USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

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FIELD EFFECT TRANSISTORS

(Unipolar Transistors)

by Nelson Hibbs, Instructor

Tektronix Product Manufacturing Training Department

At last we have what amounts to a backward vacuum tube—a p-channel FET. In this device, electron current goes from drain (plate) to source (cathode).

The Field Effect Transistor (FET) is a comparatively new device whose operation differs radically from the more familiar n-p-n and p-n-p types of transistors. The FET is a single-junction *majority-carrier* device while the n-p-n and p-n-p transistors are double-junction *minority-carrier* devices.

FET manufacturers have settled on a new series of names for the three basic leads of this device; so, once again we encounter a change in terminology. Figure 1 compares an FET, a conventional transistor and the familiar vacuum-tube triode to show this change in basic-lead terminology.

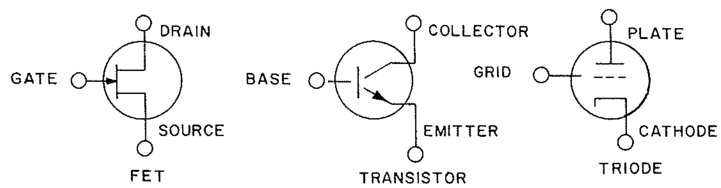

Figure 1. Comparison of basic lead terminology of FET's, transistors, and vacuum tubes.

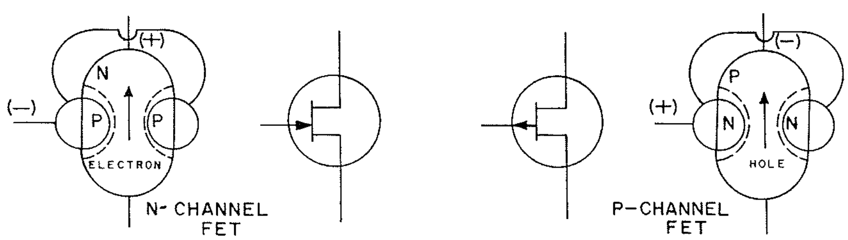

Figure 2. Comparison of an n-channel FET and a p-channel FET.

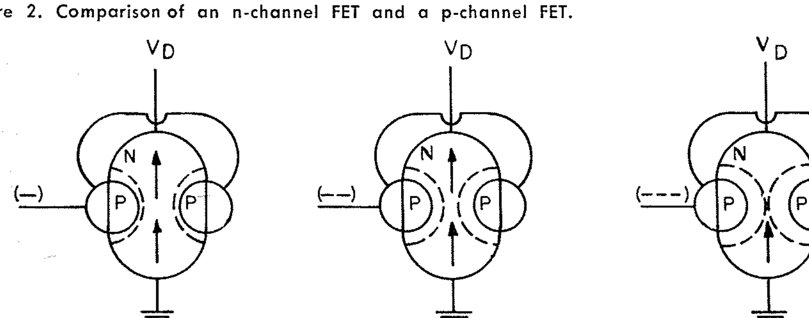

Figure 3. Illustration of how the voltage applied as back-bias can control the flow of current in an n-channel FET.

As with conventional transistors, which are represented by two types of devices (n-p-n and p-n-p), the FET is also represented by two types of devices. These are designated the n-channel and the p-channel types of devices (see Figure 2).

The electron in "n" material has a faster mobility than the hole in "p" material. Thus, the n-p-n transistor has a faster mobility than the p-n-p transistor and consequently a higher frequency response. A similar condition exists with the new FET's. The n-channel FET promises a greater frequency response than the p-channel device. This does not mean that the p-channel device is not being manufactured.

The FET is a single-junction device made up with the Source-to-Drain material (the majority-carrier path) doped in either the "n" or the "p" direction and with the Gate material doped in the opposite direction. By applying voltage so as to oppose the majority carriers in the channel (a negative voltage applied to the gate opposes electron flow in n-channel material—a positive voltage opposes hole flow in p-channel material) the device is back biased. Under these conditions, the n-channel or p-channel material becomes a constrictive layer of dielectric material past which majority carriers must flow and can thus be controlled. See Figure 3.

For a given voltage setting between the gate and the source (bias, if you will), the FET rapidly reaches a point of saturation in the source-to-drain majority-carrier path. This region of the curve gives the FET an effective R_p approaching infinity. This is where an increase in drain voltage (V_D) does not result in an increase in drain current (I_D). This area of the curve is spoken

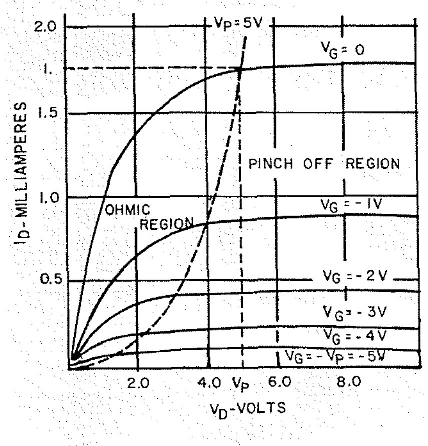

Figure 4. A chart of V_D vs I_D curves of an FET showing the pinch off region and Ohmic region at different values of bias voltage.

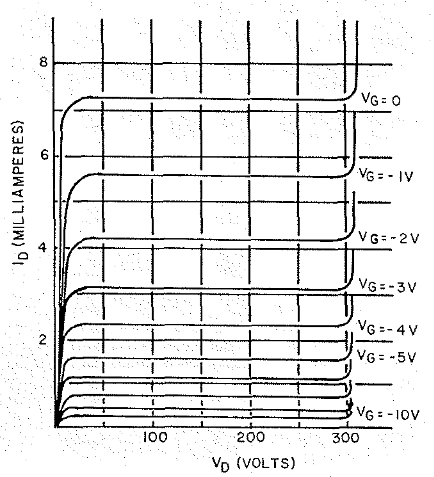

Figure 5. A chart of the V_D vs I_D curves of another FET showing Zener-knee breakdown of Gate-to-Drain back-biased diode. An extension of the curves shown in Figure 4 would reveal a similar tendency of this FET to avalanche at some certain V_D voltage.

of as the "Pinch-Off Region". See Figure 4. The area to the side of this (where an increase in V_D results in an increase in I_D—close to the graph axis) is termed the "Ohmic Region".

A study of the V_D vs I_D curves (see Figure 5) shows that with a given load line, the resultant transfer curve is non-linear. This non-linearity is relative to the deviation in the resistance represented in the majority-carrier path as controlled by the biasing voltage. The best "g_m" occurs under zero bias conditions and the forward voltage at which saturation of this path occurs is called V_p (pinch-off voltage). V_p is counted as a characteristic of the individual device. Thus, in order to find the active g_m at a bias different than zero, we must multiply the zero-bias g_m by the factor one minus the ratio of gate voltage-to-pinch-off voltage raised to the two-thirds power.

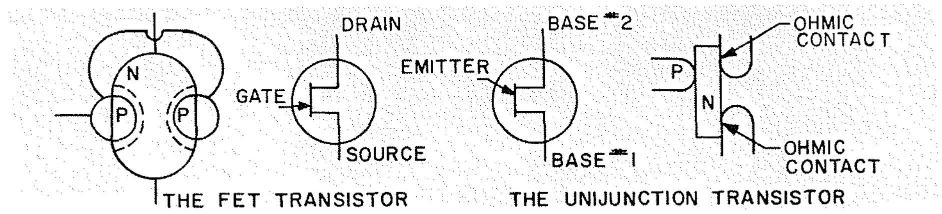

Figure 6. Comparison of an FET and a Unijunction transistor.

$$\text{Operational } g_m = g_m \text{ (at zero bias)} \left[1 - \left(\frac{V_G}{V_p}\right)^{2/3}\right]$$

Now, with a truly representative g_m available, one can closely predict the voltage gain of the device in a circuit by using the Pentode A_v formula:

$$A_v = \text{operational } g_m \times R_L.$$

Noting that the input to the device is a back-biased diode, one can see that it offers a high input impedance and that this back-biased junction will show a capacitative effect from gate-to-source and from source-to-drain. The latter also gives a miller effect. Note also, that the input-impedance will decrease with increasing frequencies at which the product $\frac{1}{2\pi f C_{GS}}$ becomes comparable to the input resistance. Also, the gain-bandwidth product will be approximately:

$$\text{Gain Bandwidth} = \frac{g_m}{2\pi\ (C_{in} + C_{out})}.$$

Again, similar to the vacuum tube pentode. This dictates the usual compromise between gain and bandwidth when using this device.

The FET should not be confused with the Unijunction Transistor. The theory of operation is totally different, although at first glance, the unijunction transistor looks almost like an n-channel FET. See Figure 6 for a comparison.

The unijunction transistor operates as a current-driven device with a *forward-biased* junction of p-to-n material injecting holes into the n material between the emitter and base #1 thus reducing the ohmic resistance of the contact. The FET operates with a voltage-driven gate and the resultant back-biased junction with the field restricting the majority-carrier flow through the body of the device. The FET, like a vacuum tube, is a normally "ON" device and must be turned "OFF". Conversely, the unijunction transistor is a normally "OFF" device (as a result of the ohmic contacts) and must be turned "ON" by the signal at the emitter—two totally different theories of operation.

To summarize the properties and characteristics of the FET:

A. Input Impedance:

1. The FET is a high-input impedance device, the input terminal is essentially looking into a reverse-biased junction.
2. The FET has input capacitance that varies inversely with V_{SG} (bias). See Figure 7.

B. Mode of operation:

1. The FET is a voltage-controlled device just as a vacuum tube pentode.
2. The FET has a very, very high R_o (R_p) characteristic similar to a vacuum tube pentode.
3. The FET has a consistently non-linear g_m characteristic.

C. Output Impedance:

1. The FET is a high-output impedance device (current source). However, different means of manufacturing

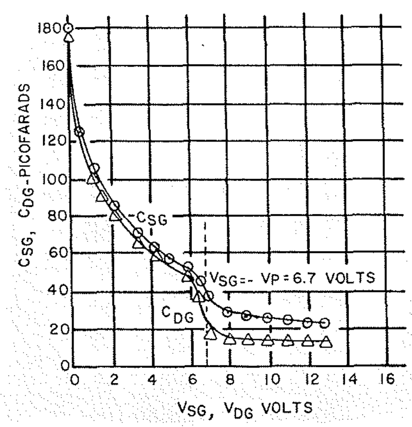

Figure 7. Variation of Source-to-Gate and Drain-to-Gate capacitance with voltage.

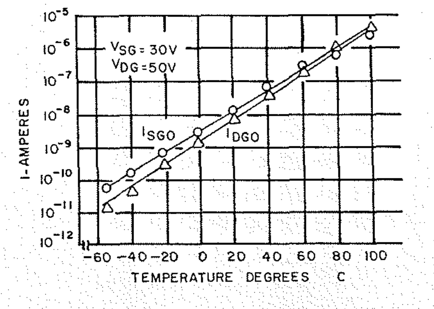

Figure 8. Plot showing leakage current from Source - to - Gate (I_{SGO}) and Drain - to - Gate (I_{DGO}) against temperature under zero bias conditions.

may result in relatively low ratings of this characteristic in comparison with the vacuum tube pentode.

Another noteworthy characteristic of FET's is their built-in protection against thermal run away. Because the input is a back-biased diode, the thermal-sensitive backward current (leakage current) flows from both the source-to-gate (I_{SGO}) and drain-to-gate (I_{DGO}). Plotting this linear current against temperature under zero bias conditions of the other element gives two straight line projections as shown in Figure 8.

This increase in leakage current in the gate junction has a resistive effect on the majority-carrier path resulting in a lower saturation current for a given bias voltage. For a graph of this action under zero bias conditions, and with the forward voltage from the drain to the source set at 50 volts, see Figure 9 (a). A cross graph of g_m and output resistance plotted against temperature is shown in Figure 9 (b). The combination

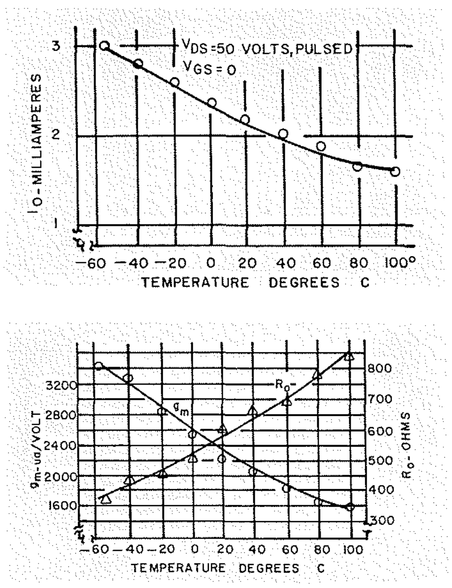

Figure 9. (a) Graph of saturation current under zero bias conditions and with the forward voltage from Drain-to-Source set at 50 volts. (b) Cross graph of g_m and output resistance plotted against temperature.

of these two reactions to temperature is such that as temperature goes up, g_m goes down and R_o (counterpart of R_p in vacuum tubes) goes up. In other words, as the gate starts to lose control of the drain current, a greater portion of the actual drain current will be passed on to the load resistor thus tending to maintain the same change of voltage at the output. This is what we mean when we say that FET's have built-in protection against thermal run away. This statement is not wholly true in the case of MOS (Metal-Oxide-Insulated) FET's.

The MOS FET's separate the gate and channel with a layer of intrinsic material. As temperature increases on this device, the channel apparently increases also as it starts to include some of the insulating layer into the main channel. The MOS FET reacts more to changes in temperature than the regular FET's even though they do away with leakage currents in the gate circuit.

With standard FET's, leakage currents in the gate lead have been reduced to the neighborhood of 0.001 to 0.0001 mA and this can be tolerated where instability of I_D with temperature change cannot.

Characteristic curves of FET's can be displayed on a Type 575 Transistor-Curve Tracer. The EMITTER-GROUND (SOURCE-GROUND) mode is used with the POLARITY control of the Collector Sweep set to NPN (for n-channel FET's) or PNP (for p-channel FET's). The POLARITY control of the Base Step Generator should be set to MINUS for n-channel and PLUS for p-channel FET's.

FET's that require more than 2.4 volts to drive them to cut off—and the great majority are in this category—will require that a 1 kΩ, 1% resistor be connected between the BASE (GATE) and EMITTER (SOURCE) binding posts on the test panel of the Type 575. This, in order to convert the BASE current, as indicated by the STEP SELECTOR switch in MA, to Gate V_{GS} voltage in volts. Thus, 1 mA per step into 1 kΩ gives 1 volt/step and twelve steps at 1 mA per step can give up to 12 volts—ample in most instances to drive any FET to cut off.

The four waveforms represented in Figures 10, 11, 12, and 13 were obtained in this manner. The FET used in these tests was an Amelco U-1346 field effect transistor.

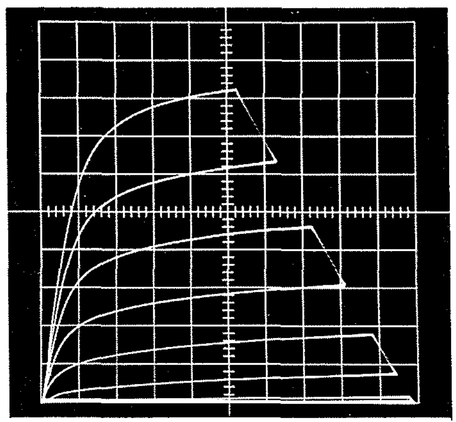

Figure 10. Drain characteristics. V_{DS} (horizontal) = 2 V/cm, I_D (vertical) = 1 mA/cm.

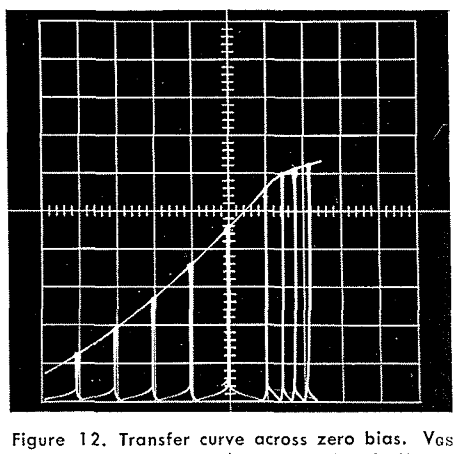

Figure 12. Transfer curve across zero bias. V_{GS} (horizontal) = 0.5 V/cm, I_{DSS} (vertical) = 2 mA/cm. *Center vertical graticule line is zero bias.* Negative bias to left, positive bias to right of center line. Crowding of markers on right hand side is due to gate drawing current.

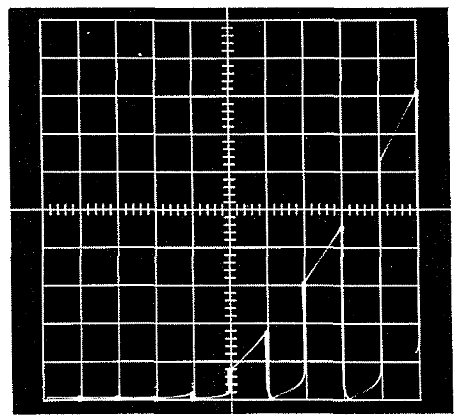

Figure 11. Drain current vs Gate Source Voltage (I_D vs V_{GS} with V_{DS} constant). V_{GS} (horizontal) = 0.5 V/cm, I_{DSS} (vertical) = 1 mA/cm.

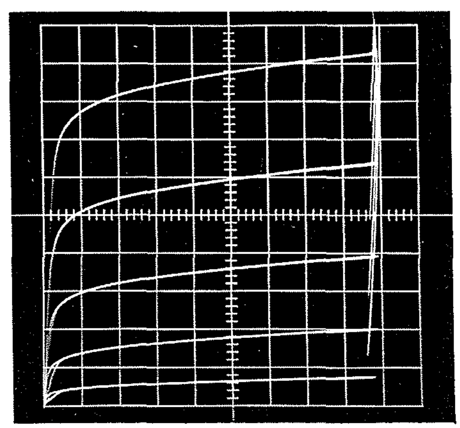

Figure 13. Drain curves showing avalanche (breakover at the Gate-to-Collector Zener Knee). V_{GS} (horizontal) = 5 V/cm, I_{DSS} (vertical) = 0.5 mA/cm.

TEKTRONIX-PRODUCED FILMS AVAILABLE

Ten films produced by Tektronix, Inc. have been certified as education films by the U.S. Information Service. These films are available on free loan as an aid to companies engaged in educational or training programs for their employees; or, if preferred, the films may be purchased.

Interested persons should contact their local Tektronix Field Office, Field Engineer, Field Representative or Distributor.

Listed below are the film titles, along with a brief review of the film:

"The Oscilloscope Draws a Graph" . . . A 20-minute color film in sound. The film explains that the oscilloscope display is usually in the form of a graph, and describes how to read or interpret the display.

"The Cathode-Ray Tube, Window to Electronics" . . . A 35-minute color film in sound with animated sequences. This film explains in simple terms how a cathode ray tube works. It depicts the heart of the oscilloscope, the cathode ray tube, as it is used in radar, sonar and many other electronic systems, including computers. The film also shows the step-by-step manufacturing process of cathode ray tubes at Tektronix, from the forming of metal "gun" parts to the final testing of completed tubes.

"The Square Wave" . . . A 25-minute black and white sound film. Discusses the theory of square waves, employed in computers and many other electronic devices; usually, in the form of coded information. Animated drawings show how sine waves contained in square waves are harmonically related. The film demonstrates the basic use of the square wave generator and oscilloscope and resulting information obtained from distortions. It discusses risetime and its importance in testing modern high speed electronic equipment. Suitable for audiences with at least a basic knowledge of electrical theory.

"Transmission Lines" . . . A 23-minute black and white sound film. Discusses the fundamentals of transmission lines. Animated drawings illustrate how electrical energy is transmitted along a line. An oscilloscope shows how reflections can occur in a line. Characteristic impedance, the importance of proper terminations, line losses, time delay, and velocity factor are also discussed.

"Time and Quantity" . . . A 27-minute black and white film in sound. Discusses the measurement of time and quantity from billions of years to billionths of a second. Shows the importance of the oscilloscope as the basic means of making accurate measurements of very small segments of time.

"The Oscilloscope, What It Is—What It Does" . . . A nine-minute color sound film. Presents a non-technical explanation of the oscilloscope and its uses. Stresses the importance of the instrument as a measuring tool in electronic and other fields. Oscilloscopes measure physical data in relation to small amounts of time. They are used in research, engineering, and education, and in production testing and maintenance of electronic computer and communication systems.

"Thevenin's Theorem" . . . A 12-minute black and white sound film. Presents a simplified approach to solving an electronic circuit which would otherwise involve complex mathematics.

"Solving the Unbalanced Bridge . . . A 17-minute black and white sound film. Normally a solution to an unbalanced bridge problem requires considerable mathematics involving three simultaneous equations. This lecture film shows and explains how simply this can be accomplished using Thevenin's Theory and Ohm's law.

"Triode Plate Characteristics . . . A 16-minute black and white sound film. Discusses plate characteristics of a typical triode (6DJ8) showing how the three basic tube characteristics, amplification factor, plate resistance, and transconductance, may be determined from a set of plate curves. It also plots a load line and shows how to determine the gain of a simple amplifier from these curves. In addition a continuous display of the curves of a tube under actual operating conditions is shown on the Type 570 Characteristic Curve Tracer, a special-purpose Tektronix oscilloscope.

"Ceramics and Electronics" . . . A 22-minute color film with sound. Shows the importance of ceramic elements in the electronic industries and stresses the application of ceramic insulating strips and other ceramic parts in oscilloscopes. It also shows the complete manufacturing process, including mixing of clays, firing, and glazing, at Tektronix.

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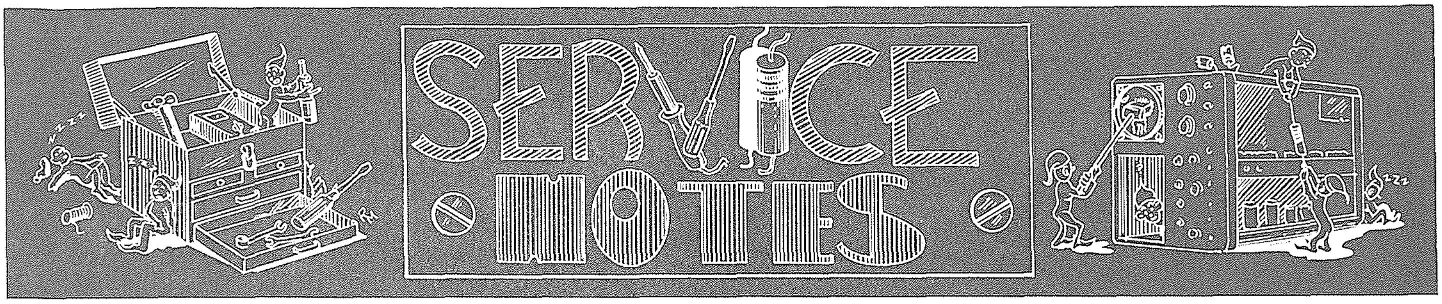
OOPS! WRONG PART NUMBER

In the October, 1965 issue of Service Scope two typographical errors involving part numbers, slipped by your editor. Both errors occurred in the article "Type M Four-Trace Plug-In Unit—Channels A, B, C, and D: Crosstalk". The part number listed as 283-0050-00 should have read 213-0005-00; and the part number listed as 210-0001-00 should have read 210-0201-00.

THE READER'S CORNER

"Current Measurements at Nanosecond Speeds" is the title of an article written by a Tektronix engineer and published in the October, 1965 issue of ELECTRONIC DESIGN NEWS. The article discusses the problems encountered when attempting to measure nanosecond and sub-nanosecond current pulses. It describes the use of a current transformer for accurate current measurements at nanosecond speeds.

Author of the article is Murlan R. Kaufman, Design Engineer with the Digital Instrument group at Tektronix, Inc. Reprints of the article are available. Contact your local Tektronix Field Office, Field Engineer, Field Representative or Distributor.



CRT MESH FILTER AND RFI SHIELD

Tektronix engineers have come up with a new CRT light filter and RFI shield that is unique. This new CRT Mesh Light Filter and RFI Shield is a metal screen of sub-visible mesh with the surface treated for extremely low reflectance. The screen is tautly mounted on a metal frame. This unique filter-shield is a direct replacement for the existing graticule cover on most Tektronix oscilloscopes. Two exceptions are the Type 422 and Type 453 Portable Oscilloscopes. The filter-shield for these instruments snaps into the CRT opening on the front panel.

The purpose of this new mesh filter-shield is to enhance visual CRT trace-to-background contrast and attenuate RFI radiated from the CRT faceplate. It accomplishes these purposes very well indeed. The curtailment of external ambient light reflections is highly efficient. Trace-to-background contrast is enhanced to a point where it provides an ability to view low-intensity traces in normal room light, or even in brighter-light environments. The metal mesh is grounded to the metal frame. Thus, when the filter-shield is in place on the oscilloscope, a ground path from mesh-to-frame-to-oscilloscope effectively carries a large part of the CRT-emitted RFI spectrum to chassis ground. Actual quantitative filtering depends upon the characteristics of the radiation and this varies between instrument types.

Following is a list of instrument types and the part number of the CRT Mesh Light Filter and RFI Shield they use:

TYPE	PART NUMBER
422	378-0571-00
453	378-0573-00
502, 502A, 503, 504, 515, 515A, 516, 517A, 524AD, 661; 530, 540, 550, and 580 Series	378-0572-00
506, 560 Series, 527, RM529, 647	378-0574-00

The CRT Mesh Light Filter and RFI Shields may be ordered through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor.

DUST COVERS FOR OSCILLOSCOPES

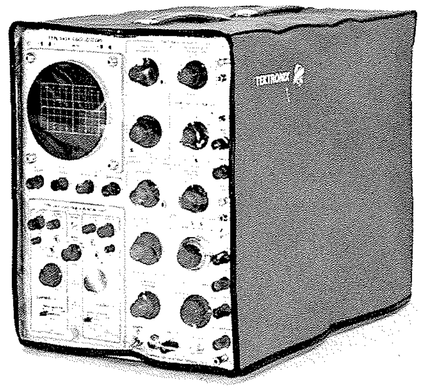


Figure 1. New dust cover for Tektronix oscilloscopes shown on a Type 545B Oscilloscope.

In response to numerous customer requests, we have designed and now have in stock dust covers for some Tektronix oscilloscopes. See Figure 1. The covers are made of blue vinyl material with a taffeta grained matte finish. There are black gimp seams around the bottom, front and back. A clear vinyl front allows easy identification of the oscilloscope and access holes in the top permit the oscilloscope to be moved with the cover in place. The Tektronix "bug" (trademark) and the word Tektronix are silk screened on the sides.

Covers are available for the following instruments:

TYPE	PART NUMBER
647 and 560 Series (except 565 and 567)	016-0067-00
500 Series	016-0068-00
565 and 567	016-0069-00
502 and 502A	016-0070-00
453	016-0074-00
422 (with AC/DC bat. pak.)	016-0075-00
422 (with AC pwr. sup. only)	016-0076-00

Covers may be ordered through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor.

TEST POINTS FOR B PLUS

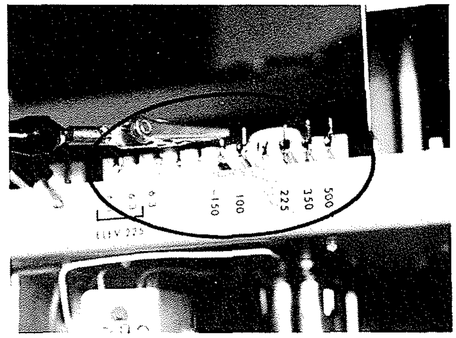


Figure 2. Short pieces of bare wire installed as B-plus test points in the ceramic strips of a Type 545B Oscilloscope.

L. E. Rishel, with the Otis Air Force Base in Massachusetts, has submitted to the Air Force and to Service Scope, a "do-it-yourself" modification that you may want to adopt.

The suggestion involves installing short pieces of bare wire in the ceramic-strip slots in Tektronix instruments at the B plus test points. These wires provide quick and easy attaching points for a voltage-measuring probe tip and are safe even when using the alligator clips often employed with a voltmeter.

We tried the modification on a Type 541A Oscilloscope (See Figure 2). Installation can be accomplished in a matter of minutes and offers no adverse effects on the scope's operation. The wire pieces need not extend more than ¼" above the ceramic strip. Installed thus, they provide an ample length for the voltage-probe tip to grasp, yet are not so long as to offer a hindrance in the normal maintenance and calibration of the oscilloscope.

With the emphasis toward ever more compact instruments, and the close spacing of components that results, we recognize the need for easily accessible test points. Some of our latest instruments have just such test points designed into them. We expect this trend to continue in future instruments.

TYPE 529 WAVEFORM MONITOR—HIGH FREQUENCY RESPONSE

Some Type 529 Waveform Monitors will show a HF (high frequency) response that differs when using the monitor push-pull, from that shown when using it single-ended. A capacitance unbalance between the "A" and "B" inputs most generally causes this unbalance. The unbalance results in a HF roll off of approximately 1.3 dB at 4 MHz. This effect becomes particularly noticeable when using the Type 529 in a balanced mode of operation, with the output terminated with a 110 or 120-ohm resistor—a practice employed by many telephone companies.

The following three-step procedure will correct the unbalance between input "A" and input "B" by balancing the emitter-to-ground capacitance of Q114 (input "A") and Q214 (input "B").

Step 1. From the underside of the Vertical Amplifier and DC Restorer chassis locate R119, a 100-ohm potentiometer that serves as the X5 Mag Gain adjustment. From R119 a bare strap runs to a 2.26 k, ⅛ W, 1% precision resistor in slot 11 of the adjacent ceramic strip. There is also a red and white wire running to another 2.26 k, ⅛ W, 1%, precision resistor in slot 9 of this same ceramic strip. Reverse these two leads at the ceramic strip. This should put the red and white wire at slot 11 and the bare strap at slot 9.

Step 2. Remove C133, a 2.8 pF, ceramic capacitor, located on the upper side of the RESPONSE switch. Re-install it on the VERTICAL MAG switch between the wiper on the last wafer of the switch and ground. Use the switch frame for ground.

Step 3. Adjust C133 for best common-mode rejection. You may need to readjust C269 for HF compensation.

