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TEKS

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TEKSCOPE

Customer Information from Tektronix, Inc.
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Cover: Measurement plug-ins and programmable calculator are symbolically coupled via an interface cable. The feature article in this issue describes the benefits of actually coupling these two elements to measure and process electrical data.

John Mulvey

The 31/53 calculator-based measurement instrumentation package

Couple a programmable calculator to a digital measurement instrument and what do you have? A quick, automatic, reliable way of doing nearly anything with measurement numbers that you wish. That can range anywhere from simply logging the numbers, to performing complex, sophisticated, mathematical calculations with them and issuing printed reports or command signals about what to do next.

The TEKTRONIX 31 Programmable Calculator serves as the central processing unit in a new instrumentation package that includes TEKTRONIX digital multimeters and digital counters. The package is small enough for bench-top use and low enough in cost for personal use by researchers and engineers. And if you unplug the calculator from the measurement instruments, both are immediately available for duty separately.

The compatible multimeters and counters are plug-ins that are among the TM 500 Series of test and measurement instruments. Essentially all it takes to make the calculator work with these plug-ins is a connecting cable and an interface unit. The interface is what is really new. We put most of the interface circuits in a special plug-in and the rest in a special frame that houses and supplies power to the plug-ins. We call the interface portion of the package a 153. When you connect a 31 to a 153 you have a 31/53 system.

The choice of multimeter or counter is yours. Two multimeters, two counters, or one of each, are acceptable combinations. Each 31/53 has at least two data acquisition channels. And you can add up to eighteen more channels by merely plugging together additional 153's. Every part of the package is plug-to-plug compatible. All you need to do when changing from one combination of measurement plug-ins to another is insert a different patch-plug at the rear panel and rearrange a few push-in jumper wires in the interface unit.

Who needs a programmable calculator coupled to a digital measurement instrument? Basically, anyone who may be (1) logging measurement data by hand, (2) performing calculations with measured data, (3) comparing measurement data with numbers in tables, (4) scaling strip-charts visually, or (5) spending too much money on computers or computer software processing measurement data.

Facing Interfacing

Making measurements with digital multimeters or counters is sometimes part of a process of acquiring data to be *analyzed*. Analysis is where the calculator comes in, of course. Hand-held calculators are very common nowadays, but the feasibility of putting calculators on-line with data inputs is not obvious to everyone. It didn't just happen that you can couple the TEKTRONIX 31 Calculator to a TEKTRONIX DM 501 Multimeter through an interface that also works with TM 500 Series counters. It was planned that way. The multi-pin connector on the rear of the calculator has been there from the beginning.

Most any digital readout device can be coupled to the 31 Calculator through an interface of your own design, if you have the time and know-how to build one. But there are too many diverse requirements to make an interface that will accommodate even a majority of digital readout instruments. On the other hand, the DM 501 Multimeter and DC 503 Universal Counter can provide nearly every kind of measurement presently done with numerous more-specialized instruments. The DM 501, for example, measures resistance and ac or dc volts and amperes over a very wide range, with 4½-digit resolution. In addition, the standard option DM 501 comes with a temperature measuring probe.

With a low-cost custom mod, you can trade the temperature measurement capability for ten times more sensitivity when measuring dc volts. That does such things as let you measure voltage and calculate temperature using the low-level dc signals from thermocouples. For example, if you are considering interfacing your digital thermometers to a minicomputer, you should think about using ordinary thermocouples and letting the 31/53 system do the whole job at a considerable cost savings.

Consider the DC 503 Universal Counter. It will measure signal frequencies to 100 megahertz, measure time intervals with a resolution to 1 microsecond, totalize counts as high as 10 million, or provide the functions of a digital clock or stopwatch. You might be considering how to interface the output of a digital flowmeter or digital tachometer to the data collection system. Flowmeters or tachometers with analog outputs are less expensive. They can work through the DC 503 and be automatically scaled by the calculator to yield the correct numbers and units. In this way the 153 becomes a sort of universal interface.

The Economy Angle

There is a natural tendency to think that a sophisticated programmable calculator should be handling difficult calculations or it will not pay for itself. Not so. There are many simple chores that can be done more economically with the 31/53 than any other way. Under program control the 31/53 can operate unattended. It can, therefore, be continually monitoring input data, performing calculations, printing out alphanumeric records, and issuing warning or command signals when needed.

Consider the case where analog strip-charts are traditionally used. It is nice to know that you have logged all the available data. But sometimes the chore of reducing reams of data to the form essential to your purposes is too time consuming to get done when needed, or to be done economically. The 31/53 will monitor data continually, also, and not only discard unnecessary data but automatically produce summaries and statistics along the way. It can even be idling most of the time and pay for itself, when you compare the cost of equipment and man-hours needed to extract pertinent data from a strip-chart.

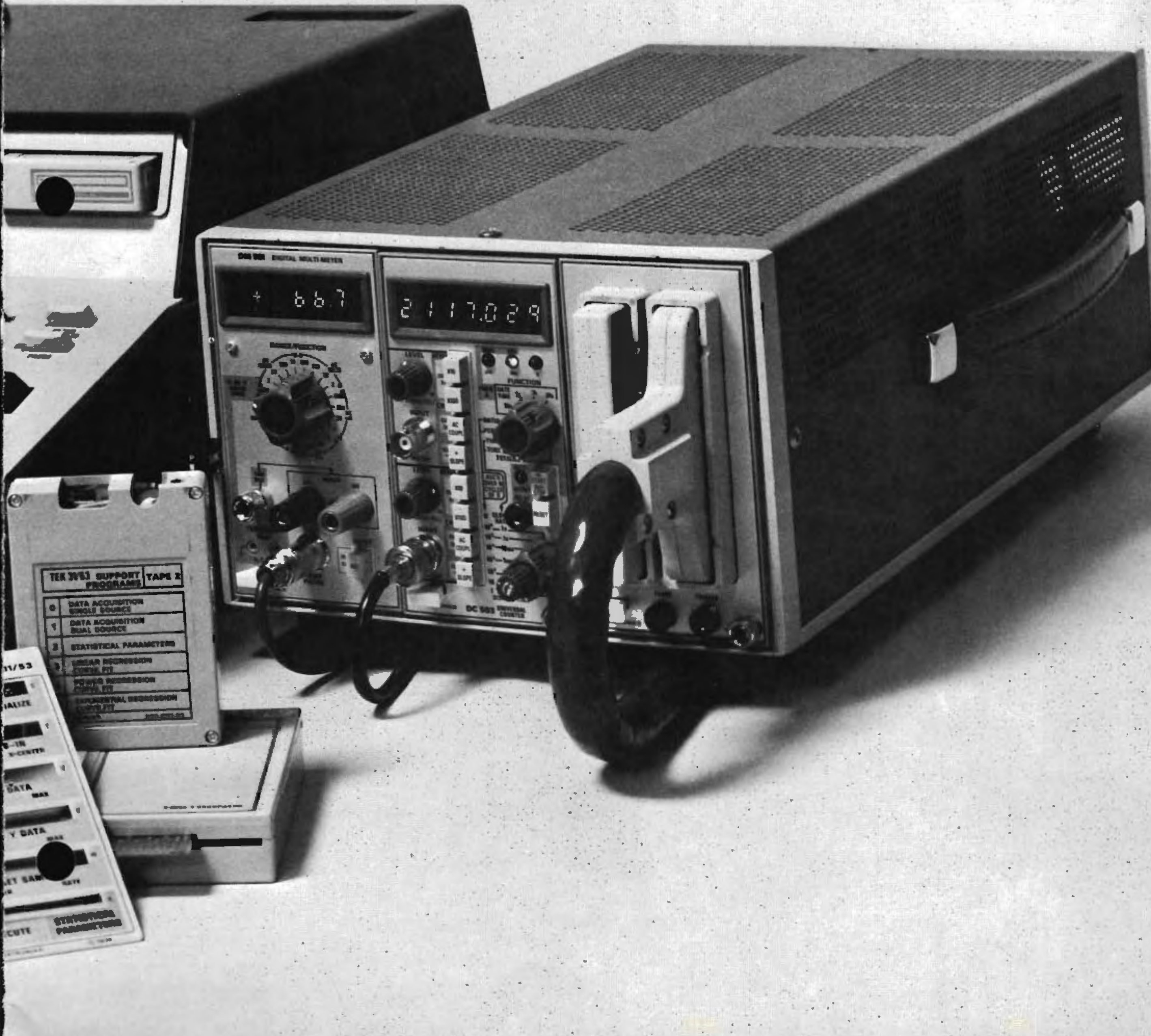
Another factor that adds up to economic benefits for even simple calculations is the speed and accuracy with which measurements and calculations can be per-

formed when you don't have to enter numbers or instructions manually through the keyboard. An unskilled calculator operator can easily be taught to push one or two specially-labeled keys to cause a set of measurement data to be entered and operated on. With a very simple program and your own labeled user-definable keyboard overlay, that sort of thing can be done. User-definable overlays are a very valuable standard feature of the TEKTRONIX 31.

