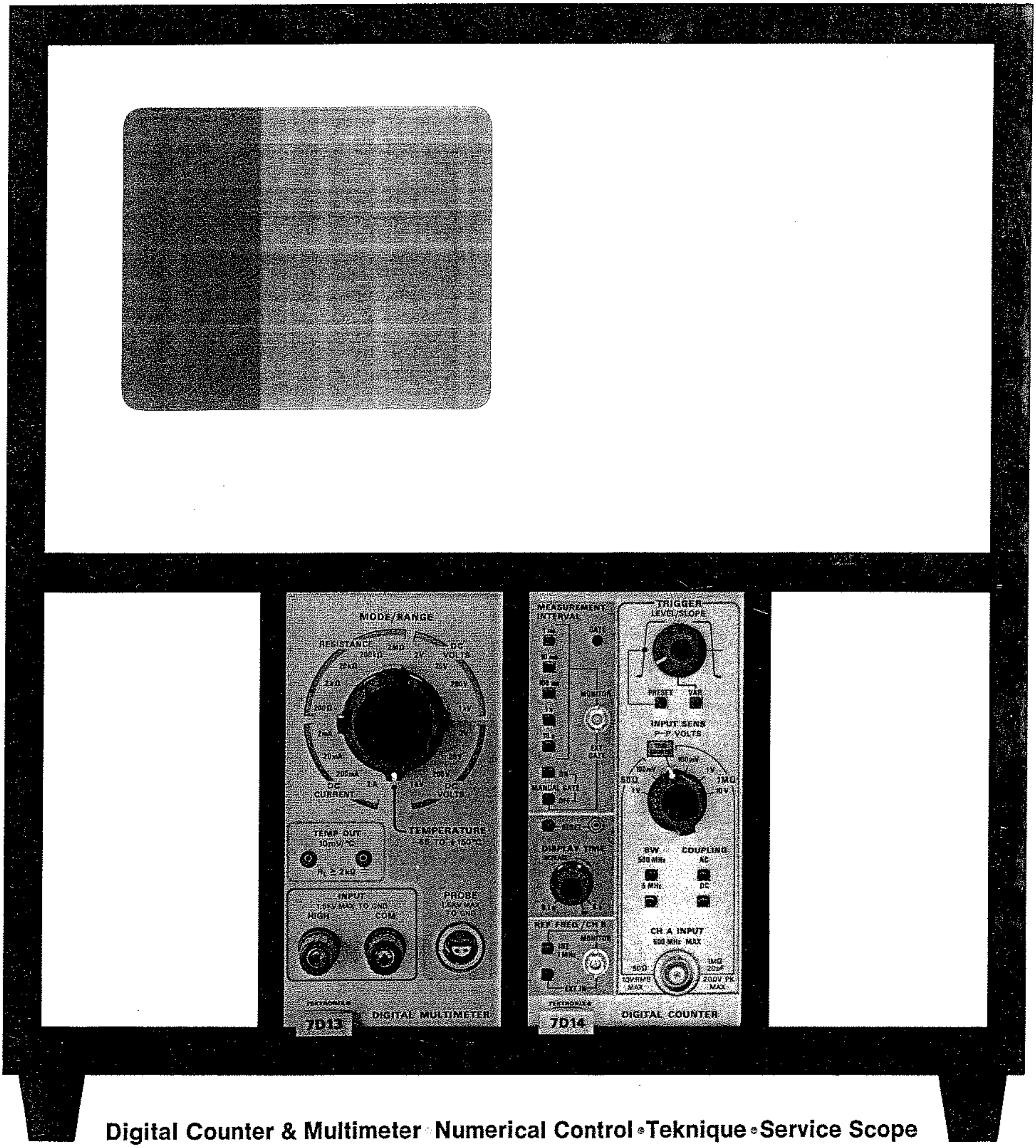
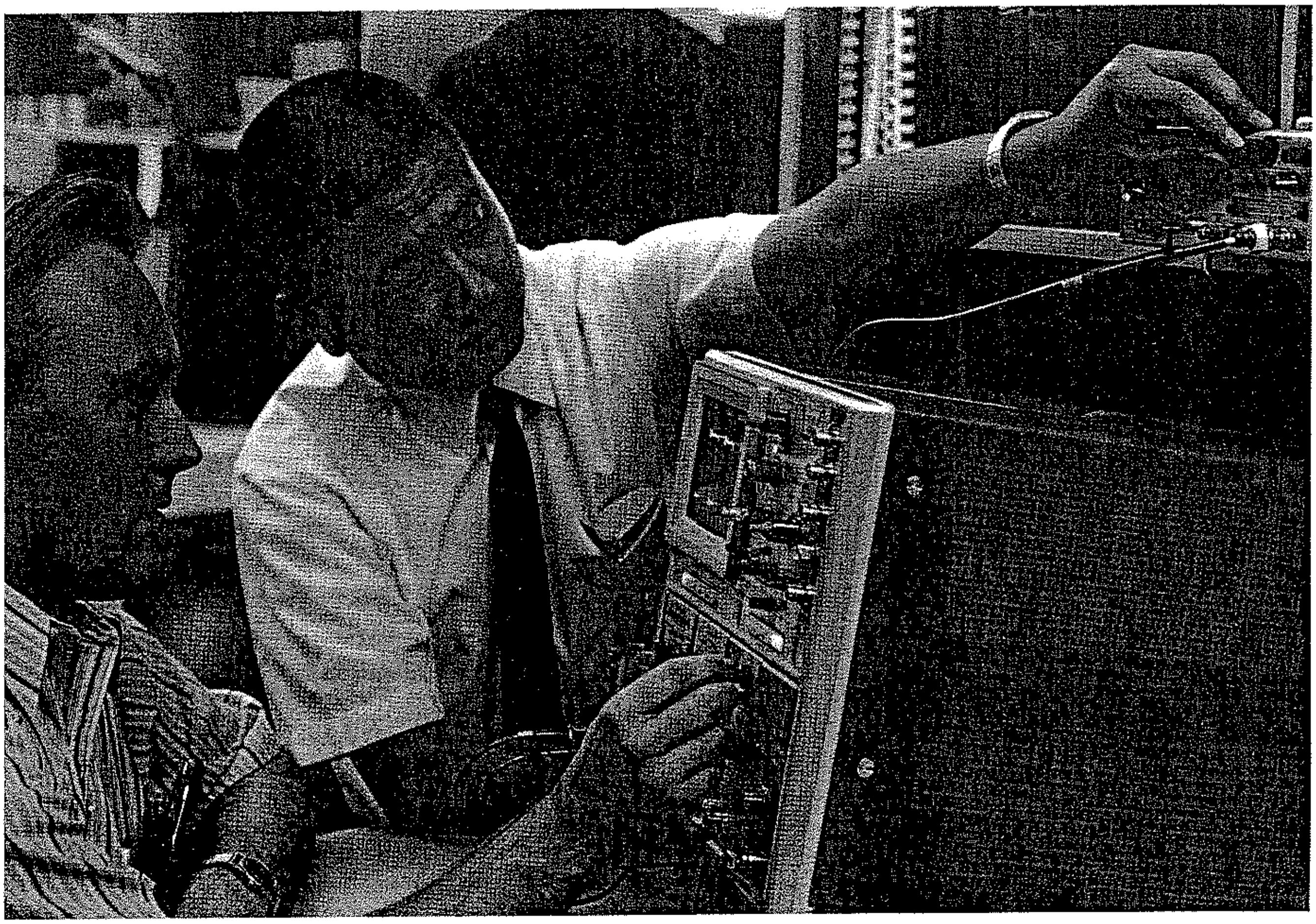
TEKSCOPE

JANUARY 1971



Digital Counter & Multimeter · Numerical Control · Teknique · Service Scope



Oscilloscopes in the last twenty-five years have advanced from relatively simple indicating devices to sophisticated measurement tools used in nearly every segment of our society. However, the basic function of displaying waveforms for time and amplitude measurement has remained relatively unchanged.

Now, for the first time, the oscilloscope can measure voltage, current, resistance, temperature, and frequency, all digitally.

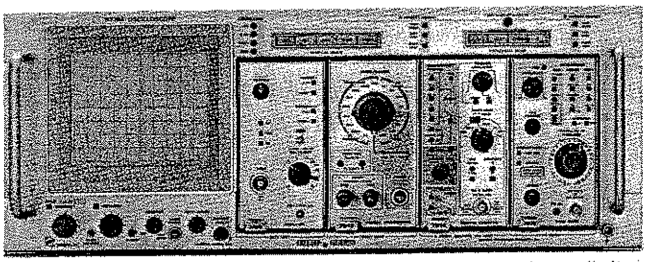
With the introduction of the 7D13 Digital Multimeter and the 7D14 Digital Counter plug-ins for the Tektronix 7000 Series, the oscilloscope assumes an entirely new role in the field of measurement.

Counters and digital multimeters are rapidly becoming necessities on the engineer's workbench. Integration of these capabilities into the oscilloscope provides an ideal answer to the space problem and, more important, offers many capabilities not available in stand-alone instruments.

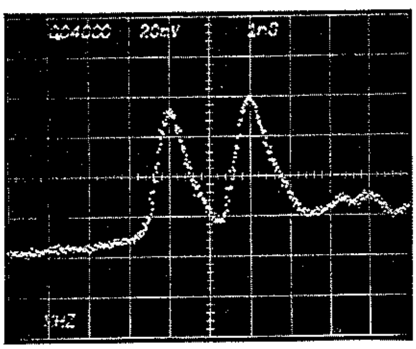
COVER—Two new plug-ins open the door to a world of measurements formerly outside the domain of the oscilloscope. The 7D14 Digital Counter plug-in directly-gated to 500 MHz and the 7D13 Digital Multimeter with temperature readout make the oscilloscope a more versatile measurement tool than ever before.