EXTERNAL GRATICULES—RECOMMENDED CLEANING METHOD

We recommend the use of a mild soap, warm water (not hot) and gentle rubbing with a soft cloth for cleaning our external graticules.

We have employed several methods including silk screening, and (only quite recently) hot stamping, to imprint the reticules on external graticules. Accurately ruled reticules composed of sharply defined, consistently thin lines aid greatly in accurately interpreting or measuring the oscilloscope display. From this standpoint, there is little to choose between the silk screening and hot stamping methods. From the standpoint of visibility however, the hot stamped reticule offers a 10-to-1 advantage over reticules imprinted by other methods.

However, both the paint used in silk screening and the ink used in hot stamping the reticules are soluble in Anstac and other solvents. *Their use as a cleansing agent will remove the reticule from the graticule!* To be on the safe side, clean all graticules with a mild soap and warm water applied with a soft cloth and light rubbing action.

P6015 HIGH-VOLTAGE PROBE — REPLACEMENT OF DIELECTRIC

Only fluorocarbon 114 should be used when replacing the dielectric in a P6015 High-Voltage Probe. This gas is sold under several trade names all of which include the number 114. This number identifies the gas with the proper characteristics for use in the P6015 Probe. We supply a small can of fluorocarbon 114 with each P6015 Probe and stock additional cans for our customers' convenience. Tektronix Part Number is 252-0120-00.

The use of fluorocarbons other than 114 can involve a hazard. Some fluorocarbons are contained under a pressure much higher than that required by fluorocarbon 114. These higher-pressure fluorocarbons can be dangerous during the disassembly of a P6015 Probe. By escaping more violently than expected, they could damage personnel and equipment.

From the standpoint of toxicity, fluorocarbons offer no problem; they are not dangerously toxic.

NEW FIELD MODIFICATION KITS

TYPE 526 VECTORSCOPE — QUIET FAN MOTOR

This modification installs a lower rpm fan motor assembly for a reduction of the audible noise experienced from the original fan motor assembly. The new assembly is a direct replacement except for the addition of a motor capacitor which requires the drilling of two 5/32" holes in the rear panel of the Type 526. This modification is applicable to Type 526 Vectorscopes, sn's 101-909.

Order from your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix Part Number 040-0412-00.

TYPE RM16 OSCILLOSCOPE — SILICON RECTIFIERS

This modification replaces the selenium rectifiers with silicon rectifiers which offer greater reliability and longer life. It is applicable to Type RM16 Oscilloscopes, sn's 101-363. Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix Part Number 040-0216-00.

TYPE 262 PROGRAMMER — AUTOMATIC SEQUENCER

This modification supplies an Automatic Sequencer for the Type 262 that will scan up to eight programs. The Sequencer consists of two etched circuits (a synchronizer circuit and a counter circuit) each mounted in its own plug-in circuit card. Installation is simple because the Type 262 Programmer was designed with the automatic sequencer feature in mind and provisions made for its addition later. To install the modification, you need only to plug the circuit cards into their respective plug-in receptacles in the Type 262.

Front panel switches, in conjunction with the Automatic Sequencer, allow for interrupting the automatic sequence in accordance with pre-established upper and lower limits. Any combination of upper, middle or lower limits may be used.

The Automatic Sequencer can be synchronized with data recording devices such as printers or card punchers or with various test fixtures.

Both manual push button and external control are retained with the Automatic Sequencer installed.

A maximum of three Type 262 Programmers in series will handle a total of 24 different measurement programs. With an Automatic Sequencer Modification Kit installed in each programmer the entire 24 measurement programs can be automatically scanned. The measurement rate can be synchronized with auxiliary equipment or determined by the Type 567 and Type 262.

In the synchronized mode of operation, the sum of the Type 6R1 display time and the Type 262 display time determines the measurement rate—up to eight measurements per second can be made in this mode.

In the triggered mode of operation, upon completion of a measurement the display is held until an external completion pulse is received. Up to six measurements per second can be made in this mode.

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TYPE 180 TIME MARK GENERATOR AND TYPE 536 OSCILLOSCOPE — SILICON RECTIFIERS

Two Field Modification Kits, one for each of the above instruments, replace silenium rectifiers with silicon rectifiers. The silicon rectifiers offer greater stability and longer life.

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180A	040-0214-00
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TEKTRONIX TECHNICAL TERMINOLOGY

A handy guide to the electronic jargon used by Tektronix-oriented people.

Generally, in learning a foreign language, one is exposed primarily to the formal mode of that language. He will probably become quite adept at reading, speaking and writing the language in this form. However, when he encounters the language in its informal mode, the colloquialisms, slang expressions and trade jargon will almost surely puzzle and confuse him. Very probably, we in the United States are more prone to indulge in the vernacular than others.

Since Service Scope travels to our friends overseas, we do try to present its articles in the formal mode of our language. We do endeavor not to employ technical jargon and slang expressions. However, many of our overseas readers have expressed an amused (and perhaps confused) interest in these terms and expressions. For their benefit, we present here a few of these expressions and their interpretations.

AB, n. or a., Carbon composition resistor (from AB, trademark of Allen-Bradley Co.).

B.A., n. or a., Blanking Amplifier.

Bloom, v.i., To increase in size. The CRT display will bloom when high voltage supplies go out of regulation, reducing high voltage and increasing deflection sensitivity.

B.O., n. or a., Blocking Oscillator.

Bounce, n., Scattering of electrons that strike deflection structures in the CRT, producing **flare** (q.v.).

Blow-by, n., Capacitive coupling through an "off" diode gate.

Breathe, v.i., to vary slightly in level at a very slow rhythmic rate.

Bump, n., a short duration, small-amplitude aberration in transient response, somewhat wider (in time domain) than a wrinkle or glitch (q.v.).
Anticipation Bump, see preshoot.
Termination Bump, aberration due to a slight mismatch in a reverse- (source-) terminated delay line, appearing in time relatively long after the leading edge of a step function.

Cap, n. or a., Capacitor.

C.F., n. or a., Cathode-Follower.

Cathode Interface, n. a tube defect, specif., development of an insulating layer between the cathode sleeve metal and the emissive coating in a vacuum tube (incl CRT), resulting in an effective RC network in series with (part of) the cathode. Electrical effect is normal gain at very high frequencies, but lower gain at low frequencies. Time constants are in the ns-μs area, and are considerably affected by cathode temperature.

Cream, v.t., To ruin or destroy absolutely (by extension from pulverize).

Crunch, v.i., To saturate.
v.t., To drive into saturation, or to destroy.

D.A., n. or a., Distributed Amplifier.

Dag., n., Conductive coating, usually of carbon, applied to the inner walls of a CRT to maintain a large equipotential area; also used to form a helical resistor around the inner walls of a CRT to maintain a specific post-acceleration voltage gradient. From aquadag, a water suspension of carbon particles.

D.C. Shift, n., Shift of DC level following a step-function, over a few seconds or tenths. Similar to Dribble-up, but in a much longer time-domain.

Dogbone, n. or a., Ceramic tubular capacitor with radial leads.

Dot, n., A single sample presented on screen in pulse-sampling. **Dot Transient Response**, transient response independence from number of samples per display (sampling).

Dribble-up, n., Disproportionately long 50-100% or 90-100% response in relation to 10-50% or 10-90% risetime; usually with reference to the nanosecond time domain. Essentially similar to "DC Shift".

E.F., n. or a., Emitter-follower.

Eyeball, v.t., Originally, to avoid parallax error in oscilloscope measurements by lining up the reflection of the pupil of the eye with a graticule line and the trace. Now, to scrutinize in general.

Flare, n., Scattering of electrons in the CRT resulting in hazy light areas on the screen. Usually caused by bounce (q.v.) or secondary emission in the CRT. **Dag Flare**, Flare resulting from the beam striking the walls of the CRT. (See Dag).

Garbage, n. Large amplitude noise, commonly low-frequency noise, as contrasted with "Grass" (broadband noise).

Glitch, n., A waveform aberration consisting of a step or transient pulse in some portion of a CRT display which would be otherwise a smooth curve or straight line. A train of two or three small glitches might be referred to as a **wrinkle** (q.v.); a glitch of relatively long duration or smooth symmetry might be called a bump (q.v.). A glitch immediately (before or after) associated with the leading edge of a pulse usually carries its own terminology—e.g., pre-shoot, overshoot, hook, etc.

Grass, n., Baseline noise (broadband). CF "Garbage".

Gun, n., Electron gun. That portion of a CRT which generates and focuses the electron beam. The term does not usually include the deflection structure. **Gun voltage** refers, however, to the voltage from the CRT cathode to the average deflection-plate voltage.

Hook, n., A time constant (stray C or dielectric losses) in a compensated divider unrelated to the nominal component values. (From the effect on the display of a step function passed through such a divider.)

Hooky, a., Exhibiting or having a tendency to exhibit a hook (q.v.), especially of dielectric materials.

Interface, n., (1) The (electrical) boundary between two pieces of related or relate-able equipment. The conditions at the interface (typically an output-input relationship) determine electrical compatibility. The interface conditions between plug-in and main frame in an oscilloscope are usually standardized for interchangeability; i.e., voltage, current, and signal levels at this point are made to fall within specified limits. In computer usage, **interface equipment** is that which acts as a transducer between electronic and electromechanical, parallel and serial, or machine and human communications systems.
(2) Cathode Interface (q.v.).

Kluge, n., A lashup, a hastily or awkwardly constructed assembly.

Kluge, v.i., To collapse or fail utterly, usually violently.

Kluge, v.t., To shut down (permanently), smash or destroy.

Miller, n., A Miller integrator (sawtooth generator).

Mono., n., A monoaccelerator CRT.

Monoaccelerator, a. or n., (A CRT) having a single accelerating field, with no further acceleration of the electron beam between the deflection structure and the screen.

Multi, n., Multivibrator. Pronounced "Mul'-tee".

P.D.A., n. or a., Post-deflection accelerator (post deflection anode), or a CRT equipped with an accelerating field on the screen side of the deflection plates. Some manufacturers call this element the **"Ultor"**. **PDA ratio:** Ratio of the gun (cathode-to-deflection-plates) to post accelerator (deflection-plate-to-screen) voltages in a CRT.

Post, n., A post-deflection accelerator, or a tube equipped with such an accelerator. "10 kV on the post" means a 10 kV potential applied to this element. Distinguished from **mono-accelerator** CRT design.

Preshoot or Prepulse, n., A small negative excursion immediately preceding (the display of) a positive-going pulse, or vice versa.

Puff, n. or a., Picofarad (pF).

Puffer, n., A small capacitor, the value of which is indicated in picofarads. **One-puffer.**

Schmitt, n. or a., Schmitt (cathode-coupled) multivibrator ("Schmitt Trigger").

Slash, v.i., To produce a streak (usually vertical) instead of a dot (q.v.) on the CRT for each sample (sampling oscilloscopes).

Slash, n., A vertically elongated dot produced by spot motion during unblanking in pulse-sampling instruments.

Spudger, n., Fully insulated tool for dressing leads or components.

T.D., n. or a., Tunnel diode (Esaki diode).

Tweak, v.t., To adjust (an inductor, capacitor or internal calibration control) very slightly.

Tweaker, n., Tool for tweaking (usually one which fits only certain components).

Tweak up, v.t., To bring into proper adjustment by tweaking.

V.A., n. or a., Vertical Amplifier.

Wrinkle, n., A short-duration, small-amplitude aberration in transient response; usually a small echo in a delay line.

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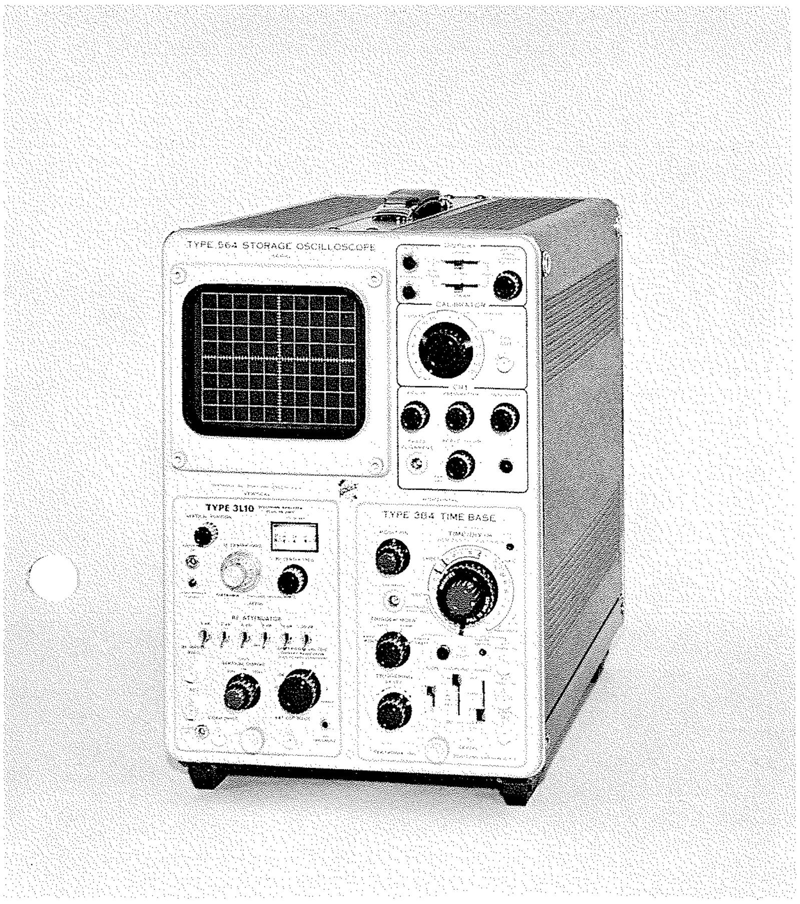
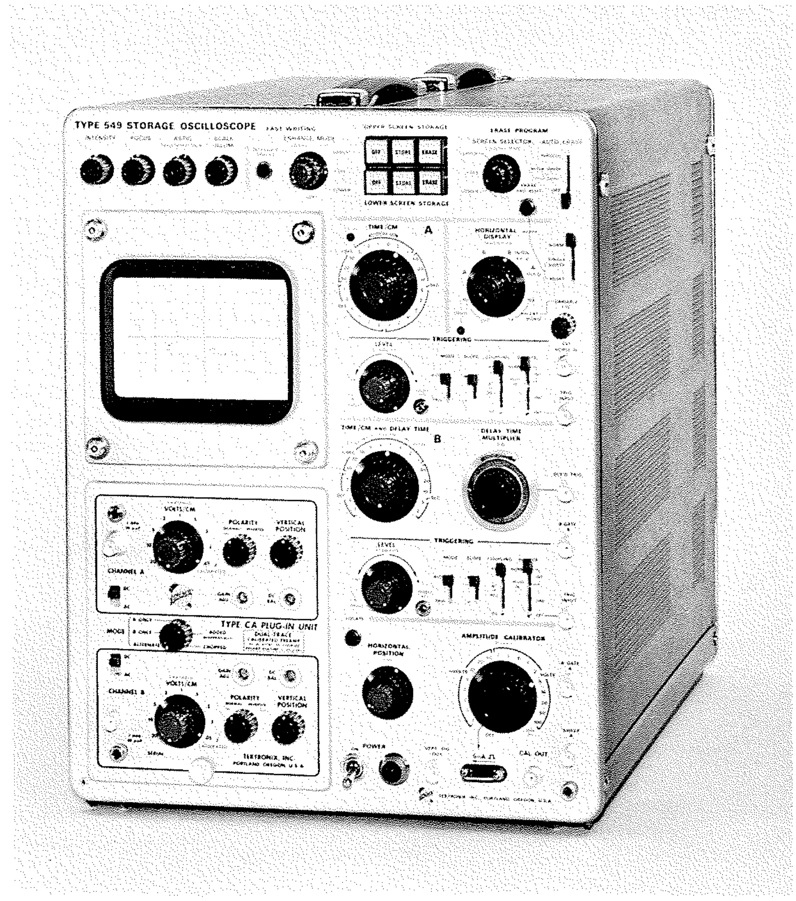
NUMBER 37 PRINTED IN U.S.A APRIL 1966





THE STORAGE OSCILLOSCOPE; WHY AND WHERE

by Geoffrey A. Gass
Tektronix, Inc.

A perhaps over simplified definition of a Storage Oscilloscope is: "A versatile instrument combining the advantages of a high speed storage system and a conventional laboratory oscilloscope."

Here are six specific applications in three general application areas where the storage oscilloscope out-performs the conventional oscilloscope.

One of the desirable and potentially more useful features of a general purpose conventional oscilloscope is its ability to display, however momentarily, erratic events. Unfortunately, the conventional oscilloscope cannot always present these events in a conveniently-observed manner. To conveniently display information for visual observation, measurement, and analysis, the conventional oscilloscope requires events that recur in identical form many times per second. Given these conditions, the display will be a bright and steady trace. Erratic events are not always so accommodating so as to repeat themselves indefinitely and allow the observer to revise or complete his estimates.

So in a conventional oscilloscope, the ability to display erratic events and the ability to present them in a conveniently observed manner are not always compatible.

A principal purpose for a high-speed storage system in a general-purpose oscilloscope, then, is to bring display convenience into greater agreement with display capabilities, preserving the unexpected waveform for as long as may be required to note down its significant characteristics and dimensions—or long enough to find a camera, requisition some film, and make a permanent photographic record.

For the most part, the purposes of a storage oscilloscope can be served by a conventional oscilloscope, a camera, and film—lots of film. The usefulness of a storage oscilloscope, then, is primarily one of degree rather than one of kind; one of convenience rather than one of unique capability. Even so, anyone who has attempted to photo-record carefully-prepared multiple-exposure of an elaborate series of waveforms, only to find that he'd already used the last exposure on his roll of film, needs no reminder that even a small improvement in the degree of assurance that critical data to be recorded *has* been recorded can be of considerable value.

In the notes below, we have outlined some of the ways in which the storage feature can be put to work in obtaining more useful and convenient oscilloscope displays for viewing or for simplified waveform photography.

GENERAL APPLICATION AREAS

The three primary uses for storage in a general-purpose oscilloscope are:

(1) To retain waveforms of single events which cannot be repeated—or which, if repeated, may change significantly with each repetition.

(2) To allow direct comparison by simultaneous display of events happening at different times, or of related repetitive events observed at various different points in a system or by means of different transducers.

(3) To retain information from very slow-moving traces—such as those from low repetition-rate sampling systems or high-resolution spectrum analyzers—until the entire display may be observed.

SPECIFIC APPLICATION AREAS

Nonrepetitive Events

Recording of random transients is the most familiar application in this area, since the storage oscilloscope may be left unattended for extended periods waiting to be triggered from an intermittent or random event. Within this category of applications are also destructive testing or testing to near yield-limits where repeated testing may change the characteristics of the device under test, and measurements of phenomena where a number of "mis-fires" may be expected before a satisfactory (e.g., worst-case) waveform may be obtained. Much testing in the mechanical and electromechanical fields falls into the non-repetitive area.

1. *Transistor Beta Characteristic Above Power Rating*

Using an operational amplifier to differentiate the collector output waveform of a grounded-emitter transistor driven by a linear ramp of current provides an output voltage proportional to the low-frequency AC beta of the transistor for a given collector load resistor. Plotting dV_c/dt against V_c gives a continuous plot of beta variation along the given load-line from cutoff to saturation if a sufficiently large base-current ramp is available[1]. Plotting dV_c/dt against I_b gives a direct indication of large-signal output linearity over the range encompassed by the current ramp.

Combining this measurement technique with the capability of completing and preserving a useful display in less than a millisecond on a storage oscilloscope permits convenient determination of characteristics at many times the nominal maximum steady-state collector-dissipation rating of the transistor, and without significant shifts in beta due to large changes in junction temperature.

A simple circuit configuration providing a linear base-current ramp of up to 5 mA peak for NPN transistors is shown in Fig. 1. For low-beta or high-power tran-

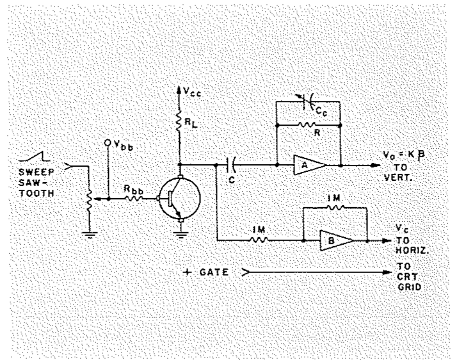


Fig. 1. Test circuit for plotting β vs I_c, V_c for NPN transistor. Differentiation V_c when I_b is a linear ramp produces a voltage proportional to β. Capacitor C_c ($\simeq 0.01$ C) corrects for overshoot in differentiator.

sistors, a power amplifier or external ramp source is required to obtain the necessary linearity; for PNP types, an inverting amplifier with output voltage swing capabilities V_{eb} must be used to provide the base-drive current ramp.

Direct calibration of the oscilloscope vertical amplifier in terms of beta per centimeter is as follows:

$$\beta/\text{cm} = \frac{(\text{Volts/cm})\ (R_{bb})}{(R_L)\ (R_f C_i)\ (\text{Ramp } dV/dt)}$$

R_{bb} is the constant-current series resistor in the base drive circuit. Ramp dV/dt may be measured at the V_{bb} test point using the internal time-base display. R_L is the collector load resistance, and R_f and C_i are the differentiating components of the operational amplifier. A quick check of calibration may be obtained by removing the transistor and shorting together the base and collector terminals of the socket. A beta of −1 should be indicated in the display.

Figure 2 shows beta variation of a Type 2N1308 150 mW germanium transistor for a 50-Ω load line and a V_{cc} of 20 V. Peak dissipation is 2 W at I_c 200 mV, V_c 10 V.

Using this circuit, families of curves for a given transistor may be displayed on the storage oscilloscope for (a) various collector load values (changing V/cm or R_f with R_L to hold the β/cm value constant), (b) various V_{cc} values, or (c) various temperature values, using external heating and monitoring equipment and triggering a single display as the temperature passes through each desired point. This type of application properly belongs to the second category below, direct comparison of events happening at different times. A waveform photograph illustrating (b) is shown in application 4.

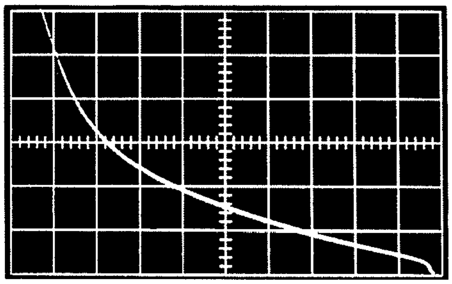


Fig. 2. Plot of β for 2N1308 transistor versus V_c, I_c for V_{cc} = 20 V, R_L = 50 Ω, V_{bb} 0 — 120 V, R_{bb} 24 k. Vertical calibration (β) 100/cm; horizontal, 2 V/cm, 40 mA/cm. Peak β of >600 is close to avalanche region for transistor. (Type 549 Oscilloscope, Type O Plug-In.)

2. *Transformer Inrush Current and Effects on Switches*

A major cause of AC power-switch failures in transformer-powered equipment is the so-called inrush current occurring during turn-on. A combination of four conditions establishes the magnitude of peak inrush current for a given turn-on: (a) the hysteresis of the transformer core material, (b) the phase angle of the AC power source at the instant of last turn-off, (c) the phase angle of the power source at the instant of turn-on and (d) the impedance of the input power loop, including the DC resistance of the transformer primary. In the worst case, inrush current amounts to essentially the peak power-line voltage divided by the DC resistance of the transformer primary circuit.

Where inrush currents alone are to be routinely measured, test-sets employing silicon controlled rectifiers and power diodes provide a means of providing a worst-case condition for each turn-on.

Where the frequency of usage does not justify specialized test equipment, or where the effects of inrush currents on the switch itself during the closure process are to be evaluated, the storage oscilloscope (with a suitable differential input amplifier and probe arrangement) permits observation of hundreds of turn-ons with minimum inconvenience or film waste, but with full assurance that permanent records may be kept of any turn-on waveform containing information of value.

Figures 3 and 4 show the test circuit for measurement of inrush current, and a typical waveform obtained by these means. A current transformer used instead of probes and a resistive shunt would allow use of a single-ended oscilloscope input. But the low-frequency response requirements to reproduce accurately the current waveforms of a transformer in a typical capacitor-input semiconductor power supply—for example—having a very small conducting angle and virtually no load for a large part of the cycle, are sometimes difficult to achieve and verify in a current transformer that will also give adequate indication of momentary peak currents in the 50 to 100 ampere region.

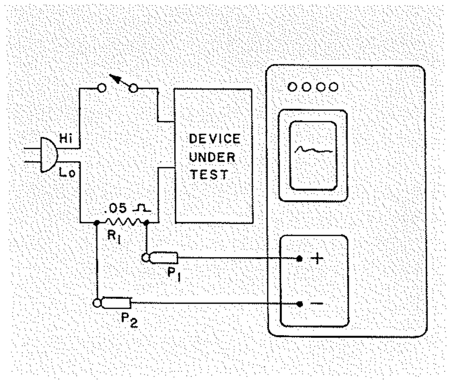


Fig. 3. Observation of inrush current using high-speed storage oscilloscope with differential input and differential probes. R_1, P_1, P_2 may be replaced with suitable wideband current transformer.

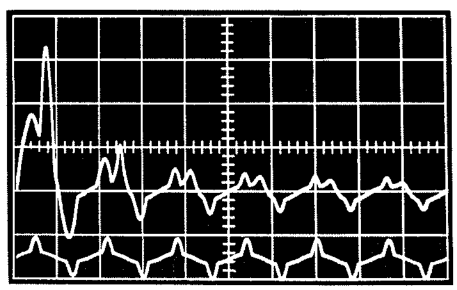


Fig. 4. Inrush current in nominal 120 V, 240 W system (upper trace) compared with current waveform after warmup. Vertical: 10 A/cm; Horizontal, 10 ms/cm. (Type 549 Oscilloscope, Type W Preamplifier.)

Figures 5 and 6 show the test circuit and typical results in measuring the potential drop across a switch in the process of closing a 60-Hz transformer primary circuit.

The display is obtained by triggering the oscilloscope from the inrush current signal. Good overload recovery characteristics in the input amplifier are essential for this measurement, as the full line voltage is impressed across the probes until the switch has closed.

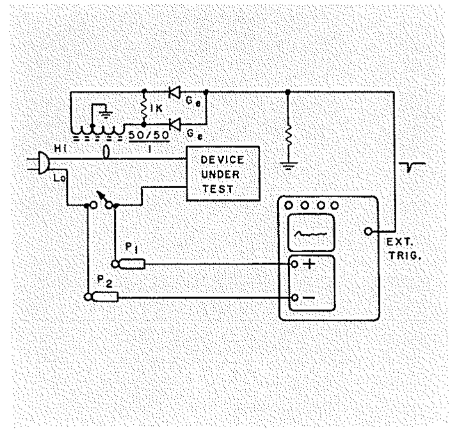


Fig. 5. Observation of switch closure characteristic during inrush. Current transformer 1:50:50 provides trigger for either polarity inrush. Switching "low" side of line makes amplifier requirements less critical.

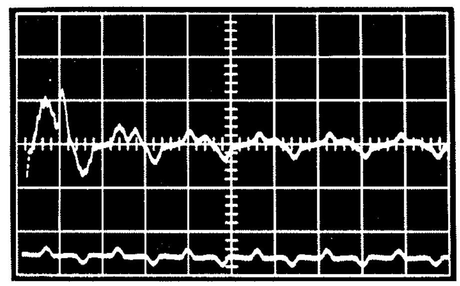


Fig. 6. Potential across switch contacts during inrush (upper trace) and after warmup. Vertical, 200 mV/cm; horizontal, 10 ms/cm. (Type 549 Oscilloscope, Type W Preamplifier.)

Direct Comparison of Events Happening at Different Times

Multiple-beam and multiple-trace oscilloscopes are designed to facilitate the direct comparison of events happening at the same, or very nearly the same time. The storage oscilloscope extends this capability to events happening at quite different times or at test points that are not conveniently close together.

3. *Speech Therapy for the Deaf*

A microphone, a storage oscilloscope, and suitable filters emphasizing the significant parts of word and syllable waveforms allow the student to practice vowels, syllables or words, with direct visual comparison of the subtle harmonic phase shifts which convey speech intelligence, against his instructor's standard waveform stored on the screen. The split storage target permits continuous trial-and-error operation on one half of the screen without losing the reference waveform on the other.

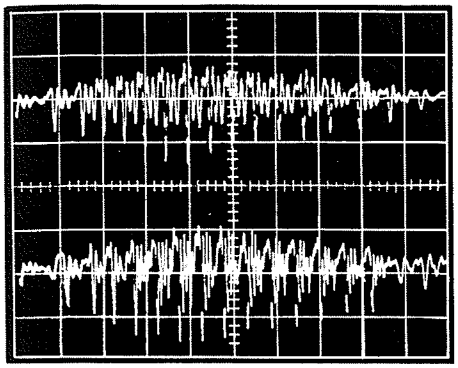


Fig. 7. Stored single-sweep waveforms of speech sounds aid in speech therapy. Upper trace: the word "reed". Lower trace: the word "red". Release of the "d" sound is offscreen to the right. Waveforms are somewhat distorted due to poor room acoustics. Sweep, 30 ms/cm. (Type 564 storage oscilloscope, Type 3A3 vertical amplifier set for 5 kHz bandwidth.)

In Figure 7, waveforms representing the pronunciation of the words "reed" and "red" are compared, using a 5-kHz bandpass filter. More elaborate normalizing systems may be employed in actual therapy work.

4. *Comparing the Effects of Circuit Adjustments*

A record of the effects of a series of adjustments or substitutions is often of value in circuit or component work. An illustration (Fig. 8) is the effect of changing collector supply voltage V_{cc} in application 1, showing the beta range for a given collector load resistance for four values of V_{cc}.

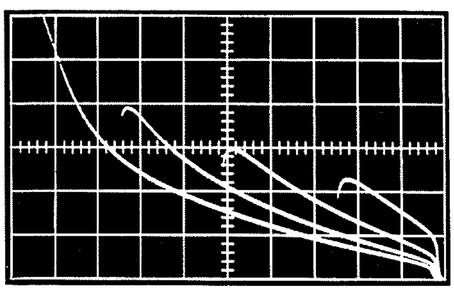


Fig. 8. Comparison of waveforms under variant operating conditions. Type 2N1308 transistor beta vs V_c, I_c as in Figs. 1 and 2, but V_{cc} of 20, 15, 10 and 5 V. Vertical calibration (β), 100/cm.