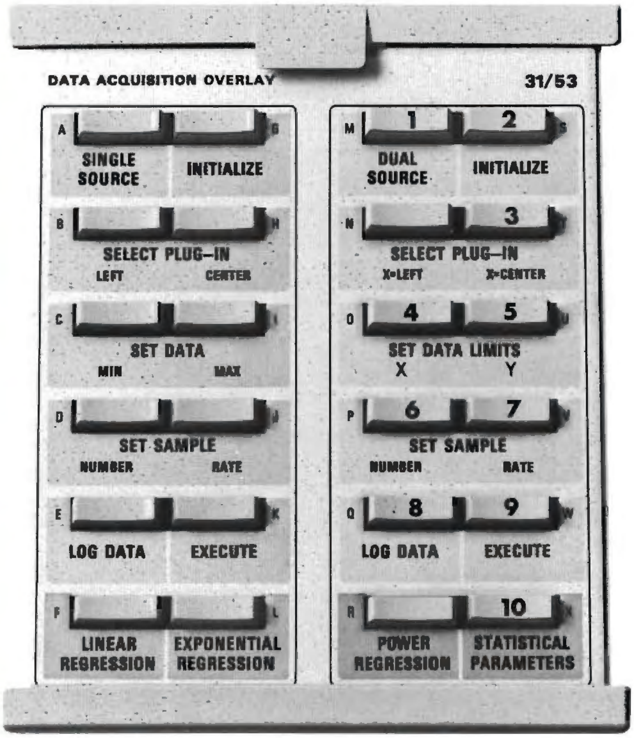
In a low-volume, precision-component production situation at Tektronix, hours of oven-stabilization time were once required that proved to be unnecessary when the 31/53 was used. Using the old method we had to wait until the oven temperature had stabilized enough so that all the data, logged by hand, could be compared to numbers in one set of tables. Using the 31/53, the precise voltage-drop across each component could be measured almost simultaneously with the measured temperature of the oven. Calculations followed immediately. The operator needed only to select the component with a switch, and push one calculator key. Efficiency was improved to where production could be more than doubled without additional equipment.

Measure, Measure, Calculate

Single measurements on individual devices or circuits seldom provide adequate data, even if we are talking about only one characteristic of the device; and there may be several characteristics to be measured. Numerous measurements often need to be made and correlated before you have adequate information. For example, if you measure the frequency of an oscillator with a high-resolution digital counter, you will usually find that the last digit or two changes each time a new reading



Typical use of data acquisition overlay



Standard software includes two special overlays and two pre-programmed magnetic tapes to go with them. The DATA ACQUISITION overlay is shown. These pre-recorded programs and overlays allow many ordinary data acquisition and analysis problems to be solved without custom software. Here is how you would typically solve a problem using the DATA ACQUISITION overlay.

1. Push DUAL SOURCE. We wish to acquire data from both measurement plug-ins.
2. Push INITIALIZE. We are prepared to make the next selections.
3. Push X = CENTER. We have a multimeter in the left plug-in compartment and a counter in the center plug-in compartment, and we would like voltage to be on the vertical (Y) axis in case a graph is ever plotted of the data pairs.
4. Push DATA LIMITS for X-axis. Follow this by keying in the minimum and maximum numerical values the acquired X-axis data may have before the program is intentionally interrupted.
5. Push DATA LIMIT for Y-axis. Follow this in the same way as for Step 4.
6. Key in the number of data-pair samples you wish to take before the test finishes. Push SET SAMPLE NUMBER.
7. Key in the number of seconds you wish to wait between each successive act of transferring acquired data to the calculator. Push SET SAMPLE RATE.
8. Push LOG DATA. We wish each datum to be printed on the paper tape. The data is stored for later analysis whether logged or not so there may be no interest in logging the raw data.
9. Push EXECUTE. We are ready to take data and want to begin.
10. Push STATISTICAL PARAMETERS after all the data has been acquired. This will yield a print-out of the Mean, Standard Deviation, and Variance on both sets of data. If we wished to see how well the data-pairs correspond to a curve expressed by one of three common equations, we could press the Linear Regression, Exponential Regression, or Power Regression key.

```
TEKTRONIX 31/53
PROGRAM E
AVG. FREQ:
(KILOHERTZ)
        591.475
MAX:
         591.56
MIN:
         591.31
RANGE:
            .25
% DEVIATION:
           .042
```

Fig. 1. Tape readout from an actual test of oscillator performance. Average frequency and minimum and maximum frequencies are readily measured and recorded.

comes up. Then you wonder what the average frequency is and how much the frequency is varying. Your counter will tell you the average frequency over a selected period of time, but you won't know what the frequency variation has been.

The 31/53 can be programmed easily to tell you all of that. Figure 1 shows a paper tape readout of just that kind of test. It took less than one minute to measure frequency 50 times, keep track of the highest and lowest readings, calculate the average frequency from all the measurements, calculate what percentage of the average frequency the maximum deviation was—and print out the results.

Most systems that would do all this faster would not be as economical. If you were to determine the short-term frequency-drift characteristics of an oscillator, as in the above example, you might need to extend the time from 1 minute to 10 minutes. In that case the low-cost calculator and counter obviously would be more economical.

Another measurement often of interest is how the oscillator frequency varies as a function of ambient temperature. With two data acquisition channels available in the 31/53, one channel can provide temperature information for repeated correlation with frequency information supplied by the other channel.

Quick Calculations—Better Measurement

You wouldn't normally suppose that the ability to make rapid calculations would have anything to do with making better measurement, but it is true. The traditional ways to measure things are often based on yielding numerical results with little or no calculation required. Sometimes unconventional methods would be better if the calculations could be done quickly and accurately. We discovered a good example when thinking about how we might easily demonstrate the curve-fitting capabilities of the TEKTRONIX 31.

Most electrical engineers know that a charged capacitor will discharge through a resistor at an exponential rate and that the time to discharge from a given voltage level to 37% of that level will be equal to the product of R and C, resistance and capacitance. How many times have you determined the value of a capacitor by (1) knowing the value of resistance it discharges through, (2) measuring the rate at which it discharges, and (3) calculating the value from this data? The 31/53 does this very well for capacitors with many microfarads of capacitance. Our components test department was delighted. Measuring the value of such capacitors by conventional methods was yielding questionable results. A difference in measured capacitance of about 20% was suspected and confirmed when comparing reactance at 120 Hertz with storage of direct voltage.

Why Calculator-Based

Both the minicomputer and the calculator have great computational power. Both will do most of the same jobs. How do you decide between systems? It is not always easy and sometimes it is a toss-up, but here is a little perspective:

Learning to operate the TEKTRONIX 31 Calculator keyboard is easy for an engineer. Learning to program the calculator is easy for anyone with programming experience. Programming a minicomputer will also be easy to anyone with programming experience if it happens that the minicomputer uses a high-level language like BASIC. This is unlikely, however, because most minicomputers are programmed using a unique assembly language. Unless you or your programming people already have experience with that kind of minicomputer, programming can be a hidden cost and a bottleneck.

Another point to keep in mind is that the bare mini is probably not all you need if you want to keep programming costs reasonable, especially if you intend to have the computer do several different jobs in its lifetime. You should also look at the benefits of at least a tape punch and tape reader before firmly fixing a price tag. And for a readout device you may need at least a teletype machine.

What About Measurement Speed

Compared to the average computer, most calculators are slow. The TEKTRONIX 31 Calculator is no exception. But the 31 is not slow compared to the rate at

How the 31/53 works

Using the DM 501 Digital Multimeter and DC 503 Digital Counter

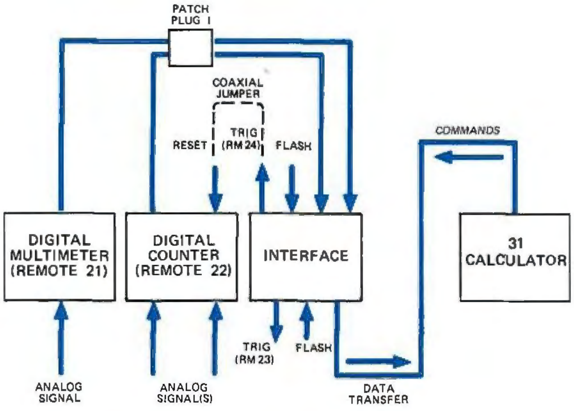
The digital multimeter repeatedly measures and converts analog signal amplitude information to digital numbers, five times per second. The counter performs a similar A-to-D conversion at a rate depending on the signal and the mode of operation of the counter, often less than five times per second.

The digital information in the readout window of the multimeter and counter is routed to the Interface via a patch plug that makes connections to the correct pins. The Interface alters the form of the digital information so that it may be transferred to the calculator in the form required by the calculator.

A REMOTE 21 command signal from the calculator initiates the transfer of data from the left plug-in, to the calculator, via the Interface. A REMOTE 22 signal does the same for the center plug-in. The command signals may be generated from the keyboard of the calculator or as part of a program in progress.

A REMOTE 24 command issued by the calculator results in a trigger signal being generated at the rear panel of the Interface. This signal is sometimes used for resetting the counter plug-in to zero. That trigger signal, or a similar one available on the front panel (addressed by REMOTE 23), can be used for other things such as stepping a relay, or scanner. Or one trigger could be used for stepping a scanner and the other for resetting a scanner. A coded burst of trigger pulses may be issued in more sophisticated applications, to distinguish between the kind of response solicited or to distinguish between devices from which a response is solicited.

The Flash connections on the front and rear panels of the Interface provide a means of signaling the calculator anytime an anticipated event takes place. This can be anything from an alarming situation, to a condition which merely tells the calculator data is ready to be taken from one of the plug-ins. The calculator is programmed to respond in some particular way as a consequence. Only a 2-microsecond pull-down pulse is required to activate the Flash condition. The calculator can be programmed to reset itself immediately so it can repeatedly recognize a new Flash condition.



which fresh measurement data arrives from a typical multimeter or counter. You don't need the speed of a computer to handle data that changes less than five times per second.