What are some of the advantages of marrying the digital counter, digital multimeter, and oscilloscope? Most obvious, of course, are savings in space and cost. For example, a 150 MHz oscilloscope complete with digital counter and digital multimeter use only 7" of rack height. A significant breakthrough for users where space is at a premium.

To you who record data on photos for your engineering handbook, another advantage readily apparent is the ability to display and photograph amplitude, time, frequency, temperature, and the wave shape all at the same time.



[illegible] 150 MHz oscilloscope, 500 MHz counter, and a digital multimeter [illegible] only 7" of rack space.



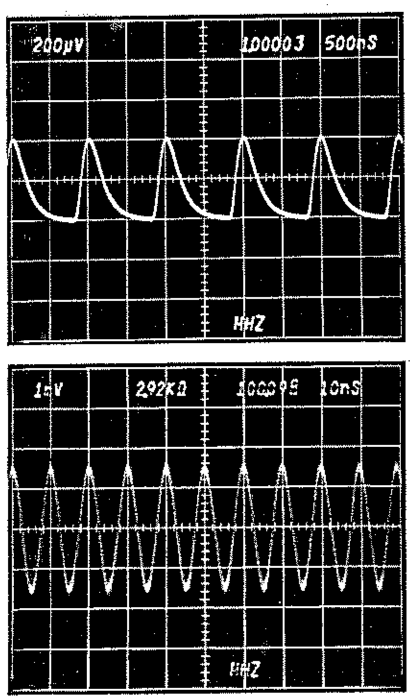
[illegible] capability of the 7D14 is dramatically illustrated [illegible] photo showing counting of a high-speed [illegible] rate, a difficult, if not impossible [illegible] counter.

Signal conditioning is a must for many applications, and the wide range of vertical amplifier plug-ins available for the 7000 Series make excellent signal conditioners for the counter. With the 7D14 in either of the horizontal compartments, a signal connected to a vertical plug-in can be internally routed to the counter by the trigger source switches. In addition to conditioning the signal, this mode of operation lets you view the signal while counting, with minimum loading of the circuit under test.

Circuit loading is given special attention in the 7D14. The wide frequency range of DC to 500 MHz, all directly-gated, calls for something other than just the 50-ohm input normally found on high-frequency counters. The 7D14 provides both 50-ohm and 1-megohm input impedances, and either may be AC or DC coupled. In addition, by using the vertical plug-ins as conditioners, the 7D14 Counter enjoys the same freedom from loading you've come to expect in oscilloscopes. The wide range of Tektronix probes, from FET's with high resistance and low capacitance to current probes with practically zero circuit loading, can be used to acquire the signal. Many of the probes can be used directly on the counter if attenuation of the signal can be tolerated. This leads us to another advantage of the counter/scope combination.

Low-level signals are not among "the counted" for most counters today. The 100 mV P-P (35 mV RMS) sensitivity of the 7D14 is better than that of most counters. However, even signals in the microvolt region can readily be counted using the vertical plug-ins as conditioners. Pictured below is a 400 μV, 1 MHz signal being counted after conditioning by the 7A22 Differential Amplifier.

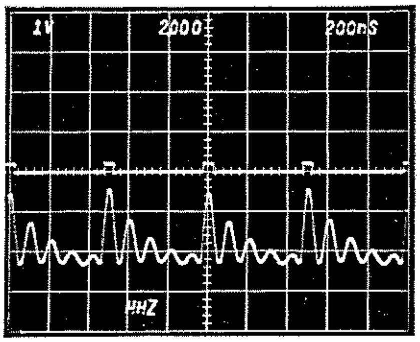
Low-level, high-frequency measurements beyond 150 MHz can easily be made using the 7A11 or 7A16 wideband plug-in amplifiers for conditioning. The photo showing a 3 mV, 100 MHz signal being counted, illustrates this unusual capability.

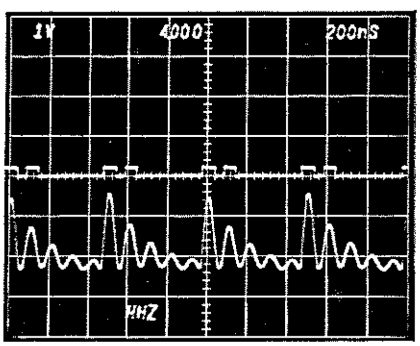


Signal conditioning using vertical amplifier plug-ins greatly expands the range of signals that can be counted. Top, a 400 μV, 1 MHz signal is counted using the 7A22 Differential Amplifier for conditioning. Bottom, 3 mV, [illegible] MHz signal is counted after conditioning by the [illegible] Amplifier.

One of the most difficult problems encountered when using conventional counters has been in determining just what the counter is counting. Noise peaks may trigger the counter or variations in signal level may cause an event to be missed. The 7D14 ends that uncertainty. Now we can see the same "shaped" input signal that the counter section actually sees.

The input signal passes through conditioning circuits in the 7D14. One of these is a Schmitt trigger which serves to reject noise and shape the input signal to the counter. The output of the Schmitt is a rectangular wave and drives the counter circuits. This makes it an ideal waveform to display on the CRT along with the input signal. With the 7D14 in a vertical plug-in compartment, we can view the Schmitt output. It can be displayed as a separate signal or "added" to the input signal to show precisely the portion being counted.





The value of the 7D14 trigger indicator when counting complex waveforms is apparent in these photos. The only change between the top and bottom photo was a slight adjustment of the counter's trigger level control.

EXTERNALLY-GATED MEASUREMENTS

Externally-gated measurements usually entail a lot of guesswork, especially when the signal to be counted is a burst. Using the 7D14 with delaying sweep plug-ins such as the 7B70/7B71 greatly simplifies these measurements.

The 7D14 is located in one of the vertical plug-in compartments and the sweeps are operated in the delaying time base mode. The signal to be measured is displayed with A time base while B time base intensifies the trace and provides the counter gate. We can set B gate (or delayed gate) to the desired width and position it anywhere along the displayed sweep. Thus, we can gate the counter for any portion of the display we choose.

Gating the counter with an external gate that coincides with the intensified portion of the trace offers many measurement possibilities. For example, measuring the duration of a ramp, time interval, counting events in a burst and the frequency in a burst are but a few of the measurements you can make using this technique.

COUNTING EVENTS IN BURST

To count the number of events in a burst, feed the burst signal into the counter Channel A input. Gate the counter externally with the delayed gate output from the scope and set the intensified portion of the sweep to bracket the burst to be counted. The counter readout displays the number of events occurring in the burst. Moving the intensified portion back and forth with the Delay Time Multiplier while observing that the counter readout remains steady will verify that all of the events in the burst are counted. This is particularly important when measuring bursts of 10 μs or shorter duration.

COUNTING FREQUENCY IN BURST

To count an unknown frequency in a burst, the setup is the same as above only the intensified portion is made shorter than burst width and positioned within the burst. The counter readout is noted. The width of the external gate, which corresponds to the intensified portion, is then measured by one of two methods.

The most accurate method is signal substitution. The burst signal is removed and a known reference frequency connected to the signal input. The counter readout is again noted. External gate duration is calculated by multiplying the number of reference frequency cycles counted, times the period of the reference frequency (Gate Width = N_{ref} x period). The burst frequency is then easily determined by dividing the number of burst cycles counted, by the gate width

$$\left(f_{burst} = \frac{N_{burst}}{\text{Gate Width}}\right).$$

The second method, though not as accurate, is somewhat simpler since it requires no external reference frequency. The external gate width is simply measured using the scope time base. Once the external gate width is measured, the frequency in the burst is calculated as before. The number of burst cycles counted is divided by the gate width

$$\left(f_{burst} = \frac{N_{burst}}{\text{Gate Width}}\right).$$

FREQUENCY COMPARISON

Frequency comparisons are commonly made by alternately feeding the two signals into the counter and noting the difference between the two readings. These measurements are made more quickly and accurately with the 7D14 using a dual-trace or differential plug-in to switch rapidly between the two signals. The 7A12, 7A13, and 7A22 are ideal for this application.

COUNTER READOUT

The 7D14 provides 8-digit readout on the CRT with leading zeros suppressed, that is, zeros leading the first major digit are not displayed. Accuracy of the counter is parts in 10^7. Why then 8-digit readout? There are a number of reasons: first, provision is made to drive the 7D14 with an external reference oscillator of greater accuracy and stability. This could easily yield measurement accuracy to the eighth place. Second, resolution; some measurements are best made using comparison techniques. Frequency difference is then of more importance than absolute frequency. The more resolution you have, the closer the two frequencies can be compared. Third, the 7D14 can be manually or externally gated for "totalizing" measurements. The 8-digit readout makes possible totalizing counts from 0 to 10^8.

7D13 DIGITAL MULTIMETER

Thus far we have discussed primarily the 7D14 Digital Counter. Now, let's take a look at the 7D13 plug-in Digital Multimeter.

The 7D13 brings several new measurement capabilities to the oscilloscope. We're accustomed to taking AC waveform measurements from the CRT, but seldom do we take DC measurements from it. Perhaps we forget the oscilloscope has that capability. More likely, we need better resolution than an oscilloscope trace provides, or we find a meter easier to read.

The 7D13 brings improved resolution and accuracy to oscilloscope measurements, plus the convenience of digital readout. In addition to measuring DC voltage, the 7D13 measures DC current, resistance, and temperature. The temperature mode is new to the digital multimeter field and brings a much-needed tool to the engineer's fingertips.

