flood guns

CE / CE2 CE3

Collector

VP
fast
Prep

save
Intensity

fast
Target

Storage Target

Transfer
Logic

Erase
Logic

Storage
Level

Persistence

Transfer Storage Controls

Contents

Cover: New target designs and new operating modes yield direct-view storage writing speeds in excess of 1000 cm/μs. Transfer storage techniques produce fast writing speeds with relatively long viewing times.
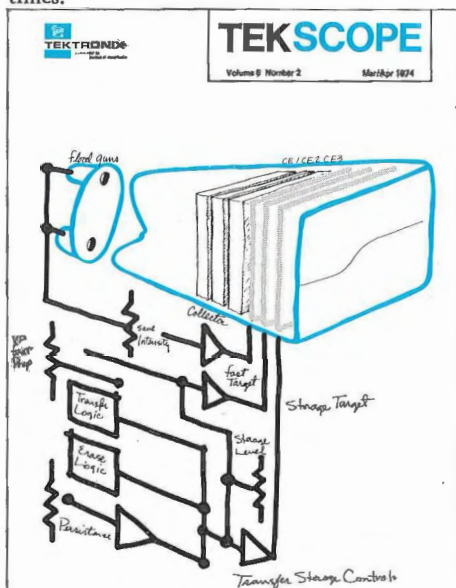
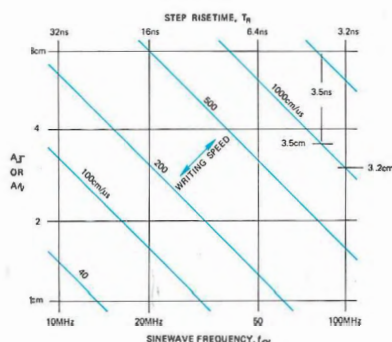# A 1000 cm/μs storage oscilloscope

Gene Andrews

Fig. 1. This nomograph shows a writing speed of 1000 cm/μs will display a 3.5 ns risetime, 3.5 cm in amplitude and a 100 MHz sine wave of 3.2 cm.
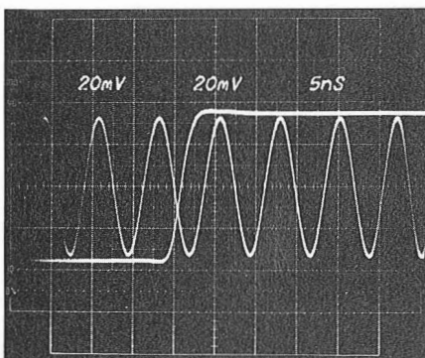

Fig. 2. A stored display of a sine wave and step of equal maximum speed. Note relative amplitude.

Just two years ago laboratory storage scopes with stored writing speeds from 100 cm/μs to 400 cm/μs were introduced. The fastest of these instruments could store single events having a risetime of 9 ns and 3.5 cm in amplitude. Now a new storage scope, the TEKTRONIX 7633, moves this performance up to 1000 cm/μs to capture single risetimes of 3.5 ns at an amplitude of 3.5 cm.

To relate this performance to your measurements let's review the speed needed for recording single sinewaves and steps.

Writing speed relationships

For sinewaves the maximum writing speed, WS, is measured in terms of frequency, f, and amplitude, A_{N}, as in Equation 1.

$$WS_{N} = \pi f A_{N} \qquad (1)$$

$$WS_{\Gamma} = k A_{\Gamma} T_r \qquad (2)$$

Equation 2 describes the maximum writing speed of the vertical edge of a pulse in terms of amplitude, A_{Γ}, and 10 −90% risetime, T_r. The value of k ranges from 0.8 for a linear ramp, to 2.2 for single-pole RC response. A k value of 1.0 is suitable for typical step responses limited by a few poles.

A nomograph of Equations 1 and 2 is given in Figure 1, for the 10 MHz to 100 MHz range. Note that a 1000 cm/μs stored writing speed can record a 100 MHz sinewave 3.2 cm in amplitude, or a 3.5 ns risetime of 3.5 cm amplitude. From the nomograph one might say that 1000 cm/μs is 100 MHz storage, 100 cm/μs is 10 MHz storage, etc. (specifically for signals 3.2 cm in amplitude).

A sinewave and step of equal maximum speed are shown in Figure 2. The sinewave frequency is 70 MHz, and the step risetime of 5 ns corresponds to a system bandwidth of 70 MHz (from $T_r = 0.35/f$). The amplitude ratio, A_{Γ}/A_{N}, equals 3.5/3.2. The displayed writing speed is:

$$WS_{N} = \pi f A_{N}$$
$$= 3.14 \times 70 \text{ MHz} \times 6.4 \text{ div} \times 0.45 \text{ cm/div}$$
$$= 630 \text{ cm/μs}$$

Thus far we have neglected the horizontal, or time base, component of speed. In Figure 2, where the horizontal speed is one-sixth that of the maximum vertical speed, only a 1% increase in speed results from including the horizontal component. If the time base speed is doubled, to one-third the maximum vertical speed, the increase goes up to 5%. These small corrections permit neglecting the horizontal component for most maximum speed considerations.

Although sinewaves are not typical of signals we normally record, they are used for speed verification for a couple of reasons—an accurate speed is easily set up by selecting frequency and amplitude; and speed through an area is verified in a single pass since the maximum speed occurs twice each cycle.

Now that we can relate the writing speed of the scope to the signals it will capture, let's look at the operation of the storage crt used in the 7633.
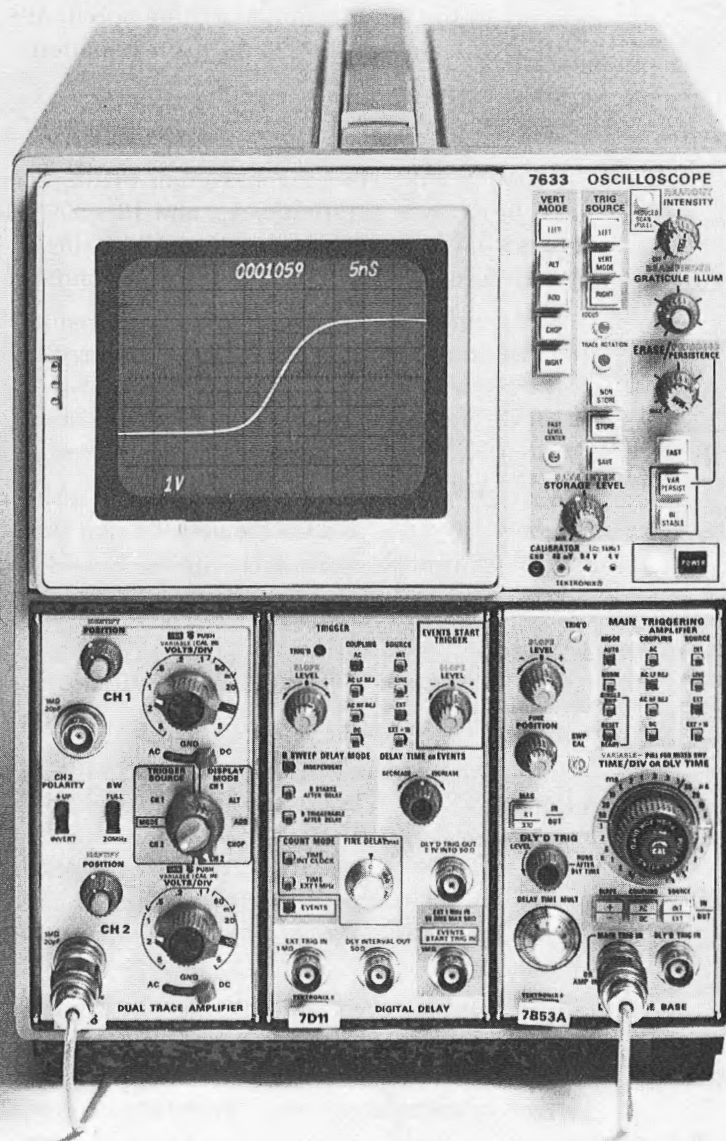
The transfer storage crt

The crt used in the 7633 is, in principle, a transmission-modulation reading direct-view storage tube. In more common terminology we know it as halftone transmission storage or variable persistence storage. One of the undesirable characteristics of the halftone transmission storage tube is that unwritten areas of the storage target begin to fade positive due to positive ion generation in the flood electron system of the tube. As a result, after a few minutes, signals can no longer be distinguished from the bright background.

