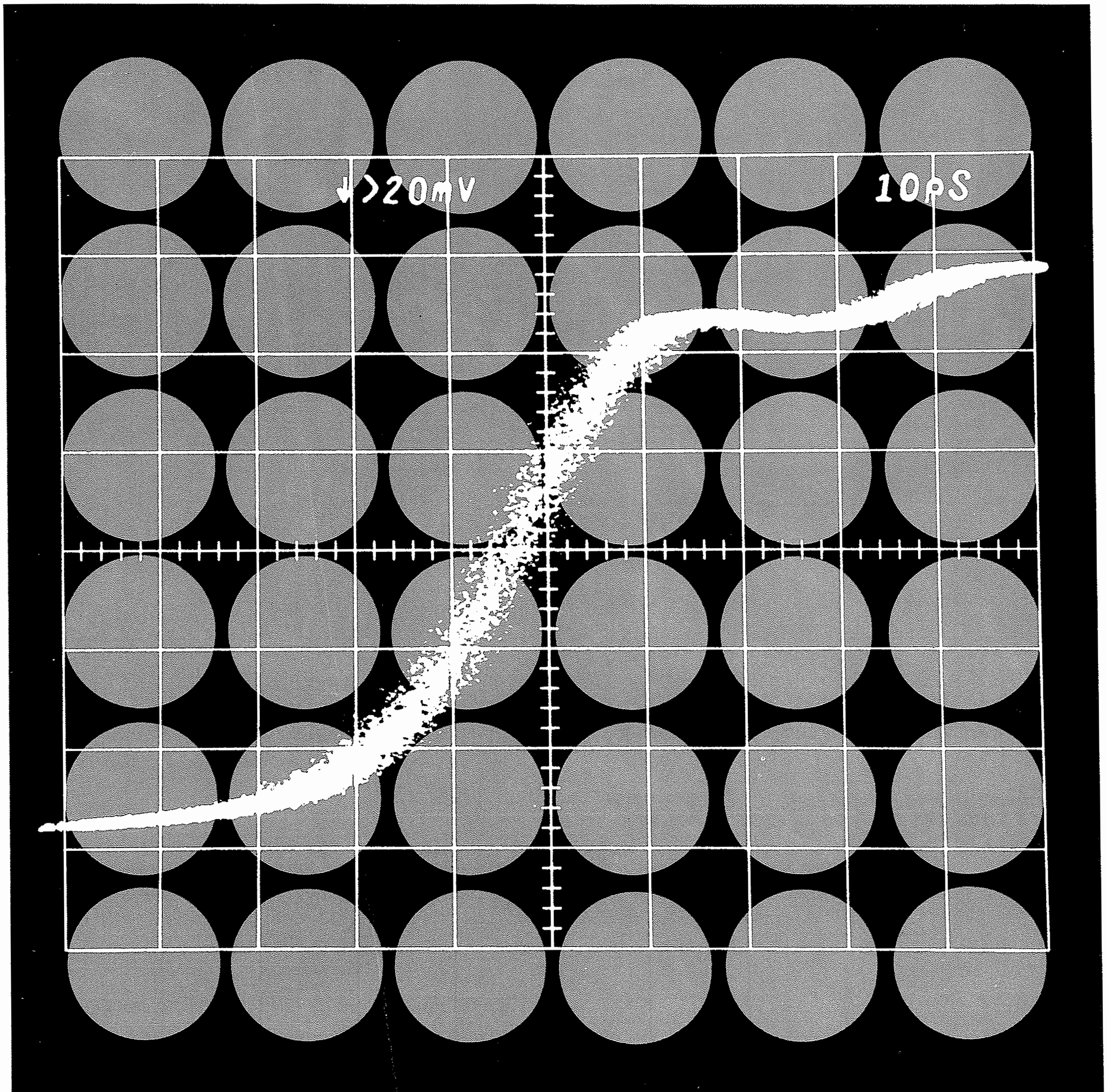
TEKSCOPE

FEBRUARY 1970



Al Zimmerman, Program Manager, and George Frye, Project Engineer, confer over a 7T11 Time-Base Unit.

Measuring Jitter with a Sampling Oscilloscope

By Al Zimmerman

COVER—The excellent jitter performance (less than 10 ps) is clearly shown on a randomly sampled fast rise display.

The oscilloscope is a useful tool for measuring time jitter between two different but repetitive events. The **sampling** oscilloscope is particularly well-suited for these measurements because of its extremely fast sweep rates and low internal jitter. Jitter measurement resolution to within a few picoseconds may often be achieved.

Typical examples of time jitter measurements include:

(a) Measuring the inter-period jitter of a repetitive signal source.

(b) Measuring the pretrigger-to-pulse jitter of a pulse generator.

(c) Determining the uncertainty of threshold crossing detectors (comparators) due to noise, etc.

(d) Verifying the oscilloscope's jitter specs.

SOME TERMINOLOGY

"Noise" is the term we shall use to describe a random broadening of the oscilloscope trace in the vertical direction, while "jitter" will be used to describe a random broadening in the horizontal direction. In the sampling oscilloscope, the apparent trace broadening occurs as individual display dots are misplaced along one or both axes.

The causes of noise and jitter are many and varied. Some are truly random, or aperiodic, in nature while others are uniformly periodic. Unless the noise or jitter source is synchronous or very nearly synchronous with the oscilloscope sweep rate (or scanning rate in a sampling oscilloscope), even periodic causes such as hum or RF often *appear* to result in random dot displacements. No matter how many or what the causes are, the result is a statistical distribution of dots along either a vertical or horizontal cross-section of the trace.

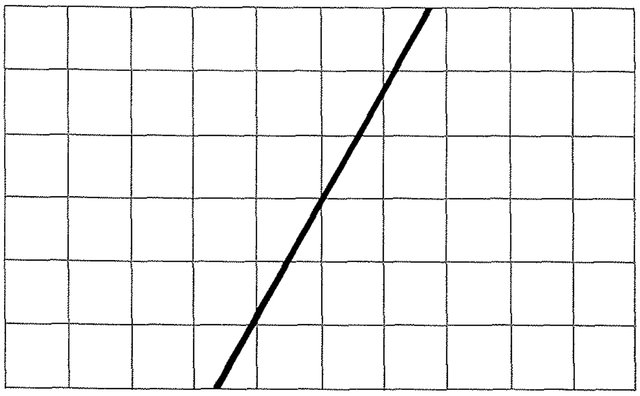
NOISE AND JITTER INTERACTION

When it comes to measuring jitter, a problem arises when noise is also present since these separately-caused effects tend to interact in the display. See drawing 1. *A sloping waveform will suffer both a vertical broadening and a horizontal broadening from either noise or jitter.* While one may always observe noise independently by displaying a horizontal baseline, the analogous operation for a completely independent jitter observation is impossible. In practice, jitter measurements with an oscilloscope must either *reduce the effect* of noise to the point of insignificance in the display *or* the jitter measurement *must be corrected* to remove the effect of noise.

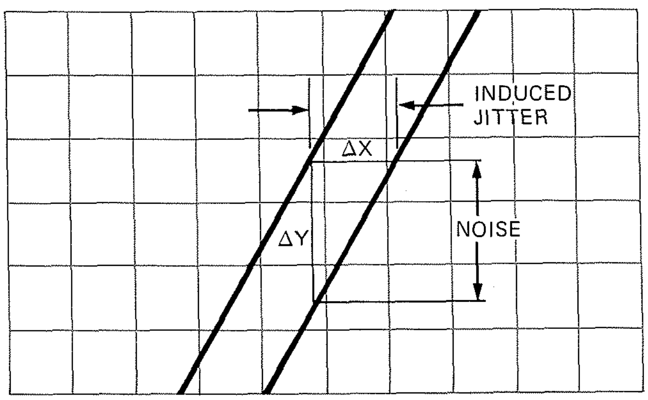
The *first approach* requires a large dV/dt for the input signal relative to vertical volts per division divided by horizontal seconds per division in the oscilloscope display. This produces a steep slope and may provide the required independence of noise and jitter in the display. Either the risetime of the available signal, the risetime of the oscilloscope, or the permissible signal amplitudes may impose the ultimate limit on the dV/dt which may be displayed, however.

