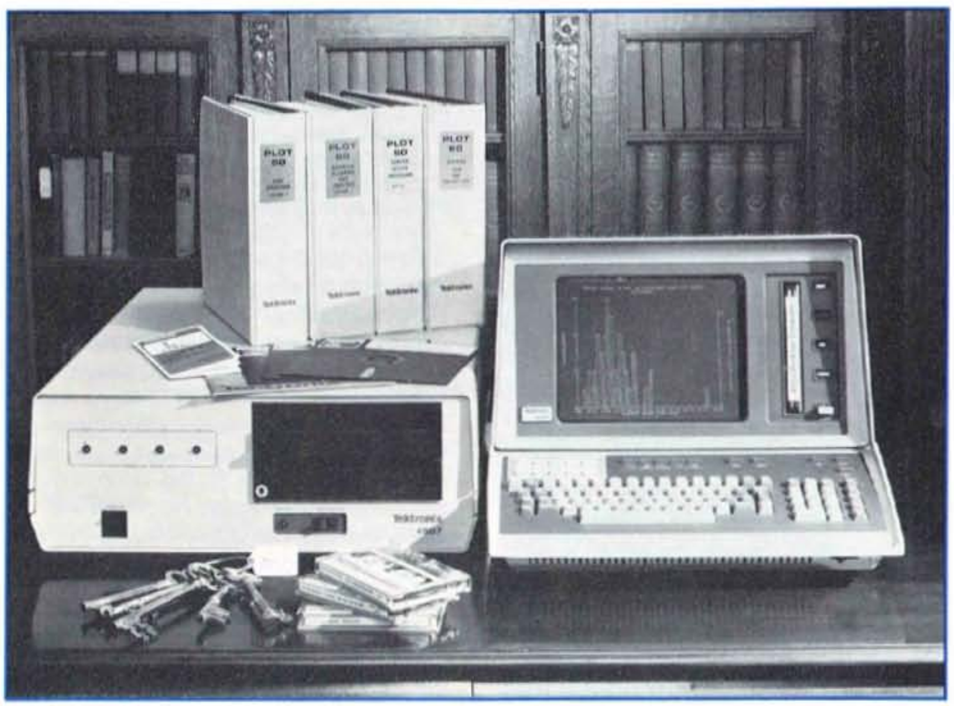


Fig. 1. The New Generation PLOT 50 Software is the key to easy use of the graphic power available in Tektronix 4050 Series desktop computers.

Design problems

A number of design problems had to be addressed early in the development of the New Generation PLOT 50 Software. Our market research indicated that few 4050 Series users' applications were static. Graphic computing system applications are diverse, and we had to learn more about application requirements in detail. Other factors to be considered included user familiarity with the hardware, user interface trade-offs between menus and commands, and differences in the learning curves of frequent-versus-infrequent users.

We decided that most 4050 Series users know far more about their applications than about their computing equipment. It was our task to provide the conventions of the applications to shorten the learning time for uses. Further, it was essential to provide a friendly interface with the software (and the hardware). Many vendors advertise friendly products; our challenge was to satisfy a wide range of user needs efficiently. In tangible terms, a first-time user should be able to operate the software within two to four hours after power-up, without having to study a user's manual.

Help and convenience for users

Most of the New Generation PLOT 50 Software packages include help files, tutorials, and menus. The tutorials quickly walk the user through product functions to rapidly achieve familiarity. The help files give details of program operation. For example, with the 4052D10 Document Preparation package, the user can display (with one function key) the menu of editing and formatting commands. Upon selecting a command, the user sees (on-screen) a description and an example of operation for that command. After obtaining the needed help, the user can easily return to the portion of the program where difficulty was encountered and then continue with the application from that point.

Most users prefer to first concentrate on solving their application problems and then spend secondary effort familiarizing themselves with the hardware and software to be used in that application. The New Generation PLOT 50 Software politely reminds users to check peripherals (and what to check for) to ensure proper operation.

In 4054D06 Picture Composition and 4052D07 Interactive Digitizing, the alignment of tablet menus and source documents is not important because easy and quick reference points are established which enable the software to make the necessary adjustments. For example, skewing errors are noted and automatically corrected so plotter output is not skewed relative to the X and Y axes. In each of the application packages there are many additional conveniences that help users to quickly become productive.

Application conventions

To better understand application conventions, we exchanged ideas with experts in several application areas. As an example, one exchange helped us to better understand what statistical techniques many users expect to employ when conducting small-sample statistical analysis. These "wants" then became the application conventions. We integrated these conventions into a simple-to-learn package that provides users with state-of-the-art techniques that key on graphics (through pattern recognition) to add meaning to users' data.

The value of graphics

Most of the New Generation PLOT 50 packages are built around the power of graphics. Conventional graphic techniques, such as scatter plots (as used in statistics) are included, as well as some unique new routines, such as box-and-whisker plots and normal curve overlays for viewing data. A brief review of some of these routines is helpful in understanding the power of graphic interpretation.

The statistics packages include routines for producing a box-and-whisker plot (see figure 2). The box represents the distribution of data about some observable median, while the edges of the box relate to quartiles, and the fences (whiskers) mark the range of most of the data in the distribution. The user has the option of examining one box at a time, or a number of boxes, to view variables within a group, or to look at a comparison of groups.

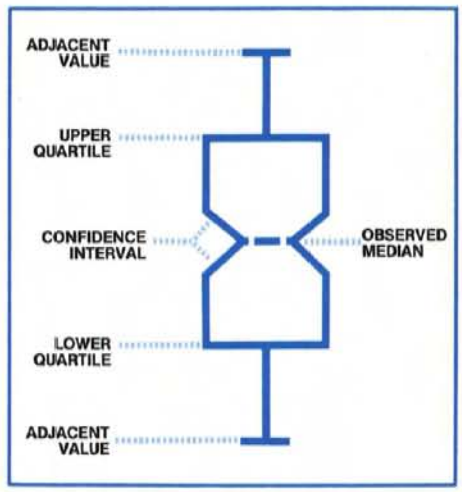


Fig. 2. Box and whisker plots enable the user to quickly determine if a statistical sample contains a high percentage of valid data. Use of such plots can save valuable time otherwise spent analyzing poorly-distributed data.

Recall that the purpose of the exercise in this statistics package is to analyze a small sample. Studying notches increases the user's productivity. Notched-box plots are used to note significant differences between two sets of data. Two sets of data whose notched intervals do not overlap are significantly different at roughly the five percent level (see figure 2). The value of this graphic technique lies in the speed with which the user can determine whether two groups of data are significantly different statistically.

Another of the exploratory plotting routines in the Statistics packages is the Normal Curve Overlay. In this case (see figure 3), a normal bell-shaped curve is inverted and plotted over a histogram representing

New Generation PLOT 50 Software Library

4050D02 Statistics Tests and Distributions *(Disk)*	Disk-based statistics for small sample and experimental analysis plus exploratory plotting routines
4050D03 Statistics Analysis of Variance *(Disk)*	ANOVA featuring one-, two-, and three-way classification techniques plus exploratory plotting routines
4050D04 Statistics Multiple Regressions *(Disk)*	Multiple, weighted, stepwise multiple, and polynomial regressions and exploratory plotting
4050D13 Statistics Library *(Disk)*	4050D02/4050D03/4050D04 (above) packaged as a library at discount
4054D06 Picture Composition *(Disk)*	Electronic "sketchpad" using graphic primitives (line, arc, circle, point, box, text) to create working drawings or pictures and sub-pictures using 4050 Option 30 Dynamic Graphics
4052 Interactive Digitizing *(Disk)*	For production (bulk) digitizing tasks in cartographic, design engineering, and strip chart analysis applications including editing and basic calculations
4052D10 Document Preparation *(Disk)*	Powerful command-driven package for formatting, editing, and preparation of multi-page documents
4050D11 *(Disk)* **4050A17** *(Tape)* **MicroPert 2 - Project Management**	State-of-the-art desktop offering of PERT and CPM techniques including rich set of resource management facilities, graphic charting, and reporting options
4050A16 Presentation Aids *(Tape)*	For the creation of overhead presentation materials based on template construction including bar charting, line graphs, pie charts, and text

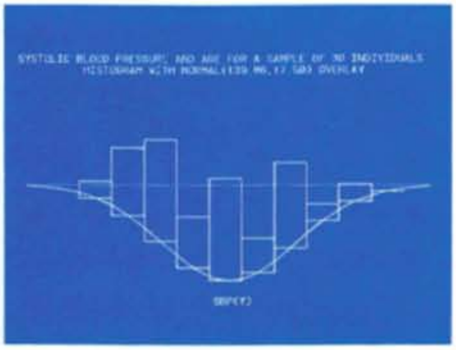


Fig. 3. The Normal Curve Overlay plotting routine enables even a casual statistics user to quickly spot deviations from an arbitrarily defined zero line.

the distribution of the data in the sample. The dotted line represents an arbitrarily defined zero-line as a reference point, so that even a casual statistics user can quickly see deviations from the zero-line. These graphic techniques are included in our software because they are easy to learn and provide powerful insight into the data being analyzed.

There are several of these plotting techniques in most of the New Generation PLOT 50 Software packages. They are available by answering only a few questions, by selecting an item from a menu, or by selecting the appropriate key on the 4050 Series device. In other words, no programming is needed. Access to the power of these graphic techniques is simple and quick.

Commonality

Each of the three Statistics packages comes with a Function Key Overlay that fits on the keyboard of the 4050 Series computers. The same functions are located on the same keys in every package. For example, Master Menu is key 10, Data Entry is key 1, Print and Plot are keys 7 and 8, respectively. This is not a major product feature but indicates the care employed in designing the products so users will find them easy to learn and operate correctly.

Fatal errors

Previous software offerings did not include provisions to protect users who lacked hardware familiarity, from destroying programs. For example, if you tried to plot a set of data by selecting a histogram function, with no data present in memory, the program usually crashed and you had to restart. Today, the operating system checks to make sure data is present before attempting to create the graph. If no data exists, polite instructions appear on the screen to guide the user to the next step to keep the program going. This type of design provides not only friendly software but forgiving software.

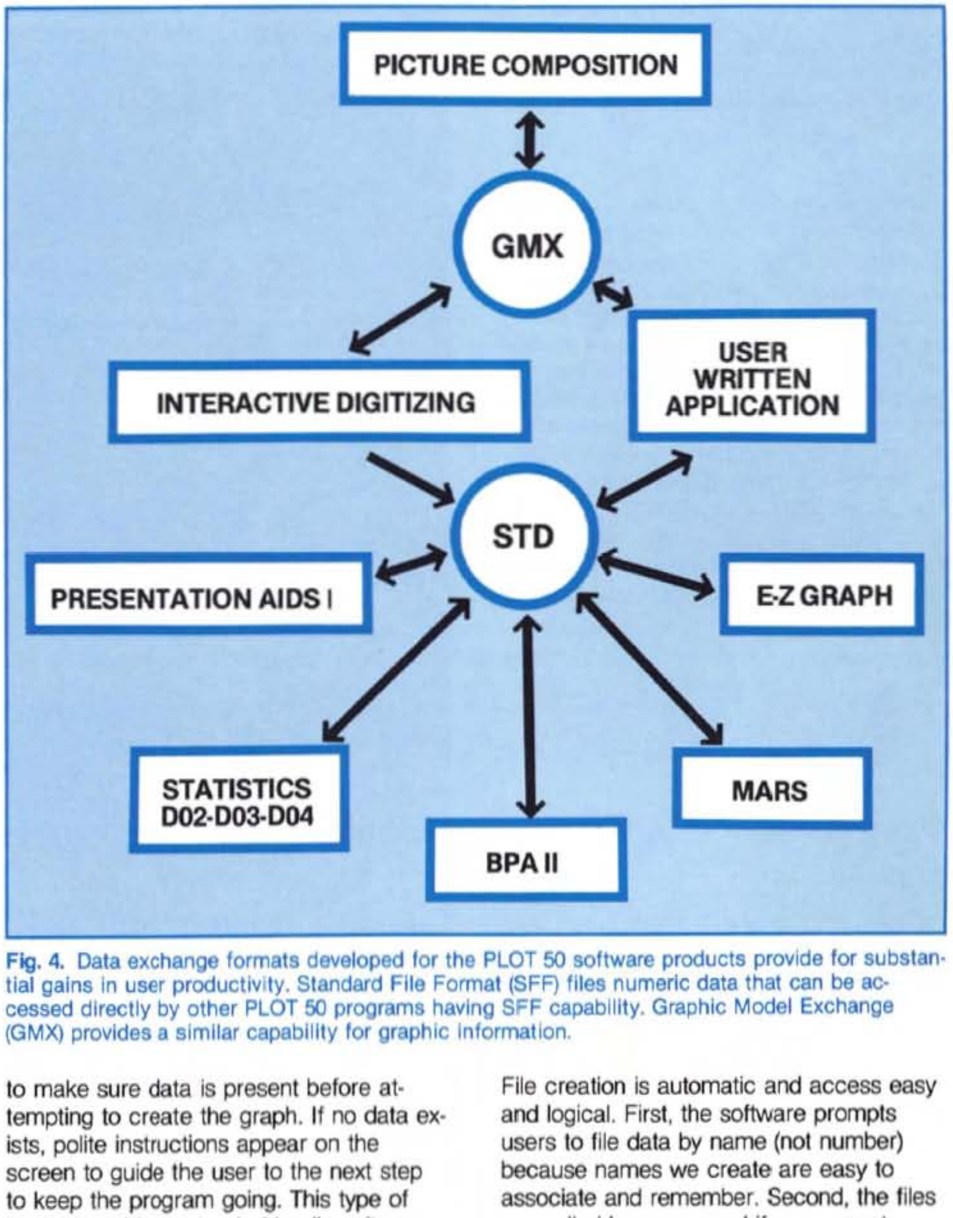


Fig. 4. Data exchange formats developed for the PLOT 50 software products provide for substantial gains in user productivity. Standard File Format (SFF) files numeric data that can be accessed directly by other PLOT 50 programs having SFF capability. Graphic Model Exchange (GMX) provides a similar capability for graphic information.

PLOT 50 Software exchange formats

Two data-base-oriented standard filing techniques were developed by Tektronix for these (and future) software products. The Standard File Format (SFF) is a technique for storing data in such a manner that the data can be accessed by other PLOT 50 programs having SFF capability. (We have found few users who enjoy worrying about marking files and fretting over file sizes.) When data entry is complete, the user need activate only one key or function for SFF construction to occur automatically.

File creation is automatic and access easy and logical. First, the software prompts users to file data by name (not number) because names we create are easy to associate and remember. Second, the files are called by name, and if you cannot remember the names of all of your files, directories allow you to recall the files one at a time or to list all of them.

The Graphic Model Exchange (GMX) can be considered the graphic complement of SFF. In SFF, the user stores numeric information. In GMX, the user stores graphic or pictorial information. This means that a graph created by one software package can be called by name by another software package (with GMX capability) and another operation be performed on that same file (see figure 4).

What SFF and GMX mean to the user are tremendous gains in efficiency because the data need be entered in the computer only one time (as opposed to entering the data for each different program).

Summary

For people who are not skilled computer programmers, the New Generation PLOT 50 Software products provide the capability to access the graphic power of the desktop 4050 Series and apply it quickly to their problem-solving tasks. The need for productivity gains takes precedence over the novelty of learning new software or hardware. For those who have the desire to use it, the programming and computing power of the 4050 Series is always available. These New Generation PLOT 50 Software products offer a wide range of users the opportunity to unlock the power of the 4050 Series and use it to their own advantage. ■

Three New Portable Oscilloscopes Designed for Field Service Use

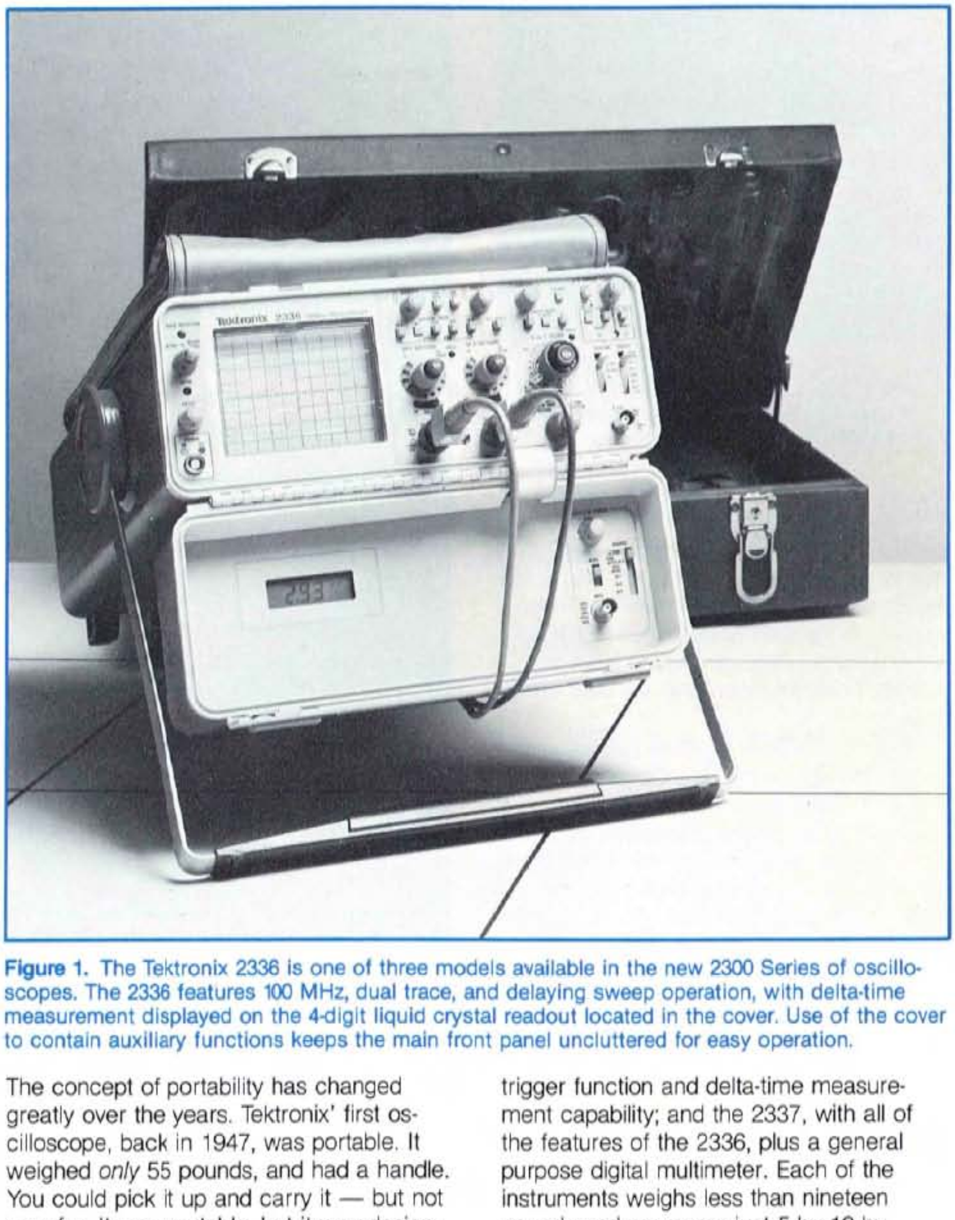


Figure 1. The Tektronix 2336 is one of three models available in the new 2300 Series of oscilloscopes. The 2336 features 100 MHz, dual trace, and delaying sweep operation, with delta-time measurement displayed on the 4-digit liquid crystal readout located in the cover. Use of the cover to contain auxiliary functions keeps the main front panel uncluttered for easy operation.

The concept of portability has changed greatly over the years. Tektronix' first oscilloscope, back in 1947, was portable. It weighed *only* 55 pounds, and had a handle. You could pick it up and carry it — but not very far. It was portable, but it was designed primarily for laboratory use.

Today, many oscilloscopes designed primarily for portability are purchased for laboratory use, and their design is optimized to accommodate both functions.

The new Tektronix 2300 Series Oscilloscopes are designed expressly for portability — and more precisely — for field service. Small, rugged, and reliable — they are built to work in adverse environments.

The 2300 Series includes three instruments: the 2335, a dual-trace, 100-MHz bandwidth, delaying sweep oscilloscope; the 2336, identical to the 2335, with a B-trigger function and delta-time measurement capability; and the 2337, with all of the features of the 2336, plus a general purpose digital multimeter. Each of the instruments weighs less than nineteen pounds and measures just 5 by 12 by 17 inches.

Concentrating on portability

Because field service requirements were the prime consideration, the designers of the 2300 Series concentrated on reducing size and optimizing ruggedness and reliability, rather than introducing new features. There were, of course, other important factors to consider, such as operating ease, display size and resolution, and serviceability, to name just a few.

The dimensions of the cathode ray tube (CRT) usually dictate the minimum length and height of an oscilloscope package.

Because of its mass, size, and complex structure, the CRT is also the component most vulnerable to physical shock. Thus, work on the 2300 Series began with redesign of our smallest, 100-MHz, high-performance CRT. The result is a CRT 30 percent shorter than its predecessor, having a 6.4 by 8.0 centimeter display area, with trace intensity and spot size optimized for a bright, sharp, high-quality trace.

Unique CRT mounting improves ruggedness

In designing a very portable oscilloscope, CRT breakage is a vital concern. Conventionally-mounted CRTs are supported at both ends — a technique that has proven reliable but which can result in high stress being applied to the CRT if the instrument is subjected to a severe drop.

The 2300 Series use a cantilever mounting system that enables the CRT to withstand shocks three to four times greater than conventionally-mounted tubes can handle. The new mounting system consists of a single mounting that fastens the front of the CRT to the oscilloscope's front subpanel, using just four screws (see figure 2). A key element in the mounting system is the Tek-manufactured ceramic tube, which makes it possible to tighten the mounting screws directly into the CRT's funnel.

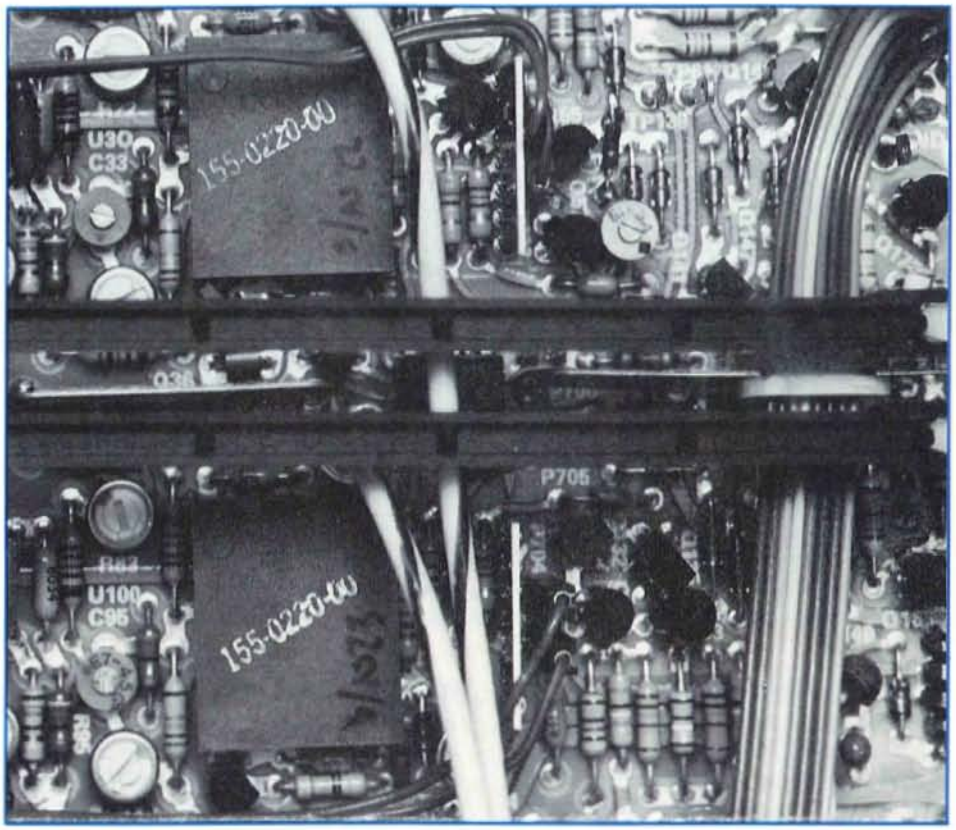


Figure 3. The hybrid preamplifier circuit used in all of the 2300 Series provides many of the advantages of an integrated circuit but required considerably less development time.

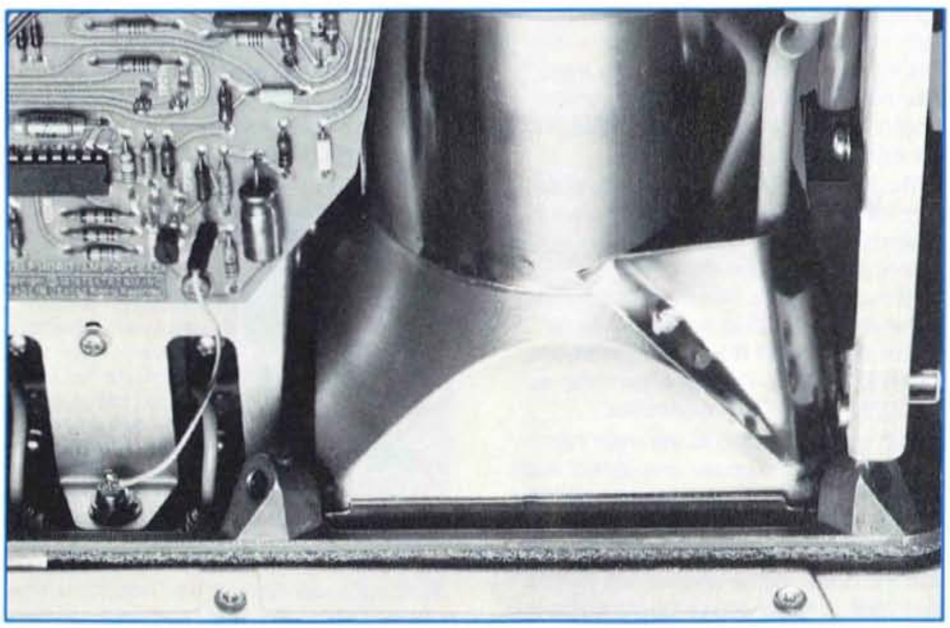


Figure 2. Unique mounting system which supports the CRT only at the front panel reduces probability of damage to the CRT should the instrument be subjected to a severe drop.

Circuit boards add support

One of the challenges in portable-oscilloscope design is to pack in all the performance needed, yet make the instrument easy to service. In the 2300 Series, this challenge was met by having the circuit boards all face outward, forming a box-like structure around the CRT. This arrangement provides excellent access for servicing. In addition, the circuit boards and their mountings serve as internal structural support for the instrument's chassis. Irregular-shaped boards were used where necessary, to utilize the available space.

Circuit-board real estate was conserved through judicious use of integrated circuits and thick-film hybrid circuits. The preamplifier circuit (figure 3) is a hybrid consisting of components silk-screened onto a ceramic substrate, with transistors soldered directly onto the substrate. This technique yields much of the advantage of an integrated circuit, with a shorter development time than that required for custom ICs.

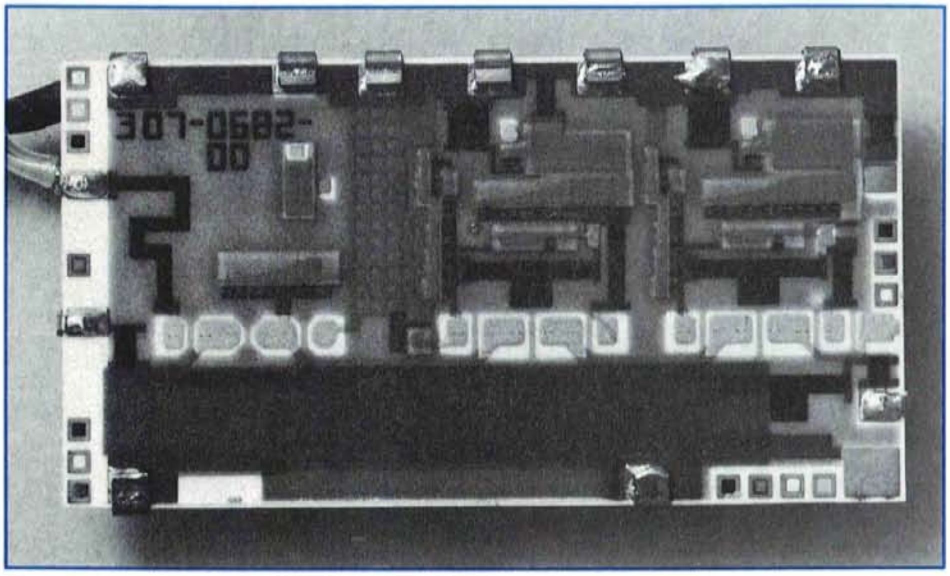


Figure 4. Two-stage hybrid attenuator uses laser-trimmed resistance and capacitance values to create a compact, preadjusted attenuator that requires no adjustment after installation in the instrument.

A laser-trimmed attenuator

The input attenuators in the 2300 Series are also unique. Smaller than conventional designs, the attenuators are compensated by laser trimming prior to installation in the instrument and never need adjustment. In contrast, the typical attenuator has many adjustments and must be adjusted after installation in the instrument. The new design reduces instrument calibration time and is more reliable than its predecessors.

Deep-drawn cabinet provides protection

The single-piece, deep-drawn cabinet housing the 2300 Series is a significant achievement. Pure aluminum could easily be formed to the required depth but was not strong enough. Working closely with experts in deep drawing aluminum, Tek engineers helped develop one of the deepest drawn cans of 6061 T6 alloy ever manufactured. This accomplishment was essential in making the 2300 Series lightweight and strong.

The cabinet also plays an important role in realizing the design goal for electromagnetic interference (EMI). Portables often operate within the strong radio-frequency fields of radio and television transmitters, industrial machinery, and so forth. Close attention was given to EMI at every step of the instrument design, resulting in an EMI specification of 10 volts per meter (radiated susceptibility).

A new front-panel concept

In addition to the CRT, another factor that determines instrument size is the front-panel space needed for the controls. Controls can be made small and closely spaced but the instrument will be difficult to operate. The 2300 Series designers use a new approach that effectively doubles the front-panel space without increasing instrument size. Portables need a cover to protect the front-panel controls during transit. Why not use the cover to house auxiliary functions, such as delta time readout and the digital multimeter?

The cover for the 2300 Series is drawn from the same tough alloy as the main instrument cabinet. Depending on the model, a panel is mounted in the cover to contain additional functions. The 2335 has nothing in the cover; the 2336 contains a liquid crystal display and B trigger controls; and the 2337 contains the same elements as the 2336 plus a digital multimeter.

The cover is hinged to the main instrument cabinet, and power and control leads are coupled to the cover panel through a flexible, flat cable. A beryllium-copper shield provides EMI protection. One can expect that the cover will be opened and closed hundreds of times during the life of the instrument. To verify reliability, the cable was tested up to 100,000 openings and closings without an electrical failure.

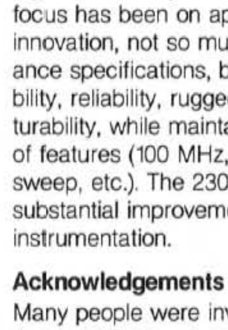
Considerable thought was given to both logical organization and spacing of the front-panel controls to ensure straightforward, easy operation. All of the positioning controls are in a row at the top of the panel, mode switches are just below, and the step attenuators and time per division controls are lined up in the center. This arrangement makes the oscilloscope easy to use, even by inexperienced technicians.

A new target for innovation

Usually, in designing a new oscilloscope, the bulk of the effort is applied to developing new circuitry. In the 2300 Series, the focus has been on applying technology and innovation, not so much to expand performance specifications, but to increase portability, reliability, ruggedness, and manufacturability, while maintaining a popular set of features (100 MHz, dual trace, delaying sweep, etc.). The 2300 Series represent a substantial improvement in field service instrumentation.

Acknowledgements

Many people were involved in the design of the 2300 Series. A special note of thanks goes to Mike Kyle, project leader for mechanical design, and to Dave Hargis and Earl Orme who worked with him. Special thanks to John Taggart, project leader for electrical design, and Dave Allen, Gene Cowan, Jim Godwin, Carl Matson, and Ted Nelson, all electrical designers for the project. Dennis Bratz provided valuable insight into manufacturing techniques and performed production evaluation. My thanks also to others who contributed to the project. ■



Peter Zietzke joined Tek in 1974 following graduation from Montana State University at Bozeman with a B.S.E.E. He has been involved with portable scope design since coming with Tek, working on two of the 200 Series Miniscopes, as project manager for the 442, and currently as project manager for the 2300 Series. Pete's outside activities include building miniature boats, trains, doll house furniture, etc., restoring vintage cars (he has two Packards in process), and fiddling with new circuits.

A High Resolution Color Picture Monitor for Television and Laboratory Use

Joe Hallett is Marketing Product Manager for television picture monitors. He joined Tek in January 1980 from GTE Sylvania, where he worked on development of electronic displays and equipment for cathode ray tube production. Joe received his B.S.E.E. in 1955 from Northeastern University in Boston. In his leisure hours Joe enjoys skiing, photography, travel, and amateur radio.

John Horn is Project Manager for the 690SR. He has been with the television products group since coming to Tek in 1960. John has contributed to the design of many products including the 528 Waveform Monitor, 650 and 670 Series Picture Monitors, and the 1420 Series Vectorscopes. John enjoys the outdoors — camping, hiking, and sailing.

Television stations, production studios, development laboratories, and quality control facilities need precise color picture monitors to accurately display every signal detail, whether generated by a conventional color television camera or by a computer-based imaging system.