To overcome this limitation in view time, we have added another storage target to the conventional halftone storage tube (see Figure 3).[1] The two targets are called the fast target and storage target, respectively.

The image is first written on the fast target and is then transferred to the storage target which, by proper selection of operating voltage, can be operated in either a variable persistence mode or a bistable mode. In the bistable mode the image can be stored until you choose to erase it.

Perhaps at this point we should clarify the use of the terms "variable persistence" and "halftone." The crt can display shades of gray, but since both the instrument and the crt are optimized for high-speed variable persistence performance rather than multi-tonal performance, "variable persistence" is the more appropriate term.
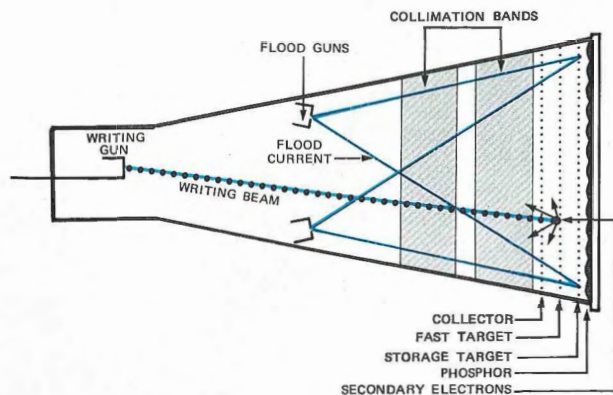

The 7633 Storage Oscillosope

Fig. 3. The transfer storage tube contains two storage targets to achieve fast writing speeds with long viewing times.

Writing speed and view time

There is a direct relationship between writing speed and view time. To better understand this relationship let's look at the factors determining the writing speed of a storage crt as shown in Equation 3.

$$WS = \frac{(I_b/TW)\,(\delta\text{-}1)}{(\Delta V)\,(C/A)} \qquad (3)$$

Where:

WS is stored writing speed.

I_b/TW is the current density at the target—beam current, I_b, per trace width, TW.

$(\delta\text{-}1)$ is the net positive electron charge for each electron arrival—secondary emission yield, δ, minus the arriving electron.

ΔV is the minimum voltage change on the target surface that results in writing for the specified area.

C/A is the capacitance of the target surface to the target mesh per unit area.

For further discussion, the parameters ΔV and C/A are combined to $\Delta VC/A$, the charge sensitivity of the target.

We noted earlier that view time is limited by the number of residual gas atoms near the storage target, being ionized by flood electrons and collecting on the target surface charging it positive. The signal waveform "washes out" as the background increases in brightness until the signal can no longer be seen. The faster the writing beam moves across the target, the less the charge placed on the target, and the more rapidly the trace is obscured by ion activity.

Trading writing speed for view time

Figure 4 shows some of the writing speed versus view time trading to be made in using a given variable persistence scope and in choosing a particular crt target. Note that a range of writing speed and view times are available. At the highest writing speed we see the sensitivity limit where it is no longer possible to achieve more speed by accepting less view time.
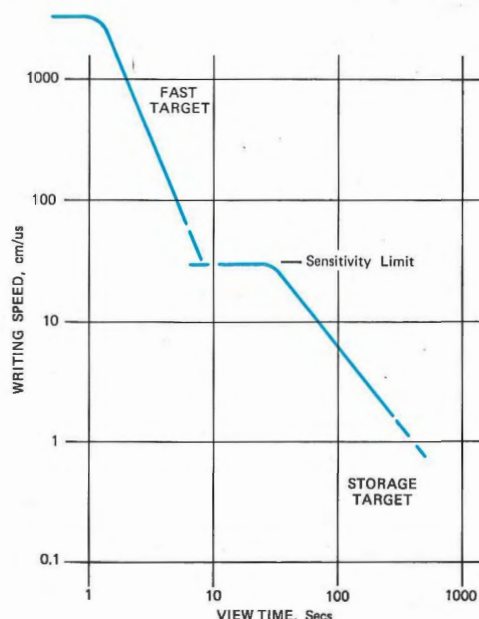

Fig. 4. Graph showing writing speed versus viewing time for two different storage targets.

The operating point along the WS and VT curve is determined by the storage mesh voltage. The storage level control, a front-panel control on TEKTRONIX variable persistence scopes, permits you to move down the curve by decreasing the storage mesh voltage, for a longer view time as less writing speed is needed.

As the fast target curve in Figure 4 suggests, it is possible to make targets with higher writing speeds. However, when this speed increase is a result of improved charge sensitivity, the rate of positive ion charging is increased and the view time suffers proportionately.

The charge sensitivities of the fast and storage targets in the 7633 crt are 5 picocoulombs/cm² and 500 picocoulombs/cm², respectively, giving the fast target a 100:1 charge sensitivity advantage. Looking at the fast target performance in Figure 4 we see a writing speed above 1000 cm/μs can be achieved. But the view time is below 1 second — much too short for useful viewing. It is evident we have traded too much view time for writing speed.

Transfer, don't trade

This is where the transfer technique becomes useful. During the 0.1 second following waveform capture by the fast target, the image is transferred from the fast target, to the storage target. A gain of about 1000X in the stored charge image accompanies this transfer. Now at the fastest writing speed of 1000 cm/μs we have a minimum view time of at least 30 seconds which is more than adequate for most high-speed applications.

New modes, new speeds

The fastest stored writing speed of the 7623 storage oscilloscope introduced in mid-1972 is 100 cm/μs (200 cm/μs for Option 12). Using basically the same crt, how is writing speed increased to 1000 cm/μs? This is accomplished with two new modes of operation—reduced scan selection and fast variable persistence.

In the reduced scan mode, the operating voltage on the crt write gun is increased from 1500 V to 3000 V. Referring to Equation 3, I_b/TW increases by about 2.5X and δ-1 is higher by about 1.6X for a total increase in speed of 4X. The useful display area is 8 $\times$ 10 div (.45 cm/div) in this mode.

Operating the storage target in the fast variable persistence mode rather than the fast bistable mode as in the 7623, provides a speed improvement of 3X. Referring again to Equation 3, the ΔV of the fast target is reduced by 3X due to the new operation of the storage target. This is because less change is required for storage, and gray scale signal levels are not discarded.

Combining the reduced scan with fast variable persistence, a typical speed increase of 12X is realized over the full-scan, fast-bistable mode of operation.

The 7633 storage controls

To conclude our discussion let's consider briefly the front panel controls for the 7633 (See Figure 5). A set of three push buttons selects display modes of NON-STORE, STORE and SAVE. The SAVE mode has three uses:

1) To prevent loss of the captured signal. Erase and sweep cycles are locked out in this mode.

2) For extended retention of the variable persistence displays. Turning the SAVE INTENSITY down reduces the flood electron current and extends the view time in proportion to the reduced intensity. It can be turned off for hours of retention.

3) To set up a "Babysitting" mode which will automatically give the above two performances after a future event. The "Babysitting" mode is entered by pressing the SAVE push button after ERASE.

Another set of push buttons selects storage modes of FAST, VAR PERSIST and BISTABLE. Note that the
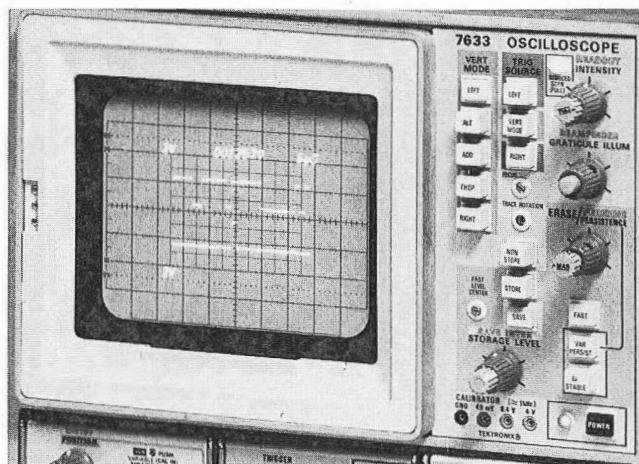

Fig. 5. Front-panel controls permit a choice of storage modes and operating conditions for optimum performance on your application.

