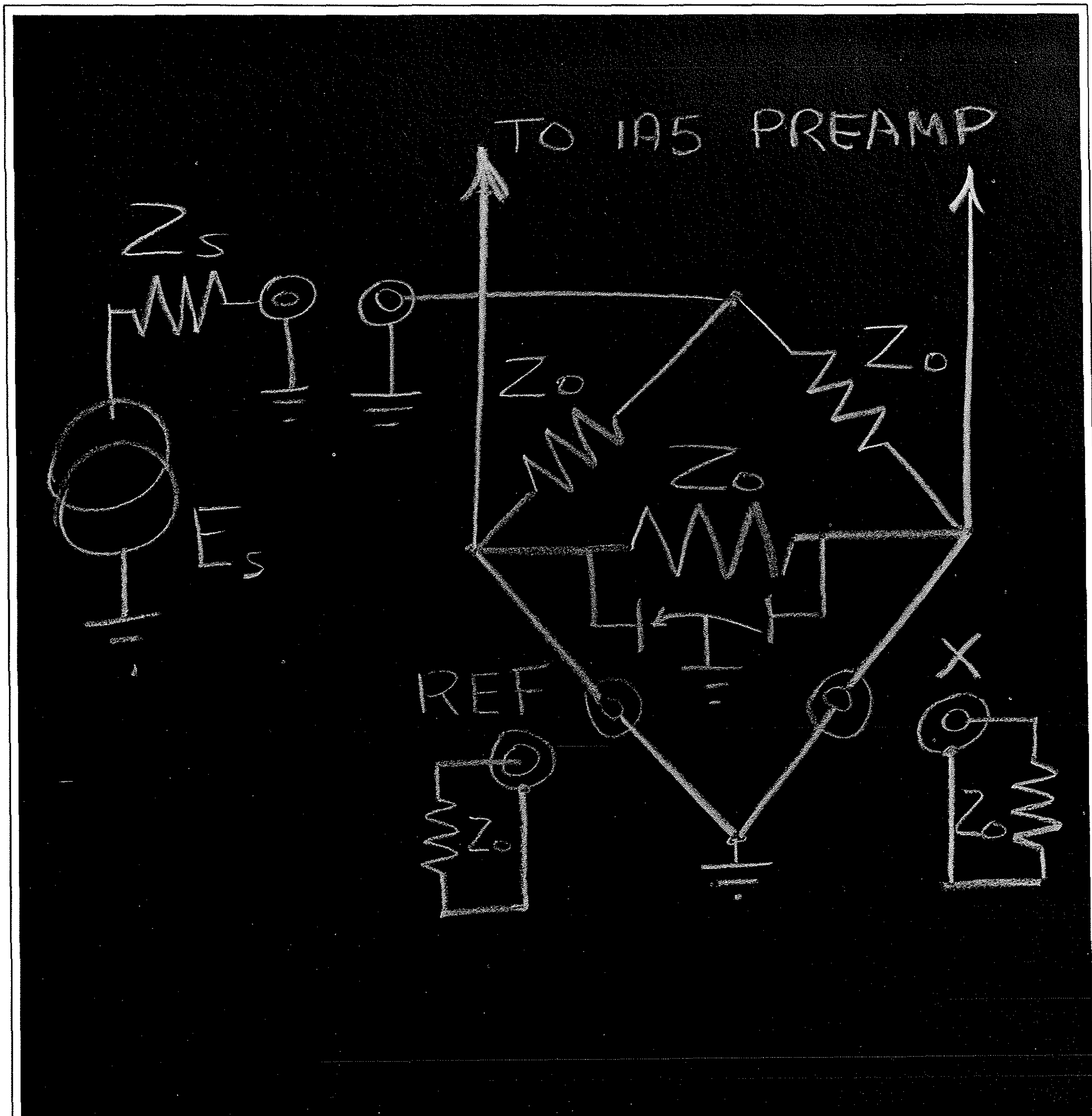
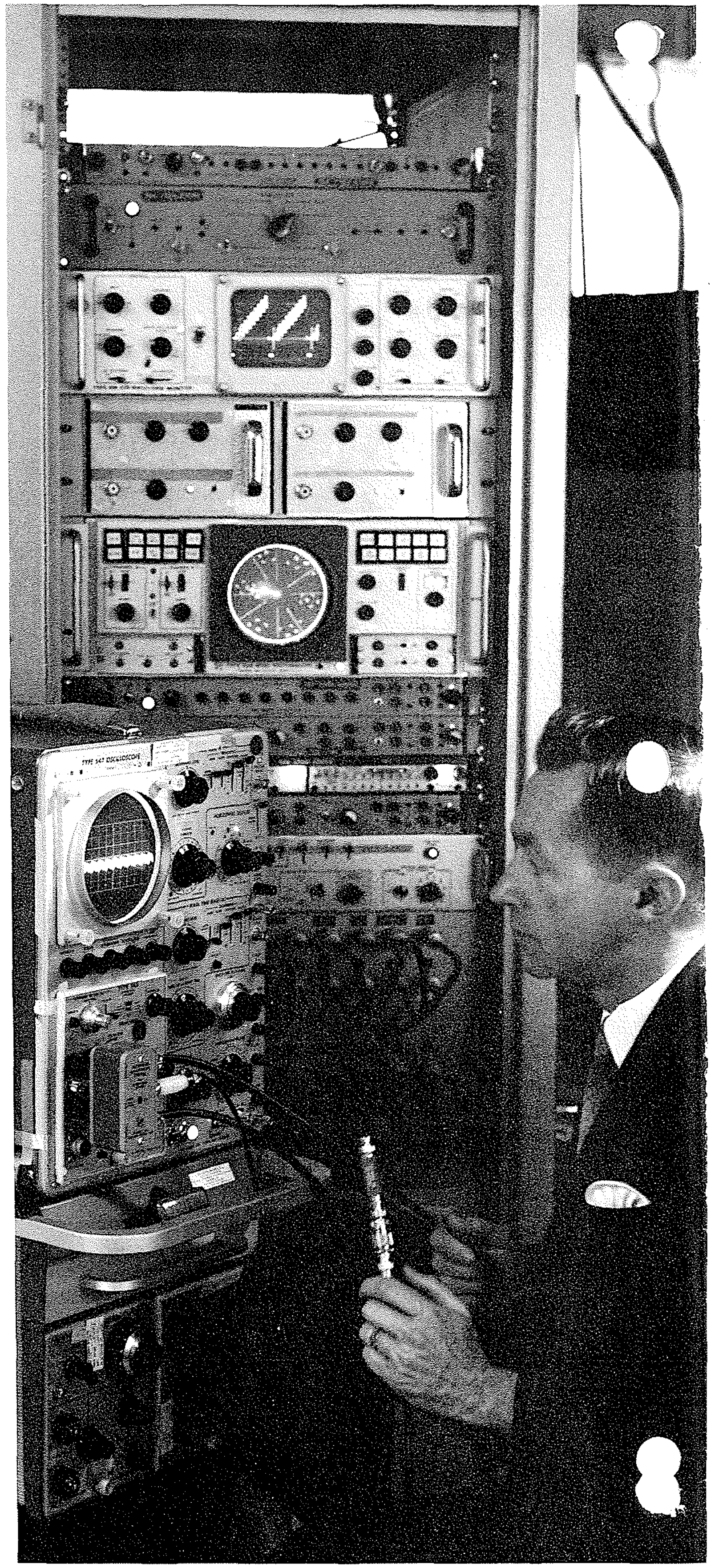
TEKSCOPE

AUGUST 1969



measuring return/loss



Return-loss measurements are a powerful tool for quickly indicating the extent of an impedance mismatch or a discontinuity in a video transmission system. The use of a 1-mV, DC-10 MHz differential preamplifier as an error detector allows direct observation of system performance over the complete video bandwidth.

Return-loss techniques accomplish basically two types of measurements. The simplest is the verification of the performance specifications of instrumentation.

The second area of interest for return-loss measurements is looking into long cable systems that may have a number of monitors, distribution amplifiers, etc., bridging the line. Return-loss can give the user a good measurement of the degradation contributed by each component of the video transmission system, including coaxial cable condition.

As a result, with proper test signals applied, return-loss measurements provide indications closely related to picture impairment.

COVER The Tektronix Return-Loss Bridge consists of a basic 75-Ω Wheatstone Bridge with a 1-mV, 10-MHz Type 1A5 differential amplifier null detector. *See story on page 2.*

At left: Charles Rhodes, Program Manager of Television, Low Frequency, and Medical Instrument Engineering, measures return loss.

Modern color TV broadcasting studios require that a number of monitors, processing amplifiers, distribution amplifiers, VTR's, oscilloscopes, and other equipment all be driven by a signal passing down a relatively long length of coaxial transmission line. In some cases, since the signal may pass several times through the same type of amplifier, a large cumulative error can result if the amplifier provides an incorrect source or load impedance to any frequency component of the video signal.