Operated in the data-capture mode the 31/53 can store ten-digit numbers at a maximum rate of about 16 per second. If it is given a pause periodically, it can process the captured data during those pauses. When logging data the alphanumeric printer will print about 2½ lines per second, 16 characters to the line. This is not very fast by some standards, but it is often much faster than needed. You should ask yourself how fast you really need information from your system.

Another consideration should be the extent to which your system must be doing the same thing day after day, or month after month. If you are wondering whether a dedicated measurement instrumentation system of any kind is feasible, think about how the equipment can be used to advantage if production demands are not as great as you expected. The TEKTRONIX 31 Calculator can be unplugged from a 31/53 and used in a different job immediately. The TM 500 Series of counters and multimeters can also be used alone, wherever electrical measurements are being made.

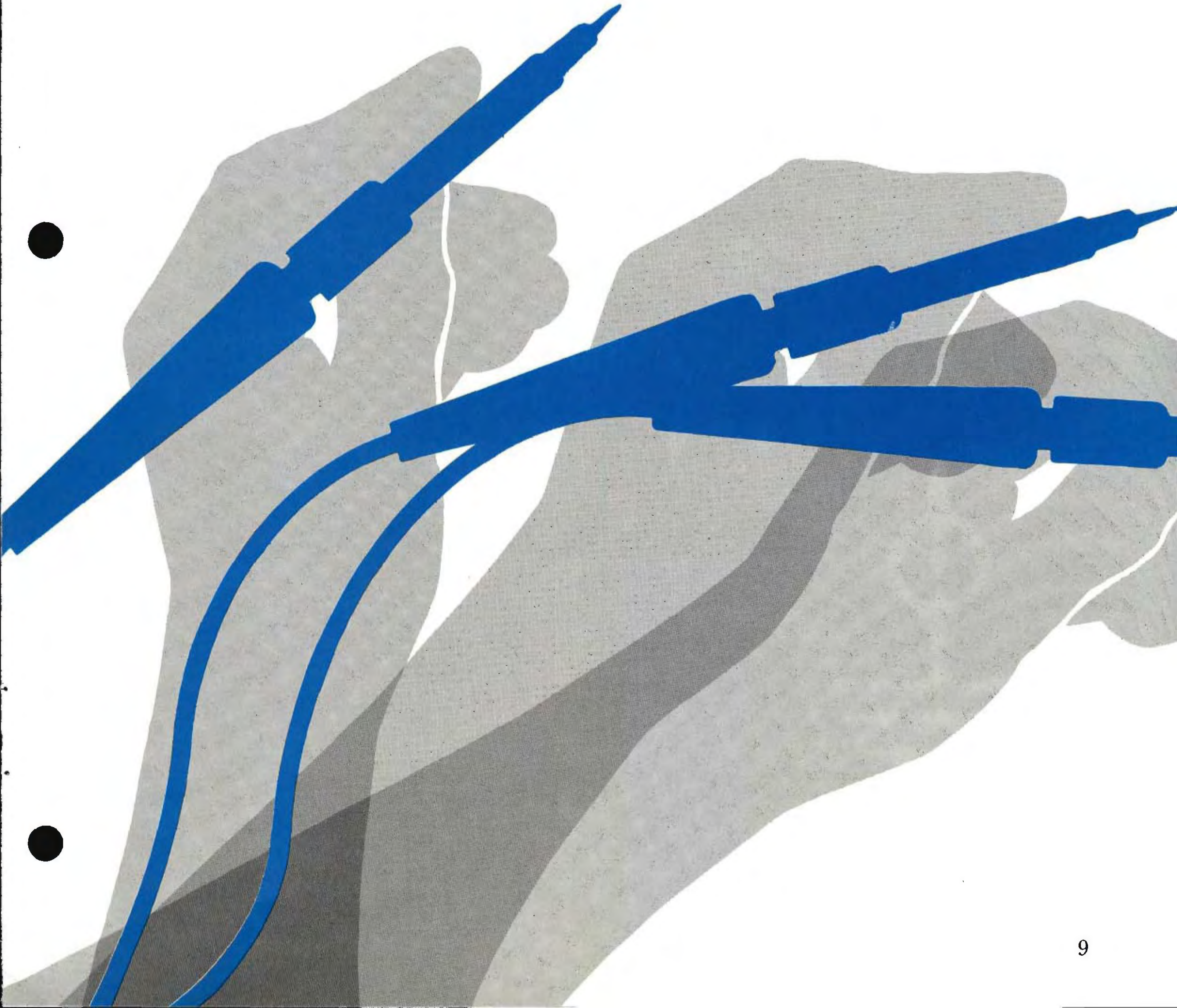
What You Get

The 31/53 is shipped with standard software consisting of two pre-recorded magnetic tape cartridges, two corresponding keyboard section overlays, and a 31/53 system manual. One of the two overlays, the data acquisition overlay, is shown on page 6 with a step-by-step example of how it may be used. After inserting the Data Acquisition tape cartridge you can put your 31/53 to work immediately by pushing the keys identified on the overlay that perform the desired functions. Custom software can be developed for you in the USA by a highly competent Tektronix system analyst near you.

Using your oscilloscope probe

Riley Stock

When a probe is needed to accomplish a measurement function, the typical concept which comes to mind is a passive voltage probe. These probes constitute, by far, the greatest number of probes in use today. Part I discussed passive probes and several of the considerations required in their use. In Part II the world of probes is broadened to include two less well known, but exceptionally useful classes of probes. First, the active, or FET, probe is discussed in the context in which Part I presented the passive probe. The second section presents some of the considerations which can lead to the selection of a current probe as the most appropriate and least circuit-disturbing signal acquisition method.



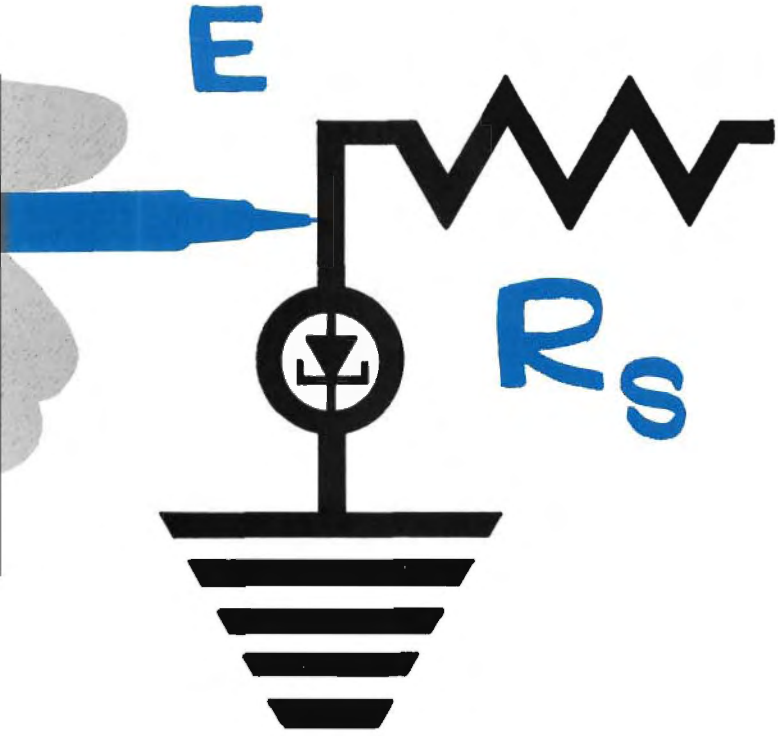
PART II Active and Current Probes

Active probes

Two prime advantages of active probes are: the isolation provided between the measurement point and the probe cable and scope, allowing high input resistance and low capacitance to be achieved; and full bandwidth without input signal attenuation.

Most active probes are compatible with either 1MΩ or 50Ω scope inputs without using external adapters. When working in the 50Ω mode, a 50Ω cable can be used to extend the probe length without increasing capacitive loading. However, longer cables will slow the risetime.

The typical active probe uses a FET input and contains both ac coupling capability and voltage offset for observing signals riding on top of a dc level. The active probe used in this discussion is the TEKTRONIX P6201 probe. It uses a FET input and has a probe only bandwidth of dc to 900 MHz with a risetime of 0.4 ns or less. Other active probes will provide similar advantages within their frequency capability. For example, the P6045 will handle signals up to 230 MHz.



Measuring pulse signals

To provide for a common basis of comparison with the passive probe, the same signal source used in Part I is used for this discussion of active probe performance. The source consists of an ideal step-function generator providing a voltage step of infinitely fast risetime. The source impedance is 200Ω shunted by 20 pF, resulting in a source risetime of 8.8ns (Figure 1(a)).

As we noted in Part I, the capacitive loading caused by applying a probe to the circuit under test can significantly alter the risetime of the signal we desire to measure. If the probe resistance approaches that of the signal source (within two orders of magnitude) risetime can also be affected.