PERSISTENCE and ERASE controls are located together and provision is made for periodic erase. This can be used in three ways:

1) To periodically erase independent of the number of waveforms stored during the period.

2) To accept one waveform for each erase period (time base set to single sweep).

3) To erase at the end of sweep (or sweeps). The period is adjusted to end during the sweep and the erase cycle is delayed to the end of that sweep.

The STORAGE LEVEL control, as mentioned previously, permits us to decrease the storage mesh voltage for longer view times as less writing speed is needed. The FAST LEVEL CENTER adjustment is provided to separately adjust the fast mesh voltage for the desired tracking of the STORAGE LEVEL on the two meshes.

The REDUCED SCAN switch operates independent of the display and storage modes and permits choosing full-scan operation when the last 4X writing speed increase is not needed. It is also convenient to set up the reduced scan display in nonstore before going to storage operation.

All of the 7000 Series advantages

In addition to high-speed versatile storage, the 7633 offers all of the advantages of the 7000-Series Oscilloscopes. Crt readout is standard equipment and you can select from 30 different 7000-Series plug-ins to "custom tailor" the instrument to your job and expand its capabilities as the need arises.

Acknowledgments

The author thanks everyone on the 7633 project for their dedication in making this a significant product.

1. "Three New Instruments, Three Kinds of Storage" Tekscope, July, 1972.

Using your oscilloscope probe
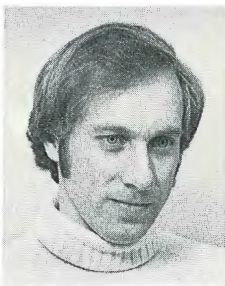
Riley Stock

This is the first of a two-part article which discusses oscilloscope probes, what happens when you attach them to your circuits, and some of the advantages offered by active probes and current probes. Part I deals with the type of probe familiar to most of us—the passive voltage probe.
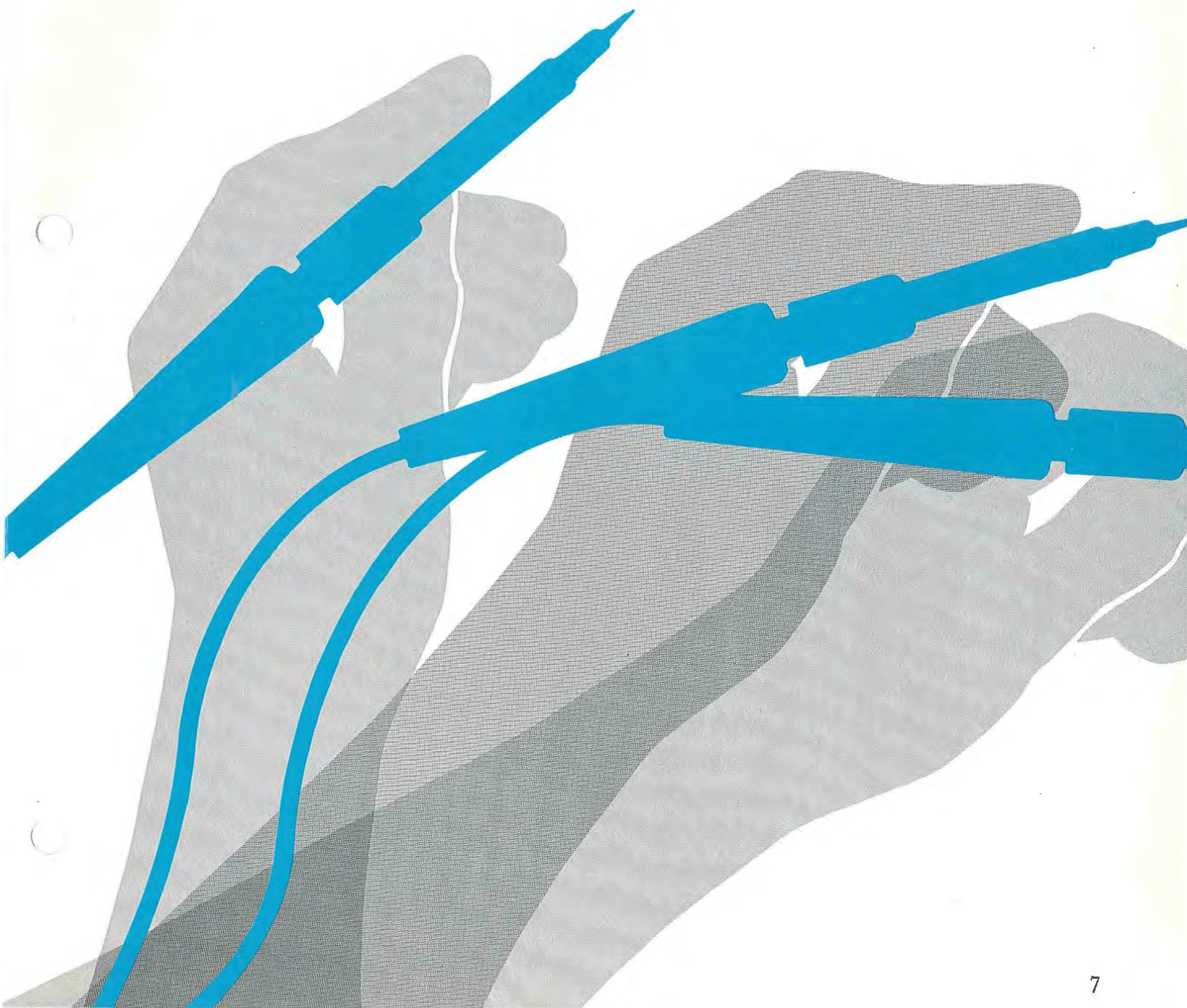
PART I The passive voltage probe

Seeing is believing. Or is it? No doubt there have been times when the signal you viewed on your oscilloscope didn't measure up to what you expected. After thoroughly checking out your circuitry you turned a suspicious eye on the scope—but did you stop to consider the probe?

The function of the ideal probe is to couple the signal of interest to the oscilloscope without affecting the signal source or the signal waveshape. As is often the case, the ideal probe for every measurement doesn't exist. However, a knowledge of probe characteristics and how they affect the circuit under test will help you approach the ideal for your particular application.

The passive probe is, by far, the most common type in use today and provides the greatest convenience for general purpose work. It is also the least expensive. The term "passive" is used to distinguish this type of probe from one that uses active devices, such as FETs, to achieve high input impedance and low input capacitance, even in a 1X mode.

Passive probes come in a variety of sizes and shapes, with differing characteristics. The typical probe consists of a probe assembly, a ground lead and a shielded cable equipped with a suitable connector for the oscilloscope input. Most probes feature interchangeable tips and ground leads for easy connection to various test points. A unique feature of most Tektronix probes is the Tektronix-patented coaxial cable with a resistance-wire center conductor. This distributed resistance suppresses ringing due to the mismatch between the cable and its terminations, when viewing fast pulses on wideband oscilloscopes.

Probes load the circuit

Low and medium frequency oscilloscope inputs are usually one megohm shunted by 8 to 50 pF of capacitance. Many instruments with bandpass above 200 MHz have a 50-ohm input impedance and some have both a 50-ohm and one-megohm input.

When the scope is applied to the circuit under test, the input capacitance and resistance loads the circuit and may alter the signal to be viewed. Sometimes, the loading alters the operation of the circuit itself. These loading effects can be minimized by using an appropriate probe. If the signal amplitude permits, an attenuator probe can be used, reducing both dc loading and capacitive loading. Figure 1 shows a schematic representation of an attenuator probe and oscilloscope input. The probe and scope input essentially form an RC divider. Since $R_1 C_1$ must equal $R_2 C_2$ for equal attenuation at all frequencies, we can see that as R_1 increases, C_1 must decrease. Thus, the capacitance at the probe tip can be reduced by going to higher values of attenuation. Common probe attenuations are X10 and X100, with some probes having provision to switch between X1 and X10. Others have plug-on attenuators covering a wide range of attenuation from X1 to X100.