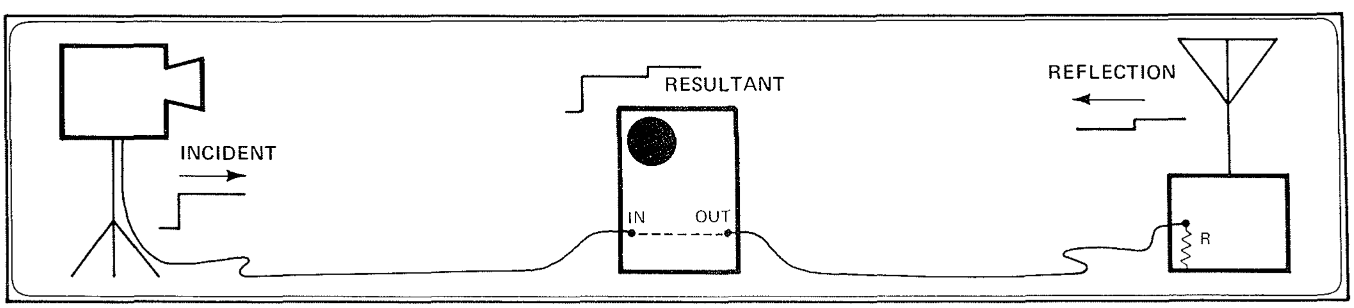
When coaxial transmission lines feed a number of different instruments, the method of making connections is important. For this reason, a loop-through technique is often used since transmission of wide-band video signals must be on constant impedance transmission lines. The impedance characteristic of the cable is critical to transmission quality and shielding requirements dictate that coaxial cables be used. If the input impedance, coaxial connectors and cable used within each instrument were perfect, no measurable effect upon the transmission would occur. Unfortunately these parameters are not perfect so a figure of merit of the quality of video transmission systems is important.

Looping a signal through an instrument means a portion of the transmission path the signal traverses is now within the instrument. Therefore, it is necessary to know what effect this additional signal path contributes to the overall video system. Because a connection must be made to the center conductor, an incorrect impedance can cause a mismatch and cause energy to be reflected. Ideally, the termination should be an impedance exactly equal to the characteristic impedance of the line to prevent reflections and match the two impedances in magnitude and phase.

If the two impedances are not matched, standing waves on the line produce erroneous voltage or current readings. Fig 1 illustrates a case where a camera is located 100 feet from a monitoring point. The coaxial cable runs from the camera, loops through the monitoring point and is terminated at the transmitter. If the transmission line is not perfectly impedance matched at the receiving end, energy will be reflected back. The monitoring point will observe the instantaneous sum of the camera signal and the signal reflected from the termination. Therefore, the signal measured at the monitoring point may differ considerably from the signal measured at the termination. As an exaggerated example, suppose an oscilloscope were displaying the signal at a point of minimum voltage—a minimum caused by relatively high standing wave ratio on the line. A second oscilloscope located 46 feet (¼ wavelength at 3.58 MHz) from the first will observe a drastically different display.

A typical transmission segment might consist of the connectors and cable (including loop-through facilities) connecting two active elements. The last point in the segment is the termination resistance into which the energy is delivered. Since the line effectively ends when a signal encounters the input impedance of an active element, information cannot be obtained beyond that point. Thus, a television transmission system is measured segment by segment. Return loss measures the amplitude and phase of the reflections developed from impedance discontinuities. Reflections can occur whether the discontinuity is in the line itself or caused by an instrument bridging the line.

Fig 1. The oscilloscope views the instantaneous sum of the incident and reflected signal.



For many years the effects of an impedance mismatch have been discussed in terms involving reflection coefficient (ρ), a standing-wave ratio (SWR), characteristic impedance of the transmission line (Z_o), and termination impedance (Z_t).

Transmission line theory develops the concept of a "reflection loss" which is derived from the reciprocal of the coefficient.

$$\rho = \frac{\text{Reflected Voltage}}{\text{Incident Voltage}}$$

Reflections are created because of impedance mismatch. Therefore, the reflection coefficient may also be expressed in terms of characteristic impedance and termination impedance.

$$\rho = \frac{\text{Reflected Voltage}}{\text{Incident Voltage}} = \frac{Z_t - Z_o}{Z_t + Z_o}$$

In the past few years, European and Australian TV engineers have referred to the term "return loss" (reflection loss). Return loss is being used by Tektronix and other manufacturers of video equipment to specify the performance characteristics of inputs and outputs of 75-Ω TV equipment. By definition, "return loss" is 20 $\log_{10}$ of the reciprocal of the reflection coefficient.

$$\text{Return loss, dB} = 20 \log_{10} \frac{Z_t + Z_o}{Z_t - Z_o} \frac{\text{(Incident Voltage)}}{\text{(Reflected Voltage)}}$$

Note that an open and short circuit will both produce a return loss of 0 dB, while a perfect impedance match results in a return loss of ∞ dB.

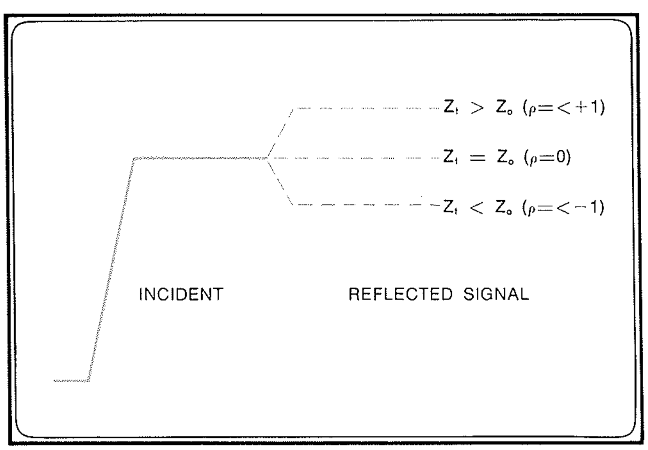


Fig 2. An incorrect termination impedance causes a reflection whose amplitude is proportional to the size of the mismatch.

TEKTRONIX RETURN-LOSS BRIDGE

The Tektronix Return-Loss Bridge consists of a simple Wheatstone Bridge with three fixed 75-Ω resistors and two removable 75-Ω resistive terminations mounted on matched cables. The capacitor across the center of the bridge permits balancing of stray capacitance from the bridge arms to ground. This configuration offers a matched load to both the signal generator and the reflected wave from the unknown impedance. The test signal is applied to the top of the bridge (one side is grounded to allow single-ended testing), and the error signal is measured across the output terminals. The rugged passive components are mounted in a compact housing for attachment to the Type 1A5 Differential Unit.

The error signal is processed by the Type 1A5 Differential Unit which acts as a balanced detector. This unit, when used with the Tektronix Return-Loss Bridge provides DC-10 MHz performance at 1-mV deflection factor. This preamplifier, which works into any of the Tektronix Type 530, 540, 550 and 580* Series Oscilloscopes, is the heart of the measuring system.

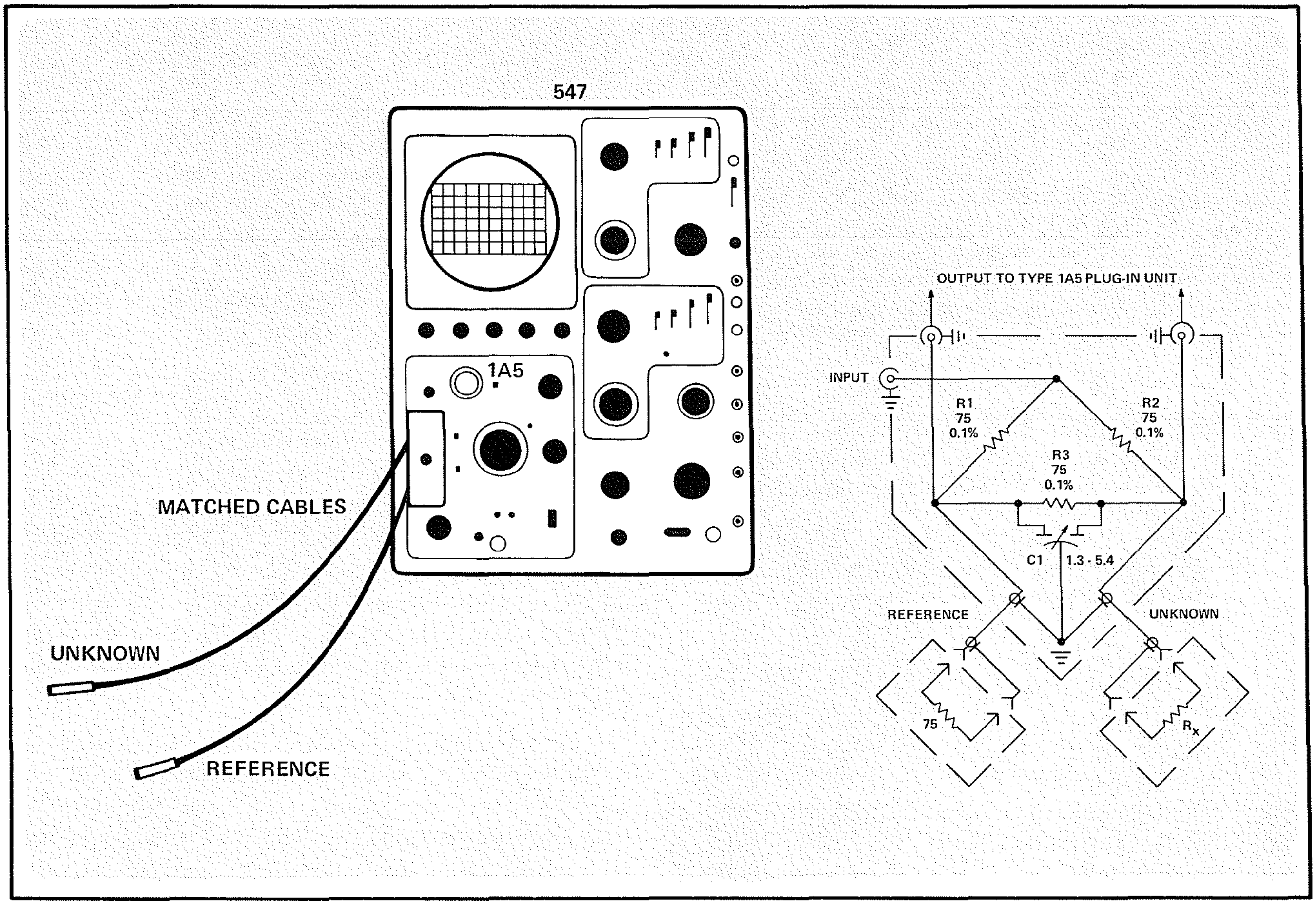
The Tektronix Return-Loss System is specified at −54 dB over the full 10 MHz bandwidth of the system. Since 46 dB is equivalent to an impedance discontinuity of less than 0.5%, the bridge provides more resolution than is usually required.