In Figure 1(b) we see the effect of applying the P6201, with 10X attenuator head (1.5pF, 1MΩ), to our signal source. The capacitive loading of the P6201 has increased the pulse risetime from 8.8 ns to 9.5 ns. In Part I of this article we noted that the loading effect of the probe on the signal source could be stated as the percentage change in risetime. In this instance the loading effect is:

$$\frac{t_{r3} - t_{r1}}{t_{r1}} \times 100 = \frac{9.5 - 8.8}{8.8} = 8\%$$

This is a considerable improvement over the 48% increase in risetime caused by the typical high impedance 10X passive probe, and somewhat better than the 12% decrease in risetime caused by the low-resistance, low-capacitance P6048 passive probe.

We also noted that loading is directly related to probe capacitance, assuming the probe resistance (R_p) to be much larger than the source resistance (R_s). When the probe resistance approaches that of the source, the source impedance is effectively reduced, causing a decrease in the risetime and a considerable reduction in signal amplitude.

Measuring low-level signals

One of the prime advantages of an active probe is full bandwidth at 1X attenuation with minimum circuit loading. This is essential when viewing fast signals in the millivolt region. The P6201 (X1) probe has an input resistance of 100KΩ and a capacitance of 3pf. Let's see what happens to the risetime and amplitude when we apply it to our typical signal source.

Figure 1(c) shows the risetime increased from 8.8 ns to 10 ns for a change of 14%. Though somewhat greater than the 8% of the P6201 (X10) the error is comparable to the 12% error caused by the low-resistance, low-capacitance P6048 passive probe. And note that the P6201 (X1) has negligible effect on signal amplitude.

From the graph in Figure 2 we see that the active probe provides a more accurate risetime measurement than does the passive probe, over a wide range of source risetimes. However, at lower values of source impedance or slower risetimes the small differences in measurement error may not justify the difference in cost between the passive and active probes.

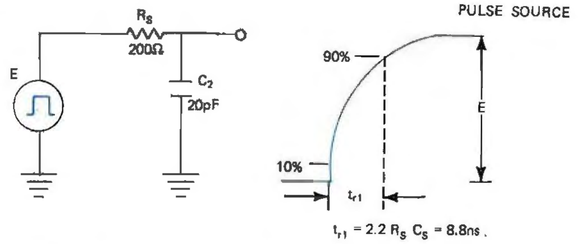


Fig. 1(a). Typical pulse signal source.

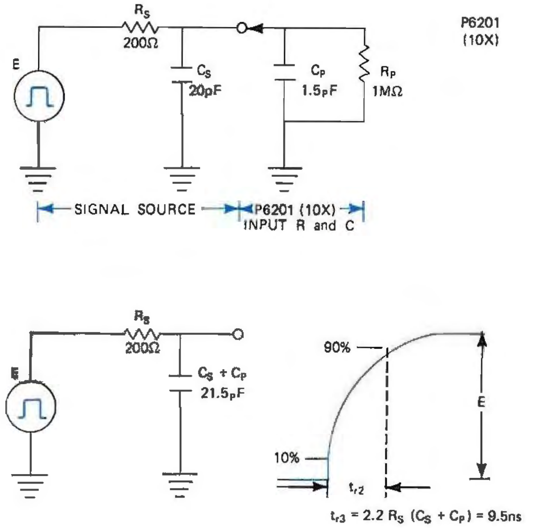


Fig. 1(b). P6201 (10X) probe added to typical pulse source.

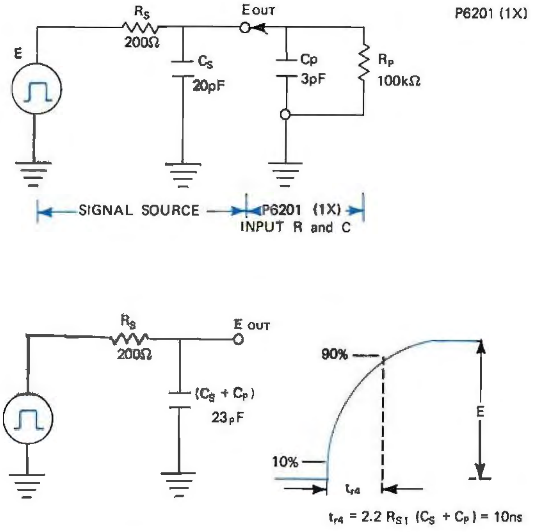


Fig. 1(c). P6201 (1X) probe added to typical pulse source.

Measurement of sine wave signals

Now let's see how the active probe performs when measuring sine wave signals. Figure 3(a) shows the same 10 MHz sine wave source used in Part I. Applying the P6201 (10X) probe we find the source is loaded by a probe resistance (R_{p3}) of 1 MΩ and a capacitive reactance (X_{p3}) of 11 kΩ. This compares with an R_p of 40 kΩ and X_p of 1.7 kΩ for the typical high impedance passive probes (See Figure 4).

Since $R_{p3} >> R_s$ it can be disregarded. However, the shunting effect of X_{p3} in parallel with X_s yields a total reactance, X_{ct}, of 790Ω. The resulting impedance is $Z = \sqrt{R_s^2 + X_{ct}^2} = 815\Omega$. E_{out} with the P6201 (10X) applied becomes $\frac{790}{815} \times 100 = 97\%$ (Figure 3(b)). We see that at the 10 MHz frequency the P6201 has negligible effect on the signal output amplitude.

The advantages the active probe offers for measuring sine wave signals are: a more gradual decrease of R_p with increasing frequency, and a lower input capaci-

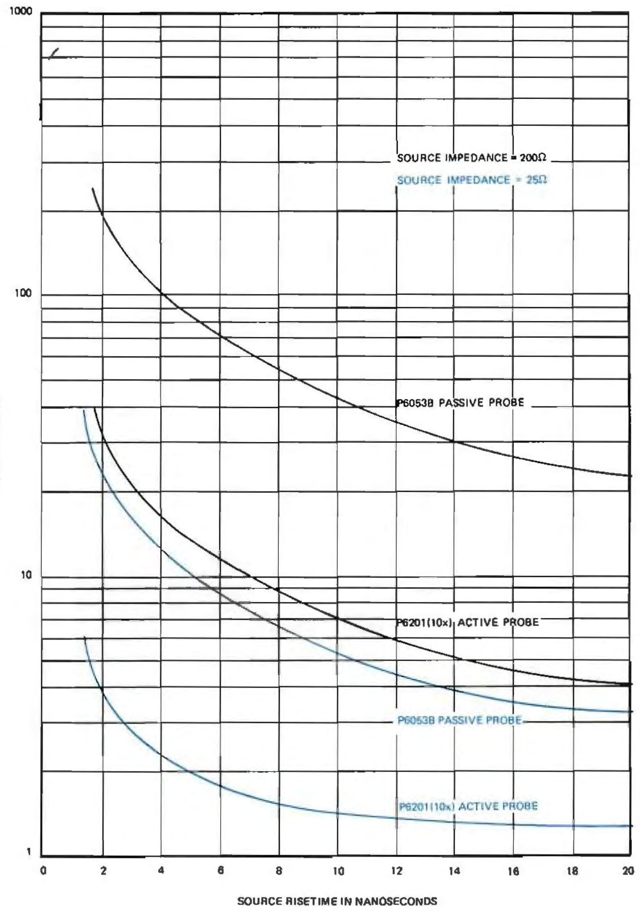


Fig. 2. Relative performance of the P6201 and P6053 when measuring various risetime signals from a 200Ω source and a 25Ω source.

tance providing higher X_p. These characteristics become even more important as the signal frequency increases. For example, if the frequency of our typical source is increased to 50 MHz, the P6201 (10X) causes a change in source output voltage of 3%, while the typical passive probe causes a change of 20%.

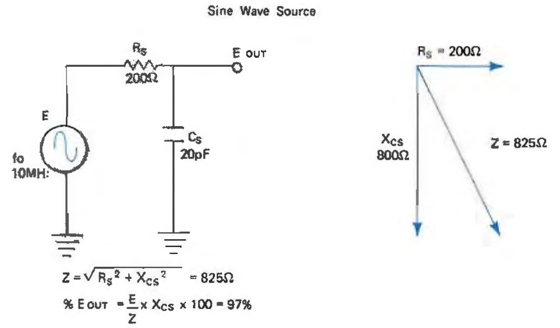


Fig. 3(a). Typical sine wave signal source.

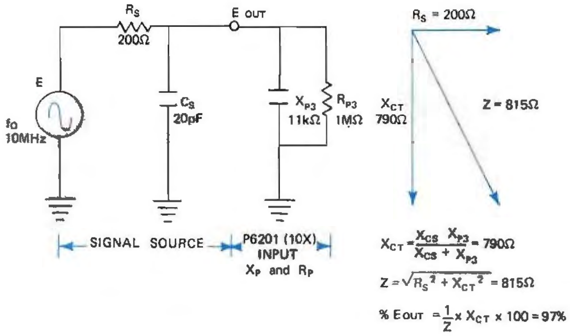


Fig. 3(b). The P6201 (10X) probe to typical sine wave source.