It must also be noted that a large signal should be used relative to the inherent noise level of the oscilloscope. *Simply turning up the vertical sensitivity (volts/div) to get a steeper slope does NOT reduce the interactive effect of noise upon jitter.* Anything done to increase the signal-to-noise ratio DOES reduce the effect—at *ANY* sensitivity setting.

The *second approach* to a solution for this problem involves a subtractive correction to the observed jitter based on measurements of waveform slope and noise. Before we describe how to make such a correction, however, we need to look further into the question of how to measure the observed jitter from a noisy, jittery trace.



Drawing 1. No noise.



Drawing 2. Jitter induced by noise.

THE HUMAN FACTOR

A significant problem which plagues both noise and jitter measurements is the subjectivity of display interpretation. Different people find it difficult to agree on the same reading from the oscilloscope screen. The problem is due to the "skirts" on the gaussian or near-gaussian dot distributions encountered. When asked to describe the boundaries or limits of such a distribution, one person will tend toward a peak-to-peak interpretation which includes *all* the dots while another person will discount the more widely scattered dots and consider only the central portion of the distribution. Since most people seem to tend toward the latter interpretation; it is difficult to specify or to describe such a display with much precision.

MEASURING NOISE

In the April '69 issue of TEKSCOPE, a "tangential trace" technique was described for measuring noise displayed on a conventional (non-sampling) oscilloscope. The same technique can be used for measuring noise on a sampling oscilloscope. A typical setup is shown below.

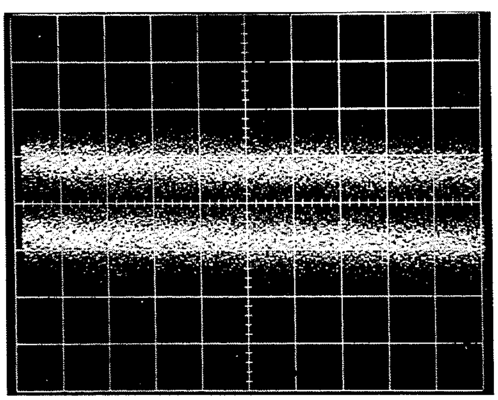


Photo 1. Initial setup for tangential noise measurement.

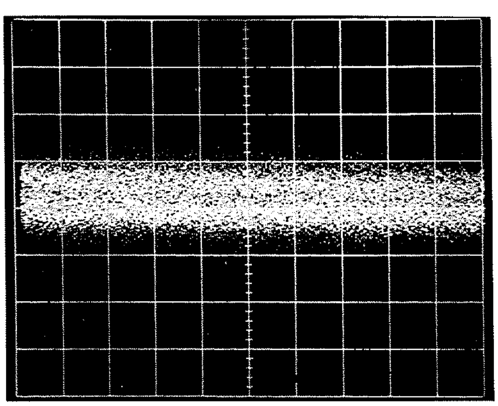


Photo 2. Final adjustment. Dark band between the noise bands has just vanished.

In this technique, two traces are produced by adding a slow squarewave to the vertical signal and adjusting the square-wave amplitude to achieve "tangency" of the two traces. It can be shown for a gaussian distribution, that tangency is achieved when the squarewave value (N_{SW}) is exactly *twice* the RMS noise value.* It can also be shown (see chart 1) that the displayed noise value (N_D) which contains 90% of the dots is approximately *three times* the RMS noise value (N_{RMS}). From these relationships the following statement is derived:

$$N_D \cong 3N_{RMS} = 3/2\ N_{SW}$$

*Garuts, Val., "A Simple Method for Measuring Preamp Noise," Tektronix Engineering Instrument Specification Guidelines.

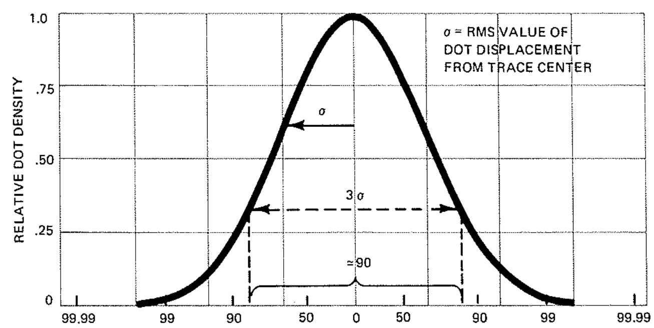
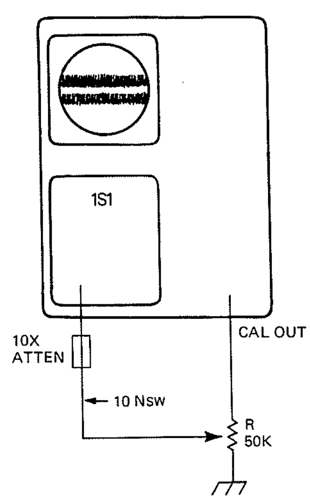


Chart 1. The percentage of dots contained with a cross-section of a trace is approximately 90% (3 σ).

MEASURING NOISE (N_{SW})

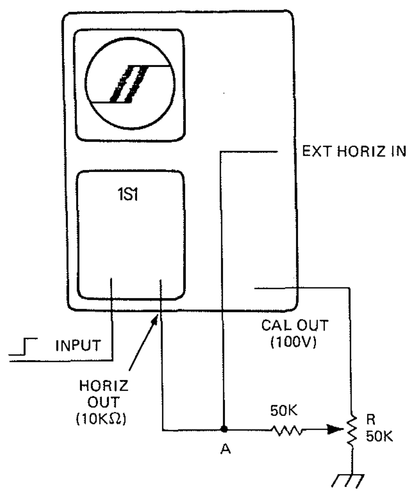


MEASURING JITTER

Several techniques similar to the tangential-trace method for measuring noise have been suggested for measuring the horizontally summed effects of time jitter and and noise which we shall simply call "observed jitter". One of these techniques is shown below (J_{SW}). Here a square wave is added to the slow speed horizontal signal causing the displacement of a fast-rising portion of the display. The square-wave amplitude is again adjusted to achieve tangency, but this time its value must be in terms of the resulting time displacement of the tangent traces. This is most easily done by switching to MANUAL SCAN on the sampling sweep and observing the effective time displacement caused by the square wave alone. The resulting jitter relationships are:

$$J_D \cong 3J_{RMS} = 3/2\ J_{SW}$$

MEASURING JITTER (J_{SW})



CORRECTING FOR NOISE

It must be emphasized that the display-jitter measurement described *includes* a contribution due to vertical noise. If one wishes to describe the *time jitter* independently from the induced contribution from noise, it will be necessary to subtract out this contribution. Thus, noise-corrected time jitter (J_{NC}) may be easily found

$$J_{NC} = \sqrt{J_D^2 - \left(\frac{N_{SW}}{\text{slope}}\right)^2}$$

where the slope is simply $\Delta Y/\Delta X$ of the waveform in the display. All values shown include approximately 90% of the displayed dots along a vertical or horizontal cross-section.

CORRECTING THE MEASUREMENT

Since the jitter introduced by the oscilloscope itself (J_O, usually less than 20 ps) may be a significant part of the observed jitter, it may be desired to make a similar subtractive correction for it as well. Oscilloscope jitter may be determined by viewing the triggering event directly and then making a noise correction as described above. The complete formula for time jitter corrected for noise and scope jitter (J) then becomes:

$$J = \sqrt{J_D^2 - \left(\frac{J_{SW}}{\text{slope}}\right)^2 - J_O^2}$$

Using the techniques discussed, the effects of noise and human interpretation may be reduced to allow repeatable jitter measurements to within a few picoseconds with a sampling oscilloscope.