THE TEMPERATURE SENSOR PROBE

The heart of the temperature sensor probe is an ordinary silicon npn transistor mounted in the tip of the probe. It is a characteristic of solid-state devices that the voltage across a forward-biased p-n junction is temperature dependent. It is this voltage that we use to measure temperature. There are, however, drawbacks to measuring the junction voltage (V_{be}) directly. V_{be} is not a perfectly linear function of temperature and varies from one device to another. This presents problems in measurement accuracy and, more important, in providing replacement sensors.

There is a solution to these problems. If, instead of using a constant collector current, the current is varied between a fairly high value, I_{c1}, and a fairly low value, I_{c2}, with resultant base voltages, V_{be1} and V_{be2}, we find that the base-voltage excursion (ΔV_{be}) has much-improved linearity and is proportional to absolute temperature.

The relationship between collector current, base-emitter voltage, and temperature is shown by the equation:

$$\Delta V_{be} = V_{be1} - V_{be2} = \frac{kT}{q} \ln \frac{I_{c1}}{I_{c2}}$$

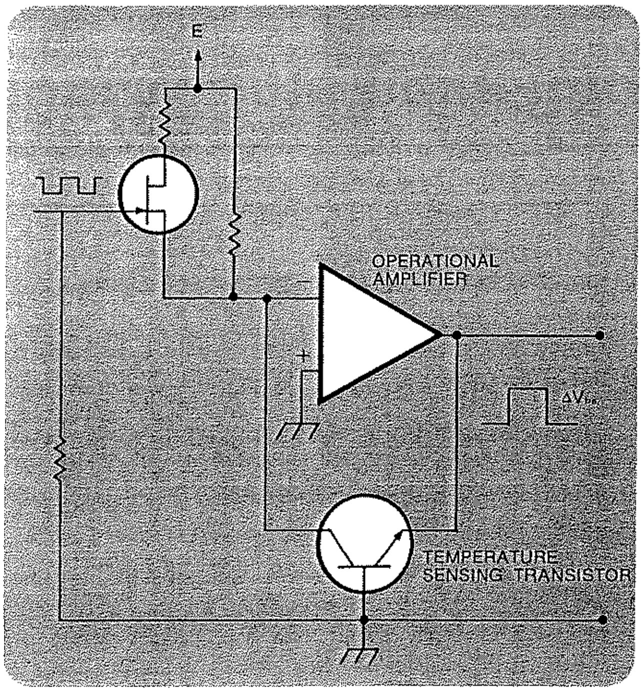
where k is Boltzmann's constant, q is the electron charge and T is temperature. Differentiation of this voltage excursion, ΔV_{be}, gives its temperature coefficient:

$$\frac{d}{dT}(\Delta V_{be}) = \frac{k}{q} \ln \frac{I_{c1}}{I_{c2}}$$

Using the switched-collector technique and measuring ΔV_{be} as the indicator of temperature change, we achieve improved linearity in temperature measurements and ease of interchangeability of the transducer transistor or probe tip.

Pictured is the basic circuit used in achieving the change in base-emitter voltage for a given change in collector current. The sensor transistor is connected in the feedback loop of an operational amplifier with the collector at the input, emitter connected to the output, and the base grounded. For a given current input, the output of the operational amplifier forward biases the emitter-base junction of the transistor to the level necessary to maintain the input collector current.

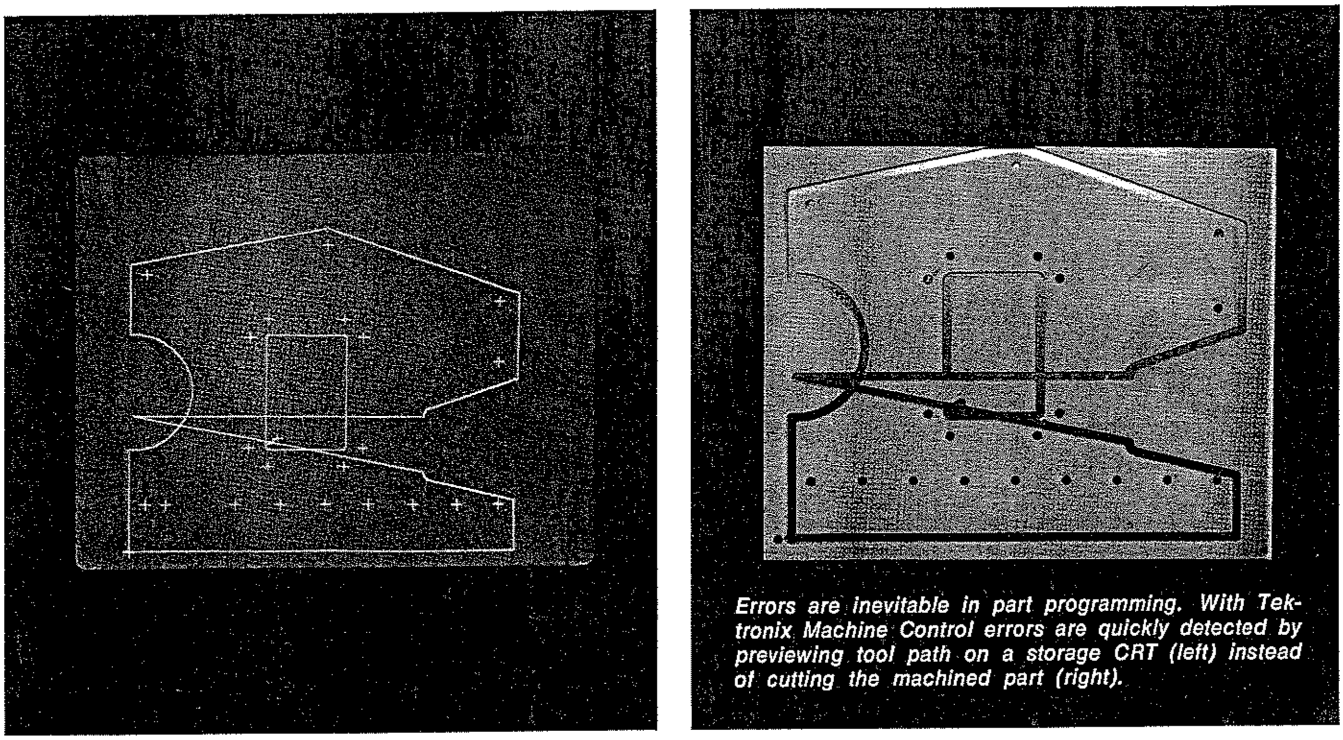
The ratio of the two levels of collector current is set at about 100:1, giving the base-emitter voltage a sensitivity to temperature of slightly less than 0.4 mV/°C.



Simplified circuit for achieving improved linearity by switching collector current and measuring ΔV_{be} as indicator of temperature change.

ELEVATED INPUT CAPABILITY

Another valuable feature of the 7D13 is the ability to float the input circuit up to 1.5 kV above chassis ground. This gives us considerable flexibility in measuring parameters that have a high common-mode voltage. The temperature probe shares this capability and can take temperatures of components elevated to 1.5 kV.



Errors are inevitable in part programming. With Tektronix Machine Control errors are quickly detected by previewing tool path on a storage CRT (left) instead of cutting the machined part (right).

NUMERICAL CONTROL

a fast method of tape

By Gary Neher and Art Andersen

Tektronix products include numerous parts requiring high-quality machining. There are too many of each part for economical, manual operation of machine tools, yet the numbers are fewer than that required for the intensive degree of automation found in the automobile or other high volume industries. The medium volume of each part to be produced means Tektronix is a heavy user of numerical control, because it is in the medium-volume production of parts where numerical control excels.

Numerical control (NC) is simply a means of directing some or all of the functions of a machine automatically from numerical instructions. These numerical instructions are introduced to the machine by some form of stored input medium such as a punched or magnetized tape. The machine control unit (MCU) interprets these instructions and directs the machine through the required operations with a combination of speed, accuracy and consistency that cannot be equalled by human operators. Although the machine tool industry is the most conspicuous use area of NC, any mechanism requiring controlled motion is a candidate for numerical control.

In our production areas we use substantial numbers of numerically controlled machine tools. These NC units are a cross section of the high quality products of a number of well-known companies. We were pleased with these products, but, since numerical control is not a static field, it was felt that we could contribute improvements. These improvements are incorporated in the Tektronix 1701 two-axis and 1702 three-axis Machine Control Units.

There are two basic types of machine tool control. The simplest is point-to-point in which the tool or part is directed to a position and a machine operation such as drilling or punching is performed. The path to that point is of consequence only in terms of time required for movement or obstacles that may exist along that path. Positioning control is another term for point-to-point control.

A more sophisticated NC concept is continuous-path or contouring control. The continuous-path MCU precisely commands tool path in multiple axes and receives confirmation of actual path through feedback. Contouring control is normally used in milling operations when cutting is simultaneous with movement. When feedback is used in an NC system, it is called a closed-loop system. Closed-loop requires a command signal from the MCU to the machine and feedback to the control from position transducers on the machine. In an open-loop system, no feedback exists. Most open-loop systems depend on precision stepping motors to maintain positioning accuracy. Open-loop systems usually sacrifice fast feedrate and accuracy.

The Tektronix 1701 two-axis and the 1702 three-axis MCU's are closed-loop, contouring units that are also useful for positioning control.

Contouring systems generally use incremental dimensioning, a technique that references each new command to the last position on the work piece. Absolute dimensioning references all positions to one common zero-reference point. All dimensions are in one quadrant, eliminating negative commands. Absolute dimensioning is usually found on point-to-point systems. It has the following advantages:

1. Part programming is directly related to the dimensions of a part drawing.
2. Part program additions or deletions can easily be made.
3. Starting in the middle of a part program is much simpler.