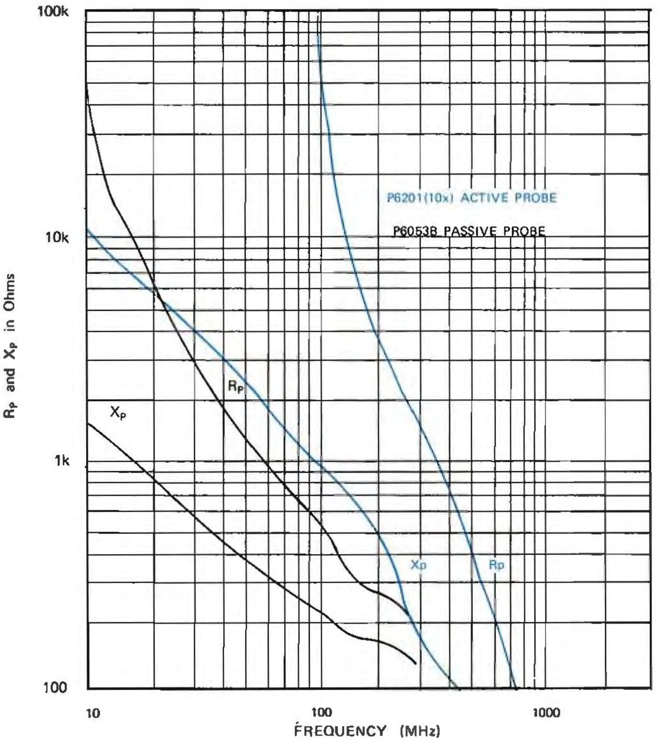


Fig. 4. Typical X_p, R_p vs. frequency curves for the P6053B and P6201 probes.

Summing it up for active probes

Active probes can provide definite advantages when viewing signals from high impedance and/or low capacitance sources. They provide the best obtainable combination of high input resistance and low capacitance, without signal attenuation; they therefore can be considered capable of providing the best general-purpose measurement capability.

Following is a summary of some general considerations for selecting an active probe:

1. Full bandwidth is provided with no signal attenuation using the 1X configuration.
2. The active nature of the probe provides the high input impedance characteristics of most passive probes and the low input capacitance of passive probes designed to work into 50Ω inputs. These features yield the best of two worlds—minimum risetime and minimum pulse-amplitude error.
3. Impedance selection to permit use with either 50Ω or 1 MΩ inputs is usually provided.
4. Probe length can be extended through the use of 50Ω cable without increasing probe loading.
5. Over-voltage capability is typically provided. However, to minimize the likelihood of over-voltage, the highest attenuation configuration should always be used when probing unknown voltages.
6. Dynamic signal range of the active probe is not as great as that of a passive probe. For example, the P6201 (1X) can handle signals up to ±600 mV. This can be extended to ±60V using the 100X attenuator. DC offset provides a measurement window of ±5.6V using the probe alone, with the range extended to ±200V using the 100X attenuator.

The current probe

Now let's turn our attention to a measurement tool often overlooked—the current probe. Current probe measurements are particularly applicable for high impedance measurement points where the voltage probe would significantly alter the circuit characteristics.

The current probe offers the lowest circuit-loading of any available probe. There is, however, an insertion impedance reflected into the circuit under test, which consists of a series resistance shunted by a small inductance. The value of this inserted impedance is associated with the design of the current-sensing unit in the probe head. In the instance of the TEKTRONIX P6042 (dc to 50 MHz current probe) the insertion impedance is 0.1Ω at 5 MHz. Thus, to realize an amplitude measurement error of less than 2%, the signal source impedance should be 50 times the insertion impedance or, in this case, 5Ω.

A second consideration in the use of the current probe is the capacitive coupling from the probe to the circuit. This coupling is the only shunt loading placed on the circuit by the probe and will vary depending upon the size and type of material of the current conductors. For example, with No. 20 AWG wire the capacitance will be $\approx$0.6pF and with No. 14 AWG it will be $\approx$1.5pF. The majority of this capacitance is to a shielding can placed about the current-sensing unit, and its effect can be minimized by using the probe ground lead when working with large voltage swings of high-frequency signals. Another technique is to select a current-monitoring point to minimize voltage swing; for example, monitoring the current on the dc supply side of a load resistor.

Some typical applications

One of the measurements for which a current probe is ideal, is looking at the output required of a generator driving a capacitive or partly-capacitive load. An example would be the gain requirements of an output stage driving the beam-blanking structure of a cathode ray tube. If voltage were monitored, a square wave would be observed. However this is not at all indicative of the current spike that the transistor needs to provide. In this particular measurement, the current probe disturbs the functioning circuit very little, whereas, the capacitive loading of the voltage probe causes a severe disturbance.

A few of the many other areas of usage include transformer design, where the current distribution is the most important parameter; the design of electric motors and generators including looking at starting currents, generated transients, and checking commutation currents; numerous SCR-oriented applications including balancing SCR currents, as well as measuring rate-of-change and peak currents.

Think current measurement

After one becomes accustomed to thinking "current," there are many areas where better measurements can be made and the resultant data is in a more useful form. For example, in evaluating transistor performance, the current probe is ideal for measuring base drive, collector current and even emitter current if the impedance is not too low. You can determine many of the operating characteristics of the transistor through analysis of the collector current waveform.

Differential measurements simplified

If differential measurements are required, the current probe is inherently a high CMRR device. The addition or subtraction of currents by passing two or more wires through the probe sensing unit provides an unsurpassed differential probe. There are no amplifiers, only the opposing or reinforcing flux fields determine the probe output. Similarly, added sensitivity may be obtained by looping the current conductor through the probe more than once.

Another useful technique is to make simultaneous voltage probe and current probe measurements to determine incircuit capacitive or inductive characteristics. If the system is compensated, i.e., has no net reactive components, the voltage and current waveforms will be congruent.

Two styles of current probes

Two styles of current-sensing probes are available. The closed-core unit, such as the CT-1, requires the current-carrying wire to be threaded through the unit. These devices are designed to allow permanent mounting within the circuit to provide continuous monitoring within a controlled electrical environment, for example, a 50Ω strip line. The second style available is the split-core unit which provides for a portion of the core to slide back allowing the current-carrying lead to be inserted without breaking the circuit.

Operational characteristics

The typical current probe has its operational capabilities described by a different set of terms than is characteristic of voltage probes. The **Amp-Second Product** is directly related to the flux saturation of the transformer core. Effectively, the Coulomb charge under one pulse is integrated to determine whether it will place the current transformer into saturation or not.

The **RMS current** indicates the power handling capability of the probe. This power limit may be the wattage capability of the terminating resistance, the wire size of the secondary winding, or a similar power-sensitive component.

The **maximum peak pulse current** rating is indicative of the voltage breakdown characteristics of the weakest component in the system.

Summing up the current probe

Though the use of a current probe may require a slight change in how we customarily evaluate circuit performance, the advantage of using a current probe in certain aspects of circuit design and evaluation make the effort well worthwhile.

Here are some general considerations leading to current probe use.

1. The current probe can be considered complementary to the voltage probe in the respect that where the voltage probe desires low impedance points for accurate measurements, higher impedance points are desired for the current probe.
2. The current probe exhibits lower loading than any voltage probe. This generally implies minimum signal amplitude attenuation and minimum risetime inaccuracies.
3. Where information on current supply requirements is needed, primarily into capacitive elements, the current probe is almost a necessity.

The P6201 dc to 900 MHz active probe.

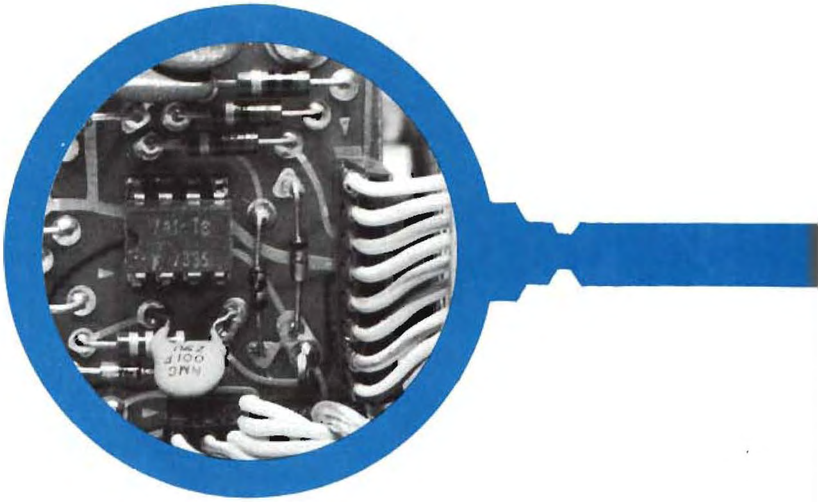
Conclusion

Both the active probe and current probe extend the measurement capability of your oscilloscope. They can yield more accurate measurements than passive voltage probes in many instances, and often provide the only means of making some measurements. They could prove to be ready-made solutions to some of your more difficult measurement problems.

The P6042 dc to 50 MHz current probe.

Servicescope

Servicing the 7904 high-efficiency power supply



The high-efficiency power supply, in some form, is used in many TEKTRONIX instruments. While this particular article deals with the 7904, some of the techniques discussed here will be helpful in servicing other instruments using this type of supply.

The high-efficiency supply, a relatively recent innovation in power supply design, provides a considerable savings in volume, weight, and power consumption. Figure 1 shows a simplified block diagram of the supply, which is essentially a dc-to-dc converter. The line voltage is rectified, filtered, and used to power an inverter which runs at approximately 25 kHz. Operating frequency is determined basically by the resonant frequency of a series-LC network placed in series with the primary of the power transformer. The inverter drives the primary of the power transformer, which supplies the desired secondary voltages. These are then rectified, filtered, and regulated for circuit use.