PROCEDURE FOR DETERMINING NOISE AND JITTER

N_{SW}

1. Adjust R for tangency.
2. Remove the 10x attenuator (applying the squarewave signal directly.)
3. Measure the trace separation in volts directly on the screen. (E_{SEP})
4. N_{SW} (in volts) $= \frac{E_{SEP}}{10}$

J_{SW}

1. Adjust R for tangency of the two step transitions.
2. Set 1S1 to MAN SCAN.
3. Measure the squarewave amplitude at A. (E_{TAN})
4. Adjust R for 8 cm deflection.
5. Again measure the squarewave amplitude at A. (E_{8CM})
6. J_{SW} (in seconds) $= \frac{E_{TAN}}{E_{8CM}}$ x (Time/Div) x 8

Basic Sampling

A brief description of the three major modes of sampling

Three new sampling units are the building blocks for sampling performance with the Tektronix 7000 Series. The 7S11 Sampling Unit accepts any one of 5 sampling heads that cover the measurement spectrum from LF, high Z (350 MHz, 1-MΩ input) to HF, low Z (14 GHz, 50-Ω input). The 7T11 Sampling Time Base provides random, sequential, and real-time sampling displays and covers the range of 5 ms/div to 10 ps/div. A built-in VHF synchronizer provides the ability to view 12.4 GHz signals without requiring additional equipment. The 7M11 is a dual 75-ns delay line unit designed for the viewing of triggering events in low repetition rate applications.

The use of random sampling permits the user to observe *prior to,* coincident with, or after the displayed signal without sacrificing display lead time. Thus, the random sampling oscilloscope provides an important measurement capability that conventional oscilloscopes do not provide (i.e., look ahead of the triggering point).

The timing circuitry used in the 7T11 uses a time measurement rather than a time programming process for horizontal sample positioning in equivalent time. That is, the horizontal position of the dot on the screen is determined by the measurement of the time interval between strobe and trigger. The same process is used in both Random and Sequential operation, with only the method of strobe timing changing between the two modes. The staircase generator now never drives the CRT directly—it is only used as a reference source of voltage.

Two major advantages are achieved by this method:

1) Improved timing linearity, especially at the start of the slewing ramp; starting transients in the slew ramp show up as dot position nonlinearities instead of timing nonlinearities.

2) Reduced display jitter. Comparator noise that results in strobe jitter shows up as dot jitter, not display jitter. The display jitter displayed becomes a function of the noise level of the integrator circuit used for the time measurement plus the few picoseconds of jitter in the trigger recognition and strobe drive circuits. This new development provides a display jitter specification of less than 10 ps.

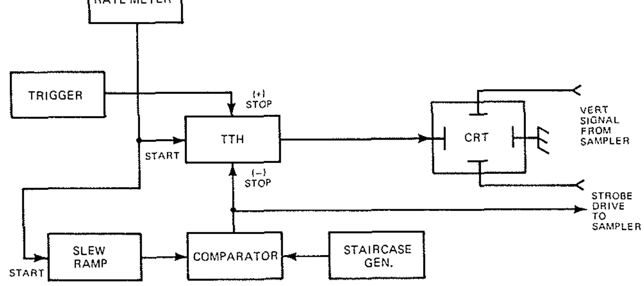
The Random Sampling process is composed of two basic operations:

1. Originating the sample pulses randomly distributed in a time window around the part of the signal to be displayed.

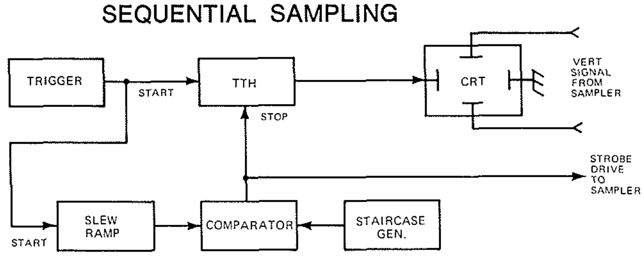
2. Constructing a pulse display by deriving two analog signals, representing X and Y coordinates, from a series of those samples.

To originate sample pulses, the ratemeter measures the trigger rep rate and starts the slew ramp to generate samples within the time window. The Time-to-Height Converter (TTH) includes two stop inputs, one + and one −. When the ratemeter produces a start command at a programmed time before the predicted arrival of the Trigger event, the Slew Ramp runs and produces a strobe when a comparison with the staircase is made. (Note—There is no fixed time between the slew ramp and the next trigger signal.) The TTH does not initially make any output excursion, because the + input signal equals the − input. If the trigger arrives first, a + stop command occurs and the TTH runs negative until a

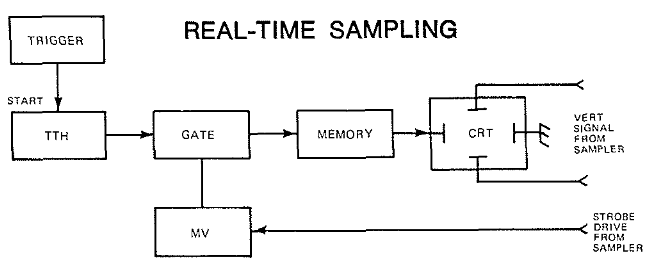
RANDOM SAMPLING

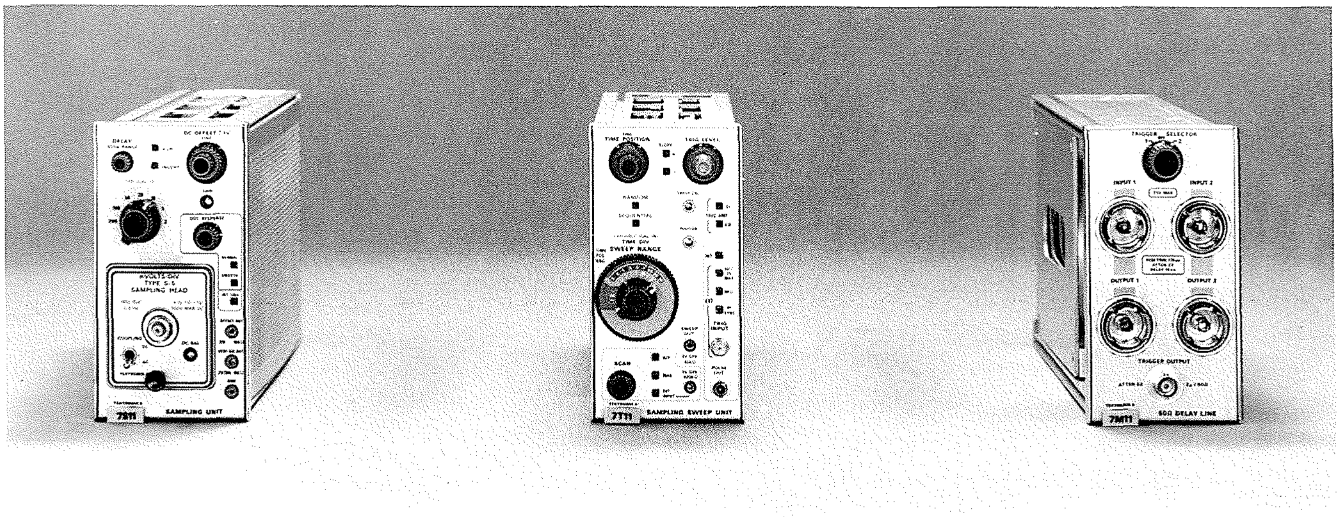


SEQUENTIAL SAMPLING



REAL-TIME SAMPLING





Three versatile new Tektronix Sampling Units. From left: 7S11 Sampling Amplifier, 7T11 Sampling Time Base, and the 7M11 Dual Delay Line.