Preservation of Complete Slow Displays

The problem of retrieving data from oscilloscope displays of slow-rate information can result in loss of information either because the beginning of the slow trace is forgotten when the display is finished, or the display is deliberately completed at a faster than optimum rate, resulting in loss of information in the display itself.

5. *Sampling System at Low Signal Repetition Rates*

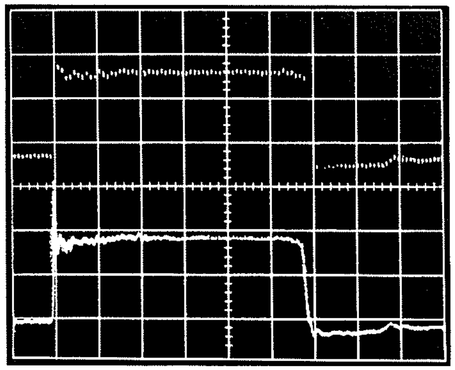


Fig. 9. Use of storage oscilloscope and manual scan feature of sampling system to obtain optimized dot density where needed. Upper trace, 10 dots/cm. Lower trace, manual scan. Fill-in required about 10 seconds with 100 Hz sampling rate, but provided same detail as $>$1000 dots/cm requiring $>$1.5 minute sweep. (Type 564 oscilloscope, Type 3T77 time base.)

The upper trace of Fig. 9 illustrates a case of possible information loss when a sampling oscilloscope dot density setting is insufficient to resolve all the significant data. In this particular case, the signal repetition rate was 100 Hz, completing the display shown (100 samples) in 1 second, but with a serious loss of information in the leading edge which occurred "between dots", so to speak. The alternative of increasing dot density to 1000 dots/cm to obtain the necessary resolution would have required over 1.5 minutes to complete the display.

The problem was solved in the lower trace by storing the low dot-density trace, and then using the manual scan of the sampling system to increase dot density only at the points where needed, completing the display in minimum time, and revealing the 70% overshoot which was hidden in the first trace. Whether with manual scan or internally-controlled high dot-density, the storage oscilloscope facilitates retrieval of high-resolution waveform information even from very slow-repetition-rate events from sampling systems.

6. *High Resolution Displays from Spectrum Analyzers*

The maximum sensitivity and resolution of a spectrum analyzer are achieved only when the dispersion (frequency sweep) df/dt is made to be very small. For normal viewing, in order to obtain a useful repetitive display, it's usually necessary either to confine the dispersion to a very narrow value, or keep the resolution low in order to maintain reasonable sensitivity and a usable display repetition rate.

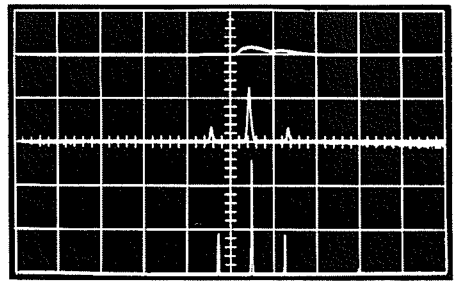


Fig. 10. Effects of df/dt on high-resolution spectrum analysis. Dispersion of 10 kHz, resolution 1 kHz. Sweep rates are: Upper trace, 20 ms/cm (50 kHz/s); middle trace, 200 ms/cm (5 kHz/s); lower trace, 2 s/cm (500 Hz/s). Signal is second harmonic of 5 MHz carrier modulated by 1 kHz squarewave (Type 549 Oscilloscope, Type L10A/1L10 Plug-In Spectrum Analyzer).

Figure 10 illustrates the effect of df/dt sweep rate on sensitivity and resolution in a representative spectrum analyzer application. Observing the second harmonic of a 5-MHz carrier modulated by a 1-kHz squarewave, a sweep of 10 kHz in 200 ms with a nominal 1-kHz resolution (top trace) produces only a hint of the signal and possible sidebands. Holding the same dispersion and resolution but reducing the sweep rate to 200 ms/cm (5 kHz/s) begins to reveal the true nature of the signal. In the bottom trace, reducing the sweep to 500 Hz/s provides sufficient resolution to identify the modulating signal as a squarewave. Time required to complete this 10 kHz sweep was 20 s. The advantage of the storage tube in preserving the entire display becomes evident.

SUMMARY

Applications making best use of the capabilities of a storage oscilloscope are those involving (a) non-recurrent waveforms, (b) comparison of waveforms of non-simultaneous events and (c) displays requiring several seconds for completion. Within the writing speed limitations of the instrument used, the storage feature may be used as a substitute for, or as an aid to, oscilloscope photography. Representative applications in these areas are: plotting transistor beta above nominal power rating; measurement of transformer inrush current and its effect on power switches; comparison of human speech waveforms; and improving resolution of sampling oscilloscope and spectrum analyzer displays.

Photographic Note: Waveform photographs reproduced here were taken with Polaroid® No. 47 film, using an exposure of 1/5 s at f/5.6, except Figs. 7 and 9, which were taken at 1/2 s, f/11.

[1]John V. McMillin, "Simple Curve-Tracer Displays Transistor Beta" *Electronics*, August 24, 1962.

TYPE 564 STORAGE OSCILLOSCOPES — REMOTE ERASE FEATURE

This modification provides an external Remote-Erase feature for the Type 564 Storage Oscilloscope.

It installs a circuit assembly which contains two monostable multivibrators—one for the Upper display area and one for the Lower display area. When activated from either the front panel Erase controls or the Remote-Source Erase controls these multis erase their respective display areas. The Remote-Source Erase control can be any switch contact that can short a wire from the Type 564 to ground or any equipment that can provide a negative-going 5-to-10 volt pulse for the multi of each display area.

The external connections are brought out to a four-contact connector on the rear of the Type 564 and a mating connector is included to permit attachment of the Remote-Erase control.

This modification applies to Type 564 Storage Oscilloscopes, all serial numbers. Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-0352-01.

P510 CATHODE-FOLLOWER PROBE —PROBE REPAIR KIT

This modification kit contains the parts necessary to repair several P510A Cathode-Follower Probes. The instructions are divided into sections, so that any individual portion of the probe can be repaired.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0287-01.

TYPE 531, TYPE 535, TYPE 541 AND TYPE 545 OSCILLOSCOPES—CHOPPING-TRANSIENT BLANKING

Installation of this modification supplies a means of applying a blanking voltage, to the cathode of the oscilloscope CRT, to eliminate switching transients from the display. These transients will occur when a multiple-trace plug-in unit—installed in the oscilloscope—is operated in its chopped mode. The blanking voltage is applied by activating a switch installed on the rear panel of the oscilloscope.

The modification involves the changing of V78 tube socket to a 9-pin type and adding a CRT CATHODE SELECTOR switch to the rear panel. Also, V78, a 6AU6 vacuum tube, operating as a Multi-Trace Unit's Sync Amplifier in the oscilloscope, is changed to a 6DJ8. One half of the 6DJ8 is used as the Sync Amplifier and the other half is used to generate the blanking voltage.

This information applies to Type 531, Type 535, Type 541, and Type 545 Oscilloscopes, serial numbers 101 to 20,000 and to all Rack Mount instruments in these types with serial numbers 101 to 1000.

Order from your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0403-00.

TYPE 532 AND TYPE RM32 OSCILLOSCOPES—SWEEP LOCKOUT

Your Type 532 or Type RM32 Oscilloscope can be modified for the study of one-shot phenomena by installation of this kit.

The Sweep Lockout feature permits you to "arm" the sweep to fire on the next trigger to arrive. After firing once the sweep is locked out and cannot fire again until rearmed by pressing the RESET button. All original features of the instrument are retained.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0147-00.

TYPE 453 OSCILLOSCOPE—PORTABLE-TO-RACKMOUNT CONVERSION

This modification supplies the necessary mechanical components and hardware to securely rackmount the Type 453 Portable Oscilloscope.

A special feature of this kit is the Rackmount Rear Support assembly. A Type 453 correctly installed as a rackmount and using the Rear Support assembly will successfully withstand an environmental shock of 30 G's or vibration of 4 G's. This can be an important consideration for Type 453's installed in mobile or shipboard units and in aircraft.

A frame, assembled from components and hardware in the modification kit, allows the oscilloscope to be mounted in a standard 19" open or closed relay rack, or slide out tracks.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0420-00.

TYPE 526 VECTORSCOPE — QUIET FAN MOTOR

This modification installs a lower r/min fan motor assembly to reduce the audio noise-level of the fan motor assembly. The new fan motor assembly is a direct replacement except for the addition of a motor capacitor, which requires the drilling of two 5/36 inch holes in the rear panel of the Type 526.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0412-00.

OSCILLOSCOPE CRADLE MOUNT

This modification enables the Tektronix Oscilloscopes listed below to be rack-mounted in a standard 19" relay rack. Required vertical front-panel space is 17½ inches.

The modification is applicable to the following oscilloscopes: Types 524AD, 531, 532, 541, 545, and 570, serial numbers 5001 and up; also, Types 531A, 533, 533A, 535A, 536, 541A, 543, 543A, 543B, 544, 545A, 545B, 546, 547, 575, 581, 581A, 585, 585A, and 661, all serial numbers.

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DC FAN MOTOR FOR LISTED OSCILLOSCOPES

This modification enables the oscilloscopes listed below to operate on 50- to 400-cycle power lines. It installs a DC fan motor, a thermal time-delay relay, and a DC power supply relay.

The modification is applicable to the following instruments:

TYPE	SERIAL NUMBER
531A	20001-22073
535A	20001-24349
541A	20001-21454
545A	20001-27729
RM31A	1001-1579
RM35A	1001-1850
RM41A	1001-1189
RM45A	1001-1892

(Please note: If your instrument has the DC Relay Modification Kit 040-258 installed, use Field Modification Kit 040-0233-00.)

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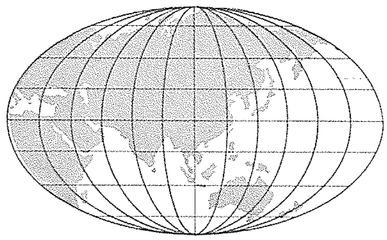

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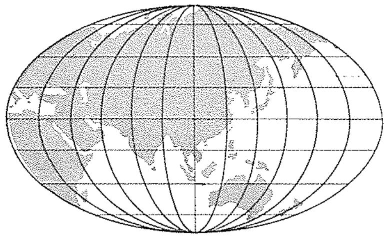

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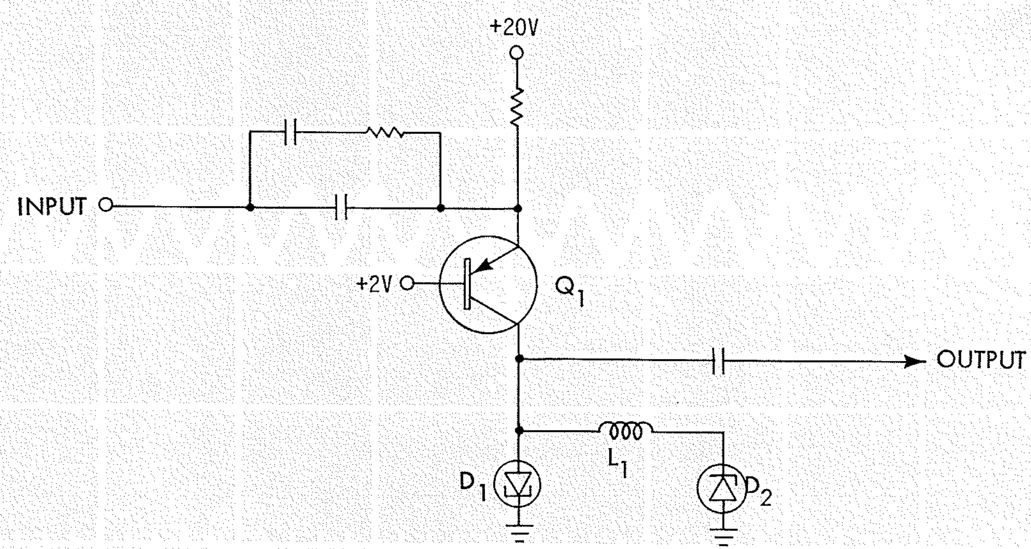


TUNNEL DIODE SWITCHING CIRCUITS AND THE BACK DIODE

By The Marketing Technical Training Department
Tektronix, Inc.

The concepts discussed in this article should lead to a better understanding of tunnel-diode switching circuits. It discusses in particular, the effect of a rather new component on tunnel-diode switching circuits—the back diode.

Several Tektronix sampling instruments incorporate the tunnel diode-back diode concept in their trigger recognition circuitry. Examples of these instruments are: the Type 3T4 Programmable Sampling Unit, Type 3T77 and Type 3T77A Sampling Time Base Plug-In Units, Type 1S1 Sampling Unit, Type 1S2 Reflectometer and Sampling Unit, and Type 5T1A and Type 5T3 Time Base Plug-In Units.

INTRODUCTION

Part I

Tunnel-diode switching circuits are widely used today in a variety of measuring and signal-generating equipment. For example: Tunnel-diode circuits are used for trigger recognition in sampling oscilloscopes, and wide-band conventional oscilloscopes, for gating sweep circuits and for generating fast-rise pulses. Some desirable features of tunnel-diode switching circuits are:

1. Fast switching speed.
2. Maximum obtainable pulse amplitude.
3. High sensitivity to triggering signals over a wide frequency range.
4. Low "idle" power dissipation.

Tunnel-diode circuit elements are combined to fulfill the above needs. One of these elements, the BACK DIODE, is responsible for improved performance in the areas of switching speed, sensitivity, and "idle" power dissipation.

This article is concerned with the theory, function and application of the back diode, in relation to tunnel-diode switching circuits. The first half of this article develops the need for such a device; the second half examines back-diode theory and discusses the function and applications of this unique diode to tunnel-diode switching circuits.

TYPICAL SAMPLING TRIGGER CIRCUIT

A basic sampling trigger circuit is shown in *Figure 1.* Q_1 is used to provide isolation between input and output. The back diode (D_2), tunnel diode (D_1), and inductance (L_1) form a one-shot multivibrator for trigger recognition. Synchronization on input signals is achieved by free-running this multivibrator.

The following discussion will develop this circuit and its related components. The emphasis will be on the function and operation of the back diode as a circuit element.

In order to understand the operation of the back diode, let us consider a few basic circuits. *Figure 2* shows a basic tunnel-diode (TD) switch.

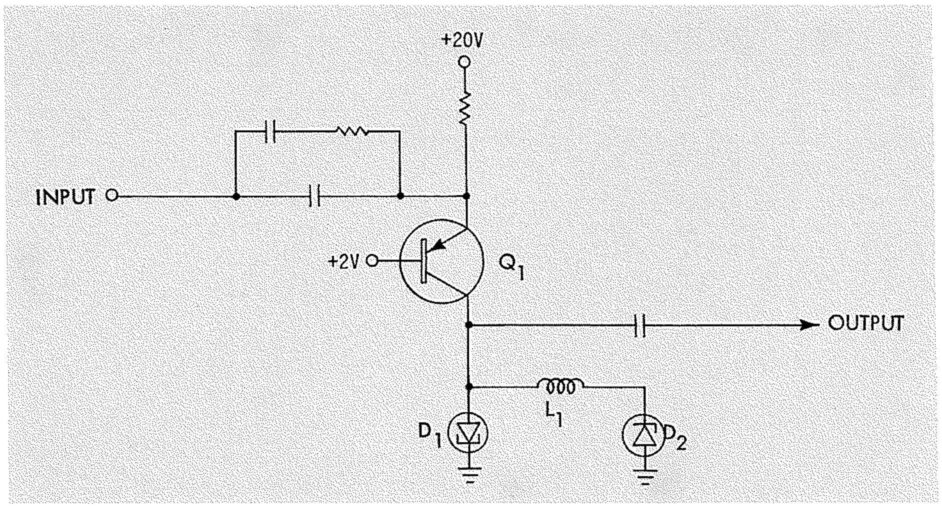


Figure 1 Typical Sampling Trigger Circuit.

BISTABLE OPERATION

A 20-V supply and a resistance, R_1, of 2.5 kΩ biases the TD at 8 mA. The DC load line is the solid line in Figure 2B. If the TD is in the low-voltage state, a 2-mA signal will cause the load line to move up toward the peak current point of the TD (dashed, or AC, load line in Figure 2B). The voltage across the TD increases along the slope of the TD curve at point "a". When the TD current reaches 10 mA (I_p), the voltage drop across the TD jumps almost instantly to the voltage at point "b". When the 2-mA signal is completed, the *load line* returns to its original mA position on the TD curve (point "c"). Notice that the *TD* does not return to the low-voltage state.

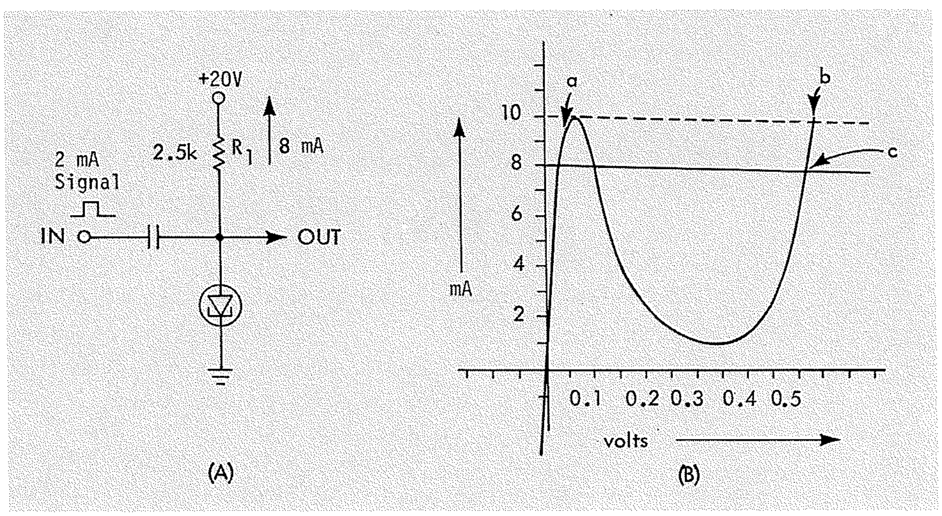


Figure 2 (A) Basic tunnel-diode switch circuit for bi-stable operation.
(B) AC and DC load lines superimposed on a 10-mA curve of the tunnel diode in Figure 2, (A).

MONOSTABLE OPERATION

The TD must return to the low-voltage state to respond to the next trigger signal. One way to insure that the TD always returns to the low-voltage state after a trigger occurs is to use a very small series R and a low voltage source. See *Figure 3.*

The 50-Ω series resistor will drop 0.4 volts at 8 mA. The TD will drop 0.03 volts at 8 mA, therefore the supply voltage will have to be 0.43 volts to put the quiescent point at "a" on the DC load line. The low impedance gives much more slope to the load line. When a 2-mA input signal arrives, the TD will switch to the high-voltage state. When the input signal ends, the load line drops below the switching point at "b" and TD reverts to the low-voltage state. The steep slope of the load line makes

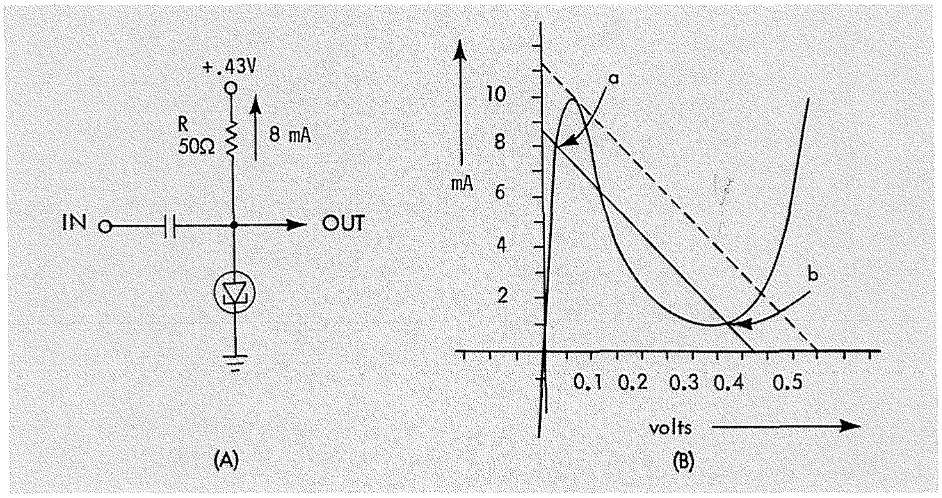


Figure 3 (A) Basic tunnel diode switch for monostable operation.
(B) AC and DC load lines superimposed on a 10-mA curve of the tunnel diode in Figure 3, (A).

the output voltage in Figure 3 less than the output voltage of the circuit in Figure 2. The duration of the output signal is the same as the input signal, resulting in monostable operation.

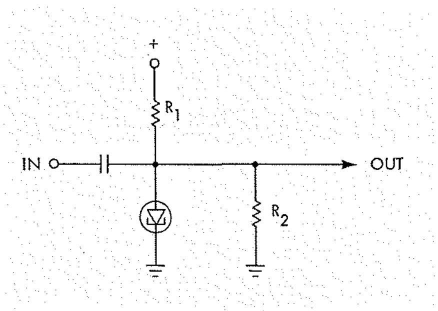


Figure 4

Figure 4 shows another method of obtaining the low impedance load described in the previous paragraph. This circuit has the same characteristics as the circuit in Figure 3 except:

1. A higher source voltage can be used.
2. Some additional current must be provided through R_1 to satisfy the needs of R_2.
3. Some additional signal current is needed to drive the shunt resistance of R_2.

A method of increasing the output voltage and switching speed is shown in *Figure 5A*. The coil provides a very flat load line during switching time (shown as dashed line in Figure 5B) because of the high impedance of the coil at the switching speed of the TD. Note the increase in the voltage excursion. Switching speed is increased because current which would have otherwise passed through R_2 is now available to charge the capacitance of the TD. This circuit is monostable if the load line is steep enough to cross only one positive slope of the TD curve. The slope of the load line depends primarily on the value of R_2. The width of the output pulse is controlled mainly by the L/R time of the circuit, where L is the inductance of L_1 and R is the resistance of R_2 in series with the impedance of the TD. The impedance of the TD in the high-voltage state is different from the impedance of the TD in the low-voltage state.

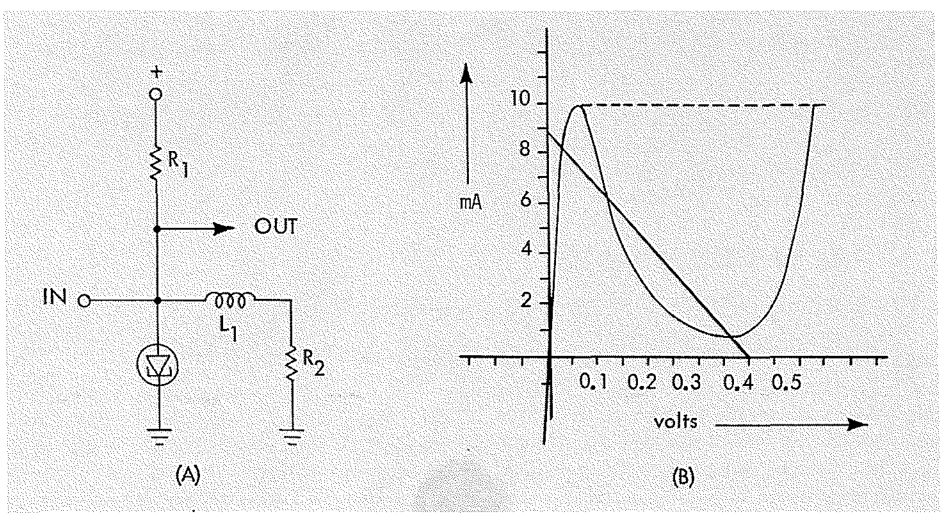


Figure 5 (A) Another version of a monostable tunnel-diode switching circuit. The coil, L_1, helps to increase the output voltage and switching speed.
(B) AC and DC load lines superimposed on a 10-mA curve of the tunnel diode in Figure 5, (A).

OSCILLATOR OPERATION

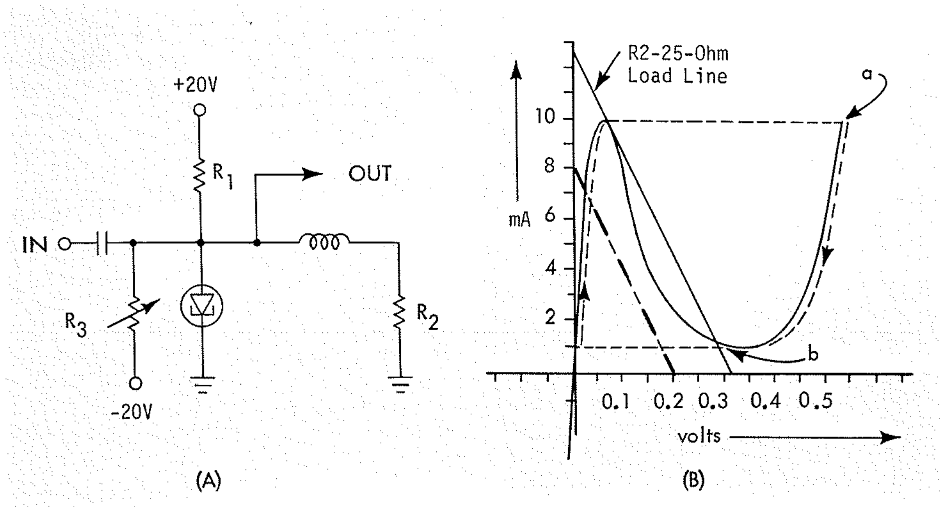
Circuit operation as an oscillator is also possible. *Figure 6* shows the addition of R_3, a bias control. Resistor values are chosen to place the TD near its current peak (low-voltage state) when R_3 is in the center of its range.

If the resistance of R_3 is reduced, more current flows from the —20-V supply and less current flows through the TD—the TD will now be biased at some point below peak current (as indicated by the dashed line paralleling the R_2 25-Ω line in Figure 6 (B). If the resistance of R_3 is increased (reducing the current through R_3), more current will flow through the TD—if this current exceeds 10 mA, the TD will switch to its high-voltage state, along the dashed load line to point "a". If the DC load line produced by R_2 intersects the lower negative resistance portion of the TD curve (point "b", Figure 6), the TD will automatically switch back to its low-voltage state. The effective load line will change from a high impedance (point "a") to a low impedance (point "b"). This change will take place at an L/R rate—when point "b" is reached, the TD will revert to a position on the DC load line, as determined by R_3. If this load line places the TD current above 10 mA, the circuit will oscillate.

CIRCUIT ANALYSIS

The tunnel diode and the resistor, R_2, in Figure 6A can be considered as parallel elements. Let us assume a value of 25 Ω for R_2. *Figure 7* shows a 25-Ω resistance plot superimposed on a 10-mA TD curve. The instantaneous current of each element can be found by drawing a perpendicular line at the voltage point of interest—for instance, at about 80 mV, the TD is close to its peak current state at 10 mA. The current through the resistor, R_2, with an 80-mV drop will be:

$$I = \frac{E}{R} = \frac{80 \times 10^{-3}}{25} = 3.2 \text{ mA.}$$



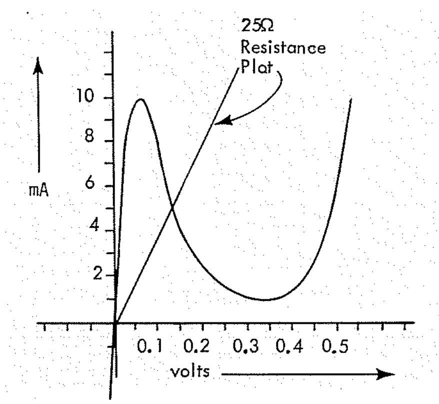


Figure 7 25-Ω resistance plot on a 10-mA tunnel-diode curve.

Figure 6 (A) The addition of a variable resistor, R_3, enables the circuit shown in Figure 5, (A), to operate as an oscillator.
(B) AC and DC load lines superimposed on a 10-mA curve of the diode shown in Figure 6, (A).

The +20-V supply must therefore furnish 13.2 mA to the TD-R_2 combination through R_1.

When a small positive-going signal is applied to the circuit in Figure 6, the TD switches to its high-voltage state. Because the coil provides a fairly flat load line (shown by the dashed line in Figure 6B), the output voltage will be a little greater than 0.5 volts. After the L/R time the DC load line will become effective and determine the current distribution through the TD-R_2 combination. The total current supplied to the circuit via the current control resistor, R_1, is about 13.2 mA. As the L/R time constant decays a greater voltage drop will appear across R_2. When this voltage drop reaches $\approx$300 mV, the current through the 25-Ω resistor will be about 12 mA—as the total current supplied to the circuit is 13.2 mA, only 1.2 mA will be available to the TD. At this current-voltage point the TD will switch back to its low-voltage state. When the circuit is at "idle"—near its current peak, the voltage across the TD-R_2 combination will be about 80 mV, and about 3.2 mA will be "lost" in the resistor, R_2.

The best component available to replace R_2 is a back diode. The back diode is simply a tunnel diode that is usually selected for its reverse conduction characteristics.

Editor's Note: This concludes the first half of this article. The theory, function and application of the back diode to tunnel-diode switching circuits will be taken up in the next (August) issue of SERVICE SCOPE.

MORE ON TEKTRONIX-PRODUCED FILMS

We have experienced a tremendous response to our announcement in the February, 1966, issue of SERVICE SCOPE on the availability of Tektronix-produced films. The requests by our readers for the use of these films have exceeded our wildest expectations and sorely taxed our ability to promptly supply the films.

We are filling all requests on a first-come, first-served basis and earnestly solicit your patience and understanding if we fail to supply the wanted film promptly. All requests from qualified sources will be honored; but, there may be a delay of several weeks in supplying some of the more popular films.