The 1701 and 1702 combine the features of the positioning and contouring control. The absolute dimensioning of the positioning control is combined with some of the interpolation techniques of the contouring control, offering a control which is adaptable to either positioning or contouring applications. Full floating-zero is a standard feature in Tektronix NC that allows the zero-reference point to be established manually at any position over the full travel of the machine.

There are two types of tape coding recognized by the numerical control industry. The standard for the industry is a code with which most of us are familiar, ASCII. However, previous to the development and widespread use of ASCII, the numerical control industry had its own standard, the EIA code. The EIA code seems to be more popular in the U.S.; ASCII is generally finding acceptance in the European market. The 1701 and 1702 can accept either code by simply changing a circuit card.

The purpose of a machine control unit is not merely to control a position or move. The control must also decode from tape and indicate to the machine tool miscellaneous and preparatory functions to be performed.

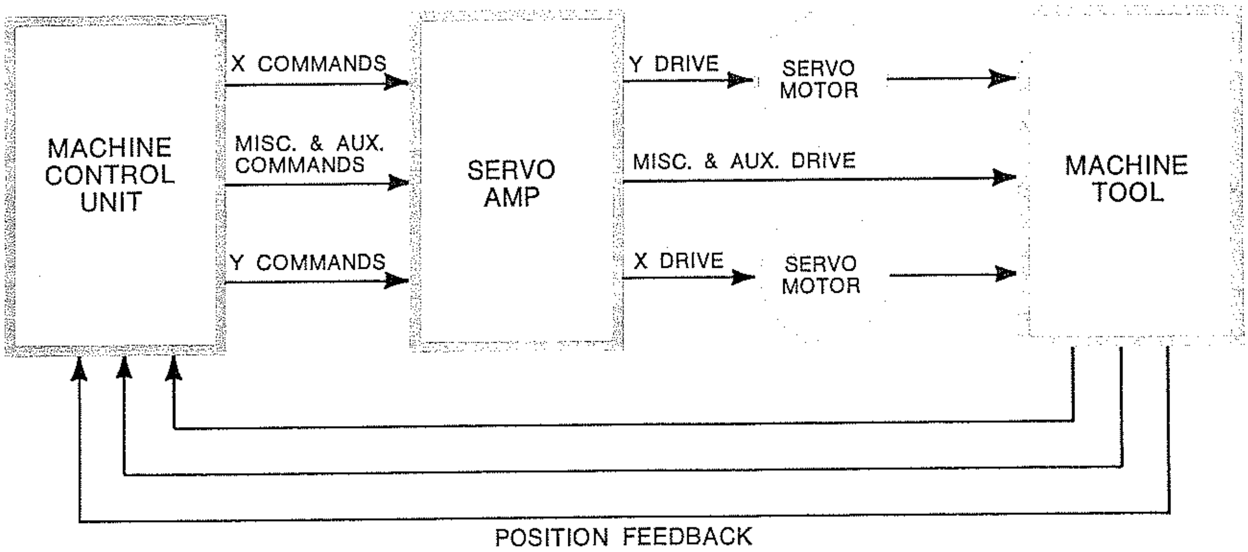
Tektronix machine control units have a standard feature, the ability to command the machine tool to perform up to 80 miscellaneous functions. Some examples of miscellaneous functions are:

1. Control of the insertion and retraction of cutting tool, punch, or drill on a 2-axis control.
2. Turning the coolant on or off for a cutting tool or drill.
3. Positioning a turret and selecting a tool.

During a part program it may be desirable to change the mode of operation of the numerical control via preparatory functions. Some examples of preparatory functions are:

1. Selecting linear or circular interpolation on a contouring control.
2. Inhibiting the deceleration function of the control.

Tektronix has entered the NC field with two and three-axis, closed-loop contouring machine control units. These machine control units (MCU) are a direct result of the influence of our own extensive machine-tool user experience (from programming to machining) combined with established product design skills. Tektronix MCU's offer the machine-tool user and the machine-tool manufacturer the new program-tape-verification option, along with easier maintenance through functional layout and many features not found in other units in its price range.



PART PROGRAMMING

As the application of numerical control has increased, there has been, naturally, a proportional increase in the need for methods to provide the necessary instruction coding for efficient operation of the machines. This instruction coding lies under the broad classification of part programming.

Part programming is defined as the technique used to provide all the data, in some coded form, to instruct the machine tool, through a numerical control unit. The MCU controls coordinate-motions, plus all of the auxiliary functions such as the spindle rotation speed and the table traverse feed necessary to produce the desired work-piece. The part programming technique may be as straightforward as manual coding each separate instruction in the MCU or as sophisticated as using a computer language, such as APT, and a large computer. A sophisticated program might define all the geometric elements of a part along with inputs to control five simultaneous axes of motion such as required to produce the complex impeller wheel for a gas turbine.

A strip of one-inch wide, eight-channel punched tape is the typical medium of part programming. This punched tape programs the machine control unit. After programming and tape punching, a very significant problem becomes apparent. How do you verify that the punched tape does, in fact, have the correct data to produce the desired part?

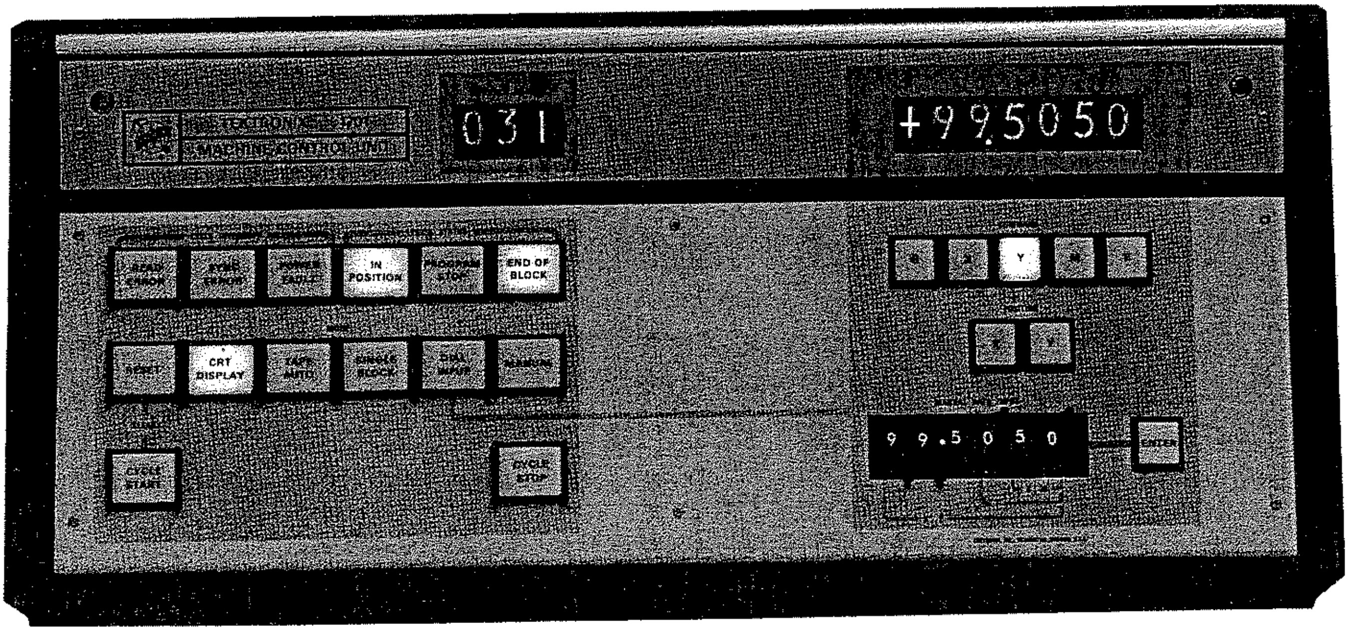
In other words, how do you check for programming errors? One of the least desirable, but most direct ways of checking, is to try to produce a first part on the machine from the untried tape. A second, and more tedious method, is to double check each entry on a printout of the tape against the original part program source (the part drawing). A better approach is to use some plotting device to graphically display tool paths programmed by the tape.

The plotting device that proved to be best-suited for fast tape verification was the Tektronix 611 Storage Display Unit. The 611 had been proven to be an excellent plotter of computer-generated graphics. It could follow the tape-reader speed of 300 characters per second, therefore, a part program could be plotted in seconds, rather than minutes.

Unique to the 1701 and 1702 Machine Control Units is the built-in ability to interface with the 611 Storage Display Unit for previewing programmed tool path. The 611 reveals the programmed tool path before actual machining takes place and graphically reveals most programming errors. Most programming errors are time-wasting, gross errors, potentially destructive in terms of ruined workpieces, broken tools, or even machine damage.

In evaluating the graphic method of tape and program verification for Tektronix numerical controls and allied products, the following requirements for optional utility were reached:

1. While graphic checking during interim programming phases is valuable, it is highly desirable to be able to verify the actual tape that will be used in operation on the machine.
2. The graphic display must be produced much more rapidly than the machine cycle time to produce the part.
3. Permanent file copies of the display should be easily obtainable.



A close look at the panel of the 1701 Two-Axis Machine Control Unit shows the standard features of sequence, command and position readout and manual data input. The 1701 is a full-performance, closed-loop, contouring control competitive in price with open-loop systems.