There are two particularly critical places in the typical television program production facility where a precise color monitor is needed. One is the point at which the final television product is displayed to the executive responsible for final approval of the product. The monitor must accurately portray the program material complete with any compromises or defects that may be present. A subjective judgment will be made to determine whether the final product is acceptable.

A second critical viewing position is at camera-control positions where the quality of the original signal is established. Registration of the three primary colors at the camera is a critical task; the highest-resolution monochrome monitors are often used in making the initial setup. During production, an accurate color display allows the operator to observe slight adjustment errors and make corrections while the production continues. Only a monitor with excellent convergence can be used for this task.

In these, and other applications, the monitor is the quality standard and it must be extremely stable so that it is not suspect when picture defects are noted.

The Tektronix 690SR Color Picture Monitor is designed for just such critical viewing applications. With the appropriate plug-in interface module, the 690SR can display pictures originating in either a television system or a digital image buffer.

Wide-range deflection circuits produce horizontal scan rates from 15 kHz to 37.5 kHz. The 690SR accommodates conventional interlaced raster display formats including the standard 525-line and 625-line television systems and can operate at more than 1024 lines per frame for computer applications. Convergence circuits track picture size, aspect ratio and scan rate to allow operation in special applications, with only minor readjustment.

A high quality CRT

The key element in a high-resolution monitor is a high-resolution cathode ray tube (CRT). The 690SR uses a delta-gun, dot-shadowmask CRT with an extremely fine shadowmask structure; triad spacing is 0.31 millimeter as compared with 0.6 to 0.8 millimeter for home television picture tubes. There are approximately 1800 phosphor dots vertically and 1400 horizontally for each color, in the CRT screen. Efficient phosphors permit the use of relatively high brightness levels without sacrificing picture quality.

Inherent in current CRT technology is a tradeoff between fine screen structure and screen uniformity. For those applications where the operator must be close to the display screen, the fine screen is less objectionable than coarser screens. However, for greater viewing distances a medium resolution (0.4 to 0.6 millimeter) CRT provides better screen uniformity and adequate fineness. The medium resolution CRT is offered as an option for the 690SR.

Easy convergence adjustment

Complementing the high-resolution picture tube are high-stability convergence circuits. The specified convergence accuracy is better than 0.5 mm; this is the maximum separation permitted between any pair of red, green, or blue picture elements (center to center) and corresponds to less than 0.1 percent of picture height anywhere on the screen.

The convergence circuit adjustments are precision potentiometers with large, easy to set knobs located in a lockable front drawer where they are easily accessible to qualified personnel. Color coded graphics adjacent to each control provide a convenient reminder of each control function. The convergence signals are matrixed in such a way that beam motions are approximately up-down or left-right in response to control movements. This greatly simplifies convergence setup.

A solid white

One of the major concerns in a television program production is that the color temperature of "white" be set accurately and not drift. Drifting white balance causes unnatural colors to appear, which is particularly offensive to everyone if skin tones, snow, or other light-colored areas are involved. It is particularily objectionable to a sponsor to see the color of the product distorted in a commercial production.

To reduce the need for white-balance adjustment, the 690SR employs beam-current feedback to offset changes in the CRT cutoff characteristics as the tube ages. Carefully designed video circuits ensure that tracking errors (differences in video gain between red, blue, and green channels) are held to less than two percent. While it is not feasible today to eliminate white-balance adjustments entirely, the 690SR reduces these adjustments to the level of routine maintenance. Such stability ensures that if a problem is visible during critical viewing of a television production, it is not likely to be in the picture monitor.

Modularity for configurability

Modular construction makes it easy to configure the 690SR for different applications. The plug-in interface module processes the video input signals for application to the mainframe.

In the typical display of computer-generated pictures, a simple RGB interface can be used because no color decoding is required. In this case, the red, green, and blue signals are buffered and conditioned to drive the 690SR mainframe inputs. Sync separation is provided to obtain the horizontal and vertical triggers needed by the mainframe scan control circuits.

The NTSC television signal decoder is the first interface available for the 690SR. The NTSC decoder contains sync separation, color decoder, horizontal AFC, and other functions necessary for operation of

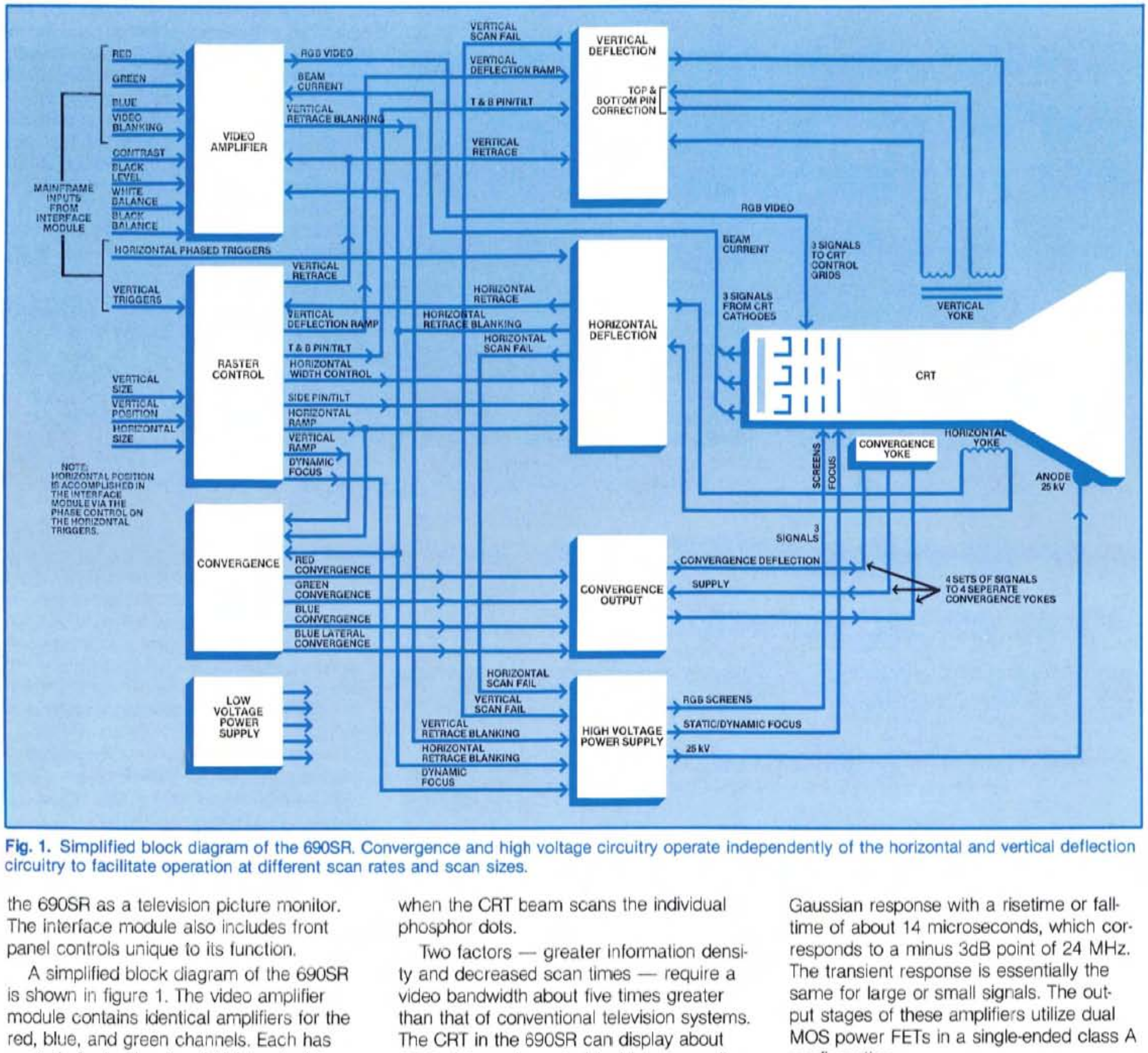


Fig. 1. Simplified block diagram of the 690SR. Convergence and high voltage circuitry operate independently of the horizontal and vertical deflection circuitry to facilitate operation at different scan rates and scan sizes.

the 690SR as a television picture monitor. The interface module also includes front panel controls unique to its function.

A simplified block diagram of the 690SR is shown in figure 1. The video amplifier module contains identical amplifiers for the red, blue, and green channels. Each has controls for low-level and high-level white balancing. A feedback loop in each channel senses CRT cathode current once per displayed field. This signal maintains the black-level current at a preset level, thus minimizing changes in color balance caused by CRT aging.

The video response is matched to the high-resolution CRT to minimize moire patterns caused by out-of-band signals beating with the sampling frequencies produced when the CRT beam scans the individual phosphor dots.

Two factors — greater information density and decreased scan times — require a video bandwidth about five times greater than that of conventional television systems. The CRT in the 690SR can display about 1000 picture elements (pixels) per scan line as contrasted with the 400 to 500 pixels per scan line of conventional television. (This resolution is not the same as the number of phosphor dots along a horizontal line, as the CRT beam spot size is larger and determines resolution.) In addition, the line-scan time can be shortened from the conventional 52 microseconds to as little as 20 microseconds, to achieve a comparable improvement in vertical information density without flicker. The video amplifier has a Gaussian response with a risetime or falltime of about 14 microseconds, which corresponds to a minus 3dB point of 24 MHz. The transient response is essentially the same for large or small signals. The output stages of these amplifiers utilize dual MOS power FETs in a single-ended class A configuration.

In the 690SR, wide-bandwidth video response and fast scan rates combine with the beam profile and fine-pitch phosphor pattern of the CRT to provide a display system suitable for both conventional television and high-definition television and graphics.

The raster-control module

The 690SR operates over a wide range of vertical and horizontal scan rates. The key to wide-range operation is the raster-control module. This module translates the interval between successive horizontal and vertical triggers, and horizontal and vertical size information, into signals that represent linear displacement across the CRT screen. From this positional information, all scan and correction signals are developed. This unique architecture minimizes readjustments for scan size, linearity, convergence, and dynamic focus when scan rates are changed.

The conversion from time to position across the CRT screen is accomplished using horizontal and vertical constant-amplitude ramp generators. The ramp generators are unique in that ramp amplitude is independent of control signal frequency. Further, the slope of the ramp is changed without changing the integrator timing components.

The basic ramp generator circuit (figure 2) consists of a comparator, Miller integrator, switching transistor, and peak detector. A control signal (the horizontal retrace blanking pulse) turns on the switching transistor, thereby discharging the integrator capacitor. The high period of the control pulse corresponds to the horizontal retrace time. When the control pulse goes low, the transistor turns off and the Miller integrator produces a linear ramp whose amplitude is determined by the reference voltage setting. The slope of the ramp is determined by the values of R_t and C_t and the output voltage of the comparator. The peak detector detects the peak voltage of the output ramp. If the peak voltage is less than the reference voltage, the output voltage from the comparator decreases, increasing the current flowing through the Miller integrator.

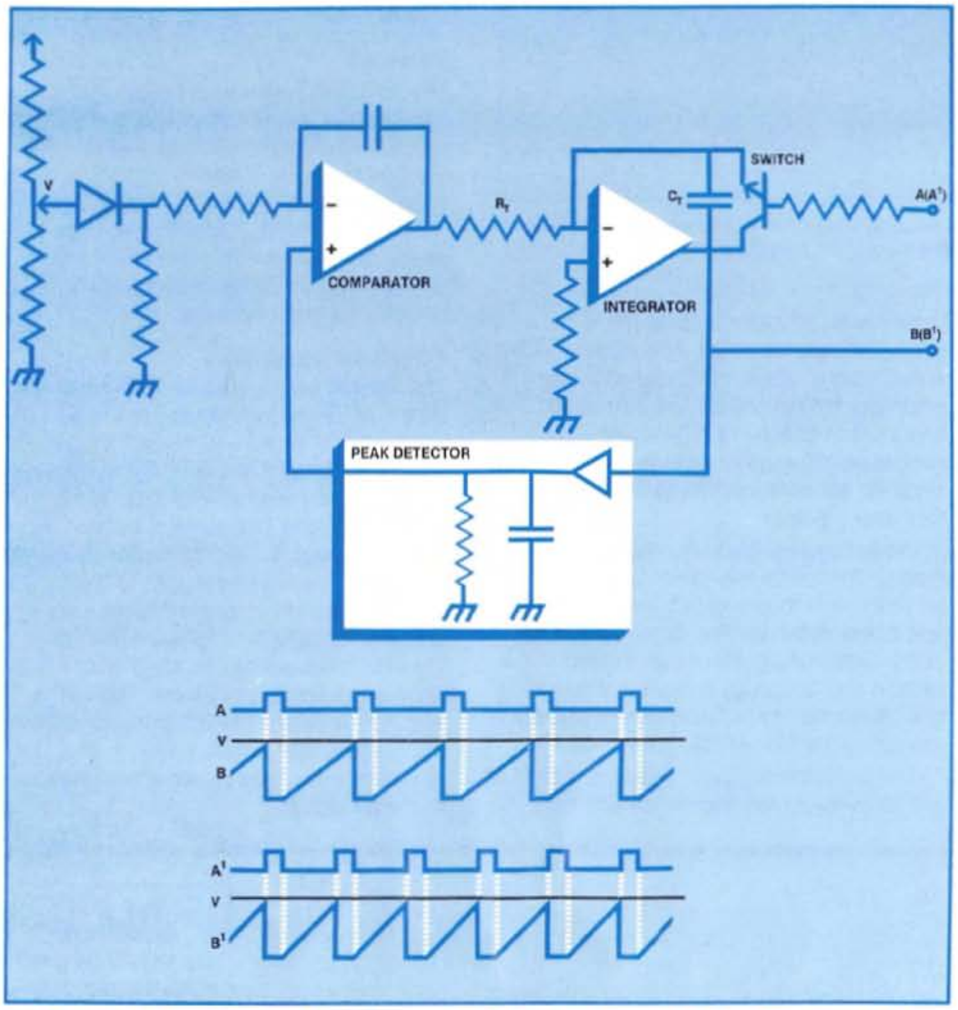


Fig. 2. Simplified schematic of ramp generator with constant-amplitude output independent of control signal frequency. Output of peak detector provides feedback signal to adjust Miller integrator current as needed to maintain constant output amplitude.

The slope of the ramp increases to restore the peak of the ramp to the level of the reference voltage. Thus, the amplitude of the ramp is determined by the reference voltage, independent of the control pulse frequency.

The raster control module also provides pincushion and tilt correction signals to the horizontal and vertical deflection modules. A dynamic focus signal, sent to the high voltage supply, maintains a sharp focus over the entire screen. The horizontal and vertical ramp signals are sent to the convergence module to provide beam-position information.

The convergence circuits

The convergence circuitry uses low-power active techniques with quality potentiometers and other components to ensure stability and reliability. The convergence module, located in the front drawer, provides the precision correction waveforms, and the convergence output module provides the driving signals for coils in the convergence yoke.

The convergence circuitry drives two sets of coils — one set in the main convergence yoke, and a second set in an auxiliary yoke. In the main convergence yoke, the red and green coils control both the horizontal and vertical positions of their respective beams. The blue coil, however, is positioned such that it controls only the vertical position of the blue beam. Horizontal positioning of the blue beam is controlled by the blue-lateral signal, which drives the auxiliary yoke. The coils in this yoke are oriented such that the magnetic field created provides horizontal positioning of the blue beam but has little affect on the red and green beams (figure 4).

Four convergence-correction signals are generated to drive the convergence coils: red convergence, green convergence, blue convergence, and blue-lateral convergence. Each of these four signals is a combination of convegence-correction signals. The primary correction signals consist of essentially half parabolas, which, when their amplitude and polarity are adjusted, change the convergence linearity of a given area of the display. The secondary convergence-correction signals consist of "B" shaped and "S" shaped waveforms that affect the symmetry top-to-bottom and left-to-right.

The convergence matrix is made up of divider networks that allow various magnitudes of the signals to be picked off to

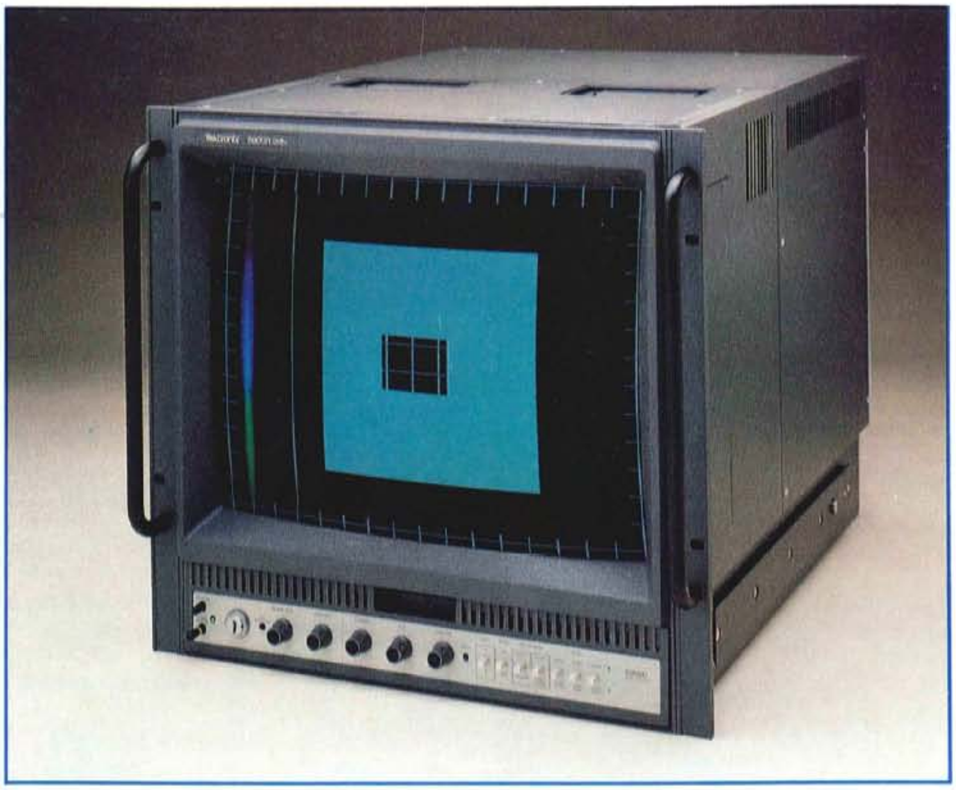


Fig. 3. The 690SR Color Picture Monitor is a high-resolution monitor suitable for both color television production and digital imaging applications. The Option 01 NTSC decoder interface is in use in this photo.

drive specific convergence coils. These individual signals are then summed to create the four convergence-correction signals. The signals are matrixed in such a way that beam motions are generally up-down and left-right in response to control movements, thus greatly simplifying convergence setup.

The deflection amplifiers

The horizontal deflection module contains resonant-scan circuits for driving the horizontal deflection yoke windings. Unlike many display deflection circuits, the 690SR horizontal deflection circuits operate independent of the high-voltage supply, thus avoiding compromises in deflection performance and making the high voltage (and picture size) independent of scan rate.

The vertical deflection module contains a linear power amplifier to drive the vertical deflection yoke windings. Also located within this module are the linearity correction amplifiers for top and bottom pincushion and top and bottom tilt. These are active circuits whose outputs provide a correction signal to the center of the vertical deflection yoke windings.

Protective circuitry in the raster-control module limits both the vertical and horizontal scan rates to prevent excessive dissipation in the deflection and convergence circuitry. Scan-fail signals are generated in the vertical and horizontal deflection modules to shut down the high-voltage supply, thereby protecting the CRT should either scan fail.

The high-voltage power supply is a high-efficiency switching type, which provides 25 kV to the CRT, along with other CRT operating potentials. Output ripple is synchronized to the horizontal frequency. The dc (static) focus output is adjustable independent of the anode voltage.

A rugged design

Another unusual feature of the 690SR is its physical design. The 690SR is designed to withstand severe shock and vibration, and relies mainly upon convection cooling to maintain conservative operating conditions for its electronic components. The structure and cooling method are interrelated, with the structural supports also serving as thermal guides to direct convection heat flow.

The 690SR is listed under Underwriters Standards 478 and 1244 (Pending, June 1981), certified per Canadian Standards Association bulletin 556B, and complies with European safety standards IEC 348 and IEC 435.

Summary

The 690SR is a new type of high performance color monitor for professional use in television production facilities and development laboratories. It has features which make it adaptable to both conventional television and digital computer environments, and has built-in potential for expansion to serve these rapidly merging technologies for years to come.

Acknowledgements

The authors would like to acknowledge the efforts of all who contributed to the success of the 690SR project. Wayne Olmstead was project leader and designed the deflection modules and raster control system; Gary Andrews did the interconnect system and the NTSC decoder; Archie Barter designed the Z-axis, low voltage supply, and did early work on the high voltage circuitry; Dan Baker completed the high voltage supply; Dan Teichmer worked on an interface to be announced soon; and Clayton Wahlquist, who has since left the company, designed the convergence circuitry. Our thanks also to others who made valuable contributions to the project. ■

6/81 99AX-4809

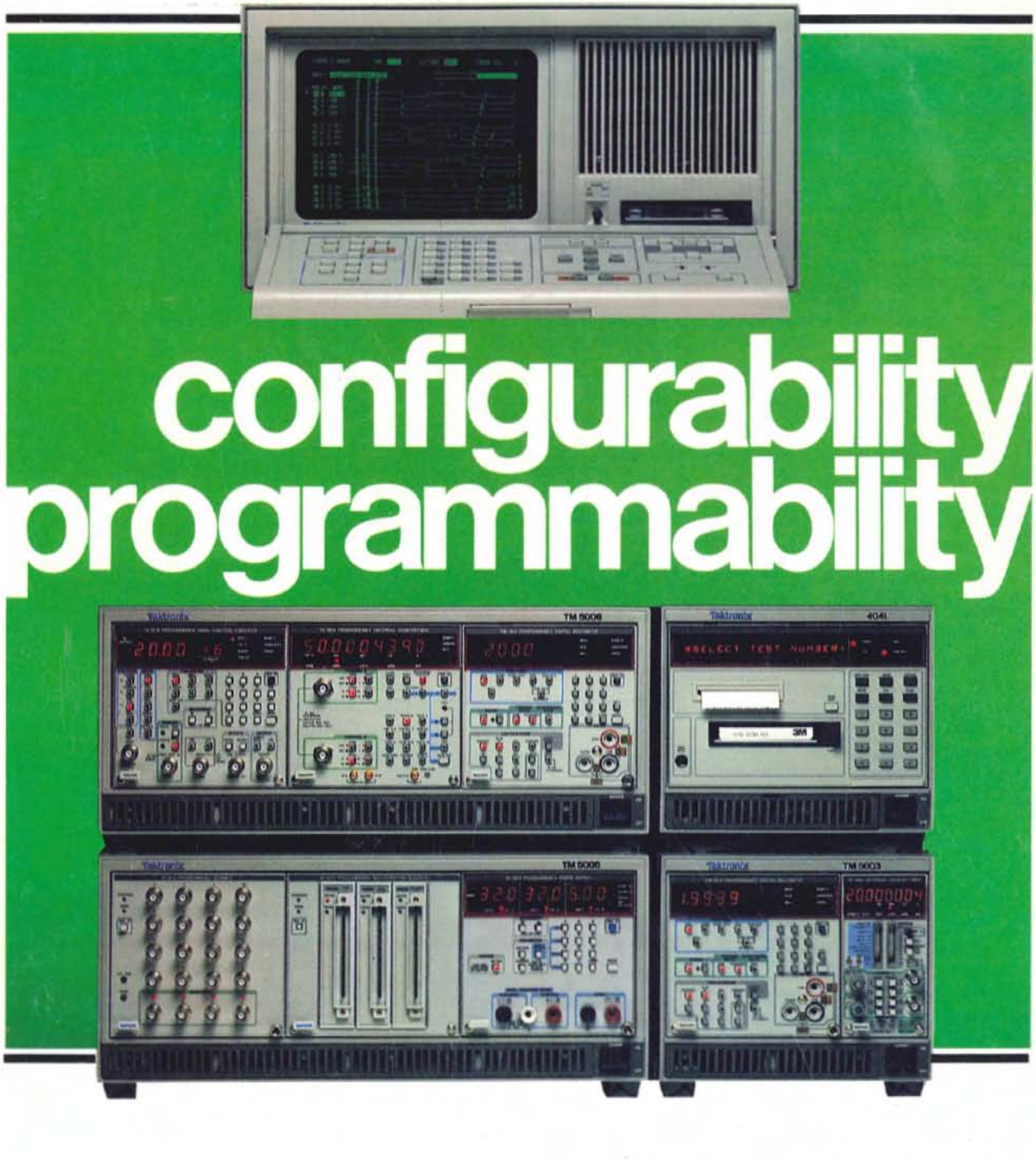
Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

BULK RATE
U.S. POSTAGE PAID
TEKTRONIX, INC.

TECHNICAL INFORMATION
FOR TEKTRONIX CUSTOMERS

VOLUME 13 NUMBER 3
SEPTEMBER 1981

Tekscope



Tektronix
COMMITTED TO EXCELLENCE

Tekscope CONTENTS

TM 5000—A New Family of IEEE-488 Programmable Instruments

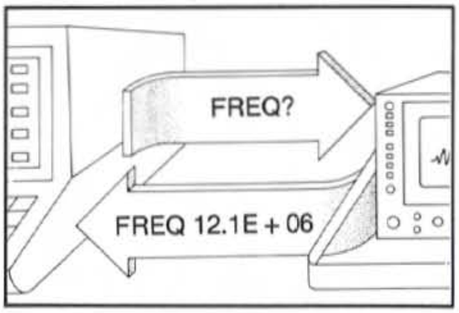
The TM 5000 Series combines the compactness and configurability of the TM 500 Series with unprecedented programming ease and compatibility in a family of programmable instruments.

Configurable State-of-the Art Logic Analyzer Gives Choice of Performance

Plug-in modularity lets you configure the DAS 9100 Digital Analysis System to your particular task, and then update the system as your needs change. Data acquisition capabilities range from 104 channels at 25 MHz to 16 channels at 330 MHz and 8 channels with 1.5 nanosecond resolution. Pattern generation modules provide word widths of up to 80 channels at speeds to 25 MHz.

Codes and Formats Standard Adds Compatibility and Capability to IEEE-488 Instruments

A Tektronix-developed standard of codes and formats enhances compatibility among IEEE-488 instruments and reduces the cost and time required to develop systems and application software.



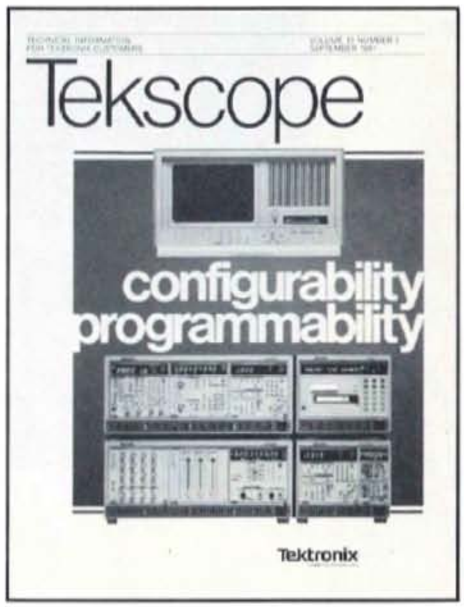
Customer information from Tektronix, Inc.
Beaverton, Oregon 97077

Tekscope is a quarterly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique.

Editor: Gordon Allison
Graphic Designer: Michael Satterwhite

Cover

Configurability and programmability characterize both the DAS 9100 Digital Analysis System (top) and the TM 5000 Series general purpose instruments (bottom). Plug-in card modules allow you to configure the DAS for today's logic analysis needs and update the system as your needs change. Plug-in instrument modules provide the same flexibility for your automated test and measurement needs. Both systems are programmable via the IEEE-488 bus or an RS-232 interface and conform to the Tektronix Codes and Formats Standard.



TM 5000—A New Family of IEEE-488 Programmable Instruments

Bob Metzler is Marketing Manager for the General Purpose Instruments business unit, which includes both TM 500 and TM 5000 Series products. Bob joined Tek in 1973 after several years of design work in the communications field. He received his B.S. in physics from the University of Louisville in 1960 and has an M.B.A. from the University of Portland. For recreation Bob enjoys backpacking with his family, listening to jazz and classical music, and dabbling in photography.

Many of today's "systems" resemble what we used to call conglomerations. Adoption of the IEEE-488 interface standard has made it easier to mechanically and electrically interconnect instruments from multiple vendors. However, other elements (not defined by IEEE-488) differ from instrument to instrument making it difficult to integrate the pieces into an effective operating system.

As discussions for a proposed new family of programmable instruments progressed, it became apparent that much of the compatibility problem centered around the codes and formats used to encode and transmit data within a system. Accordingly, a set of standard codes and formats for IEEE-488 instruments was formulated and adopted at Tektronix.

With the establishment of the codes and formats standard the task of developing a powerful, yet simple, IEEE-488 control software came into sharper focus. It seemed feasible to develop a set of software that would make instrument programming straightforward and easy to understand.

The goal for the overall program was to provide a versatile, modular, programmable instrumentation system that could be programmed and used by a diverse group of people—those involved in research, design, manufacturing, servicing, and other areas. The system should accommodate users having little or no programming experience as well as those capable of tackling complex measurement problems.

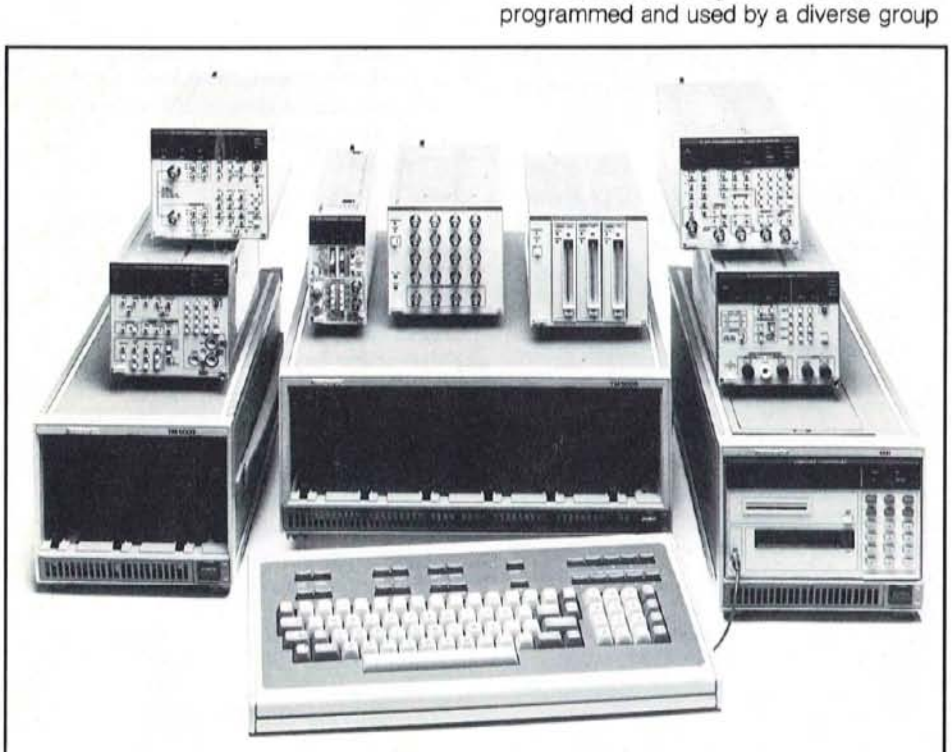


Fig. 1. The TM 5000 Series—a programmable test and measurement system that is easy to configure, easy to program, and occupies a minimum of space.

An instrument-oriented BASIC

Because of its wide use in industry, BASIC was selected as the basis for the new software. BASIC can be quickly grasped and applied to a wide variety of problems and tasks, and can be put to work with a minimum understanding of the language as a whole.

Several enhancements to BASIC adapt it to the instrumentation task. One extends the maximum length of variable names from two characters out to eight, thus increasing the programmer's ability to identify variables with their English equivalents, or close approximations. As an example, the variable "channel" could be written CH, CHA, CHAN, or CHANNEL.

Another enhancement permits variables to be defined exclusively within the confines of a subroutine. This feature lets programmers break down a complex program into subroutine modules that can be approached independently.

Other enhancements allow any program line to be identified with a label, and provide a flexible format for number entry.

Front-panel programming

For the instrument-oriented user, a "learn" mode provides, essentially, a "nonprogramming" method of setting up instruments on the bus. The user sets up the instrument from the front panel and by a single keystroke executes a command that causes the controller to query the instrument and store the control settings in memory. This is a fast, error-free way of programming an instrument.