Use of the Tektronix Return-Loss Bridge is quite simple. Once the bridge is balanced, the UNKNOWN termination is removed and the cable is applied to the device under test. If the device employs a loop-through input, the UNKNOWN termination should be used to terminate the device. The oscilloscope deflection thus obtained is a measure of the amplitude and phase of the reflected signal. The amplitude describes the severity of discontinuity (return loss) and the phase indicates the nature of the reactance.

Amplifier input impedances sometimes change depending whether the power is on or off. When a part of the termination impedance of an amplifier is the input impedance (as is often the case) then the input impedance of the amplifier will probably vary with power on or off. Thus, equipment must be checked under power-on and power-off conditions. This is particularly important with semiconductor equipment.

Return-loss measurements are also convenient for measuring output impedance. It is only necessary to connect the unknown arm of the bridge, and the output imped-

*Requires Type 81A Adaptor.



ance may be compared against the bridge reference resistor. This allows quick determination of incorrect output impedance at some frequency in the video band. By checking *both* the input impedance and output impedance of video distribution amplifiers, additional information is obtained about the video transmission system.

Many users will prefer to use a swept frequency oscillator to check their systems and will check each frequency in which they are interested. The only problem with this approach is that correlation of frequency information to picture impairment is difficult. Steady-state performance is not easily related to picture impairment. Although all the amplitude information is present, no phase information is available. Unless the amplitude frequency characteristic and the group envelope delay characteristic of the sytem are both known, time-domain testing with pulses is required for the additional phase information. In time-domain testing, it is possible to relate a picture impairment to the measured return loss. In sinewave testing, there is little relation between test results and picture impairment.

PICTURE IMPAIRMENT DISTORTIONS

TV distortion problems may be conveniently categorized into three broad time domains: field-time distortion, line-time distortion, and short-time distortion.

Field-time distortion may be observed using a square wave at the field frequency, i.e., 50-60 Hz. The frequency range of this distortion is limited to a few hundred hertz since at that point the energy content is small and lost in the noise. Included in this test range are the simple ohmic discontinuities, AC-coupling networks, DC impedance matches of long pieces of cable and termination resistors. Field-time distortions are indicated by a non-uniform brightness at the top or bottom of the screen.

Line-time distortions are the most easily visible picture impairments. Distortions that occur at 15-500 kHz rate and that appear across a line, show up as very ap-

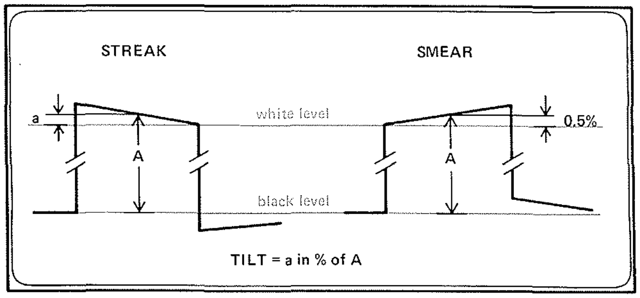


Fig 3. Common line-time distortions. An overshoot or undershoot of less than 0.5% is apparent to an observer viewing a monitor.

parent streaks or smears. As little as 0.5% tilt in a 15 kHz luminance signal can be easily seen by anyone looking at their receiver from across the room. (see Fig 3.)

Coaxial cables have significant losses in this frequency band so the video signal is generally degraded at this point. Transmission line losses, then, show up as a smear in the picture.

Short-time distortions may be considered as those distortions that occur in the last octave of frequency response of the video channel (approx 2-4 MHz). Overshoot, ringing, and rounded vertical transistions result in a soft-looking picture lacking sharp definition. This distortion is all controlled by the phase and frequency response between 2-4 MHz. A fast rise squarewave pulse at 15 kHz may be used, but it is usually more convenient to use a pulse source in which the amount of energy between 2-4 MHz is large compared to the system noise (e.g. $\sin^2$ pulse). Thus, a high rep rate signal is appropriate since you are only looking at the few hundred nano seconds around transient occurrence.

A transmission system should be tested as close to its operating voltage level as possible. A defective input amplifier may have very good return loss with a 50-mV input, but have poor performance at 1 V. If, for example, there is very low collector voltage on an input emitter follower, the collector-to-base junction could be driven into the forward bias region with a large signal. Or, overdriving an operational amplifier changes return loss drastically. Since the reason a system is being checked is to detect possible problems, test the system in such a manner as to most closely simulate actual operating conditions.

One of the major strengths of return-loss techniques is that the system is not being overtested. The bridge is excited only with those test signals which, when distorted, result in picture impairments. It does not shock-excite the system by applying frequencies that are of no interest. It basically monitors the reflected energy that is not absorbed in the load as it should be. Although the bridge tells the exact nature of the impedance discontinuity, it gives no time information as to where, physically, the fault lies.

One of the inherent advantages of a return-loss bridge is that standard television test signals may be used as a source. Thus, sine-squared, pulse and bar window, multiburst and color-bar generators all serve to provide information across the video system. In addition, sinewave oscillators, swept frequency oscillators and squarewave oscillators may all be used as sources. By choosing the proper signals, the impedance characteristics may be specified across the complete video bandwidth. Note: The return loss specified on Tektronix instruments is *always* the worst return loss of any portion of the band.

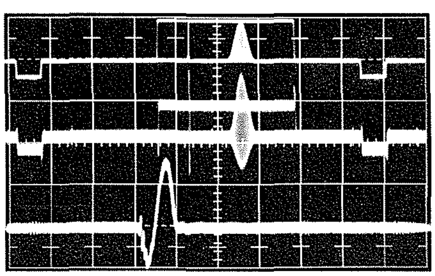
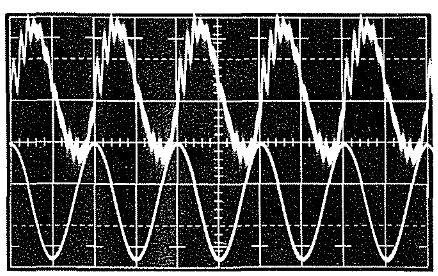
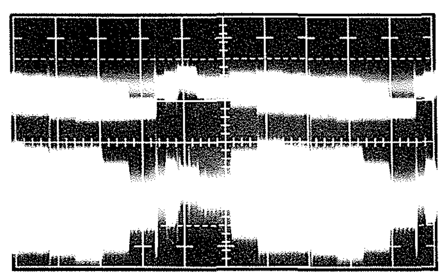
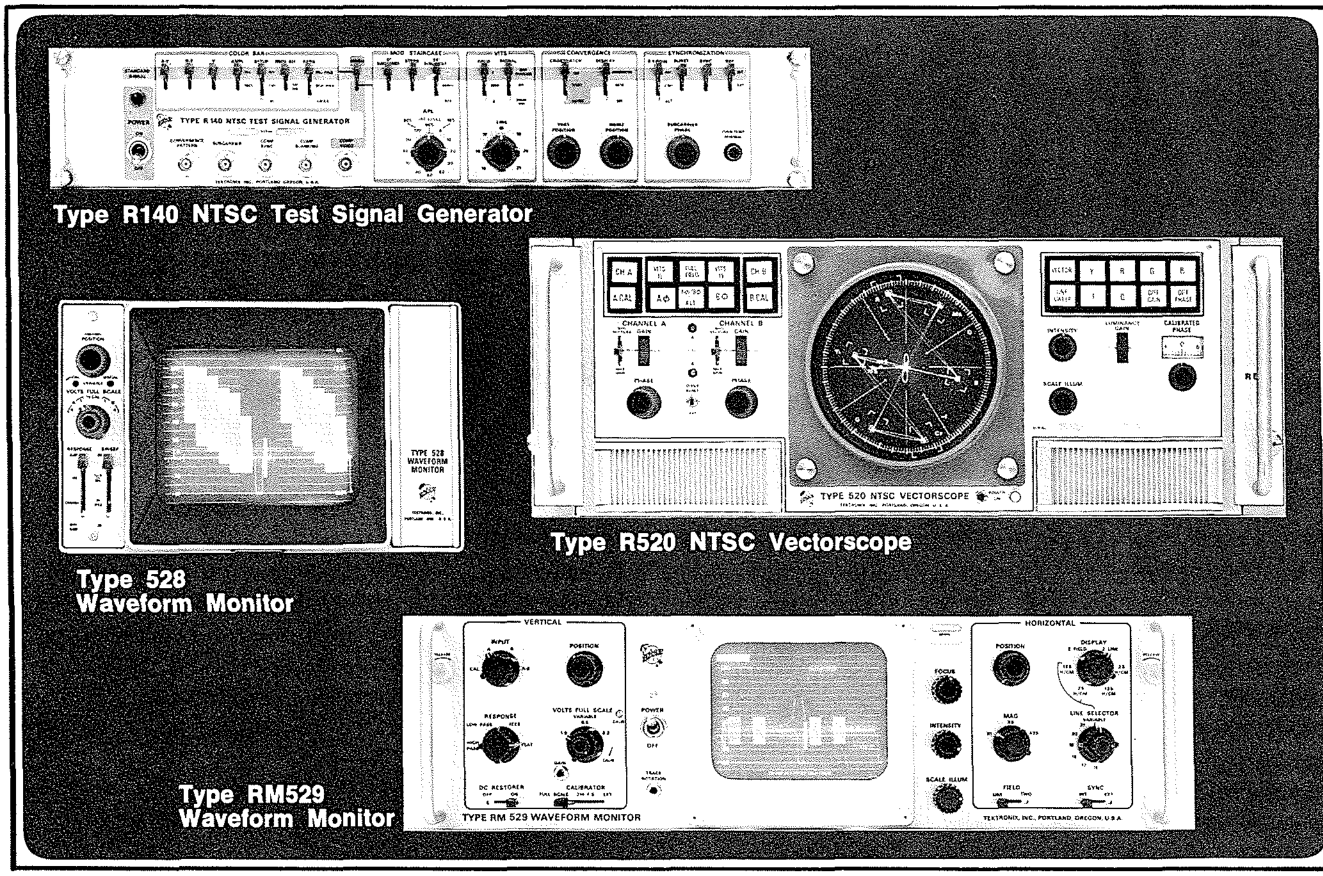