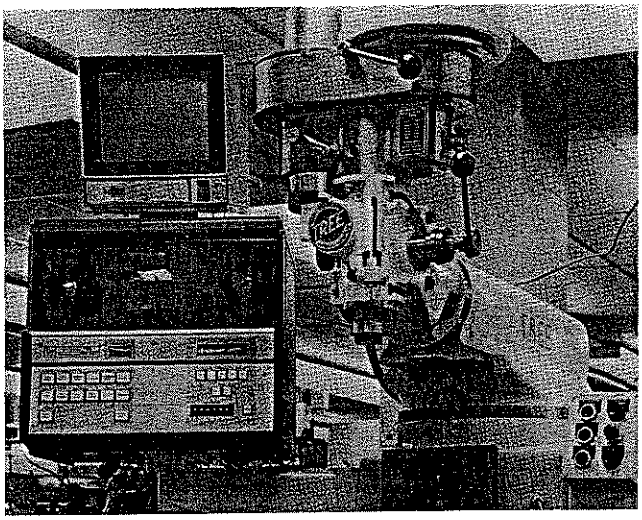
4. The coordinate and auxilary function command values on the tape should be easily read in decimal form.
5. A scaling feature would be needed to enlarge or decrease the plotted area on the 611 Storage Display Unit.
6. For three-axis paths, the ability to view total tool path isometric display is needed, plus the ability to produce all three orthographic views.
7. There should not be a necessity to modify the tape commands to produce graphic display.
8. Display capability should be offered at a low cost and be independent of a computer system.

Using the above requirements as a guideline during the product development of the 1701 and 1702 Machine Control Units, the application of the 611 Storage Display Unit and 4601 Hard Copy Printer resulted in a system which not only meets those requirements, but also provides additional benefits for system maintenance and machine tool monitoring. This system offers:

1. On-site tape verification. The actual part-program tape is checked on the same control and same machine on which the part is to be produced.
2. Rapid display. The display is generated at the maximum read rate of the tape reader (300 characters per second).
3. Hard-copy capability. With the 4601, permanent copies can be produced in 18 seconds.
4. A plot scaling feature from twice size, full size, 1/2, 1/4, 1/8, and 1/16 part size.
5. Isometric and orthographic path display for the 1702 three-axis control.
6. Low cost. Since graphic-display interface is built into the controls, the user needs only the 611 for tape verification and the 4601 (if permanent, hard copies are desired).

Graphic tool path verification capability is a unique feature of Tektronix 1701 and 1702 Machine Control Units. The controls use standard EIA or ASCII word address tape format, absolute dimensioning, programmable feedrates, sequence number display, command and position display to six decades and manual data input capability. The controls provide command of axis movements up to 99.9999 inches in each axis with 0.0001 inch resolution. Both the 1701 and 1702 are closed-loop controls capable of driving either electric or hydraulic servo systems.

To use the Tektronix system of tool path verification, the programmer or operator connects the 611 (and 4601, if hard copies are desired) to the output connectors provided on the control. He then loads the program tape to be checked into the MCU, selects the scale size to be used, and depresses the "CRT DISPLAY" button and the "CYCLE START" button. The machine control unit will then read the tape at 300 characters per second and produce a plot of the total motion of the tool as coded on the tape. The display will show a line plot of all the milling paths, plus centerline marks for hole locations and termination points of non-cutting moves. On the 1702, for three-axis displays, the operator can select one of the three (X-Y, Y-Z, X-Z) orthographic views, or he can select the isometric mode to see the total cutting path in one view.

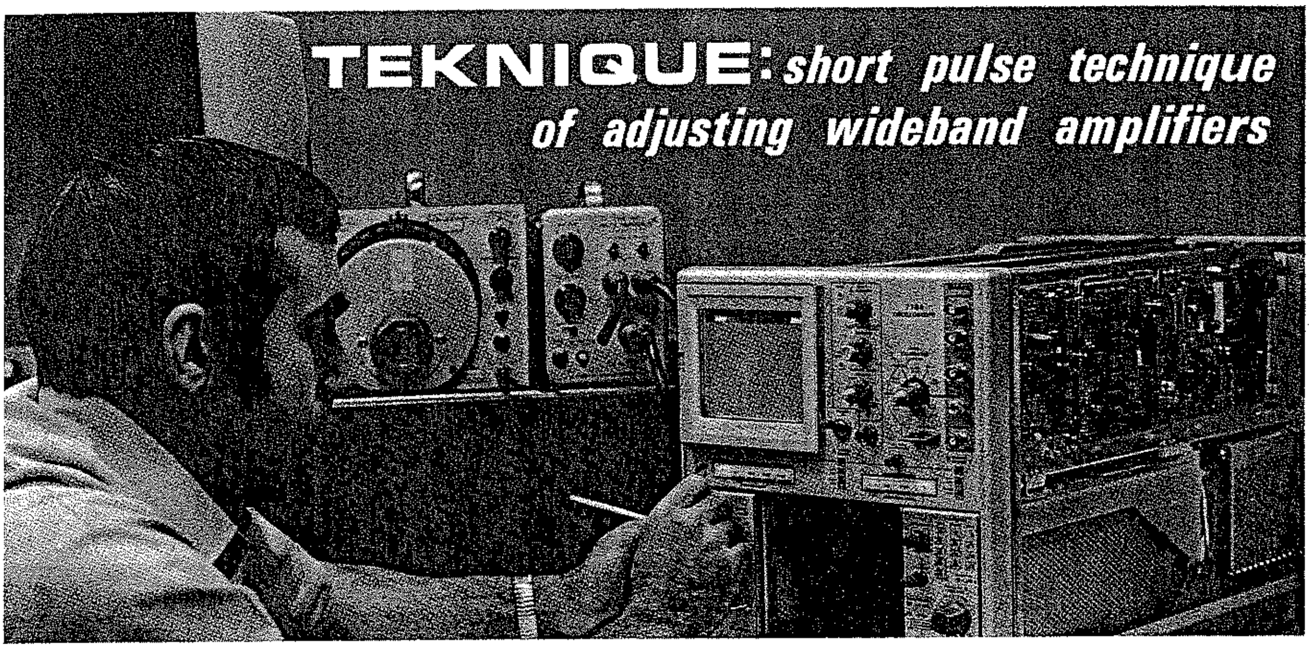


A 1701 Two-Axis Machine Control Unit mounted on a vertical milling machine.

These views, plotted on the 611, are used to check the tool path for general part configuration and for common errors, which are easily identified on such a plot. For more precise verification of certain areas of the tool path, the user may use a larger scale factor to get more detail. The user can step the display through one command at a time, and use the six-decade Data Display on the MCU front panel to show the actual dimension programmed on tape. This same Data Display can be used to verify the feedrate and auxiliary functions programmed in each block of tape. Once the tape is verified the 4601, if used, can be activated to produce permanent copies of the plot shown on the 611.

After verification is performed, the 611 can be disconnected for use at other machine tools and the MCU returned to machine control. If the 611 remains connected to the system, an additional "over-plot" is produced while the machine is in operation. With this over-plotting feature, a trace of actual tool path while machining is shown on the 611 Display Unit. This feature allows the operator to verify that the machine tool is actually traveling along the path directed by the tape commands plotted previously during tape verification. During corrective maintenance of the numerical control system, another benefit occurs from the control-to-storage tube interface. When using the "CRT DISPLAY" mode with a 611 Display Unit, if the tool path plot is correct, the maintenance technician knows the problem is probably in the machine tool. If the plot is incorrect, the trouble is probably in the MCU. Thus, troubleshooting time is greatly reduced and expensive down time is kept at a minimum by means of this graphic tool.

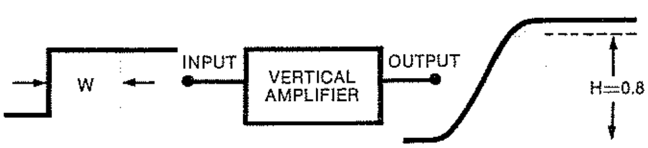
TEKNIQUE: *short pulse technique of adjusting wideband amplifiers*



By Carl Battjes
Manager in Portable & Low Frequency Instruments

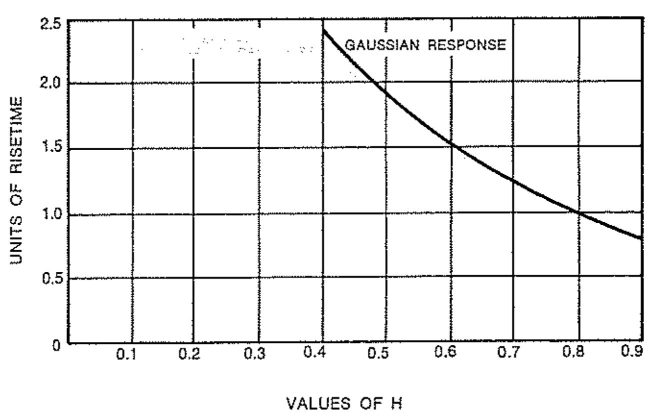
Adjusting wideband amplifiers for maximum bandwidth consistent with minimum aberrations can be a difficult, time-consuming task. Use of short pulse techniques makes the chore much easier.

This technique uses short and long duration pulse inputs of equal amplitude to measure bandwidth and risetime. If we drive an amplifier with equal amplitude pulses, one whose pulse duration "W" equals the amplifier risetime, the other of relatively long duration, the output pulse amplitudes will bear a definite relationship. That is, the short pulse height "H" will be 0.8 that of the long duration pulse. If amplifier risetime is faster than the short pulse duration, amplitude "H" will be greater than 0.8, if slower, less than 0.8. Using these values of "H", we can determine bandwidth and risetime. The chart at the right shows the units of risetime for various values of "H".



Once risetime has been determined, bandwidth is calculated by use of the familiar formula "bandwidth in Hz x risetime in sec = 0.35". For amplifiers exhibiting preshoot and/or overshoot, the actual bandwidth will exceed the calculated bandwidth. This is due to the variation in the bandwidth-risetime product of different responses. Tektronix vertical amplifiers typically have bandwidth-risetime products of 0.35 to 0.36.