A new controller

To fully implement the new software, a new instrument oriented controller—the 4041—was developed. The 4041 is based on the powerful 16-bit 68000 microprocessor and accommodates up to 160 kilobytes of user RAM. The standard configuration includes 32 kilobytes of RAM and a DC 100 mag-tape cartridge drive that provides up to 160 kilobytes of storage per tape. The DC 100 is used to store programs during program development, to load programs into system RAM during

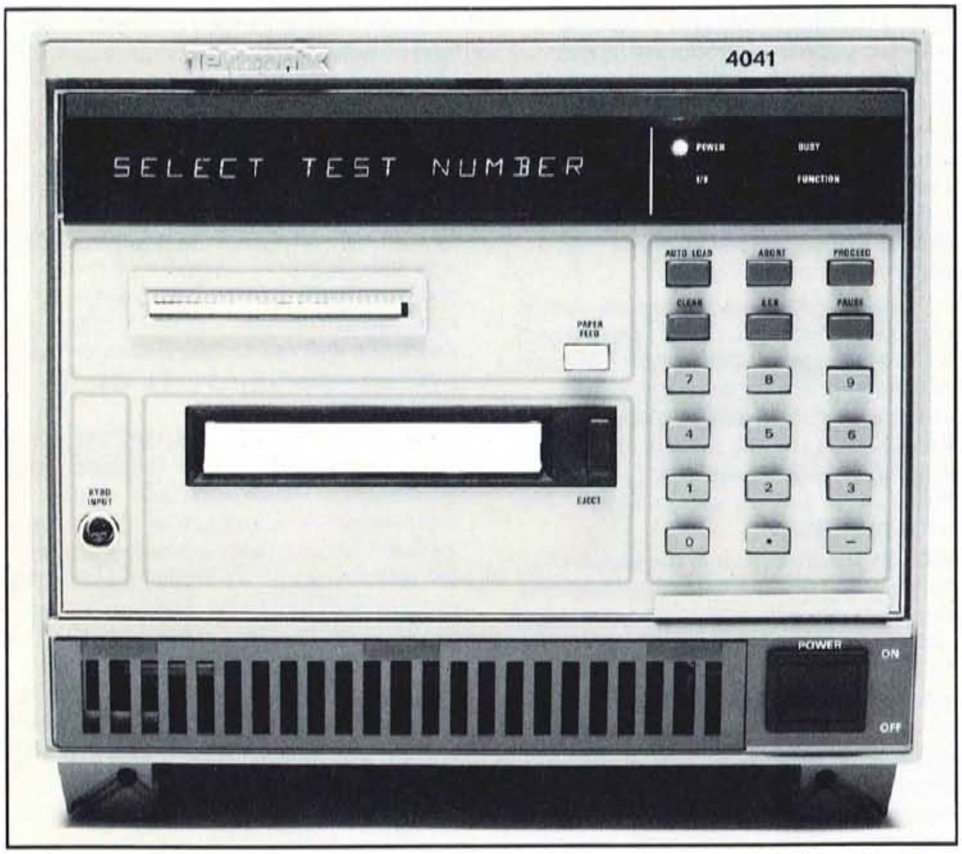


Fig. 2. The 4041 instrument-oriented controller is designed to serve needs in both engineering and production test. It can be used for program development, using an optional keyboard or any RS232-equipped terminal, or set up for "execute only" operation with programs loaded via mag-tape cartridges.

"execute only" operation, and for unattended, long-term data logging.

The 4041's front panel contains an 18-key operator keypad. Ten numeric keys, useful for entering numeric information requested by an INPUT statement, are user-definable and can be assigned subroutines by the applications program. A 20-character alphanumeric LED display communicates test procedures, operator prompts, and program results. Hardcopy is provided by a 20-column thermal strip printer.

The basic 4041 is configured for "execute only" operation. When using the 4041 for program development, an optional ROM set in a special carrier is inserted via the front panel. This firmware completes the operating system and permits users to generate and debug original programs. Source code can be written using an optional keyboard that plugs into the 4041 or any CRT terminal connected via the RS-232C port. A hardcopy printer can also be connected to the 4041 if an optional second serial interface has been installed. The 4041 is compatible in appearance and mechanical design with the mainframe of the new TM 5000 Series of programmable instruments.

A new family of programmables

While work was proceeding on the software and the controller, a parallel program was underway to develop a whole family of programmable instruments. Designated the TM 5000 Series, the family includes nine new products at introduction: a triple power supply, 135 MHz and 350 MHz universal counter/timers, 20 MHz function generator, 4-½ digit digital multimeter, 16-channel rf scanner, multi-function interface, and two power mainframes.

All of the instruments comply with the Tektronix Codes and Formats Standard and have individual IEEE-488 interface controllers. Each has its own microprocessor to perform processing locally and keep bus traffic and demands on the system controller at a minimum.

An important design decision was to make all of the functions and parameters settable from the front panel, as well as being programmable. This provides a simple, straightforward means of programming an instrument. Lighted controls and digital displays indicate the status of the instruments at all times (except for the DC 5009). A major operating convenience is front-panel display of an instrument's primary address, available at the touch of a button.

At power-up, each instrument performs a self-test diagnostic routine to verify its readiness for use. If no internal error is found, the instrument enters the local state with its current front-panel settings and default remote settings, and signals the controller it is ready for service. If an internal error is found, an error code is immediately displayed on the instrument's front panel.

TM 5000 Series mainframes

Two power mainframes: a three-compartment wide (TM 5003) and a six-compartment wide (TM 5006), house and provide power to the plug-in modules. Both TM 500 and TM 5000 plug-in modules can be plugged into either mainframe. This gives users the option to use both manual and programmable instruments in the same enclosure to optimize system performance and cost.

A key-and-slot arrangement on the plug-in interface connectors prevents inadvertent insertion of alien modules. This scheme also provides a convenient means of reserving compartments for a particular class of instrument. For example, the right-hand compartment of each mainframe is a high-power location. A PS 5010 Programmable Power Supply inserted in this position can supply twice as much power as from another location.

Separate 20-pin connectors in each compartment interface with the programmable modules. These connectors are paralleled and brought out to a single IEEE-488 connector at the rear of the mainframe.

A programmable triple power supply

The PS 5010 Programmable Power Supply is designed to furnish commonly-used positive, negative, and logic supply voltages, from a single unit. The 0 to +32 and 0 to −32 volt floating supplies (referenced to a common front-panel terminal) can each supply up to 750 milliamps. In a mainframe high-power slot, up to 1.6 amps at 15 volts is available. Programming increments are 10 millivolts from 0 to 10 volts and 100 millivolts from 10 to 32 volts. Current limiting is also programmable in 50-milliamp increments from 50 milliamps to 1.6 amps. The two supplies can be operated independently or set in a dual tracking mode.

The logic supply is ground-referenced and programmable over a range from 4.5 to 5.5 volts in 10 millivolt increments. Here, too, current limits can be set in increments of 100 milliamps over a 100 milliamp to 3-amp range.

The supplies have three operating states—voltage regulated, current limited, or undefined. Should a supply change from one state to another, for example, from voltage regulated to current limited, the PS 5010 will indicate the change on its digital display and send an interrupt to the system controller. The controller can then query the status of the supply and take appropriate action.

Unique function generator control

The FG 5010 Programmable Function Generator provides the usual capabilities plus some unique ones. For example, users can control waveform symmetry in one-percent increments from 10 to 90 percent, and can program phase from +90 degrees to −90 degrees in one-degree steps when operating in the trigger and gate modes. In the phase-locked mode, phase with reference to the locking signal can also be controlled with the same resolution and range.

Frequencies from 2 millihertz to 20 megahertz, amplitudes from 20 millivolts to 20 volts, and offsets from 0 to 7.5 volts are all programmable. An error-correction circuit maintains frequency accuracy within 0.1 percent. All of the programmable functions, parameters, operating modes, and so forth can be set up manually via front-panel pushbuttons. The FG 5010 can store up to ten setups, thereby reducing bus programming time during system operation.

Counter/Timer 1-picosecond resolution

The 350 megahertz DC 5010 Universal Timer/Counter also contributes some unique capabilities to the system. A proprietary, front-end, integrated circuit, which was designed and fabricated at Tektronix, makes possible one-picosecond averaging

Fig. 3. The FG 5010 Programmable 20-MHz Function Generator can store 10 complete panel setups and has counted-burst and phase lock capabilities as well as programmable symmetry and phase.

resolution. Single-shot time resolution is 3.125 nanoseconds.

Both the DC 5010 and the 135 megahertz DC 5009 feature a dual-input ratio architecture, with several modes for adding, subtracting, and calculating ratios of events on the two channels.

An autotrigger function measures the peak-to-peak input signal amplitude and sets the trigger level to the 50 percent point. The DC 5010 uses this same peak-to-peak information to calculate the 10 percent to 90 percent rise and fall times of the input signal. A null function subtracts an initial reading from subsequent readings, to automatically compensate for differences in cable lengths, and so forth.

All of the DC 5009 and DC 5010 functions can be controlled from the front panel or the IEEE-488 bus.

A smart 4-½ digit multimeter

The DM 5010 Programmable Digital Multimeter is a 0.015 percent instrument with extensive math capability. Besides measuring resistance and AC or DC volts, the DM 5010 calculates averages, handles offset and scaling, performs decibel conversions, has a nulling function, and makes comparison readings for a high-low-pass sorting mode. This extensive math capability makes the DM 5010 a valuable stand-alone instrument, and greatly reduces time on the bus when used in systems applications.

The DM 5010 measures up to 1000 volts DC, 700 volts true RMS AC, and 20 megohms of resistance. A user can step through the ranges or use autoranging in both manual and programming modes of operation. A dual sample rate provides 4-½ digit resolution at 3 measurements per second, or 3-½ digit resolution at 26 measurements per second. As with other TM 5000 instruments, the DM 5010 is fully programmable from the front panel or the IEEE-488 bus.

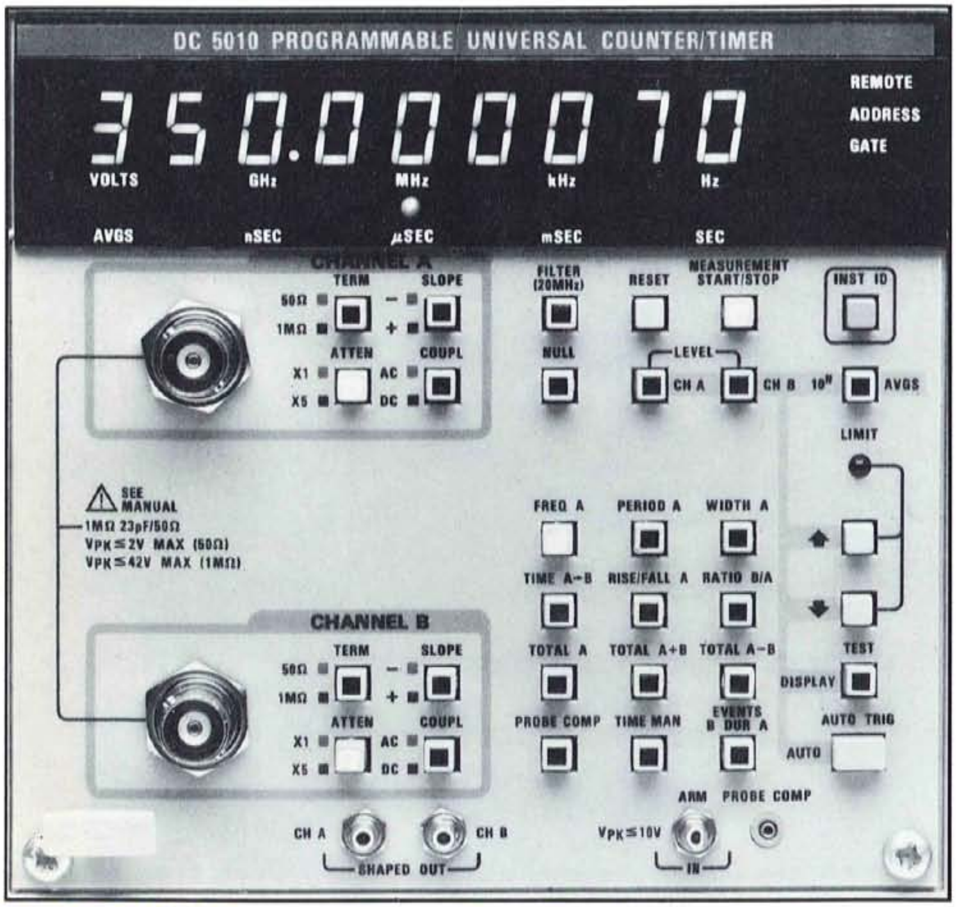


Fig. 4. The DC 5010 Programmable Universal Counter/Timer features reciprocal frequency, auto-trigger, RISE/FALL mode, and one-picosecond time interval averaging resolution.

Rounding out the system

An important part of any system activity is interfacing the test instruments to the device under test. Two products in the TM 5000 family—the MI 5010 Programmable Multifunction Interface and the SI 5010 R.F. Scanner—make the task relatively easy.

The MI 5010 and its companion MX 5010 Multifunction Interface Extender module each provide space for three plug-in cards. The purpose of the modules and their cards is to provide a programmable interface between the TM 5000 instruments and the device under test, and other non-IEEE-488 programmable instruments.

Three cards are available at introduction:

The 50M30 Programmable Digital I/O Card features 16 channels each of digital input and digital output. Both input and output are TTL compatible. Typical applications for this card include interfacing with relay drivers, switches or custom keyboards, BCD data from non-IEEE-488 instruments, and static binary words.

The 50M40 Programmable Relay Scanner Card serves as a low-frequency scanner accommodating up to 16 inputs or outputs. The card contains 16 mercury-wetted relays that can be configured 16-to-1, 8-to-1, or 4-to-1 by positioning jumpers. Typical uses include control of larger relays, scanning a multimeter input over several signal points, turning on lights or audible indicators, and so forth.

The 50M70 Programmable Development Card allows users to design their own special functions, such as digital-to-analog and analog-to-digital converters, special word recognizers, or any other function needed to complete an automated system, without concern for interfacing to the TM 5000 system. The rear portion of the card contains interface firmware, with the remainder of the card (about 20 square inches) reserved for the user's customized circuitry.

For switching high-frequency signals, the SI 5010 R.F. Scanner provides 16 wide-bandwidth channels that can be software-configured into a 16-to-1, two 8-to-1, or four 4-to-1 configurations. Optimum bandwidth is 350 MHz in the 4-to-1 configuration.

Both the SI 5010 and the MI 5010 have a real-time clock and buffer for sequence storage and execution, allowing the system controller to attend to other activities while switching commands are being implemented.

Summary

The TM 5000 Series Programmables are designed to extend the advantages of automated test systems to users previously denied access because of limited interfacing capability or programming expertise. A new instrument-oriented controller and extended-BASIC language provides versatility adequate for even the most sophisticated applications. And the modular design provides configurability and compactness unique in programmable systems.

Acknowledgements

The TM 5000 Series consists of several products, each developed as an individual project. R. Michael Johnson is engineering manager and provides overall direction for the TM 5000 program. Bob Bretl serves as overall software manager, and Bud Deibele coordinates mechanical design.

Don Hall was project manager for the FG 5010 Function Generator, Bruce Hofer for the PS 5010 Power Supply, Ken Panck for the DMM and counters, and Dave Wert for the mainframes and MI 5010 Multifunction Interface and SI 5010 R.F. Scanner.

Dave Heinen was program manager for the 4041 Controller, with Richard Crall heading up the electrical design team and Tom Hamilton the software team. Charles Brown coordinated the mechanical design.

Our thanks to these and the many others who made substantial contributions to the TM 5000 and 4041 programs. ■

Configurable State-of-the-Art Logic Analyzer Gives Choice of Performance

Bill Allen is currently logic analyzer product marketing manager. In the seven years since joining Tektronix, Bill has been a software systems analyst for computer graphics software and product line manager for the 4010 Series of computer display terminals. Bill received his B.A. in math and physics from Willamette University in 1964, an M.B.A. from Portland State University in 1976, and is presently working on his M.S.E.E. at the University of Portland.

John Huber is product line manager for the DAS 9100. Since joining Tek in 1973, he has performed diverse functions from quality control of large-screen storage display monitors to on-site service of complex semiconductor test systems. John is presently completing work on his B.S.E.E. at the University of Portland.

Tektronix customers are well aware of the benefits plug-in modularity affords oscilloscope users. Now, these same benefits are available to logic analyzer users. Selectable, plug-in card modules and a powerful mainframe let you configure the new DAS 9100 digital analysis system to meet your specific needs. You can have synchronous or asynchronous data acquisition at speeds up to 330 MHz, timing resolution to 1.5 nanoseconds on 8 channels, and data widths from 16 channels at 330 MHz to 104 channels at 25 MHz.

And the DAS can be more than just a logic analyzer. Two plug-in pattern generation modules let you generate word widths up to 80 bits at rates to 25 MHz. Combining pattern generation and data acquisition in a single modular instrument provides greater performance versatility and operating ease than is possible with separate units.

The DAS mainframe houses up to eight plug-in card modules. Two slots are reserved for the controller and time base/trigger modules, with the remaining six slots available for configuring the DAS to your specific task.

For data acquisition, there is a choice of four different modules:

Fig. 1. The DAS 9100 Digital Analysis System provides a choice of performance via plug-in card modules. An easy-to-use keyboard, selectable menus, and a large, bright display facilitates operation.

- The 91A32—32 channels and sampling rates to 25 MHz; well-suited for analyzing bus transactions.
- The 91A08—an eight-channel, 100-MHz unit with 5-ns glitch capturing capability.
- The 91A04—with four channels capable of 330-MHz acquisition and operation in a high-speed mode providing two channels of 1.5 nanosecond resolution.
- The 91AE04—a four channel, 330 MHz expander module.

Up to four acquisition modules can function in the DAS mainframe simultaneously. Memory depth is 2048 bits per channel with the 91A04 (4096 bits in the two-channel mode) and 512 bits per channel with the 91A08 and 91A32.

Two card modules are available for the pattern generator. The 91P16 basic unit provides 16 data output channels, two strobes, and a clock. An expander module, the 91P32, adds 32 data channels and four strobes. Three pattern-generator modules can function in the DAS simultaneously, to generate up to 80 channels of data and 10 programmable strobes at rates up to 25 MHz.

A common controller

The DAS uses a single Z80 microprocessor to control both data acquisition and pattern generation. You can start either function separately or both at the same time. The controller card contains 32 kilobytes of system RAM, with firmware occupying up to 128 kilobytes of ROM, part of which resides on the various modules. As the Z80 address bus is not open-ended, a way of mapping a module's firmware into the Z80 address space had to be implemented. This is accomplished by two 4-bit registers that are programmed to select the module and the particular ROM on the module to be addressed.

Communication between modules is via two busses: the controller bus—used for internal communications, and the high-speed bus, dedicated to control applications. The controller bus goes to all of the modules and carries address and data information. Faster signals, such as clocks, qualifiers, and word recognition travel the high-speed bus. Communication between the pattern generator and its extension modules is also via the high-speed bus.

Menus for manipulation

Extensive menus provide a high degree of versatility, yet make the DAS setup straight-

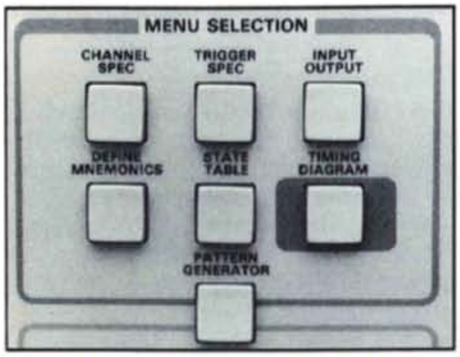


Fig. 2. The menu selection section of the DAS keyboard.

Fig. 3. The Channel Specification menu allows you to group the data input channels and arrange their display order, set probe threshold voltages, and choose the display radix (hex, binary, or octal).

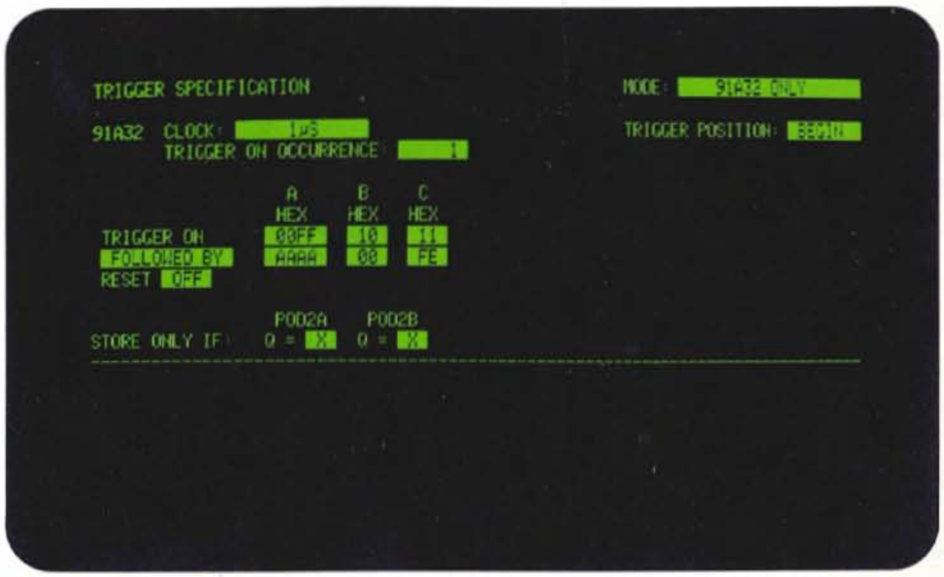


Fig. 4. The Trigger Specification menu is used to set up triggering parameters including clocks and qualifiers.

forward and easy to understand. Figure 2 shows the menu section of the DAS keyboard. There are seven general menus: five control the data acquisition function, one the pattern generator function, and one the input/output function. Several submenus can be selected from fields displayed in the general menus. At power up, all menus are automatically programmed with default values allowing immediate use of the DAS capabilities.

Also at power up, a configuration display lists the mainframe bus slots and identifies the installed modules. This display tells the user when power-up self-tests have been completed and indicates which modules pass or fail. If all elements pass, the screen displays a message instructing the user to select a channel specification, trigger specification, or pattern generation menu to program the desired function.

The Channel Specification menu (figure 3) controls the way in which incoming data is formatted and used by the trigger specification, state table, and mnemonic menus. However, it does not control how data is acquired. Once probes have been connected to the system under test, you can use this menu to change the display of data channels without manually reconnecting the probes or acquiring new data. Probe pods and channels can be grouped into logical display blocks, such as address, data, or control lines, and the order in which the groups will be displayed can be defined. A group may have from one to 96 channels. The Channel Specification menu is also used to select the radix and logic polarity of the displayed data, and for setting the probe threshold voltage for each group.

Versatile triggering provides split acquisition

The DAS provides a wide choice of trigger setups. Each DAS module has its own parameters, which are selected using the Trigger Specification menu (figure 4). With the 32-channel acquisition module installed, three-level sequential triggering (with various logical combinations), multiple trigger occurrences, arming, and delay times can be selected. Two clock qualifiers also can be set. Installation of a 91A08 module adds a 5-nanosecond glitch triggering capability and the trigger-arming capability when used with the 91A32 module.

The DAS also can acquire and display information from multiplexed microprocessor busses. With two 91A32 modules installed, a trigger specification sub-menu allows you to configure the DAS for external-split clock operation. By adding modules, up to three separate external clocks may be tracked, in turn, arming another module for asynchronous acquisition of high-speed data.

As a timing analyzer, the DAS provides state-of-the-art performance with resolution selectable from 40 nanoseconds to 1.5 nanoseconds. The timing display is enabled by selecting the Timing Diagram menu. A typical timing display is shown in figure 5. The display includes logic events stored in the acquisition and glitch memo-

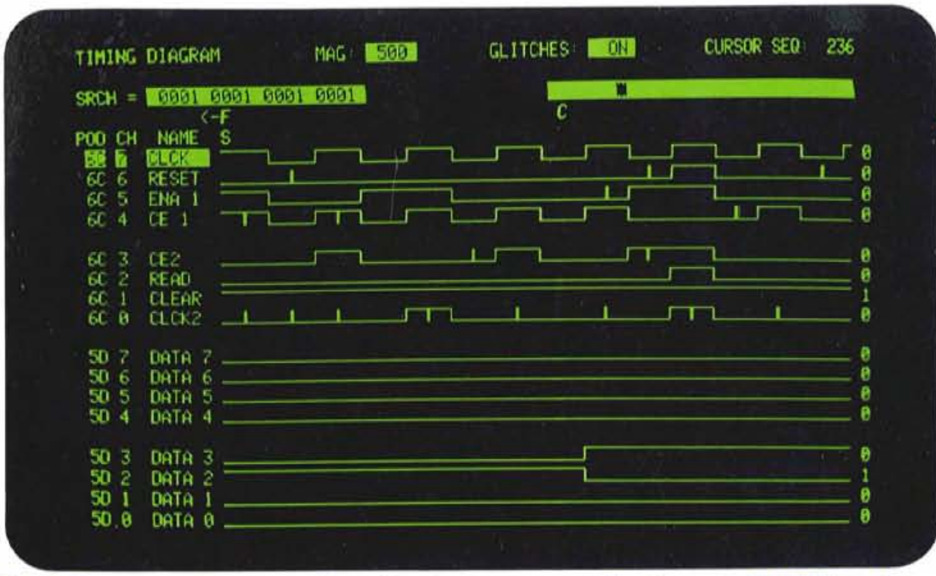


Fig. 5. The timing diagram provides glitch viewing and magnification up to 10,000 times for making high-resolution measurements. The portion of the timing window being displayed is indicated by the dark square in the horizontal green bar at upper right.

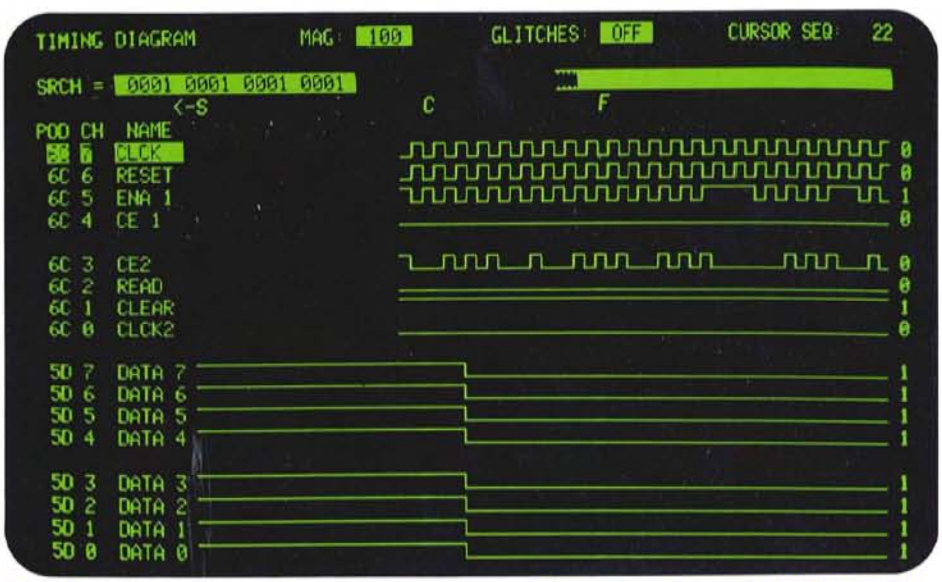


Fig. 6. This timing diagram shows simultaneous acquisition of synchronous data (low-speed acquisition) and asynchronous data (high-speed acquisition), using the trigger arming mode. The low and high-speed displays are displayed in correct time relationship.

ries, and several other elements to help you in analyzing the data.

When using multiple 330-MHz data acquisition modules, the transition time down the backplane between modules in the mainframe can be an appreciable part of a sample interval. Provision is made to automatically deskew, or balance out, the data paths in each high-speed module to assure correct time relationships. Deskewing is of particular importance in the 1.5 nanosecond resolution mode.

The DAS even allows split acquisition of data, in which slow and fast acquisition modules operate as linked logic analyzers. This operation is called the "arms mode."

Although many analyzers have an arming capability, there is an important difference in the DAS arming mode—both slow and fast data are displayed simultaneously and in correct time relationship.

To accomplish coincidence of the two data displays in the arms mode, the fast data module samples the slow data's clock and stores the result in a clock array. The DAS also records the slow and fast modules' trigger points, and the number of fast clocks occurring between the two triggers. Using these bits of information, the DAS firmware calculates what the relative on-screen positions of the data should be and displays them accordingly. The positions of the cursor and the fast and slow triggers are also displayed.

Of particular importance in split acquisition is the MAG (magnification) field, which allows you to increase the display resolution. In default, no magnification is used and the entire memory content of each channel trace is shown. You can select magnifications of up to 10,000 times in a 1-2-5 sequence (see figure 6). A memory window in the upper-right section of the screen shows the portion of memory being displayed.

When a 91A08 acquisition module is in use, glitches are always acquired. You can quickly determine whether a displayed pulse is data or a glitch by setting the GLITCH field to OFF.

The SEARCH field in the menu allows you to do two types of searches. You can search for the next change in data values (from the memory cursor location) or you can search for a specific data word. When data has been acquired using a fast internal clock rate, the search for next change of data mode allows you to quickly move to the next area of interest without continual scrolling. The logic levels present at the cursor position are displayed in binary at the right-hand edge of the screen.

The POD and CH (channel) fields at the left of the screen identify which data channels are being displayed. You can use these fields to display channel traces in any order you choose and can label each trace with a name consisting of up to six characters. The trigger cursor indicates the position of the trigger word on-screen. Both fast and slow triggers are indicated in split acquisition timing displays.

Mnemonics enhance state table displays

The Channel Specification menu provides great flexibility in formatting data for the state table display. Once data is acquired, it can be moved around easily and grouped for fast, efficient analysis. The State Table menu (figure 7) gives you a choice of displaying data residing in acquisition memory, or displaying data from reference memory separately or simultaneously with acquisition memory. You can also choose to mask out columns of data so that they are ignored during memory comparisons, or select a portion of the data in reference memory, for comparison.

The state table display can be enhanced by use of the Define Mnemonics menu (figure 8). With this menu you can identify events with a word and more easily follow data transactions acquired by the DAS. Mnemonics can be linked to individual probe inputs for easy separation of data. Up to 256 mnemonics can be assigned.

When the Define Mnemonic menu is selected, the menu "reads" the Channel Specification menu to find out how the channels are grouped together. It then provides a mnemonic table for each valid group. All 256 mnemonic values can be entered under one table or divided into as many as 16 separate groups. The group table can be used to disassemble data displayed in the state table.

A trailing words field lets you specify whether a given mnemonic applies to more than one data value. Many assembly languages use a series of data words for one instruction. You may want to specify a mnemonic on the first word and disable disassembly on the remaining words. The trailing words feature gives you this capability for up to nine trailing words. In addition, you can use mnemonics for labeling calls to subroutines or for defining your own custom labels.

The pattern generation function

In the introductory paragraphs of this article we discussed briefly the pattern generation capabilities of the DAS—word widths up to 80 channels, clock rates to 25 MHz, and up to 10 programmable strobes. Now let's consider this function in greater detail.

The basic pattern generator module provides 16 channels of data output, plus two strobe outputs and a clock output. An extension module adds 32 data outputs and four more strobes. The basic module and two expansion modules can be plugged into the DAS to provide a total of 80 data channels and 10 strobe outputs. Up to 254 different words can be defined in a single program.

Like the logic analyzer function, the pattern generator is menu driven. Two submenus direct input from the keyboard to set up the pattern generator for the specific application. The Program sub-menu (figure 9) allows you to specify clock source and rate, response to input signals from the system under test, and to program the data output. Seven instruction keys (figure 10) are used with this menu. You can:

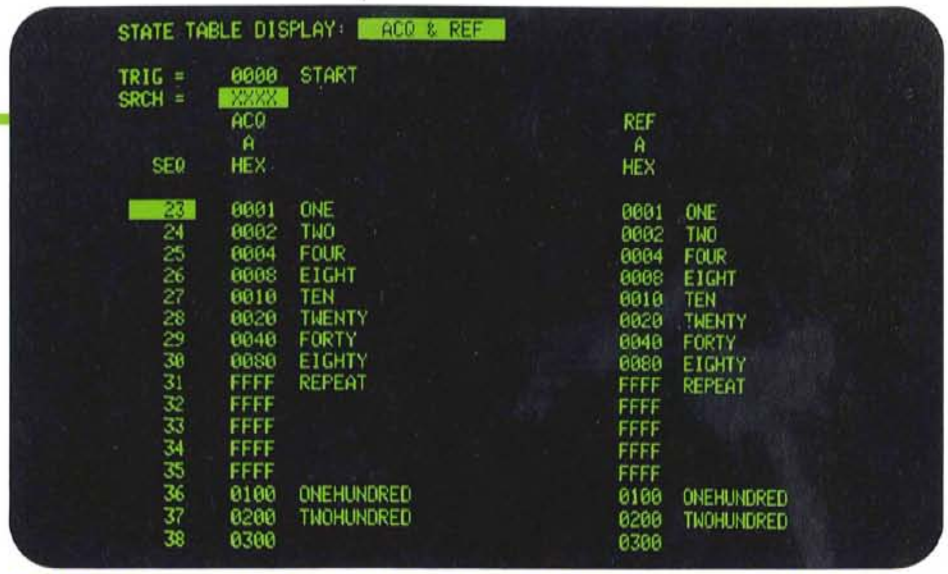


Fig. 7. Using a state table display, both acquisition and reference memory can be viewed simultaneously for easy comparison of newly acquired data with known data.

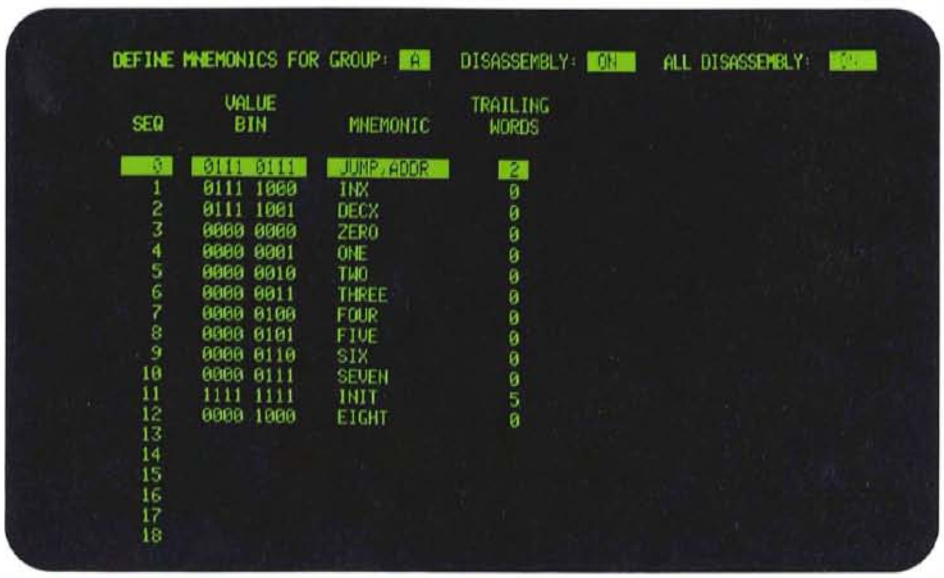


Fig. 8. The Define Mnemonics menu allows you to label numerous values with a custom word of up to 10 characters. The trailing-words feature allows you to apply a given mnemonic to more than one data value.