Fig. 1. Upper—T and 20T $\sin^2$ pulse and bar input: 0.5 V/cm. Center—Differential display: 1 mV/cm. Note that the ≃54 dB return loss of the bar (line time) is less than that of the ≃48 dB pulses (short time). Z_t is > Z_0 and 1/500 mismatched or ≃75.2 Ω. Lower—T pulse magnified and repositioned. The initial negative portion indicates a shunt C condition. Fig. 2. Upper—Differential display of subcarrier: 1 mV/cm. Lower—Single ended display of reference input: 0.2 V/cm. The return loss is 45 dB (0.56/0.003). By externally triggering, the upper signal is shown to be lagging 90° indicating a shunt C situation (leading 90% would indicate series L). Fig. 3. Upper—Return loss of a TV monitor with switchable termination in 75-Ω position (≃48 dB). Lower—Return loss increases substantially when reversing IN and OUT connections (≃39 dB). Both displays: 1 mV/cm.



TEKTRONIX INSTRUMENTS WITH RETURN-LOSS SPECIFICATIONS

An excellent source for return-loss measurements is a Pulse and Bar Window Generator. This pulse source contains sufficient information to check for all three categories of distortions. Pulse and Bar Window Generators have large energy components at field-frequency, line frequency, and band edge (short-time distortion) all at the same time.

Another source that works well for return-loss testing is a sine-squared pulse of T to 2T. The T pulse has zero frequency response at 8 MHz with 0.5 energy at 4 MHz while the 2T pulse has frequency response points at 4 MHz and 2 MHz respectively. As a result, these sources are ideal for short-time distortion testing. Sin^2 pulse and bar testing is useful for checking line-time distortion since the sin^2 bar signal will not ring in a properly tuned system (when used for line distortion testing, the leading edge is neglected). An auxiliary 50 or 60 hertz square wave should be used for field-time distortion checks.

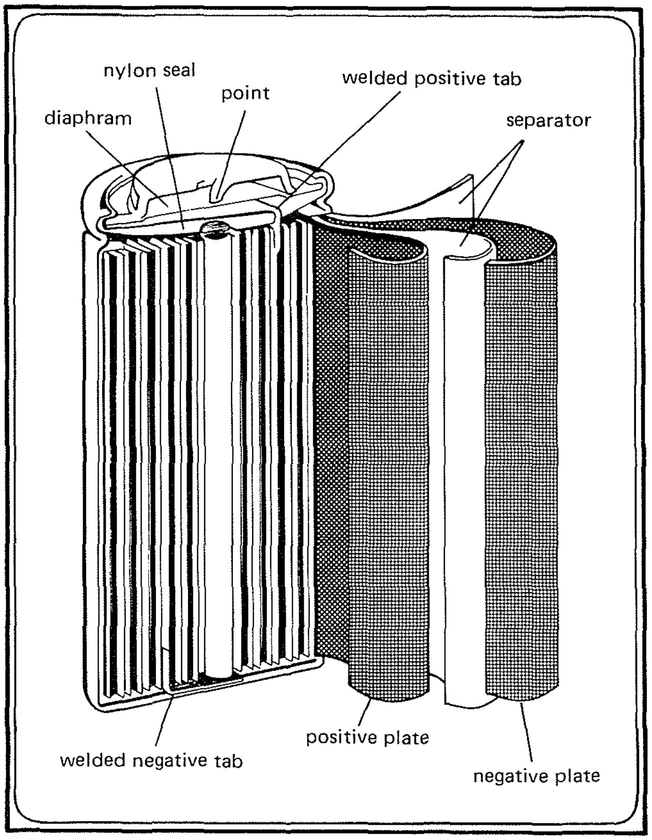
A color-bar generator (e.g., Tektronix Type 140 NTSC and Type 141 PAL Test Signal Generators) provides a good signal for return-loss checking. The white reference pulse of 6-7 microseconds duration gives a good indication of line-time distortions. The large amount of energy at the color subcarrier frequencies provide information on short-time distortions. In addition, the split-field signal of the Type 140 gives a fair indication of field-time distortion.

Sine-wave generators are also useful with a return-loss bridge. One of the virtues of a sine-wave generator is that a great deal of energy may be generated at a single frequency. In the case where it is necessary to override a large adjacent radio transmitter source, a return-loss bridge could be used. By decreasing bridge sensitivity and raising the level of input source, the strong noise source can effectively be "overpowered". This technique is quite difficult with sin^2 generators or color-bar generators, since it calls for a much larger than normal amplitude.

Return-loss measurements provide the video transmission line user with an accurate measure of reflections due to impedance discontinuities. By choosing the proper signal source, impedance characteristics may be measured across the complete video bandwidth.

For reference consult: (1) E. Friedman and F. Davidoff, "The Video Return-Loss Bridge" J. SMPTE, Aug. '68. (2) F. Davidoff, "Status Report on Video Standards" IEEE Video Signal Transmission Subcommittee 2.1.4, June '69.

nickel cadmium battery review



Cross-section diagram of a typical coiled electrode sintered plate cylindical cell.

The widespread use of rechargeable cells in electronic instrumentation provides a new accessibility in the use of modern instruments. This article points out some parameters of concern to the battery-powered instrument user.

The following explanation applies specifically to the sealed "C" and "D" Nickel-Cadmium (NiCd) cells used by Tektronix to power the Types 321A, 323, 410 and 422 Mod 125B. For the purposes of this review, a "battery" consists of one or more cells.

BASIC PRINCIPLES

Nickel hydroxide is the active material of the positive plates in nickel-cadmium batteries. Cadmium is the active material of the negative plates, and the electrolyte is usually a water solution of potassium hydroxide or sodium hydroxide. The use of an alkaline electrolyte allows use of a nickel screen or a sintered nickel plate to retain the active materials. This type construction reduces the corrosion of the electrode structure by the alkaline electrolyte to an extremely low rate and contributes to the long life associated with NiCd cells. The drawing illustrates the construction of a typical nickel-cadmium cell.

SEALED VS UNSEALED CELLS

The major differences between sealed and unsealed NiCd cells are that sealed cells use a minimum amount of electrolyte and a gas permeable separator, while unsealed cells use an excessive amount of electrolyte and a separator material that is nonpermeable to gas.

Oxygen generated in sealed cells during overcharge (see section on OVERCHARGE) is recombined and causes heat dissipation at the end of the charge cycle. In unsealed cells, oxygen is liberated without generating heat.

Sealed NiCd cells need little maintenance, are efficient at high discharge rates, accept long-term overcharging and operate in any position over a relatively wide temperature range. For these reasons, all Tektronix portable oscilloscopes use sealed NiCd cells. All following information pertains to sealed cells only.

DC-powered Oscilloscopes manufactured by Tektronix which use NiCd sealed cells. Pictured are the Type 321A (DC 6-MHz), Type 410 Physiological Monitor, Type 323 (DC 4-MHz) and Type 422 Mod 125B (DC 15-MHz).