The relationship between short and long duration pulses holds for a variety of amplifier responses, the main source of error being lack of equality in the 10% and 90% slopes. This lack of equality is not of consequence for wide-bandwidth amplifiers since such amplifiers tend to have a high degree of symmetry. The chart shows the value of "H" for several responses and the percentage of errors in risetime and bandwidth associated with each response. The first five curves show the effect of symmetry on risetime determination accuracy. If an amplifier has many stages, the response has more poles and the step response more symmetry.

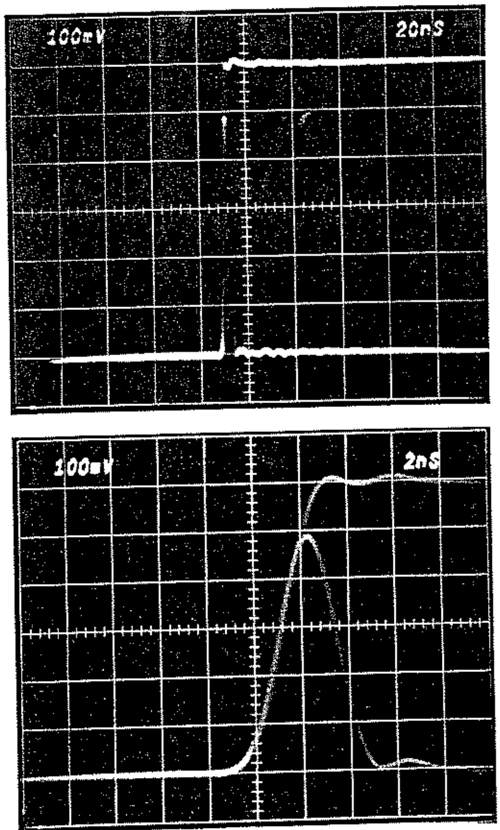


The photo at the left shows the setup for adjusting the 7A16 Amplifier using the short pulse technique. The signal source is a Tektronix Type 109 Pulse Generator which generates alternate pulses of independent length. A Type 113 Delay Cable provides the long duration pulse and the 2.4 ns charge line the short duration pulse. Cutting the 2.4 ns charge line to proper length is accomplished using a 568/230 Sampling System. The 5-ns, 50-Ω cables supplied as accessories for the 109 are a convenient source of charge lines since both ends have GR connectors. Output of the 109 is terminated in 50 Ω at the 7A16 input.

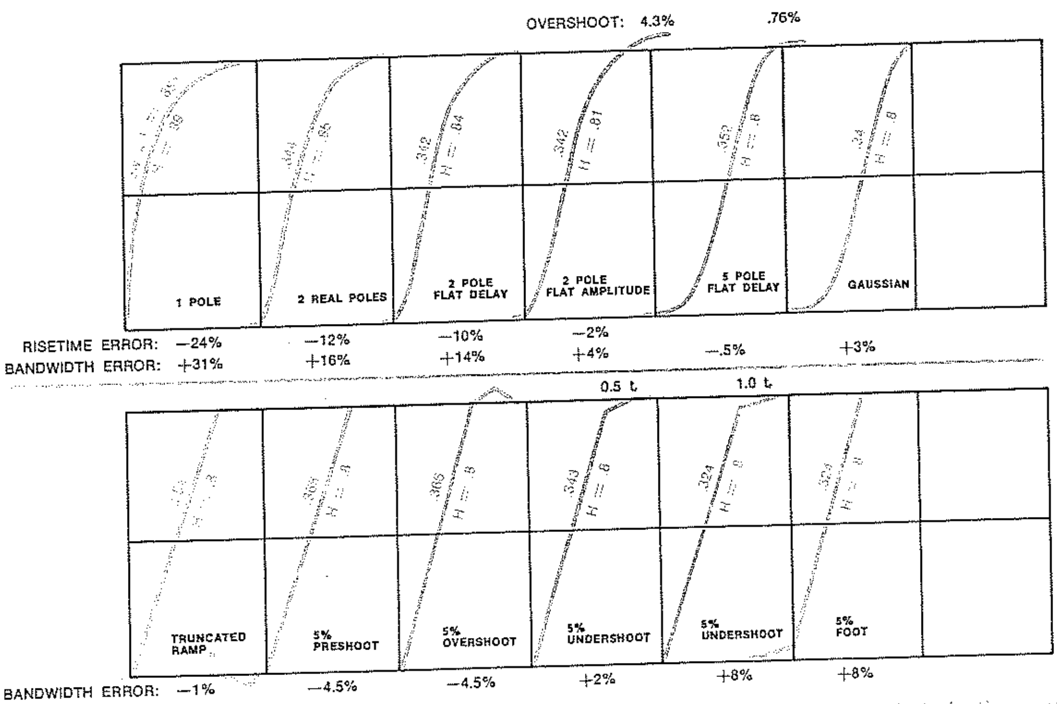
The amplifier is adjusted for minimum aberrations on the long duration pulse while observing the amplitude of the short pulse. An amplitude of 0.8 or greater assures the amplifier will meet bandwidth and risetime specs. You will notice that some adjustments have relatively little effect on the aberrations while changing the short pulse height appreciably. These adjustments should be set for maximum short pulse height consistent with minimum long pulse aberrations.

Short pulse techniques are also useful in checking the bandwidth of the amplifier system on higher attenuator settings. Constant amplitude signal generators available today lack adequate output voltage for making measurements above 1 V/div.

Using the short pulse technique not only simplifies compensation of the vertical amplifier and checking bandwidth of attenuators, but also yields better resolution for measuring the risetime of the entire vertical amplifier system.



Top photo shows dual pulse waveform displayed while adjusting amplifier for minimum aberrations using the short pulse technique. Bottom photo is the same display expanded ten times and shows correlation of risetime and short pulse height.



A "foot" has the same effect on bandwidth-risetime product as undershoot of the same magnitude and duration.

Risetime error is less than 1% where unspecified.

Effect of [illegible] response shape on short pulse height "H" and bandwidth-risetime product. Error in bandwidth caused by variation in bandwidth-risetime product and error in risetime caused by lack of equality in the 10% and 90% slopes is also shown.

SERVICE SCOPE

TROUBLESHOOTING TEKTRONIX HIGH FREQUENCY SPECTRUM ANALYZERS

By Darrell Brink
Product Service Technician, Factory Service Center

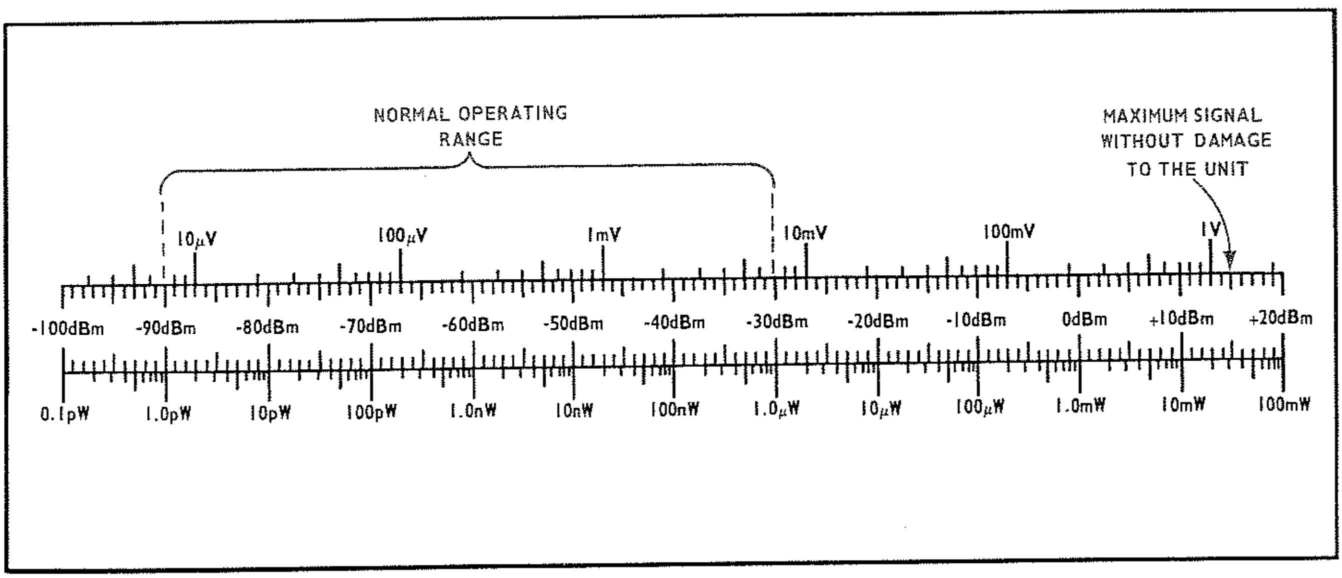
Familiarity with the function of one Tektronix Swept IF Spectrum Analyzer is familiarity with all. All use similar tunable RF oscillators and swept IF systems. The user sees an operational difference in the range covered by the RF center frequency control. The service technician will see a difference in configuration (plug-in form or a complete, self-contained unit) plus differences in RF oscillator circuitry.

The "honeycomb", containing most of the sweeper and IF circuitry, is a conspicuous feature. This method of construction provides excellent shielding between stages and simplifies troubleshooting since it can be replaced to isolate a problem.

A certain amount of troubleshooting can be done using a minimum of equipment. The noise generated internally by the analyzer and the 1 MHz markers available at the phase-lock jack on the front panel can be used as signal sources. However, a test oscilloscope, a time-mark generator such as Tek's 184 or new 2901 and a signal generator capable of 200 MHz with variable attenuation will help considerably. Higher frequency generators will be required if sensitivity or dial tracking is to be checked.