Now, just what changes occur when we attach a probe, how will these changes affect the signal, and can we determine the desired information from the display? One of the primary considerations in determining what the probe will do to the signal and circuit under test, is the impedance of the signal source. In modern circuitry source resistance varies from a fraction of an ohm to greater than hundreds of $k\Omega$ and source capacitance from 1 pF to greater than 100 pF. To minimize probe loading effects, a low impedance test point should be selected for viewing when possible.

Two types of signals should be considered when dealing with probe loading effects: (1) pulse or step-function sources dealing with amplitude, risetime (t_r) and transient response; and (2) sine wave sources concerned with amplitude and phase relationship distortion.
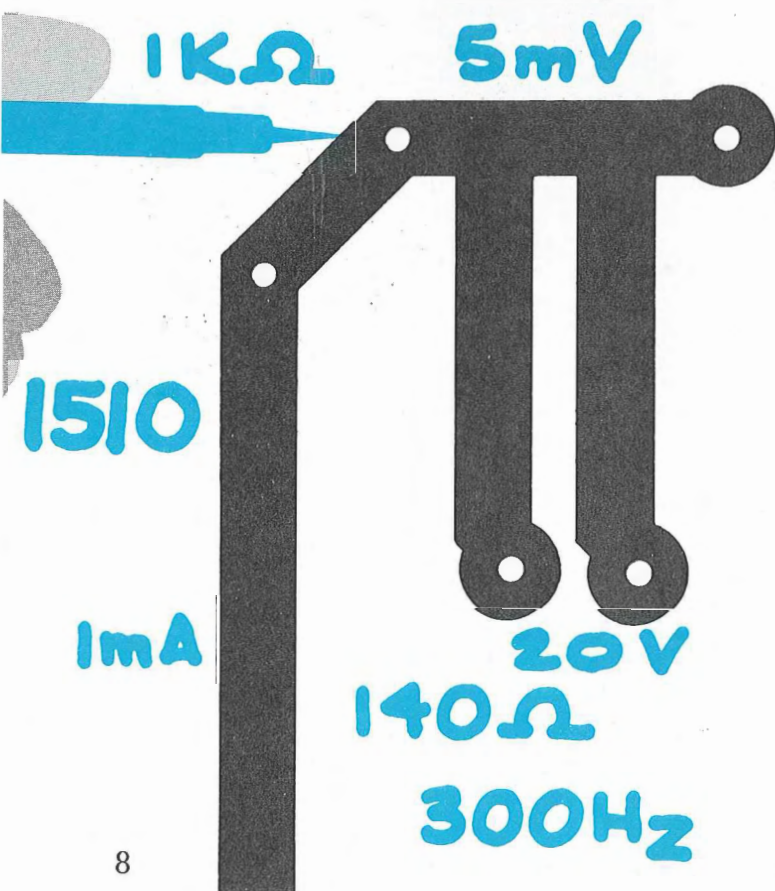
Measuring pulse signals

Let's consider what happens to a typical pulse signal source (Figure 2 (a) when we apply a probe. If the generator had a t_r of 0, the output t_{rl} would be limited by the integration network of R_s and C_s, and would be equal to 2.2 R_sC_s, or 8.8 ns. If a typical passive probe, such as the P6053B (10X, 9.5 pF, 10 MΩ) is used to measure this signal, the probes' input capacitance and resistance are added to the circuit (Figure 2 (b)). Since R_p is >>R_s, R_p may be disregarded. Using the risetime formula, 2.2 R_s (C_s+C_p), the circuit risetime, t_{r2} becomes 13 ns. The loading effect of the P6053B to this signal source is the percentage change in risetime:

$$\frac{t_{r2} - t_{rl}}{t_{rl}} \times 100 = \frac{13 \text{ ns} - 8.8 \text{ ns}}{8.8 \text{ ns}} = 48\%$$

The percentage change that results from adding a passive probe to this pulse source is directly related to the capacitance added. The calculation to determine the amount of change in risetime would be:

$$\frac{C_p}{C_s} \times 100 = \frac{9.5 \text{ pF}}{20 \text{ pF}} = 48\%$$

This is a valid approach if the probe resistance, R_p, is large when compared to the source resistance.

Now let's see what happens if we use a probe such as the P6048 (10X, 1 pF, 1 kΩ) to measure this same signal source. In this instance R_p is not ten times greater than R_s and must be considered. R_p and R_s form a dc divider, reducing the amplitude and modifying the source impedance. Using Thevenin's theorem a new generator source voltage and a new source resistance (Figure 2(c)) is calculated resulting in: $t_{r3} = 2.2$ R_2 (C_s+C_p) = 7.7 ns. Note that in relating this risetime to the risetime of Figure 2 (a), our original circuit, the P6048 caused a change from 8.8 ns to 7.7 ns. The percentage of change is less than that caused by the P6053B.

$$\text{Percent change} = \frac{7.7 \text{ ns} - 8.8 \text{ ns}}{8.8 \text{ ns}} \times 100 = -12\%$$

It is interesting to note that rather than degrading the signal by slowing the risetime, the probe modified the source resistance and decreased the risetime making it faster than it should be. But take a look at the output amplitude; it has been decreased to 83.3% of the value without the probe, due to the voltage divider formed by R_p and R_s. In the first example, there was no change in the signal source amplitude when the probe was applied.

And so we see that the choice of probe depends to a large extent on which signal parameter we desire to measure. Low capacitance is desirable when measuring risetime, but high resistance is more important when measuring amplitude. Choosing a low impedance test point is desirable for both risetime and amplitude measurements.
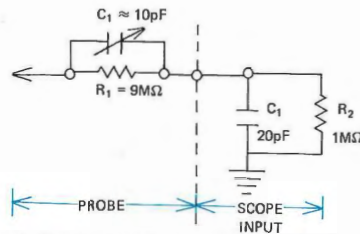

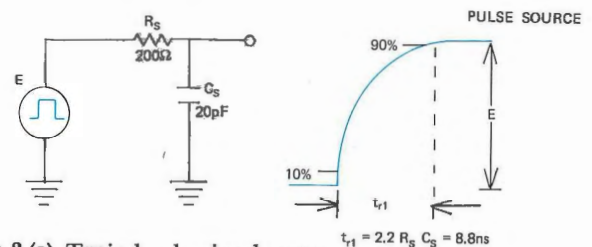Fig. 1. Typical 10X attenuator and scope input.

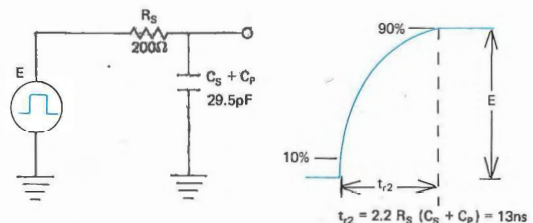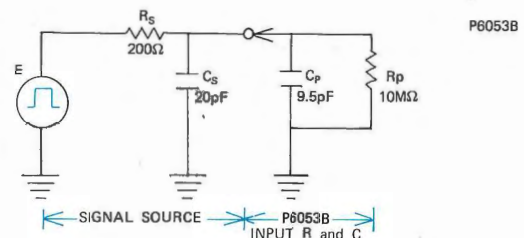Fig. 2 (a). Typical pulse signal source.
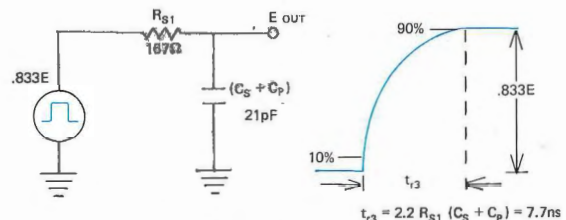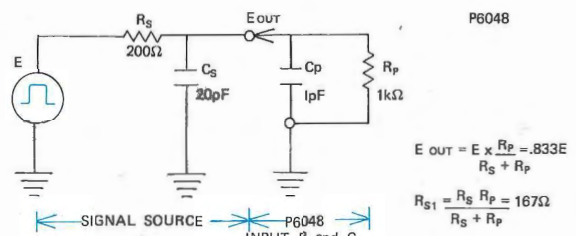

Fig. 2 (b). P6053B probe added to typical pulse source.