CHARGE CAPACITY AND EFFICIENCY

The energy rating of cells and batteries is usually specified in Ampere Hours (Ah). Energy ratings of the "C" and "D" size NiCd cells currently in Tektronix instruments are specified at 1.5 or 1.8 and 4.0 Ah respectively. Actual Ah capacity of new cells can be as much as 30% greater than the specified value. This fact should be allowed for when considering charge times.

Charge efficiency is defined as the ratio of the recoverable charge to the original charge expressed as a percentage. It is normally close to 100% except at the end of the charge cycle when oxygen is liberated. An exact efficiency is not usually specified because of self-discharge. To allow for both charge efficiency and self-discharge, recharge Ah must be 120 to 130% of the charge capacity.

SELF-DISCHARGE

Self-discharge occurs continuously whenever a cell has remaining charge. The major factors contributing to self-discharge rate are temperature, material impurities and the state of charge. At 45°C, self-discharge can be 5 times greater than at room temperature and as much as 15 times greater at 60°C. Immediately after charging is completed, self-discharge starts to reduce the stored energy. A fully charged NiCd cell may lose 10 to 15% of capacity within the first 24 hours. After the initially high energy loss, the rate decreases to less than 1 per cent per day or 10 to 15% per month. Thus, when maximum operating time is required, the batteries should be charged until immediately before use. Once full charge is reached, the battery may be maintained at full charge by trickle charging to offset self-discharge.

CHARGE RATE

In most Tektronix instruments, the sealed nickel-cadmium cells are charged with constant current at a C/10 rate. (1.5 Ah cells are currently being introduced which will recharge at C/6.) A C/10 charge rate means the charging current is one-tenth of the Ah rating.

EXAMPLE: If C = cell capacity in Ah and 10 = number of hours for full discharge, then for a 4.0 Ah cell, C/10 rate is

$$\frac{4.0\ \text{Ah}}{10\ \text{H}} = 400\ \text{mA}.$$

A specific charge rate for each cell type is adopted because it is typically the maximum recommended rate at which that cell type can be overcharged without damage or significant reduction in cycle life.

CHARGE TIME

To take account of charge efficiency it is recommended that 120 to 130% of the charge capacity be inserted to insure a full charge. At the C/10 rate, this implies charging for 12 to 13 hours to reach the specified Ah capacity. (14 to 16 hours takes account of the possibility that a new cell will have more than the rated Ah capacity.)

	RATED Ah		HIGH Ah	
	120%	130%	140%	160%
C/10	12 hrs	13 hrs	14 hrs	16 hrs
C/6	7.2 hrs	7.8 hrs	8.4 hrs	9.6 hrs

OVERCHARGE

Overcharging is the technique of deliberately applying more than 100% rated charge to the cells, and is the best way to bring cells to a balanced state of charge.

Because oxygen is evolved from the positive nickel plate during overcharge, it is mandatory to the design of the sealed cell, that capacity to absorb oxygen be provided. If the overcharge rate is not too large, i.e., C/10, an equilibrium condition is reached such that oxygen is recombined to form cadmium hydroxide at one plate as fast as it is being liberated at the other. In fact, both plates are provided with capacity to absorb oxygen, since during reverse charge, oxygen is liberated at the opposite plate. Overcharge energy is dissipated as heat and there is a tendency to dry out the cell electrolyte if overcharge is continued for long periods. Electrolyte loss will proportionally reduce cell life. All cells approved for use in Tektronix instruments will tolerate overcharging for an accumulated total of several weeks during their lifetime without this factor being the major cause of cell end-of-life.

When a number of cells are operated in series, charge imbalance occurs. To reduce the possibility of one or more cells going into reverse charge towards the end of the discharge cycle, charge balancing is recommended. The recommended method of charge balancing is to deliberately charge for a longer period of time than is necessary to reach maximum Ah rating. In other words, overcharge the battery. Balancing is recommended once a month or every 15 charge/discharge cycles by charging for about 50% longer than the normally recommended time.

TRICKLE CHARGE

When trickle charge techniques are attempted to take a discharged battery up to full charge, most of the energy is spent combating self-discharge. Therefore, trickle charging for a time that calculations suggest would result in full charge, may only raise the charge to 30 or 40% of its maximum value. Thus, trickle charging cannot fully charge batteries, but does provide a useful method of maintaining full charge.

When battery operation is not required for several days or weeks and the battery is fully charged, trickle charge makes up the energy lost through self-discharge and and maintains the battery in a fully-charged condition.

DISCHARGE

Operating time is a function of the load current represented by the instrument, the actual Ah capacity of the battery, the operating temperature and the depth of the discharge chosen. All Tektronix instruments provide an indication when these endpoint voltages are reached. (e.g., front-panel warning light or battery condition indicator.) *Caution: It is important that operation be terminated within 15 minutes of the time when the endpoint voltage is reached to avoid possible damage to the cells.* Discharging below end point voltage is a major cause of cell damage, particularly when considered together with charge imbalance.

REVERSE CHARGE

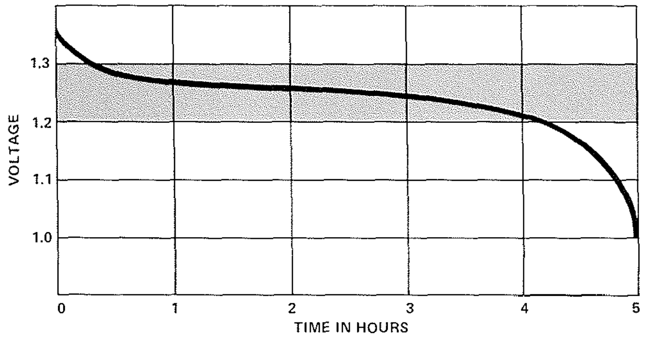
Reverse charging occurs when a low cell in a series is discharged beyond the point where it reaches 0.0 V. From this point the remaining cells in the series supply charge current to the low cell, but with reversed polarity.

A certain rate of reverse charge is not damaging to a cell, but at higher rates, undesirable consequences occur. A battery passes through three stages in reverse charge. First, it will exhibit a 0.2 V barrier potential for a considerable charge. Second, it will rise to 0.7 V when hydrogen and oxygen begin to evolve without combining within the cell, so that the internal pressure increases. Third, it will come to full reverse charge with considerable hydrogen being evolved and with a potential as high as 1.5 V. At this stage the relief valve may vent, releasing gas and some electrolyte. The relief valves on some of the cells we use vent at six atmospheres (100 psi) and do not reseal.

Ability to exceed the reverse barrier potentials is a function of reverse current. At C/20, no damage is likely. At C/10, there is perhaps a 1% chance of exceeding the first barrier potential. At C/5 and above, however, damage is likely. Some types of cells that have vented can be detected by a white deposit around the relief valve.

VOLTAGE CHARACTERISTICS

The best means of currently determining the condition of cells is to measure their individual voltages accurately. Because the no-load voltages can be misleading, voltages should be measured while operating the instrument. First, establish that no cells are short circuit (zero) by measuring the individual cell voltages. Then, check that the charge current is correct for that instrument. Next, overcharge the battery by charging for approximately 24 hours. Individual cell voltages should be measured again on load after operating the instrument for one hour. Any cell differing by more than 50 mV from the majority is suspect and should be examined and perhaps replaced. Whenever a cell is replaced, the battery must be overcharged to balance the capacity.



Typical voltage characteristic for a single cell discharged at a C/5 rate. Normal operation usually lies within the band.

BATTERY LIFE

In Tektronix instruments, terminating discharge between 1.04 and 1.19 V/cell, (90% discharge), 500 to 600 charge/discharge cycles can be expected before "end of life". End of life is defined to be when the recoverable Ah capacity has fallen to 80% of the specified value. This does not mean that the cell is unusable after this time.

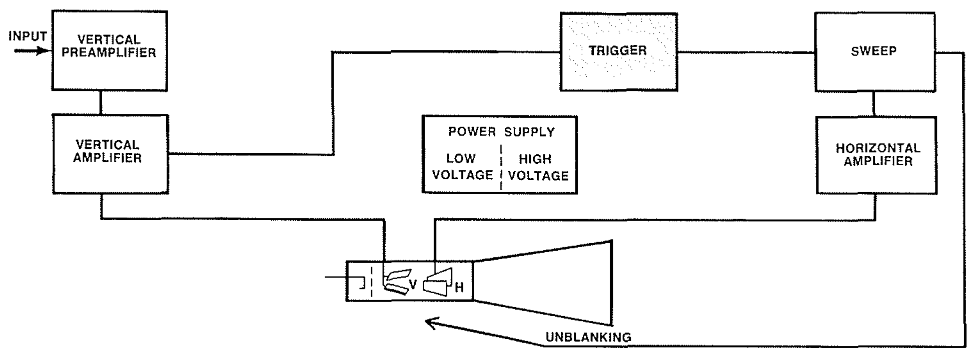
A cell can be stored in either a charged or uncharged condition for extended periods of time. At room temperature, a cell would be expected to have a shelf life of three to five years, although a cell which has been stored for this length of time could not be expected to exhibit maximum cycle life.

In the event of a catastrophic failure of one cell in a relatively new battery, there is no reason why the single cell should not be replaced, providing the recommended charge balancing procedure is carried out after installation of the new cell.