As with oscilloscopes, analyzer problems can often be isolated to a particular section by observing the pattern on the CRT. To insure seeing any signals or noise that may be present, it's usually best to start troubleshooting with the front panel controls set for wide dispersion, maximum gain, and minimum IF attenuation. With plug-in analyzers, be sure the oscilloscope SAWTOOTH OUT is connected to the analyzer SWEEP INPUT—this is often overlooked by the operator. The time base should be set to "free run" at 5 ms/div or slower. A note of caution is in order before applying a signal to the analyzer RF input. *Care should be taken not to exceed the maximum power limits of the input.* For linear operation no greater than —30 dBm should be applied. Signals greater than +15 dBm may damage the unit. See chart below.

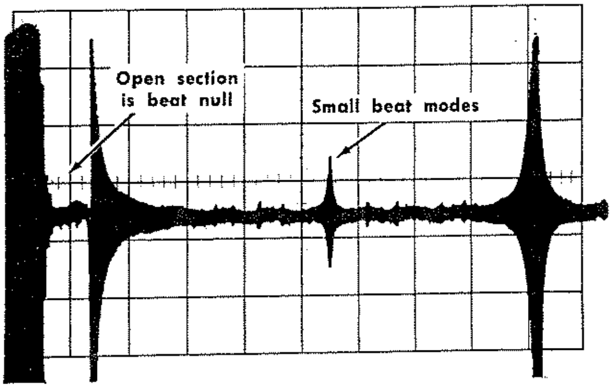
The most common problems encountered in these analyzers are defective mixers and oscillators. Let's take a look at these and other areas that may cause difficulty.



Volts-dBm-Watts conversion chart for 50 Ω impedance.

RF OSCILLATOR SECTION

RF oscillator operation can be checked by applying a known signal to the analyzer and tuning the oscillator to it, or by turning on the PHASE LOCK and checking for beat notes as the oscillator is tuned through its range. Assuming that the phase lock is working, beat notes should be seen across the entire oscillator range as shown below. An *RF oscillator failure* will usually result in the loss of beat notes and signal across all or part of the bands.



Typical display showing presence of phase lock beats, as the RF center frequency control is rotated.

The 1L20 and 491 utilize more than one RF oscillator to cover their respective range. If you suspect oscillator problems, switch to a range which uses a different oscillator. If the problem still exists, the difficulty probably is elsewhere in the analyzer.

An *open oscillator filament* in early vintage plug-in analyzers will remove the +75 volts feeding the 10 volt power supplies, causing them to be very low. In this case, a dead oscillator causes other symptoms such as complete loss of gain and possibly horizontal or vertical positioning problems. Later model 1L20's (above s/n 1150) have zener diodes across the filaments to prolong their life. These diodes also prevent the 10 volt supplies from dropping due to an open filament.

Another type of RF oscillator failure, particularly in the band C oscillator in the 491, is a phenomenon known as *"squegging"*. Squegging occurs when the oscillator breaks into another mode of oscillation and extra sidebands appear or the main signal "breaks up". A low-frequency sinewave several volts in amplitude, e.g., 30 kHz and 10 volts peak-to-peak will appear on the band C oscillator B+ lead (orange wire).

Squegging generally will not occur throughout the band, but only at one or two points. Phase lock beat notes will usually appear distorted and very noisy when squegging occurs. The only cure is to replace the oscillator. Should this be necessary, and if you are not properly equipped to do a total realignment of the RF section, we recommend the complete RF assembly or the complete unit be returned to Tektronix for repair.

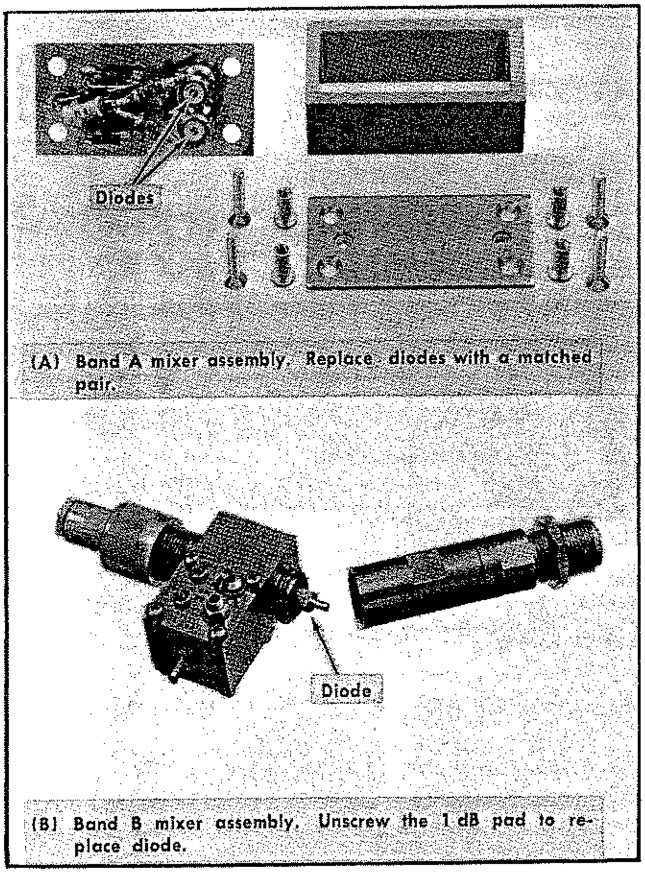
MIXER SECTION

Excessive power inadvertently applied to the analyzer input causes most mixer failures. The presentation on the screen will depend somewhat on the band being viewed. For example, *if the mixer fails in band B* of the 1L20 or 491, you may see a signal on screen (shorted or open diodes still pass signals), however, sensitivity will be down. Varying the mixer peaking knob will have little or no effect on the signal amplitude, and noise amplitude or "grass" will appear normal.

Mixer diode failure in band A of these units typically results in large, spurious signals appearing on screen at about 37.5 MHz, and they cannot be tuned out with the internal mixer adjustments. The mixer peaking control has no effect, as it is out of the circuit when band A is selected.

Mixer diode failure is best confirmed by replacement of the diode. The usual practice of checking diodes with an ohmmeter should not be used, as the current supplied by the ohmmeter may damage the device. Care should also be exercised when replacing the diodes. If soldered in, be sure to "heat sink" them with pliers to prevent damage.

To replace the mixer diode in band B of the 1L20/491 or in the 1L30, remove the mixer from the instrument and carefully unscrew the barrel from the body using a wrench and a vise. Then remove the diode with a pair of pliers. When installing the new diode, be careful not to break the fingers on the contacts in the mixer. Often it requires some force to push the diode into the contact.



(A) Band A mixer assembly. Replace diodes with a matched pair.

(B) Band B mixer assembly. Unscrew the 1 dB pad to replace diode.

Mixer assemblies for bands A and B of the 1L20.

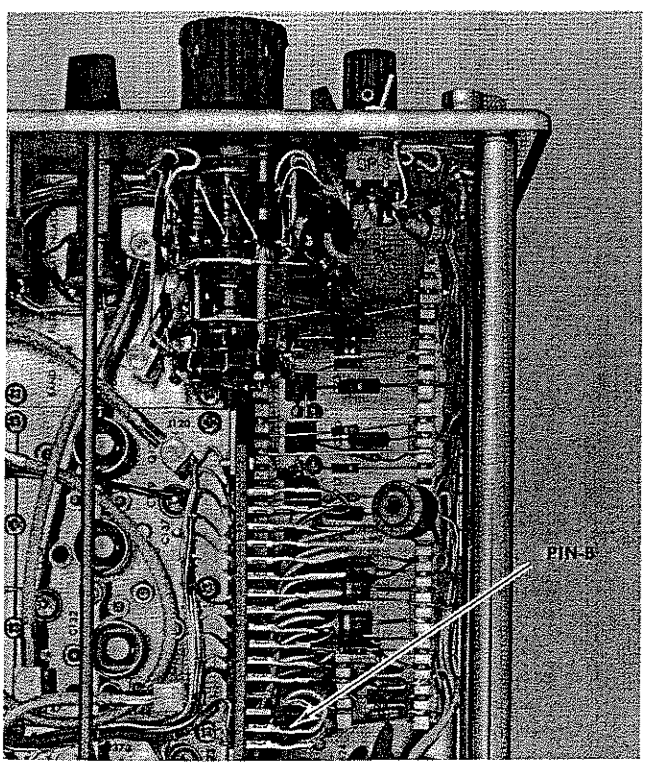
SECTION

Although not as common as "front end" problems, the IF section sometimes causes trouble.

Loss of gain can generally be traced to the IF system. When the gain is turned up and little or no noise is seen on screen, the trouble can be in either the honeycomb or the output stages. The output of the honeycomb can be checked with an oscilloscope for noise of about 1 volt peak-to-peak when the GAIN control is fully clockwise. *Absence of noise* could mean the 70 MHz crystal oscillator in the narrow band IF section of the honeycomb has quit. If that is the case, a slight adjustment of the oscillator coil, L444, should cause the noise to suddenly appear. A defective transistor in the wide band amplifier, narrow band amplifier, or resolution sections of the honeycomb will cause a loss of noise also.

Sufficient noise out of the honeycomb, but none on screen in a plug-in analyzer, could mean a defective recorder output transistor Q650, output amplifier V620, or detector diodes D660 and D661. In a 491, check amplifiers Q620, Q630, Q631, and the detector diodes D640 and D641. A failure of Q640 or Q641 will usually shift the trace off screen.