Fig. 2 (c). P6048 probe added to typical pulse source.

Measuring sine wave signals

Now let's consider the effects of using the same probes and the same source resistance and capacitance, with the generator supplying sine waves rather than pulses. Here we will be concerned with amplitude changes and phase relationships.

We should keep in mind that the specified probe input capacitance and resistance, e.g., 10 MΩ and 10 pF, were measured at dc or low frequency (<1 MHz). However, as signal frequency increases, the equivalent probe input impedance changes. Figure 4 shows how the input X_p and R_p of the P6053B probe change with frequency.

Let's assume a source frequency of 10 MHz and a generator voltage of one volt, and see what the source output voltage will be before any probe is applied (Figure 3 (a)). We see that E_{out} of the source only, is 97% of the generator voltage. Now let's apply the P6053B (10X, 9.5 pF, 10 MΩ) probe and see the effect on the source voltage. (See Figure 3 (b)). From the graph in Figure 4 we find that R_p is 40 kΩ and X_p is 1.7 kΩ. Since R_p is $>>R_s$, it can be disregarded in the calculations. X_p is in parallel with X_s giving us a total reactance, X_{ct}, of 545 Ω. From Figure 3 (b) we see that with the P6053B applied, the source output voltage has decreased to 94% of the generator voltage. This represents a 3% change from the unloaded source output voltage.

Now let's see what happens to the source voltage when we apply the P6048 (10X, 1 pF, 1 kΩ) probe. (See Figure 3 (c)). Since R_p is 1 kΩ and $<10R_s$, we must consider it in our calculations as in the case of the pulse signal source. X_p is 16 kΩ and in parallel with X_s, resulting in X_{ct} of 760 Ω. We find that with the P6048 applied, the source output voltage is 81% of the generator voltage, for a change of 16% from the unloaded source voltage.

Comparing Figures 2 (b) and (c) with Figures 3 (b) and (c), we can see that for risetime measurements, the low-capacitance P6048 yields better accuracy than the P6053B, while for sine wave amplitude measurements the dc loading of the P6048 causes a larger error than the capacitive loading of the P6053B. Note from Figure 2 (c) that the P6048 also causes a substantial amplitude error.

Phase relationships

Since most attenuator probes have a capacitive element it is evident that the probe will introduce phase shift in the signal being viewed. Source impedance is an important factor in determining the amount of phase shift that occurs. For example, consider an amplifier driven from a 10 MHz, 50 Ω source and having an output impedance of 2 kΩ. (See Figure 5 (a)). Let's look at the input and output using two 10 MΩ, 10 pF probes. Referring to Figures 5 (b) and (c) we see there is a difference in phase of about 49° due to the impedance difference in the points being measured.

Now let's look at the same two points using two 1 kΩ, 1 pF probes. (See Figures 5 (d) and (e)). The phase difference has been reduced to about 2°. However, the 1 kΩ probe causes a 67% signal loss due to resistive loading. Depending on the application, it may be desirable to select a probe which offers a better compromise between phase shift and signal loss, or we may use a different probe for the respective measurements.
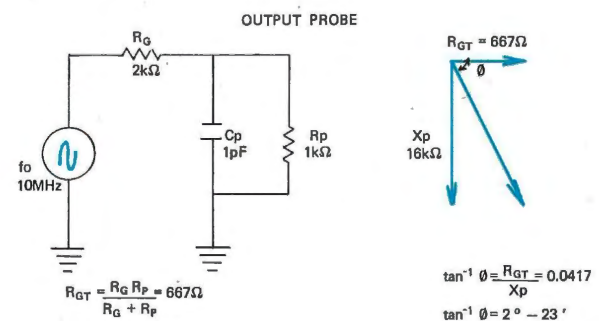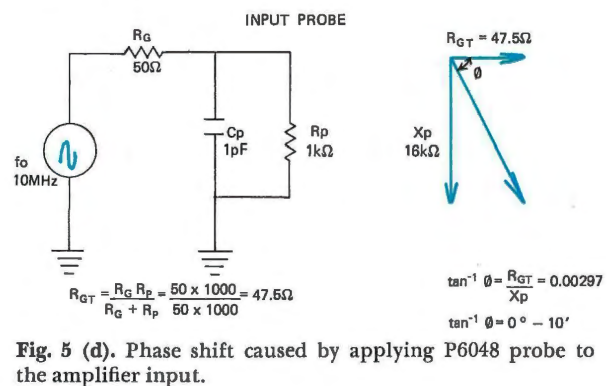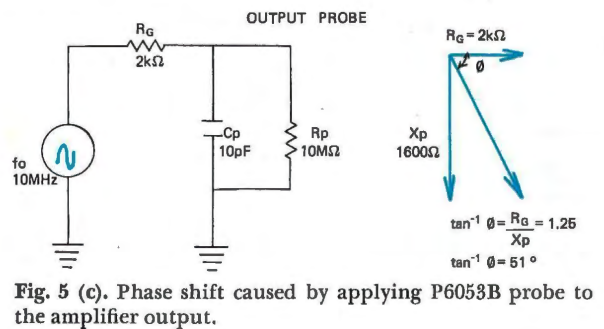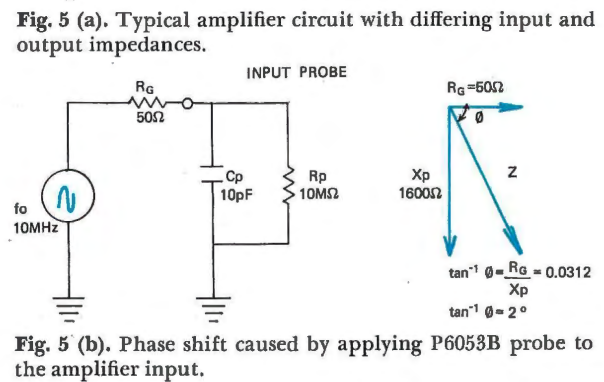
Summing it up

From this brief discussion we can see that what seemed a relatively unimportant part of our measurement system, actually determines to a large extent what we see displayed on our oscilloscope screen. All probes do not have the same effect on the signal. And one probe is not the ideal for all measurements.

Here are some general rules we can follow to make better measurements when using a probe:

1. Always check the probe compensation on the oscilloscope being used to make the measurement.
2. Choose the lowest impedance test point possible to view the signal.
3. When making risetime measurements:
   a. Choose a probe with R and C as low as possible.
   b. Scope and probe risetime should be short relative to the signal risetime.
   c. Observed risetime is approximately equal to the square root of the sum of the squares of all the risetimes in the system. These risetimes include the risetime of the signal source, the specified probe risetime, the specified scope risetime, and the calculated risetime of the scope/probe input system, including the effect of the source impedance.
4. When making amplitude measurements:
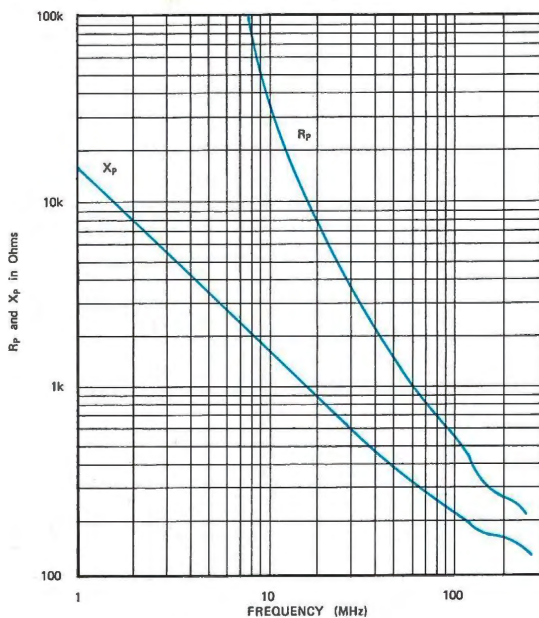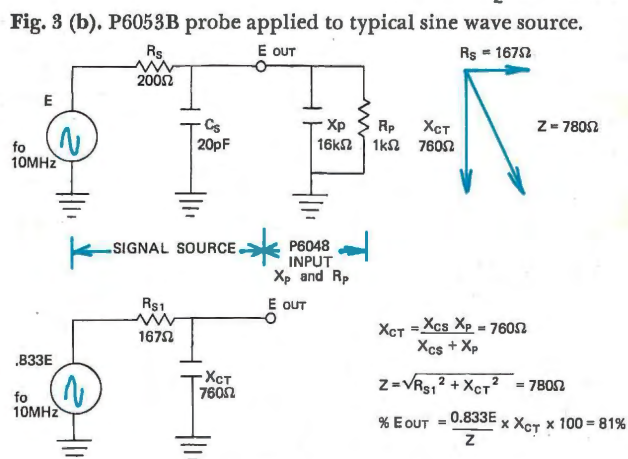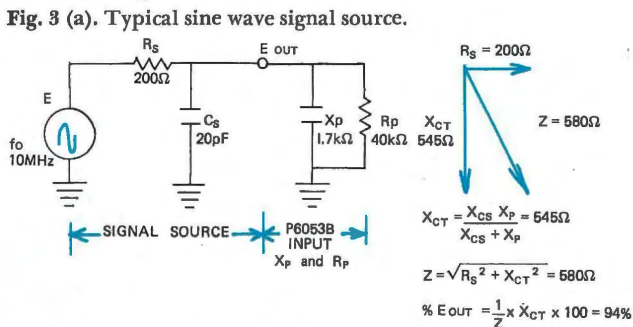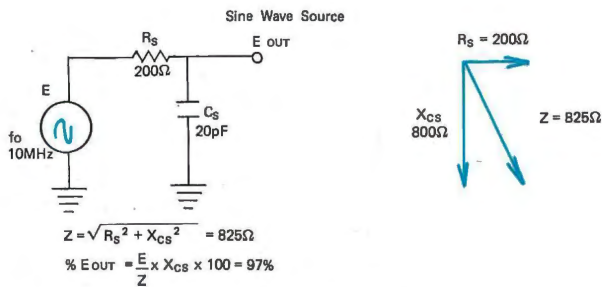   a. For sine wave measurements, choose a probe which has the highest input impedance at the frequency of interest. Remember, loading error changes with frequency.
   b. For pulse measurements, choose a probe which has a large input resistance relative to the source impedance. Input C is of no concern if pulse duration is about five times longer than the input RC.

In the second part of this series we will discuss active probes and current-measuring probes. While not as widely used as the passive voltage probe, they provide a valuable extension to the signal measuring capabilities of your oscilloscope.

$$Z = \sqrt{R_S{}^2 + X_{CS}{}^2} = 825\Omega$$

$$\% \, E_{OUT} = \frac{E}{Z} \times X_{CS} \times 100 = 97\%$$

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

$$X_{CT} = \frac{X_{CS} \, X_P}{X_{CS} + X_P} = 545\Omega$$

$$Z = \sqrt{R_S{}^2 + X_{CT}{}^2} = 580\Omega$$

$$\% \, E_{OUT} = \frac{1}{Z} \times X_{CT} \times 100 = 94\%$$

Fig. 3 (b). P6053B probe applied to typical sine wave source.

$$X_{CT} = \frac{X_{CS} \, X_P}{X_{CS} + X_P} = 760\Omega$$

$$Z = \sqrt{R_{S1}{}^2 + X_{CT}{}^2} = 780\Omega$$

$$\% \, E_{OUT} = \frac{0.833E}{Z} \times X_{CT} \times 100 = 81\%$$

Fig. 3(c). P6048 probe applied to typical sine wave source.

Fig. 4. P6053B probe (3.5 foot cable), typical X_p, R_p versus frequency curves.

Fig. 5 (a). Typical amplifier circuit with differing input and output impedances.

$$\tan^{-1} \emptyset = \frac{R_G}{X_p} = 0.0312$$

$$\tan^{-1} \emptyset = 2°$$

Fig. 5 (b). Phase shift caused by applying P6053B probe to the amplifier input.

$$\tan^{-1} \emptyset = \frac{R_G}{X_p} = 1.25$$

$$\tan^{-1} \emptyset = 51°$$

Fig. 5 (c). Phase shift caused by applying P6053B probe to the amplifier output.

$$R_{GT} = \frac{R_G \, R_P}{R_G + R_P} = \frac{50 \times 1000}{50 \times 1000} = 47.5\Omega$$

$$\tan^{-1} \emptyset = \frac{R_{GT}}{X_p} = 0.00297$$

$$\tan^{-1} \emptyset = 0° - 10'$$

Fig. 5 (d). Phase shift caused by applying P6048 probe to the amplifier input.

$$R_{GT} = \frac{R_G \, R_P}{R_G + R_P} = 667\Omega$$

$$\tan^{-1} \emptyset = \frac{R_{GT}}{X_p} = 0.0417$$

$$\tan^{-1} \emptyset = 2° - 23'$$

Fig. 5 (e). Phase shift caused by applying P6048 probe to the amplifier output.

11

Teknique

Bob Beville

Triggering the oscilloscope from logic signals

The triggering circuits of conventional oscilloscopes leave much to be desired when attempting to analyze logic signals. While the dual triggering afforded by delaying sweep operation permits you to view long pulse trains in detail, it doesn't fully meet the needs associated with making digital measurements.

Logic designers will recall that in designing digital circuits it is routinely necessary to construct frame pulses, index pulses or other event-signifying markers to initiate specific circuit functions. These signals make ideal trigger points for the test oscilloscope and are often made available for that purpose. Sometimes special trigger-trap circuits are designed into the equipment expressly to facilitate servicing. Field engineers servicing a piece of malfunctioning digital machinery resort to such items as extender cards, latch cards and word-recognition circuits to construct a "trigger trap" near, in time, to the point they wish to observe.

One of the techniques used in troubleshooting digital circuitry is appropriately called "babysitting." This usually employs the single-sweep feature of an oscilloscope to indicate, circuit block by circuit block, that the equipment is functioning to that point. It is a time-consuming procedure and yields marginal information. Another technique, equally time-consuming, involves single-stepping the machine clock and recording the status of input and output functions.

Such needs and techniques as these have led digital designers and service personnel to request digital triggering features on their oscilloscopes — features that accommodate the many special problems of digital designing and troubleshooting.

A Better Way

The new TEKTRONIX 821 Word Recognizer is designed to meet just such needs when working with Transistor-Transistor Logic (TTL). It is a small instrument powered from the probe-power outlets of the 7000 Series, 475 or 485 Oscilloscopes, or five-volt logic supplies. The 821 contains a four-input AND gate, a babysitter flip-flop, and light-emitting diode (LED)

input and output indicators. A 50-ohm TTL output permits cascading up to four 821's to achieve a word length of 16 bits. Strobing ability is included. And a front-panel switch changes the function of the unit from word recognizer to that of logic driver.

Serving mostly as an AND gate, the 821 has four color-coded input probe leads for connecting to the desired logic points. The Word Selector switches, one for each input, select the logic level: positive TRUE (1), negative TRUE (0) or an off position labelled "X" for 'don't-care' situations or applications requiring less than four inputs. The output of the 821 is a TRUE TTL level at 50 ohms, ideal for externally triggering an oscilloscope.