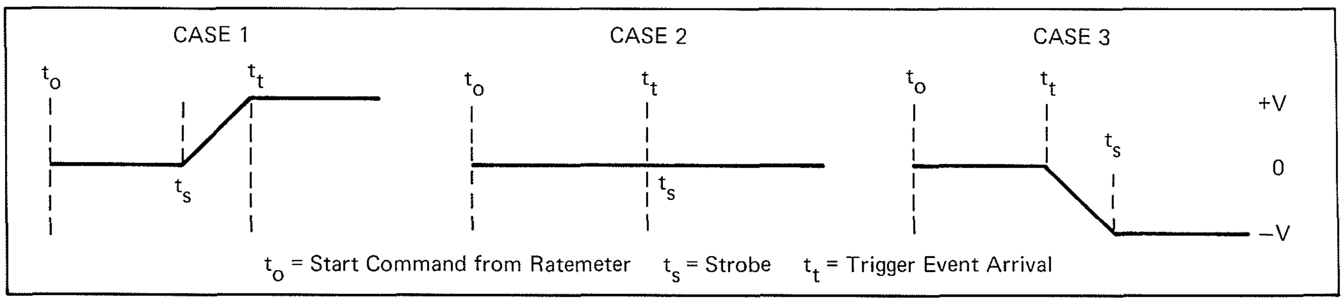


Fig. 1. Random sampling time relationships. Case 1 illustrates the condition where the strobe occurs before the trigger. Case 2 illustrates the condition where the strobe and trigger are coincident. Case 3 illustrates the condition where the strobe occurs after the trigger.

strobe drive pulse and — stop command comes from the comparator. The dot is then deflected to the right of the center on the CRT. If the Trigger and Strobe events both happen simultaneously, the TTH. produces no change in output voltage. If the Strobe occurs before the trigger, then the TTH runs positive and the dot moves to the left a distance proportional to the time difference. The ratemeter provides maximum display dot density by gathering the samples around just that section of the waveform that is used for the CRT display.

The samples which fall outside the time window do not have any contribution to the display construction and are kept as few as possible. If too many samples fall outside the time window, an error signal is generated to improve the ratemeter "guess". This ensures that the horizontal signal tracks with the staircase over the average of many samples.

In sequential sampling, the sampler is programmed to produce strobes when commanded by the 7T11. The block diagram shows a TTH added to the standard sequential sampling time-base. A slew ramp is used as is a staircase generator and comparator. The major differences from conventional sampling circuitry is that the staircase generator does not drive the CRT directly. Instead the strobe drive from the comparator occurs at a programmed point in time. The TTH then measures the difference in time between the Trigger and Strobe drive events and places the dot on screen at a position corresponding to that point in time where the strobe actually occurred (which may not be exactly the same as where it was programmed to occur). The ramp rates of the TTH and the slew ramp are equal.

The basic block diagram for real-time sampling is very similar to that of a standard real-time oscilloscope. The arrival of a trigger starts the timing ramp, or TTH. The Sampler is programmed to free run. When a strobe occurs, the Real-Time Multivibrator (MV) fires, causing the gate to conduct. The Memory tracks along with the TTH ramp until the gate quits conducting. It then remains at that level until the next strobe arrives.

The width of the Memory gate strobe sets the lead time ($\simeq$3 μs) of the instrument. The display appears as a series of dots starting from the left-hand side of the screen. For each triggering event, one sweep across the screen is produced with each dot spaced about 20 μs from the preceding one.

Specifying Product Performance

By Rich Nute

The basic purpose of specifying product performance is to allow comparisons with competitive products or other methods of measurement. This article discusses the reasons for specifications and explains some of the criteria for Tektronix specifications.

WHY SPECIFY?

Specifications arise from the need to describe products as clearly as possible. When a product provides a measurement capability, the user must know, first, what functions it performs, and second, how well it performs those functions.

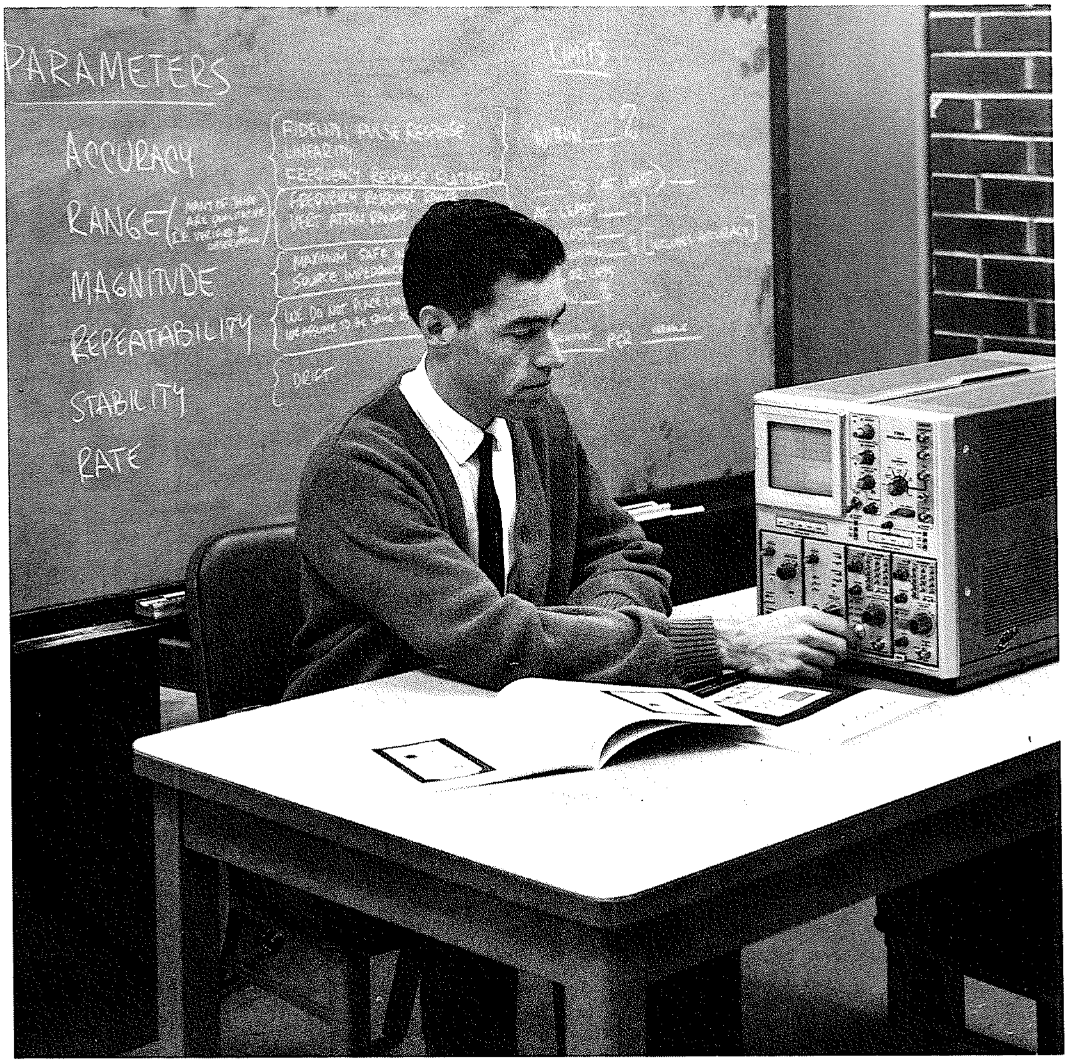
The oscilloscope is a tool that measures amplitude as a function of time. The tool is chosen based upon the user's needs for amplitude and time measurement. Thus, we need to know both the functions and how well it performs. We specify that the user can determine (1) whether a given product can make his measurements, and (2) whether the measurement can be made with the desired accuracy.

WHAT IS A SPECIFICATION?

A specification is a series of statements listing the functions of a product and describing how well those functions are performed. The specification describes the product, but it differs from other descriptions: It is absolutely factual, and subjective modifiers are avoided. We don't say "good stability" or "wide range". These are subjective expressions—How good is "good" stability for circuit design applications? "Wide" bandwidth oscilloscopes used for computer design are quite different from "wide" bandwidth oscilloscopes for TV service work.

Specifications provide no judgements to simplify the information contained in them. Each statement carries equal weight with all other statements. No prior judgement is made that one statement is more important than another. The bandwidth statement of an oscilloscope vertical amplifier gets the same emphasis as does the sweep output statement. The specification is a technical, impersonal statement objectively describing functions and performance.

A specification is an assertion which claims to be true. Therefore, a specification statement must be verifiable. Verification is an essential part of every specification. The verification procedure should be implied by the specification statement. Tektronix instruction manuals contain a performance check section which describes in detail how to verify *all* specification statements.



Rich Nute, Component Evaluation Manager

SPECIFICATION STATEMENTS

Specification statements fall into two major categories: function and performance. In designing (and using) a specification, functions must be described before performance may be described.