Pre-regulation of the voltage applied to the power transformer is accomplished by controlling the frequency at which the inverter runs. A sample of the secondary voltage is rectified and used to control the frequency of a monostable multivibrator. This multivibrator, in turn, controls the time that either half of the inverter can be triggered, thus controlling inverter frequency. Pre-regulation to about 1% is achieved by this means.

Now let's turn our attention to troubleshooting the instrument.

Look for the clues

Stop, look and listen. You can often save valuable time by noting symptoms that can serve as clues to the section in trouble. For example, the high-efficiency supply has two basic failure modes:

1) The inverter is working in the "burst" mode, as evidenced by a ticking sound occurring about four times a second.
2) The scope is dead, no inverter operation at all, possibly the sign of a blown fuse.

Let's examine these two problems separately.

Problem 1: The inverter is working in the burst mode. The plug-ins have been removed to eliminate them as the source of trouble and the problem still exists.

Procedure: Remove the line plug and set CONTROL ILLUM to OFF and GRAT ILLUM counterclockwise. Remove the instrument side panels and locate the Z-axis board located on the right side of the instrument at the rear.

Using a VOM, take resistance readings at the supply test points located on the Z-axis board. See Figure 2. Contact the +5V lamp supply at the rear wafer of the CONTROL ILLUM switch (red and black lead).

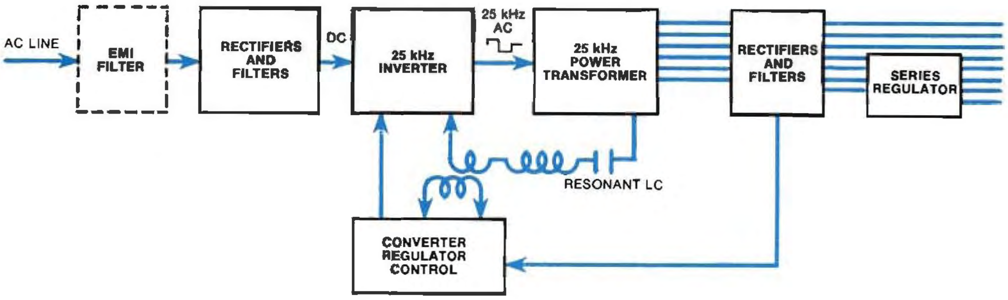


Fig. 1. Simplified block diagram of a typical high-efficiency power supply.

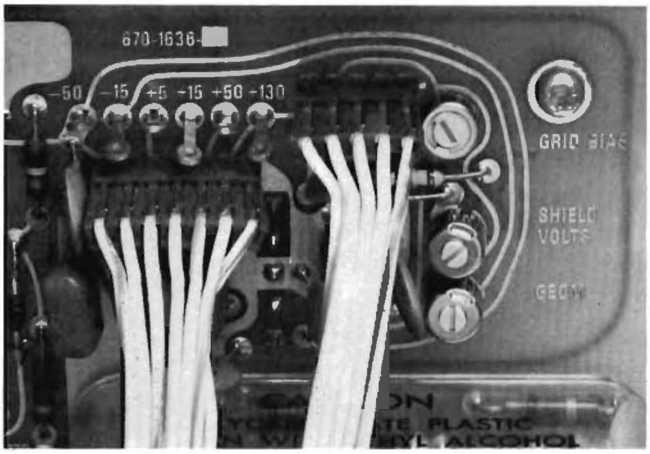


Fig. 2. Power-supply test points on the Z-axis board.

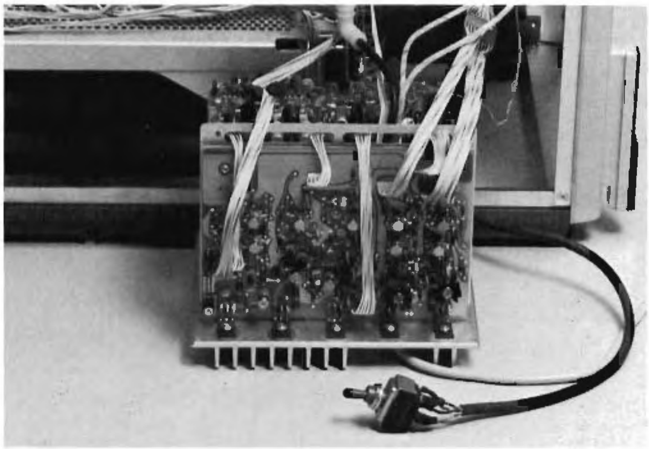


Fig. 3. The high-efficiency supply extended for servicing.

A. Check resistance of the supplies and mainframe.

Supply	Scale
+130V = 6 kΩ	X1k
+50V = 2 kΩ	X1k
+15V = 90 Ω	X100
−15V = 100 Ω	X100
−50V = 250 Ω	X100
+5V lamp = 800 Ω	X100

A low resistance reading usually indicates trouble in the mainframe. Since only troubles in the power supply will be considered in this procedure, continue on to the next step.

To perform the next step it is necessary to remove the power supply unit from the mainframe. This is easily done by removing the four screws holding the power unit to the rear frame of the instrument and then sliding the unit out the rear. Disconnect all connections between the mainframe and the power unit. (The POWER switch can remain mounted in the scope front panel.) When disconnecting the crt anode lead, ground it to the scope frame momentarily to dissipate any stored charge.

B. Check resistance of the mainframe only, taking readings at the same test points on the Z-axis board and CONTROL ILLUM switch.

Supply	Scale
+130V = 6.6 kΩ	X1k
+50V = 2 kΩ	X1k
+15V = 90 Ω	X100
+5V = 65 Ω	X100
−15V = 110 Ω	X100
−50V = 2 kΩ	X100
+5V lamp = infinite	X100

If the mainframe readings are as listed, the trouble is probably in the power unit.

To gain access to the components inside the power unit, remove the nut holding the POWER switch to the front panel and remove the switch and its interconnecting cable through the rear of the instrument. The unit is now completely free of the mainframe, making it easy to remove the power-unit covers.

A note of caution is in order at this point. The primary storage capacitors, C1216 and C1217, remain charged with high voltage dc for several minutes after the line power is disconnected. A neon bulb located on the power supply inverter board flashes when this stored voltage exceeds about 80 volts. Do not remove the power-unit covers while this light is flashing.

After removing the covers the power unit can be positioned as in Figure 3 and the leads connected so the unit can operate. A pair of multi-pin cable extensions (Tektronix Part Nos. 012-0577-00 and 012-0578-00) are available to extend the cables between the low-voltage regulator board and the main interface board on the mainframe 7904 and 7704A.

There are a number of faults that will cause the supply to operate in the burst mode. Let's examine the symptoms and the probable causes individually.

Symptom 1: Burst operation—resistances are normal.

Probable cause: One of the semi-regulated supplies is overloaded.

Procedure: Check the semi-regulated voltages at the points indicated on the capacitor-rectifier board (Figure 4). With your test scope set for a sweep of 10ms/div, vertical sensitivity for an on-screen display using a 10X probe and dc coupling, the voltage waveforms should resemble that of Figure 5.

If the burst voltage pulse is within ≈15% of the stated semi-regulated value the supply is probably all right. If abnormally low, remove the power, wait for the large filter capacitors to discharge and then check the tantalum filter capacitors associated with the supply for shorts or leakage.

To speed servicing, you can use a 1.5 kΩ, 2 watt insulated resistor to short the storage capacitors (C1216 and C1217). Do not place a dead short across the capacitors as this can damage them.

Symptom 2: Burst operation—semi-regulated voltage normal.

Probable cause: High-voltage circuit problems or inverter control circuit problems.

Procedure: With the line power off, disconnect the crt anode lead and short it momentarily to ground to bleed off any charge. Disconnect multi-lead cables P1675 (green), and P1704 (yellow), at the Z-axis board.

If the power unit now operates properly, a crt failure or problem in the mainframe high-voltage circuitry is indicated.

If burst operation persists with these cables disconnected, replace U1275 and check the components in the inverter control loop. A good place to start checking is pins 6, 7, 10 and 11 back to T1235 and then pins 8 and 9 back to T1230.

Another point to check is the over-voltage protection circuitry Q1248 and VR1246. If the zener voltage of VR1246 has shifted it can cause erratic operation.

If these circuits are normal, remove the low-voltage regulator chassis and check on the high voltage board for shorted or leaky components.

Problem 2: Now let's consider the conditions which cause either the 2 amp or 4 amp fuse to blow.

Symptom: The scope is inoperative and the 4 amp fuse is blown.

Probable cause: Trouble in the line input circuitry or in the inverter section.

Procedure: Remove the line plug from ac power and discharge storage capacitor, C1216 and C1217, using the 1.5 kΩ, 2 watt resistor. Check diode bridge, CR1215, and the associated line input circuit for a shorted component, then replace the four amp fuse.

If these circuits appear normal, connect the line plug to a variable line source and advance the line voltage from 0 to 20 V ac. Using your test scope check the waveform on each of the storage capacitors (C1216, C1217). The capacitor should have a 60 Hz waveform displaced by some amount of dc as in Figure 6. The dc voltages should be equal in amplitude and of opposite polarity. These waveforms permit you to check the condition of the bridge rectifiers and storage capacitors.

Symptom: The scope is inoperative and the 2 amp fuse is blown.

Probable cause: Malfunction in the inverter.