The older the cells are, the less justification there is in replacing individual cells because the resulting pack is no better than the worst remaining cell. Bearing in mind the age of the cells and what proportion are defective, a logical decision can be made as to whether individual cells or the whole battery should be changed.

Users need not be concerned about the differences in charge state between the battery and the new cell if the repaired battery is charged for a period of time that will bring the weakest cell to full capacity.

SERVICE SCOPE



TROUBLESHOOTING THE TRIGGER CIRCUITS

By Charles Phillips

Product Service Technician, Factory Service Center

This fourth article in a series discusses troubleshooting techniques in the trigger circuits of Tektronix instruments. For copies of the preceding three TEKSCOPE articles, please contact your local field engineer.

For effective troubleshooting, examine the simple possibilities before proceeding with extensive troubleshooting. The following list provides a logical sequence to follow while troubleshooting trigger circuitry:

1. Observe CRT display characteristics.
2. Check control settings.
3. Isolate trouble to block.
4. Thorough visual check.
5. Check voltages and waveform.
6. Check individual components.

Tektronix trigger circuits are designed to respond to a wide variety of input signals. Since many of these input signals are unsuitable as sweep-initiating triggers, signals are first applied to a trigger circuit where they are converted to pulses of uniform amplitude and shape. Thus, regardless of the input signal configuration, it is possible to start the sweep with a pulse that has constant amplitude and risetime. The trigger circuitry allows the operator to start the sweep on either slope of the waveform, select any voltage level on the rising or falling slope of that waveform, and filter out selected frequencies of the input signal for greater ease and repeatability in triggering.

The triggering of the general purpose oscilloscope may be broken down into five basic parts: (1) vertical amplifier trigger pickoff circuitry, (2) input coupling circuitry, (3) input amplifier, (4) trigger pulse generator, and (5) automatic triggering circuitry.

The trigger pickoff circuitry acts as a buffer to keep trigger circuitry from changing the operation of the vertical amplifier, yet pass the amplified vertical signal to the trigger circuit with minimum distortion. Input coupling circuitry allows selection or rejection of various frequency components of the triigger signal. The input amplifier provides gain to assure the trigger pulse generator of sufficient input for proper circuit operation. The automatic triggering circuitry used in older Tektronix instruments eliminated control of coupling and level and provided a baseline in absence of signal at a 50-hertz rate. The automatic triggering used in the more recent Tektronix instruments provides all normal trigger functions as well as a bright baseline in the absence of a trigger signal.

Although trigger circuits vary in their complexity and sophistication, the essentials are the same in all instruments. Nearly all Tektronix trigger circuits use a Schmitt Multivibrator for the trigger pulse generator. Most trigger circuits incorporate a trigger sensitivity control to permit adjustment of the minimum size signal to which the circuit can respond. Fig 1 illustrates simplified block diagrams for vacuum-tube circuits and solid-state circuits. Individual trigger circuits vary but all circuits make use of some of the basic functions listed below.

CONTROLS AND ADJUSTMENTS

Front-panel controls used in conjunction with the internal controls are typically:

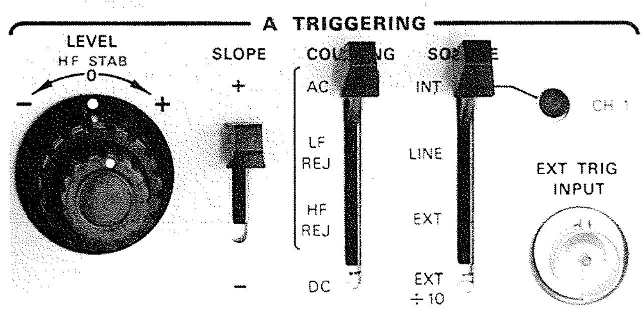
1. SLOPE (+, −)
2. COUPLING (AC, AC LF REJ, AC HF REJ, DC)
3. SOURCE (INTERNAL, EXTERNAL, LINE and PLUG-IN or CH 1)
4. TRIGGER LEVEL
5. MODE (NORM, AUTO, SINGLE SWEEP)
6. STABILITY

The basic internal adjustments of a modern oscilloscope are the following:

1. Trigger level centering adjust—controls trigger circuit symmetry to enable all coupling modes to work properly with the slope switch.
2. Internal trigger DC level adjust—allows the center of the LEVEL control to be set exactly to 0 volts in the DC mode.
3. Trigger sensitivity—controls the minimum signal response—minimum sensitivity limited by noise.

When troubleshooting trigger problems, a few simple steps can often determine which stage of the trigger is at fault. Checking operation of trigger circuit in different sources, modes, slopes, and coupling positions will often isolate a problem. Observing the effect of the stability and level controls gives additional information. In checking trigger circuits, always be sure that sufficient signal is being applied to obtain a large observable deflection. (≃1 cm)

Varying the trigger SOURCE switch between INTERNAL and EXTERNAL triggering checks the trigger pickoff circuitry. Comparing operation in different trigger modes can usually localize a problem to a specific trigger stage (e.g., noting a difference in operation of the trigger circuit in AUTO or NORM may suggest the faulty stage).



Typical Oscilloscope Triggering Controls

Once the problem has been traced to a specific block, a close visual check may pinpoint the problem. Substituting tubes or transistors offers a quick means of checking a suspected stage. Always return the original component to its place if the problem remains.

When troubleshooting a new trigger circuit, take some time to familiarize yourself with the block diagram and schematics. Spending a few minutes with the instrument manual can give valuable insight into the particular problem.

TRIGGER OPERATION

A simple, convenient general method to check proper trigger circuit operation is to apply a calibrator signal to the oscilloscope. Using the INTERNAL trigger source, adjust the controls and vertically center at least 1 cm of calibrator signal on the CRT display. Set the triggering LEVEL control to zero and place the coupling control in the AC LF REJECT position (called AC-FAST on some oscilloscopes). This is

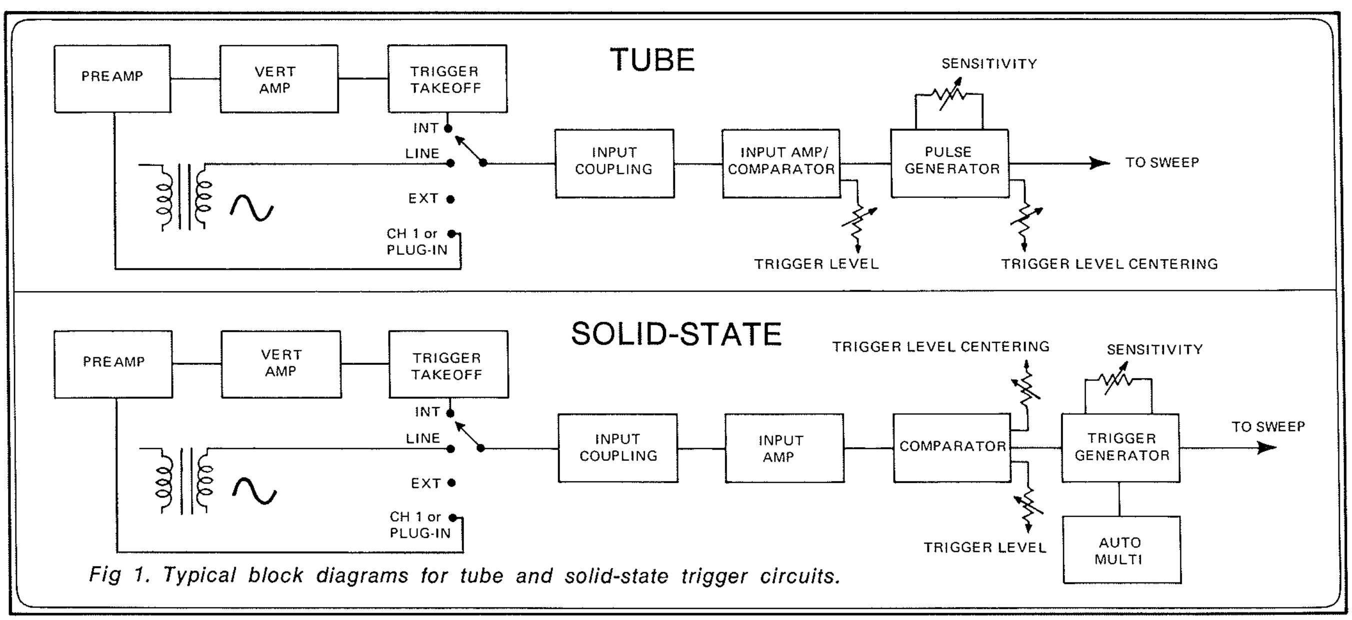


Fig 1. Typical block diagrams for tube and solid-state trigger circuits.