- Specify each word in the pattern generation sequence
- Loop to labeled program lines
- Call labeled subroutines and return from them
- Program incremental counting
- Repeat a word n number of times
- Hold the same data output for n clock cycles (with clock output disabled)
- Halt data output
- And select the number of active strobes.

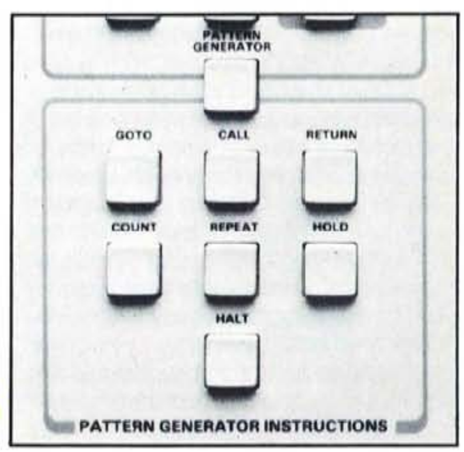


Fig. 10. The pattern generator instructions keyboard simplifies entering instructions in the program.

Fig. 9. The Pattern Generator Program sub-menu is used to set up the pattern generator's output program and select the programmed strobes.

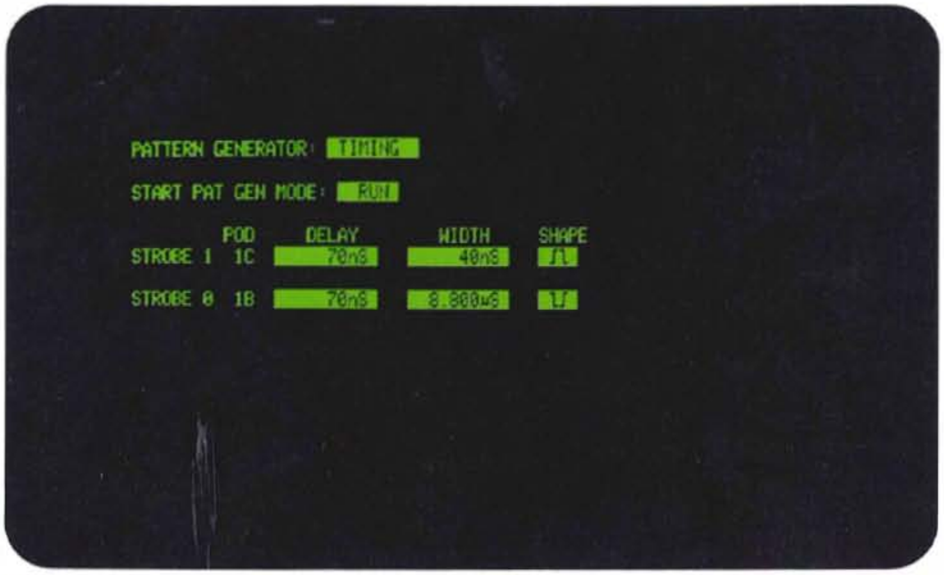


Fig. 11. The Pattern Generator Timing sub-menu is used to define the characteristics of the programmable strobes and the pattern generator's start mode (either run or step).

The pattern generation Timing menu (figure 11) provides control of two pattern generation functions: the mode in which data will be output—continuous or step by step, and the characteristics of each strobe output. Three characteristics can be defined—delay of the strobe output with respect to the output clock edge, duration of the strobe, and the polarity of the strobe. The strobe outputs can be programmed and combined in a manner to simulate bus management activity and thus control the input of a programmed pattern sequence to a prototype.

Interaction with the prototype is enabled by programming the pattern generator to respond in specific ways to active inputs on the DAS's pause, inhibit, and interrupt lines. An active "pause" signal from the prototype will cause the pattern generator to stop at its most recent step in programmed data output until the prototype releases the "pause." The pattern generator will then resume output at the next step in the pattern program. If the prototype initiates an "inhibit" signal, the pattern generator's data output lines go tri-state, effectively disconnecting them from the bus. If the prototype asserts the "interrupt" line, the pattern program will jump to a specified subroutine, execute it, and then return to the main pattern program flow. It is possible to have subroutines nested inside the interrupt routine. The system permits up to 16 levels of nesting.

Interfacing the pattern generator

Two different pattern generator probes were developed to provide interfacing with the various logic families. The TTL/MOS version has active pull-up and pull-down and accommodates large swings and relatively slow rise and fall times.

Each probe provides ten output channels: eight data, one strobe, and one clock. Additional lines connect to voltage rails and establish the high- and low-level thresholds.

The external clock, and pause, inhibit, and interrupt signals are input to the pattern generator via a clock probe plugged into the trigger/timebase module. The same probe provides a master-external-clock input and two additional external-clock lines for external-split-clock operation of the 32-channel data acquisition module.

DAS applications expanded

Several optional features allow you to apply the DAS to applications outside the usual design realm. The DC 100 Magnetic Tape Drive Option provides over 160 kilobytes of permanent storage that can be used for saving test patterns used in designing and troubleshooting a product. These saved patterns are quite useful in testing and evaluating a product in production. Instrument setups and mnemonic tables also can be stored and used to automatically restore the DAS to a particular setup.

Another option provides the DAS with RS-232, IEEE-488 GPIB, and hard copy unit interfaces. The RS-232 and IEEE-488 interfaces allow you to operate the DAS from a controller in networked or automated test applications. The remote programming language supports all operations which can be performed from the instrument keyboard and some additional commands that are useful for automated test applications.

The RS-232 interface also allows one DAS to be linked with another in a master/slave arrangement for remote operation. The master DAS serves as the controller for setting up and operating the remote slave DAS, and does not have to have the same complement of modules as the slave.

An optional composite video output allows documentation of test results and operating parameters through the use of a hard copy unit such as the Tektronix 4612 or 4632. This port also may be used for connecting to a remote monitor for group viewing.

Self-test diagnostics

When an instrument performs as many functions as the DAS, it is important to have self-test at power up. Each time the DAS is powered up, internal diagnostic tests automatically check out the major mainframe components and operating firmware.

During the first phase of the self-test, the DAS tests the major blocks of RAM and ROM and initializes I/O ports. After initialization is complete, a screen display (figure 12) lists the installed modules, which slot they reside in, and whether each passes or fails the self-test. Procedural options are listed at the bottom of the display. An extended diagnostic menu can be called up to run tests that fully check out any module or the entire system.

To allow you to check out the probes used with the DAS, a diagnostic lead set is provided that facilitates connection between a pattern generation probe and an acquisition probe. A preset walking-ones pattern allows you to test the complete path from the pattern generator, through the pattern generator and acquisition probes, to the acquisition module. This setup is also a convenient vehicle for learning how to operate the instrument.

Summary

The DAS 9100 is a unique combination of state-of-the-art logic analyzer and pattern generator. It is designed to allow you to efficiently simulate, stimulate, and analyze the response of digital circuitry. Modular design lets you configure the DAS for today's tasks and expand it to meet future needs. It is easy to operate, yet versatile enough to handle even the most demanding application.

Acknowledgements

Steve Palmquist headed up the DAS design team, which included analog and digital circuit designers, software designers, and mechanical designers. Dave Chapman designed the controller and trigger/time base modules, the 91A08, and the I/O card; Steve Palmquist designed the 91A32 and the 91P16 and 91P32 pattern generator modules; and Glenn Gombert designed the 91A04 high-speed module. Robin Larson did the analog design including probes and power supplies.

Gerd Hoeren was the software project leader, ably assisted by Mark Pettet, who designed the interpreter and the trigger and time base menus. Steve Sutton designed the state table and pattern generator menus; Dennis Lamb designed the Define Mnemonics and I/O menus; and Jerrs Sewell defined and designed the remote programming capability (IEEE-488 and RS-232).

Ben Demise did an outstanding mechanical design job fitting the DAS into Tek's new standard mechanical package.

Many others were involved in prototype construction, evaluation, and putting the DAS into production. Our thanks to all for their valuable contributions to the DAS project. ■

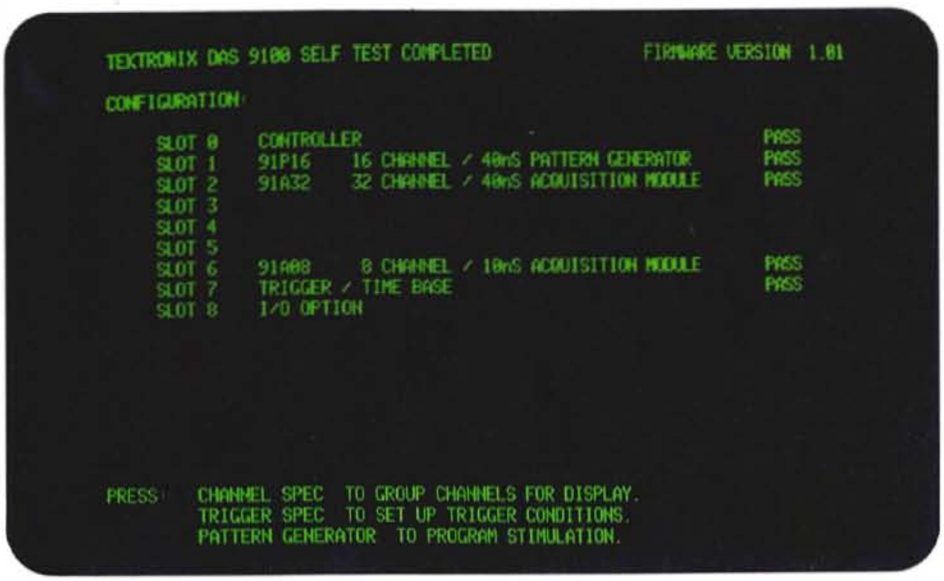


Fig. 12. The Configuration menu is automatically displayed at power-up. It lists the installed modules, the firmware version resident in the DAS, and whether each module passes or fails the power-up self-tests.

Codes and Formats Standard Adds Compatibility and Capability to IEEE-488 Instruments

Bob Cram is manager of the Automated Instrument Compatibility Evaluation group. He started with Tek in 1973 and joined the evaluation group following five years as Metrologist with the Electrical Standards group. While a part of the Standards group he did extensive development work on automated calibration procedures. Bob received his BA in physics from Linfield College in 1967 and performed graduate work at the University of Colorado in Boulder. His leasure time activities include ham radio and astronomy.

Exciting new measurement capabilities are announced almost daily in the form of microprocessor-based products designed to operate as stand-alone instruments or as part of an automated measurement system.

The IEEE Standard 488, introduced in 1975, makes the task of assembling a system much easier by defining a standard interface for programmable instruments. The standard covers three basic aspects:

Mechanical—the connector and the cable.

Electrical—the voltage levels for logic signals and how the signals are sent and received.

Functional—the tasks that an instrument's interface is to perform, such as sending data, receiving data, and triggering the instrument.

Using the interface standard, instruments can be designed for basic compatibility. However, this standard is only the first step in ensuring compatibility. Instruments from various manufacturers still differ in the way in which data is encoded and transmitted. The situation can be likened to two persons trying to converse over the telephone; they have a physical connection, but unless both speak and understand the same language, little communication takes place.

To resolve this dilemma for instrumentation, Tektronix has developed a codes and formats standard. This standard establishes a common message structure, describes communication elements and how they will be combined, defines control protocol, and standardizes features that are particularly important to test, measurement, and analysis systems.

Because nearly all of today's IEEE-488 instruments use ASCII-coded characters to send and receive data, Tektronix has chosen ASCII coding as standard. In addition, nearly all instruments that send or receive numbers use the ANSI X3.42 standard format. This format states, in effect, that there are three types of numbers—integers, reals, and reals with exponents—and that they should be sent with the most significant character first. Table 1 shows examples of these formats.

Note that while a number has been defined, its use has not. The codes and formats standard places no restrictions on the use of a number. It does not matter whether a number is from a multimeter, counter, or spectrum analyzer. In all cases, the syntax, or structure, of the number is the same.

Instruments that incorporate microprocessors can perform complex functions. To have a computer or instrument controller fully interact with such devices requires code and format conventions more comprehensive than those that simply define numbers.

For instance, consider a device that makes a group of measurements and is asked to report them. This requires a group of numbers to be sent. In the Tektronix standard, a comma is used to separate one number from another. As an example, a digital multimeter might send measured output voltage limits as −2.32, 1.65.

Further, suppose that another device makes two different types of measurements, such as frequency and phase, and is asked to report them. There should be a means for identifying each type. This is done by sending a "header" that is a description of the number. If headers and

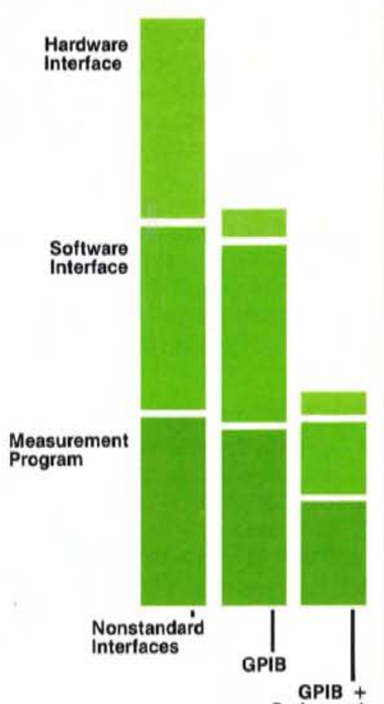


Fig. 1. Set-up times are decreased and ease-of-use is increased (improved productivity) when instruments use GPIB combined with standard Codes and Formats and user-oriented operating conventions.

Table 1: Number Formats (ANSI X3.42)

NR1	375 +8960 −328 +0000	Value of "0" must not contain a minus sign.
NR2	+12.589 1.37592 −00037.5 0.000	Radix point should be preceded by at least one digit. Value of "0" must not contain a minus sign.
NR3	−1.51E + 03 +51.2E − 07 +00.0E + 00	Value of "0" must contain an NR2 zero followed by a zero exponent.

numbers are sent sequentially, they must be separated from each other. A semicolon is used for this purpose; for example, FREQ 3570; PHASE 72.

These well-defined formats significantly enhance data communication compatibility over the IEEE-488 bus.

The human interface

The rapid growth in the numbers of instruments that include an IEEE-488 interface means more people will be involved in connecting these instruments together to perform some measurement function. Typically, the people will have widely divergent skill levels. The manner in which an instrument can be programmed will determine the skill level required to effectively use it. For instance, consider an IEEE-488 programmable power supply. It can be designed in one of two ways. The first is with minimal intelligence that allows the instrument to accept some code that can be conveniently interpreted and executed. As an example, some power supplies require the sequence 0 8 E 3 to put out 20 volts. Here, the "0" stands for the 0-to-36 volt range, and the "8E3" is the ASCII representation of the hexadecimal commands required.

The second method is to design the power supply with a microprocessor and intelligence to accept easily understood numbers. In this instance, to put out 20 volts from the positive supply of a multiple-supply instrument, the programmer simply sends the character sequence "VPOS 20". This method of interacting is obviously easier for the person writing the original program and also for someone who later has to figure out what the program is supposed to do.

Numbers in easily read formats are easily handled by both computers and people. It is also necessary to send instructions to an instrument in a format other than numbers. For example, in setting up a measurement, you may want to specify: trigger external, peak auto, and function sine. In these instances, we can treat the first word as a header and the second word as a data type that is different from a number.

Other data types, called arguments, are useful for various purposes:

Character arguments—for sending information relevant to a header but not expressable as a number; for example, GRATICULE ON or COUPLING DC.

String arguments—for sending text to a display or printer.

Binary block arguments—for sending binary data of known length.

Link arguments—for sending certain types of instrument commands.

End block arguments—for sending binary data of unknown length or format.

The same general format can be used for all types of communications on the IEEE-488 bus. Table 2 defines the message structure used for Tektronix instruments.

Message conventions

While the use of standard codes and formats enhances compatibility between devices using the IEEE-488 bus, it does not solve all of the compatibility problems. Well-defined operational conventions are also needed.

A good example is the need for a standard way to terminate messages. Two methods are currently in use: the first sends printer format characters such as CR or CR LF; and the other asserts the EOI line during the time the last data byte of the message is sent.

The first method provides opportunity for confusion. For example, it is possible for a message to contain a sequence of binary coded bytes which, if perceived as ASCII, will appear to be a CR LF and thus be misinterpreted.

The second termination method—asserting EOI concurrently with the last byte—unambiguously terminates the message. This is the method specified in the Tektronix Codes and Formats standard.

Other problems can be created by the lack of good message handling conventions. A classic example is a programmable power supply which executes each individual command as received. If the programmer neglects to set the current limit first and programs a substantial increase in output voltage, the device under test could be damaged. A power supply designed to execute a command only after receiving the entire message terminated by asserting EOI would not present this problem.

This same convention prevents misunderstandings between a computer and a measurement instrument. When instructed to send a measurement message, an instrument sends EOI only when the message is completed, and no more data is sent unless directed by the computer to do so. Thus, the computer knows the message is complete, and the instrument has not been stopped in the middle of talking.

The Tektronix Codes and Formats standard defines a message to be a complete block of information. It begins when a device starts sending a message and ends when EOI is sent concurrently with the last data byte.

Obviously, it is important to also clarify the beginning of a message. An instrument sending a message may be interrupted by the computer taking control, perhaps to conduct a serial poll. When the instrument becomes a talker again, it should resume sending the message. Thus, the message beginning is defined as the time when a device enters the talker active state for the first time following a reset or a previously sent EOI.

There are other elements in the message convention. When a device is made a talker, it should always say something. If it has nothing to say, it should send a byte of all ones concurrent with EOI. This tells the listening device that no meaningful data is forthcoming and prevents tying up the IEEE-488 bus while the computer waits for a nonexistent message.

A listening device should always handshake, even when it does not understand or cannot execute a particular message. Under no circumstances should a device execute a message it does not understand. After EOI is received, if the listening device is confused, it should send out a service request and, on a serial poll, notify the controller that the message was unclear.

Status byte and query convention

The Tektronix Codes and Formats standard also includes a status byte convention to augment that provided by IEEE-488. The IEEE-488 standard defines a facility to send a byte of status data to the computer. However, it assigns only one bit—bit 7—which shows whether a device is, or is not, requesting service.

There is a need for instruments to report other kinds of status and/or errors to the computer. One common need is for instruments to report if they are busy or ready (bit 5 is used for this purpose). Another need is to report abnormal conditions being encountered (bit 6 is selected for this). More complex conditions are reported by other status byte configura-

Table 2: Device-Dependent Message Structure

A message represents a given amount of information whose beginning and end is defined. It is communicated between a device functioning as a talker and one or more devices functioning as listeners.

A message begins when the transmitting device is initially addressed to talk and the receiving device is addressed as listener.

A message is composed of one or more message units separated by message unit delimiters. A message unit delimiter is a semicolon.

The message ends when the talking device asserts EOI.

There are two message unit types:

1. Mixed Data Message Unit.
   Two acceptable formats are:
   a. Header (in character argument format followed by a space and optional arguments of any type separated by commas).
   b. Noncharacter argument followed by optional arguments of any type separated by commas.
2. Query Message Unit.
   Consists of a character argument such as "SET", "ID", or "FREQ" followed by a question mark.

Argument Types and Examples	**Definition**
Character Argument: TRIGGER	One alphabetic ASCII character optionally followed by any number of ASCII characters excluding space, comma, semicolon, question mark, the control characters, and rubout.
Noncharacter Arguments: Number Argument −12.3	A numeric value in any of the formats shown in Table 1.
String Argument "Remove Probe"	Opening delimiter (single or double quote) followed by a series of any ASCII characters except for the opening delimiter, and a closing delimiter identical to the opening delimiter.
Binary Block Argument % | 2 bytes (16 bit binary value) | Binary Data (waveform values) | 8 bits (checksum)	"%" followed by a 2-byte (16 bit) binary integer specifying the number of data bytes, plus a checksum byte which follows the data bytes. The checksum is a twos complement of the modulo 256 sum of the preceding binary data bytes. This includes the two bytes comprising the 16-bit integer specification.
Link Argument NT.PT:1024	Character argument (label) followed by ":" and a value represented in any of the above argument types.
End Block Argument @ABCDEFGHIJKL E O I	"@" followed by a block of data with EOI set concurrent with the last data byte. End block can only be the last argument in a message and cannot be followed by a message unit delimiter.

tions as shown in Table 3. These status bytes are useful for most purposes; however, some instruments may have conditions that are peculiar to them. Bit 8 is used to indicate that a status byte is particular to an instrument.

A standard coding for the status byte is a convenience when programming a system, especially if all instruments use the same coding. This allows a common status byte handling routine to be written for all instruments.

To supply even more detailed information than the status byte can convey, a set of queries are used. Queries take the form of a header followed by a question mark.

A typical example is shown in figure 2. Here, the computer has asked the instrument to state its frequency setting.

A SET? query makes it possible to develop a program using an instrument's front panel as an input to the computer. The programmer using this feature may never need to know the instrument's IEEE-488 bus commands. Implementing a SET command restores the instrument to the state it was in when the SET? query was invoked.

Some fine touches

As instruments get more complex and possess computer-like capabilities, more operational conventions will be needed. These conventions should make the instrument easier to use if the intelligence is used properly. Here are some examples of conventions adopted by Tektronix to enhance both computer/instrument compatibility and human/system compatibility:

- While an instrument should always send numbers in the correct format described earlier, it should receive numbers forgivingly. Specifically:
  - Negative zero numbers should never be sent, but they should be accepted.
  - Any number sent in scientific notation should be sent exactly as defined in ANSI X3.42 standard; that is, with the decimal point included. Some computers violate this standard by omitting the decimal point. This "illegal" number should be received with an implied decimal point following the least significant digit.
  - If an instrument receives a number whose precision is greater than the instrument can handle internally, the number should be rounded off, not truncated.
- An instrument should recognize both spaces and commas as argument delimiters. Multiple spaces or commas should not be construed as delimiters for null arguments.
- An instrument should receive headers and character arguments in both upper and lower case and equate them (a = A, b = B). Some desktop instrument controllers have a problem sending upper case alpha characters.

Table 3. Status Byte Convention

Name	Code	Function
Normal conditions:		
Normal status	000X 0000	Response to serial poll when condition of instrument is normal.
SRQ query request	010X 0000	Tells controller to query device for service needed.
Power on	010X 0001	Reported after every power on. Tells controller that device is on the bus.
Operation complete	010X 0010	Tells controller that a task is completed.
Abnormal conditions:		
ERR query requested	011X 0000	Reports error but does not identify it. Controller should send query to identify errors.
Command error	011X 0001	Reports that message received cannot be parsed.
Execution error	011X 0010	States that message cannot be executed.
Internal error	011X 0011	States that device is out of calibration or is malfunctioning.
Power fail	011X 0100	Notifies controller that power failure is occurring. Controller may take action to save data or flag suspect operation.
Execution error warning	011X 0101	Warns that device has received and is executing a command but that a potential problem exists.
Internal error warning	011X 0110	Warns that device has an internal failure but is continuing to function.

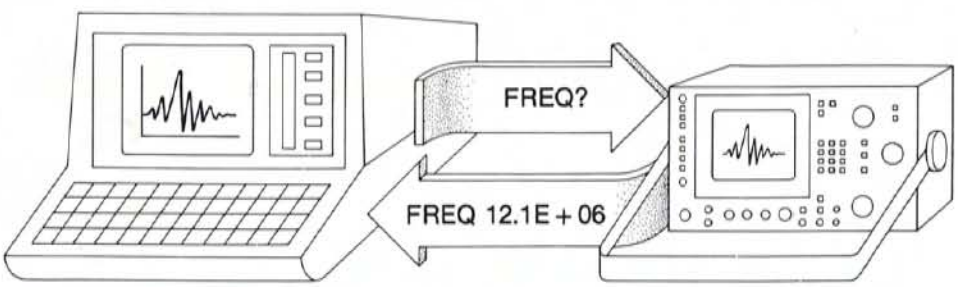


Fig. 2. The use of easy-to-remember queries is an important feature of Tektronix GPIB instruments. Many query commands are formed by adding a question mark to the mnemonic for the setting to be queried.

- An instrument sending data about its front-panel status should use headers and character arguments that correspond to the front-panel nomenclature.

Compliance with these conventions make Tektronix instruments "friendly" to a casual or inexperienced programmer and compatible with most computers.

There are other features built into Tektronix intelligent instruments that enhance their usability. Here are two examples:

The Service Request (SR) function and corresponding status byte are very important. They can alert the instrument controller to new events or possible malfunctions. For example, sometimes a computer or instrument does not want to be interrupted. For these cases, an RQS OFF message can be sent to disable any service requests. To turn the service request capability back on, an RQS ON is sent.

Another useful convention relates to the Device Trigger (DT) function. Sometimes a command message sent to an instrument should be executed immediately. At other times, the command should only set up the instrument, and the desired action should be executed when the Group Execute Trigger interface message is sent. To make the instrument execute commands immediately, the message DT OFF is sent. Conversely, to make the instrument defer execution of commands, the message DT followed by a descriptive character argument such as TRIG or GATE is sent.

Summary

The Tektronix Codes and Formats standard is designed to extend the compatibility of programmable instruments. This standard should reduce the cost and time required to develop system and applications software by making it easier to generate and understand the necessary device-dependent coding.

Operational conventions are an important part of the standard. They ensure that communications over the bus take place in a logical, consistent manner and avoid ambiguities between the transmitted and received message. ■

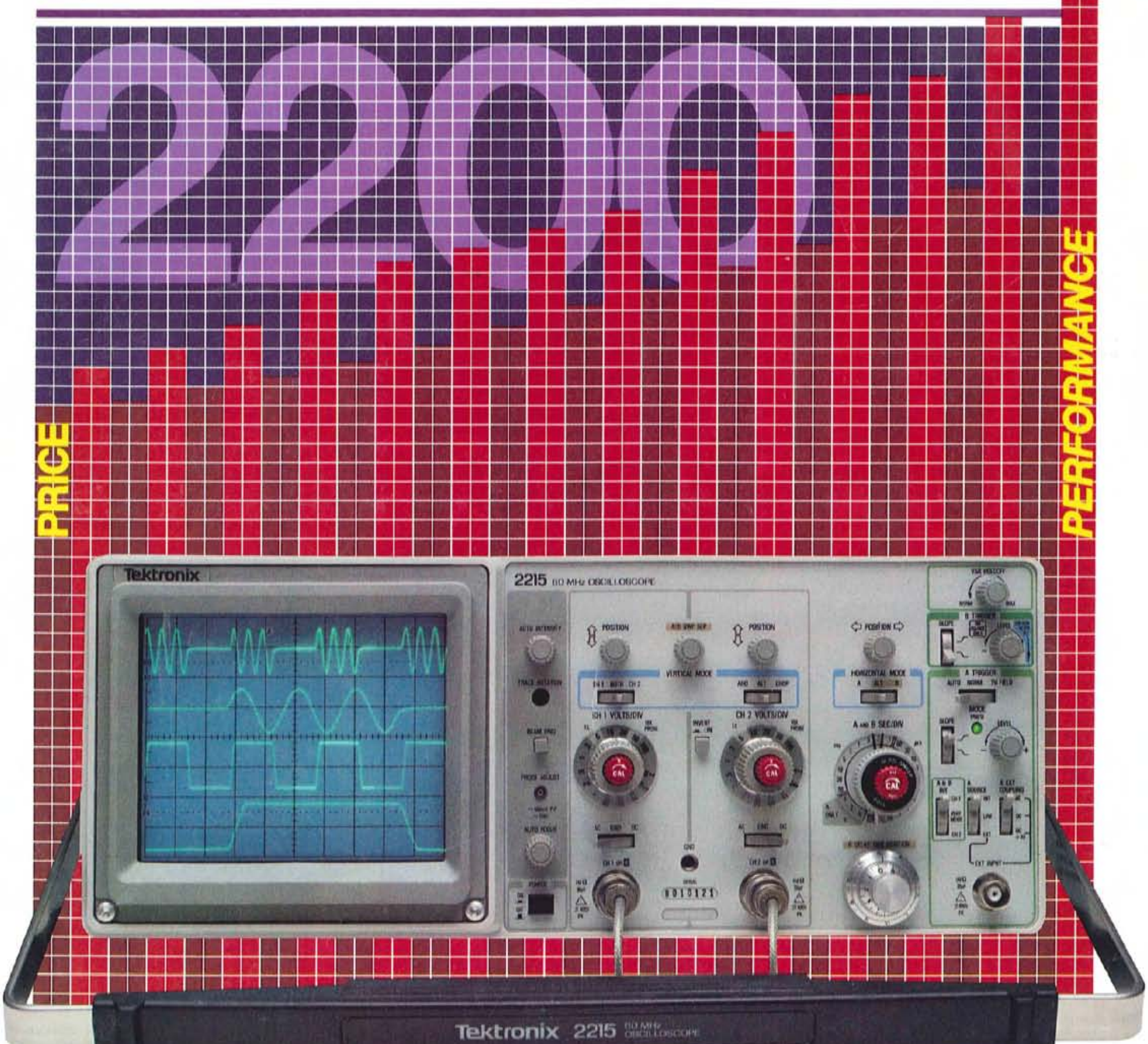
9/81 99AX-4896

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

TECHNICAL INFORMATION
FOR TEKTRONIX CUSTOMERS

VOLUME 14 NUMBER 1
MARCH 1982

Tekscope

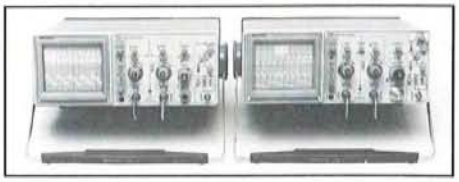


Tektronix
COMMITTED TO EXCELLENCE

Tekscope CONTENTS

Designing a New Price/ Performance Standard for Portable Oscilloscopes

New design concepts and production techniques are combined to produce a series of portable oscilloscopes that set a new price/performance standard for the industry.



A Multiple-User Software Development Unit

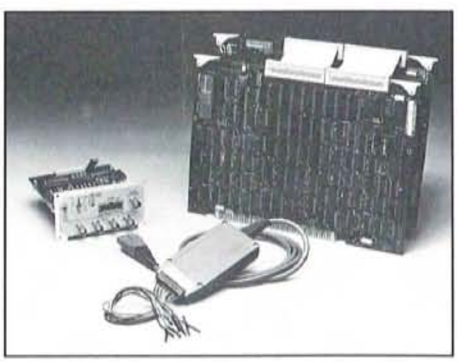
The new Tektronix 8560 Multi-user Software Development Unit is a team-oriented design tool. Accommodating up to eight workstations simultaneously, the 8560 provides a powerful, flexible solution to software development problems.

A Powerful New Tool for Integrating Microcomputer Hardware and Software

Integrating newly-written software and prototype hardware becomes an orderly, efficient process, when using the Tektronix 8540 Integration Unit designed for use with the 8560 or other host computer.

A Real-Time Debugging Tool for the 8500 Series MDL

The Trigger Trace Analyzer option for the 8540 Integration Unit and the 8550 MDL, provides unprecedented trigger depth to allow you to examine even the most complex portions of your user programs.



Customer information from Tektronix, Inc.
Beaverton, Oregon 97077

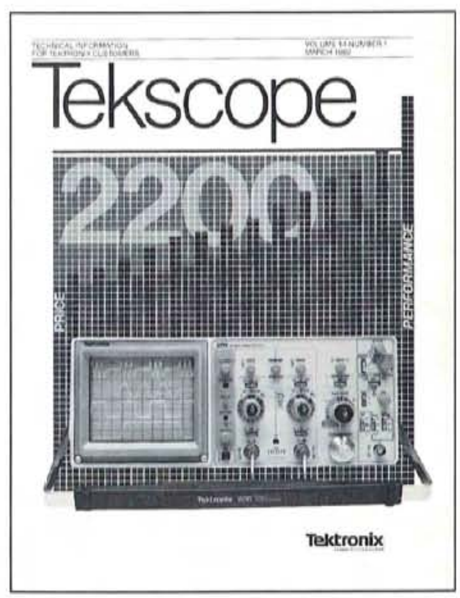
Tekscope is a quarterly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique.

Editor: Gordon Allison
Graphic Designer: Michael Satterwhite

Tektronix is an equal opportunity employer.

Cover

Traditionally, oscilloscope comparisons considered performance—bandwidth/risetime, vertical sensitivity, writing speed, sweep rates, triggerability. And Tektronix oscilloscopes set the performance standard. Now, another factor—price/performance—is assuming increasing importance. And, again, Tektronix sets the standard, with the introduction of the new 2200 Series Portable Oscilloscopes.



Designing a New Price/Performance Standard for Portable Oscilloscopes

Figure 1. The Tektronix 2213 and 2215 Portable Oscilloscopes provide 60-MHz dual-trace, delayed-sweep operation and a full 8 by 10 cm display in a package weighing only 13.5 pounds (6.1 kg).

Expansion of electronics into nontraditional areas is generating an increasing demand for moderately-priced oscilloscopes to use in designing, manufacturing, installing, and servicing these new products.

Several manufacturers, both domestic and foreign based, recently have introduced instruments to this marketplace. The challenge for Tektronix was to develop a quality instrument which would be superior in performance, competitively priced, and supportable by our worldwide sales and service organization.

A thorough evaluation of the measurement needs indicated a series of instruments should be developed to best serve the diverse applications.

First of the new series to be introduced are the Tektronix 2213 and 2215 60-MHz Oscilloscopes. Both feature dual trace, delayed sweep operation, sweep speeds to 5 ns/division, and 8 by 10 centimeter full size displays. Instrument weight is less than 14 pounds—accomplished by using new construction techniques and a unique high-efficiency power supply design.