A qualitative statement describes the functions of a tool. Most instrument functions are represented on the front panel of a measuring instrument. For example, an oscilloscope dual-trace vertical amplifier mode switch indicates functions. Channel 1, Alternate, Added, Chopped, and Channel 2 are mode descriptions that provide essential function information. Verification of qualitative specification statements is made by observation—the instrument either possesses these qualities (functions) or it does not. Qualitative statements describe the controls and functions of the instrument.

A quantitative statement defines the performance of the tool. Performance is determined by how well a given function does its job. The vertical system of an oscilloscope displays signals at 5 mV/div—function. Its accuracy is 3% of 5 mV/div—performance. Verification of quantitative specification statements is made by measurement—a comparison with a standard. Performance statements provide a figure of merit for comparison of measurement tools, and, therefore, are the more important of the two kinds of specification statements.

A quantitative statement consists of two parts: A definition of the characteristic being specified, and the value assigned to that characteristic. In other words, a parameter and its limits.

PARAMETERS

A parameter is an arbitrary constant to which values (limits) may be assigned. There are relatively few real parameters used to specify analog oscilloscopes, but these are used over and over again in describing performance. For example:

PARAMETER	EXAMPLE
Accuracy:	Vertical deflection factor accuracy. Time-base accuracy.
Range:	DC offset range. Frequency response range.
Magnitude:	Sensitivity. Sweep output amplitude.
Stability:	Drift with temperature.
Repeatability:	This parameter is not usually specified for oscilloscopes. (Repeatabilty is sometimes erroneously assumed to be the same as accuracy.)
Rate:	This parameter is not directly specified for oscilloscopes; an example is sweep repetition rate, but this is usually implied by specifying sweep hold-off time.

Often, specifications are unclear because of poorly defined parameters. Avoiding vague specifications is a prime consideration in designing a product specification.

The most crucial test of a specification statement is to ask, "How can this be verified?" If the parameter cannot be measured or interpreted without further definitions and qualifications, then it cannot be useful. The specification must describe the products as clearly as possible.

LIMITS

Associated with each parameter is a set of limits, high and low. In a specification, the limits define the bounds of performance. The vertical deflection factor accuracy (parameter) is within 3% (performance limits) of indicated deflection factor. The limits of a parameter are described with words such as:

Within 3% of indicated value
7 ns or less
At least 150 MHz

In this way, we define the performance limits of a product.

However, the word "limits" can be taken in two ways. In one sense every product has performance limits. It doesn't do all we want it to do. An oscilloscope may be limited to 50-MHz frequency response. In a different sense, vertical deflection factor may be accurate within 3%. Because this limit is specified, the oscilloscope is an accurate measuring tool of known performance.

ERRORS

No product does its job perfectly. There are always errors introduced by the measuring tool. Errors are usually expressed as a percentage. Whenever percentage is used, the question must always be asked, "Percentage of what?" Though not expressly stated, it is implied to be "of indicated deflection factor". Or, we can turn this around and say that the signal may be 3% different than measured.

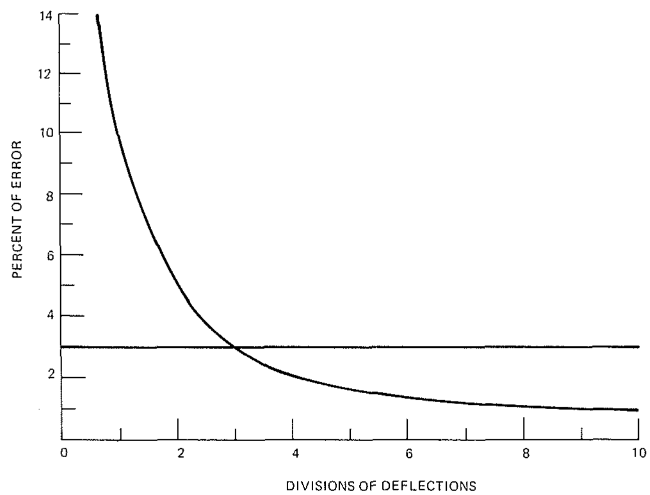


Fig. 1. The straight line indicates a cumulative error while the curved line indicates a discrete error.

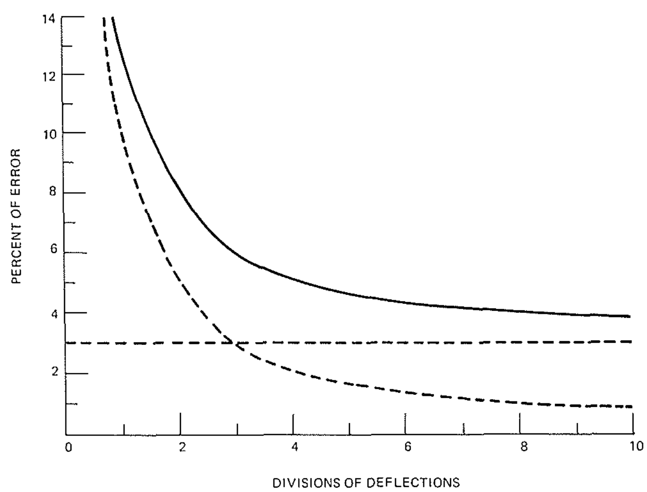


Fig. 2. Combined cumulative and discrete errors.

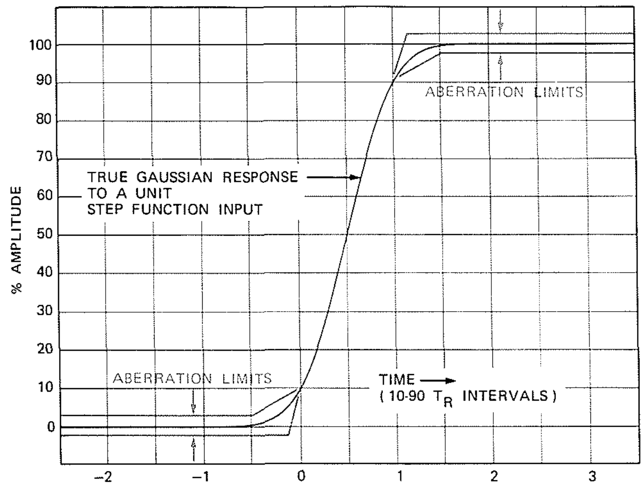


Fig. 3. Typical Oscilloscope Step Response.

Errors are of two types, cumulative and discrete. A cumulative error is expressed as a percentage of indicated value. An oscilloscope time base contains cumulative errors. No matter what sweep speed is used, the error is a constant, e.g., 3% of indicated value.

A discrete error is expressed as a magnitude. When reading values of a signal on the CRT, the center of the trace is uncertain. If the trace is 0.04 divisions wide, then this is a constant error. For a time-interval measurement of 0.4 divisions, the error is 20%. For a time-interval measurement of 8 divisions, the error is 1.0%. For a discrete error, the percentage error changes with magnitude.

Oscilloscope sweep delay specifications combine both cumulative and discrete error statements. Accuracy statements take the form "within 1% and 0.02 multiplier divisions".

Even with this rigorous approach to designing specifications, some statements are still not clear because of the lack of a standard for comparison. Oscilloscope step response is an outstanding example. Even if there were a perfect step from which to measure step response, there is no mechanism to clearly convey the deviation from that perfect step. If aberrations are 3% or less, a useful picture is still not conveyed since many different responses are possible within the band provided.

In spite of efforts to be as complete and thorough as possible in designing a specification, it is the responsibility of the user to interpret specifications. Specifications are written as independent functions—that is, each statement should stand by itself, regardless of other functions. As a result, all electrical statements are true over the entire specified temperature range.

A specification must compromise statements for the sake of clarity and assume that the user can determine the modifying conditions of other specification statements. When vertical deflection factor accuracy is specified within 3%, we do not qualify this statement as a function of frequency. The frequency response of an oscilloscope is defined at its —3 dB point, which is a 30% error in deflection factor accuracy. The user must put these two pieces of information together and determine that the oscilloscope exceeds its 3% accuracy limit well below its —3 dB frequency.