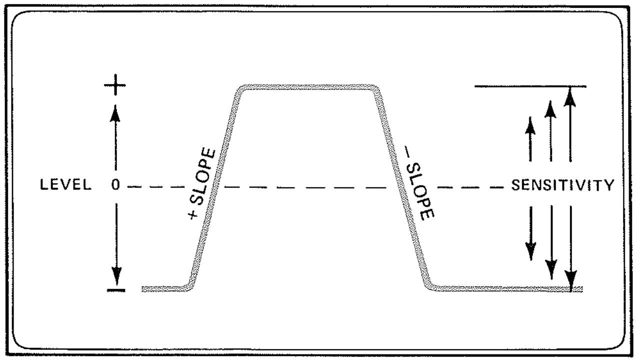


Fig 2. The sensitivity adjust determines the minimum circuit response (in mV). The trigger level centering assures proper slope and level operation in all coupling modes.

typically the most difficult position in which to make trigger adjustments. If the circuit functions properly in this position, you can be assured that the circuitry is good. Set the sweep speed for the appropriate speed to observe 5-10 cycles of the square wave signal. Preset the trigger sensitivity (if there is one) to midrange. Note: If the instrument has a STABILITY control, adjust the control until the trace free runs and then backoff the adjustment 10-15°.

Adjust the trigger level centering for proper switching as the slope switch is switched from + to —. Decrease the signal amplitude slowly, continually adjusting the trigger level centering control, until switching occurs while changing POLARITY. If a problem develops, try changing the tubes or transistors in the comparator and the trigger generator or pulse generator stages. Continue this procedure until the signal amplitude is decreased to 4 or 5 mm.

Next, apply the signal to the external input source and adjust the trigger sensitivity until the scope triggers on + and — SLOPE with 200 mV of input signal. Check to be certain that the scope will not trigger on either polarity at 100 mV. Caution: Do not adjust the trigger sensitivity to be overly sensitive or the oscilloscope may respond to noise pulses. In addition, tube circuits normally age in such a manner that the circuit becomes more sensitive with age. Once the trigger sensitivity is properly set, then the triggering level centering may be more finely adjusted.

Next, select the AC (sometimes called AC-SLOW) position of the COUPLING switch and note whether polarity remains correct. (A problem here usually indicates the large coupling capacitor is defective.) With 0.5 cm of signal, place he COUPLING switch in DC and adjust the internal trig DC adjust for a stable display. Note: Because of signal attenuation in the DC position, approximately twice as much signal is required as in the AC position. In the DC-coupled mode, any movement of the front panel POSITION control will act as a change in DC level and interfere with circuit adjustments. Once a stable display is obtained, check for proper circuit operation in both positions of the POLARITY switch.

TRIGGER PROBLEMS IN TRANSISTOR CIRCUITS

Troubles in the auto-multi block are indicated when triggering with a signal is normal, but there is either no trace or a blinking trace in the automatic mode. This usually indicates a defective or leaky transistor. If a free-running trace is present with signal input conditions, disable the auto-multi block to confirm proper operation of the NORM mode.

A problem in the trigger generator is usually indicated by NO triggering capability. The most common problems in the trigger generator are TD's and transistors. The TD, as well as the transistors, may be checked using a Tektronix Type 575 or 576 Curve Tracer. Defective gating diodes in the Trigger Generator show up as an inability to trigger on one slope. If the problem appears to be a free-running display with no trigger capability in either slope (AUTO mode), the bifilar transformer should be checked. If trigger operation is erratic in HF SYNC, suspect a slow-switching TD.

Comparator stage problems are usually indicated by insufficient range of the variable controls. If this condition arises, change the transistors to determine if the problem is devices or circuitry. If switching of devices unbalances the circuit in the opposite direction, replace the device(s) as they are unbalanced.

TRIGGER PROBLEMS IN TUBE CIRCUITS

If the trigger input stage has a vacuum-tube input, a leaky stage will show up as drift in adjustment. Leakage may be easily checked by monitoring the input to the trigger amplifier/comparator from the triggering level circuit and then switching the SOURCE from INT to EXT. A shift of more than 200 mV indicates excessive leakage.

If triggering is erratic near 0 on the trigger level, but control is okay at other points, suspect a defective trigger LEVEL control. If erratic triggering on small signals is noted in INT, the internal trigger pickoff path should be checked for excessive noise.

No trace without input in the AUTO mode (other triggering normal) indicates a weak Pulse Generator tube. If the problem is a bright trace without input the STABILITY and PRESET should be checked for proper operation and adjustment.

NOTE: If possible, use aged tubes or allow tubes to age-in several hours before final realignment for most stable adjustment.

NEXT: Troubleshooting the Sweep

INSTRUMENTS FOR SALE

3—Type 535, SN 5342; SN 10979; SN 1326. Price: $960 (Each.) 1—Type 545, SN 5292. Price: $1,125. 4—Type 53/54B, SN 6626; SN 7334; SN 5460; SN 7713. Price: $75. (Each.) 1—Type 111, SN 000262. Price: $150. 1—Type T, SN 001240. Price: $100. 1—Type 180A, SN 6269. Price: $110. All equipment is in good working order. Contact: Teletek Enterprises, P. O. Box 118, Carmichael, California 95608.

1—Type 564, SN 006132. 1—Type 3A72, SN 005718. 1—Type 2B67, SN 015969. Contact: Mr. Stan Lindberg, Anocut Engineering, 2375 Estes Ave., Elk Grove Village, Illinois 60007. Telephone: (312) 437-5400.

1—Type 533A. Never used. 1—Type CA. Approximately one year old. 15—Type RM529. Never used. Contact: H. D. Addington, WATL TV, 1810 Briarcliff Rd., Atlanta, Georgia 30329. Telephone: (404) 633-4111.

1—Type 422, AC Model, SN 3551. Under three years old. Used less than 30 hours. Can ship in original foam container. Price: $1000. Contact: R. Edward Stemm, Inc., 17W480 Lake St., Addison, Illinois 60101. Telephone: (312) 279-2440.

1—Type 545/1A2. Extra plug-ins Types D; K; 81 adapter. 127 plug-in power supply. Scope cart, calibration instruments 84 and 180A time-mark generator. Instruments were used in calibration business and are in perfect condition. Contact: Fred Bell. Telephone: (213) 429-3739.

Several Type 517A. Without power supplies. Several kinds of CRT's. Contact: Mr. Bruce Blevins, 176 Barranca Rd., Los Alamos, New Mexico 87544. Telephone: (505) 668-4458.

1—Type 1L20, SN 1285. One year old. Only used once. Contact: Mr. Stan McWhinney, Canadian Electronics Ltd., P. O. Box 2330, Edmonton, Alberta, Canada. Telephone: (403) 429-4981.

2—Type 513D, SN 1933 and SN 668. 2—Type 514D, SN 2795 and SN 3025. Price: $250. (Each.) Crating extra, F.O.B. our plant. Contact: Arenberg Ultrasonic Laboratory, 94 Green St., Jamaica Plain, Massachusetts 02130.

1—Type 514AD, SN 4188 with stand. Good condition. Price: $349. Contact: Mr. Wally Cheesman, Glencourt Electronics, 3508 Nob Hill Blvd., Yakima, Washington 98902. Telephone: (509) 452-0166.

1—Type 323. Good condition. Contact: Kalman Isaacs, 1805 Strahle St., Philadelphia, Pennsylvania. Telephone: (215) 742-3179.

1—Type 561A. 1—Type 3A6. 1—Type 2B67. Scopes are approximately two years old. Price: $850. (Entire unit.) Contact: De Frees Leasing Company, Tiburon, California. Telephone: (415) 435-1107.

1—Type 535, SN 1482. 1—Type CA, SN 002884. Both in very good condition. Price: $600. (Entire unit.) Contact: Mr. Phillip Dooley, 308 McBroom St., Barstow, California 92311. Telephone: (714) 587-0651.

1—Type 512. Price: $125. Contact: Mr. James W. Boynton, 10 Pennsylvania Ave., Yonkers, New York 10707.

1—Type 317. Good working condition. Price: $600. Contact: Mr. Laurence C. Keeler, Greb X-ray Company, 1412 Grand Ave., Kansas City, Missouri 64106.

1—Type 513D. Price: $250. 1—Type 514D. Price: $200. 1—Type 110. Price: $395. 1—Type 53/54K. Price: $95. 1—Type 53/54E. Price: $95. 1—Type 53/54B. Price: $85. 1—Type 531. Price: $495. 1—Type 535A. Price: $750. 1—Type 541. Price: $695. Contact: Mr. Frank A. Aamodt, KFMB TV Channel 8, San Diego, California. Telephone: (714) 232-2114.

2—Type 561A/67/72. Price: $630. (Each.) 1—Type 503. Price: $395. Contact: Mr. Carl Wasson, Micromatic Hone Corp., P. O. Box 192, Berne, Indiana 46711. Telephone: (219) 589-2136.

1—Type 531, SN 5429. 1—Type 53/54G, SN 2189. Scope has trigger "preset" and power supply rectifier modifications. Contact: Mr. John Unruh, Jr., 1722 East Rose Ave., Orange, California. Telephone: (714) 633-3450.

1—Type 531A, SN 20404. Price: $575. 1—Type B, SN 20936. Price: $90. 1—Type 543, SN 962. Price $675. 1—Type CA, SN 59106. Price: $150. 1—Type G, SN 6948. Price: $110. 1—Type 202-1. Price: $85. Contact: Mr. Don Wickland, Ferroxcube Corp., 5455 South Valentia Way, Englewood, Colorado. Telephone: (303) 771-2000.