A new approach

The price/performance targets set for the 2200 Series were formidable. A new approach to design, manufacturing, and marketing was essential if we were to reach our goals. We took a long, hard look at our traditional manufacturing procedures, looking for areas where we could become more productive. One of the most promising areas for improvement was our basic approach to oscilloscope construction. The typical oscilloscope contains eight to ten printed circuit boards. This requires a lot of board handling, plus cables and connectors to interconnect the boards. We needed a new approach. By contrast, the 2213 has only three circuit boards: a main board, front panel board, and a small attenuator/sweep board. The main and front-panel boards are connected by soldered-in straps, which provide maximum reliability yet afford flexibility for servicing. For example, any component on the front-panel board can be replaced without removing the board.

Most of the cabling in the 2200 Series is in the form of circuit board runs, a technique that requires careful design to avoid crosstalk between adjacent conductors. The new approach reduces cabling and connectors by 90 percent and mechanical components by 65 percent, compared to other instruments of the same class. The reduction in parts and connectors contribute to improvements in reliability, serviceability, and light weight, as well as cost.

Another area that afforded opportunities for cost reduction was component selection. Commonality of parts simplifies stocking and reduces inventory costs. The front-panel lever switches in the 2213/2215 are an excellent example. Most are three-position slide switches (the two-position trigger slope switches are the same switch slightly modified). Limiting the lever switches to three positions has the additional benefit of simplifying the front panel, making the scopes easy to operate.

Another component cost-saving technique involves the X1–X10 gain-switching amplifier used in the vertical amplifier system. To get the component density needed to achieve the targeted bandwidth, the attenuator resistors are thick-film deposited on a substrate. A commercially-available, 5-transistor array in a 16-lead dual-in-line package is then attached to the substrate using reflow soldering techniques. This takes much less time than bonding the individual wires of a chip to the substrate.

As you would expect, automated parts insertion is employed extensively, with about 70 percent of the parts machine inserted.

Some operating niceties

While manufacturing efficiencies were a prime design consideration, equal attention was given to achieving the high performance and reliability goals set for the 2213 and 2215.

One of the goals was to include a delayed sweep capability in the 2213, the lowest-priced scope in the series. A unique approach that does not require a separate delaying sweep provides a low-cost delayed sweep capability suitable for many applications.

In the INTENSified horizontal mode, the signal that triggers the sweep also starts a delay generator. When the selected delay time has elapsed, a Z-axis signal is generated that intensifies the trace for the remainder of the sweep. Delay is selectable over a range of 0.5 μs to more than 4 ms.

Switching to the DLY'D horizontal mode displays the same sweep (without intensification) but the start of the sweep is delayed with respect to the trigger signal by the amount of delay selected.

For the more complex delaying sweep applications, the 2215 provides dual time base delaying sweep operation with alternate-sweep display and triggered B sweep.

The 2213 and 2215 also include operating conveniences not found on even the more expensive oscilloscopes. Automatic intensity and focus circuitry maintains a bright, sharp trace over a wide range of sweep speeds. Automatic intensity control eliminates the need for a separate intensity control for the delayed sweep, which was sometimes a confusion factor for novice scope users.

The auto-intensity circuit (figure 2) looks at the sweep duty cycle and generates a Z-axis control signal proportional to the duty cycle. Separate duty cycle circuits are used for the delaying and delayed sweeps and produce Z-axis correction appropriate for each time-base.

The auto-intensity signal is also applied to the focus circuitry to cause the focus voltages to track changes in intensity level.

Versatile triggering

Both the 2213 and 2215 feature peak-to-peak automatic triggering with level control over the full range of the trigger signal. A TV FIELD mode provides stable triggering at TV field rates. Triggering on horizontal sync and other repetitive pulses is enhanced by a variable holdoff control.

In the interest of operating simplicity, selection of some trigger modes, such as INTERNAL AC and DC are not provided for on the front panel. They are, however, operative within the instrument. When you are in the NORMAL triggering mode, the trigger is DC coupled. Conversely, in the AUTO mode, the trigger is, essentially, AC coupled. All triggering is independent of the vertical position control setting, and the trace can be positioned anywhere on-screen without having to readjust the LEVEL control.

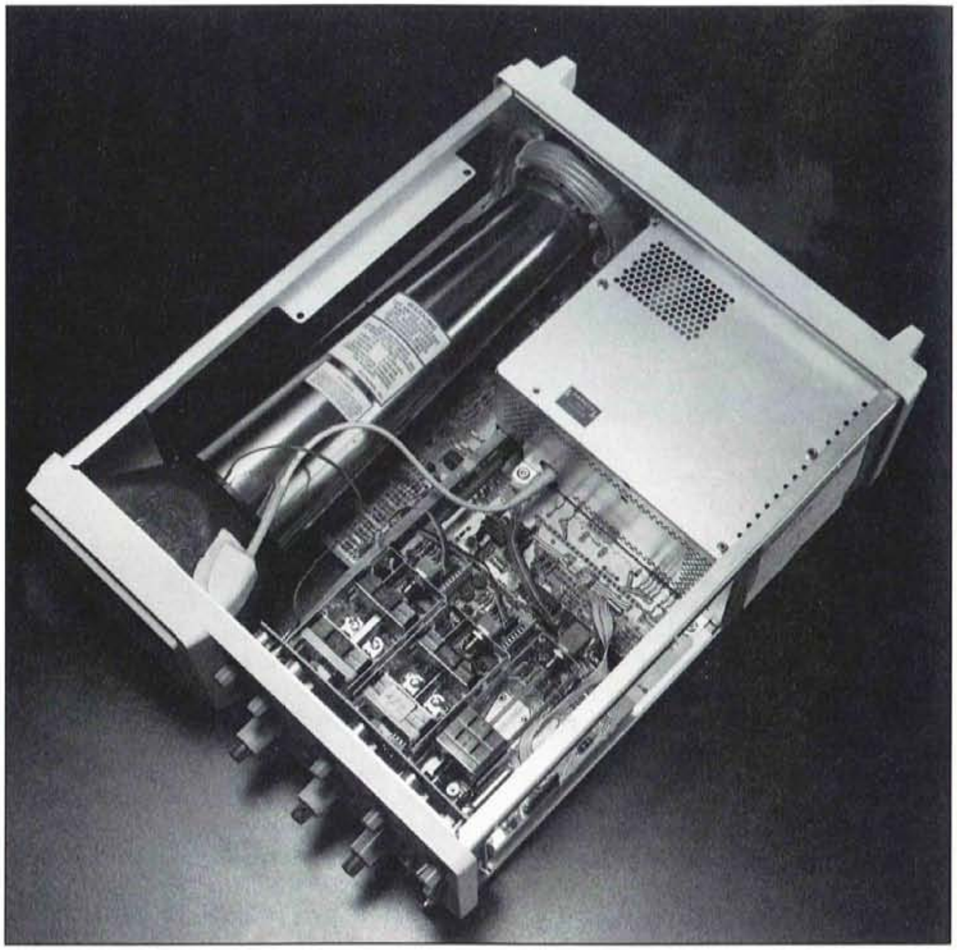


Figure 3. New design and construction techniques result in the use of only three circuit boards in the 2213. Most cabling is in the form of circuit board runs, which reduces the need for connectors and enhances reliability.

Reducing the weight

In a portable instrument, a few pounds make a lot of difference. Weight reduction received a lot of attention in the 2213/2215 design. The mechanical package is a monocoque; that is, the instrument case contributes greatly to the structural strength of the package. This technique limits the need for heavy internal structural members.

A new high-efficiency power supply design allows operation over a wide range of ac line voltages without the need for the typically heavy ac power transformer. A single high frequency transformer supplies all of the secondary voltages needed, including the crt anode voltage drive via a

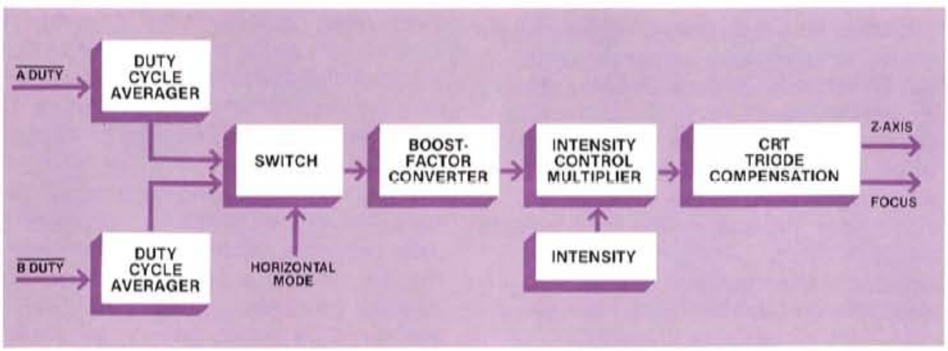


Figure 2. Simplified block diagram of automatic intensity and focus circuitry. Circuit accommodates changes in both A and B sweep rates.

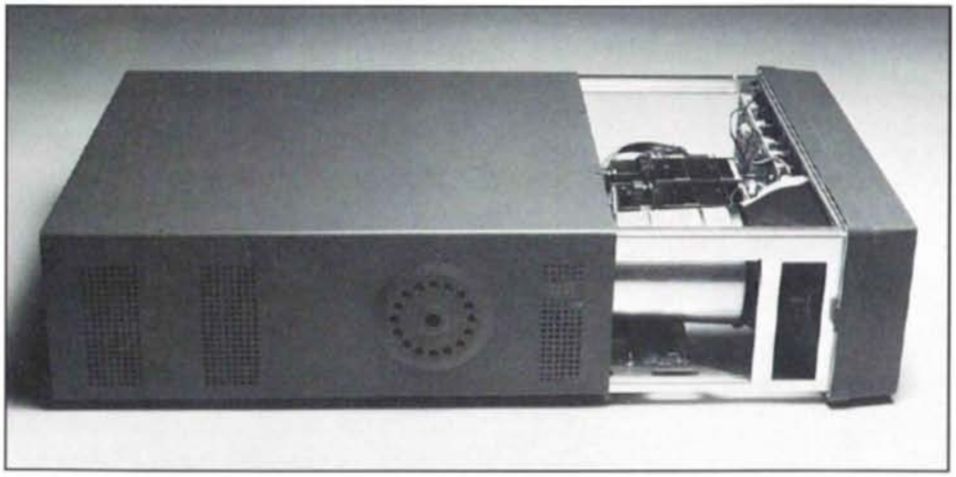


Figure 4. The one-piece cabinet provides structural strength, helping to eliminate the need for heavy structural members.

Jerry Shannon is an innovator of products that provide more measurement capability at lower cost. Prior to proposing development of the 2200 Series of portable oscilloscopes, Jerry was responsible for development of two other major product families at Tek—the TM 500 Series of modular instruments and the 5000 Series of low-cost plug-in oscilloscopes. When he isn't busy figuring out new ways to do more with less, Jerry enjoys flying and camping.

high voltage multiplier. All of these factors contribute to the light weight of the new portables.

Complete accessories

Accessories are an important element in oscilloscope design. The new P6120 10X attenuation probes designed for the 2200 Series provide full 60-MHz bandwidth operation at the probe tip. A new IC-grabber probe tip makes it easy to connect to integrated circuit pins with minimum danger of shorting between pins.

For the traveling user, an optional front cover and accessories pouch provide protection for the front-panel controls, and keeps manuals and probes conveniently stored.

The Tektronix C-5C scope camera and Model 200C SCOPE-MOBILE cart are also among the optional accessories available for the 2200 Series.

A new marketing concept

An important part of the 2200 Series planning involved discussions on how to most effectively market moderately-priced instrumentation. Research indicated that relatively few purchasers of this type of equipment need a demonstration before making the purchase decision. Accordingly, a factory order desk was established to provide price and delivery, or technical information, directly to the customer. Those customers requiring a demo, or service of their instruments, have our sales and service facilities available to them worldwide.

Summary

Designing a new price/performance standard for portable oscilloscopes has proven to be an interesting challenge. A new approach to building oscilloscopes has shortened production times, improved reliability, reduced instrument weight, and produced a quality instrument of superior performance at a competitive price.

Acknowledgements

In any major project, many people are involved with translating an original design concept into the finished project. Roland Crop headed up the electrical design team, with Roger Stenbock doing the sweep and z-axis. Roger also assisted Dick Schuessler and Ron Barrett on the vertical. Calvin Diller designed the trigger circuitry and vertical attenuators. Dennis Keldsen contributed the unique power supply design. Jamie Navia and Bob Twigg had responsibility for the mechanical design. Primary responsibility for product evaluation was handled by Matt Zimmermann, Stan Kohl, and Harvey Gjesdal. Valuable marketing viewpoints were provided by John Gragg, Jack Doub, and Marshall Pryor. My thanks to these and all who have worked so hard in making the 2200 Series project a success. ■

A Multiple-User Software Development Unit

Microcomputer software development is becoming, more and more, a team effort. And, as with any team-oriented project, there are problems of communication, keeping current on the status of each element in the project, and efficiently integrating the individual elements into a finished product.

The new Tektronix 8560 Multi-User Software Development Unit is a team-oriented design tool. Accommodating up to eight workstations simultaneously, the 8560 provides a powerful, flexible solution to software development problems. The 8560, teamed up with the Tektronix 8540 Integration Unit or the 8550 Microcomputer Development Lab[1], lets you accomplish every phase of software development, from initial design to hardware/software integration, effectively and efficiently. (The 8540 Integration Unit is discussed in an article commencing on page 9 of this issue.)

Figure 1. The Tektronix 8560 Multi-User Software Development Unit (lower left) accomodates up to eight workstations, including multiple 8540 Integration Units and line printers.

Hardware overview

The 8560 uses a multiple-processor architecture (see figure 2). The LSI 11/23 main processor executes the operating system, assemblers, compilers, editors, and utility programs. A Z80-based disk controller handles both flexible and hard disk drives. The main processor makes high-level requests and the disk controller handles the details, such as seek optimization, locating the current track and sector, reading and writing blocks of data, and checking for errors.

To relieve the main processor of the burden of handling all of the I/O traffic, an 8088-based processor is provided for each group of four I/O ports. Over 90 percent of terminal I/O is off-loaded from the main processor. The I/O ports are configurable for RS-232 operation up to 9600 baud and RS-422 at 153.6 kilobaud.

Memory in the standard system consists of 128 kilobytes of random access memory (RAM), 35.6 megabytes of hard disk storage, and one megabyte of flexible disk storage for transportable memory. Options expand RAM to 256 kilobytes, with additional hard disk capacity to be available at a later date.

An advanced operating system

The 8560 uses a powerful multitasking operating system called TNIX*. TNIX is a customized version of the popular UNIX** Version 7 operating system, optimized for microprocessor software development. UNIX is a well-established system and includes all of the tools essential for increasing programmer productivity—file management, program development, module build control, interuser communication, system maintenance, and text processing.

The command language chosen for a software development system can be a major contributing factor to software productivity. A well-designed command

[1] "A Microprocessor Development Lab with an Expandable Future," Tekscope Volume 13, Number 1, March 1981.

* TNIX is a trademark of Tektronix, Inc.

**UNIX is a trademark of Bell Laboratories, Inc.

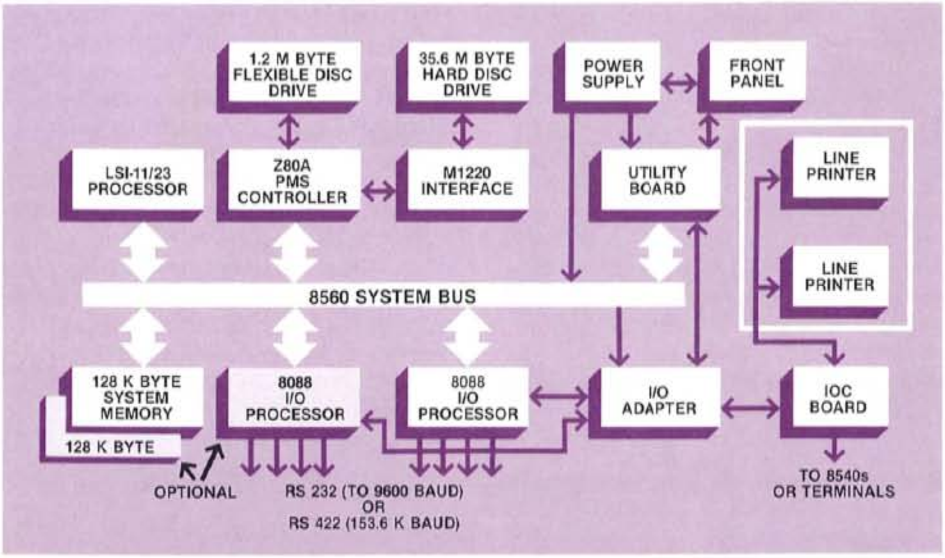


Figure 2. Block diagram of the 8560 Multi-User Software Development Unit. The multiprocessor architecture optimizes performance of the various functions and permits tasks to be carried out in background mode.

language should: be easy to learn, be flexible enough to be customized for individual needs, support powerful command files, and allow unambiguous task processing and information flow.

Learning time can be minimized through the use of a menu-driven command language. However, once the language is mastered, the requirement to use menus can impede productivity (see figure 3).

The TNIX menu-driven program (GUIDE) overcomes the necessity for users to respond to menu-driven queries. As a task proceeds, GUIDE prints out the commands being used, which helps to shorten learning time. However, one doesn't have to use GUIDE for entering commands. Once the system is learned, the user can enter commands directly. Command menus on the 8560 also can be changed, allowing the user to customize the system.

Command files allow multiple commands to be executed quickly and without typographical errors. Most systems allow parameters to be passed to a command file, thereby increasing their flexibility and ease of use. The 8560's command language also allows variables to be defined by the user, and supports structured programming commands like "if...**then**... **else**", "**for**" loops, "**while**", "**until**", and "**case**" statements. As an example, see figure 4. When these concepts are combined and used in a command file, users

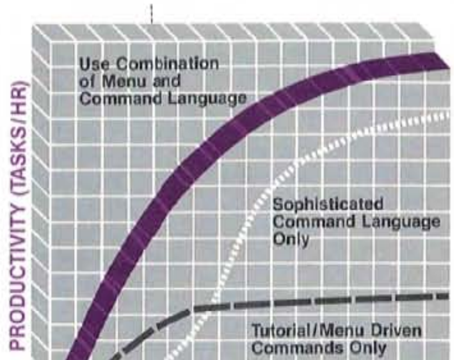


Figure 3. This graph depicts the relative productivity achievable with a system that employs menu-driven commands, with a system that does not, and with one that uses a combination of menu and command language. The 8560 uses the latter approach.

```
set `ls | grep '.out'`
do
   lptr $i
done
```

Figure 4. The above command file checks the current directory for all files with the extension ".out" and outputs them to the lineprinter.

can define or combine commands to perform tasks that would normally require large, complex programs to accomplish.

The 8560 also allows the output of one command to be passed as input to another command, without the use of temporary "holding" files. This "**pipe**" construct allows information to be easily passed through the system while being processed by a series of commands. Large amounts of data can be quickly reduced to a manageable amount and output in a format allowing quick analysis by the user. All I/O devices are handled as ordinary files, thereby eliminating the special programming usually required to handle external devices.

Multitasking increases productivity

A multitasking system increases a software designer's productivity by performing two or more tasks at the same time. With the 8560, time-consuming tasks, such as assemblies or compilation, can be executed in "**background**" mode while the user is free to perform simpler tasks, such as editing or file manipulation, in normal (foreground) mode. The 8560 supports two lineprinter ports, allowing listings to be printed in background mode (otherwise known as lineprinter spooling) while users proceed to perform other tasks. By having two lineprinter ports, users can access either high-speed/medium-quality, or low-speed/high-quality printers on the same system. Short printout jobs don't have to await completion of a lengthy printout, and printout quality does not have to be sacrificed. Background tasks also can be prioritized to minimize the impact of multitasking on other 8560 users.

File management

In a multi-user system, with source code or documentation shared by several users, file management is a critical element. The 8560 uses a hierarchical file structure that permits multilevel directories and controlled access to files. Directories allow a user to quickly locate files of interest without having to peruse the entire list of files on the disk.

Access to files is controlled by assigning each user a unique password. Three groups of users may access each file on the 8560. These include the owners of the file, members of the owner's group, and all others. Each of these groups may be assigned read, write, and execute permission.

Another important 8560 file management feature is the ability to link to files in other directories. The same information can be found under multiple directories, without requiring duplicate files. When a file is updated, the same information is available to someone accessing the file through a different directory. The need to recopy modified files is eliminated.

The capability to directly execute, copy, or link to another's file, with appropriate access control, contributes greatly to productivity in a multi-user environment.

Automated build control

In any major software development task, program management is critical. The large number of interdependent modules generated by the design team must be combined without build errors. Build errors usually result from combining wrong modules or wrong versions of the correct modules.

The 8560 uses an automated approach to the build problem. Using a command called "**make**", programs can be automatically generated from only the most up-to-date source code. "**Make**" utilizes a description file, which defines all intermodule dependencies, and associated commands to generate each module. Upon execution, "**make**" compares the modification date of an output module (i.e. an output file) with the appropriate input module (i.e. source code file). If the modification date of the input module is later than that of the output module, then the output file is recreated. This procedure greatly reduces the time needed to produce an executable program because it is no longer necessary to reassemble or recompile every module.

Interuser communication

Effective comunication between team members is essential for software development to proceed smoothly and with a minimum of problems. The 8560 takes an innovative approach to interuser communication. A command called "**mail**" allows a user to send a message to another user and store it in a private mailbox for that user. If a user has mail, the system automatically notifies the user when he or she logs into the system. The mail can be quickly viewed and then either deleted or retained for future reference. A user can also use the mail system to receive notification when a spooled printer output is completed.

Each user can determine who else is logged into the system and send a message directly to a user by executing the "**write**" command and referencing the user-identification. To avoid interruption of a critical task, each user can decide whether or not to allow direct communication. If necessary, a command requiring special authorization is provided to send a system message to all users regardless of messages being turned off.

Users can also use the 8560's documentation tools with the mail system, to generate memos and so forth.

Optional software expands capability

TNIX includes several optional software packages that allow a user to add capability as needed. An ***auxiliary utilities package,*** containing over 30 programs, enhances operating flexibility. An "**awk**" command allows the user to search a file for a selected pattern and then execute a command upon its occurrence. This is a powerful tool for reducing data from the optional Trigger Trace Analyzer. Another command, "**bc**", provides a binary calculator that lets the user enter arithmetic operations into the system and get results back with unlimited precision. This command also performs base number conversions, such as binary to octal, hexadecimal, etc. Other programs in this package provide batch editing, general preprocessing, and useful file manipulation.

The ***documentation package*** is another extremely useful option. This package greatly simplifies the many tasks involved with producing quality documentation. For example, when text is entered into a file, formatting commands are included to generate the page layout desired. The resulting file is then passed to a formatting utility that produces the document. To change the page layout, only the lines containing format commands need be changed. The formatting utility will automatically generate the revised layout. If the text is to be typeset, as for manuals production, the 8560 can generate output suitable for commercial phototypesetters.

Other time-consuming tasks, such as table generation and typesetting of mathematical equations are efficiently handled by special commands. There are commands to look for spelling errors, generate a permuted index, and so forth. In addition, special reports, manuals, business letters, specifications, and other documents can easily be created on the 8560. Users have complete control over paragraph justification, indentation, underlining, bold-facing, page headers and trailers, footnotes, and character fonts. These "active" documentation tools improve productivity substantially.

The optional ***native programming package*** contains 23 programs which provide high level and assembly language support for the 8560. A C compiler can be used to develop utilities that will enhance 8560 operation. Several supporting programs simplify and extend the use of C.

A "program beautifier" command will clarify program structure by indenting nested loops, procedures, and so forth.

Programs to perform syntax checking and program linking are also provided. In addition, an assembler is included for developing special purpose routines which can execute faster.

BASIC, another high level language, is also provided for development of a variety of applications.

The auxiliary utilities, text processing, and native programming packages are provided to allow the user to tailor the operating system to a particular need. As category C software, they carry a low priority for updating; however, these packages have been under development for several years and typically are error-free.

Summary

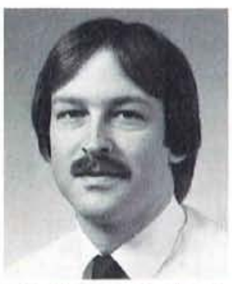
A software development system should enhance individual and team efforts in producing a reliable, quality product. It should eliminate many of the tedious programming, documenting, and manual software management tasks that design teams encounter.

The 8560 Multi-User Software Development Unit meets all of these requirements, and more. The innovative interuser communications system facilitates sharing of design information. A hierarchical file system with controlled access allows files to be organized and accessed in a manner that maximizes team productivity. Automatic build control and user-programmable command files save hours of processing time and keyboard entry. And the companion 8540 Integration Unit allows software and hardware to be integrated in a controlled manner, with effective tools for rapidly isolating and resolving any problem that may exist.

The TNIX operating system includes several commands designed to maximize efficiency when using the 8540 Integration Unit with the 8560. For example, the operating system recognizes those commands that are uniquely 8540 and passes them directly to the 8540. The system also can selectively access up to eight 8540s connected to a single 8560. The following article discusses the 8540 Integration Unit.

Acknowledgements

The following people were instrumental in the development of the 8560: Tom Clark was the 8560 project manager, with Al Baker as hardware manager, and Bob Wood as software project leader. Errol Crary was the program manager. Bob Tice, mainframes manager for the 8500 Series, also made valuable contributions to the project. Mechanical design was coordinated by Phil Sheeley. Our thanks to these and the many others who made the 8560 project a success. ■



Chuck Smith, Marketing Product Line Manager for the 8560, has been with Tek six years—most of the time as a part of the Information Display Division. He was associated with 4050 Series Marketing and was Advanced Products Manager for the Graphic Computing Systems group. Chuck received his BSCS from Michigan State University in 1973 and currently is working on his MBA at the University of Portland. In his leisure time Chuck enjoys black and white photography, softball, volleyball, and personal computer projects.

A Powerful New Tool for Integrating Microcomputer Hardware and Software

Figure 1. The 8540 Integration Unit, pictured with the CT8500 CRT Terminal and prototype control probe, provides complete coverage of the hardware/software integration process during microcomputer design.

Integrating newly-written software and prototype hardware can easily consume as much time as writing the software itself. The new Tektronix 8540 Integration Unit turns this difficult task into an orderly, efficient process.

The 8540, with an 8560 Multi-User Software Development Unit (or other host computer) and a system terminal, forms a complete microcomputer development system. The system provides a powerful set of tools for testing microcomputer programs and prototype hardware, with full-emulation and PROM programming capabilities.

Software is developed on the 8560 (which also provides mass storage and file management) and then is downloaded to the 8540 via the built-in high-speed (153.6 kilobaud) interface.

For host computers other than the 8560, an optional communication interface is available. The major interface parameters of this interface are software selectable through the 8540's operating system, so the communications package can be tailored to individual host situations.

Using commonly available RS-232-C ports and the optional communications interface package, the 8540 can be interfaced to most host computers in a matter of minutes. All communications parameters, such as parity, echo, and turnaround delay, can be set directly from the keyboard.

Three basic operating modes are available. The *object code transfer* mode permits transferring object code modules between the host and the 8540's program memory, with full error checking and recovery during the process.

Terminal mode allows the user's terminal to communicate directly with the host computer. The terminal is physically connected to the 8540; however, a single command routes the terminal directly to the host, making the 8540 transparent to the user.

Local mode provides direct communication between the terminal and the 8540, for controlling the emulation and debugging process.

Emulator support

The 8540 uses interchangeable emulator modules to allow you to configure the 8540 to your application. The 8540 supports both 8-bit and 16-bit microprocessors including those listed in Table I.

Table 1

Chips The 8540 I.U. Supports

16-bit	8-bit	
Z8001	6809	8088
Z8002	6800	8048
8086	6808	8039
68000	6802	8039-A
TMS9900	Z80A	8035
SBP9900	8080A	8021
SBP9989	8085A	8022
	8049	8041A

Using an emulator processor identical to that targeted for the prototype, the 8540 provides real-time emulation. This means that the prototype code can be executed at the specified operating speed of the target processor, while under control of the 8540's debug system.

Three modes of real-time emulation

Emulation takes place in three progressive modes that allow gradual introduction of hardware and software. In mode 0 (system mode), the software is executed on the 8540's emulator processor. Program input and output can be simulated using system resources in the console display, keyboard, or 8560 file system. Thus, you can begin debugging your program before the prototype hardware is available, or continue debugging should the hardware become inoperable.

In the next phase, Mode 1, the 8540 emulator connects directly to the prototype hardware via the prototype control probe. In this mode, the program resides in 8540 memory and can be transferred to prototype memory in sections as small as 128 bytes. This technique, called mapping, allows the program to be gradually transferred into the prototype on a step-by-step basis. The program can interact with prototype I/O, development system I/O, or both.

In Mode 2, all of the code resides in the prototype memory. This mode is used to make a final check with the actual prototype memory devices (such as ROM or PROM) in place. The control probe remains in the microprocessor socket on the prototype to provide continual debugging control during program execution.

During all three modes of emulation, prototype code execution is under control of the 8540's powerful debug software. For easy reference, key breakpoints may be entered using mnemonic labels (symbols) instead of numeric addresses. At each breakpoint, the status of all of the processor's key registers, flags, and status bits is displayed. You can also display the processor's register status and associated code execution on a cycle-by-cycle basis. Any register or memory location can be modified right from the keyboard.

The 8540 debug commands are integrated into TNIX, the 8560 Software Development Unit's operating system, so the user can control both 8540 and 8560 resources with a unified, compatible syntax. This capability also allows the 8540 to use 8560 resources, such as file I/O and data reduction, to enhance the debugging operation.

Trigger trace analyzer

Many debugging situations require detailed analysis of real-time code execution and the effect on other key points in the hardware. The trigger trace analyzer (TTA), a modular option to the 8540, provides a complete facility to acquire real-time data in both 8-bit and 16-bit processor-based systems. Up to 255 bus transactions occurring before, during, or after a specified event can be captured. An 8-channel data acquisition probe allows you to select and monitor up to eight points in the prototype hardware. For further details on the trigger trace analyzer see the article commencing on page 12.

System overview

The 8540 operating system (OS/40) is similar to DOS/50 Version 2, the operating system developed for the 8550 Microcomputer Development Lab[1]. A few commands are different, but the key difference is that commands execute much faster in the 8540 as they are stored in PROM memory rather than on disk.

[1] "A Microprocessor Development Lab with an Expandable Future," Tekscope Volume 13, Number 1, March 1981.

A functional block diagram of the 8540 is shown in figure 2. A dual-processor architecture (in a master/slave arrangement) enables the 8540 to support several different microprocessors, using the same operating system. In this configuration, the system processor serves as the master, and the emulator processor as the slave. The system processor and emulator processor have completely separate memory space so that system program and user (prototype) programs do not conflict.

The 8540 contains a 100-line system bus structure that provides most of the connections to the plug-in modules and options housed in the mainframe. The emulator controller board separates those control and signal lines that are dedicated to either the system section or the program section. Both the system processor and emulator processor share the basic bus structure, with the emulator controller serving as arbiter under the direction of the system processor.

The system processor resides on the system controller board and provides overall control of the 8540. It directs all I/O activity for the system peripherals, performs all system utility functions, and executes the debug program—controlling the emulator processor through separate debug hardware.

To allow you to configure the 8540 for your specific application, the emulator processors are designed as plug-in modules and assigned option status. An emulator option includes both hardware and software for the target microprocessor or microcomputer. The emulator processor interfaces with the prototype hardware via a prototype control probe. Advanced probe design makes the emulator processor

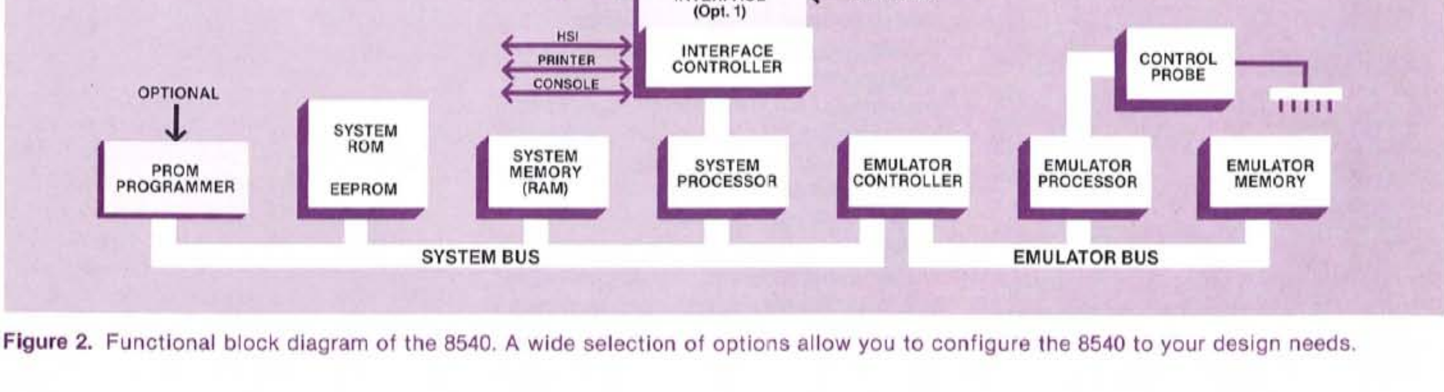


Figure 2. Functional block diagram of the 8540. A wide selection of options allow you to configure the 8540 to your design needs.