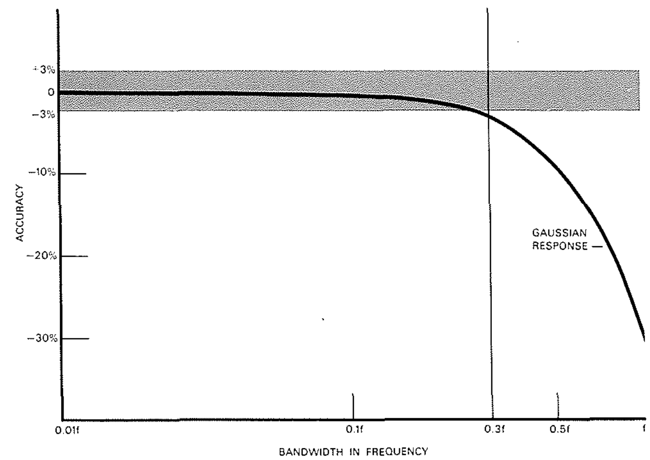


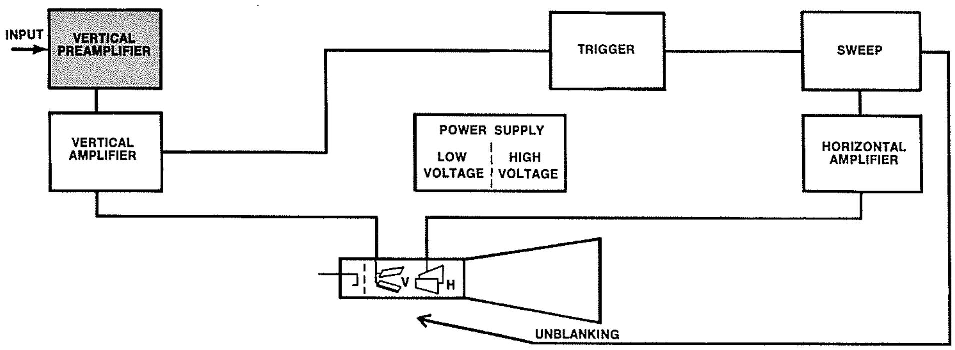
Fig. 4. Oscilloscope Frequency Response. Note that 3% deflection accuracy is exceeded far below the —3 dB point.

Specifications have both positive and negative connotations. We specify because we want to call attention to a particular measurement capability—for example, accuracy. Conversely, we must specify negative attributes of oscilloscopes to keep the user from assuming an error does not exist.

No oscilloscope has perfect step response. Therefore, if we say aberrations are within 3% of the input signal, there is a negative connotation about performance. Thus, limits define both intended performance (accuracy) and unintended performance (aberrations).

At Tektronix, everyone is concerned about specifications because the specifications describe and characterize the product. The ideas presented here are the result of the contributions of Tektronix people—Design Engineers, Calibrators, Manual Writers, Advertising Writers, Field Engineers, and Customers.

SERVICE SCOPE



TROUBLESHOOTING PREAMPLIFIERS

By Charles Phillips
Product Service Technician
Factory Service Center

This sixth article in a series discusses troubleshooting techniques in the preamplifiers of Tektronix instruments. For copies of the preceding five TEKSCOPE articles, please contact your local field engineer.

Substituting vertical preamplifier plug-in units is an excellent means of checking performance to the vertical amplifier input. Once a problem is isolated to a specific plug-in unit, plug-in circuit boards may isolate the problem even further. Once a problem has been traced to a specific block, a close visual check may pinpoint the problem. Often, burned components or loose leads can be spotted that shorten the troubleshooting job. Substituting the tubes or transistors offers a quick means of checking a suspected stage. **Always** return the original component to its place if the problem remains.

In the case of a plug-in, be certain the plug-in is seated properly and that there is no open connection. Plug-ins that use interlocks are particularly susceptible to this type of problem. Place the input selector to the DC position and turn off X10 amplifiers if they are available.

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

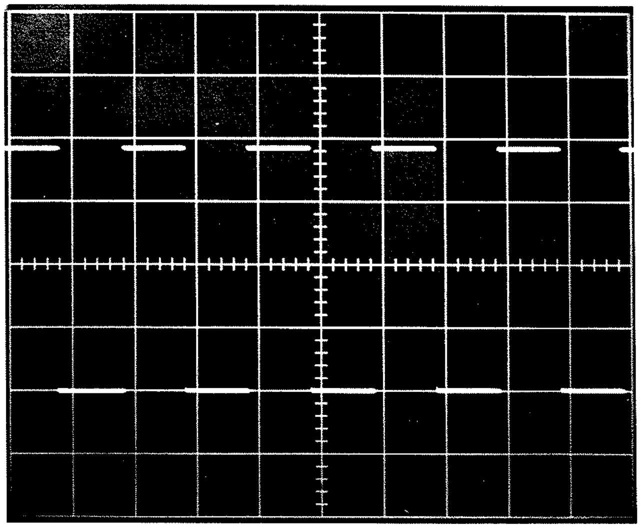
When no spot is seen, use the trace finder or the position indicator to see which direction the spot is deflected. Use the position controls to see whether the display may be centered. Should the indicator lights show that the trace is deflected off screen, invert the display. If the display goes off screen in the other direction, the problem is before the invert switch.

For problems after the invert switch, use a shorting strap, and starting with the output stages of the preamplifier, work stage by stage towards the input amplifier. The stage is working normally when the signal short causes a trace near the vertical center line of the CRT. A defective stage is indicated by the short not centering the trace on the CRT.

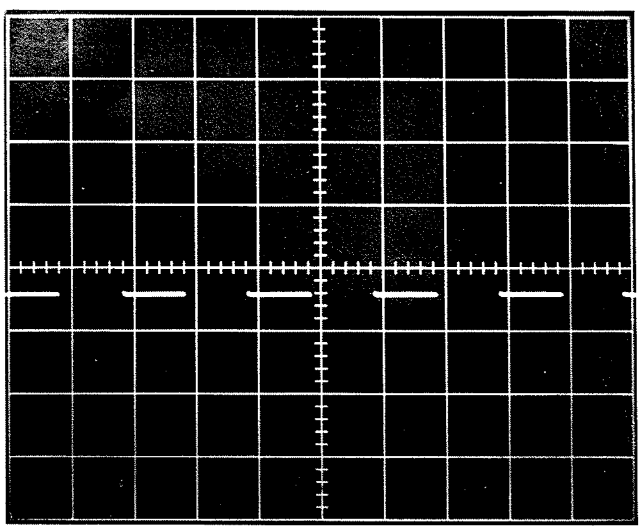
If the amplifier is well-balanced, the position control will be close to midrange when the trace is centered. If a problem exists, switch the output stages to obtain balance near the potentiometer midrange point.

Select output tubes or transistors so that the trace may be positioned off screen in both directions.

Set the calibrator to a convenient figure such as 1 V. Adjust the vertical sensitivity to 0.2 V/div and select a single channel mode. Position controls and the attenuator balance should be adjusted midrange. In some cases, it is convenient to turn the variable gain counterclockwise to lessen the effect of the attenuator balance control.



Attenuator error with 4 div of deflection (2½% per mm).



Attenuator error with 10 div of deflection (1% per mm). Centerline reference.

Good balance is particularly important in multi-trace instruments. For example, good balance is indicated by both traces of a dual trace being within a centimeter of center screen. It's often wise to switch tubes or transistors until A is the upper trace and B is the lower trace (when all controls are centered). In general, when tubes are replaced by raw tubes, be certain to operate the instrument overnight and rebalance.

A technique that may be used to optimize attenuator accuracy is to apply 10 centimeters of CRT deflection and use the oscilloscope as a null detector. This method is particularly valuable on oscilloscopes with limited vertical scan. By using the center line as a reference, DC couple a signal 10 times the attenuator setting on the straight-thru attenuator position.

For example, at 50 mV/div, apply a 500-mV signal to the input. Position the trace so the upper portion of the waveform is aligned with a convenient vertical reference. Check each attenuator position for deviation always keeping the ratio of signal to attenuator 10:1. Under these conditions, each mm of CRT display is equal to 1% error. This method provides much greater resolution since CRT characteristics (geometry, compression, expansion, edge defocusing, etc.) do not enter into the measurement accuracy. After the attenuator ratios are checked for proper values, then gain can be set.