When *noise is present on screen but no signal*, most likely the sweeper is not running or the signal is being lost prior to the honeycomb. A quick way to check sweeper operation is to look at the waveform on pin M of the square pin connector strip of the honeycomb. The signal should appear as a large nonlinear sawtooth. Your manual shows the typical waveform. Normal sweeper operation at this point would indicate that the signal is being lost in the mixer, filters, or cables between the analyzer input and the wide band mixer transistor, Q140.



Output of "honeycomb" can be checked on pin B of the square pin connector. Other key test points are on this same connector.

When working in these circuits, you will find a BNC-to-Sealectro adapter cable very useful as you can insert a 200 MHz signal from a generator at any point up to the input of the honeycomb to help isolate the trouble. Generally, mixers will have a loss of 15 to 20 dB; filters, cables and switches, virtually no loss.

If the sweeper is defective, the analyzer display may appear as either *no signal, extreme nonlinearity of frequency markers, or a short sweep*. The waveform observed on pin M may be a badly distorted sawtooth, a squarewave, or just a DC voltage, depending upon the problem.

Since the sweeper has two feedback loops, troubleshooting can be difficult. However, there are several checks that can be made to isolate the trouble. Set the dispersion range switch to kHz and see if normal operation can be obtained. This eliminates the MHz discriminator diodes. If the symptoms are still present, return the range switch to MHz and check the DC voltage on pin P of the honeycomb. It should be adjustable to about −0.8 V DC with the IF CF (amplitude comparator) range pot (R290) if the amplitude regulating loop is operating. If it cannot be adjusted, continue on to the next check as something else may be causing the loop to lock up.

Next, check the DC voltage on pin M of the honeycomb. If it's within the range of about +14 to +55 volts, the discriminator loop is probably operating, and the trouble probably is a defective sweeper transistor, Q310, or output amplifier, Q340-Q350. However, other active components in the sweeper circuitry can also be suspect. Abnormal voltage readings on pin M usually indicate a problem in the discriminator loop. Grounding the discriminator output (pins N and O) will establish a reference for checking operation of the loop. Checking voltages at several points around the loop should disclose which stage is at fault. For example, the collector of Q260 should go to about +6 V under this condition.

PHASE LOCK SECTION

Phase lock beat notes are produced on the screen when the RF oscillator signal is beat against the internal 1 MHz reference oscillator signal. If the RF oscillator is working, loss of the beat notes can be caused by the 1 MHz crystal oscillator not running. Adjusting the oscillator coil, accessible through a hole in the phase lock chassis, may cause the oscillator to start.

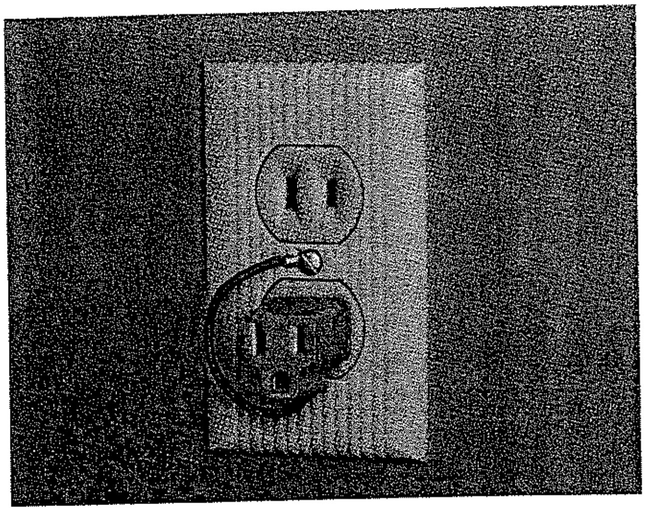
Improper avalanche adjustment can also cause loss of beat notes, low amplitude beat notes, or excessive noise. Check your manual for the proper adjustment procedure.

The trace shifting off screen when the LOCK CHECK button is depressed can be caused by a defective lock check switch, or a leaky capacitor across the switch.

UNGROUNDED INSTRUMENT HAZARD

No one knowingly grabs a bare power line. Yet, many of us are inviting this experience by using instruments that are not properly grounded. There are many ways the power line can accidentally come in contact with the instrument frame; vibration wearing through the insulation where the lead touches the chassis, an accidental touch with the soldering iron, connection to another instrument with faulty insulation. Whatever the reason, the danger is the same. To be safe, make sure the instrument is properly grounded.

One area often overlooked is the 3-to-2 wire adapter supplied with many instruments. Its purpose is to allow the three-pin plug, now used on most power cords, to plug into the older style two-pin power outlets. Unless the ground lead projecting from the adapter is properly grounded, the mainframe of your instrument is *not* grounded. The proper practice is to connect the lead from the adapter, to the ground screw of the two-wire outlet as shown in the photo. In older installations this screw may not be grounded. A quick check with a voltmeter between the ACTIVE output and the ground screw on the outlet will tell you. If the screw is not grounded, an alternate ground should be found for the adapter lead.



Some applications call for measuring voltages across components elevated to a hazardous potential. One approach has been to "float" the scope by removing the ground to the power system. Much safer techniques are now available to make most of these measurements. Your field engineer will be glad to help you with them.

INSTRUMENTS FOR SALE

564, 3B3, 3A6 with Cart, $1450. R. Ahnemann, Redactron Corporation, 100 Parkway Drive South, Hauppauge, N. Y. 11787. (516) 543-8700.

541A, 53C, $750. 310, $250. Jim Woodworth, Broadcast Products, Inc., 12330 Wilkins Avenue, Rockville, Maryland 20852. (301) 933-3400.

113. Mr. Oberton, Ikor, Inc., N.W. Industrial Park, Burlington, Mass. 01803. (617) 272-4400.

Two S-4 Sampling Heads, $500 each. Dynetics, Inc., Box 845, Bellevue, Wash. 98009.

531A, 53/54C, $595. Dick Everson, Box 63B, Friendsville, Penn. 18818.

535, $450. 545, $1000. 545A, $1100. Liberty Electronics, Inc., 548 Broadway, New York, N.Y. 10012. (212) 925-6000.

541A, CA, $1200. Mr. Sperber. (201) 276-3944.

545, 53/54C, D, $1100. Bill Bradford, 12772 Hickory Branch Rd., Santa Ana, California 92705. (714) 838-1218.

561B, 3S2, 3T2, Two S2 Heads. $1750 complete. Wilmar Electronics Leasing, 2103 Border Avenue, Torrance, Calif. 90501. (213) 320-6565.

Two - R561A's, Five - 2A60's, Two - 2B67's. Al Kutas, Dorex, 10221 Nottingham, Westminster, California 29683. (714) 523-1566 or (714) 531-9914.

422 with AC current Probe, $1100. Earl Olson, Electro-sonic Oil Tools, Inc., 2560 Wyandotte St., Mountain View, Calif. 94040. (415) 964-0555.

547, $1595. Mr. W. A. Brown, Rt. 4, Riddles Bend, Gadsden, Alabama 35904. (205) 442-5449.

535A, CA. Gene Clark, 1722 East 7th St., Duluth, Minn. 55812. (218) 724-0307.

3B3, Two - 2A61's. Make offer. Dick Robertson, ACL, 9125 Gaither Road, Gaithersburg, Maryland 20760. (301) 948-5210.

502A with C-27 Camera. Bids must exceed $1000. Pete Momcilovich, Int'l.-United Corp., P.O. Box 88870, Seattle, Wash. 98188. (206) 248-1550.

310A, $450. Hugh Neil, Jr., Special Instruments Laboratory, Inc., P.O. Box 1950, Knoxville, Tennessee 37901. (615) 525-9538.

D54 with P6011 and P6012 Probes, $550. Robert Stout, 5546 Little Lake, Bellaire, Texas 77401. (713) 668-9803.

545A, 1A1, CA, 500/53A Scope-Mobile Mod 2, $1400 complete. Bob Cobler. (916) 273-0322.

535, $850. 545, $950. Pat Gee, Mobilscope, Inc., 17734½ Sherman Way, Reseda, Calif. 91335. (213) 342-5111.

511AD. Dean Fredericks, 1814 Johnson St., N.E., Minneapolis, Minn. 55418. (612) 781-2583.

B Plug-In, $100. D. C. Malatesta, EMCEE Electronics, Inc., P.O. Box 32, New Castle, Delaware 19720.

D53A with TD51, A, G, and two probes, $750 complete. C. E. Price, Medatron, Inc., 1724 N. Main St., Dayton, Ohio 45405. (513) 274-2053.

561A with 3A3 and 2B67. Richard F. Hahn, 630 Fountainhead Way, Naples, Fla. 33940. (813) 649-2081.

RM564, 3A72, 2A60. Jack Hattan, Meditron, 1981 S. Ritchey, Santa Ana, Calif. 92705. (714) 541-0468.

3S2, 3T2, Two - S3's, 3B3. Charles Weyble, Moore Systems Div., 1212 Bordeaux Drive, Sunnyvale, Calif. 94086. (408) 734-4020.

535A with CA Plug-In. Best offer over $900. Wayne Broyles Engineering Co., 1403 Austin, Irving, Texas 75060.

547, 1A1, $2250. 114 Pulse Generator, $300. C. French, 61 Cody Lane, Los Altos, Calif. 94022. (415) 941-2339.

INSTRUMENTS WANTED

575, 576. Liberty Electronics, Inc., 548 Broadway, New York, N.Y. 10012. (212) 925-6000.

530 Series Scope/1A7A/160 Series/360/1121. Sigmund Hoverson, Physics Department, Texas A & M University, College Station, Texas 77843. (713) 845-5455.

581A with Plug-In. Edward Withey, Laurel Drive, Lincoln, Mass. 01773. (617) 897-7647.

A-2440

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