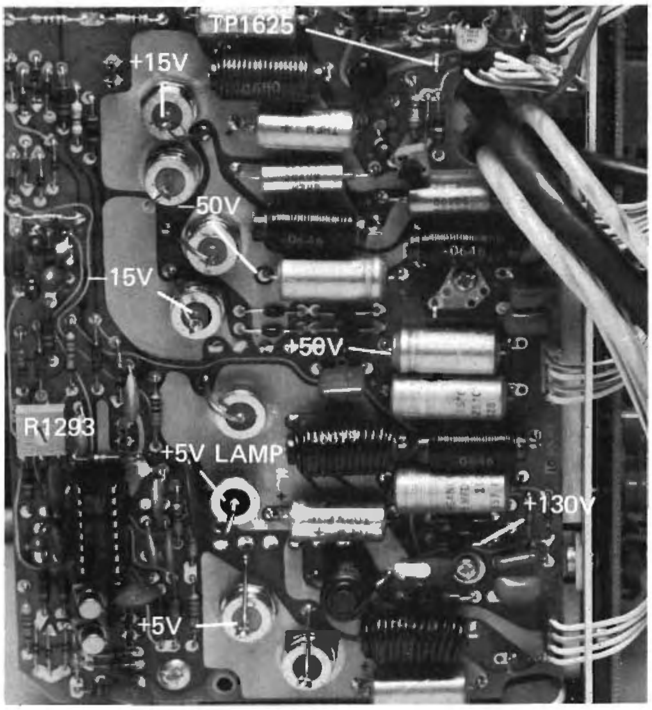


Fig. 4. Partial view of the capacitor-rectifier board showing voltage check points and key components.

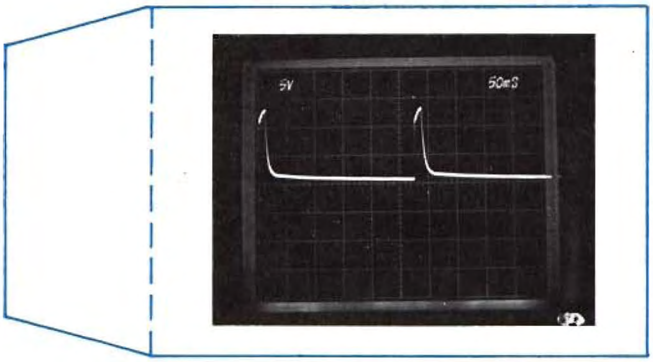


Fig. 5. Typical supply voltage waveform when operating in the "burst" mode.

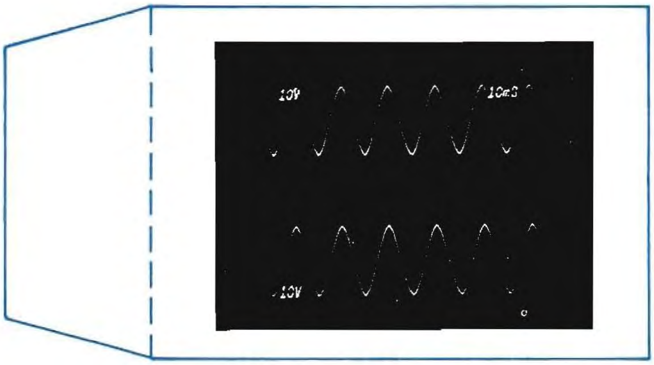


Fig. 6. Typical waveforms on C1216 and C1217 with line voltage set to about 20V.

Procedure: Remove the line plug from the variable line source and manually discharge the storage capacitors as before. Remove the gray cover from the inverter board. Remove Q1234, Q1241, CR1234 and CR1241 from the inverter board (Figure 7) and check their characteristics with a curve tracer or VOM.

Install the checked components in the inverter board and replace the 2 amp fuse. Locate T1230 on the inverter board and note a black wire loop that passes through small toroid T1235. Connect a current probe (TEKTRONIX P6021 with passive termination, or equivalent) to the black lead and set the test scope for an equivalent vertical sensitivity of 1A/div and set the time base for 2 ms/div.

Connect the line plug to the variable line control which should be set at 0V. Slowly increase the line voltage and note a burst waveform of ≈20 kHz occurs at ≈60 V ac (Figure 8). As you continue to increase the line voltage, stable operation should occur at about 85 V ac. Figure 9 shows the normal waveform at 115 V ac. Note that the test scope sweep speed has been increased to 50 μs/div. Analysis of these waveforms should give you a clue to the circuitry in trouble.

Symptom: The inverter does not run and the fuses are alright.

Probable cause: Inverter circuit malfunctions.

Procedure: Remove the line plug and discharge the storage capacitors as before. Remove Q1234, Q1241, CR1234 and CR1241 and check their characteristics with a curve tracer.

Install the checked components and check the circuit for operation as in the preceding procedure. If the power unit is still inoperable, connect your test scope, using a 10X probe, to TP1234 on the inverter board (see Figure 7). Set the variable line control at 20 V ac and check to see that the 60 Hz waveform is approximately dc centered (Figure 10). If not centered, check Q1246, CR1232, CR1240, CR1242, CR1249 and CR1244 for shorts or leakage.

Increase the line voltage to 60 V ac and check to see that the 60 Hz waveform has start triggers at each negative tip. If no start triggers occur, check CR1238 characteristics on the curve tracer.

Symptom: Unstable inverter operation.

Probable cause: One of the semi-regulated voltages is of improper value.

Procedure: With the current probe attached to the black wire loop associated with T1230, adjust the variable line voltage for the most stable waveform. (The 20 kHz waveform should be limited to 5 amps peak-to-peak.)

Referring to Figure 4, check the raw voltages on the capacitor-rectifier board with your VOM. They should be as follows:

Check +15V dc at CR1345 for ≈ +17V dc.
Check −15V dc at CR1347 for ≈ −17V dc.
Check −50V dc at CR1362 for ≈ −54V dc.
Check +50V dc at CR1358 for ≈ +54V dc.
Check + 5V dc at CR1313 for ≈ + 7V dc.
Check +5V dc lamp supply at CR1312 for ≈ +5V dc.
Check +130V dc at CR1323 for ≈ +130V dc.

For stable operation of the inverter control circuitry, +5V lamp, −17V dc and +130V dc must be present on the capacitor-rectifier board and −50V dc must be present on the low-voltage regulator board.

Symptom: Stable inverter operation when the multilead cables P1675 (green) and P1704 (yellow) are removed.

Probable cause: Crt circuit malfunction.

Procedure: Remove the line plug and disconnect P1675 and P1704 from the Z-axis board. Place the VOM on the cables to hold P1675 and P1704 down on the bench so that voltage readings can be taken. Apply power to the setup and set the VOM to the 60 V dc scale. With the positive meter lead on pin 2 and negative lead on pin 3 of P1675 (green) you should read ≈25 V. (Auto focus check.) With the positive lead on pin 4 and negative lead on pin 5 (P1675) you should read ≈35V. (Auto focus check.) Moving to P1704 (yellow), with the positive lead on pin 1 and negative lead on pin 2 you should read ≈35V. (Auto focus check.)

With the positive lead on pin 7 and negative lead on pin 6 of P1704 (yellow) check for ≈25V. (Exercise caution as pin 7 is elevated to 3 kV.) This is a crt grid bias check.

Change the VOM setting to the 60 V ac scale and apply the leads to pins 8 and 9. Check for ≈8V ac. This is a crt filament check.

If the auto focus or bias voltages were low or zero in any of the previous checks, there is the probability of shorted or leaky diodes on the high voltage board. These can be checked using the 100 kΩ scale on the VOM.

If the crt filament voltage was low or zero, remove the high-voltage assembly and check for open runs on the circuit board.

A quick operational and cal check.

After locating and repairing the malfunction, it would be good to make a quick operational and calibration check before installing the power unit back into the mainframe. Here are the points to check and adjust:

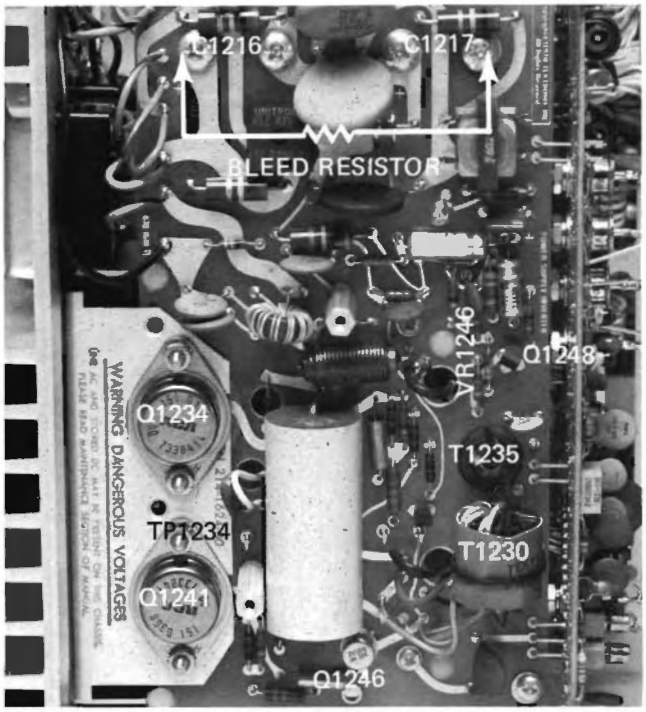


Fig. 7. Partial view of the inverter board showing where to apply bleeder resistor to discharge C1216 and C1217.