A new Tektronix-produced film is now available to schools or to companies engaged in educational or training programs for their employees. This film like the previously announced ones may be obtained on a free loan basis, or may be purchased. Title of the new film is 'Transresistance". It is a lecture-type film that offers an explanation of the transresistance method of analyzing transistorized circuitry. (An article in the December, 1964, issue of SERVICE SCOPE, "Simplifying Transistor Linear-Amplifier Analysis" discussed transresistance as an aid in troubleshooting or evaluating transistor circuits.) Audiences for this film should have a sound basic knowledge of transistor theory and terminology.

People interested in showing these films should contact their local Tektronix Field Office, Field Engineer, Field Representative, or Distributor.

THE READER'S CORNER

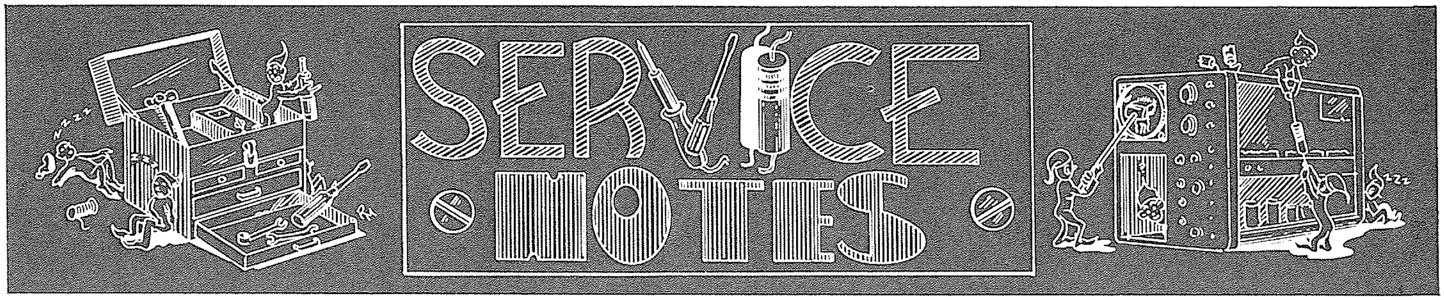
Here are some additional articles, authored by Tektronix personnel, that have appeared in recent issues of trade publications. Listed along with the author's name and the title of the article is the magazine and the month of issue in which the article appeared. Also included is a thumb-nail sketch of the article's content.

Local Tektronix Field Offices, or your Tektronix Field Engineer, Field Representative or Distributor can supply you with reprints of these articles.

"Differential Comparator Extends Measurement Accuracy," by John J. Horn, Design Engineer. Electronic Design, October 25, 1965. A discussion of how a differential comparator can refine oscilloscope voltage-amplitude measurements for either DC or pulse signals.

"Advances in Storage Oscilloscopes," by Donald C. Calnon, Project Engineer. Electronic Industries February, 1966. Discusses state-of-the-art storage tubes and the more versatile oscilloscope they make possible. Some terminology is defined.

"The Sampling Oscilloscope: A Nanosecond Measurement Tool," from information supplied by Tektronix, Inc. The 1965 Test Instrument Reference Issue (A Cahners publication). Tells how the sampling oscilloscope displays high speed phenomena. Explains how it buys sensitivity at the expense of time.



AN INSULATED EXTENDER FOR A PROBE'S RETRACTABLE-HOOK TIP

Here is a "do-it-yourself" project you may want to try. This insulated extender for a probe's retractable-hook tip can be made from an ordinary paper clip and two pieces of insulation or "spaghetti". It makes a handy extension for reaching into those hard-to-get-at places when trouble shooting or checking circuits.

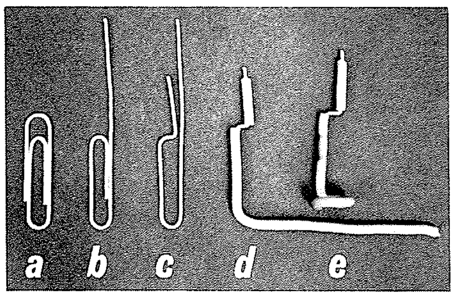


Figure 1. Progressive steps in forming the retractable-hook tip extender.

Figure 1 shows the steps in forming the extender. A. Start with an ordinary paper clip. B. Straighten the outside wire. C. Bend the inside wire to leave a crook. D. Bend the longer wire to form a right angle to the short wire and slip two pieces of insulation over the wire leaving the crook bare. E. With the retractable-hook tip, grip the partially formed extender at the crook and wrap the longer insulated portion around the shaft of the retractable-hook trip to form a one turn coil. *Figure 2* shows a probe with the retractable-hook tip gripping the completed extender.

The extender will offer no problems when used with oscilloscopes having bandpass capabilities of up to 50 MHz. We do not recommend the use of the extender with the Type 580 Series Oscilloscope and the P6008 combination. With this combination, when investigating high frequency signal, the probe ground strap must be kept as short as possible for best results. A probe ground strap in excess of three inches will cause objectionable ringing. An extender and hook tip combination on the probe requires that the probe ground strap be at least 5" inches in length.

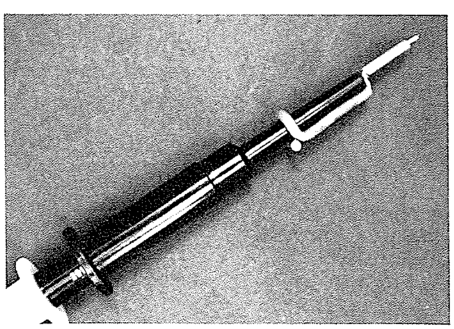


Figure 2. Completed insulated extender in position on a retractable-hook tip.

Our thanks for this idea go to a member of our Instruction Manuals Group, Keith Morrill, who developed the extender and brought it to our attention.

SOLDERING FLUX OR SOLDER RESIST ON ETCHED-CIRCUIT-CARD CONNECTOR TABS

Incompletely removed soldering flux or, more rarely solder resist, can cause poor contact between the connector tabs on etched circuit cards and the connector sockets into which the tabs fit. Soldering flux can be removed with Socal, Fotocal (denatured alcohol), Freon, or Chlorothene. Use a Q-tip to apply the cleaner.

Solder resist which is more tenacious may require a light abrasive, such as a lead pencil eraser, for complete removal. *Use the eraser very lightly.* The connector tabs and connector sockets for Tektronix etched-circuit cards are gold plated to assure a minimum of contact resistance. Care must be taken not to remove this plating.

CRT MESH LIGHT FILTER AND RFI SHIELD—PART NUMBER CORRECTION

In the February, 1966, issue of SERVICE SCOPE we announced a new CRT Mesh Light Filter and RFI Shield. We included a list of oscilloscopes plus the part numbers of the particular filter-shield the instrument would accept.

We have since discovered several errors in that list. Also, we now have a model to fit the Type 321A Oscilloscope.

Here is the corrected list:

TYPE	PART NUMBER
321A	378-0577-00
422	378-0571-00
453	378-0573-00
All Tektronix oscilloscopes with 5" round CRT's	378-0572-00
506, 527, 529, and 561A	378-0575-00
647	378-0574-00

TRANSISTOR FAILURE IN HYBRID CIRCUITS

When an otherwise unexplainable transistor failure occurs in a hybrid circuit, it pays to consider, as a probable cause, an intermittent short in what appears to be a perfectly good vacuum tube. There have been instances where failure of a transistor located in the grid circuit of a vacuum has been traced to intermittent arc-over in the tube. Frame-grid tubes such as the 6DJ8 are particularly prone to this type of failure; but, they are by no means the only offenders. Normally a grid-wire breaking and shorting to the plate will wipe out the tube. There have been some, however, where the short has "healed" itself after passing enough current to destroy an associated transistor.

DUST REMOVAL AND TEKTRONIX INSTRUMENTS

In all Tektronix instruments using forced-air ventilation, the air entering the instrument is filtered. Nevertheless, some dust will eventually penetrate into the interior. This dust should be removed occasionally due to its conductivity under high humid conditions. The best way to clean the interior is to first carefully vacuum all accessible areas. Next blow away the remaining dust with *dry low-pressure* compressed air. Avoid the use of high-velocity air which might damage some of the components. Remove stubborn dirt with a small soft paint brush or a cloth dampened with a mild water-and-detergent solution.

Pay special attention to high-voltage circuits, including parts inside the high-voltage shield. Arcing in this area due to dust or other causes may produce false sweep triggering which in turn will cause an unstable CRT display.

Don't neglect those instruments that do not use forced-air ventilation. Dust will collect in these instruments too. Its presence will have the same effect on these instruments as in the case of forced-air ventilated equipment. The same removal procedure applies to both types of instruments.

Air Filter—The air filter (too often one of the most neglected parts of an instrument) should be visually checked every few weeks and cleaned if dirty. Obviously, more frequent inspection and cleaning will be required for those instruments located in areas with severe environmental conditions.

Older Tektronix instruments use a metal mesh filter. Later instruments use a more recently developed plastic-foam material as the filter element. The following information applies to both types of filter material. To clean the filter, wash it out as you would a plastic sponge (swish metal mesh filters up and down and around). Use a mild warm water-and-detergent solution. Rinse the filter thoroughly and let it dry. Coat the dry filter with fresh "Filter-Kote" or "Handi-Kote". (These products are available from your local Research Products Company, and from some air-conditioner suppliers.) Let the filter dry thoroughly before reinstalling.

The plastic-foam filter is quite a bit more efficient than the older metal-mesh filter. It can be used as a replacement on some of the Tektronix instruments that came equipped with metal-mesh filters. Here is a list of those instruments and the plastic-foam filter kit they will accept.

TYPE	REPLACEMENT KIT NO.
541, 541A, 543A, 545, 545A, 551*, 555*	050-0123-00
175	050-0087-00
1121, 123, 133	050-0148-00

*This replacement kit is for the indicator unit only. Order replacement kit 050-0253-00 for the power supply unit of these instruments.

NEW FIELD MODIFICATION KITS

In the April issue of Service Scope, in this column, we typographically elevated the P510A Probe to the status of a Cathode Follower Probe. A cathode follower it is not! The P510A is a ten times probe that presents an input impedance of 10 megohms paralleled by 14 pF. This probe has not been produced since 1959. It was, in its day, however, a very popular probe and many are still in use, performing very well with the instruments for which they were designed.

The Field Modification Kit 040-0287-01 which was reviewed in this column last issue contains the parts necessary to repair several P510A Probes.

OSCILLOSCOPE CRADLE MOUNT—INCORRECT PART NUMBER

The correct part number for the Oscilloscope Cradle Mount Modification Kit reviewed in this column last issue is 040-0281-00. This is the modification kit that alters the following instruments to fit into a standard 19" relay rack: Type 524AD, 531, 532, 535, 541, 545, and 570, serial numbers 5001 and up; Types 531A, 533, 533A, 535A, 536, 541A, 543, 543A 543B, 544, 545A, 545B, 546, 547, 575, 581, 581A, 585, 585A, and 661, all serial numbers.

TYPE 532 AND TYPE RM32 OSCILLOSCOPES—SILICON RECTIFIERS

This modification replaces the selenium rectifiers in a Type 532 or Type RM32 Oscilloscope with silicon rectifiers. Silicon rectifiers offer greater reliability and longer life. The modification is applicable to Type 532 Oscilloscopes serial numbers 101 through 6921 and Type RM32 Oscilloscopes, serial numbers 101 through 499.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0218-00.

MAXIMUM INTENSITY MODIFICATION KIT—FOR LISTED OSCILLOSCOPES

This modification replaces the one megohm INTENSITY potentiometer of the listed oscilloscopes with two two-megohm potentiometers in parallel. One potentiometer serves as the front-panel INTENSITY control. The other serves as the MAXIMUM INTENSITY control and is screw-driver adjusted. With this arrangement, when observing phenomena at slow sweep speeds the MAXIMUM INTENSITY control can be adjusted to provide the best phosphor protection and prevent the CRT phosphor from burn damage. Or, when observing phenomena at the fastest sweep speeds, the MAXIMUM INTENSITY control can be adjusted to provide the best writing rate.

The modification is applicable to the following instruments, all serial numbers:

Type 531	Type 535	Type 543
Type 531A	Type 535A	Type 543A
Type 532	Type 541	Type 545
Type 533	Type 541A	Type 545A
Type 533A		

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0159-00.

TYPE 551 OSCILLOSCOPE—12-kV HIGH-VOLTAGE TRANSFORMER

This modification replaces the 10-kV High-Voltage transformer with a 12-kV transformer in Type 551 Oscilloscopes, all serial numbers. The increased high voltage offers greater trace intensity at the fastest sweep speeds.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0238-00.

BLANK PLUG-IN UNITS

Two modification kits supply the necessary "skeleton" parts (with assembly instructions) to construct blank plug-in units. These units are intended to house circuitry of your own design to provide special-purpose plug-in units.

Modification-kit instruction sheets list pertinent electrical information so that the installed circuitry may be designed to be compatible to the oscilloscope for which the special-purpose plug-in unit is intended.

Special plug-in units may be made to operate in conjunction with a standard Tektronix plug-in unit or with a second special plug-in unit.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor.

For Tektronix Oscilloscopes using Letter Series or 1 Series Plug-In Unit, specify Tektronix part number 040-0065-00.

For Tektronix Type 560-Series Oscilloscopes, specify Tektronix part number 040-0245-00.

TEKTRONIX TYPE 1S2 MAKES REFLECTOMETERY EASY

As an analytical technique in the study of high-speed transmission systems and components, TDR (Time Domain Reflectometry) has won wide acceptance. This is particularly true since the advent of the sampling oscilloscope and its fractional nanosecond risetimes.

A new Tektronix oscilloscope plug-in unit, the Type 1S2 Sampling Unit, provides an unusual degree of user convenience for TDR measurements—and does so without sacrificing its sampling capability. The Type 1S2 is designed to operate in Tektronix Type 530, Type 540, Type 550, and Type 580 (with Type 81 Adapter) Series Oscilloscopes.

The essential parts of a TDR system include a fast-flat-top pulse source for launching an incident waveform into a test line. The Type 1S2 contains, within itself, two such pulse sources: (1) a tunnel diode supplying a quarter-volt pulse with a 50-picosecond risetime (giving a TDR system risetime of 140 picoseconds) for observing, with a high degree of resolution, small discontinuities in relatively short 50-ohm systems; and, (2) a one-volt pulse with 50-ohm source impedance and a 1-nanosecond risetime to maximize the signal-to-noise ratio when observing discontinuities in long 50-ohm transmission lines. Either pulse can be fed (via the signal channel containing the sampling-oscilloscope pickoff) into the line under test.

A TDR system discloses, basically, three types of information: (1) the *type* of discontinuity the incident edge encounters as it travels down the line under test, (i.e., whether it meets a new characteristic impedance, or whether it sees a lump of series inductance or shunt capacitance); (2) the *magnitude* of the discontinuity (such as the actual value of shunt capacitance or series inductance); (3) the *location* of a discontinuity with respect to the pulse source and the oscilloscope.

These three types of information can be obtained separately from the Type 1S2. The *type* of discontinuity and its *magnitude* are obtained from the vertical axis of the display. The Type 1S2 offers two sets of scale units on the vertical axis; one calibrated in reflection coefficient "ρ" (rho), and the other in volts per division. A switch provides for scale selection. With the switch in the ρ position, one can read the display of a reflection directly in terms of percent of the incident-pulse amplitude.

By means of an OFFSET control, one can position the display vertically. Also, since the offset voltage itself is available at a front panel jack, slide back measurements of reflection—either in terms of ρ or volts—can be made. The primary function of the OFFSET control, however, is to provide a variable voltage which is essentially added in series to the Type 1S2 input. With this arrangement, when an operator is confronted with a small reflection of interest sitting on a DC voltage, the DC voltage can be cancelled out using the OFFSET control. The signal of interest can thus be examined at a more revealing deflection factor.

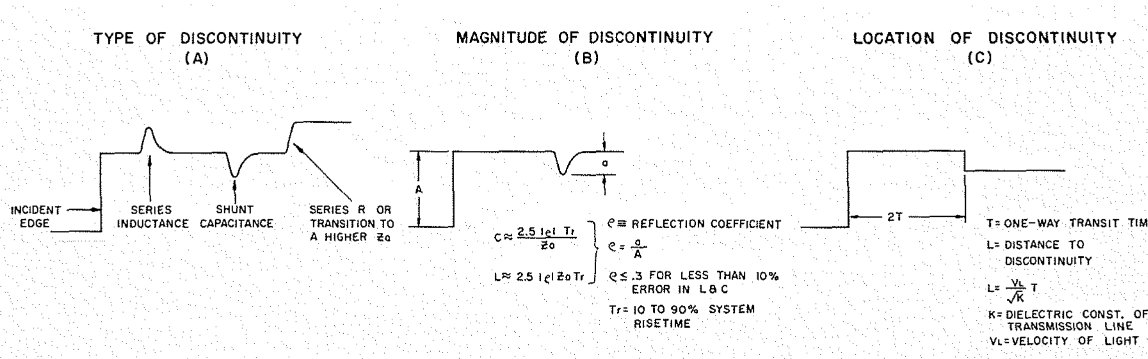
The third type of information, that of the location of a discontinuity is displayed on the horizontal axis of the Type 1S2. This axis also offers two sets of scale units; one calibrated in distance-units per division, the other, in time-units per division. The desired scale is selected via a HORIZONTAL UNITS/DIV front panel control. The actual horizontal units per division changes with the setting of three controls. Therefore a readout indicator is provided to automatically calculate and directly display the actual distance or time units per division.

Separating the processes of locating the discontinuity and analyzing the degree or size of the discontinuity is often desirable. This is very easy to do with a Type 1S2 Unit. When a position range has been selected and the POSITION control set to zero, the leading edge of the incident pulse will be positioned or referenced to the "1" vertical graticule line (graticule lines numbered 0 through 10—left to right), independent of the time-distance settings of the RANGE control. Turning the POSITION control will now cause the leading edge of the incident pulse to go off screen to the left and will bring the aberration, caused by a "down-the-line" discontinuity, to the reference line. With the aberration so positioned, the location of the discontinuity can be determined by multiplying the reading of the POSITION control by the selected range.

When a discontinuity has been thus located, advancing the MAGNIFIER control will expand the display horizontally about the reference line.

With the HORIZONTAL UNITS/DIV switch in the DISTANCE position and the DIELECTRIC control set to the dielectric of the line under test, the location of a discontinuity can be determined directly in meters. DIELECTRIC control positions for air, TFE, and polyethylene lines are provided. The PRESET position of this control provides a relative velocity of propagation from 0.6 to 1. This extends the instrument's distance calibration for use with foam transmission lines, many printed-circuit strip lines and lines with other unusual dielectrics. When a test line is composed of unknown or several different types of dielectrics, it may be more convenient to use the time-scale calibration. The POSITION control will then indicate the round-trip transit time of the incident edge down the test line and back to the oscilloscope.

As a sampling unit, the Type 1S2 offers a flexible high-speed trigger circuit that accepts pulse and sinewave triggering through 5 GHz. However, the low sampling density that occurs in the display at low trigger rates makes trigger rates above 1 kHz desirable. The through-signal channel is then available to provide 90-ps risetime along with vertical deflection factors from 5 mV/div to ½ V/div, and time units from 1 μs/div to 100 ps/div. In either mode of operation—TDR or Sampling—single sweeps are available for photography or storage convenience along with a manual or external scan of the display; most convenient when driving X-Y or Y-T recorders directly from outputs provided at the Type 1S2's front panel.



IDEALIZED WAVEFORMS SHOWING THREE KINDS OF INFORMATION FROM A TDR DISPLAY

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon, U.S.A. 97005

TSL

Frank L. Greenwood
Department of Transport
Telecommunications, Attn: CMO
Room 1217, 3 Temporary Building
Ottawa, Ontario, Canada 9/65

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 39 PRINTED IN U.S.A AUGUST 1966

TUNNEL DIODE SWITCHING CIRCUITS AND THE BACK DIODE

By The Marketing Technical Training Department
Tektronix, Inc.

PART II

This is the concluding half of an article intended to give the reader a better understanding of tunnel-diode switching circuits. The first half of the article appeared in the June, 1966 Service Scope. It reviewed the several methods of tunnel-diode circuit operation and, in a circuit analysis, developed the need for a device, such as the back diode, in these circuits. This half of the article discusses the theory of the back diode and the application of this rather new device to tunnel-diode circuits.

BACK DIODE

In order to avoid the waste power in R_2, during "idle" time of the circuit, the ideal component to replace R_2 would be a 200-mV zener diode (see Figure 8). Normally when the TD is biased on the first positive slope, there would be essentially no current supplied to the zener. The steep slope of the zener that extends between the peak and valley current points of the TD would cause very positive switching back to the low-voltage state. Unfortunately, 200-mV zeners are not available.

A more practical solution is the use of a back diode[1].

The back diode is simply a tunnel diode that is usually chosen for its reverse conduction characteristics. If the peak current is small compared to the operating current, the peak current can be ignored. The BD-4 back diode has a peak current of from 50 μA to 100 μA (see Figure 9A). When a 200-mA peak to peak sinewave is applied to the BD-4, the E-I characteristics of the back diode are represented by the curve in Figure 9B. Notice that the negative resistance characteristic cannot be seen.

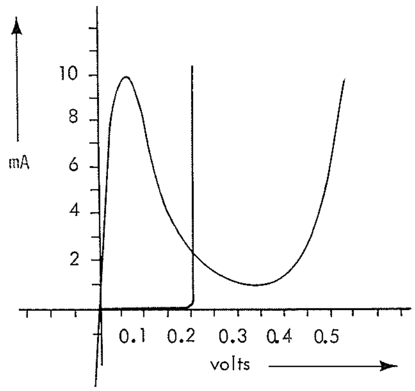
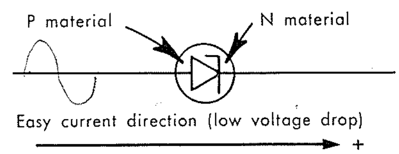


Figure 8 Curve of a hypothetical 200-mA zener diode superimposed on a 10-mA tunnel-diode curve.

[1]The back diode is a tunnel diode whose reverse characteristics are being used. Just as there are many symbols for tunnel diodes, many symbols have been used for back diodes. In order to avoid confusion, the symbol shown below has been chosen to represent a "backward" diode in this article.



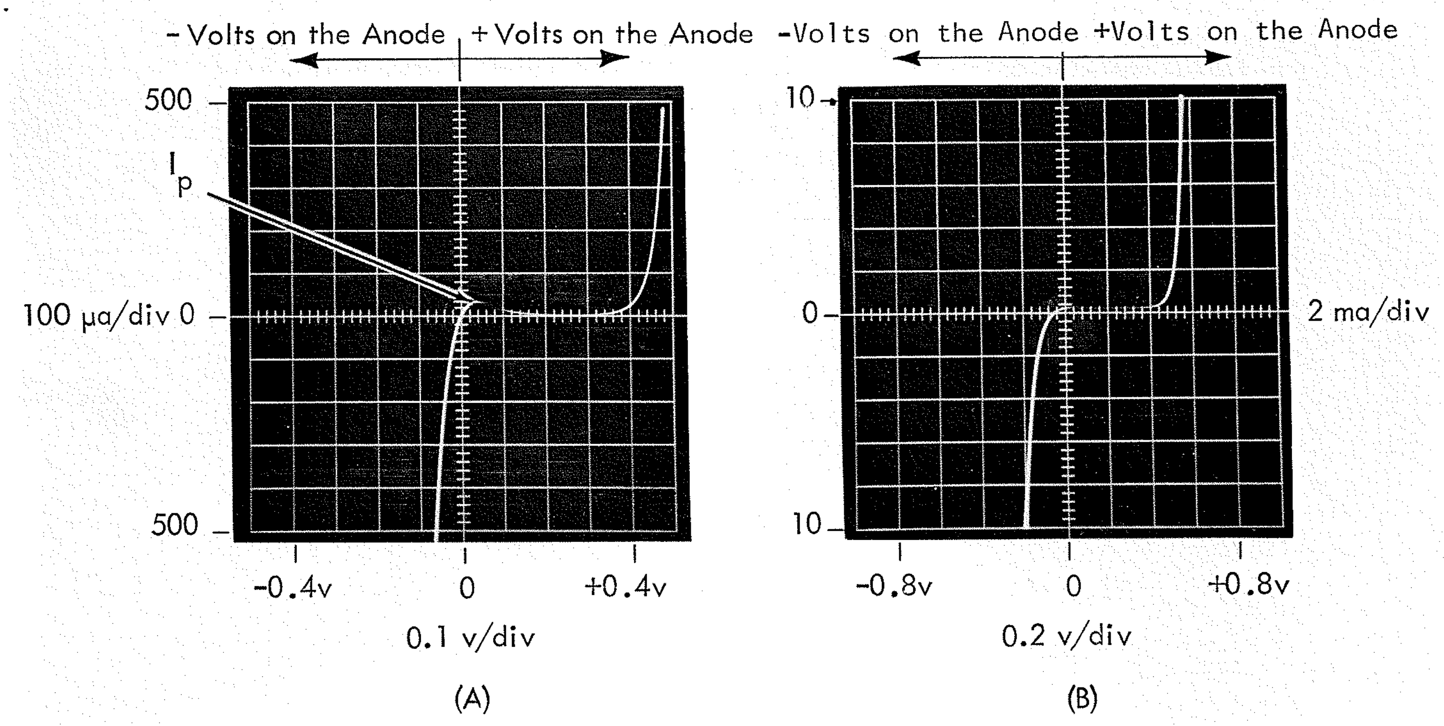


Figure 9 (A) Waveform photo showing peak current of a BD-4 back diode.
(B) Waveform of a BD-4 back diode with a 20-mA sinewave applied.

Since the back diode is operated in the reverse direction, the conduction curve in Figure 9B must also be reversed to give a proper picture of the conduction characteristics of the device. See Figure 10. Notice this appears like a regular diode with a low-voltage zener region and an extremely low forward voltage drop. Any TD can be used as a back diode, although the high forward-current tunnel diodes will have a less desirable "reverse" characteristic.

Figure 11A shows curves of a tunnel diode type TD253B and a back diode type BD-4 superimposed. These curves were taken on a Tektronix Type 575 Curve Tracer with the vertical deflection factor set to 1 mA/div and the horizontal set to 0.1 volts/div.

In Figure 11B, if the TD bias resistor, R_3, is adjusted so that the tunnel diode is biased at some current below I_p, the TD circuit is in a triggerable mode. The new DC load line, using the back diode as a load for the TD, is shown in Figure 12. The curve of the load line is the inverse of the impedance of the back diode. The AC load line is still the flat line (dashed) produced by the coil. At the time the peak current on the tunnel diode is reached, the current in the back diode is approximately 1 mA. This compares to 3.2 mA of "lost" current when using the 25-Ω resistor. As more current flows in the back diode, the non-linear impedance decreases substantially. The back diode must conduct about 10 mA when switching the TD to the low-voltage state. At this point (10 mA) the impedance of the BD-4 is about 2 Ω. This low impedance will cause a very positive "back to low-voltage state" switching of the tunnel diode. The non-linear impedance of the BD-4 offers the following advantages over a resistor:

1. The high impedance at low current insures that the triggering point of the TD does not depend on the rate of rise of the trigger signal because the L is essentially disconnected.
2. The very low impedance at high current will insure that the TD always returns to its low-voltage state after a trigger.

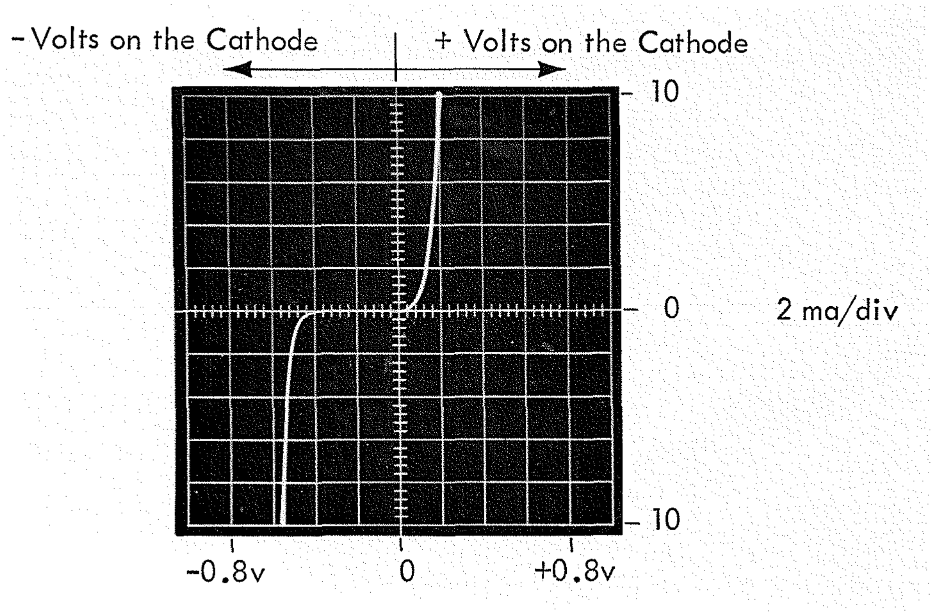


Figure 10 Conduction curve in Figure 9, (B) reversed to give a proper picture of conduction characteristics.