Problem: Microphonic noise that appears when switches and controls are moved. A simple consistent method of checking microphonics is to rap the instrument at the top of the front panel firmly with the palm of your hand.

Solution: Tubes are the most common offenders. Replace as required. If a control or switch is noisy, spray a good contact cleaner directly on the contacts. For noisy potentiometers, use a hypodermic needle and insert one drop on the shaft, contact, and seams. Do not remove the potentiometer covers. In the case of intermittent problems, rotate the instrument in 90° increments and make the above microphonic check on each axis.

Problem: Grid current gain error on DC measurements. If grid current causes a 4-cm signal reference to shift 2 mm, the error is 5%. Check by selecting a reference line on the most sensitive attenuator position. Terminate the input with a 50-Ω termination and keep within 2-mm maximum trace shift.

Solution: Replace input tube to correct this problem.

Problem: Input cap leakage causes the trace to go off screen when operating in the AC mode with a DC voltage applied. For example, at 5-mV sensitivity when checking power supply ripple, 50 mV of leakage will cause the display to be positioned off screen. To check for cap leakage, go to the AC position and center the trace at 50 mV/div sensitivity. Apply ≃500 V to the input and see how far the trace moves.

Solution: The capacitor should be replaced if trace shift exceeds 50 mV.

Problem: Input capacitance range incorrect. It is important that all attenuator ranges have an equal RC so the probe doesn't have to be re-adjusted as the volts/div is changed. When calibrating—if you have dual channels, you want both channels to match.

Solution: Physical arrangement of the input coupling cap can alter the capacitance range of the adjustment if needed. If a capacitance normalizer isn't available, one channel input C can be set to midrange and a 10X probe used to compensate the other dividers.

Problem: Position balance and range. If amp is balanced, the position control will be close to midrange when trace is centered and this will allow the position control to move the trace off screen in either direction.

Solution: Switch output stages to get proper balance.

Problem: Spike on front end of fast rise pulse that cannot be adjusted out. (Cathode interface.) Because DC filaments are used in nearly all plug-ins, varying line voltage does not change the pulse leading edge as it does in an oscilloscope amplifier.

Solution: Replace output amplifier tubes or plate load resistors.

Problem: Tilt on chopped waveshape exceeds 1 mm.

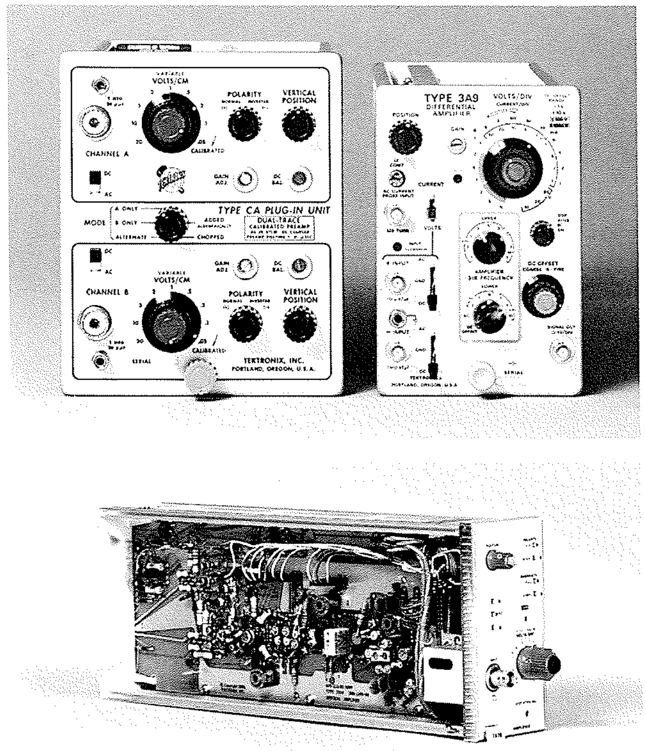
Solution: Select balance amplifier tubes (or transistors) for minimum tilt. Check for leakage in one or more of the switching diodes.

Problem: Interactive trace display, trace is displaced as other trace is positioned across it.

Solution: Check for leaky diodes in switching circuit.

Problem: Bandpass of each channel of a multi-trace unit does not match.

Solution: Select input cathode followers or switch for match.



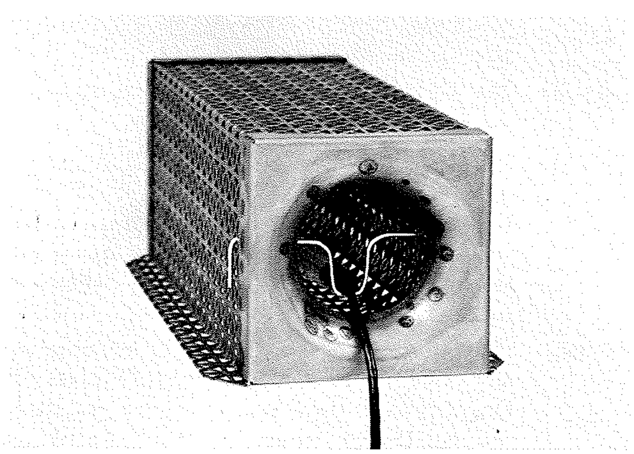
Tektronix plug-in preamplifiers are manufactured in several different configurations. Upper—Letter-Series and 560-Series Plug-Ins. Lower—New 7000-Series Plug-In.

SOLDERING IRON SAFETY TIP

Here's a convenient tip to prevent light weight pencil soldering irons from continually falling on the floor. The small 15-watt irons now commonly in use for circuit board work often fall from their holders when their cord is brushed.

Take a 6-inch piece of 14 or 16 gauge wire and place a U-shaped bend in the center of the wire. A little experimenting will quickly find the optimum wire shape to securely hold the iron in place. Adjust the wire so the iron must be lifted to be removed from its holder. Attach the wire to the holder with two right angle bends at the extremes of the wire.

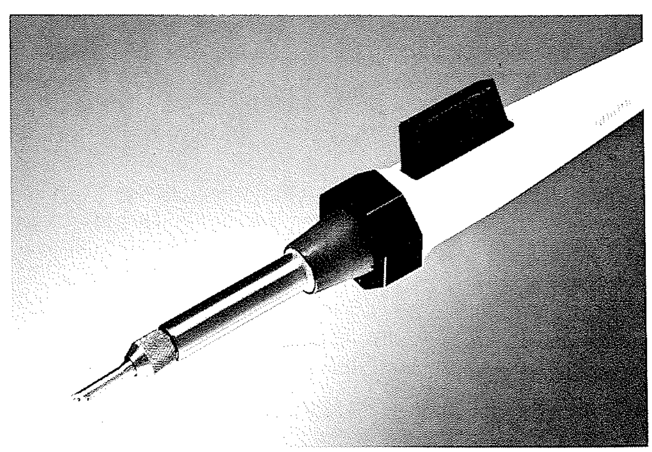
The same technique will also work for the larger 25 and 40 watt irons.



NEW SOLDERING IRON DESIGN

New soldering irons are currently available that are particularly convenient for your circuit board work. The model shown utilizes a built-in solder remover and makes use of special tips with holes in them. The solder is drawn into the tip as the bulb is depressed, thus simplifying the repair job.

An additional advantage of this design is that when removing components from printed circuit boards the hole in the tip provides a convenient method of straightening the ends of the wire. Thus, the component can be removed neatly and cleanly with minimum interference with the board.



USED INSTRUMENTS

INSTRUMENTS FOR SALE

1—Type 547, SN 4975. 1—Type 1A1, SN 13860. 1—Type 202-2. All in excellent condition. All for $2,000. Contact: Sterling Bradley, 717 Goodyear, Irving, Texas 75060. Telephone: (214) 255-7071.

1—Type 535, SN 11516. 1—Type K, SN 012282. Price: $525. Contact: John Phelps, General Electric Co., Electronics Park, Bldg. 9, Rm. 117, Syracuse, New York 13201. Telephone: (315) 456-3763.