As with any AND gate, the 821 output remains TRUE for as long as the inputs comply with the selected switch pattern. The leading edge is the triggering edge in most cases. The output will fall following the first input that disables the AND gate, indicating the AND function is over. This is useful in some applications. For example, in a 4-bit binary counter, the only unique triggers normally available are at the count of 8 or 16 (carry). With the 821, a trigger can be derived on each of the counter states. See Figure 1.
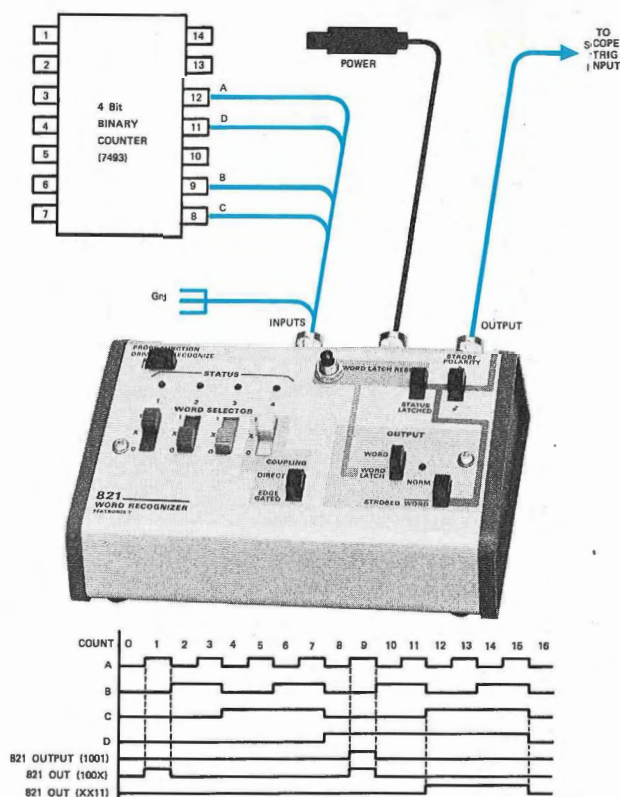

Fig. 1. The 821 connected to a 4-bit counter and set to output at the count of nine (1001). Bottom three waveforms show output of 821 set at 1001, 100X and XX11.

Expanded bit capability

Since the output is TTL compatible, 821's can behave as TTL components if desired. An 821 then, can be used to drive another 821. Should an application requiring more than four inputs arise, such as on tape readers, printers, teletypes, terminals or other byte-oriented machinery, the ability of one 821 to enable another would be useful. An input called EXPANDER INPUT is provided for this mode. When this input is left disconnected or driven TRUE by a positive TTL level from another 821 or other TTL logic, the AND function is enabled. This is valuable in constructing the 8-input AND gate. The output of the first 821 provides the enabling signal to the second 821, provided the first 821 performs its portion of the eight-bit AND function. This configuration is useful in triggering on control characters, escape characters, End of Block, or any ASCII character that is set into the Word Selector switches. See Figure 2.
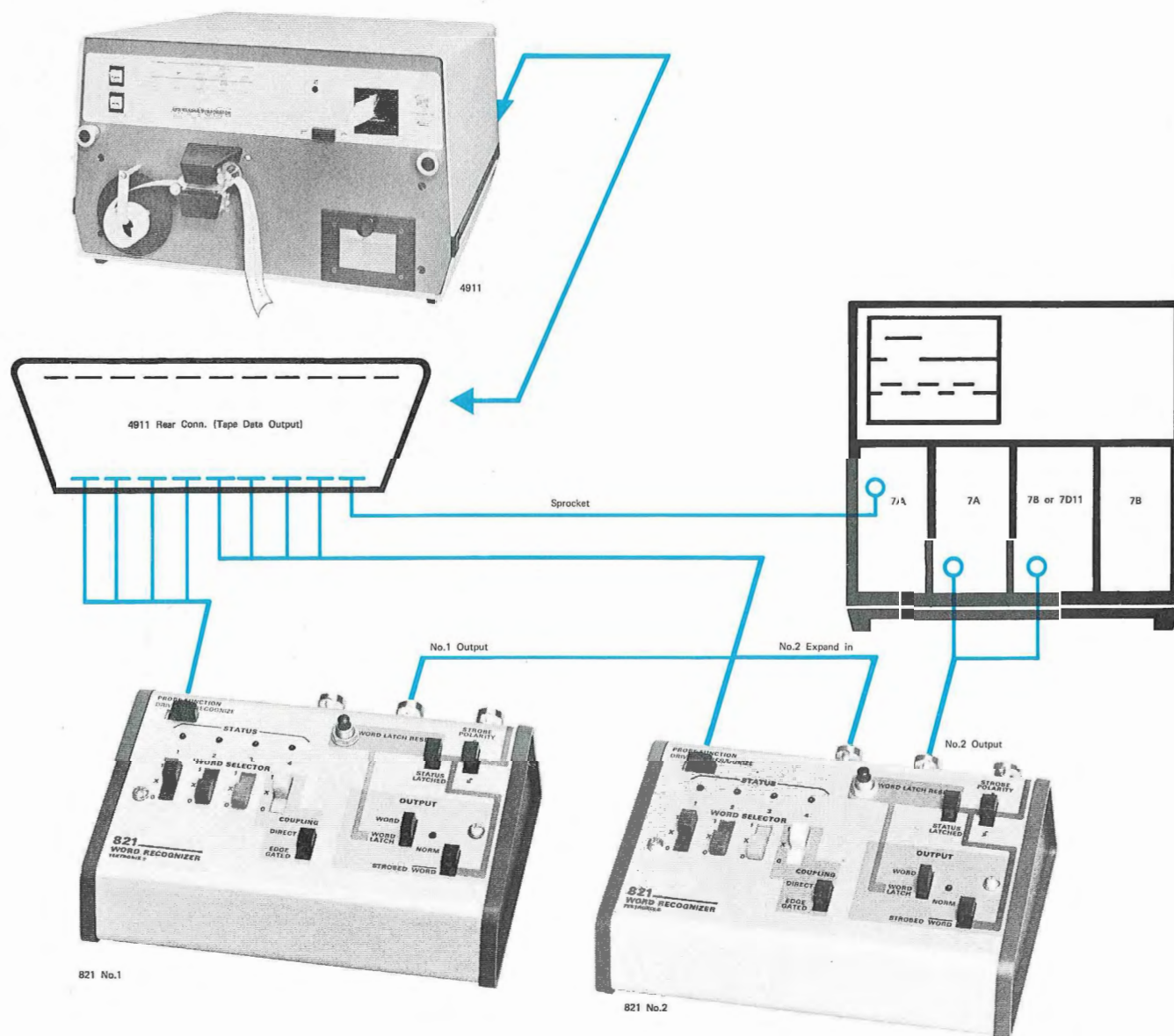

Fig. 2. Two 821's connected in EXPANSION configuration perform an eight-input trigger trap.

The status indicators

Activity on the output of the Word Recognizer is shown on the front panel by an LED indicating the occurrence of the selected word. The LED remains on if the input word is quiescently at the word being recognized.

The logic states of each input is indicated by LEDs above the respective Word Selector switches. Each input, through a buffer, is applied to a bistable latch. The status-indicator LEDs are connected to the latch outputs and normally follow the input levels. Dynamic inputs are indicated by the flashing on and off of these LEDs. Static conditions are displayed, as are sequenced conditions such as those experienced when operating digital equipment in single-clock-single-instruction mode. The 821 can also acquire data presented in parallel format. In this mode, the STROBE INPUT, with suitable choice of strobe polarity, can be driven to capture and store the input's status. See Figure 3.
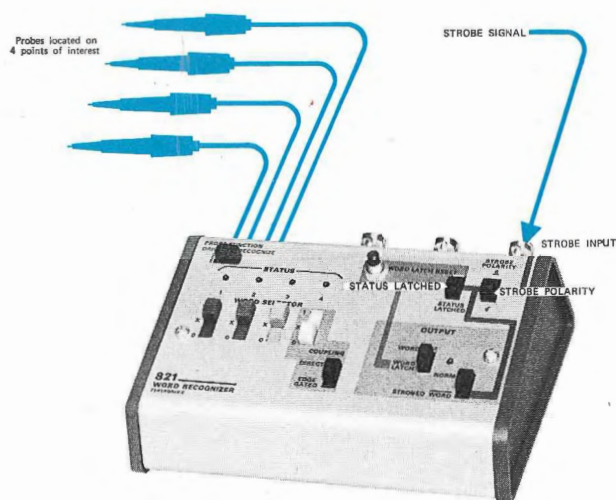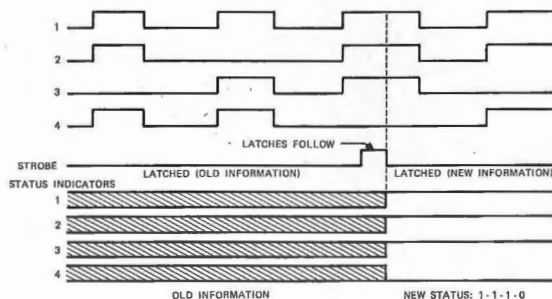

Fig. 3. In a data stream, the information on four lines may be strobed into the Status Indicator Latches after the active edge of the strobe signal.