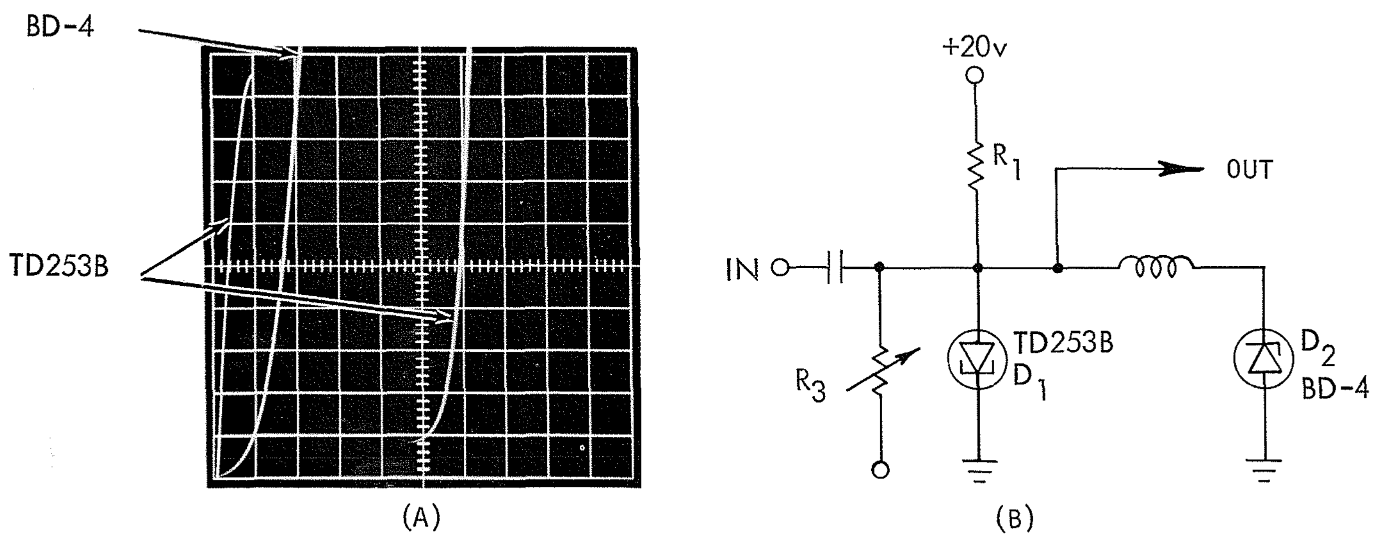


Figure 11 (A) Curves of a TD253B tunnel diode and a BD-4 back diode superimposed.
(B) Same circuit as in Figure 6, (A) except here a back diode, D_2, is the load for the tunnel diode.

3. The static power requirements are less.

The BD-4 also aids in operation of the circuit as a count-down unit. It has been noted that the circuit in Figure 11B will oscillate if the TD is biased above the peak current point. Current switching will take place between the TD and the back diode. The frequency can be influenced by changing bias on the TD. If the circuit has a free-running frequency of 49 MHz and a 200-MHz signal is applied, the TD multivibrator circuit will synchronize with some sub-multiple of 200 MHz—in this case 50 MHz. In any case, the output frequency will be some sub-multiple of the input frequency when the input frequency is significantly higher than the circuit free-running frequency.

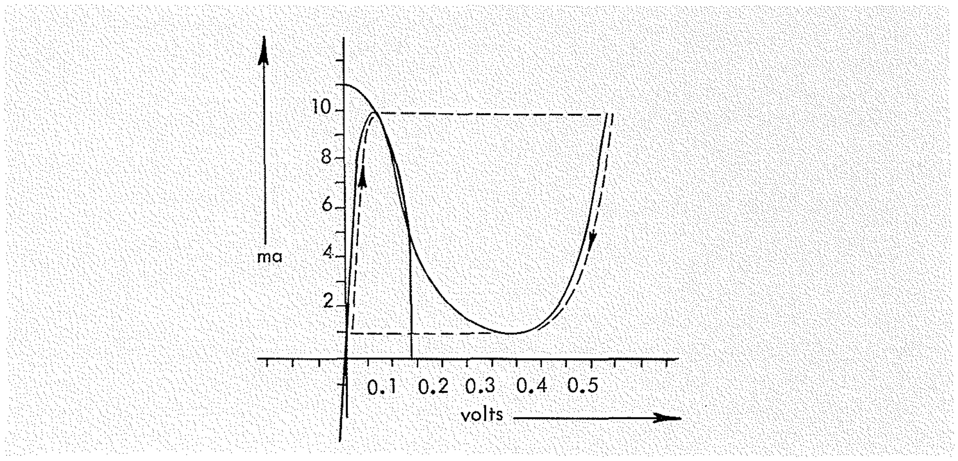


Figure 12 AC and DC load lines of tunnel diode in Figure 11 (B) superimposed on a 10-ma tunnel-diode curve.

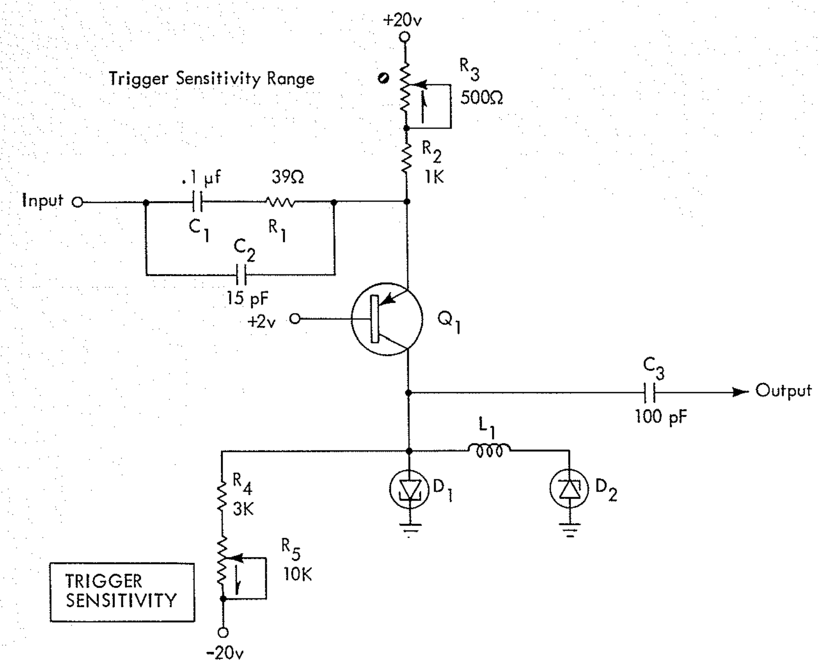


Figure 13 A few refinements to the circuit in Figure 11 (B) are included in the circuit shown here. See text for explanation.

A few refinements to the circuit in Figure 11B are included in the circuit in Figure 13. The transistor is a fast PNP device which isolates the voltage excursion of the TD circuit from the input signal. Static current in the transistor is adjusted by R_3 to compensate for circuit values and peak current differences of TD's. Normally, R_3 is adjusted for a free-running TD circuit when R_5 is at the center of its range. When R_5 is set in the center of its range, the circuit operating conditions are as follows:

1. Current from the —20 V supply to D_1 anode is $\frac{E}{R} = \frac{20\text{ V}}{8\text{ k}\Omega} = 2.5\text{ mA}$.
2. D_1 must be biased at peak current which is 10 mA.
3. D_2 will have a reverse current of ≈1 mA.
4. Current in Q_1 must equal R_4, R_5 current plus D_1 current plus D_2 current which total 13.5 mA.
5. Voltage drop across R_2, R_3 is +20 V minus emitter voltage of +2 V (base voltage) plus ≈0.6 V (base-emitter drop) which equals 20 — 2.6 or 17.4 volts.
6. Required total resistance of R_2, R_3 is $\frac{E}{I} = \frac{17.4\text{ V}}{13.5\text{ mA}} = 1.29\text{ k}\Omega$.
7. Current requirements are satisfied when R_3 is adjusted for 290 Ω.

The input signal is AC coupled by C_1 and C_2. If the input frequency is sufficiently high, the impedance of C_1 can be ignored and input impedance is R_1 in series with the transistor emitter resistance; 39 Ω + 11 Ω = 50 Ω. The small capacitor, C_2, provides additional high-frequency coupling of the input signal to compensate for the increase in emitter resistance at higher frequencies, thus the input impedance is held fairly constant throughout the circuit operating range. Since the input impedance is a predictable 50 Ω, the signal current can be found by $I = \frac{E\text{ signal}}{R\text{ input}}$. For a 10-mV signal, I becomes $\frac{10\text{ mV}}{50\,\Omega}$ or 0.2 mA. An increase in current is required to switch D_1 so the circuit responds to positive signals only.

When triggered operation is desired, R_5 is set ccw of center (less than 5 kΩ). More current is furnished to the transistor collector by R_4, R_5 — perhaps 2.7 mA. The additional 0.2 mA through R_4, R_5 subtracts from the current in the TD. The TD is biased at 0.2 mA below peak current or 9.8 mA. A positive 10 mV signal will cause an increase of current in Q_1 of 0.2 mA and the TD will switch. The TRIGGER SENSITIVITY control is usually adjusted so that the current requirements of D_1 are compatible with the input signal.

When synchronized operation is desired, D_1 is made to free-run by reducing the shunt current through R_4, R_5. (R_5 is adjusted for greater than 5 kΩ.) D_1 current increases to greater than peak current and D_1, D_2 and L_1 act as an oscillator. The oscillating frequency is influenced by the additional current through D_1, D_2 and L_1 when the resistance of R_5 is increased. As current increases, frequency decreases because even though the time constant remains the same, a longer time is required to switch the *additional* current from D_1 to D_2.

Let us assume the TD has just switched to the high state. Current through D_2 increases exponentially as fast as L_1 and the impedances of D_1 and D_2 will allow. As the current in D_2 increases, current in D_1 will decrease proportionally until D_1 switches to the low-voltage state. At this time, the current in D_1 will increase as current in D_2 decreases until D_1 peak current is reached and switching occurs again.

When a high-frequency signal is applied at the circuit input, each positive peak will cause a small increase of current in Q_1. If D_1 is almost ready to switch when a current increase occurs in Q_1, the switching of D_1 and the positive peak of the input signal occur coincidently. (The increase in Q_1 current will cause D_1 to switch.) When the free-running frequency of D_1 D_2, and L_1 is such that one of several input signals always causes D_1 to switch, the TD multivibrator circuit will be in synchronization with the input signal. Since the TRIGGER SENSITIVITY setting influences the free-running frequency of the circuit, it can be adjusted to achieve optimum synchronization.

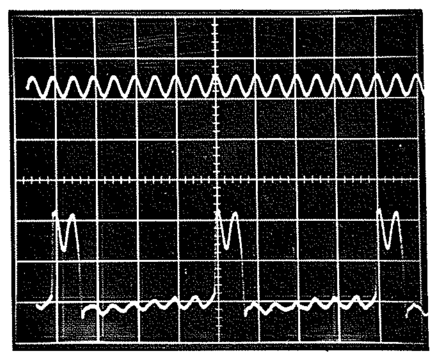


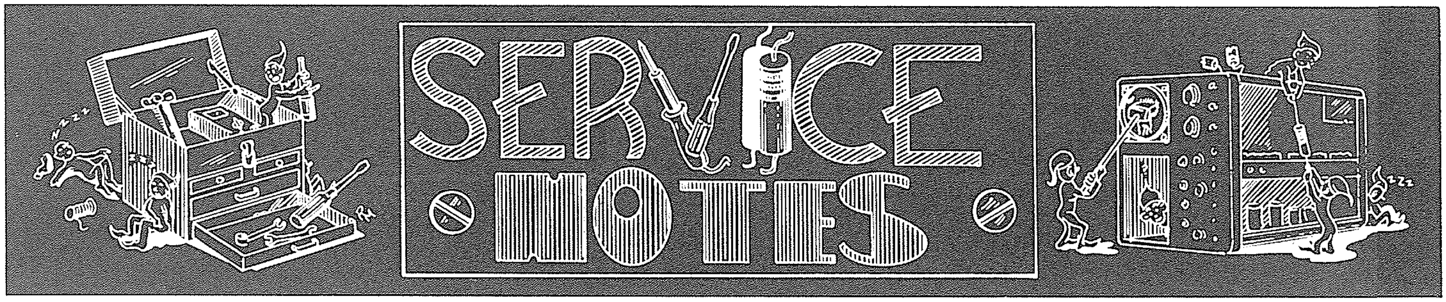
Figure 14 Waveform photo showing a 200-MHz input signal on the upper trace and the synchronized switching of the TD circuit on the lower trace.

The photo in Figure 14 shows the 200-MHz input signal on the upper trace and the synchronized switching of the TD circuit on the lower trace.

The obvious advantages of this type of trigger circuit are:

1. The circuit is *very* sensitive to small input signals.
2. The circuit can be made to oscillate and produce a trigger in the absence of an input signal.
3. In synchronous operation, high-frequency input signals can be converted to a more useable frequency.
4. The TD circuit operates at low power levels so radiation interference is correspondingly low.

In the interest of simplicity the influence of the usual hold-off circuitry has been deliberately ignored. By adjusting circuit values in Figure 13, current in Q_1 has been increased to include TD bias current normally supplied by the hold-off circuitry.



TYPE 580/580A SERIES OSCILLOSCOPES WITH TYPE 82 DUAL-TRACE PLUG-IN UNITS—A SYSTEMATIC STEP-BY-STEP PROCEDURE FOR MAKING GAIN ADJUSTMENTS

A Type 580/580A Series Oscilloscope in combination with a Type 82 Dual-Trace Plug-In Unit has eight gain adjustments which must be adjusted in the proper sequence to realize optimum vertical-amplifier performance. These eight gain adjustments —five potentiometers and three solder-in resistors—are necessary to compensate for the effects of parameter variations of transistors and tubes. Before we outline a systematic step-by-step procedure by which these adjustments are made, we should point out that the three solder-in resistors are selected during the initial factory calibration of the Type 82 and Type 580 Series Oscilloscope—*they will very seldom require changing*. However, to make a complete story, the selection procedure for each of the three solder-in resistors has been included in the adjustment procedure. The adjustment procedure was written with the Type 581A and Type 585A Oscilloscopes in mind. Certain notes have been added to make the procedure equally useful for the Type 581 and Type 585 Instruments.

The step-by-step gain adjustment procedure which follows is intended to delete one step in the Calibration section of the Instruction Manuals for the Type 580 Series Oscilloscopes and to replace one step. The steps deleted and replaced will depend upon whether the calibration procedure you are following is for a Type 581, Type 585, Type 581A, or Type 585A Oscilloscope. If your Instruction Manual is for a:

Type 581, delete step 15, page 6-8; replace step 16, page 6-9.

Type 585, delete step 15, page 6-9; replace step 16, page 6-10.

Type 581A, delete step 11, page 6-6; replace step 14, page 6-6.

Type 585A, delete step 11, page 6-6; replace step 14, page 6-7.

The Type 580 Series Indicator (Oscilloscope) deflection factor (Volts/cm) must first be verified before using the indicator for plug-in calibration.

Adjustment of the Type 580 Series Indicator Gain:

1. Install a Type 84† Plug-In Test Unit in the Type 580 Series Indicator.

   NOTE: If a Type 84 Plug-In Test Unit is not available, a Type 82 Dual-Trace Plug-In Unit can be used to provide the push-pull signal required—see Step 4-c. A second *calibrated* scope is the instrument you would choose to verify that the Type 82 Plug-In was delivering 100 millivolts peak-to-peak to the input of the indicator.

2. Set the Type 84 DISPLAY SELECTOR to CAL (2 cm), ALT. SYNC and free run the sweep.

3. Rotate the Type 580 Series Indicator Vert. Gain Adj. full clockwise (R1015).

4. Check the gain limits:
   a. If the deflection is less than 2.3 cm, the 6DJ8's on the upper vertical chassis and/or the 7788 CRT driver tubes may need replacements. (Type 581 & 585 used a single 7699 CRT driver tube.)

   NOTE: Typical voltage gains for each of the three sections of the vertical amplifier will be useful in determining if tubes should be replaced for insufficient gain. Typical gains are:

Delay Line Driver section (lower vertical chassis)	X3 gain
Vertical Output section (upper vertical chassis)	X5 gain
CRT driver chassis	X4 gain

   b. If the CRT deflection is greater than 2.5 cm, add a 2W 180-Ω resistor (R1016)* between the Vert. Gain Adj. pot (R1015) and the cathode bus wire. (R1016 replaces a wire strap.) Until Type 585A, sn 10870, R1016 was usually 0 Ω (wire strap) and not listed in the manual. If GE 6DJ8's are used in the vertical amplifier, gain may be excessive—requiring use and selection of R1016. R1016 can have any value between 0 Ω and 200 Ω.

   c. Vary the line voltage from 105—125 V AC. With marginal tubes, the CRT display will shift vertically about 1.8 mm and the peak-to-peak deflection will change about 2 mm (10%). With new tubes, line voltage variation will cause virtually no vertical shift or gain change. Return the line voltage to 117 V AC.

   NOTE: With a 2-cm display and change of line voltage from 105—125 V AC, vertical trace shift of 0.5 cm and a peak-to-peak deflection change of nearly 1.0 cm can be expected on a Type 585 which has not been modified by installation of kit 040-0303-00 (Vertical DC Filament Supply Modification Kit).

   Type 585A should not produce 1.0 cm of CRT deflection when 100 mV of peak-to-peak signal is *differentially* applied to the indicator between pins 9 and 11 of the Amphenol connector. A Type 82 or 86 Plug-In Unit develops a differential (push-pull) signal at these pins.

Adjustment of the Type 82 Gain:

Remove the Type 84 Plug-In Test Unit from the indicator and install the Type 82; allow 10 to 15 minutes warm-up time. Perform all manual checks and adjustments pertaining to gas, microphonics, position range, and grid current before starting the gain adjustments.

NOTE: Prior to sn 3000, the Gain Bal. Adj. pot was in Channel B instead of Channel A and designated R277. For these early Type 82's, Steps 1-5 should be performed in Channel B; Step 7 should be performed in Channel A.

1. Set Channel A and B VOLTS/CM to 0.1, VARIABLE VOLTS/CM clockwise and MODE switch to A only.

2. Apply 0.2 V from the Type 585A calibrator (±3%) to the A Channel input.

3. a. Vary the line voltage from 105—125 V AC. If the change in CRT deflection is 5—10% greater than the change noted in Step 4 c of the Type 585A adjustment section, replace the three output 6DJ8's in the Type 82. 6DJ8's with low transconductance will reduce the gain of the Type 82 output amplifier as much as 10%.

b. Mechanically center the front panel X1 GAIN ADJ. control. Rotate the Gain Bal. Adj. (R177), located on the circuit board assembly near Channel A Attenuator switch. If the range is not approximately ±3 mm (nominal 2-cm CRT deflection), select and install a new value of R550.* Typical range of R550 is 10 Ω to 68 Ω.

c. Change the 0.2-V calibrator signal to Channel B, MODE switch to B only (front panel X1 GAIN ADJ. is still mechanically centered), and select R262* for approximately 2-cm CRT deflection. Reducing the value of R262 will increase the CRT deflection; typical range of R262 is 390 Ω to 1.5 kΩ. (R262 is in parallel with R267 and, if present, is located on the circuit board assembly near B attenuator switch.)

4. a. Adjust the X1 GAIN ADJ. for exactly 2 cm of CRT deflection.

   b. Change the 0.2-V calibrator signal to Channel A, MODE switch to A only and adjust the Gain Bal. Adj. for exactly 2-cm CRT deflection.

5. With the calibrator signal still applied to Channel A, change the GAIN switch to X10 and the calibrator signal to 20 mV.

6. Adjust the X10 Gain Adj. (R356) for exactly 2-cm deflection.

7. Turn MODE switch to Channel B only, change the calibrator signal to Channel B and adjust the X10 Gain Adj. (R456) for exactly 2-cm deflection.

† The Type 84 designation for the Plug-In Test unit for the Type 580 Series Oscilloscopes has been changed to a Tektronix part number — 067-0523-00. This part number, rather than the Type 84 designation, should be used in ordering or referring to the Type 580 Series Oscilloscopes Plug-In Test Unit.

* The resistors identified by an asterisk are the three solder-in resistors that along with five potentiometers comprise the eight gain adjustments with which this procedure is concerned.

TRANSISTOR TESTING WITH THE TYPE 575 TRANSISTOR-CURVE TRACER AS AN AID TO TROUBLE-SHOOTING

Usually when a transistor fails one junction becomes shorted or open. Quick checks for opens or shorts can be made on suspect transistors by using a Type 575 Transistor-Curve Tracer to determine whether a typical family of curves can be produced. Nearly every transistor can stand a collector voltage of about 2 volts without danger of breakdown; and, base current drive of up to 100 microamperes will almost never exceed dissipation limits with only 2 volts on the collector. So, by limiting the collector voltage and the base drive on the Type 575, you can quickly and safely make non-destructive tests to determine if the transistor is functioning properly. To do this you need only to know whether the transistor is an NPN or PNP type, which leads go to the emitter, the base and the collector, and how to set up the Type 575. (Pages 2-5 and 2-6 in the Operating Instructions section of the Type 575's Instruction Manual contain information on how to set up the Type 575 to display a family of curves.)

The Beta of most transistors is usually between 10 and 200. Therefore, a vertical mA/division setting of about 20 times the amount of base current per step will usually produce a display of a typical-looking family of curves on the CRT of the Type 575. Putting it in terms of front-panel controls for the Type 575, the CURRENT OR VOLTAGE PER DIVISION switch (located in the Vertical block) should be set to a value on the COLLECTOR mA range, that is 20 times the value of the mA PER STEP setting of the STEP SELECTOR switch (located in the Base Step Generator block).

From an instrument troubleshooting standpoint, the Type 575 is a valuable tool. Transistor characteristics can be easily matched for use in push-pull solid state amplifiers. Verification of tunnel diode, zener diode, and signal diode characteristics is a relatively simple task. For maintenance activities, it proves to be quite a time saver.

NEW FIELD MODIFICATION KITS

TYPE 316 AND TYPE 317 OSCILLOSCOPES—DC FAN MODIFICATION

Installation of this modification enables the Type 316 and Type 317 Oscilloscopes to operate from a 50-to-400-cycle power source. The kit supplies a DC fan assembly and the necessary hardware and components along with step-by-step instructions for easy installation.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0228-00.

TYPE 316 AND TYPE 317 OSCILLOSCOPES—SILICON RECTIFIERS

This modification replaces the selenium rectifiers originally used in the power supplies of the Type 316 and Type 317 Oscilloscopes with silicon rectifiers. The new rectifiers offer more reliability and longer life than selenium rectifiers.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0212-00.

TYPE 422 OSCILLOSCOPE—PORTABLE-TO-RACKMOUNT CONVERSION

This modification is applicable to Type 422 Oscilloscopes, AC powered only. It is not applicable to Type 422 instruments with AC/DC Battery Power Supply.

The modification supplies an R422 Rackmount Assembly for rackmounting the Type 422 Oscilloscope. This assembly has two oscilloscope compartments. With this arrangement, two Type 422 Oscilloscopes can be mounted side-by-side in the same relay rack. Or, one Type 422 may be rackmounted in either the right or left compartment, leaving the remaining compartment to be used for storage of accessories or other equipment. A convenient pulldown door is provided for the storage compartment.

The kit also includes two Rackmount Rear Support brackets with instructions for their installation. These brackets are required when two Type 422's are rackmounted side-by-side. When properly installed the two Rackmount Rear Support brackets enable the Type 422's to withstand an environmental shock or vibration as described in the Characteristic section of the Type R422 Instruction Manual (page 1-3). If only one instrument is rackmounted, support to the storage compartment side of the assembly is not required.

The assembled R422 Rackmount Assembly may be installed in any standard 19-inch open or closed relay rack.

The slide-out tracks used on the Type 422 consist of two assemblies, one for the right side and one for the left side. Each assembly consists of three sections. The stationary section attaches to the rack, the chassis section attaches to the surrounding instrument frame, and the intermediate section fits between the other two sections. This allows the instrument to be pulled forward and extend out of the rack.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0419-00.

TEKTRONIX TECHNICAL PUBLICATIONS

A considerable number of varied forms of Technical Publications have been produced by Tektronix during the past few years. The main purpose of these publications is to educate the customer in techniques unique to Tektronix, and thus, enable him to apply our products more usefully. They also provide a fuller explanation of certain procedures and technical information mentioned all too briefly in some Instruction Manuals.

Much of the need for such a range of publications has been reduced because of the considerable improvements to, and expansion of material in many Tektronix Instruction Manuals.

PROGRAMMED INSTRUCTION

The use of Programmed Instruction is becoming quite widespread throughout the United States and many overseas countries. The Product Technical Information Department at Tektronix produces a range of such books. These are designed to be used as self-teaching devices to complete the training (of an individual who has some electronic background) in the theory of operation of Tektronix circuits.

At the present time eight programmed volumes are available and four more will be added to the range shortly. Two further volumes are available published in conventional text-book form.

Details are as follows:

Semiconductor Series	Order Part Number
Volume 1 Basic Theory	062-0053-00
Volume 2 Diode Devices	062-0112-00
Volume 3 Transistors	062-0067-00
Volume 4 Circuit Analysis 1	062-0216-00
Volume 5* Circuit Analysis 2	062-0217-00
Volume 6** Reference for Vol's 1 and 3	062-0422-00
Volume 7** Reference for Vol's 4 and 5	062-0432-00

Analysis of Passive Networks	Order Part Number
Volume 1 DC Equivalent Circuits	062-0605-00
Volume 2 AC Theory	062-0606-00
Volume 3 Integrators	062-0607-00
Volume 4 Differentiators	062-0608-00
Volume 5* Circuit Application	062-0609-00

Time Domain Reflectometry	Order Part Number
Volume 1*	062-0703-00
Volume 2*	062-0704-00

* Not presently available. To be added to the range in the near future.

** Available in conventional textbook form only.

The publication "Junction Functions" (061-0662-00) is no longer available. It has been superseded by Programmed Instruction.

In addition to these books several other specialized booklets are currently available. These are prepared in conventional text form and in the main cover specific applications or techniques:

Sampling Notes—First published in 1962. Describes basic repetitive sampling techniques (N, 3S76, 4S1, etc). 061-0557-00.

Storage to Picoseconds, a Survey of the Art—Reprint of magazine article, August, 1963. Comparison of sampling and conventional oscilloscope techniques. 061-0991-00.

Spectrum Analyzer Notes—A basic approach to the use of analyzers. 062-0433-00.

Strain Gage Measurement Concepts—A new booklet, published in 1966, describing basic techniques, circuits and applications to oscilloscope displays. 062-0710-00.

Some Transistor Measurements Using the Type 575—Describes exact use of instrument with varied types of semiconductors, 1959. 070-0192-00.

Typical Oscilloscope Circuitry—A 300 page book analyzing basic Tektronix circuits in use up to 1964. 070-0253-00.

Magnetic Ink Character Recognition—Published in 1962, this booklet describes the oscilloscope displays derived from Magnetic Ink readers. 070-0283-00.

Rackmounting Instructions—1964, information concerning the installation of the majority of Tektronix instruments in standard 19" (48.5 cm) racks. 070-0440-00.

Operational Amplifiers and Their Applications—1965, detailed techniques and uses. 070-0526-00.

Oscilloscopes at Work No. 1—Measurement of High Current Forward-Reverse Recovery Times in Signal Diodes—Technique utilizes Tektronix sampling system. A2271.

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Getting Acquainted with Spectrum Analyzers—A basic approach to analysis, reprinted from articles appearing in Service Scopes No.'s 31 and 32, April and June, 1965. A2273-1.

Fundamentals of Selecting and Using Oscilloscopes—A booklet designed to provide abridged details of the entire Tektronix product range and how to select an instrument for a particular application. X2146-7.

Some currently available booklets relate to Tektronix Instruments no longer in our product range. These will be of interest to customers who possess the instrument types concerned. Supplies of the booklets are rather limited.

Some Basic Circuits Used in Tektronix Instruments—Published in 1960, details of then current circuits—known as FIP-1. 061-0139-00.

Measuring the Angular Velocity and Acceleration Characteristics of Rotating Machines—1959, refers in the main to techniques involving the Rotan Angular Transducer—now discontinued. 061-0151-00.

567/3S76/3T77/6R1 Data Flow Diagram—1963, interconnections and signal paths diagram using the 6R1—not the 6R1A. 061-0938-00.

Using Your Oscilloscope Type 535/45—1958, not "A or B" series. FIP-1. 070-0185-00.

A Primer of Waveforms and Their Oscilloscope Displays—1960, basic waveform analysis, simple circuit discussion—FIP-7851. Refers to obsolete instruments and publications but still a good training guide. 070-0190-00.

Using Your Oscilloscope Type 535A/545A—1959. 070-0239-00.

Maintenance and Calibration of Type 545A Oscilloscope—070-0282-00.

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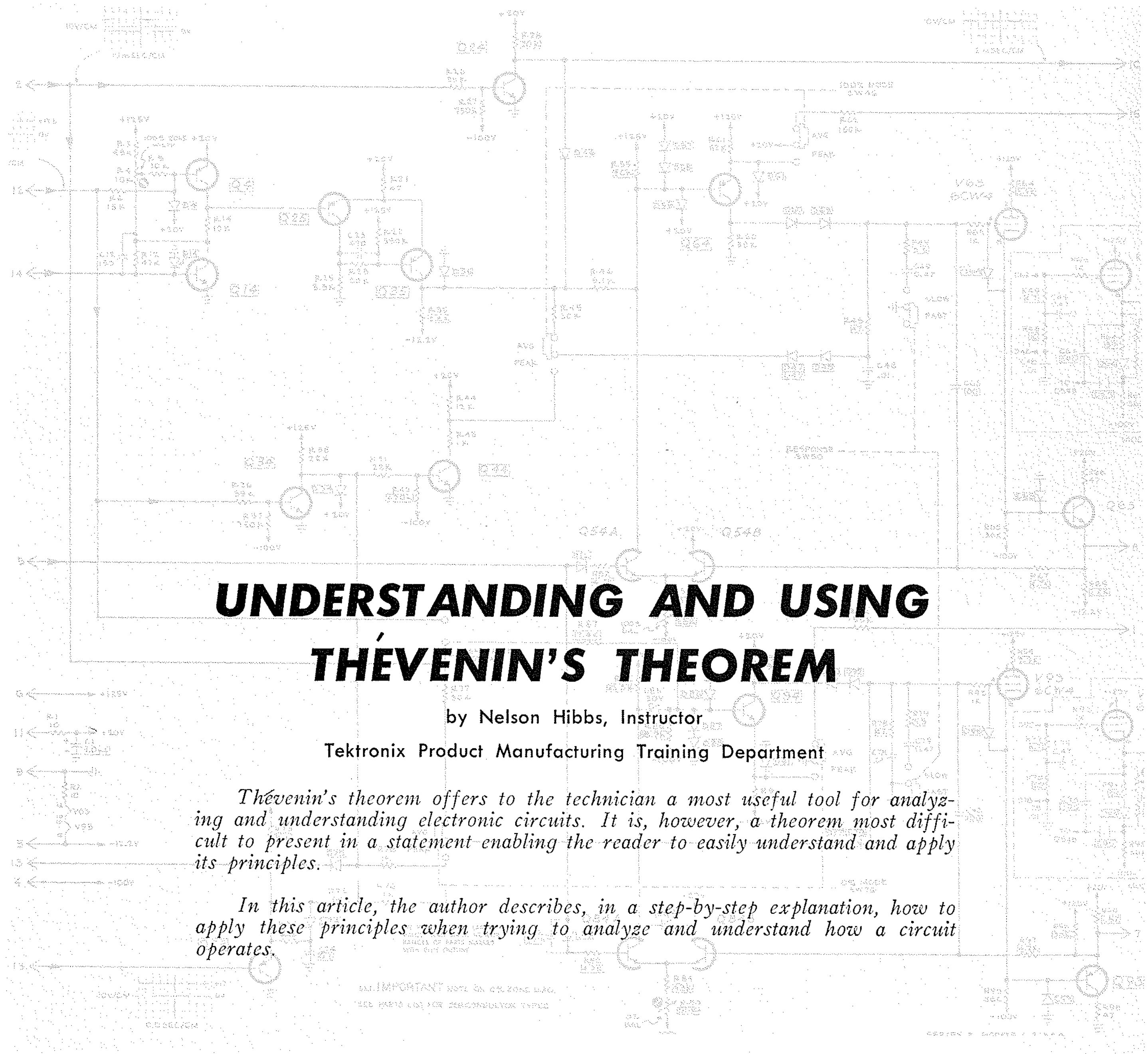

UNDERSTANDING AND USING THÉVENIN'S THEOREM

by Nelson Hibbs, Instructor

Tektronix Product Manufacturing Training Department

Thévenin's theorem offers to the technician a most useful tool for analyzing and understanding electronic circuits. It is, however, a theorem most difficult to present in a statement enabling the reader to easily understand and apply its principles.