1—Type 316. Perfect condition. Price: $400. Contact: N.C. Planning Dept., Fenn Mfg. Co., Fenn Road, Newington, Connecticut 06111. Telephone: (203) 666-2471.

1—Type 63, SN 283. Factory reconditioned. Used approximately 8 months. Price: $100. 1—Type 2B67, SN 25788. Used approximately 8 months. Price: $200. Contact: Roger Kloepfer. Telephone: (517) 487-6111, Ext. 231.

1—Type 1A1. 1—Type 1A2. 1—Type 516. All instruments are about 1 year old. Contact: Lee Merritt, Interactive Data Systems, 17785 Skypark Circle, Irvine, California 92664. Telephone: (714) 549-3329.

1—Type 453, SN 28439 with Type P6010. Never used. Price: $1,400. Contact: Mr. George Patterson. Telephone: (313) 663-8791.

1—Type 3A7 Plug-In, SN 513. New. Contact: Marty Husmann, Eastman Kodak Co., 925 Page Mill Road, Palo Alto, California 94304. Telephone: (415) 327-7200.

1—Type R543B, SN 00910 with Type H, SN 015509. Like new. Price: $1000. Contact: Terry Wilson, Communications Contact, Inc., 618 National Avenue, Mt. View, California 94040. Telephone: (415) 961-1480.

1—Type 3A9. Contact: George H. Halsey, 45 Foundry Avenue, Indiana, Pennsylvania 15701. Telephone: (412) 463-7446.

1—Type 514D. Excellent condition. Price: $300. Contact: D. D. Brunnenmeyer, 2533 Clear Lake Way, Sacramento, California 95826. Telephone: (916) 363-2730.

1—Type 546, SN 002286 with CA plug-in. Three months old. Price: $1850. Will deliver within 100 mile radius. Contact: Mr. Porter Schultz, Box 247, Aptos, California 95003. Telephone: (408) 722-4177.

1—Type 502A, SN 206670. Price: $700. 1—Type 502, SN 5769, modified to a 502A. Price: $700. Contact: Mr. Herbert Grams, Lawson Co., 2011 West Hastings, Chicago, Illinois 60608. Telephone: (312) 226-5300, Ext. 340.

1—Type 323, SN 300822. Price: $900. Contact: Melvin A. Holznagel, Route 4, Box 273A, Sherwood, Oregon 97140. Telephone: (503) 625-7121.

1—Type 1A7A, SN 20351. Price: $450. Contact: Wilhelm F. Kartak, 10720 S. W. Fonner, Tigard, Oregon 97223. Telephone: (503) 639-4568.

1—Type 561A. Approximately 5 years old. Price: $600. Contact: Mr. R. C. Dodds, 4932 Glacier, San Diego, California 92112. Telephone: (714) 287-1280.

2—Type 535A, SN 32495 and SN 32335. Both with CA plug-ins. Price: $830. (Each). Contact: d b Electronic Enterprises, 13526 Pyramid Drive, Dallas, Texas 75234. Telephone: (214) 241-2888.

1—Type 502A, SN 26362. Price: $750. Approximately 2 years old, in good shape. Contact: Cort Platt Metrology, Inc., 126 Jackson Avenue North, Hopins, Minnesota 55343. Telephone: (612) 935-1441.

1—Type 503, SN 008159. Price: $550. Includes table and miscellaneous accessories. Contact: Wesley Wilson, Jr., Wesley L. Wilson Company, 5938 West Montrose Avenue, Chicago, Illinois 60634. Telephone: (312) 282-5535.

1—Type B, SN 018696. Excellent condition. Contact: J. P. Stein, Emcee Electronics, Inc., P. O. Box 32, 177 Old Churchmans Road, New Castle, Delaware 19720.

1—Type 514D, SN 1163. Price: $300. Contact: Mr. Leonard Valle, 3143 Mildred Street, Wayne, Michigan. Telephone: (313) 722-2185.

1—Type 535A, SN 24917. Price: $1000.
1—Type 535A, SN 25772. Price: $1000.
1—Type CA, SN 30061. Price: $225.
1—Type B, SN 14320. Price: $100.
Contact: Mr. Charles Weiss, Communication Radio, 150 Jerusalem Avenue, Massapequa Park, New York 11762.

1—Type 575, SN 010888. Excellent condition. Contact: Jack Cannon, EE Dept., Vanderbilt University, Nashville, Tennessee 37203. Telephone: (615) 254-5411.

1—Type 514 AD, SN 3708. 1—Type 512, SN 3286. 1—Type 315, SN 2207. 1—Type 531/53A, SN 1714/597. 1—Type 531/53B, SN 3366/1736. 1—Type 531/53B, SN 619/2672. 1—Type 121. Contact: Fred Muessigmann, Watson Instrument Co., 446 Lancaster Avenue, Malvern, Pennsylvania 19355. Telephone: (215) 647-3777.

1—Type N, SN 335. 1—Type 280, SN 246. Recently completely recalibrated and are in very good condition. Contact: Mr. Warren Herne, Teledyne, Inc., Crystalonics Div., 147 Sherman St., Cambridge, Massachusetts 02140. Telephone: (617) 491-1670.

1—Type 576, SN 004583. Excellent condition, used very little. Completely recalibrated. Price: $900. Contact: Carrier Corp., Carrier Parkway, Syracuse, New York 13201. Attn: Jack Fields. Telephone: (315) 463-8411, Ext. 3365 or 3366.

INSTRUMENTS WANTED

1—Used 3B3 Time Base Unit. 1-2 years old. Contact: Roger Kloepfer. Telephone: (517) 487-6111, Ext. 231.

1—Used 611 Oscilloscope. Contact: Mr. R. H. Roberts, Dallas Cap and Emblem, 2924 Main Street, Dallas, Texas 75226. Telephone: (214) 742-4511.

1—Type 647A with plug-ins. Consider Type 647 if very reasonable. Any condition. Contact: John H. Cone, 775 South Madison, Pasadena, California 91106. Telephone: (213) 792-5271 noon to midnight.

1—Type 519. Contact: George Lichterman, R. E. Goodheart Co., Inc., P. O. Box 1220, Beverly Hills, California 90213. Telephone: (213) 272-5707.

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TEKSCOPE

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

1970 CUSTOMER FACTORY TRAINING SCHEDULE

The curriculum for the Tektronix Customer Training Center in Beaverton, Oregon, is listed below. Courses vary in length from 2-4 weeks and are provided at no cost for customers passing the Tektronix Entrance Exam. For further details on the Tektronix factory training program, refer to the August, 1968, Service Scope pages 8-9. For additional information and course availability, consult your local field engineer.

454/453

January 12-23
March 16-27
June 1-12
August 17-28
November 2-13

454/453/422

January 12-30
March 16-April 3
June 1-19
August 17-September 4
November 2-20

Spectrum Analyzer 491/1L10/1L20/1L30

May 4-15
October 5-16

Spectrum Analyzer 491/1L10/1L20/1L30/1L5

May 4-22
October 5-23

530/540

February 2-13
April 13-24
September 14-25
November 30-December 11

530/540/545B/1A1/W

February 2-20
April 13-May 1
November 30-December 18

530/540/550/1A1

September 14-October 2

544/546/547/556/1A1

April 13-May 1
August 17-September 4

Storage 549/564B

June 15-26

561B/3A6/3B3

February 23-March 6
July 27-August 7

561B/3A6/3B3/565/564B/2B67

February 23-March 13
July 27-August 14

Sampling 561B/3S2/3T2

May 4-15
October 5-16

Sampling 561B/3S2/3T2/1S2

May 4-22
October 5-23

Sampling 561B/3S76/3T77A

March 23-April 3
September 14-25

Sampling and Readout 561B/3S76/3T77A/6R1A

March 23-April 10
September 14-October 2

Sampling and Readout 568/3S6/3T6/230/241

February 16-March 6
June 8-26
November 30-December 18

647A/11B2A/10A2A

August 3-14

585A/82

July 6-17

585A/82/545A/1A1/W

July 6-24

New Generation 7704/7A12/7A16/7B70/7B71

November 30-December 18

S-3130 Digital System

January 12-February 6
March 9-April 3
April 13-May 8
July 6-31
September 14-October 9
October 19-November 13