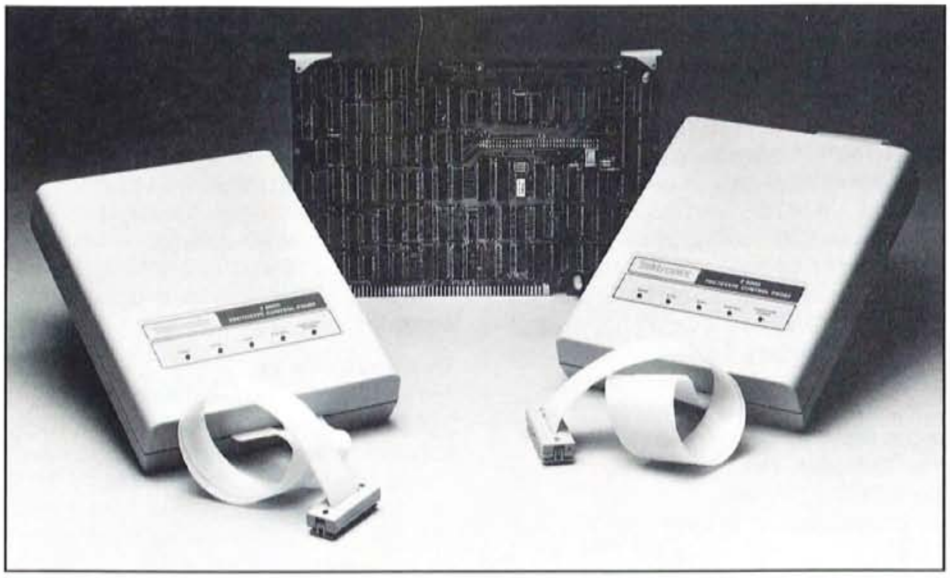


Figure 3. Emulators and prototype control probes for the 8540 feature state-of-the-art design that allows your programs to run at the full operating speed of the target microprocessor.

practically transparent to the prototype and allows prototype code to be executed at the full operating speed of the target processor, without adding wait states or stretching clock pulses (see figure 3).

Versatile memory manipulation

Memory in the 8540 consists of two major sections—system memory and program memory. System memory includes 240K bytes of ROM, which contain the operating system and software for optional equipment. Also resident on the ROM board are 4K bytes of EEPROM used for updating the operating system and for storing unique user-developed command strings. The contents of the EEPROM can be changed from the system terminal keyboard.

The operating system is loaded from system ROM and executed in the 64K-byte system RAM. User symbol table information employed in symbolic debugging is also stored in system RAM.

Program (emulator) memory consists of 32K bytes of static RAM, optionally expandable to 256K bytes. It is used for storing prototype code downloaded from the 8560 or the host computer.

The system processor has control of both system memory and program memory. As previously mentioned, in emulation mode 1, program memory can be mapped into prototype memory in 128-byte blocks, allowing orderly transfer of proven program segments to the prototype.

When working with devices such as the Z8001/Z8002, 68000, and 8086, whose addressing capabilities exceed the 8540's program memory, the Memory Allocation Controller (optional with the Z8001/2 and 68000 emulators) can be used to allocate program memory in 4K-byte blocks over an address space of up to 64M bytes.

PROM programming

Once the prototype code is debugged, it can be put into firmware using the optional PROM programmer available for the 8540. The PROM programmer consists of a controller board, front-panel assembly, and a characteristic module to adapt the programmer to whatever PROM family you require. The 8540 currently supports 2716, 2732, 8748, 8741A, and 8755 PROMs.

System diagnostics

When attempting to integrate software and prototype hardware, it is essential to know that your integration tools are working properly. The 8540 has two resident diagnostic test programs for verifying system operation.

The power-up diagnostic tests are run automatically during power-up or restart conditions. These tests verify the circuitry within the 8540 that is required to boot and transfer the operating system from ROM into the 8540's system memory.

Should a fault occur that prevents the operating system from booting or prohibits ROM-resident diagnostics from running, a program called Critical Function Monitor (CFM) is automatically entered. The CFM contains several test routines and a limited set of user commands that are entered from the system terminal. This program, in conjunction with a series of LEDs located on the system controller and system RAM boards, will usually isolate the source of trouble.

The ROM-resident diagnostics provide a means of verifying system performance, and a tool for troubleshooting in the event that a failure is detected during the running of a test. The menu-driven diagnostics are easy to use, and run automatically after being initiated by the user.

Summary

The 8540 Integration Unit is designed to help you accomplish the entire software/hardware integration process in an orderly, efficient manner. The 8540 can be easily interfaced to most host computers or any of the 8000 Series of Tektronix microcomputer development units, such as the 8560, 8550, and 8001. State-of-the-art emulators allow your programs to run at full speed, while the advanced trigger trace analyzer captures up to 255 bus transactions and select logic operations for analysis. The 8540 supports most popular 8- and 16-bit microprocessors and microcomputers.

Acknowledgments

The 8540 design team included Tom Clark as engineering manager; Dennis Stolarski, hardware project leader; Roger Crooks, software manager; and Bruce Stofer, software project leader. The hardware evaluation manager and project leader were Norm Dodge and Dave Marsh, respectively, with Dave Loney and Ray Epperson performing similar roles for software. ■

Author:
William G. Bevan
Marketing Product Manager

A New Real-Time Debugging Tool for the 8500 Series MDL

The Trigger Trace Analyzer (TTA) is a modular option for the 8540 and 8550 that allows you to monitor the buses and selected control signals in prototype hardware, while your program executes at normal speed. The TTA provides precise control of the selection of data to be stored and analyzed. Up to 255 bus transactions and logic signals from various points on the prototype can be captured and stored in the TTA's acquisition memory and displayed for analysis.

The TTA monitors 64 bits of information that you can select in any combination (using software commands) to define a trigger signal for acquiring data or for other purposes. The 64 bits of information monitored include:

- the address bus (up to 24 bits)
- the data bus (8 or 16 bits)
- the data acquisition probe (8 bits)
- the emulator-dependent bus signal interface (up to 11 bits)
- the external event qualifier (1 bit)
- counter output signals (4 bits)

All of these signals are input to an event comparator, which functions as a word recognizer (see figure 2). The output of the event comparator is ANDed with the output of a programmable general-purpose counter, to generate a trigger signal. There are four such trigger channels in the TTA. These triggers can be used independently or interactively to construct a powerful data acquisition trigger. The outputs of the four trigger channels also are available externally (via BNC connectors on the TTA interface panel) for triggering external equipment.

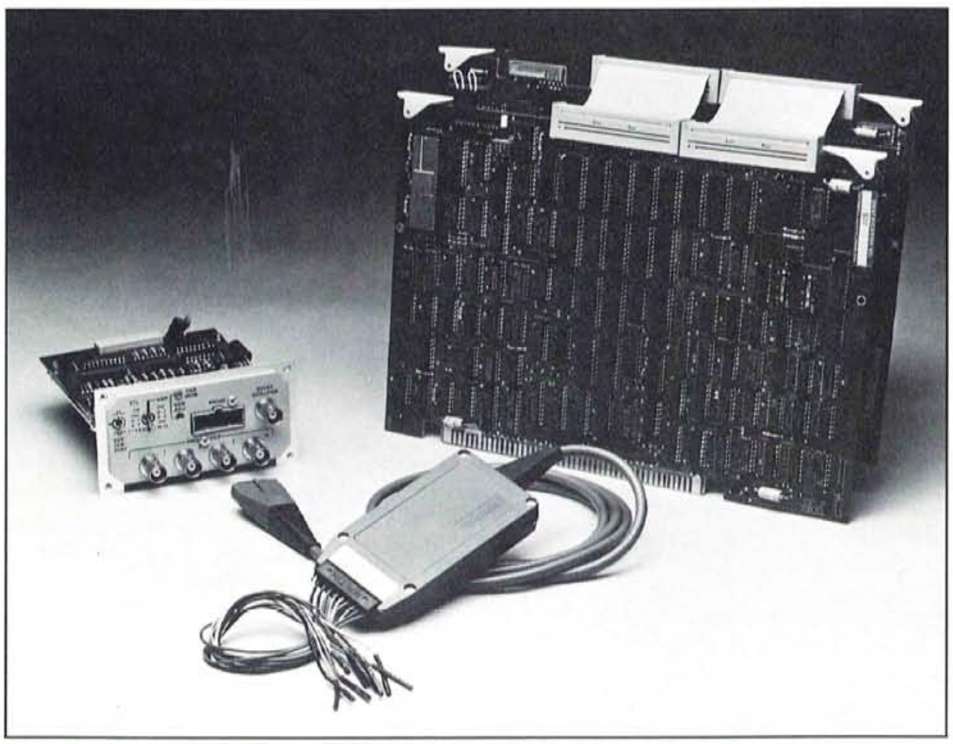


Figure 1. The Trigger Trace Analyzer option includes two plug-in modules, bus interconnecting cables, an 8-channel signal acquisition probe, and an interface panel that includes the four trigger channel outputs.

Defining an event

To better comprehend the flexibility the TTA offers in defining a trigger point, let's consider some of the event control commands used to specify which input data constitutes an event. There is a separate command for each of the event comparator input sources. There is also one command that you can use to specify all inputs—the "**eve**" command. The "**ad**" command is used to define a specific address or range of addresses as an event. The commands

```
ad 1 105E
ad 2 500 530
```

specify that event 1 occurs whenever the program accesses address 105E, and that event 2 occurs whenever the program accesses an address within the range 500 to 530, inclusive. The "**ad**" command can include a "**-n**" command modifier that defines the event as anything other than the value specified. For example,

```
ad -n 4 1000 10FF
```

defines event 4 as any address outside the range 1000 to 10FF.

Another event command, "**ctr**", defines an event as a pattern of the outputs of the four counters associated with the event comparators. The pattern can include 1's, 0's, or X's (don't cares). For example, the command

```
ctr 1 10X0
```

causes event 1 to occur when counter 1 is high and counters 2 and 4 are low.

In addition to triggering on individual events, it is possible to trigger on the occurrence of multiple events. By using the "**cons**" command, events can be linked together so that the occurrence of one event arms the comparator of the following event. All of the events within a sequence must occur on consecutive cycles of the specified type. The "**cons**" command requires you to select one bus

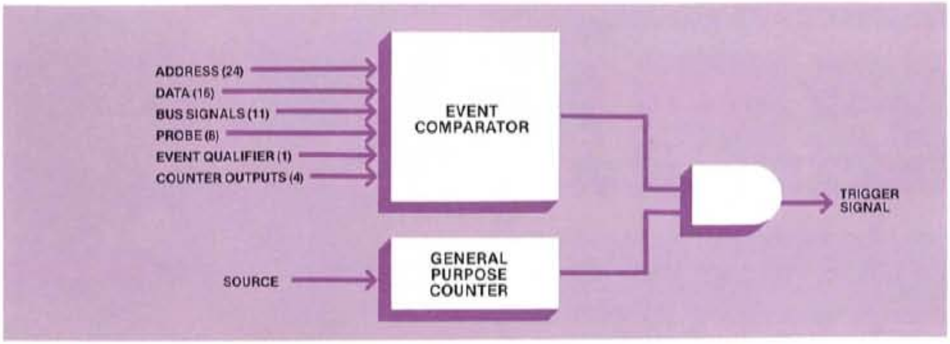


Figure 2. Each trigger channel has its own 64-input event comparator and programmable general-purpose counter. You can select from several event control commands to specify which input data constitutes an event. The four trigger channels can be linked together to provide almost unlimited trigger selections.

mode in which all of the events are considered. The bus modes are: **cyc**—all bus cycles are allowed; **fet**—only fetch cycles are considered; and **emu**—only emulator-dependent bus cycles are considered.

The general-purpose counters

We discussed, previously, the ability to specify the output of the four general-purpose counters as inputs to the event counter, to construct an event. The counters also can be used singly or together for other purposes. Let's take a look at their capability.

The "**cou**" command defines the counter operation. This command selects a value to be counted, a source that is counted, a gate signal that will enable or disable the counting process, and the kind of signal that will be output when the counting operation is completed. For example,

```
cou 2 v=4  s=ev1  o=delay
```

programs counter 2 to be asserted after the fourth occurrence of event 1.

The "**v**" or value parameter may be set anywhere between 1 and 65,536, with the value assumed to be decimal unless specified otherwise.

The source parameter, "**s**", options include counting of: clock intervals from 200 ns to 2 ms in decimal steps; occurrences of event signals for channel 1, 2, 3, or 4; occurrences of trigger signals for channel 1, 2, 3, or 4; the number of bus transactions; the number of emulator cycles; the emulator's clock signal; and the event qualifier signal. Only one of the latter three may be selected at one time. However, each of the four counters may operate on the selected signal.

A gate parameter, "**g**", places a restriction on the indicated counter and specifies those conditions during which the counter may count. Most of the conditions involve the output state of the next lower number counter, so the "**gate**" parameter is only valid for counters 2, 3, and 4.

The "**restart**" parameter allows you to have the counter reloaded with its initial "**value**" when the "**gate**" source is asserted. The options are ON and OFF.

The last counter parameter to be considered is "**output**". As the name implies, this parameter controls the output of the counter. There are five options: when "**arm**" is specified, the counter output remains high; "**disarm**"—the output remains low. When "**pulse**" is specified, the counter output is low, pulses high when counting is complete, then goes low again. In "**delay**", the output is initially low, and goes high after counting is complete. "**timeout**" produces the reverse of "**delay**".

The breakpoint command

The breakpoint command controls the effects of an event's trigger signal. For each trigger, this command can set a breakpoint, clear a breakpoint, and enable or disable the "**continue**" function.

The breakpoint, if enabled, causes a program to halt execution when an event and its associated trigger signal occur. A trace line is displayed on the system terminal and control is returned to the operating system. The "**cont**" function, if enabled, interrupts the program when the event and its trigger signal occur, and a trace is displayed. However, control is returned to the program, which continues execution at full speed.

The breakpoint parameters "**stop**" and "**cont**" can be set as a parameter in most of the event and counter commands.

The acquisition memory

Now that we have discussed how thoroughly we can define *when* data will be captured, let's look at *what* data can be captured. The acquisition memory is a 255-by-62-bit buffer. The input data available for storage includes that monitored by the event comparators with the exception of the counter outputs (see figure 3).

The "**acq**" command specifies what data is to be stored when the trigger signal occurs. "**acq all**" stores all of the most recent 255 bus transactions, which can include the eight inputs from the P6451 data acquisition probe. "**acq ev4**" stores only those transactions defined as event 4. A parameter called "**for expression source**" allows you to specify acquisitions at some point other than the end of a program. The *expression* must evaluate to some number between 1 and 65536. The *source* portion of this parameter identifies a specific kind of bus transaction, with the options available identical to the source parameters used with the "**cou**" command. An "**aftertrig 4**" parameter disables the counting of the source until trigger 4 occurs.

A typical acquisition command may appear as this:

```
acq all for 10 cyc aftertrig4
```

which would store all bus transactions until the occurrence of the tenth cycle after the occurrence of trigger 4.

The display command, "**disp**", allows you to select the portion of acquisition memory to be displayed on the system terminal. You may display all of the bus transactions stored, or display only some number of transactions you want to see.

The information displayed when you enter the display command includes an address, data, an opcode mnemonic, the states of the eight data acquisition probe signals, and symbols representing the type of bus operations that occurred.

A typical application

Now let's consider a typical application that involves using two channels of the TTA.

Problem: Provide timing for an interrupt routine located at 1000H to 1024H.

Solution: Trigger channel one is used to

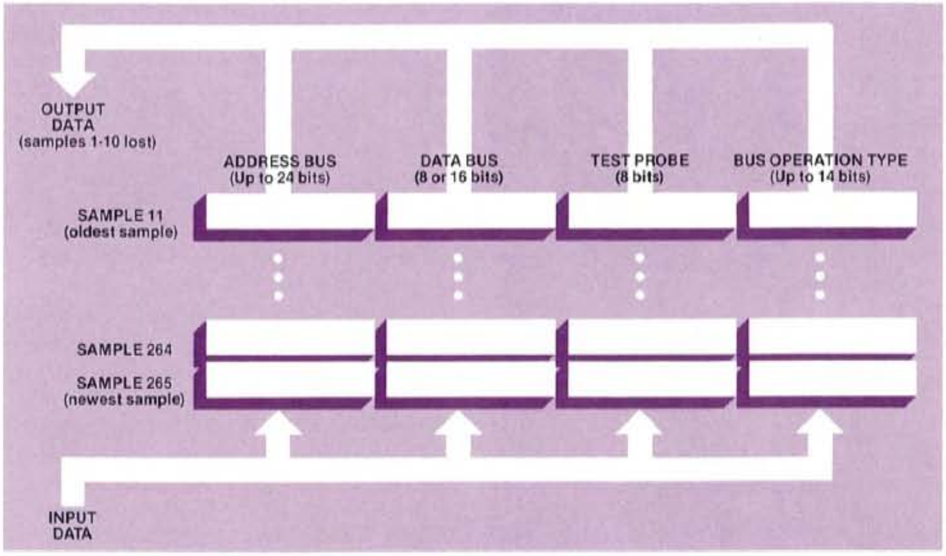


Figure 3. The acquisition memory is similar to the buffer memory of a logic analyzer. This figure shows the contents of the acquisition memory after 265 samples of input data have been taken. Only the most recent 255 samples are retained.

detect the start of the interrupt routine and activate channel two's counter. When the interrupt routine is completed, channel two's word recognizer is used to stop the counter. The following command sequence is entered:

ad 1 1000
ad 2 1024
cou 2 v=0 s=200NSEC o=ARM
g=SEQH-s

Where: ad 1000 enters the hexadecimal value 1000 into the address portion of the channel one word recognizer.

ad 1024 enters 1024H into the channel two word recognizer

cou 2 selects the channel two counter

v=0 puts the channel two counter's initial value at zero

s=200NSEC selects 200 nanoseconds as the counting unit

o=ARM sets up EVENT 2 to cause the breakpoint

g=SEQH selects channel one's trigger output as the source that will enable the counter

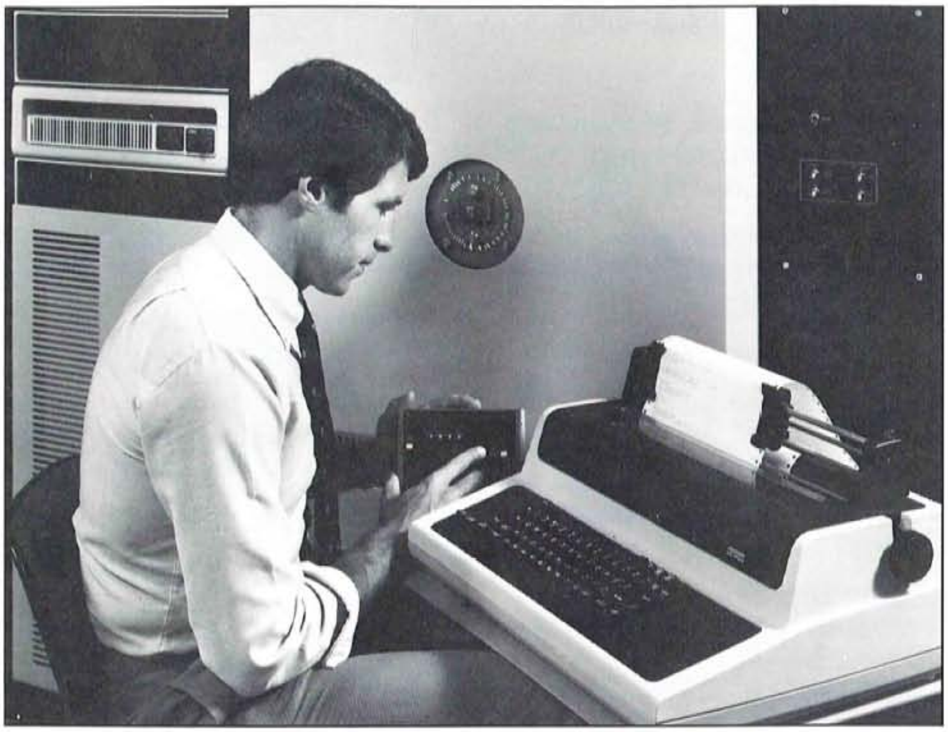
-s indicates that a breakpoint will occur when the channel two trigger goes active

This command sequence produces a channel one trigger at the start of the interrupt routine, 1000H. This trigger then activates the channel two counter which begins counting in 200 nanosecond increments. Channel two's word recognizer produces a trigger when the interrupt routine is completed at 1024H. This second trigger causes a breakpoint to occur that automatically stops the counter. The resulting counter value is then read by calling up the trigger status display, which will show the counter's value at the time of the breakpoint.

Conclusion

The trigger trace analyzer option for the 8540 and 8550 is a powerful real-time debugging tool. You have almost unlimited capability to specify the trigger conditions for acquiring data while your program executes at full speed. Bus transactions, plus logic states from eight selected points in the prototype hardware, can be captured and stored for analysis. The TTA is a valuable adjunct to the 8540 and 8550 in facilitating software and hardware prototype integration. ■

New LSI Production Test System Features Vertical Test Station



The S-3220 LSI Production Test System

The new S-3220 accommodates analog devices and dual-family hybrids such as CODECs and ADCs, in addition to high-speed digital circuits. The S-3220 is offered as a production-oriented complement to the engineering and characterization capabilities available for S-3270 Test System users. The S-3220 utilizes the TEKTEST III control software used in all S-3200 systems; thus, programs originally developed for engineering use can easily be condensed and used in high-volume production or incoming inspection environments.

The essential test-related features of the larger systems are retained in the S-3220, allowing (with no loss of speed or accuracy) functional (pattern) testing as well as DC parametric and single-pass AC parametric testing.

The S-3220 is the first S-3200 Series system with a vertical test station. This new mechanical configuration enables the user to interface a wide variety of automatic device handlers and wafer probers with minimal interconnect cabling. The vertical test station is integral with the control/stimulus equipment rack, resulting in reduced floor space requirements—an important consideration in production areas.

The S-3220 system software—TEKTEST III—is a high-level, English-like language. It provides the extensive data logging and data reduction capability needed by users in all segments of the semiconductor industry. ■

New 19-inch Computer Display Terminal Features Color

The 4113 intelligent color terminal is intended to answer the need of CAD and mapping markets for computer design tools with high data communications speed, high addressability, and a virtually limitless choice of colors.

With host communications up to 9600 baud (19.2K baud with flagging), the 4113 provides display speed suitable for a broad cross-section of CAD and mapping applications. User interactivity is enhanced through locally-retained picture segments.

The 4113 has 4096 × 4096 points of addressability viewable in 640 by 480 blocks, with local zoom and pan capability.

In its basic three-bit-plane configuration, the 4113 allows the user to work with eight colors simultaneously. An optional fourth bit plane enables displaying of up to 16 colors at once. The user can select from as many as 4096 colors, each variable by lightness, hue, and saturation.

The Tektronix Color Standard is used, which makes color selection precise, fast, and easy to learn.

An optional three-port RS-232-C peripheral interface enables local control of devices such as the Tektronix 4662 and 4663 Interactive Digital Plotters, 4641 and 4642 Printers, and Tektronix hard copy units and graphic tablets. ■

The 4113 Computer Display Terminal

Tekscope Index 1980-81

Volume 12 Number 1 1980

A Portable High-Performance Microwave Spectrum Analyzer

The Tektronix 492 is a New-Generation Spectrum Analyzer

Making Measurements with the 492

Packaging a Spectrum Analyzer for Performance, Maintainability, and Survival

A Switching Power Supply for the 492 Spectrum Analyzer

Volume 12 Number 2 1980

Portable Analyzer Speeds Test and Service of Microprocessor-Based System

An Automatic Video Signal Parameter Measuring Instrument with Logging Capabilities

Developing a Practical Automatic Television Parameter Measuring and Logging System

Volume 12 Number 3 1980

Digital Waveform Processing in a High-Performance 7000-Series Oscilloscope

Automatic Distortion Analyzer Speeds Distortion Measurements

Volume 12 Number 4 1980

A User-Programmable Logic Analyzer for Microprocessor Design

Digital Storage and Plug-in Versatility Distinguish New 10-Mhz 5000-Series Oscilloscope

A Programmable Data Communications Tester for First-Line Technicians

Volume 13 Number 1 1981

A Microprocessor Development Lab with an Expandable Future

Two New Hard Copy Units Feature Low-Cost, High-Contrast Copies

Programmable Calibration Generator Speeds Instrument Checkout

Slewed-Edge Signals Simplify Fast Sweep Timing

Volume 13 Number 2 1981

Two New Graphic Terminals Expand Graphic Capabilities

Software Innovations Increase Productivity of Desktop Computer Users

Three New Portable Oscilloscopes Designed for Field Service Use

A High Resolution Color Picture Monitor for Television and Laboratory Use

Volume 13 Number 3 1981

TM 5000—A New Family of IEEE-488 Programmable Instruments

Configurable State-of-the-Art Logic Analyzer Gives Choice of Performance

Codes and Formats Standard Adds Compatibility and Capability to IEEE-488 Instruments

3/82 99AX-4897

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

TEKTRONIX®
committed to
technical excellence

MAR/APR 1974

NEW PRODUCTS and LITERATURE

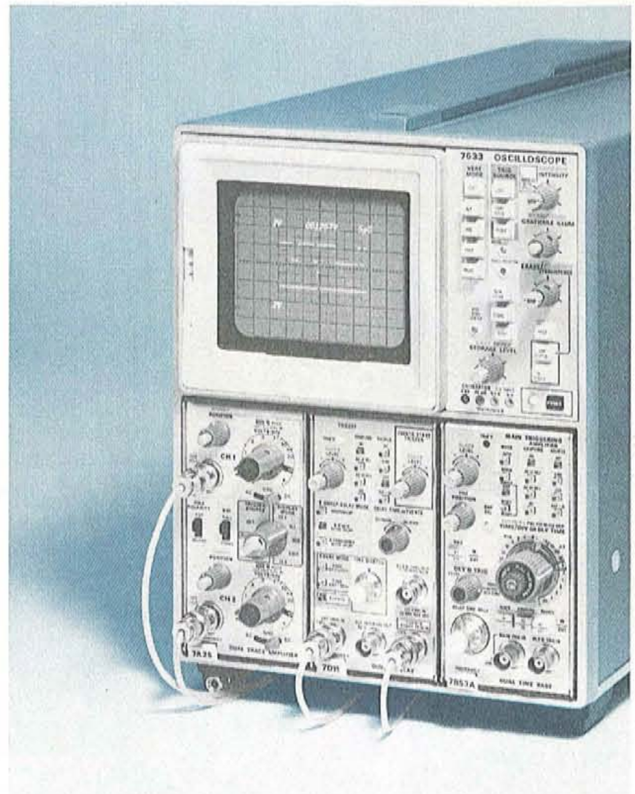
SUPPLEMENT NO. 3 TO 1974 CATALOG

7000-SERIES PLUG-IN OSCILLOSCOPES

The 7633 Storage Oscilloscope is a 100-MHz direct-view storage oscilloscope with a stored writing speed capability of 1000 cm/μs. The instrument features multi-mode storage including variable persistence, bistable and conventional nonstore modes. In addition, a fast writing 8 x 10 div (.45 cm/div) mode is included which provides the instrument's top writing speed.

Crt readout provides quick on-screen reference of measurement parameters. And a selection of 30 different 7000-Series plug-ins permits 'custom-tailoring' the instrument to the job from the outset, and expansion of its capabilities as the needs arise.

The 7623A Storage Oscilloscope is electrically the same as the 7633 without the fast-writing reduced scan mode of operation. All other operating modes are included, with a stored writing speed of 135 cm/μs in the fast storage mode. The 7623A offers low-cost multi-mode storage for those applications not requiring the faster stored writing speed of the 7633.



7633 Storage Oscilloscope **$3650**
R7633 Storage Oscilloscope **$3750**
Option 1 w/o Crt Readout .... **Sub $400**

7623A Storage Oscilloscope **$3000**
R7623A Storage Oscilloscope **$3100**
Option 1 w/o Crt Readout .... **Sub $400**

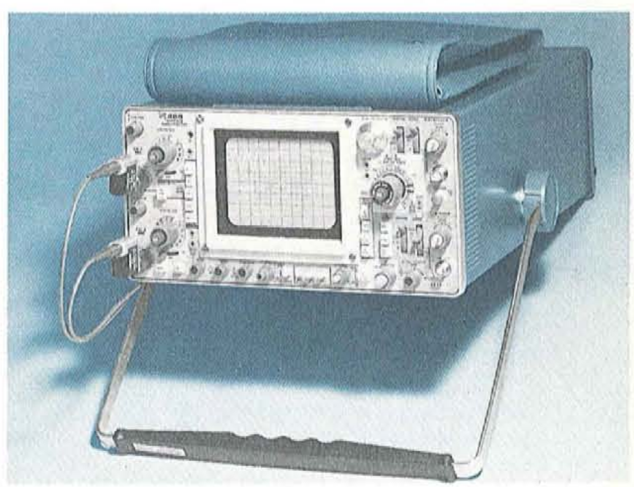
PORTABLE OSCILLOSCOPES

The 466 Storage Portable extends laboratory-standard storage oscilloscope measurements from the test bench into the field. The 466 features variable persistence and fast transfer modes of storage; and in fast, reduced scan operation can achieve a stored writing rate of 1350 cm/μsec.

Its bandwidth is DC to at least 100 MHz within —3 dB. Using its X10 magnifier, the 466 achieves a 5-nsec/division sweep rate. Vertical deflection sensitivity is 5 mV/division.

With many features and operator conveniences based on the well-proven 465 portable oscilloscope, the 466 is designed for use with minimal operator training. Its easy-to-use controls are functionally grouped to facilitate operation.

Without panel cover or accessories, the 466 weighs just 26 pounds.



466 STORAGE PORTABLE OSCILLOSCOPE **$3850**

Return the enclosed inquiry card for further information on the products, or copies of the literature described in this supplement.

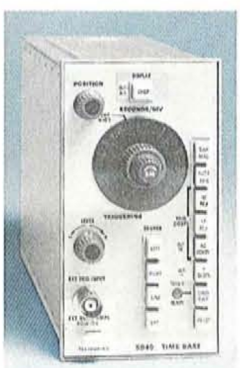
U.S. Sales Prices FOB Beaverton, Oregon

The 5A38 Dual Trace Amplifier is designed for use in the 5400-Series Oscilloscopes. It provides two input channels with 35 MHz bandwidth and deflection factors ranging from 10 mV/div to 10 V/div. Operating modes include channel 1 only, channel 2 only (normal or inverted), dual trace (alternate or chopped), and added. Crt readout of the deflection factor is included in the 5A38.

5A38 Dual Trace Amplifier $350

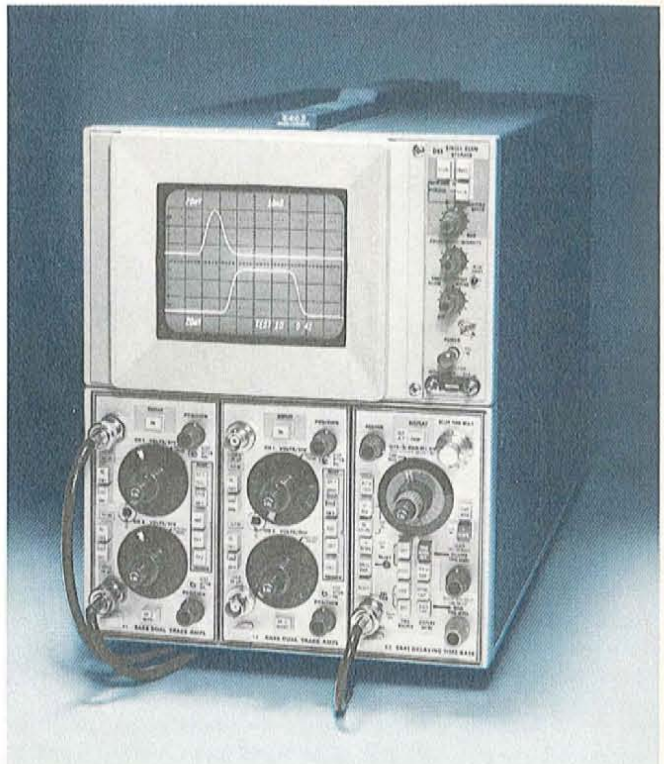
The 5A45 Single-Trace Amplifier provides the 5400-Series Oscilloscope with 60 MHz bandwidth and deflection factors from 1 mV/div to 10 V/div (25 MHz bandwidth below 5 mV/div). Crt readout of the deflection factor is included.

5A45 Single-Trace Amplifier $250



The 5B40 Time Base operates in the 5400-Series Oscilloscopes to provide sweep rates from 0.1 μs/div to 5 s/div. Sweep rate is extended to 10 ns/div by the 10X magnifier. Capabilities include internal and external triggering to 60 MHz and single sweep operation. Circuitry for crt readout of sweep rate is included.

5B40 Time Base $275



The 5403/D41 Variable Persistence Storage Oscilloscope provides a low cost means of conveniently displaying hard-to-view waveforms. Low rep rate signals are easily viewed as continuous traces. With the 5 μs/div writing speed, single-shot phenomena and extremely low rep rate signals can be readily viewed in normal room light. As part of the versatile 5400 Series the 5403/D41 includes 60 MHz bandwidth, crt readout of deflection factors, three plug-in capability, easy bench-to-rackmount convertibility, and a choice of 20 plug-ins.