In this article, the author describes, in a step-by-step explanation, how to apply these principles when trying to analyze and understand how a circuit operates.

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INTRODUCTION

Thévenin's theorem is one of the most useful extensions of Ohm's law ever devised. It is, however, a theorem most difficult to present in a statement that enables the reader to readily understand and easily apply its principles. For this reason perhaps, some college courses in electrical engineering do not delve into the theorem in any depth until in the senior year.

Once the electronics student or technician does understand Thévenin's theorem, he will find it a most useful tool for analyzing and understanding electronic circuits. The theorem is a general transformation which reduces any combination of active and passive circuit elements to a simple equivalent circuit consisting of a voltage source in series with an equivalent passive element. It is a general theorem applicable to all combinations of passive circuit elements.

With Thévenin's theorem, one can replace any portion of a circuit with a voltage source and an impedance in series, provided the portion replaced has only one pair of terminals. The voltage source in the Thévenin's equivalent circuit will have a value equal to the open circuit voltage appearing at the pair of terminals, and the series impedance will be the impedance that would be seen looking into the pair of terminals with all energy sources turned off and shorted.

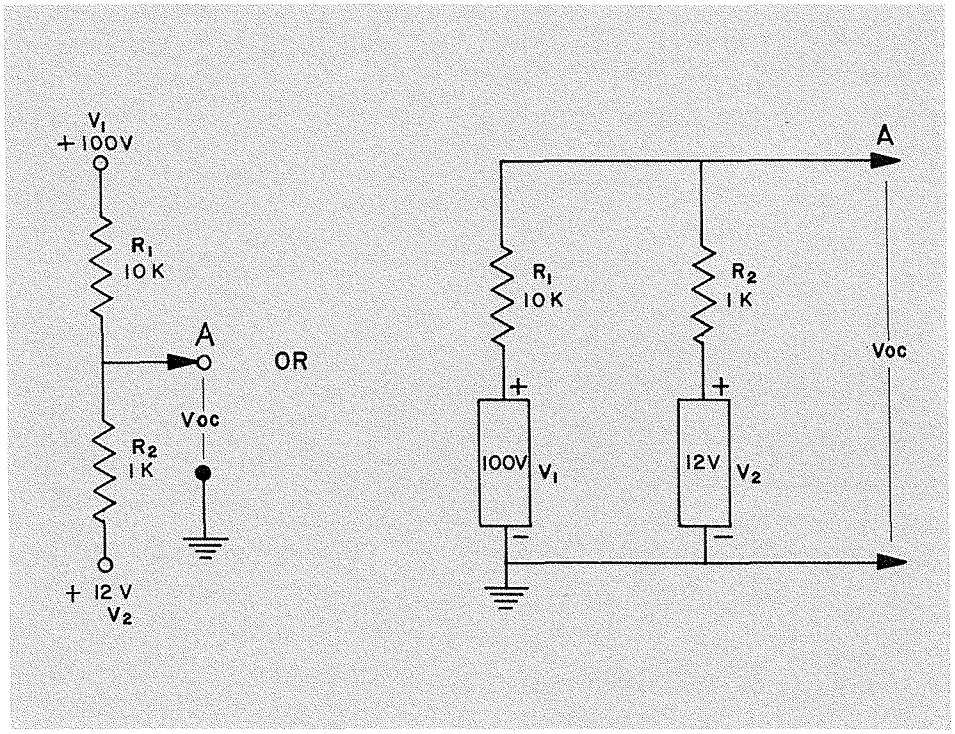

Figure 1. A simple circuit consisting of ideal voltage sources (no internal impedance) and resistors.

In this writer's opinion, one of the more understandable presentations of Thévenin's theorem is put forth by Phillip Cutler in his book "Electronic Circuit Analysis, Volume 1, Passive Networks".* On the bottom of page 18 Cutler writes, "1-5 Thévenin's Theorem. Thévenin's theorem states that any linear network of impedances and generators, if viewed from any two points in the network, can be replaced by an equivalent voltage source V_{oc} and by an equivalent impedance Z_{th} in series".

We will take a look at the mechanics by which this is achieved in a moment; but before we do, let us see what this presentation actually says.

Apparently the first thing we need is a linear network of impedances and generators. To keep it simple, we will use resistors for the impedances and good solid voltage supplies for the generators. Our circuit might then look like the circuit in Figure 1.

Cutler's statement of Thévenin's theorem next says we must view this circuit from two points in the network; let us select for these two points, the ground and common lead at point A. Next it tells us that Thévenin pointed out we can make a substitution for the complex network made up of a single voltage source (which he called V_{oc}) and a single series resistance (which he called Z_{th}).

Let us define V_{oc} and Z_{th}. Since ground is one point of reference and the common lead the other, V_{oc} becomes the voltage difference between these two points. Thus in the circuit in Figure 1,

$$I = \frac{V_1 - V_2}{R_1 + R_2}$$

$$V_{oc} = V_2 + I\ (R_2)$$

$$= V_2 + \frac{(V_1 - V_2)\ R_2}{R_1 + R_2}$$

$$V_{oc} = 12\,V + \frac{88 \times 1\,k}{10\,k + 1\,k} \text{ or } 20\,V.$$

If we assume we are using ideal batteries for our "good solid voltage supplies" we will, of course, have zero impedance within the voltage sources. Looking back then into the circuit from our selected reference points, through the resistors to the zero impedance point, we will see an impedance made up of the parallel resistance of the two divider resistors and this impedance becomes Z_{th}. Thus in the circuit in Figure 1,

$$Z_{th} = \frac{10\,k \times 1\,k}{10\,k + 1\,k} \text{ or } .91\,k \text{ ohms.}$$

According to Thévenin's theorem, these two units, V_{oc} and Z_{th}, will be seen in series when used as a substitute for our simple circuit, see Figure 2.

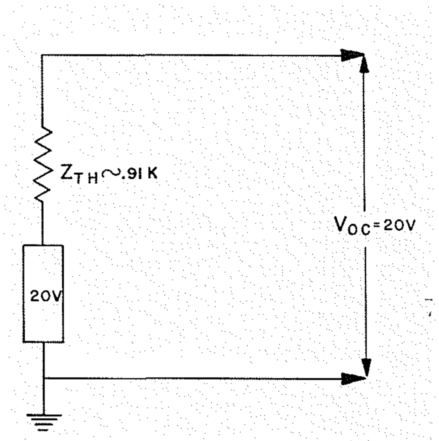

Figure 2. Thévenin's equivalent of the circuit in Figure 1.

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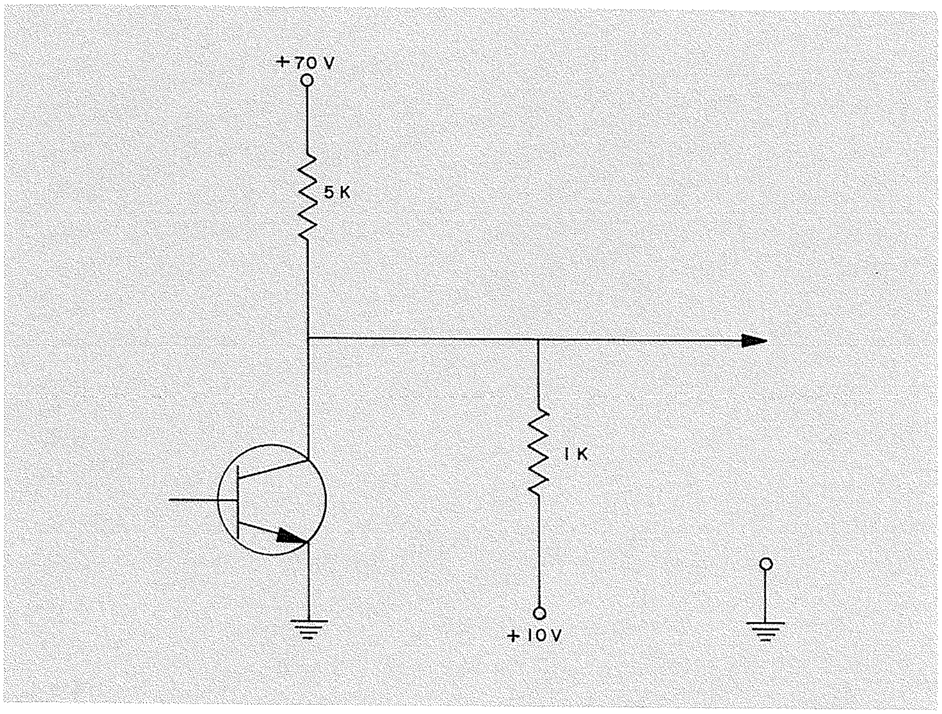


Figure 3. Transistor with a split collector load.

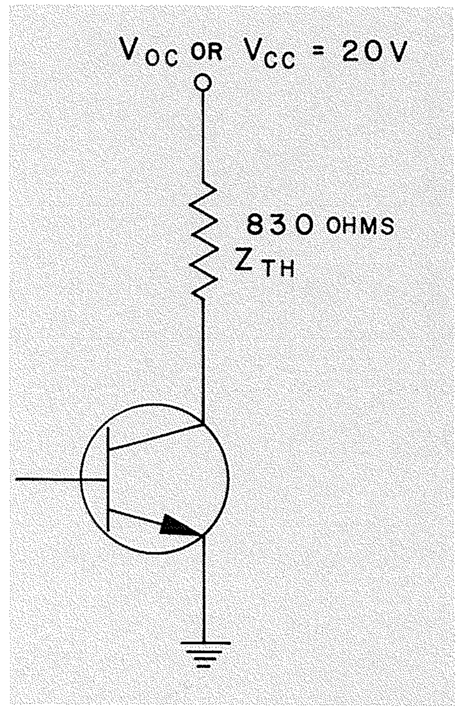


Figure 4. Thévenin's equivalent of the circuit in Figure 3.

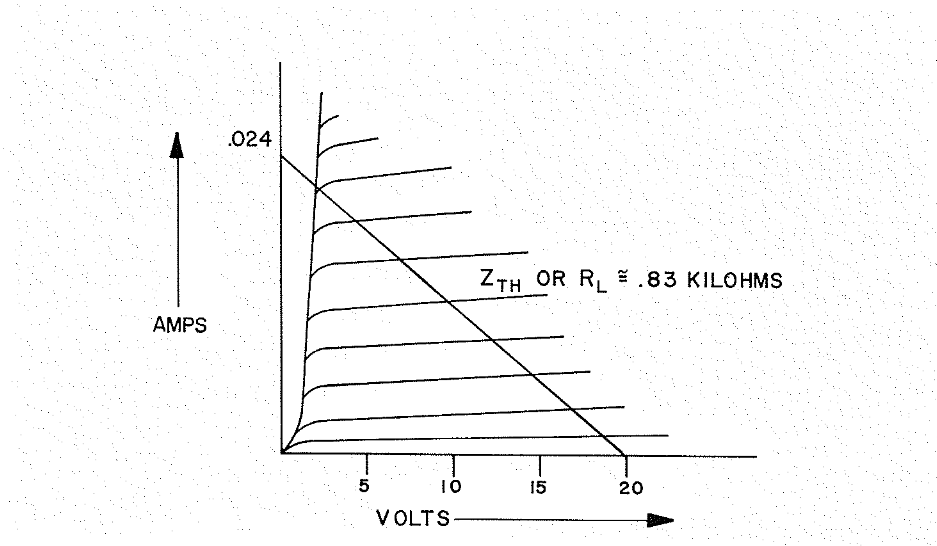


Figure 5. Load line drawn on the collector curves for the transistor in Figure 3 showing where the transistor is operating in that circuit.

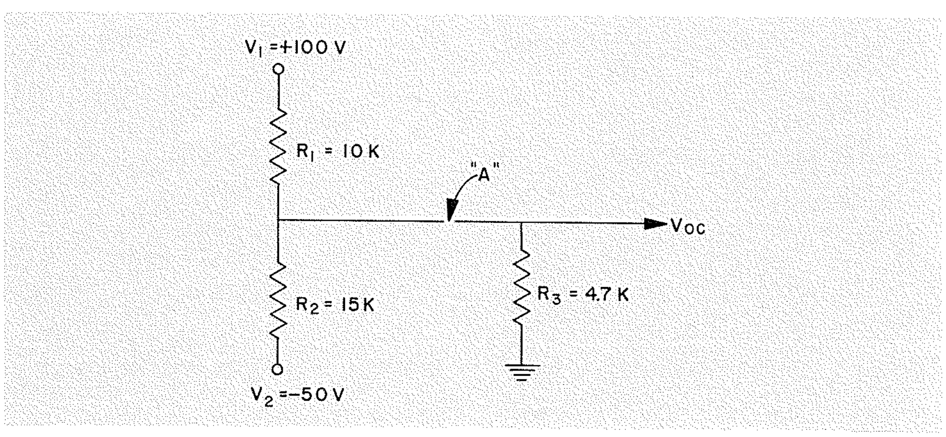


Figure 6. Illustration of a circuit a bit more complex than the one shown in Figure 1.

Now let us put this idea into the practical framework of a real circuit.

Figure 3 shows a transistor with a split collector load. Let us assume we have the collector curves for this transistor and we would like to draw in the load line to obtain an idea of where the transistor is operating and how we can expect it to perform in this circuit. We now need to know what the effective V_{cc} is and how much resistance is in the actual effective R_L. Applying Thévenin's theorem, V_{cc} turns out to be the V_{oc} and R_L becomes the Z_{th} of the theorem, thus the Thévenin substitute for the circuit in Figure 3 would be the circuit shown in Figure 4. We can now draw in the load line for the transistor as shown in Figure 5.

Naturally, the more complex linear networks will require a bit more figuring and will establish the reason for labeling Thévenin's voltage as V_{oc}, or open circuit voltage, rather than calling it the unloaded divider voltage or something else. However, as you have just seen, the figuring will involve only some very basic mathematics with which the electronic technician is (or should be) very familiar. There are other methods of analyzing complex linear circuits; but, they involve simultaneous equations which are time consuming; and, beyond the scope of this article.

As an example of a more complex circuit, let us consider the circuit in Figure 6. The procedure, when using Thévenin's theorem and analyzing a complex circuit, is to progressively apply the theorem to portions of the circuit until all elements of the

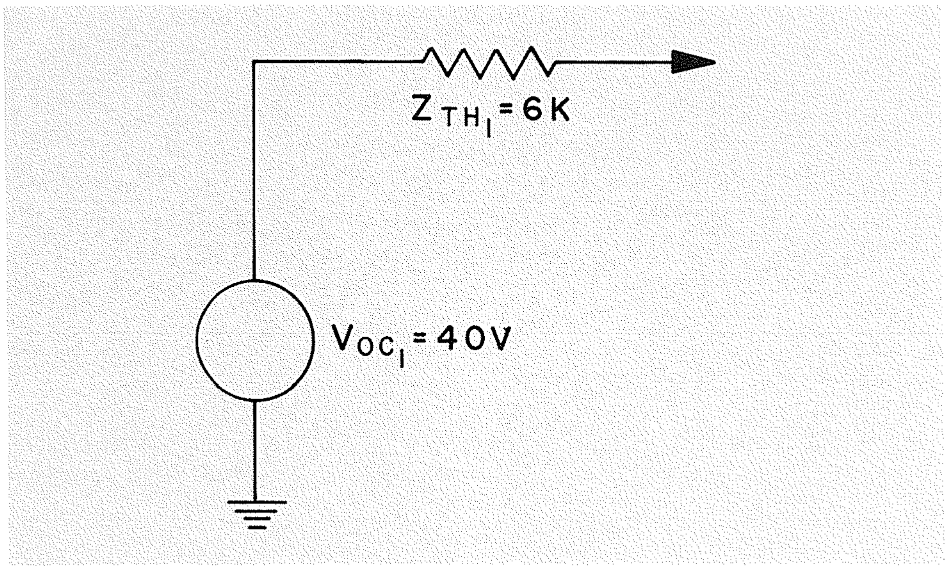


Figure 7. Thévenin's equivalent for that portion of the circuit in Figure 6 up to point "A".

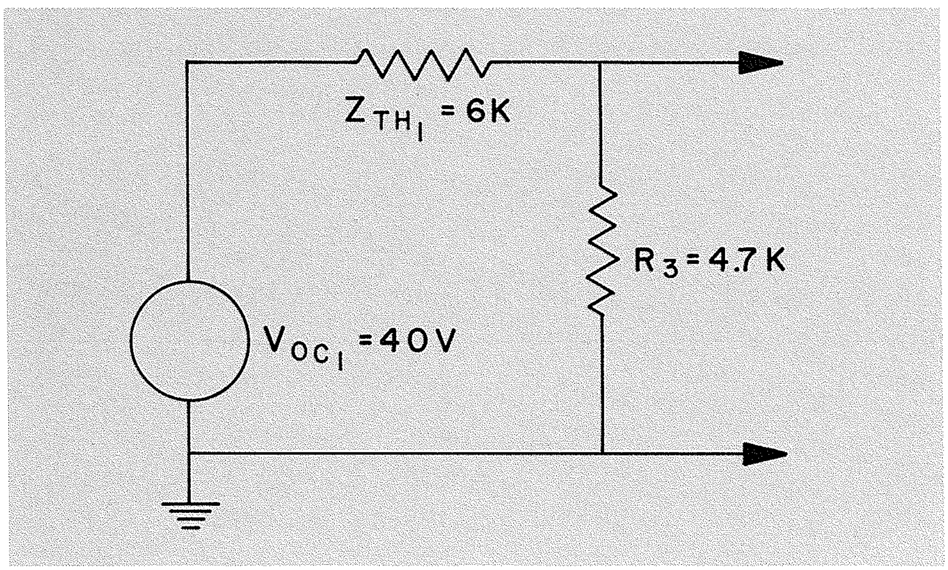


Figure 8. The circuit in Figure 6 redrawn with portion "A" replaced with the Thévenin equivalent.

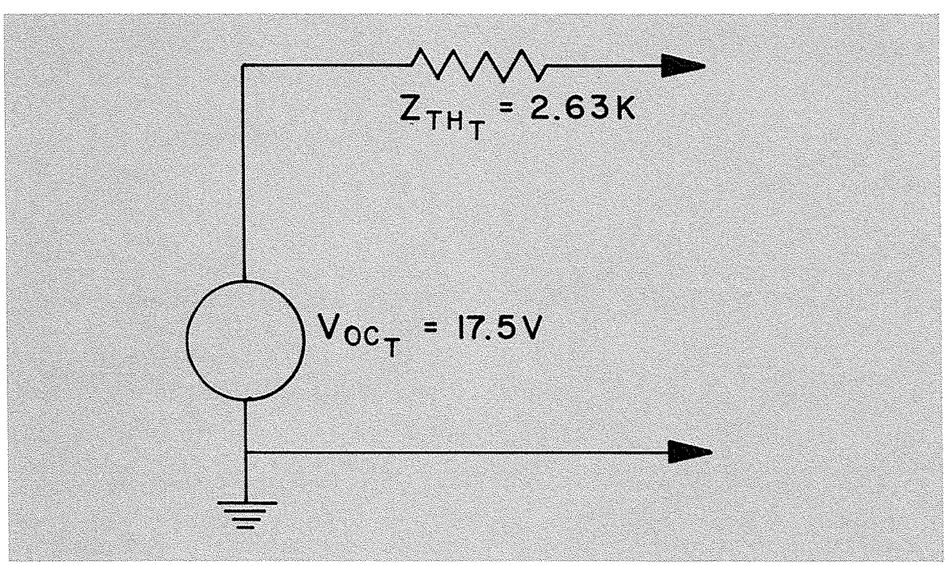


Figure 9. Thévenin's equivalent for the entire circuit in Figure 6.

circuit have been considered. If in Figure 6 then, we break the circuit at point "A", we can solve for V_{oc} and Z_{th} up to this point. In the interests of clarity, let us call the open-circuit voltage and impedance up to this point V_{oc_1} and Z_{th_1}, and the open circuit voltage and the impedance of the entire circuit V_{oc_t} and Z_{th_t}.

Thus:

$$V_{oc_1} = V_2 + \frac{(V_1 - V_2)\ R_2}{R_1 + R_2}$$

$$= -50\ V + \frac{[100\ V - (-50\ V)]\ 15\ k}{15\ k + 10\ k}$$

$$= -50\ V + \frac{150\ V \times 15\ k}{25\ k}$$

$$= -50 + 90\ V$$

$$= 40\ V$$

$$Z_{th_1} = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$= \frac{15\ k \times 10\ k}{15\ k + 10\ k}$$

$$= \frac{150\ k}{25\ k}$$

$$= 6\ k$$

The Thévenin equivalent then, for that portion of the circuit in Figure 6 up to point "A", is the one shown in Figure 7.

We can now redraw the circuit in Figure 6, replacing that portion of the circuit up to point "A" with its Thévenin equivalent. This gives us the circuit shown in Figure 8. We can now apply Thévenin's theorem to this circuit and obtain our original objective; ie, a complete analysis of the circuit in Figure 6.

Thus:

$$V_{oc_t} = \frac{V_{oc_1} \times \overset{4.7K}{\cancel{417}}\ k}{Z_{th_1} + 4.7\ k}$$

$$= \frac{40\ V \times 4.7\ k}{6\ k + 4.7\ k}$$

$$= 17.5\ V$$

$$Z_{th_t} = \frac{Z_{th_1} \times R_3}{Z_{th_1} + R_3}$$

$$= \frac{6\ k \times 4.7\ k}{6\ k + 4.7\ k}$$

$$= 2.63\ K$$

The open circuit voltage (V_{oc}) and the impedance (Z_{th}) then for the circuit in Figure 6 is 17.5 V and 2.6 k, respectively, and the Thévenin equivalent circuit is the one shown in Figure 9.

From the foregoing, it should be apparent that in analyzing complicated circuits we open the circuit so that we consider only two supplies and their resistances at a time. Look at the circuit in Figure 10. Here we would open the circuit at point "A", take V_1 and R_1 and V_2 and R_2 and simplify them into one voltage supply and its series resistance. To this we would add the next supply and its series resistance, apply the procedure of Thévenin and find this new equivalent, and so on, until we had simplified the entire circuit.

It is not difficult to use Thévenin's theorem once you understand it. We hope that in this article we have given you a better understanding of the theorem and a new tool for circuit analysis.

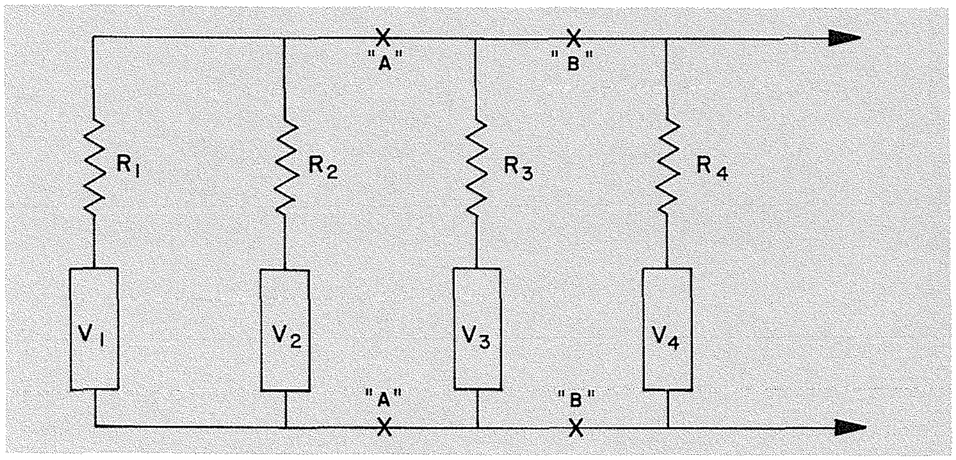
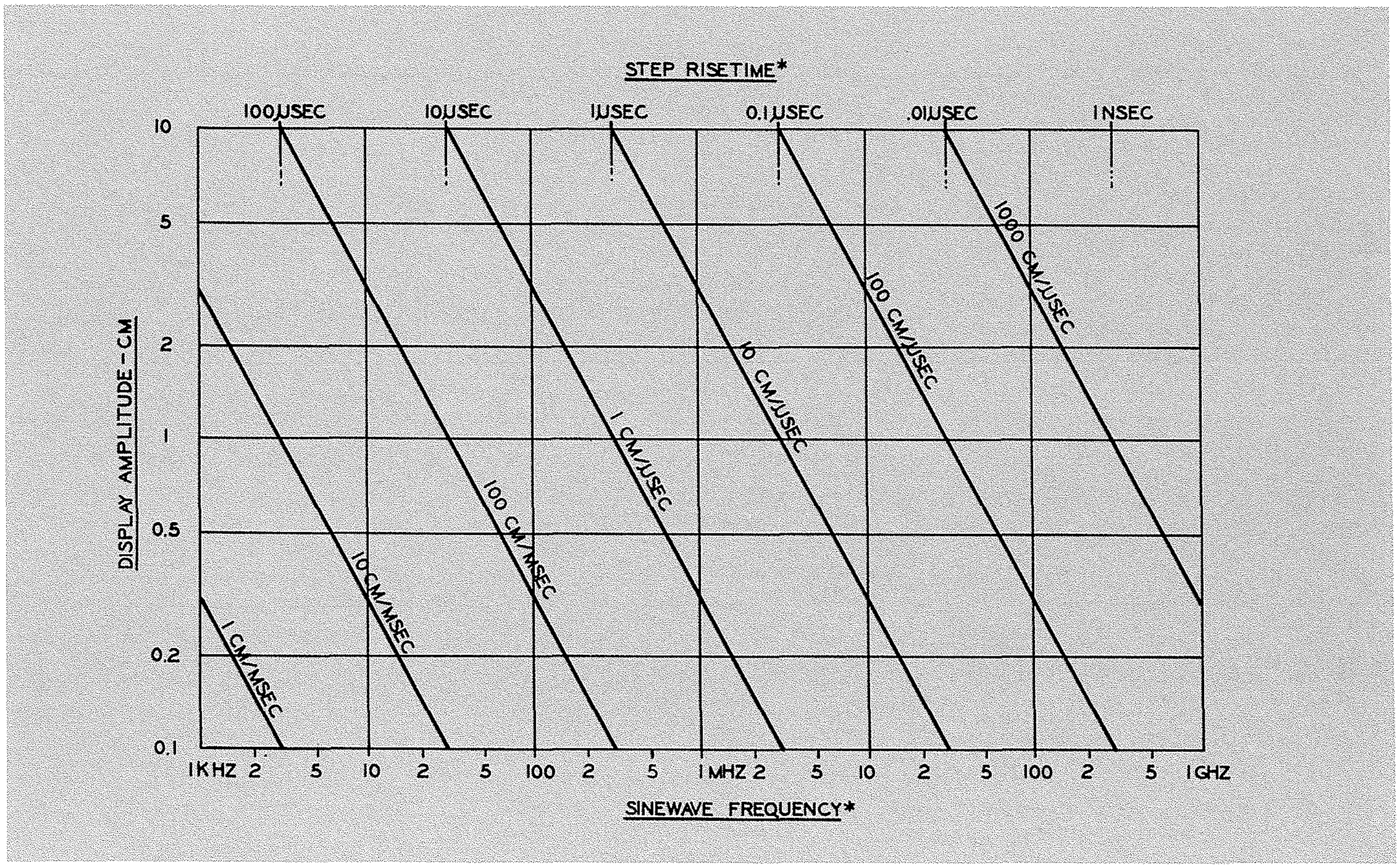


Figure 10. When using Thévenin's theorem to analyze a complicated circuit, open the circuit so that only two supplies and their associated resistors are considered at a time.

WRITING SPEED IN PRACTICAL TERMS



*If the principal spot velocity component is vertical. This chart was computed for 10-90% risetime displayed at about 55° angle from the horizontal and for sinewaves having a peak to peak amplitude about 3X the width of one cycle, to minimize the effect of the spot velocity vector introduced by the time-base.

HOW TO USE THE CHART

Use any two factors to find the third.

Example 1: Determine what oscilloscope/camera system is required to photograph, on a single-shot basis, a display of 100 MHz sinewaves on 6 cm high.

Reading up from 100 MHz and across from 6 cm, we find the intersection to be somewhat beyond 1000 cm/μs diagonal. If the fastest recording system available has a single-shot writing speed of 300 cm/μs, it becomes evident from the chart that the maximum amplitude of 100 MHz sinewaves that can be fully recorded is about 1 cm. Larger amplitudes may record at the peaks, but not at the "zero" crossing.

Example 2: A storage oscilloscope having a single-shot writing speed of 1 cm/μs is to be used to display a single transient having a risetime of 200 ns. What is the maximum amplitude that will allow the entire leading edge to be stored?