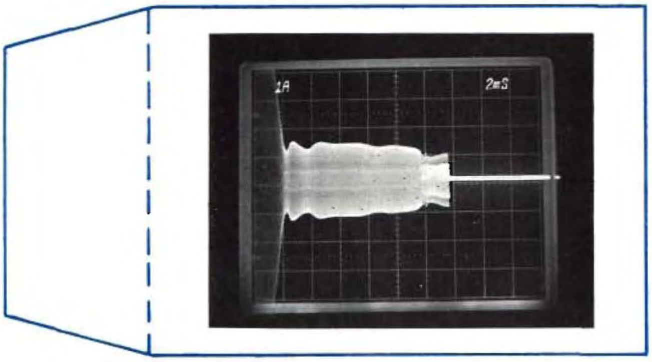


Fig. 8. Current waveform at T1230 showing burst operation at a line voltage of about 60V.

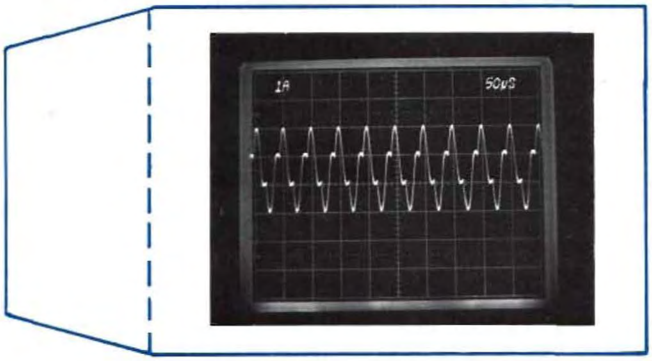


Fig. 9. Current waveform at T1230 for normal inverter operation at a line voltage of 115V.

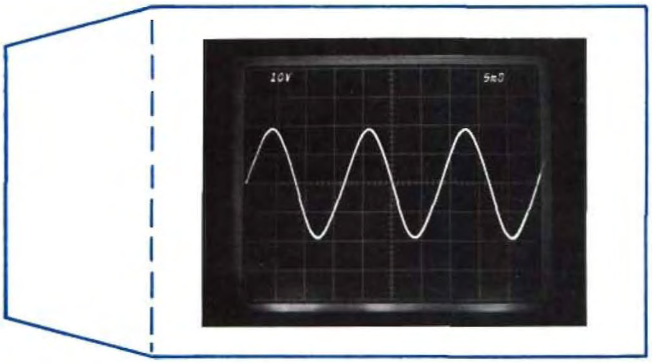
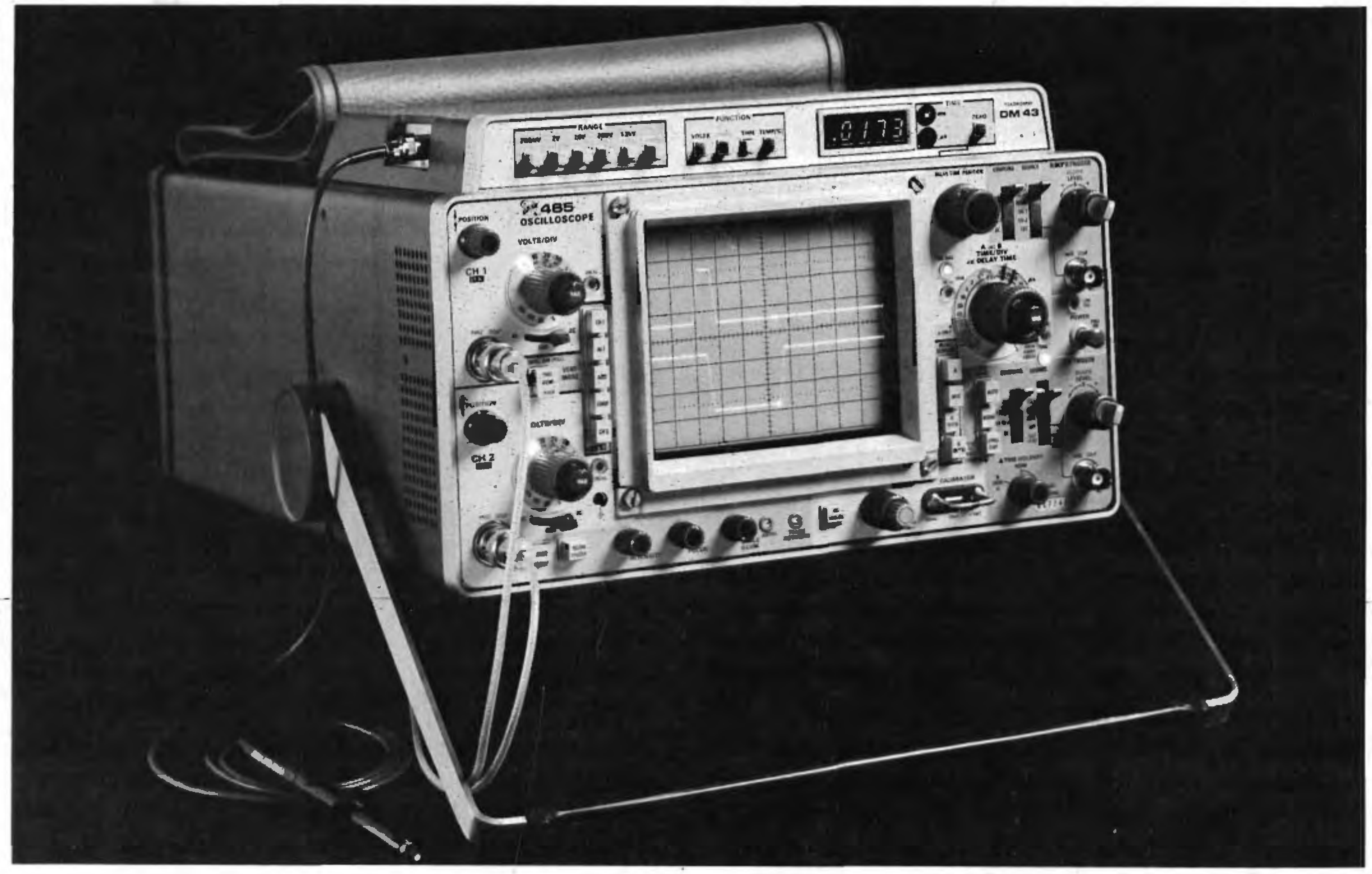


Fig. 10. Waveform at TP1234 on inverter board with line voltage set to about 20V. Waveform should be equally displayed from center-screen.

1) Connect a precision dc voltmeter (0.1% or better) to the −50V sense and ground sense points on the low-voltage regulator board near P1483 (orange). Adjust R1513 (−50V adjust) for −50V, ± 0.1V.
2) Check +50V supply for +50V, ± 0.25V.
3) Check +15V supply for +15V, ± 0.1V.
4) Check +5V supply for +5V, ± 0.05V.
5) Check −15V supply for −15V, ± 0.1V.
6) Check the above supplies for regulation while changing variable line voltage from 90V ac to 132V ac.
7) Connect the voltmeter between TP1625 and ground on the capacitor-rectifier board and turn inverter adjustment (R1293) full ccw to full cw and check for a voltage range of −49V to +132V. If unable to adjust to these voltages, try replacing U1635 and check Q1627, Q1631 and VR1635.
8) With the mainframe CONTROL ILLUM to OFF and GRAT ILLUM full ccw and all plug-ins removed, set the line voltage to 117V ac and set R1293 for +40V.
9) Connect a pair of 1X probes to a vertical amplifier in your test scope suitable for differential measurements. Check the ripple of the supplies on the sense points located on the low-voltage regulator board as follows:
   −50V, less than 2 mV.
   −15V, less than 1 mV.
   +5V, less than 1 mV.
   +15V, less than 1 mV.
   +50V, less than 3 mV.
   +130 V, less than 500 mV at +130V test point.
   +5V lamp, less than 25 mV at pin 4 of P1415 (green).

This completes the troubleshooting and recalibration procedure. Remove the extender cables and other connections, replace the power unit cover and reinstall the power unit in the mainframe.

Digital Timing Measurement The Easy Way........



Digital timing measurement with improved resolution, 1% accuracy, increased freedom from error, faster operation, and greater operator convenience. The new TEKTRONIX DM43 with its unique direct numerical readout of time intervals adds all of these advantages to the field proven 465 and 475 oscilloscopes. What's more the DM43 includes precision digital meter capabilities as well. The DM43 is also available in the new 466 and 464 Fast Storage Portable Oscilloscopes.

The DM43 provides a direct numerical readout of the time between any two points on the oscilloscope screen selected by the delay time position control. 3½ digit resolution and the 1% accuracy of the DM43/oscilloscope combination provide convenient measurement of critical digital system timing in field servicing, in production, and in the design lab. Speed of measurement, freedom from error, and operator convenience are all improved since no dial readings or mental calculations are needed to arrive at a final reading.

Dc voltage measurement with an accuracy of 0.1% from 0 to 1200 V, resistance measurement within 0.75% over the range 0 to 20 MΩ, and the convenience of temperature measurement with a probe over the range −55°C to +125°C add still more to the versatility of the DM43. In field servicing, in production, and in design laboratory applications the DM43/Portable Oscilloscope combination provides the capability to meet almost any measurement need, and it's all in one compact package which can easily be carried wherever tests must

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