5403/D41 Oscilloscope $2275
R5403/D41 Oscilloscope $2275

Options

Option 1	Without crt readout	sub $350
Option 3	Programmable crt readout	add $ 60
Option 4	Protective panel cover (cabinet model only) ...	add $ 15
Option 5	Reduce writing speed to 1 div/μs	sub $300

PRODUCTS LISTED IN PREVIOUS SUPPLEMENTS

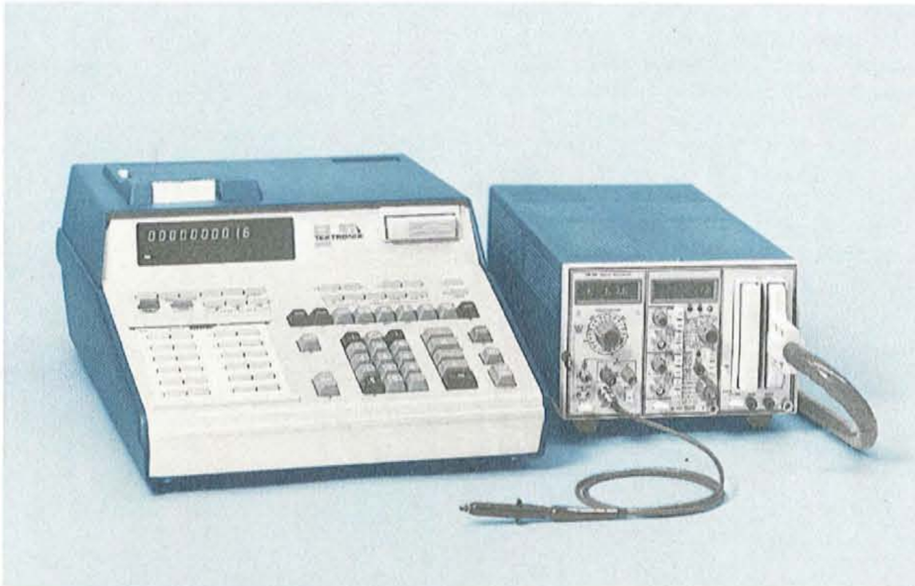
Supplement No. 1

7L13 Spectrum Analyzer
7D12 A/D Converter and M1, M2, M3
7A24 Dual Trace Amplifier
R7912 Transient Digitizer
DPO/3100 Measurement System
5403 Oscilloscope System
214 Storage Oscilloscope
4623 Hard Copy Unit
4014/4015 Computer Display Terminal
Plot-10/Decision Maker

Supplement No. 2

31/10 Graphic Calculator System
D61 Oscilloscope
D75 Oscilloscope
408 and 412 Monitors

COMPUTER INSTRUMENTATION SYSTEMS

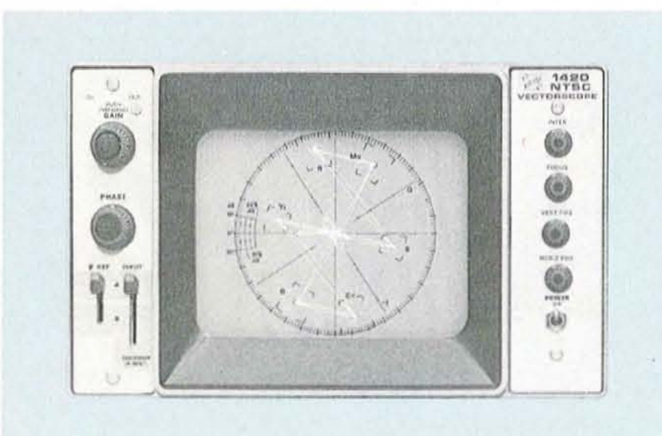


The 31/53 Computer Instrumentation System. Tektronix introduces a major innovation in computer instrumentation systems with its newly announced 31/53 system. Containing an expandable memory processor, a wide range of program step capability, an alphanumeric keyboard and printer, digital tape cartridges, a complete library of standard mathematical and statistical software, interfacing to D/As and to an optional high performance digital plotter, the system is being marketed for less than $6000. Included in this price are typical multimeters and counters of the TM 500 Series.

Capable of data acquisition, data transformation, data processing and analysis, the system enables the user to log, store, compare, and analyze measurement data as it arrives. Voltages to 2 kV, current measurement to 2 amps, resistance measurement to 20 megohms, frequencies from DC to 550 MHz and a wide range of temperatures in Fahrenheit and centigrade—all these are available in a single standard 31/53 system. Data can be recorded and viewed on an alphanumeric thermal printer, an easy to observe readout and a high performance plotter. Data transformation and analysis are accommodated by the expandable programming capability of the system. 512 program steps is the system standard. Up to 1000 memory registers are available.

Markets for which the portable system is designed include those largely manually served in the past by stand alone meters and counters in rackmounted higher-priced systems. These markets include design, evaluation and manufacturing of electronic products, including components; computer field servicing; mechanical design and evaluation; and the firm's long established medical, physics, resource exploration, engineering and atomic energy fields.

TELEVISION PRODUCTS



The 1420-Series Vectorscopes are compact, ½-rackwidth instruments designed to display vectors of the chrominance and burst components of either an NTSC (1420), PAL (1421) or PAL M (1422) composite video signal. This series provides a low-cost way to meet basic vectorscope requirements in CCU's VTR's and similar applications. The instrument is particularly well suited for side-by-side rack mounting with the TEKTRONIX 528 Waveform Monitor. The 1420 weighs a little over 15 pounds with an optional carrying case.

The internal graticule is designed for the vector display of color bars and burst. A special graticule feature allows differential gain or phase errors to be determined to reasonable accuracy for many applications — within 2° and 5%.

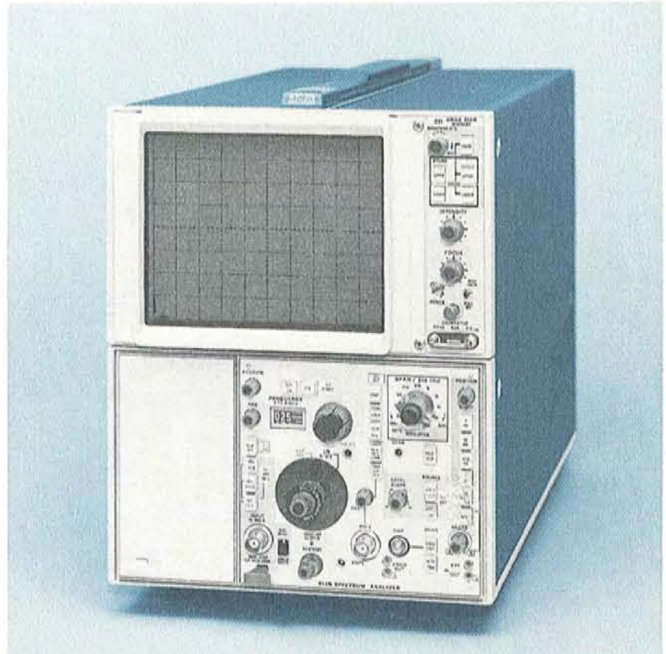
Two loop-through inputs accept the signal for display on the crt or for externally locking the subcarrier regenerator oscillator. A front-panel lever switch selects the signal from either of the inputs for phase locking the subcarrier regenerator. A second front-panel lever switch selects the signal to be displayed on the crt and can attenuate one channel for viewing large signals. A front-panel GAIN control varies the size of the crt display above and below unity.

PAL (1421) and PAL M (1422) displays are switchable to an "NTSC FORMAT".

NTSC Vectorscope 1420 .... **$1450**
PAL Vectorscope 1421 .... **$1450**
PAL M Vectorscope 1422 .... **$1500**

SPECTRUM ANALYZERS

The 5L4N Spectrum Analyzer covers the low-frequency range from 0 to 100 kHz and offers both high performance and economy. Unique features include pushbutton selection of 50 Ω, 600 Ω or 1 MΩ input impedance with calibration appropriate to the selected impedance. Dynamic range is 80 dB with intermodulation distortion more than 70 dB down from two full-screen signals. A built-in tracking generator is standard. This low-frequency swept-front-end spectrum analyzer operates with any 5000-Series System, using two of the three compartments. We recommend the 5L4N Spectrum Analyzer with a D11 Storage Display Unit and 5103N mainframe as the optimum system for all applications.



5L4N Spectrum Analyzer	**$1950**
5103N/D11 Storage Scope	**$1095**
Complete Price	**$3045**

SEMICONDUCTOR MEMORY TEST SYSTEMS

S-3400 Systems. Tektronix signals a major commitment to the semiconductor memory test systems market by announcing a new series of systems. Four models are initially offered designated S-3420 through S-3450. The low cost S-3420 is configured for general receiving inspection applications. The S-3430 and S-3440 are function testers equipped for bipolar (ECL, TTL) and MOS memory ICs, respectively. The S-3450 provides both function and dc parametric test capabilities. Each system features interactive keyboard as well as stored program operation. Stored programs are loaded with paper tape. Because of the modular nature and bus structure of the S-3400 systems each offers many options and each is field expandable.

Prices will vary from $40,000 upward dependent upon options chosen. Deliveries are expected to begin within 90 days after receipt of order.

NEW LITERATURE

TM 500 Series Application Note No. 4 describes a method of measuring resistances up to 20 Ω with a resolution of one milliohm using the DM 501 Digital Multimeter and the PS 501 Power Supply.

TM 500 Series Application Note No. 4 describes a method of measuring resistances up to 20 Ω with a resolution of one milliohm using the DM 501 Digital Multimeter and the PS 501 Power Supply.

Photometry/Radiometry Application Note No. 6 discusses the use of the TEKTRONIX J16 Digital Photometer in making luminance and illuminance measurements, and stresses the importance of color correction and cosine correction.

CRT Recording Cameras booklet contains complete information on TEKTRONIX Cameras, including a camera selection check list and a discussion of films, lenses, etc.

U.S. Sales Prices FOB Beaverton, Oregon

NOVEMBER 1972

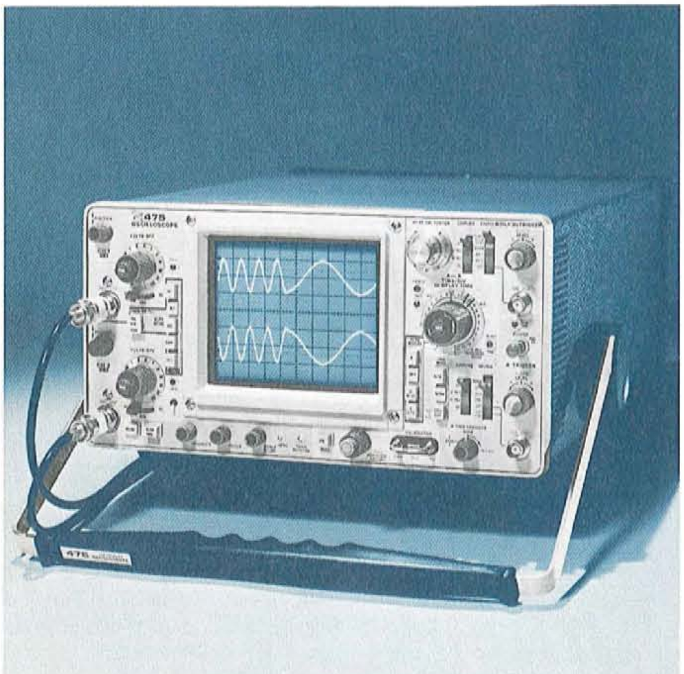
11/72

TEKTRONIX®

NEW PRODUCTS

SUPPLEMENT NO. 1 TO 1973 CATALOG

PORTABLE OSCILLOSCOPES



465 and 475 Oscilloscopes—The low cost of the 465 with 100 MHz bandwidth at 5 mV/div and the 475 with 200 MHz at 2 mV/div represents a price/performance breakthrough for portables that assures top value for the future.

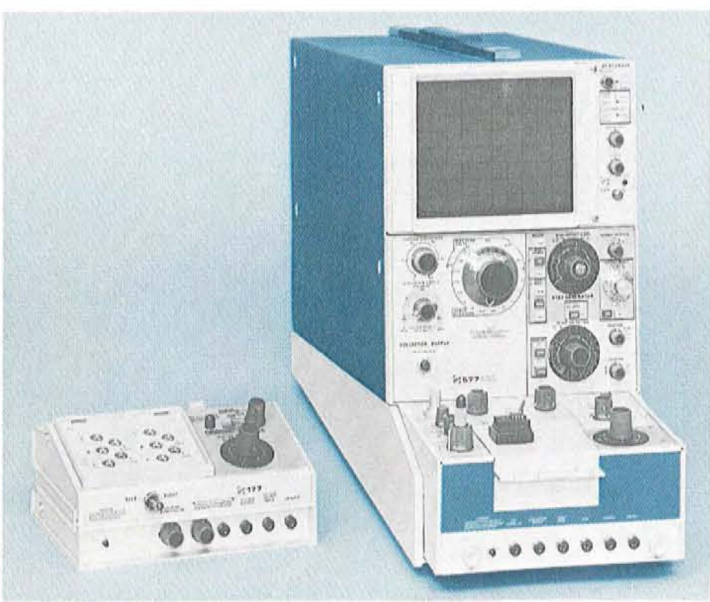
A big 8 x 10-cm CRT display, new versatile trigger selection, trigger view, and automatic volts/div readout are just a few of the many features designed into these lightweight portable instruments.

At less than 23 pounds, the new 465 and 475 are easy to carry (25.3 pounds with panel cover and accessories). They use less travel space and are about 20% lighter than the TEKTRONIX 453A and 454A, the world's most widely traveled oscilloscopes.

The 465 and 475 can be operated from either a free-standing battery pack or one which attaches directly to the oscilloscope. Both are small and lightweight, providing a handy solution for making measurements in difficult environments.

465 Oscilloscope	$1725
Option 4 EMI Modification	Add $75
Option 5 TV Sync Separator	Add $100
475 Oscilloscope	$2500
Option 4 EMI Modification	Add $75

SEMICONDUCTOR CURVE TRACERS



The 577 Curve Tracer is a solid-state system for measuring the parameters of semiconductor devices such as linear ICs, tunnel diodes, Zener diodes, signal diodes, rectifier diodes, NPN or PNP transistors, field effect transistors, and silcon controlled rectifiers. The 577 can be used with either the D1 Storage or the D2 Nonstorage display module.

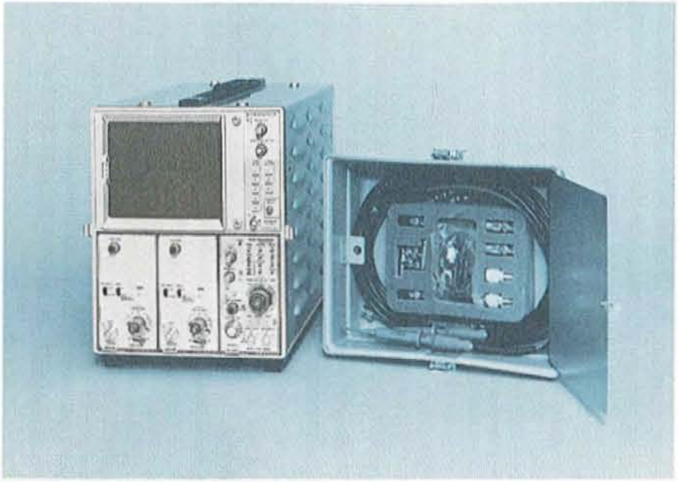
Two test fixtures are presently available for the 577. The 178 Linear IC Test Fixture introduces the capability of displaying the characteristics of linear ICs; gain, common-mode rejection ratio, power supply rejection ratio, input current, supply current, and 1/F noise are among the characteristics that can be displayed. The 177 standard test fixture enables fast, reliable measurements of the characteristics of two-, three- and four-layer semiconductor devices.

577/D1 Storage Curve Tracer	$2000
577/D2 Nonstorage Curve Tracer	$1550
177 Standard Test Fixture	$300
178 Linear IC Test Fixture	$900

Return the enclosed inquiry card for further information on the products, or copies of the literature described in this supplement.

U.S. Sales Prices FOB Beaverton, Oregon

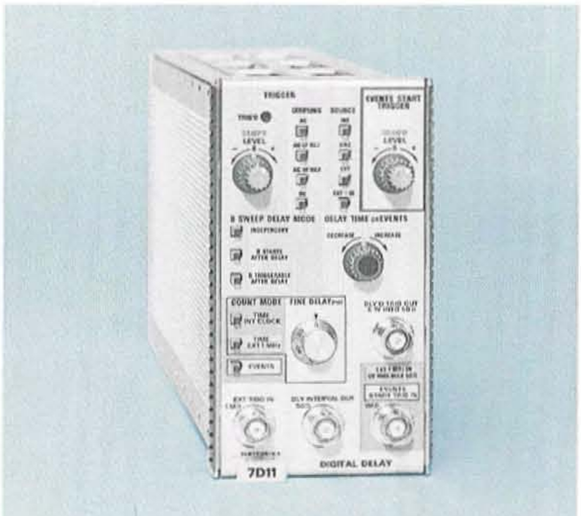
7000-SERIES PRODUCTS



The 7603N Option 11S Ruggedized 50-MHz Oscilloscope System meets rigid environmental and electrical specifications required by the military. The complete system is qualified under MIL-0-24311(EC) and appears on U.S. Navy QPL-24311. Tektronix, Inc. has developed and built into this system performance which is unmatched in versatility and flexibility. The System consists of a three-plug-in mainframe, two single-trace amplifiers, a dual time base, and a front-panel cover with probes and accessories.

This system (mainframe and plug-ins) is compatible with the TEKTRONIX 7000-Series product line, providing added measurement convenience and flexibility. TEKTRONIX 7000-Series Plug-ins include Amplifiers, Samplers, Spectrum Analyzers, TDR, Curve Tracer, Differentials, and other Time Bases.

7603N Option 11S Oscilloscope System (AN/USM-281C) $3025



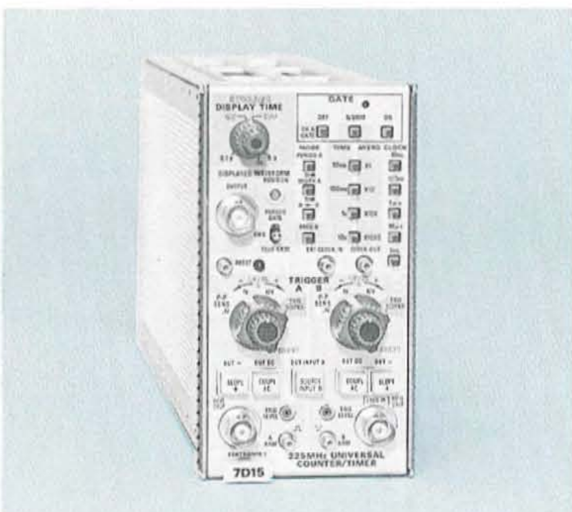
The 7D11 Digital Delay Unit provides very accurate, stable delays for TEKTRONIX 7000-Series Oscilloscopes with CRT READOUT. The unit offers both time delays and the ability to delay by a number of events. These delays enhance scope waveform viewing, and are available as output signals for other applications.

Delay-by-Time: Following a trigger and after a pre-selected time, this unit will give a delayed trigger output. The delay time is indicated on the scope CRT READOUT and is displayed along with the measured signal.

Delay-by-Events: Following a selectable number of events after a master sync or index pulse, the unit provides delay outputs. The low-jitter delayed trigger output is especially useful in disc, computer, radar, and other timing applications.

Accuracy: 0.5 ppm ±2 ns. Jitter: less than 2.2 ns. Delay time: 100 ns to 1 second. Resolution: 1 ns.

7D11 Digital Delay Unit $1475



The 7D15 Universal Counter/Timer provides more convenient counting and timing measurements with greater accuracy and confidence at a lower cost per measurement.

The 7D15 can be used with all 7000-Series Oscilloscopes with CRT READOUT. Signals from the scope can be used to arm and control the Counter/Timer. The measured signal can be seen on the CRT, along with the measurement interval and the counter Schmitt trigger signal. Signals can be preconditioned through the various 7000-Series plug-ins.

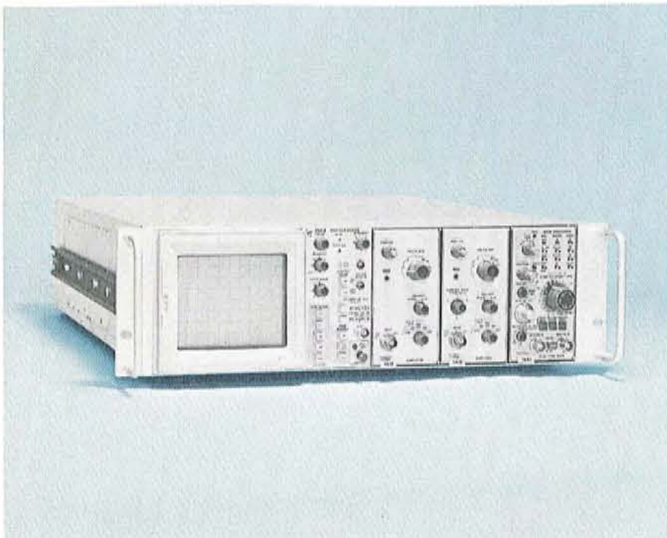
There are eight modes for this DC-to-225 MHz Counter/Timer: Time Interval • Time Interval Averaging • Period • Multi-period • Frequency • Frequency Ratio • Totalize • Manual Stop Watch.

Resolution is 10 nanoseconds in single-shot time measurements, and 100 picoseconds in time interval averaging. TEK's unique CRT READOUT displays a full eight digits.

7D15 Universal Counter/Timer $1475

U.S. Sales Prices FOB Beaverton, Oregon

The R7903 Oscilloscope is the widest bandwidth, real-time oscilloscope available in a 5¼-inch rackmount today. General purpose measurements up to 500 MHz at 10 mV/div can be made using the 7A19 Amplifier plug-in.



A complete line of plug-ins is available for a variety of applications. Included are: Amplifier, Time Base, Digital Counter, Digital Delay, Digital Multimeter, Spectrum Analysis, Sampling, TDR, and Curve Tracer plug-ins.

CRT READOUT is available on the R7903. Its use reduces set-up time and measurement errors; it also increases operator accuracy and speed.

The R7903's performance can be extended to 1 GHz via direct CRT access with the 7A21N Direct Access plug-in. Less than 4 V/div driving signal is required and the input can be either single ended or differential. CRT READOUT and vertical amplifier functions are bypassed and inoperative when direct access is used.

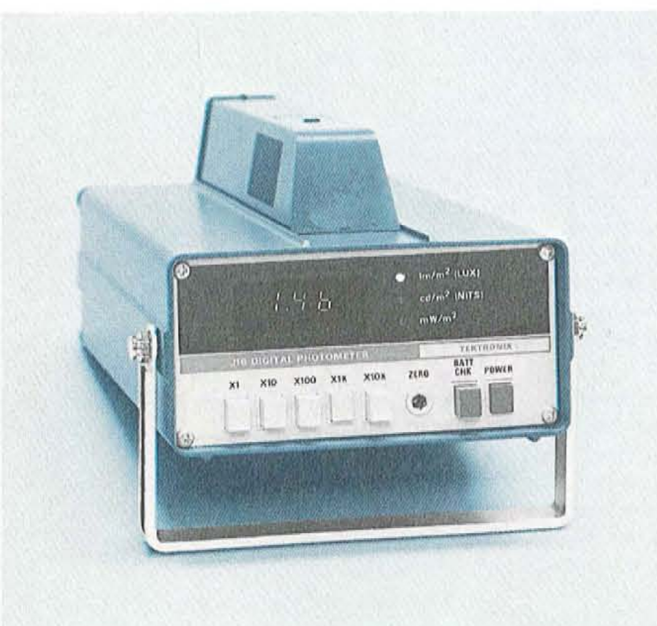
The R7903 system includes instrument options, thus allowing you to custom tailor the system to your measurement requirments. These options give you: • a brighter CRT for increased writing speed • EMI modification • phosphor change • pulsed graticule for single-shot photography • deletion of CRT READOUT.

R7903 Oscilloscope **$2900**

R7903 Options

Option 1	**W/O CRT READOUT**	**Sub $400**
Option 3	**EMI Modification**	**Add $75**
Option 4	**Max Brightness CRT**	**Add $350**
Option 8	**Phosphor Change (P11)**	**No Charge**
Option 10	**Pulsed Graticule**	**Add $100**

ELECTRO-OPTIC PRODUCTS



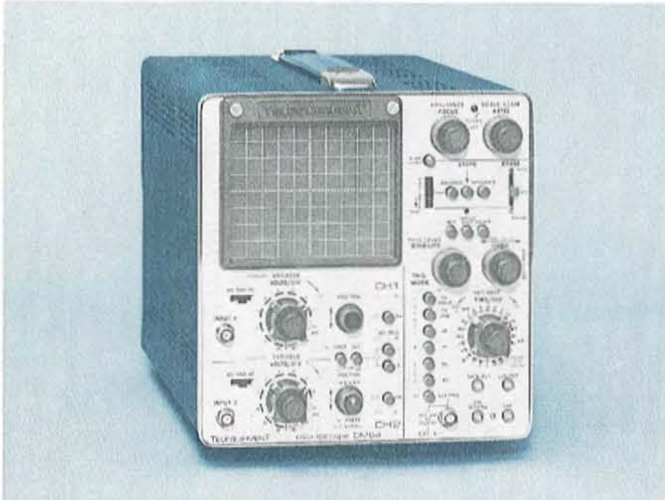
The J16 Option 2 Digital Photometer/Radiometer is a portable photometer/radiometer which provides measurement readout in metric units. A choice of five probes provides accurate measurements of illuminance in Lumens/m^2 (Lux), irradiance in Candelas/m^2 (nits), and luminance in milliwatts/m^2. Each probe uses a silicon photodiode which has excellent long-term stability and reliability. Easy-to-read 2½-digit LED readout reduces measurement error, particularly in low ambient light conditions.

At least two hours of continuous operation is provided by the internal rechargeable batteries. A shoulder strap is provided for carrying ease and the bottom of the case and probe have a standard ¼ inch—20 mount for tripod or optical bench use.

A standard version of the J16 Photometer/Radiometer is also available which provides readout in conventional units.

J16 Option 2 Digital Photometer/Radiometer without Probe ..	**$600**
J6501 Illuminance Probe, Option 2	**$200**
J6502 Irradiance Probe, Option 2	**$250**
J6503 Luminance Probe, Option 2	**$250**
J6504 Uncorrected Probe	**$150**
J6505 LED Test Probe, Option 2	**$250**

TELEQUIPMENT PRODUCTS

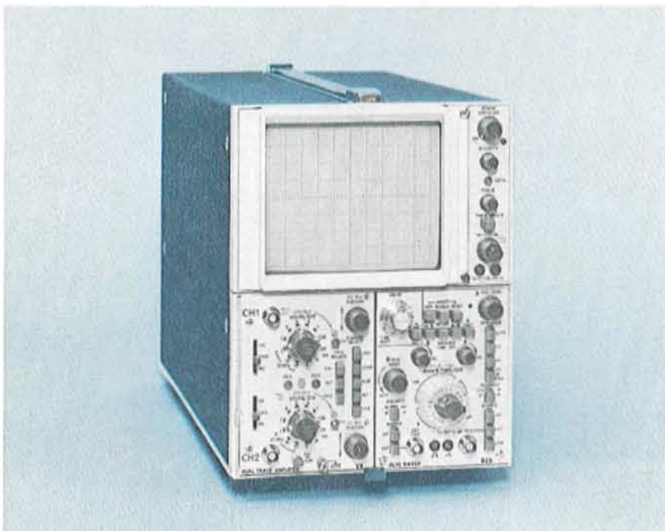


The DM64 Oscilloscope, the world's least expensive bistable storage oscilloscope, is now available in the TELEQUIPMENT product line. The heart of this oscilloscope is the proven CRT from the TEKTRONIX 560-Series Oscilloscope storage line. The CRT is a single screen version of the CRT used in the 564 and provides a full 8 x 10-cm display area.

The normal stored writing speed is at least 25 cm/ms. Writing speed can be increased to at least 250 cm/ms by using the Enhanced Mode. The storage view time is up to one hour.

The bandwidth of the DM64 is 10 MHz at a deflection factor of 10 mV/cm; using the X10 gain extends the sensitivity to 1 mV/cm. Sweep rates extend from 100 ns/div to 2 sec/div. A full complement of vertical display modes is included: channel 1, channel 2 (normal and inverted), chopped (approx 150 kHz rate), alternate, and added. X-Y relationships can be measured with the same ease as Y-T measurements.

DM64 Oscilloscope **$1095**



The D83 Oscilloscope—A bandwidth of 50 MHz at 5 mV/div and the concept of plug-in selectability are the main features of this oscilloscope. The plug-ins include a differential amplifier, a dual-trace amplifier, and a Dual Time Base. The CRT in the D83, from the field proven 7000-Series TEKTRONIX line of oscilloscopes, has a display area of 8 x 10 div — 1.22 cm/div. A 15-kV accelerating potential gives the D83 a clear and bright display to view and measure delayed sweeps. Sweep rates extend from 2 s/div to 100 ns/div (to 10 ns/div with X10 magnifier).

A full complement of vertical display modes is included: channel 1, channel 2 (normal and inverted), chopped (approx 350-kHz rate), alternate, and added. Signal delay permits viewing the leading edge of the waveform.

D83 Oscilloscope	**$800**
V3 Dual-Trace Amplifier	**$295**
V4 Differential Amplifier	**$295**
S2A Dual Time Base	**$400**

NEW LITERATURE AVAILABLE

Digital Counter Application Note describes use of the 7D14 Digital Counter and a current probe to make frequency measurements. Advantages of this method of measurement as well as complete instructions are given.

The TELEQUIPMENT Catalog provides complete information on the entire TELEQUIPMENT product line, including a characteristic curve tracer, and the new storage and plug-in oscilloscopes.

Machine Control Data Sheets on TEKTRONIX N/C systems are available in a packet which explains the position of Tektronix, Inc. as a machine control supplier. The 15 data sheets include information on turning, milling, positioning, verifying, and editing applications.

Spectrum Analysis and CATV Systems Booklet discusses the new FCC requirements for cable television systems and how a TEKTRONIX Spectrum Analyzer can be used to make these and many other measurements. Also includes a brief tutorial on spectrum analyzers and specifications of TEKTRONIX Spectrum Analyzers.

Time Domain Reflectometry Application Note No. 2 covers some fundamentals of coaxial cables. This note, written in an easy-to-read question and answer style, leads you through some of the old mysteries of coaxial cables. The paper covers such items as how to figure dB losses in a line and how to determine the optimum impedance of a cable. These and other questions are answered using very little math.

U.S. Sales Prices FOB Beaverton, Oregon

TEK TM 500 TM 5000

SEP 23 1985

USER NEWSLETTER
SUMMER 1985

TM NOTES
TEST AND MEASUREMENT

Select the Right System for the Highest Return

Also In This Issue

GURU Links IBM PC to GPIB Instruments. . . at Low Cost	**2**
MP 2902 Performs a Variety of Audio Tests. . . without Programming	**4**

Consider the Alternative: Test and Measurement Automation

Are you making manual tests and measurements? Are they too slow? Do they require too much labor? Are they too unreliable because of poor repeatability or operator errors?

Test and measurement automation may offer a solution. Finding an automated solution to a test and measurement problem is a three-step process:

1. Is the test or measurement suitable for automation?
2. What kind of system would be best—a specific-application system or a general-purpose system?
3. Which particular system is best for your needs?

This article suggests guidelines for answering these questions while focusing on computer-controlled test and measurement instrumentation that uses the IEEE Standard 488 communications bus.

The articles on pages 2 and 4 describe two systems at opposite ends of the spectrum of possible system solutions. One is GURU, a low-cost, highly versatile, general-purpose solution for users who want to use their IBM PC or IBM PC compatible personal computers to run individually selected test and measurement instruments. The other system is the MP 2902 Audio Measurements Package, a set of high-performance, programmable audio instruments run by a controller designed specifically for test and measurement systems.

When Is the Cost of a System Justified?

One way to identify and prioritize test and measurement automation opportunities, is to *ask yourself these questions:*

1. Which operations have the highest labor costs? Cutting high labor costs is a major automation benefit, but don't forget to consider the

Continued on page 6

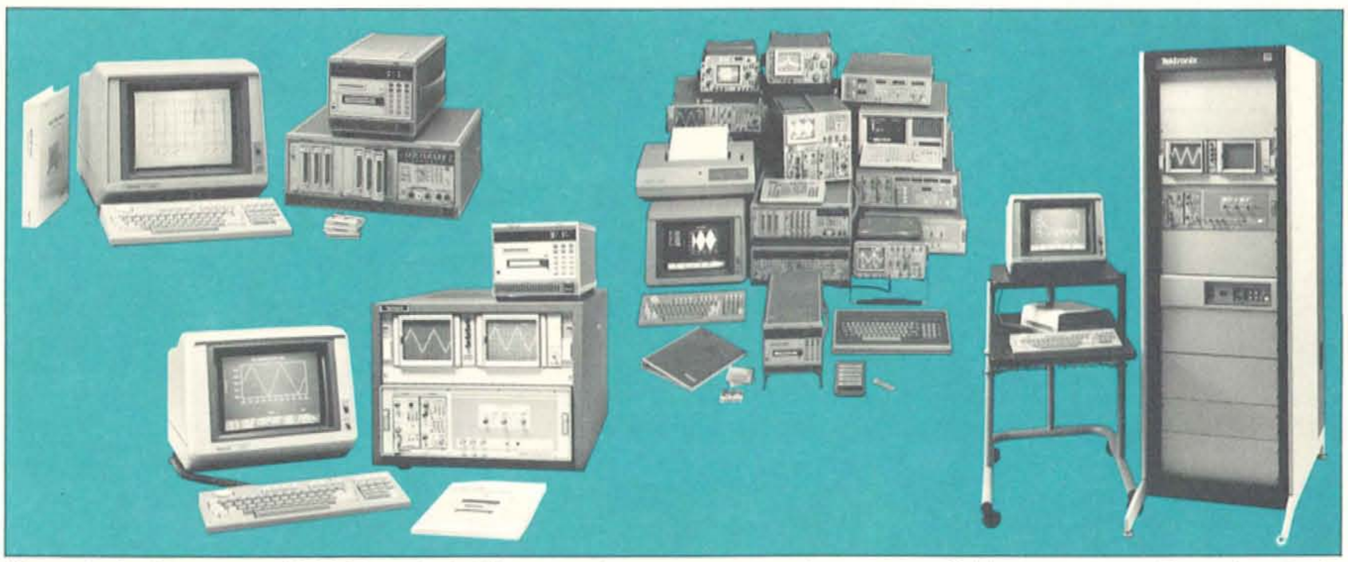


Figure 1. A wide range of IEEE Standard 488 test and measurement systems are available to meet specific and general-purpose automation needs. The Tektronix systems shown here, left to right, are: MP 2901 Inspection Test Station Measurement Package; MP 2101 Acquisition/Processing Measurement Package; a few of the many configurable Tektronix test and measurement instruments; and the MS 3101 Acquisition/Processing Measurement System.