Reading down from 0.2 μs (note that 0.2 μs would be to the *left* of 0.1 μs) to intersect with the 1 cm/s line, we find that about 2 mm is the maximum 100% amplitude that will assure storage of the 10-90% risetime with a single sweep. However, if gaps in the trace are allowable, a larger amplitude may be attempted.

SERVICE NOTES

TYPE W HIGH-GAIN DIFFERENTIAL COMPARATOR UNIT—CALIBRATION INFORMATION

Some confusion exists concerning Step 6 of the calibration procedure, Adjust DC Level R280, on page 5-3 in the Type W Unit's Instruction Manual. In step "a," you are instructed to connect a VOM between the emitter and connector leads of Q184. The problem is that the manual fails to point out that there is a test point installed in the ceramic strip nearest the amphenol connector in the Type W Unit and this test point is at the emitter lead of Q184. Some in attempting to perform this step are mistakenly connecting to the top of R281. Trying to adjust for 6 volts differential between this point and the collector of Q184 will lead to frustration. The reading will never be less than approximately 9 volts. The required reading must be made directly between the emitter and collector leads of Q184. Figure 1 shows a view through the rear panel of the Type W Unit. The points to which the VOM must be connected when adjusting the DC level of R280 are clearly identified.

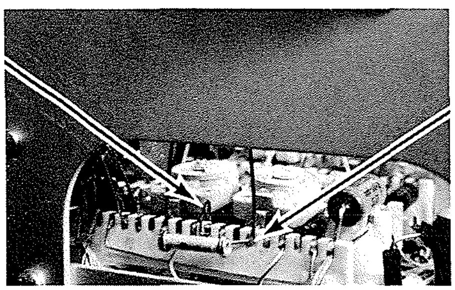


Figure 1. Arrows indicate the points to which the VOM must be connected when adjusting the DC level of R280.

We also call your attention to a correction to Step 22, Check Input A 1000X Attenuator, on page 5-8 of the calibration procedure of the Type W Unit. Change the information in your manual to agree with the following:

22. Check Input A 1000X Attenuator

a. Set the W Unit controls as follows:

COMPARISON VOLTAGE 0.011 v ~~(0-0-11)~~ (0-1-10)
INPUT ATTEN 1000

b. Check that the trace is centered.

c. Set the Vc RANGE switch to ~~+11~~ +1.1

d. Check that the trace ~~coincides with graticule center within a tolerance of ±0.2 cm.~~

e. Set the Vc RANGE switch to 0.

Doesn't move more than ±.2 cm when switching Vc range switch between the 0 position and the +1.1 position. J.A.M.

TYPE 422 OSCILLOSCOPE WITH BATTERY PACK — BATTERY PACK VOLTAGE CHECK

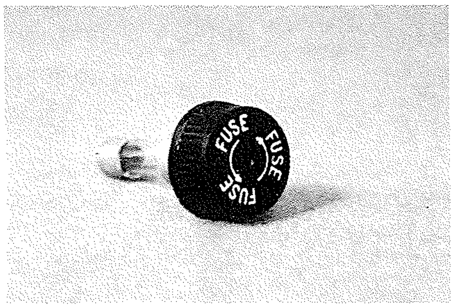


Figure 2. Type 422 Oscilloscope 3-ampere fuse holder with the thin-shell back pierced to allow insertion of a VTVM lead.

Here is a simple method for checking, under normal load conditions, the charge remaining in the battery pack of a Type 422 Oscilloscope.

First modify the 3-ampere fuse holder by piercing a hole thru the thin-shell back (see Figure 2). The thin-shell is composed of a plastic material and quite easily pierced with a metal scribe. To check the battery voltage, turn the POWER MODE switch to the INT BATT. position, turn the front panel POWER switch to ON, and insert one lead of a VTVM in the hole pierced in the 3-ampere fuse holder and connect the other lead to ground.

This method allows an accurate check of battery-pack voltage without removing the pack or power supply from the instrument.

TYPE 527 AND TYPE RM527 WAVEFORM MONITORS — USE WITH A GENERAL ELECTRIC TYPE TV83 DEMODULATOR

The following information concerns Type 527 and Type RM527 Television Waveform Monitors located in television transmitter installations, and then, only when they are used in conjunction with a General Electric Type TV83 Demodulator to monitor percent of modulation.

The flag pulse produced by the TV83 Demodulator will charge the coupling capacitor (C29) in the Type 527 and Type RM527 to a greater-than-normal value. This overcharge will exist for about 2 ms. While it exists, the over-charge will deactivate the Trigger and DC Restorer circuits in the Type 527 and Type RM527. During this period, the black level of the waveform under observation will be displaced about 30 IRE units above or below its normal level.

The solution to the problem is:

1. In the Sweep Trigger circuit of the Type 527 or Type RM527, remove the cathode lead of D32 (a 6061 diode) from ground.
2. Connect the cathode lead of a second 6061 diode (Tektronix part number 152-0061-00) to the cathode lead of D32.
3. Connect the cathode lead of the new diode to ground.
4. Install a 560 k ½ W, resistor (Tektronix part number 315-0564-00) between the junction of the two diodes and the —140 V supply.

(Figure 4 is a partial schematic showing the above four steps.)

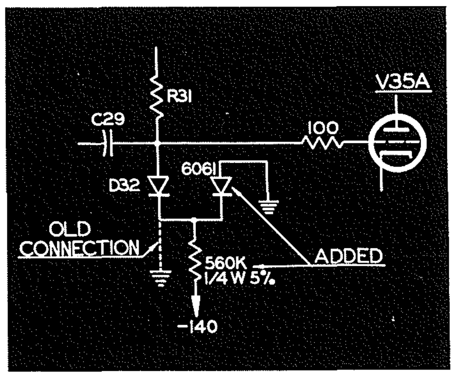


Figure 3.

5. In the DC Restorer portion of the Vertical Amplifier circuit, change the capacitor, C582, from a 100 pF to a 0.0033 μF capacitor (Tektronix part number 283-0051-00).

If the instrument you are concerned with is a Type 527 with a serial number below 745, or a Type RM527 with a serial number below 1190, we suggest you consult your Tektronix Field Engineer before attempting the above improvements.

BENT BNC CONNECTORS

Occasionally a female BNC connector will encounter an impact and become bent so it is no longer round. Often you can avoid the tedious and time-consuming job of replacing this damaged connector. If the connector is not too badly bent, the driver end of an Excellite #6, 3/16" nut driver makes an excellent tool for straightening it. The driver has just the right outside dimension to allow its insertion in the connector. After insertion, a little judicious wobbling will generally return the connector to a usable condition.

ADDITIONAL INFORMATION ON TEKTRONIX TECHNICAL PUBLICATIONS

Service Scope Number 39, August 1966 detailed some of the Tektronix Technical publications that are currently available. We are listing more of these items below and also some information regarding Technical Data which is obsolete and not now available.

TEST SET-UP CHARTS

These charts are reproductions of the front panels of Tektronix Oscilloscopes (combined with plug-in units where applicable). They enable an operator to set up the front panel controls for a particular display or series of displays. Charts are available in pads of 100 for the following instrument/plug-in arrangements.

INSTRUMENT	PART NUMBER
422	070-0513-00
453	070-0529-00
502	070-0482-00
502A	070-0488-00
503	070-0483-00
531	070-0492-00
532	070-0493-00
541	070-0494-00
545A/CA	070-0481-00
545A/R	070-0485-00
545A/Z	070-0486-00
547/1A1	070-0479-00
561A/2A60/2B67	070-0540-00
561A/3S76/3T77A	070-0548-00
567/3S76/3T77/6R1	070-0487-00
567/3S76/3T77A/6R1A	070-0547-00
567/3A2/3B2/6R1A	070-0541-00
570	070-0484-00
575	070-0480-00
575/MOD 122C	070-0489-00
262 Program Card	070-0490-00
262 Aux. Program Card	070-0491-00

TECHNICAL ARTICLE REPRINTS

Service Scope Number 35, December, 1965 carried a list of reprints that were available at that time. Stocks of the following are now exhausted:

Pulse Reflections Pin Down Discontinuities

How to Get More Out of Your Spectrum Analyzer

Measuring the Cost of Programmed Instruction

How to Measure High Current Recovery Lines in Signal Diodes

The following reprints are available in addition to those shown in Service Scope Number 35.

Current Measurements at Nanosecond Speeds by Murlan R. Kaufman. EDN (Electronic Design News). October 1965. Uses and applications of Tektronix High Frequency Probes and current transformers.

Advances in Storage Scopes by Donald C. Calnon. ELECTRONIC INDUSTRIES, February 1966. A description of recent advances in Tektronix Bistable storage CRT's and oscilloscopes.

Interpreting Spectrum Analyzer Displays by Morris Engelson, MICROWAVES, January 1966. A review of typical displays illustrating the versatility of Spectrum Analyzers in microwave measurement.

Monitoring of Vertical Interfield Test Signals by Charles Rhodes, JOURNAL OF THE S.M.P.T.E. (Society of Motion Picture and Television Engineers) February 1966. Methods of interpreting and displaying, with the aid of Tektronix TV Waveform Monitor, VIT signals which permit continuous quality control of TV signals.

Solid State Oscilloscope Circuitry by Tektronix Engineering Staff, ELECTRONIC PRODUCTS, February 1964 describes the development of the Type 647 oscilloscope circuitry.

Where to Use Storage Scopes by Geoffrey Gass, ELECTRONIC PRODUCTS, November 1965. Six applications for the storage scopes showing the display convenience available with storage facilities.

OBSOLETE PUBLICATIONS

The following is a list of current publications that should be ordered instead of the obsolete publications shown in the left-hand column. These obsolete publications may be available in limited quantities but, in most cases, have not been up-dated since 1960 or so. Those marked * are out of stock completely.

OBSOLETE PUBLICATION	REPLACED BY (Order Part No.)	CURRENT PUBLICATION
Fundamental Electronic Concepts for oscilloscope use and maintenance (1956)*	070-0190-00	A primer of Waveforms and their Oscilloscope Displays
'Junction Function' (1960)*		Programmed Instructions, Volumes 1-7. Basic Semi-conductors.
Calibrating the 181 Time-mark Generator (FIP-2) 1960	070-0292-00	Type 181 Instruction Manual
Adjusting the Delay Line and VA in the 541/545 (FIP 4) 1958	070-0203-00 070-0198-00	Type 541 Instruction Manual Type 545 Instruction Manual
310 Condensed Operating Information (FIP-6) or 310A Condensed Operating Information (FIP-6A) or 310A Recalibration and Trouble shooting (FIP-9)	070-0244-00	310/310A Instruction Manual
Calibrating the Type 105 square wave generator. (FIP-7) or Operating Information on the Type 105 (FIP 11581)	070-0371-00	Type 105 Instruction Manual
Type 517 re-calibration procedures (FIP-1282)	070-0229-00	517/517A Instruction Manual
Notes on the Practical Photography of Oscilloscope Displays (FIP-3)*	070-0383-01 070-0527-00	C12 and C27 Camera Manual and C30 Camera Manual
Interpreting Oscilloscope Displays of Magnetic Ink Testers* (FIP 10)	070-0283-00	Magnetic Ink Character Recognition
Frequency Comparisons using roulette patterns. (061-0147-00, A2024)	Service Scope No. 26 June 1964	(Up-dated in Service Scope article)

These reprints and publications are offered on a first come first served basis. When quantites are exhausted they will not be reordered.

For price and availability details concerning all the above described publications and any other Technical Publication originated by Tektronix please contact the Tektronix Field Office, Distributor or Representative in your area or write to

International Marketing
Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97005
U.S.A.

or

Tektronix Limited
P.O. Box 36
St. Peter Port
Guernsey, Channel Islands
British Isles

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon, U.S.A. 97005

N. VAN EYK
DEPARTMENT OF TRANSPORT
T & E SYSTEMS LAB
BOX 4028, STATION E
OTTAWA, ONTARIO, CANADA

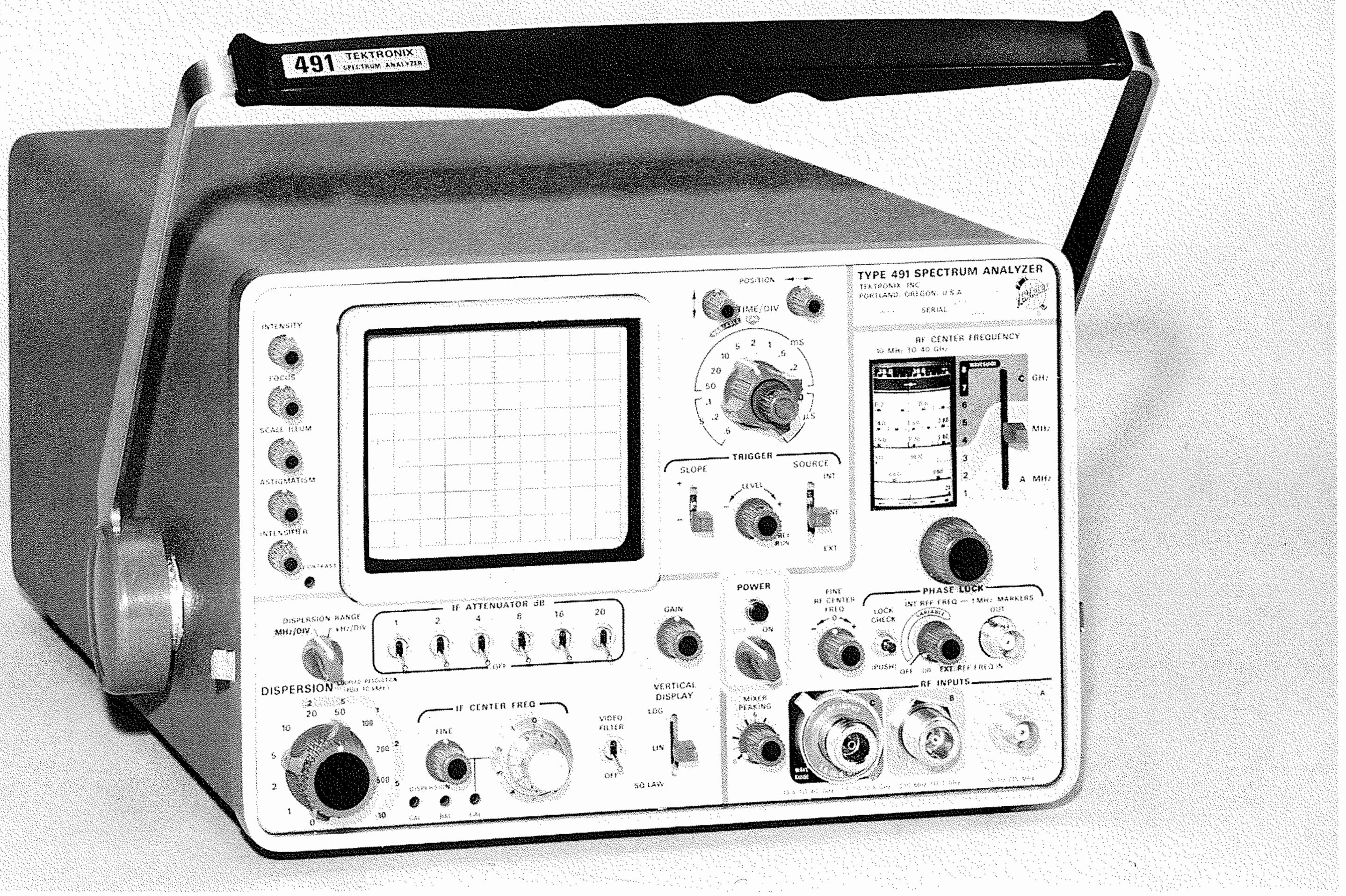
4/66

Service Scope

TEKTRONIX®

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 41 PRINTED IN U.S.A DECEMBER 1966



INTERPRETING SPECTRUM ANALYZER DISPLAYS

by Morris Engelson
Project Engineer
Tektronix, Inc.
Beaverton, Oregon

Reprinted from Microwaves, January 1966 issue.

Here is a portfolio of typical displays illustrating the versatility of spectrum analyzers in microwave measurement. By their clarity, these photos also provide a standard for proper instrument and equipment settings.

INTRODUCTION

Spectrum Analyzer displays illustrated in this article include: frequency stability (long- and short-term), amplitude modulation, frequency modulation, pulse modulation, ECM measurements, time-domain measurements, balanced modulator adjustment, antenna pattern measurements, video pulse spectra, and wide-dispersion measurements.

It is assumed that the reader is reasonably familiar with the operating principles of the superheterodyne spectrum analyzer. Therefore, the accompanying discussion stresses the interpretation of the displays rather than the procedures to generate them. For background reading, however, the appended bibliography is suggested.

All displays are actual, unretouched photos. Figures 1 through 33 were taken by Russ Myer of Tektronix using the following Tektronix instruments: spectrum analyzer plug-ins—1L10, 1L20, 1L30, 3L10; oscilloscopes—547, 549, 555, 564; time domain plug-ins—1S1, 3B4; signal sources—114, 184, 190. Figures 34 and 35 were taken by George Thiess of Microwave Physics Corp.

In all photos each horizontal division is one cm.

FREQUENCY STABILITY

The spectrum analyzer can measure both long- and short-term frequency stability. But the measurement is limited by:

(1) Spectrum Analyzer Stability. Obviously oscillator stability cannot be measured if the unit under test is more stable than the oscillators used in the spectrum analyzer.

(2) Resolution Capability. The analyzer's ability to determine the type and/or source of the instability depends strongly on the instrument's resolution bandwidth. For example, we cannot determine whether an oscillator is FM'ing at a 60 or 120 hertz rate when spectrum analyzer resolution is 500 hertz.

Short-term stability. This measurement concerns fast frequency changes such as those caused by power-supply noise and ripple, vibration or other random factors.

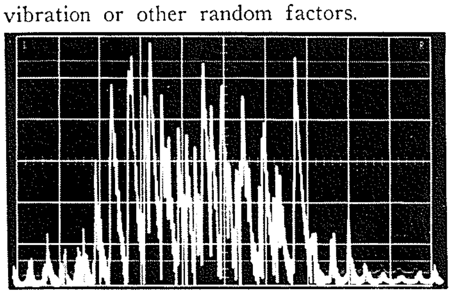


Figure 1.

Fig. 1 shows the random FM characteristic of a 3-GHz klystron. Spectrum analyzer dispersion is 2 kHz/cm and the resolution is 1 kHz. Oscillator FM is about 10 kHz—equivalent to 3 ppm.

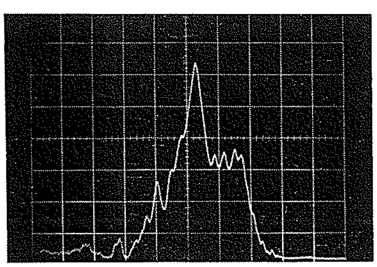


Figure 2.

A short-term stability measurement taken on a storage scope is shown in Fig. 2. A stored display is convenient here because of the extremely slow sweep speeds necessary to narrow-dispersion displays. Dispersion is 50 Hz/cm, resolution is 10 hertz and the input signal is 60 MHz. The test signal has a spectral width of about 150 hertz. This is equivalent to a stability of 2.5 ppm.

Long-term stability. Here we show the measurement of frequency drift as a function of time. The procedure depends on the characteristics of the spectrum analyzer used. One could photograph the screen at given intervals, and compare the position of the signal on the various photographs. If the spectrum analyzer has an auxiliary vertical output capable of driving a paper chart recorder, a permanent record can be obtained without photography.

The use of a storage oscilloscope is even more convenient with the scope set on a single sweep and triggered at appropriate intervals, thus storing a complete record of drift on the CRT.

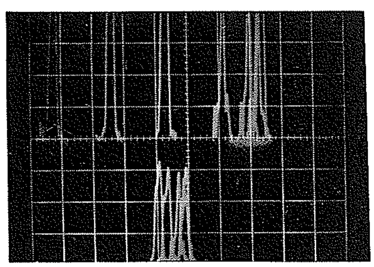


Figure 3.

For the storage-scope photo of Fig. 3, spectrum-analyzer dispersion is 1 kHz/cm, and the input frequency is 60 MHz. The upper half of the screen shows the drift of an unstabilized oscillator as it was heated. The oscilloscope was manually triggered at one-minute intervals. The drift was about 2 kHz per minute during the first three minutes, but diminished in rate thereafter, becoming nearly stable by the sixth minute. The total drift is on the order of 6.5 kHz or 108 ppm.

Temperature compensation can be computed easily since the amount and direction of drift is known. The lower half of the photo shows the drift after modifying the oscillator. Total drift is now about 1 kHz, an improvement of 6.5:1.

AMPLITUDE MODULATION

Modulation frequency and modulation percentage are the quantities usually desired in an AM measurement. Spectrum analysis is particularly useful in complex situations such as multi-tone modulation or overmodulation.

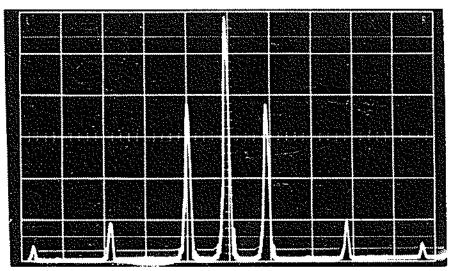


Figure 4.

Fig. 4 shows an overmodulated AM signal. Note the characteristic AM spectrum, consisting of a carrier and two sidebands, and the presence of additional, unwanted sidebands. Spurious sidebands, together with primary sidebands where amplitude is greater than one-half the carrier (100% modulation yields sidebands which are one-half the carrier amplitude) positively identify overmodulation.

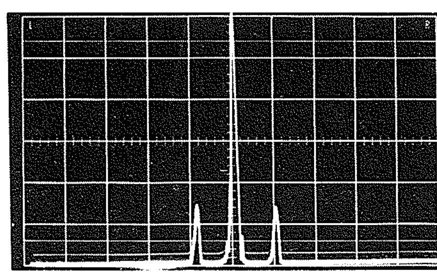


Figure 5.

Fig. 5 shows the same signal, but with the modulation reduced to 50%. The dispersion of the spectrum analyzer is 1 kHz/cm; the vertical display is linear. Thus, the modulating frequency is seen to be 1 kHz. Since the sideband amplitude is one-quarter that of the carrier, the modulation is 50%.

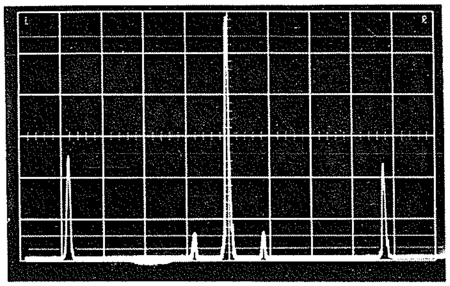


Figure 6.

Fig. 6 was photographed at a dispersion of 2 kHz/cm; vertical display is linear and center frequency is 60 MHz. Observe that the 60-MHz carrier is modulated at two frequencies; 1.6 and 7.5 kHz. Modulation is approximately 85% at 7.5 kHz and 20% at 1.6 kHz.

Overmodulation can be distinguished from two-tone modulation in two ways, evident by comparison of Figs. 4 and 6: (1) Spacing between overmodulated sidebands is equal while two-tone sidebands are arbitrarily spaced; (2) The amplitude of overmodulated sidebands decreases progressively from the carrier, but amplitude of two-tone sidebands is determined by the modulation percentage and can be arbitrary.

FREQUENCY MODULATION

FM measurements generally concern modulation frequency, spectral width, index of modulation and deviation. A typical FM

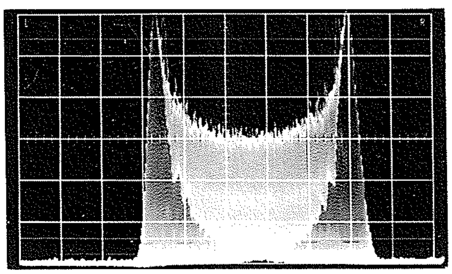


Figure 7.

spectrum is shown in Fig. 7. Dispersion is 200 kHz/cm and the spectral width is about 1 MHz. The exterior modulation envelope, typically resembling a $\cos^2$ curve, identifies the frequency modulation. The interior envelope appears on the screen because the FM rate is of the same order as the analyzer's resolution bandwidth. Consequently side bands are not resolved adequately and the trace cannot return to the base line at every pulse.

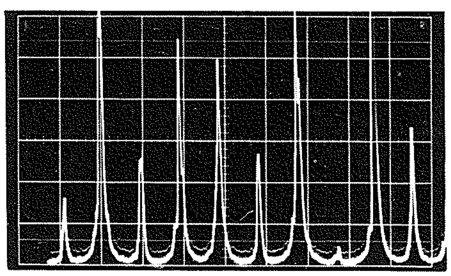


Figure 8.

The same FM signal appears in Fig. 8 but the dispersion has been reduced to 10 kHz/cm and the resolution is 1 kHz. The double-envelope display does not occur and the sidebands are clearly visible. Modulation frequency is 10 kHz.

FREQUENCY DEVIATION

There is no clear relationship between spectral width and deviation, since, in theory, the FM spectrum extends to infinity. But in practice, the spectral level falls quite rapidly as shown in Fig. 7. Experience indicates that the deviation is on the order of ½ the observed spectral width.

Very accurate deviation measurements can be obtained if the modulation frequency can be varied. It can be shown that for FM the carrier goes to zero at a modulation index (ratio of deviation to modulating frequency) of 2.4; other nulls occur at other modulation indices—e.g., the second null occurs at an index of 4.8.

This knowledge is the basis of a very powerful deviation measurement method known as the carrier null method. Figs. 9, 10 and 11 demonstrate this method. These figures were taken at a dispersion setting of 200 kHz/cm and a resolution of 100 kHz.

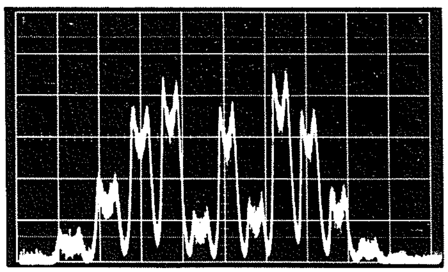


Figure 9.

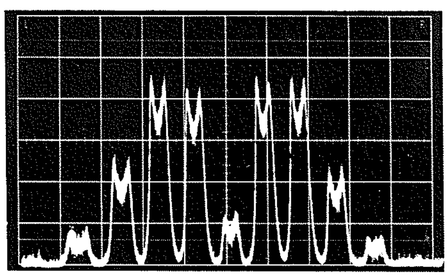


Figure 10.

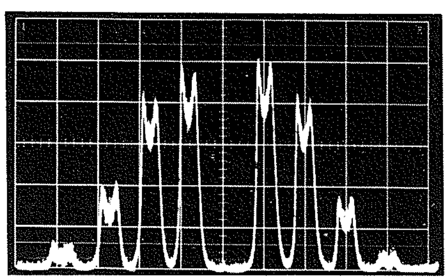


Figure 11.

Note that the spectral width is the same as in Fig. 7 but the modulating frequency has been increased so that individual sidebands can be resolved. In all three figures, the signal has been adjusted so that the carrier is at the center of the screen.

Fig. 9 shows a fairly large carrier. In Fig. 10, the modulation frequency is increased and the carrier level has decreased. In Fig. 11, the modulation frequency is increased further so that a null occurs at the position of the carrier. Since the observed modulating frequency is 200 kHz and since the observed index of modulation is 2.4, the deviation is 480 kHz.

PULSE MODULATION

Square pulses—A pulse-modulated signal generates a complex spectrum of the familiar sin x/x type. For example, a square pulse generates a spectrum described by $\sin \pi ft/\pi ft$, where t is pulse width and f is frequency deviation from the carrier. Fig. 12 shows the spectrum of a 1-GHz carrier modulated by a 0.67-μs square pulse. Observe that the spectrum is entirely above the baseline, whereas Fourier theory indicates that adjacent lobes should be out of phase by 180 deg. This phenomenon occurs because the spectrum analyzer is insensitive to phase. A second apparent inconsistency is that while the spectrum should be (in theory) solid, the display consists of vertical lines. This stems from the fact that the superheterodyne spectrum analyzer is not a real-time device. It takes many pulses to trace out the spectrum. Thus, each vertical line represents the sampling of one pulse.

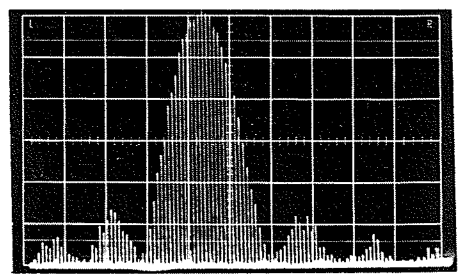


Figure 12.

Now we can manipulate the spectrum-analyzer controls to determine the characteristics of the signal. In Fig. 12 the spectrum-analyzer dispersion is 1 MHz/cm and the vertical display is linear. For a square pulse the theoretical pulse width $t = 1/f_o$, where f_o is the spectral sidelobe width. From Fig. 12, $f_o \simeq 1.5$ MHz. Therefore $t = 0.667\ \mu$s. Assuming that the vertical display is perfectly linear, we find that the ratio of main lobe to first sidelobe is 6:1.2. This is equivalent to 14 dB. More accurate measurement using the spectrum analyzer's calibrated attenuators gives a ratio of 13 dB. Theoretically, the main lobe is 13.2 dB greater than the first sidelobe.

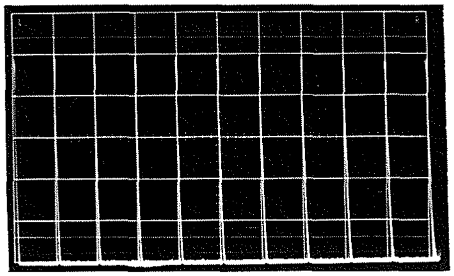


Figure 13.

Fig. 13 shows the same signal but with the dispersion set to zero. (This means that the sweep is only in time rather than in frequency; the analyzer is now a microwave receiver with a CRT readout). The display is merely a set of equally spaced lines. Since each line represents a pulse, the pulse rate can be easily measured. Here the scope is sweeping at a 1-ms/cm rate; one cycle of the modulating pulse requires 1 ms. The pulse rate is therefore 1 kHz.