2—Type 122, SN 2970 and SN 04335. Price: $60. (Each.) 1—Type 160A, SN 2663. Price: $90. 3—Type 161, SN 2077; SN 2449 and SN 2638. Price: $60. (Each.) 1—Type 162, SN 2977. Price: $60. 3—Type 163, SN 723; SN 1670 and SN 1779. Price: $60. (Each.) Excellent condition. Contact: Mobil-scope, Inc., 17734½ Sherman Way, Reseda, California 91335. Telephone: (213) 342-5111.

1—Type 565, SN 2704. Like new. Price: $1,350. Contact: Mr. R. Wittich, Hydrocraft Corp., 648 Main St., Westbury, New York 11590. Telephone: (516) 333-2640.

1—Type 547, SN 5800. 1—Type 1A4, SN B061261. 1—Type 202-2 Scopemobile. Contact: Mr. Rupenthal, Circle Leasing Corp., 126 W. Vermont St., Indianapolis, Indiana 46204. Telephone: (317) 634-3557.

1—Type 3A1 Plug-In. Contact: Mr. Jim Reidy, University of Michigan, Physics Dept., Randall Laboratories, Ann Arbor, Michigan. Telephone: (313) 764-5248.

1—Type 524AD, SN 1874. With probes and filter hood. Good condition. Price: $500. Contact: Mr. E. R. Jones, 1250 Ross St., Plymouth, Michigan. Telephone: (313) 453-4649.

1—Type 535A, SN 18406. 1—Type B, SN 017780 Plug-In. 1—Type P, SN 001387 Test Fixture. Contact: Harvey Smith, 981 North Virginia, Covina, California 91722. Telephone: (213) 332-2660 or (213) 286-5477.

1—Type RM16, SN 1029. Price: $425. Contact: Leon Lacabanne, 12207 Ridgemont Ave., W., Minnetonka, Minnesota 55343. Telephone: (612) 544-1981.

1—Type 422. 1—Type 3A6. 2—Type 564. 1—Type 3B3. 1—Type 201-2. 1—Type 3B4. 2—Type 3A74. Several miscellaneous probes. Contact: Mr. Ron Maytin, K&M Electronics Company, 109 Hopkins Place, Baltimore, Maryland 21201. Telephone: (301) 685-3140.

1—Type 1L30, SN 000152. Contact: Al Lockwood, Ogden Technology. Telephone: (408) 739-5900.

INSTRUMENTS WANTED

1—Type "M" Unit. Preferably three to four years old with UHF Connectors. Contact: Steve Allen, 328 Braniff Bldg., Dallas, Texas 75235. Telephone: (214) 357-9461.

Oscilloscope for personal use by Electrical Engineering Student. Prefer Plug-In versatility. Contact: C. S. Levine, 1002 Campbell Ave., West Haven, Connecticut 06516. Telephone: (203) 934-6287.

1—Type 109 Pulse Generator. Also wanted, a Type 113 delay line. Write giving details and price. Contact: Bruce Weitermann, 4549 North 38th St., Milwaukee, Wisconsin 53201.

1—Type 545 or 545A or equivalent. Prefer Type CA Plug-In. Contact: Dr. F. M. Vallese, 340 Ridgewood Ave., Glenridge, New Jersey 07028.

1—Type 1A1. Contact: Harvey Smith, 981 North Virginia, Covina, California 91722. Telephone: (213) 332-2660 or (213) 286-5477.

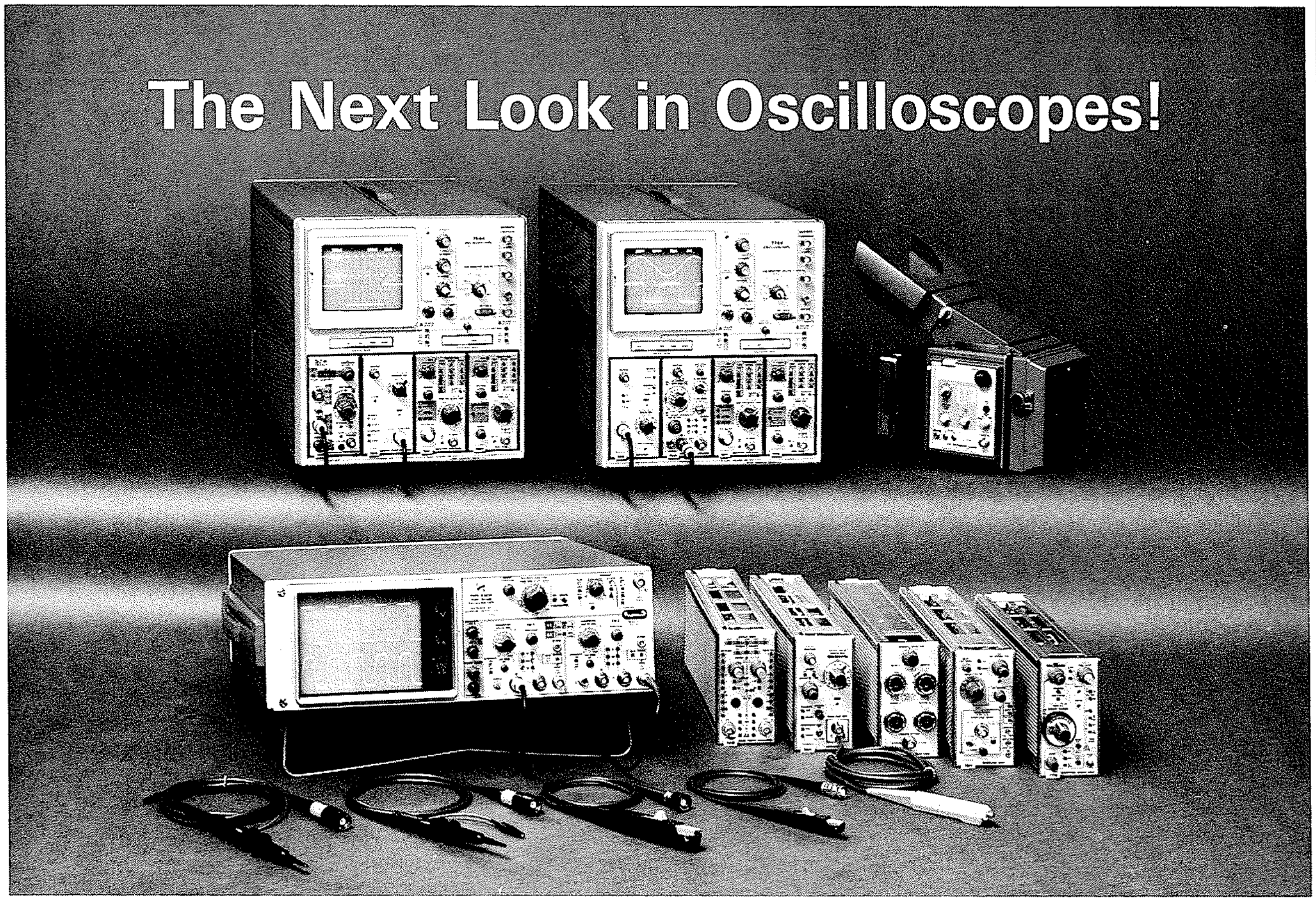
1—Type 1S2. Contact: Al Lockwood, Ogden Technology, Telephone: (408) 739-5900.

Printed in U.S.A. 7/69 SKD A-2411

TEKSCOPE

Volume 1 Number 4 August 1969

Customer Information from Tektronix, Inc., P. O. Box 500, Beaverton, Oregon, 97005
Editor: Rick Kehrli Artist: Nancy Sageser For regular receipt of TEKSCOPE contact your local field engineer.



SCALE FACTOR READOUT

Control settings, probe attenuation values, and magnifier settings are all taken into consideration and electronically read out in the CRT viewing area. A > symbol is provided for uncalibrated settings and a ↓ symbol denotes vertical channel polarity inversion.

TWO NEW MAINFRAMES

90-MHz or 150-MHz performance capability with readout is provided. Both the 7504 and 7704 accept four plug-ins and employ mainframe switching for vertical and horizontal versatility.

13 NEW PLUG-INS

The initial 13 plug-in units provide dual trace (4 trace with 2 units), differential, differential comparator, low C FET probe and amplifier, AC current probe amplifier, and wide-band conventional amplifier performance. Versatile time-base plug-in units provide a new ease in triggering and sweeps up to 2 ns/cm are available. Sampling units that accept sampling heads provide additional versatility and the sampling time-base available provides a 10 ps/div sweep.

NEW CAMERA SYSTEM

The C-50, with its electronic shutter, eliminates much of the film waste normally associated with oscilloscope photography. Range finder focusing is combined with a trace-brightness photometer to simplify and improve oscilloscope photography.

NEW LARGE SCREEN OSCILLOSCOPE

More than 50% greater viewing area (over an 8 x 10 cm display) is available in the Type R5030. This advanced design 10 μV, 1 MHz dual-trace oscilloscope also provides a fiber optic display of scale factor readout.

ADVANCED COMPONENT TECHNOLOGY

This new generation of Tektronix oscilloscopes makes extensive use of Tektronix developed and manufactured components to provide the user with the most reliable components currently available. Low torque cam switches, miniature illuminated push buttons, relays, custom integrated circuits, ceramic cathode ray tubes, and a number of other unique components contribute to superior instrument performance.

ASK ABOUT THEM ALL AT WESCON '69