Tektronix®
COMMITTED TO EXCELLENCE

GURU Links IBM PC to GPIB Instruments . . . at Low Cost

Low Cost Combines with Hardware and Software Flexibility

Tektronix GURU (GPIB Users Resource Utility) is a low-cost hardware and software tool that transforms your IBM PC into a versatile, low-cost, instrument controller. Compatible with Tektronix and other manufacturers' GPIB equipment, GURU opens the door to many applications that previously didn't justify a systems investment. (Refer to figure 1.)

On the system-solution spectrum, GURU provides basic controller functions for the smallest front-end investment.

Versatility Starts with the Hardware

On the hardware side, GURU allows you to use an IBM PC (IBM XT, IBM AT, or IBM-compatible computer) to control IEEE Standard 488 (GPIB) test and measurement instruments. The GURU hardware components are the GURU GPIB Interface Board (which is inserted in the PC) and a GPIB cable (for connecting the GPIB instruments to the IBM PC). You may connect any GPIB instrument or GPIB input/output device to your IBM PC to develop a system shaped to your specific application needs.

GURU Software Provides a Variety of Tools

A GURU manual that combines detailed hardware and software reference material with tutorial information takes the beginning user from basic GPIB concepts to applications programming.

Users may access all GURU GPIB commands from the IBM PC's **MICROSOFT BASICA** language. Thus, users who are programmers can readily develop BASIC language application programs. (Refer to figure 2.)

TPG.BAS, the GURU Test Procedure Generator, is the right tool if you want to develop test and measurement programs quickly, without coding. TPG.BAS allows users to generate a program that runs a specific test or measurement sequence without writing

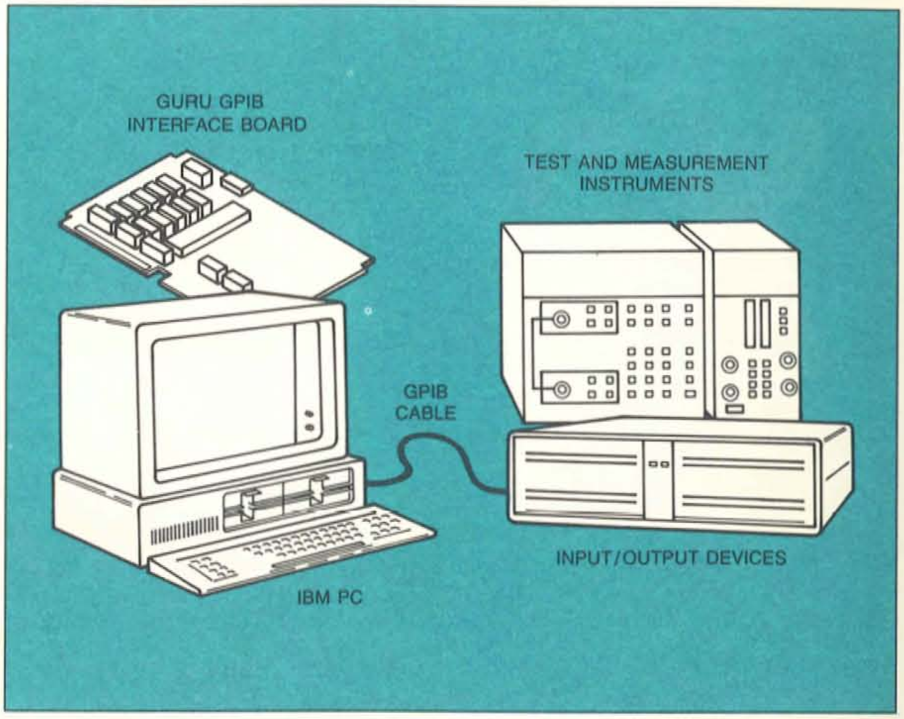


Figure 1. GURU hardware, consisting of a GPIB interface board and GPIB cable hardware, unites the powerful and versatile IBM PC with the world of GPIB test and measurement instruments.

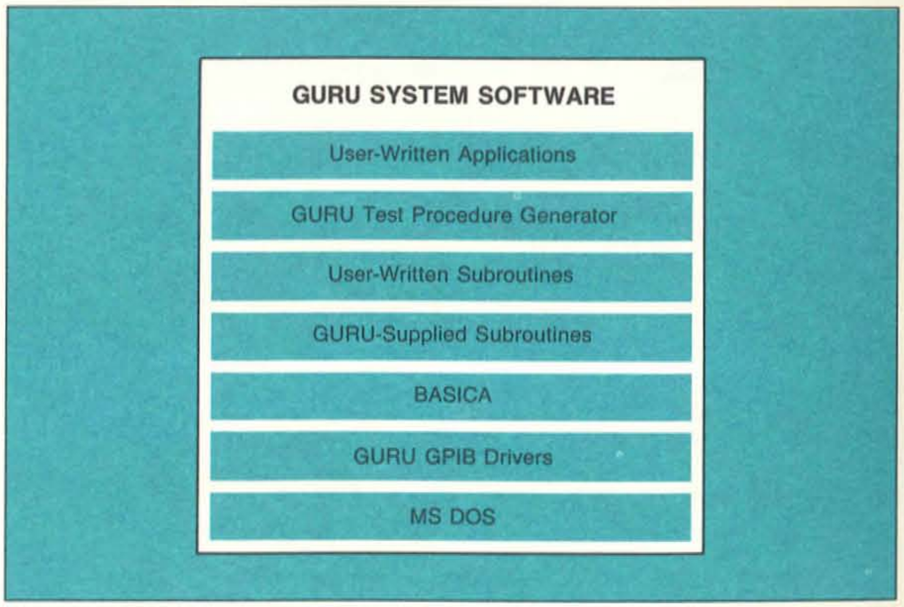


Figure 2. GURU's wide range of system software opens the IBM PC controlled GPIB test and measurement system to users with various levels of programming skills.

a single line of code. You need to know only the details of the test to be performed and the equipment to be used. TPG.BAS walks you through the test program generation process step by step, allowing you to choose items from easy-to-use, self-explanatory menus.

The test procedure generation process begins when you enter the Main Menu and select an appropriate menu item (refer to figure 3). After telling GURU what equipment is included, you can move to the Function Menu (refer to figure 4), the primary tool for developing a test procedure program. The menu includes all the individual steps that might be used in any test procedure. For example, pressing the W key adds a "wait for operator input" step to the procedure. GURU automatically asks the system operator for the information needed at each step.

TEK DIG.BAS, the GURU Digitizer program, provides menu items that allow users who have included digitizers in their systems to:

- Select a digitizer.
- Change the digitizer settings.
- Learn settings from a digitizer or restore them from a disk file.
- Acquire a waveform from the digitizer.
- Store waveform data on a disk or display it.
- Recall waveform data from the disk.

These additional functions extend the flexibility of your GPIB system to include a wide range of waveform measurements.

BASIC Subroutines Extend GURU Power

For users who want to code their own applications programs, GURU supplies **SUBS.BAS,** a set of BASIC language subroutines (refer to figure 5). These subroutines perform functions common to many test and measurement applications. The subroutines are designed for user-written applications programs, thus reducing your software effort. Each subroutine is thoroughly explained in detailed GURU documentation.

For more information about GURU, check the appropriate box on the reader reply card.

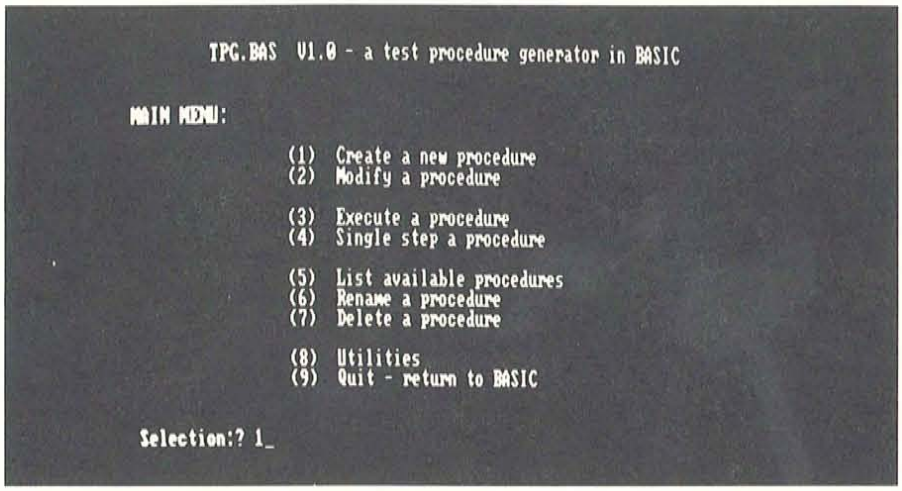


Figure 3. The GURU Test Procedure Generator Main Menu is the starting point for developing automatic test procedures for a system that uses GPIB test and measurement instrumentation.

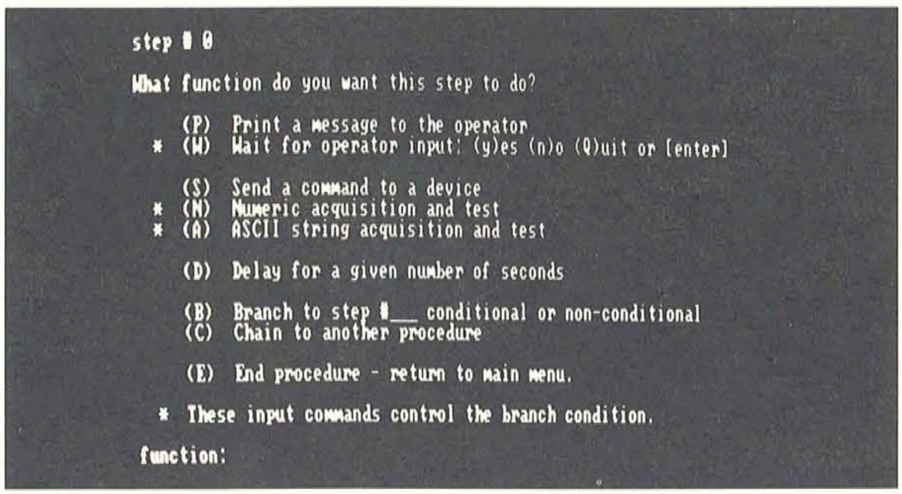


Figure 4. The GURU Function Menu lists the test procedure steps you can use to generate a test program for your specific application.

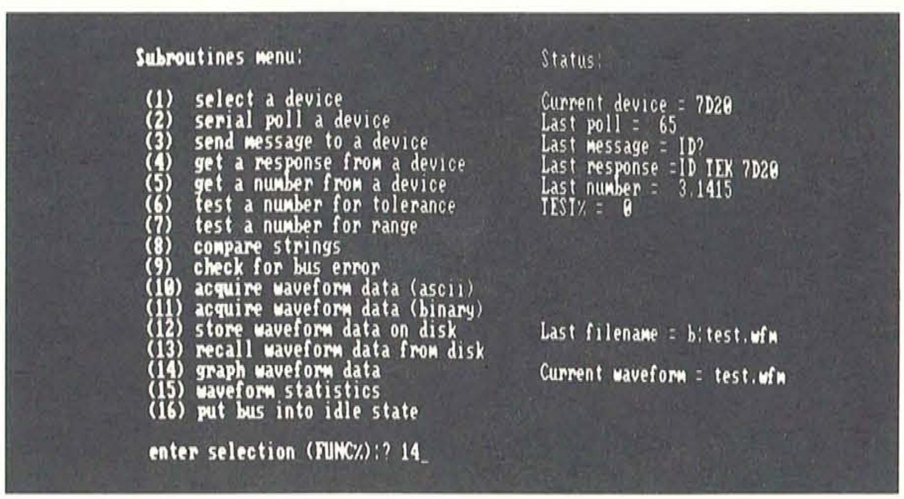


Figure 5. Item 14 on this Subroutines Menu graphs waveform data.

MP 2902 Performs a Variety of Audio Tests. . .without Programming

MP 2902 Ties Together a Package of Benefits

The Tektronix MP 2902 Audio Measurements Package *automatically* performs a wide variety of complex audio tests and measurements, without requiring you to write a single line of code. (Refer to figure 1.) The MP 2902's position in the system-solution spectrum is high performance for a specific application area (audio measurements).

The MP 2902 offers the benefits of automated top-of-the-line audio analysis equipment without the high cost of software development. For even the most complex tests, the MP 2902 speeds testing, provides fast and low-cost documentation, allows operation by lower skill operators, and ensures measurement procedures are consistent from day to day.

Producing automated test procedures for GPIB audio test equipment was time-consuming and difficult until Tektronix introduced **Audio Test Procedure Generation** software. Audio TPG is a tool which simplifies converting manual tests into software and eliminates the need for software coding, in most cases.

The MP 2902 hardware includes a distortion analyzer, oscillator, and color computer display terminal. The package software includes a test procedure generator that greatly simplifies the creation of test programs. Non-programmers need no software training to use Audio TPG to generate test procedures that may be easily converted to BASIC programs. Programmers appreciate Audio TPG's creation of documented, error-free BASIC code.

MP 2902 Hardware Unites Programmability and High Performance

The MP 2902 components are designed to work together and are selected to make measurements to international standards. Under the direction of the 4041 System Controller (designed specifically to control GPIB test and measurement instruments), the AA 5001 Programmable Distortion Analyzer, the SG 5010 Programmable

Figure 1. The MP 2902 Audio Measurements Package offers the hardware and software needed to create a variety of audio tests, quickly and easily. At low cost, it automatically documents test results in graphic or tabular form.

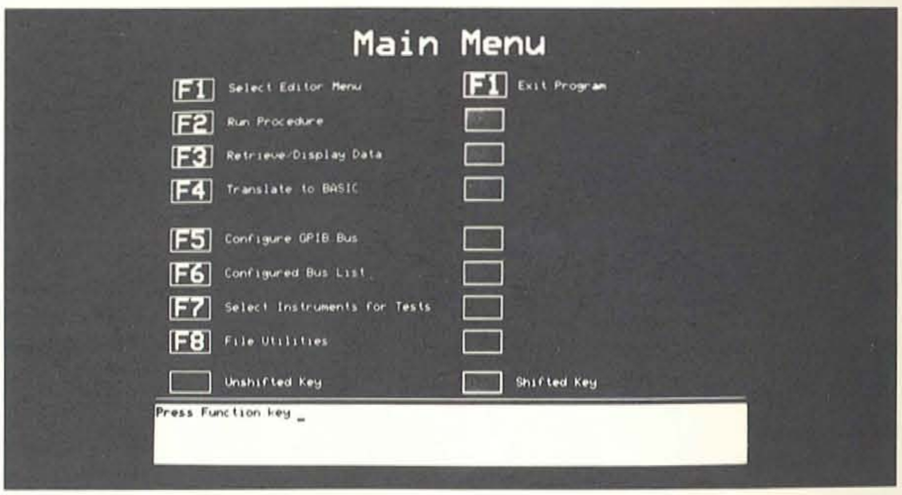


Figure 2. The Audio Test Procedure Generator Main Menu structure is simple. You first see the Main Menu when initializing the MP 2902. This menu is the starting point for a sequence of easy-to-use interactive menus.

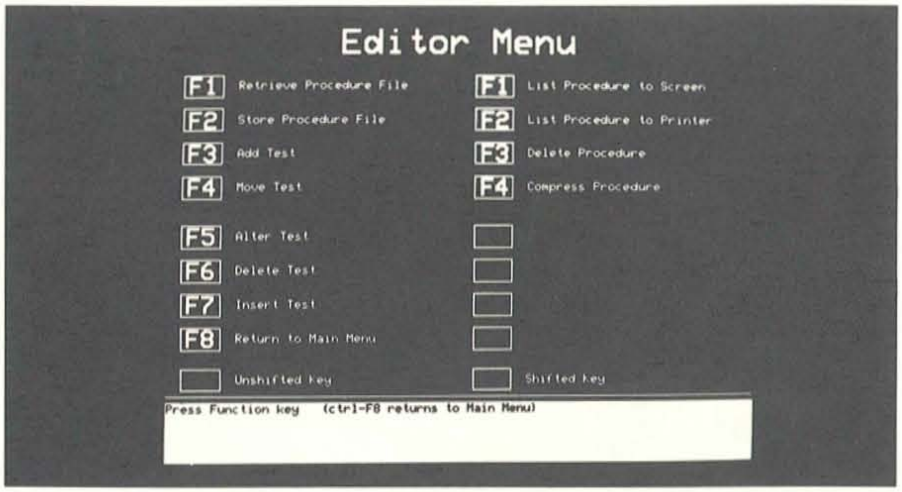


Figure 3. The Editor Menu lists the steps you can take to change the test procedure.

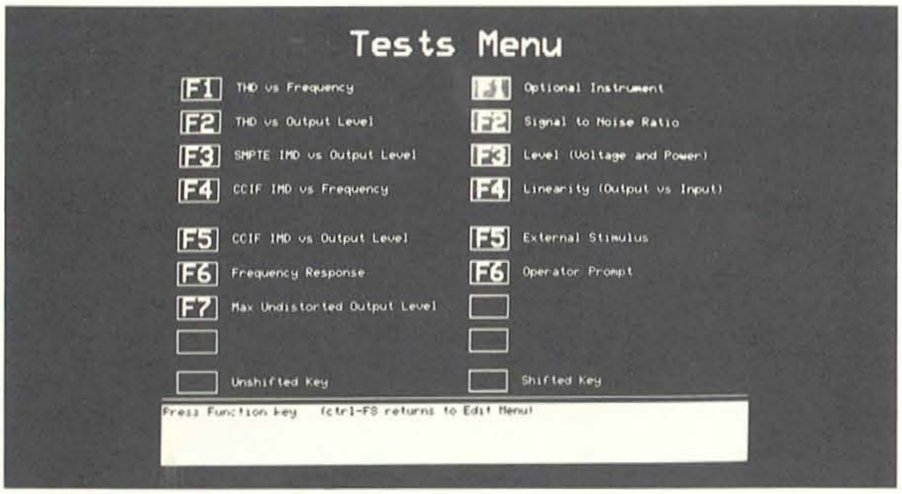


Figure 4. The Audio TPG Tests Menu lists the tests that are stored in the MP 2902, for retrieval, editing, or execution.

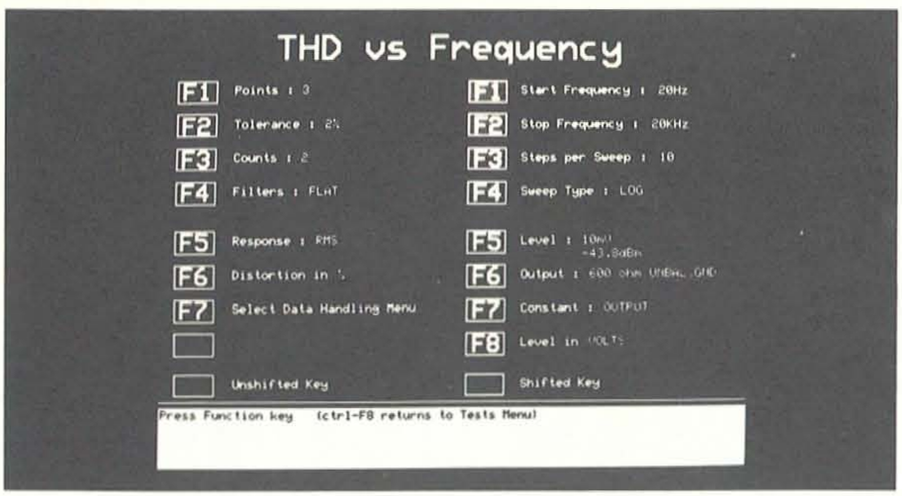


Figure 5. This THD versus frequency tests menu is an example of MP 2902 test menus. The menu lists the parameters and actions you may choose for a specific test.

Oscillator, and the optional DC 5010 Universal Counter-Timer set up and make frequency response, distortion (THD+N and SMPTE, DIN and CCIF IMD) versus frequency or level, power computed from voltage, and signal-to-noise measurements. Adding optional equipment makes automatic switching possible as well.

Using MP 2902 test and measurement instruments ensures extremely low residual noise and distortion, permitting measurements on top-grade professional and consumer equipment. This package provides fully balanced analyzer input, balanced or unbalanced oscillator output, floating or grounded, 50/150/600 Ω to match all types of audio equipment.

Software or manual control selects the synthesized frequency stimulus to four or more digits with 0.01% accuracy, offers fully programmable filter and detector selection to accommodate a wide variety of measurement standards, and provides high-level oscillator output to test headroom and clipping thresholds of line level devices. The oscillator offers burst, squarewave, and amplifier modes.

With Audio TPG, you first create a sequence of tests by following interactive screen menus displayed on the 4105 Computer Display Terminal. The test sequence consists of the steps in the manual test procedure. (You direct Audio TPG through the 4105 keyboard.)

The first menu in the sequence is the Main Menu, shown in figure 2. After creating the test procedure database, you can select a translation sequence to automatically convert the test procedure database to a BASIC program or you can execute the test procedure. The result of translation is a complete BASIC program that has utility routines to support data logging and merging of tests. You can modify the program to meet your unique test requirements.

To add, delete, or change steps in the test procedure, you call the Editor Menu (figure 3) and select the appropriate user keys on the keyboard. The Editor Menu then automatically displays the Tests Menu (figure 4), which lists the audio tests you can select for editing. Picking an item on this menu displays the parameters and actions available for a specific test. Figure 5 shows the test menu for THD-versus-frequency tests.

Continued on next page...

Continued from page 5

MP 2902 Simplifies Results Documentation

At your command, Audio TPG stores test data on tape or other storage medium . This data can be retrieved and displayed in tabular or graphic form, or printed in tabular form. Figure 6 shows a display of a frequency-dividing network's frequency response.

For more information about the MP 2902 Audio Measurements Package, check the appropriate box on the reader reply card.

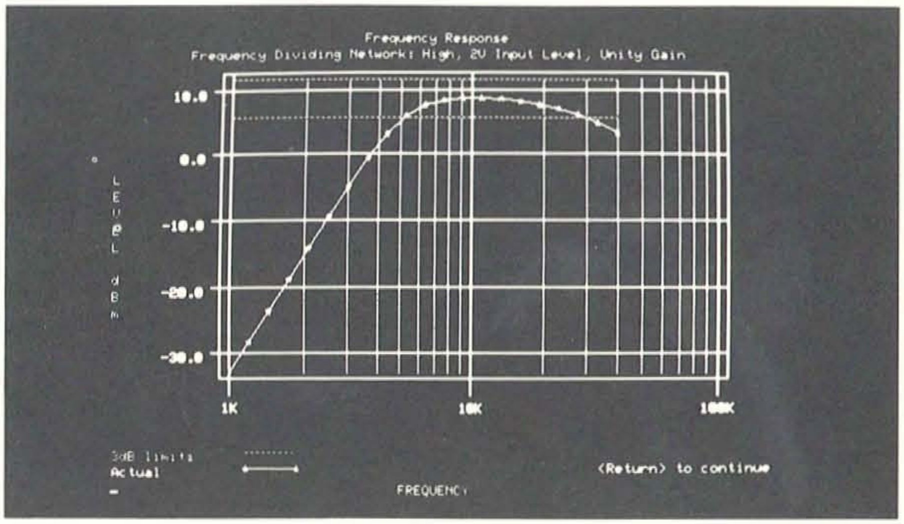
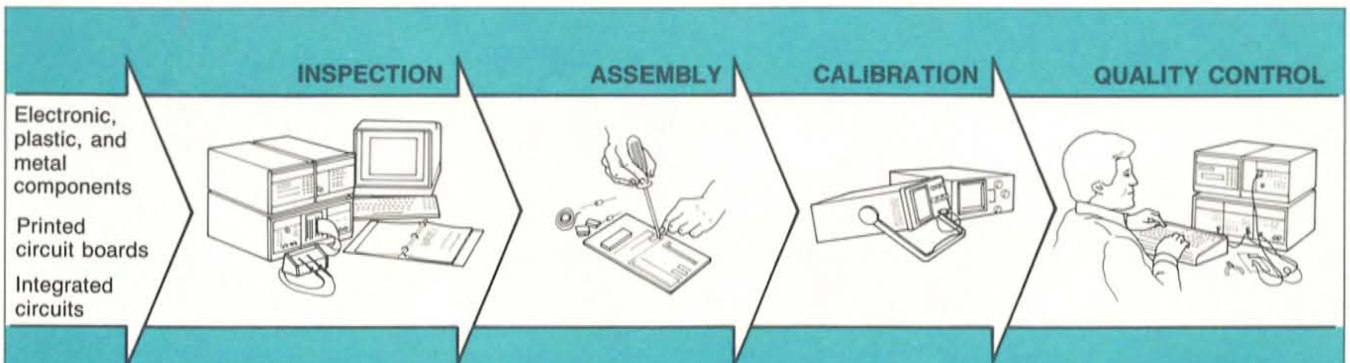


Figure 6. In this graph, the MP 2902 plots a frequency dividing network's frequency response, from 1 kHz to 40 kHz. The dashed lines represent the ±3 dB points at a 10-kHz reference frequency. The user entered the graph subtitle when the test was created.

Continued from page 1 . . .

impact of a faster process: Can downstream operations handle the higher throughput, and must upstream operations increase their output?

2. Which operations have caused quality problems? Quantifying the savings due to better quality (lower costs of scrap, reject, rework, and field failures) is difficult but important to estimate. Two advantages of automation that improve quality are consistent processing and data recording. Consistency is inherent in automation: Systems don't get tired or careless. Automation makes massive amounts of performance data available for analysis and for use in correcting quality problems. An alternative approach is to *flowchart and analyze your operations.* Look for high levels of repetitive activity; low levels of mechanical activity; high levels of data referencing, retrieving, and recording; and high concentrations of manual test and measurement equipment. Figure 2 shows a simplified example and analysis.



	Inspection	Assembly	Calibration	Quality Control
Repetitive?	Medium	High	High	High
Mechanical?	Medium	High	Medium	Low
Data quantity?	Low	Low	High	High
Test and measurement instrument use?	Medium	Low	High	High

Figure 2. In this simplified work-flow diagram and analysis, quality control is the most likely candidate for test-and-measurement automation. High levels of repetition and instrument use, plus large amounts of data, qualify this operation for automation. A high level of mechanical activity usually disqualifies an operation for automation using computer-controlled test-and-measurement equipment.

Once you have evaluated your operations for automation opportunities, and found one or more, decide whether the savings justify the expense.

If, after a thorough economic analysis, a system is justified, how should you select a system?

The first issue here is the *kind* of system: Should it be a monolithic or a modular system? In a few applications, a monolithic system may be the best solution if it uniquely answers specific needs. Otherwise, a modular system (a system of replaceable, programmable instruments run by a computer) is the way to go because it offers application flexibility (you can select special-purpose instruments for special applications).

What are the Checkpoints for Selecting a System?

By far the best approach to building modular systems is selecting instruments compatible with the IEEE Standard 488 (GPIB). Instruments built to this standard of electrical and mechanical compatibility can communicate with each other without special programming. The criteria summarized in the sidebar below will help you select from among the many IEEE Standard 488 instruments on the market today.

Product Evaluation is a Prime Candidate for Automation

When you're looking for automation opportunities, don't overlook the new-product-introduction flow. Product evaluation groups perform well defined tests (such as reliability and electromagnetic interference) on many products. Automation here can provide high payback with no risk of interfering in the manufacturing process. An additional benefit is that tests written for product evaluation often can be directly transferred to production use.

Selecting System Components

Performance and functionality. *Define the performance you need. For example, you may need a 4½-digit digital multimeter having 0.01% accuracy and a 5-MHz function generator that can provide a counted burst of square waves.*

Level of instrument programmability. *Programmable instruments may be talkers only, listeners only, or talker/listeners. That is, they may send information, receive information, or both send and receive information over the IEEE Standard 488 communications bus that connects all the instruments and the computer. Talker/listeners are best because they simplify programming, troubleshooting, and system maintenance.*

Compare the programmable (GPIB-accessible) features to the manual (front-panel accessible) features. They aren't always the same. You may need both to cover all your applications.

Instrument intelligence. *An instrument's intelligence (local processing power) allows it to do tasks that would slow the system computer. For example, some multimeters can average measurements and some oscilloscopes can perform Fast Fourier Transformations and then pass the results to the computer.*

Some instruments have the ability to store front-panel settings. These settings can be recalled by a command from the computer, making the system faster and more efficient. Also, more instrument intelligence allows you to use a less intelligent (and less expensive) controller. To reduce system cost, some manufacturers offer controllers that can be used only to run programs, not to develop them. If you build several similar systems, you can use one controller to develop programs and the other (less expensive) controllers to run them.

Command language. *The instrument's command language (not the controller's) should have powerful multifunction commands as well as commands for individual functions. For example, a single initialization command (called INIT in Tektronix instruments) should set all of an instrument's functions to an initial state. Initializing all functions individually might require you to program several hundred characters.*

SET? is another Tektronix example. With just this one query, you can ask an instrument to report all its current settings, letting you decide which you would like to change. HELP aids new users. This command tells an instrument to list all the commands that the instrument recognizes. Because the commands are mnemonic, the list helps new users find the right command.

Speed. *At first, the system speed issue seems simple: How fast can the system set up the equipment, make measurements, process the data, and record it? Looking more closely reveals that system speed is made up of many individual speeds: CPU (central processing unit), controller bus-transfer, instrument bus-transfer, local instrument processing, and instrument measurement speeds.*

Evaluate each application to decide which speeds to optimize. For example, if you need to make 1,000 voltage measurements and average them, buying a high-speed digital multimeter with lots of local processing power is investing in speed where it matters most. (Because the digital multimeter sends only one number—the calculated result—to the controller, bus-transfer speed isn't important here.) When controller speed is important, ask the controller manufacturer to run a time trial on your application.

Personal computers or system controllers? *Because of their lower price compared to system controllers, personal computers are popular for some IEEE Standard 488 system applications. Tektronix has designed the GURU hardware and software package for these users.*

The initial hardware cost of PCs is low. However, the longterm cost may be much higher. Developing software for PC-controlled systems is considerably more difficult. A PC requires detailed instructions to control messages on the IEEE Standard 488 bus. A controller performs this function automatically. For sophisticated programmers who have simple applications, the PC route may be better. For anyone who has complex applications, the system controller route is better.

Software availability. *Almost all instrument controllers can be programmed in BASIC, an easy-to-learn language that works well for most applications. Language enhancements are usually available on firmware modules (plug-in ROMs). Using these enhancements is much easier than developing your own BASIC software, and the extra cost is small.*

Documentation (manuals and other aids) and technical support (applications engineers) should also be available.

Memory size. *How much memory will you need? Typical applications require 64 to 128 Kbytes of RAM. Simple applications, using one instrument, might require only 16 Kbytes. Very complex applications might require 512 Kbytes or more. With most controllers, you can add RAM as you need it, at low cost.*

SEP 23 1985

The TM 500 Family

TM 500 is a family of manual Tektronix test and measurement instruments. They are mechanically and electrically compatible with each other. They are designed for compactness and modular mounting in eight mainframes. TM 500 instruments can function individually or in combination. The TM 500 family includes: digital counters, digital multimeters, power supplies, pulse generators, function generators, oscilloscopes, oscilloscope calibration instruments, and audio/low-frequency plug-ins.

Publisher's Statement

TM Notes informs TM 500/TM 5000 users and owners about new Tektronix instruments and about instrument applications.

For further information, contact Tektronix, Inc., P.O. Box 500, Beaverton, OR 97077. Phone (503) 644-0161. TWX 910-467-8708. Cable TEKTRONIX. Subsidiaries and distributors worldwide.

The TM 5000 Family

TM 5000 is a family of programmable, IEEE Standard 488 (General Purpose Interface Bus or GPIB) compatible test and measurement instruments. The TM 5000 family includes: digital counter/timers, power supplies, signal generators, function generators, a digital multimeter, an audio distortion analyzer, an RF scanner, and a multifunction interface system. Commands that control TM 5000 instruments conform to the Tektronix Standard Codes and Formats, ensuring quick-to-learn, easy-to-remember, and compatible programming.

For further information:

To order in the continental U.S., Alaska, Hawaii, Virgin Islands, and Puerto Rico, call your local Tektronix field office or the National Marketing Center, toll free 1-800-426-2200, ext. 506.

Austria: (222) 686602.

Belgium: (2) 720 80 20.

Denmark: (2) 845622.

Finland: (90) 722400.

France: (6) 907 78 27.

Germany: (221) 77220.

Germany, Berlin: (30) 3139081.

Africa, Middle East:
Tek Ltd., Guernsey,
Channel Islands:
(481) 35781. TELEX: 4191193 TEKGNY G.
Mail: Tektronix Ltd., POB 36, Guernsey, CI

Italy, Milan: (2) 8466446.
Rome: (6) 8278041.
Turino: (11) 3351143.

Japan, Tokyo: 448-4611.

Netherlands: (2968) 1456.

Norway: (2) 64 57 70.

Spain, Barcelona: (3) 33020 08.
Madrid: (1) 4041011.

Sweden: (8) 83 00 80.

Switzerland: (42) 219192.

United Kingdom: (5827) 63141.

Tektronix, Inc.
P.O. Box 1700
Beaverton, Oregon 97075

BULK RATE
U.S. POSTAGE
PAID
TEKTRONIX,
INC.

0421867
Mr. Thomas P. Downey
Lab Technician
Geology Dept EPS-J106
City University of New York
Convent Avenue & 138th Street
New York NY 10031

SEP 23 1985