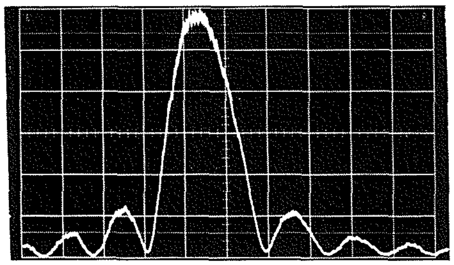


Figure 14.

As previously indicated, it is not the lines themselves, but only their envelope that is of interest. Sometimes it is advantageous to present an integrated display showing only the outline of the spectrum. Such a display, shown in Fig. 14, is obtained by using a postdetection (video) filter. This kind of display has several advantages: The baseline and its accompanying glare are eliminated and weak signals are more apparent. Noise is reduced automatically by integration and anomalies are removed. On the other hand, bandwidth and sensitivity are reduced (often by 1 to 5 dB). Sweep speed also decreases.

Sometimes it is desirable to limit the signal's spectral width by filtering, pulse shaping, etc. It then becomes important to identify low-level signals. This is accomplished by operating the analyzer in its logarithmic mode so that low level signals are enhanced relative to large signals.

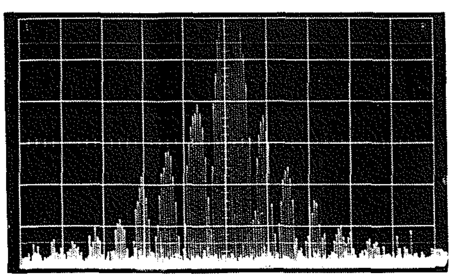


Figure 15.

In the logarithmic display of Fig. 15, the main lobe and the first eight side lobes are discernible.

PULSES IN THE PRESENCE OF FM

All signal sources, regardless of how carefully designed, have a certain amount of incidental FM. This limits the type of pulse modulation that can be used.

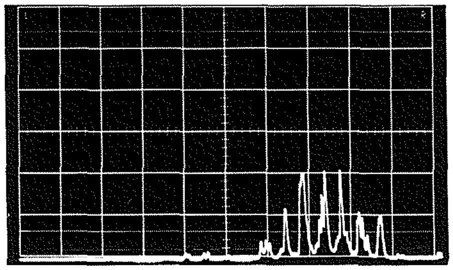


Figure 16.

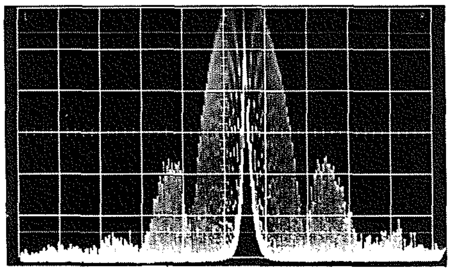


Figure 17.

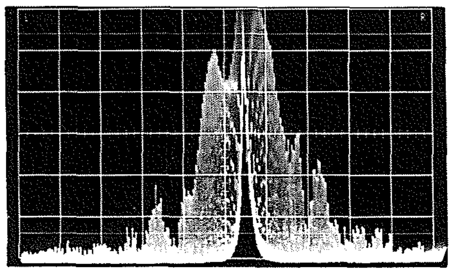


Figure 18.

Fig. 16 shows a carrier with incidental FM deliberately applied. Analyzer dispersion is 5 kHz/cm and FM spectral width is on the order of 12 kHz. Fig. 17 shows the carrier with the FM removed. (The large signal in the center of the main lobe is due to a poor on-off ratio in the modulator. This phenomenon is discussed in another section.) Fig. 18 shows the combination of FM and pulse modulations. Note that the signal is not symmetrical and that the sidelobes are uneven. An extensive discussion of pulsed RF in the presence of FM is found in Montgomery.[1]

EFFECTS OF PULSE SHAPING

Spectral width can be controlled by several means, including that of pulse shaping. The effect of pulse shape on spectral distribution s illustrated in the following spectrum analyzer displays. Fig. 19 shows the

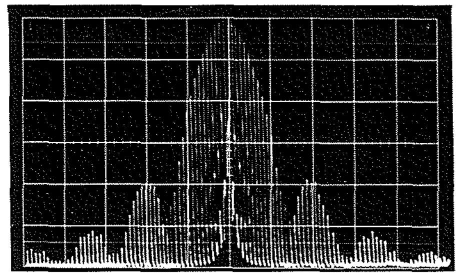


Figure 19.

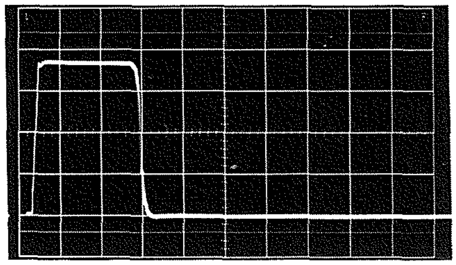


Figure 20.

conventional sin x/x spectrum of an RF signal modulated by the square pulse of Fig. 20.

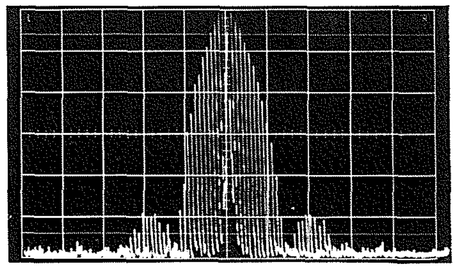


Figure 21.

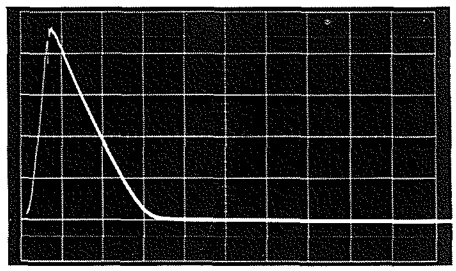


Figure 22.

Fig. 21 shows an RF signal modulated by the asymmetrical triangular pulse in Fig. 22. Note that the sidelobes in Fig. 21 are considerably lower than those in Fig. 19.

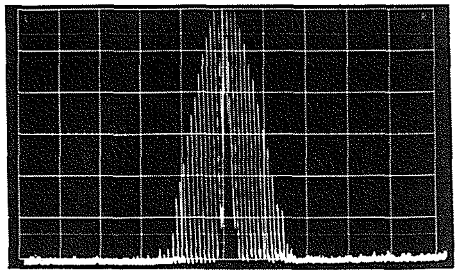


Figure 23.

Fig. 23 shows an RF signal modulated by the symmetrical triangular pulse shown

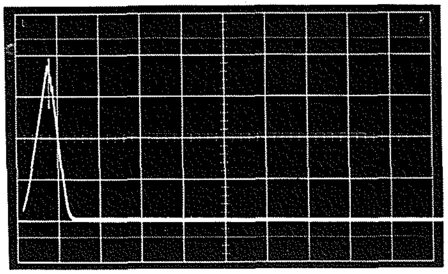


Figure 24.

in Fig. 24. Note that this spectrum is almost completely devoid of sidebands. As the effective pulse width changes, so does the width of the main lobe. The spectrum analyzer dispersion was adjusted between Figs. 19, 21 and 23, so that the main lobe would continue to occupy approximately the same number of divisions—this to better illustrate the disappearance of the sidelobes.

ECM MEASUREMENTS

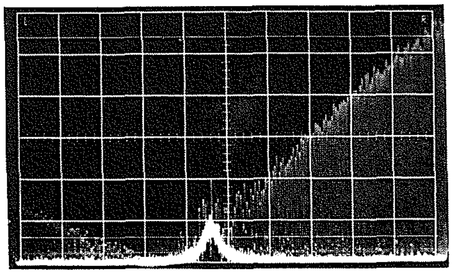


Figure 25.

In countermeasure work, intelligence is sometimes transmitted so as to be masked by another signal. An example is the transmission of information at the null point of a pulsed RF signal. Fig. 25 shows transmission of a 100-kHz-wide signal at the null point. The pulsed RF signal has been expanded using the scope horizontal magnifier control. The cw signal at the null point is clearly discernible on the analyzer but less so to a ferret receiver.

PULSE MODULATOR ON-OFF RATIO

Sometimes the carrier to be pulsed is not turned off completely during the pulse-off time. This results in a combination of cw and pulsed signals. Measurement of on-off ratio is complicated by the fact that the spectrum analyzer has higher sensitivity for cw signals than for pulsed signals. The ratio in sensitivity is $3/2\ t\beta$, where t

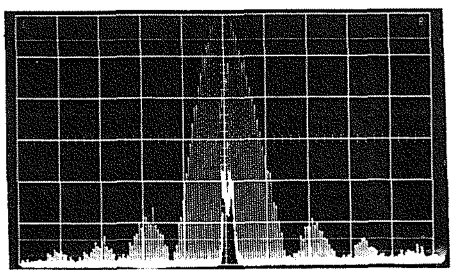


Figure 26.

is pulse width and β is spectrum analyzer's 3-dB bandwidth (resolution bandwidth).

Fig. 26 shows a typical pulsed RF signal generated by a modulator that has a poor on-off ratio as indicated by the large signal within the main lobe. Dispersion is 0.5 MHz/cm (pulse width 1.3 μs), resolution bandwidth is 100 Kc and the vertical display is linear. To find the on-off ratio we compute the loss in pulse sensitivity relative to cw:

$3/2\ (1.3)\ (10^{-6})\ (10^{5}) = 1.95 \times 10^{-1}$

. . . . . $20 \log_{10} 1/0.195 = 14.2$ dB

Next, from the vertical deflection in Fig. 26, the cw signal amplitude is 1/3 that of the pulsed signal. This is equivalent to a difference of $20 \log_{10} 3 = 9.5$ dB. The total on-off ratio is $9.5 + 14.2 = 23.7$ dB.

DUAL-BEAM SPECTRUM ANALYSIS

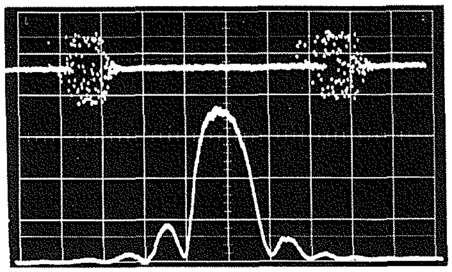


Figure 27.

It is sometimes useful to simultaneously observe both the RF spectrum and modulating waveform, as when shaping a pulse to generate a desired spectrum. With a dual-beam arrangement, we simultaneously observe changes in the modulating pulse and the resultant frequency spectrum. With microwave sampling scopes we can observe both the modulated carrier and the modulating pulse in time domain. Fig. 27 shows a dual-trace display of a 1-GHz carrier modulated by a 1-μs pulse. The upper trace is in time domain at 1 μs/cm. The lower trace is in frequency domain at 1 MHz/cm.

TIME-DOMAIN MEASUREMENTS

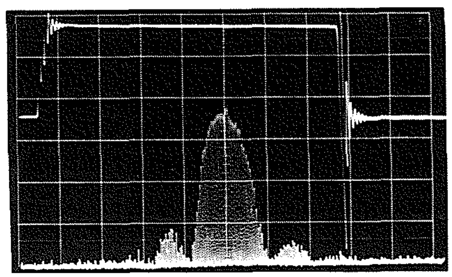


Figure 28.

Some spectrum analyzers can function both in time and frequency domains. Such instruments are not meant to replace oscilloscopes, as their sensitivity is rather poor (100 mV/cm) and their input impedance is low (50 Ω). In microwave systems, however, where detectors like to be terminated in 50 Ω, useful information can be obtained with such analyzers. Fig. 28 is a double-exposure photo showing the time domain characteristics of the modulating pulse as the upper trace and the output spectrum as the lower trace. The same display could have been obtained with a dual-beam oscilloscope.

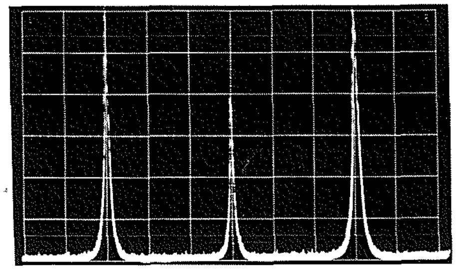


Figure 29.

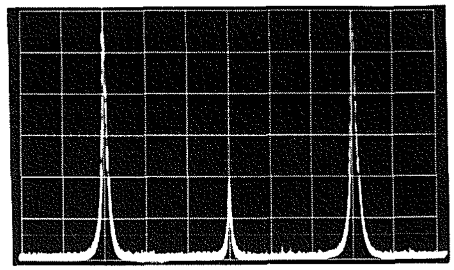


Figure 30.

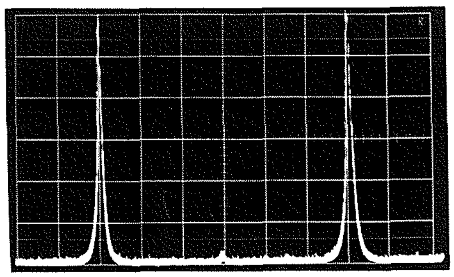


Figure 31.

BALANCED-MODULATOR ADJUSTMENT

Balanced modulators often are used to impose suppressed-carrier modulation. Figs. 29 to 31 illustrate how this application can be monitored by a spectrum analyzer. Fig. 29 shows a modulator that is not well balanced. The carrier is almost as large as the side bands. The balance controls are now adjusted to an intermediate stage of performance as shown in Fig. 30. The fully adjusted system, with the carrier almost entirely suppressed, yields the spectrum of Fig. 31.

ANTENNA-PATTERN MEASUREMENTS

The spectrum analyzer also can be used to provide antenna-pattern data. Assume that the transmitting antenna under test is stationary. A transmitted pulse is picked up by a receiving antenna and displayed on the analyzer as a typical sin x/x spectrum. If the analyzer's input frequency is centered on the main lobe and the dispersion reduced to zero we get a set of equal amplitude lines across the screen. Each line represents one transmitted pulse.

Assume now that the test antenna is rotating. A very strong signal is received when the pickup antenna is located in the main lobe of the transmitting-antenna pattern; signals are weaker in the sidelobes and minimal in the pattern nulls. If the spectrum analyzer is swept very slowly, so slowly in fact that one sweep corresponds to 360 deg. of antenna rotation, the CRT screen can be calibrated in degrees to display a complete antenna pattern.

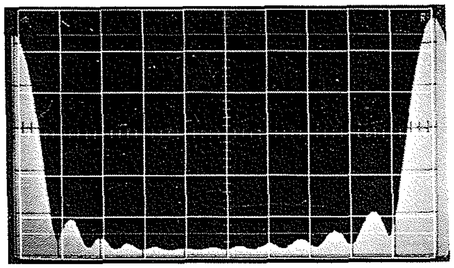


Figure 32.

Fig. 32 shows such a simulated antenna pattern. The ten horizontal screen divisions correspond to 360 deg. of antenna rotation, 36 deg. per division. Since the vertical display is linear with voltage we can compute amplitude differences directly. Thus, 3 dB is 0.707 of maximum deflection or 0.707 x 5.8 = 4.1 divisions.

The main lobe of the pattern is about one horizontal division wide at the 4.1 division height and the antenna therefore has a beam width of about 36 deg. The center of the screen corresponds to the 180-deg. position. The ratio of main lobe deflection (5.8 divisions) to that at 180-deg. rotation (0.2 divisions) is the antenna's front-to-back ratio, which for this antenna is 11.6, or 21.3 dB.

One precaution: the receiving antenna must have very low sidelobes and a narrow beam width in comparison to the transmitting antenna so as not to affect the recorded pattern. Keep in mind also that the analyzer must be swept quite slowly to record the pattern. A paper chart recorder or storage scope can therefore, be very helpful. Fig. 32 was displayed on a storage scope.

VIDEO PULSE SPECTRA

It is sometimes useful to examine the Fourier spectrum of a video-pulse train directly, without modulating a carrier. Whereas in a pulsed RF signal the spectrum is centered around the carrier frequency, the spectrum for a video pulse goes to zero frequency.

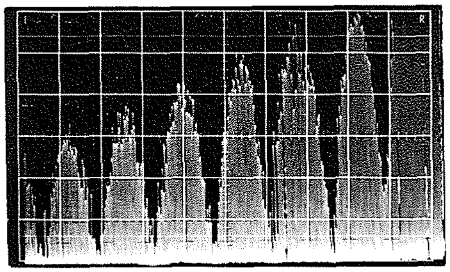


Figure 33.

Most spectrum analyzers having wide dispersions cannot display such low frequencies. However, some spectrum analyzers using balanced mixers for local oscillator suppression are suitable. Fig. 33 shows the spectrum of a 0.4-μs pulse. Analyzer dispersion is 2 MHz/cm.

WIDE DISPERSION MEASUREMENTS

A new class of spectrum analyzers having gigahertz dispersions recently has appeared on the market. The accompanying figures illustrate two applications of these new devices. Fig. 34 shows eleven signals spaced at 1-GHz intervals from 2 to 12 GHz. Analyzer dispersion is 10 GHz.

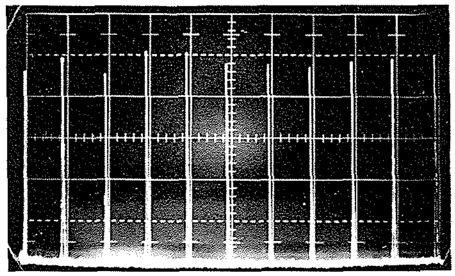


Figure 34.

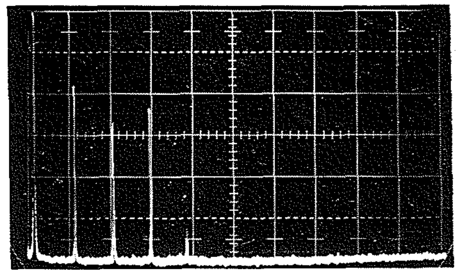


Figure 35.

Fig. 35 shows the harmonics of a 900-Mc MHz transistor oscillator. The spectrum analyzer is sweeping from 1.7 to 12.5 GHz. We observe that this oscillator has substantially no output beyond the 6th harmonic.

BIBLIOGRAPHY

Engelson, Weiss, and Frisch. "Oscilloscope Plug-In Spectrum Analyzers." Microwave Journal. March 1965.

Feigenbaum, M. H. "Introduction to Spectrum Analyzers." MicroWaves. April 1963.

Frisch, A., Engelson, M. "How to Get More Out of Your Spectrum Analyzer." MicroWaves. May 1963.

Myer, R. "Getting Acquainted with Spectrum Analyzers." Tektronix publication #A-2273.

REFERENCE

[1]Montgomery, Techniques of Microwave Measurements (New York: McGraw-Hill, 1945), RADLAB Series, Vol. XI.

SERVICE NOTES

TEKTRONIX PROBES — PROBE-IDENTIFICATION TAGS

While engaged in multi-probe applications, have you ever experienced frustration in quickly locating correlating probe ends or determining which probe cable led to which probe?

We have available, plastic probe-identification tags (see Figure 1) that help you locate correlating probe ends quickly and/or determine which probe cable leads to which probe.

These tags come in two versions, one version has a .125-inch center hole to fit around the smaller cable used on some of our probes, the other has a .178-inch — .185-inch center hole to fit around the larger cable used on other of our probes. The tags are packaged 20 tags of a center-hole size to a package — 2 tags each of ten colors.

For use on probes with the smaller cable order Tektronix part number 334-0789-00. For use on probes with the larger cables, order Tektronix part number 334-0789-01. Please order through your local Tektronix Field Engineer, Field Representative, or Distributor.

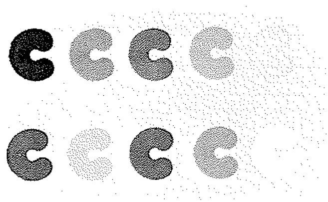


Figure 1. Probe Identification Tags

TYPE 310 AND TYPE 310A—CALIBRATION-PROCEDURE NOTES

In the Type 310 and Type 310A Instruction Manual, on page 5-12 of the Calibration Procedure section, paragraph "d" reads: "d. Connect the CAL OUT connector to the TRIG INPUT connector as well as to the INPUT connector." Change this to read: "d. Connect 0.2 V from the CAL OUT connector to the TRIG INPUT connector as well as to the vertical INPUT connector."

The specifications for the Type 310 and 310A call out 0.2 V as the trigger requirements for external trigger on these instruments. Failure to repeat the information in the calibration section of the instruction manual has caused confusion for some when calibrating these instruments. Our apologies to these people. We hope this information clears the confusion.

NEW FIELD MODIFICATION KITS

BLANK PLUG-IN

This field modification kit supplies the necessary hardware to construct a skeleton plug-in unit for use in a Tektronix Type 560 Series Oscilloscope. This kit is intended for those who wish to design their own special-purpose plug-in units.

From the information supplied in the kit, a skeleton plug-in unit can be constructed so as to be compatible with a specific Type 560 Series Oscilloscope or with several (or all) of these instruments.

The kit also supplies pertinent information so that the special plug-in may be designed to operate in conjunction with either a Tektronix-produced plug-in unit in a Type 560 Series Oscilloscope or with a second special plug-in unit.

This modification kit is applicable to the following Type 560 Series Oscilloscopes: 560, 561, RM561, 561A, RM561A (including MOD 210C), 564, RM564, 565, RM565, 567, and RM567.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0245-00.

TYPE 502 DUAL-BEAM OSCILLOSCOPE—VARIABLE TIME/CM

This modification adds a VARIABLE control to the TIME/CM switch on the Type 502 Oscilloscope. This provides a sweep rate continuously variable uncalibrated from 1 μsec/cm to over 12 s/cm.

Order through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 040-0221-00.

TYPE 524K TELEVISION OSCILLOSCOPE — PROBE POWER

This modification installs a probe power socket on the front panel of the Type 524D Television Oscilloscope. This allows a P500CF cathode-follower probe to be used with the oscilloscope. DC filament voltage for the probe's vacuum tube reduces hum to a minimum.

The P500CF Probe presents a low input capacitance with minimum attenuation.

This modification kit replaces the Type 524D Probe Power Modification Kit (Tektronix part number 040-0059-00) which provided AC filament voltage for the probe's vacuum tube. It will also convert a Type 524D with the 040-0059-00 modification kit installed from AC to DC filament voltage for the probe's vacuum tube.

Order through your local Tektronix Field Office Field Engineer Field Representative or Distributor. Specify Tektronix part number 040-0273-00.

CORRECTION NOTE

In the October, 1966 issue of Service Scope there is a typographical error on page 4. The set of equations just opposite Figure 4, as printed reads:

$$V_{oc_t} = \frac{V_{oc_1} \times 417\,k}{Z_{th_1} + 4.7\,k}$$

It should read:

$$V_{oc_t} = \frac{V_{oc_1} \times 4.7\,k}{Z_{th_1} + 4.7\,k}$$

USED INSTRUMENTS FOR SALE

1—Type 511 Oscilloscope, sn 111. Price: $175. Contact: R. R. Chittenden, Electro Mechanical Company, P.O. Box 7886, Portland, Oregon. Phone: 289-8885.

1—Type 517 Oscilloscope, sn 781, with power supply and probe, good condition. Would like cash or a Type 541 Oscilloscope with a Type 53/54 C Dual-Trace Plug-In Unit. Contact: G. L. Boelke, 505 Main Street, West Seneca, New York 14224.

1—Type 515A Oscilloscope, sn 1687. Contact: Mr. George Dupont, New York Stock Exchange. Phone: 212-HA 2-4200 x 463.

1—Type Q Transducer and Strain Gage Plug-In Unit, sn 1742. About 2 years old, new condition. Price: $275.00, FOB West Palm Beach, Florida. Contact: Jerry Strasser, Solitron Devices, Inc., 1177 Blue Heron Blvd, Riviera Beach, Florida. Phone: 305-848-4311.

1—Type 585A Oscilloscope; 1—Type 82 Dual-Trace Plug-In Unit; 1—Type 202-2 Scope-mobile® Cart; and 1—C12R Oscilloscope Camera with projected graticule. Available for immediate delivery. Price: 10% off catalog list price. Contact: Mr. H. Brawley, 25 Hemlock Street, Norwood, Massachusetts. Phone: 617-769-3888.

1—Type 511 Oscilloscope, sn 438, P11A CRT. Price: $150.00. Contact: R. S. Komp, Box 372, Fairhaven, New York 13064. Phone: 315-947-1921.

1—Type 131 Amplifier. Approximate age 14 months. Contact: Tom Thompson, Bemis Bag Company, 325 - 27th Avenue, N.E., Minneapolis, Minnesota.

1—Type 105 Square Wave Generator. Price: $175. 1—Type 112 Preamplifier; 1—Type 121 Preamplifier. Price: $110 each. 1—Type 180S1 Time Marker. Price $290. We are interested in either purchasing or trading for used Type 321 Oscilloscope and Type 575 Curve Tracer. Contact: Denes Roveti. Technical Director, Roveti Instruments, 1643 Forest Drive, Annapolis, Md. 21403.

1—Type 561A Oscilloscope, sn 6000; 1—Type 3S76 Dual-Trace Sampling Plug-In Unit, sn 402; 1—Type 3T77 Sampling Sweep Plug-In Unit, sn 340. Contact: Allen Avionics, P. O. Box 350, Mineola, New York.

1—Type 512 Oscilloscope, sn 1997, includes most modifications. Was completely overhauled in 1961. Contact: Mr. J. R. Harkness, Briggs & Stratton Corp., P.O. Box 702, Milwaukee, Wis. 53201. Phone: 414-461-6600.

1—Type 551 Oscilloscope, sn 757; 1—Type 53/54 C Dual-Trace DC Plug-In Unit, sn 20847; 1—Type 53/54 H Wide-Band High-Gain DC Plug-In Unit, sn 591. Excellent condition, less than 200 hours total operation. Price: $1400 total, or will sell separately. Contact: Dr. B. J. Wilder, Neurology, J. Hillis Miller Health Center, University of Florida, Gainesville, Florida. Phone: 904-376-3211, Ext. 5418.

1—Type 544 Oscilloscope; 1—Type 1A2 Dual-Trace Plug-In Unit; 1—P6016 AC Current Probe; 1—Type P Fast-Rise Test Plug-In Unit, sn 2530. About 4 years old, new condition. Price: $50.00.

USED INSTRUMENTS WANTED

1—Type 531, 532 or 533 Oscilloscope less plug-in. Please state condition and price when answering. Contact: Mr. J. R. Harkness, Briggs & Stratton Corp., P.O. Box 702, Milwaukee, Wisconsin 53201. Phone: 414-461-6600.

1—Type 515 or Type 535 Oscilloscope. Contact: Fidelitone, Nick L. Miku, 6415 North Ravenswood Avenue, Chicago, Illinois 60626. Phone: 312-274-0075.

Wanted to buy used Type 516 Oscilloscope. Contact: Tim Denning, Tim's Electronic Service, Houghton, Iowa. Phone: 319-469-2364.

Used 500 Series Oscilloscope, at least 15 MHz band. Contact: Jim Worthington, 301 Longview Drive, Monroeville, Pennsylvania.

1—Type 310 or Type 310A Oscilloscope. Contact: Mr. R. L. Goodman, Clark Dunbar, 325 Jackson St., Alexandria, Louisiana. Phone: 318-443-7306.

1—used Type 515 Oscilloscope. Contact: Mr. John Bohinko, 117 Abbot Street, Plains, Pennsylvania.

1—Type 543B Oscilloscope; 1—Type 1A2 Dual-Trace Plug-In Unit; 1—Type 1A7 Differential Amplifier Unit. Contact: Brooks Delecktro, 41 East 42nd Street, New York, New York 10017. Attn: Miss Brooks. Phone: 212-687-4940.

Used Type 536 Oscilloscopes and Type T Time-Base Generator Plug-In Units. Contact: Mr. Julie, Julie Research Laboratories, 211 West 61st Street, New York, New York. Phone: 212-Circle 5-2727.

For complete information contact your Field Engineer, Field Representative, or Distributor.

MISSING INSTRUMENTS

Following are the instruments reported to us in the past 60 days as lost or presumed stolen. With each instrument (or group of instruments), we list their legal owner. Should you have any information on the present whereabouts of these instruments, or information that might lead to their eventual recovery, please contact the individual or firm listed here as the owner. If you prefer, you may relay your information to any local Tektronix Field Office, Field Engineer, or Field Representative.

1—Type 533A Oscilloscope, sn 3465; 1—Type CA Plug-In Unit, sn 19411; 1—Type D Plug-In Unit, sn 8630; 1—Type Z Plug-In Unit, sn 541, were removed from the premises of Electramatic, Inc., over Labor Day weekend. Anyone having information concerning these instruments, contact Mr. Arnold Gilbertson, 3324 Hiawatha Avenue, Minneapolis, Minnesota 55406. Phone: PA 1-5074.

Mr. Forrest Barker with the Los Angeles City College, has lost his four 502 Oscilloscopes. The serial numbers are 8506, 8854, 9280 and 9779. Mr. Barker would appreciate hearing from anyone with information on the whereabouts of his instruments. His phone number is 213-633-9141, ext. 259.

1—Type 310A Oscilloscope, sn 21352. This instrument disappeared, and is presumed stolen, from a car about two months ago. If you have information concerning this instrument, please contact Mr. Bill Wise, Mosler Safe Company, Pittsburgh, Pennsylvania.

1—Type 516 Oscilloscope, sn 1539, was reported missing last week of September, 1966. Contact: M. J. Coppler, Florida Telephone Corp., Leesburg, Florida. Phone: 904-787-4525.

1—Type 422 Oscilloscope, sn 1672 disappeared and is presumed stolen from Jean C. Bisset, "GEWSEN" Western GEEIA Region, McClellan AFB, California 95628.

1—Type 321 Oscilloscope, sn 000106 presumed stolen. Anyone having information concerning this instrument please contact: Mr. Vourganas, Baird Electronics, 630 Dundee Road, Northbrook, Illinois. Phone: 312-272-2300.

1—Type 321A Oscilloscope, sn 1366 disappeared on approximately May 13, 1966. Contact: Univac, Plant 3, St. Paul, Minnesota.

1—Type 321A Oscilloscope, sn 00194 reported missing on October 25, 1966. Contact: Univac Division (Sperry-Rand), 3645 Warrensville Center Road, Cleveland, Ohio 44122. Attn: W. Uminski. Call Collect, Phone: 216-752-7000, Ext. 36.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

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