Latch on to the affirmative

A feature to assist troubleshooting techniques such as "babysitting" monitoring and single-clock-single-instruction operation is the WORD LATCH. In this mode the output of the 821 (and its LED indicator) will go TRUE if the expected word comes and sets a flip-flop internal to the 821. Figure 4 illustrates this application.

Using the WORD LATCH in conjunction with the EXPANDER INPUT the 821 becomes a multipoint condition indicator. An 821, in conventional WORD mode, enabling another 821 in WORD LATCH mode, becomes an 8-input latch. Two 821's in WORD LATCH mode, each applied to the same four points, one enabling the second, can indicate if one four-bit word preceded another.

Measuring time between non-adjacent words

Occasionally we find it useful to measure the time duration between two non-adjacent words or timing points. The WORD LATCH RESET feature is applicable here. As illustrated in Figure 5, the WORD LATCH would be set by the first word. A second 821, outputting on the second word, is applied to the WORD LATCH RESET of the first. The WORD LATCH output waveform then will be set from the time of the first word until the second. This waveform can then be observed on a scope or applied to a universal counter in Time Interval mode. A push button is provided for manually resetting the latch.
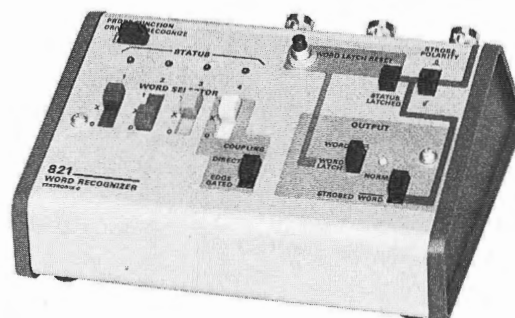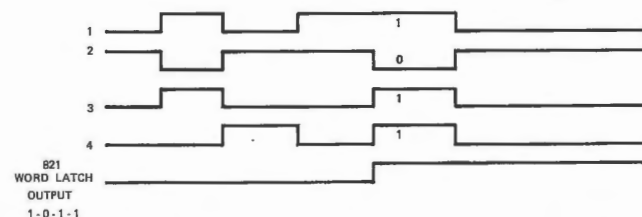

Fig. 4. An 821 in WORD LATCH modes sets and remains set once it recognizes the desired word.

Display the negative

Yet another mode of the Word Recognizer is the ability to be strobed to determine if the word present on the inputs is the desired word or not. This is useful when the desired word, a known pattern of bits, is subject to occasional faulting or dropouts. When the word pattern is good, the circuit must not be misbehaving, hence there is no object in triggering a scope to observe good information. The STROBED $\overline{\text{WORD}}$ (not WORD) function, in effect, interrogates the AND gate and determines at the strobe time if the inputs have indeed AND'd and conform to the pattern of bits set by the Word Selector switches. On the outcome of this decision: "Do the inputs and Word Selector switches mismatch?", the 821 output will go TRUE signifying "YES, they do mismatch" or remain FALSE, indicating a match was found. This configuration will be useful around sector preamble decoders and similar READ oriented circuits. Also malfunctions of circuits being subjected to temperature or power supply tolerancing can be observed in this mode.

Again, the expansion mode for strobing more than four inputs is applicable. It is required that only the last 821 be placed in the STROBED $\overline{\text{WORD}}$ mode and is the only one that need be strobed. The 821's before it are in the conventional WORD mode because of the 'pass it on' nature of the expansion configuration. This application is shown in Figure 6.
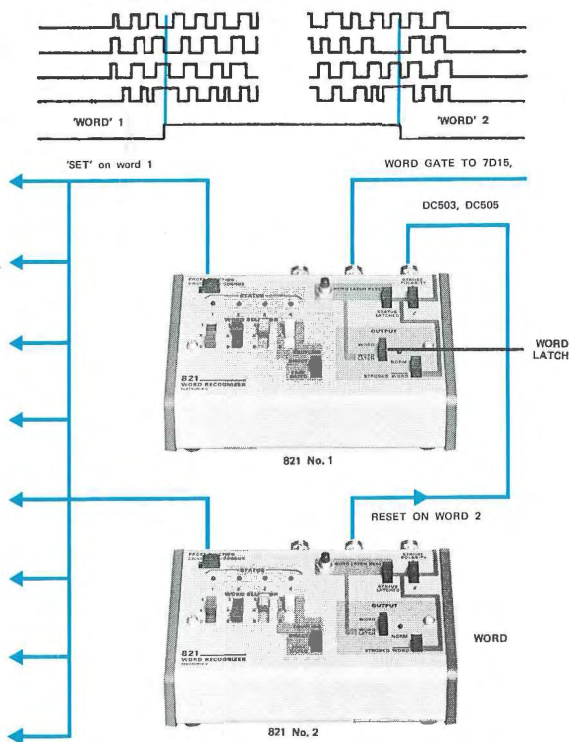
The 821 can serve as more than just a source for externally triggering scopes. Other applications attendant to, or independent of, triggering a scope sweep are: deriving the EVENTS START signal for 7D11 Digital Delay or DD 501 Digital Delay plug-ins; and deriving the START (A) or STOP (A,B) signal for universal counter measurements using the 7D15, DC 503, or DC 505 Universal Counter plug-ins.

The 821 as a logic driver

Thus far we have discussed the 821 as a word recognizer. Switched into the DRIVE mode, the input probes of the 821 become outputs capable of driving up to six TTL loads each. This is useful in situations where inputs are to be manually stepped through their logic truth tables. The Word Selector switches determine the levels of the driving outputs, 1 for HIGH or TRUE, 0 for LOW or FALSE. The 'don't care' (X) position opens that particular probe line. The LED status indicators, as do the Word Selector Switches, show the word chosen.

Summary

Some problems and methods of troubleshooting digital circuits have been discussed. The success of some techniques require the ability to contrive the proper trigger signal in order to look closely at the problem. A few applications using the 821 Word Recognizer to construct a more desirable trigger were described. The 821 should help solve untold numbers of triggering problems and speed isolation of the actual equipment malfunction.

Acknowledgments

Fig. 5. A pair of 821's can construct a gate waveform from the occurrence of one "word" to another, for measuring the time interval between them.

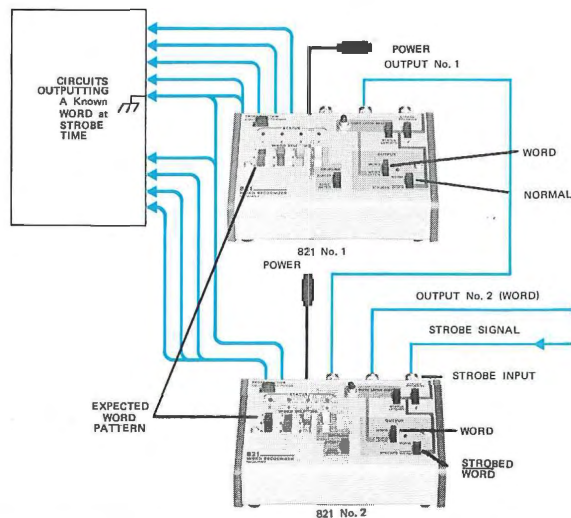**Fig. 6.** Two 821's in an 8-bit STROBED WORD configuration will output if the "word" is not in the expected word pattern.

Servicescope

Sherwin Feetham

Servicing the TELEQUIPMENT D67 oscilloscope

The D67 is manufactured in England by Telequipment, a wholly-owned Tektronix, Inc. subsidiary. It is a low-cost instrument featuring dual trace, delaying sweep operation and a bandwidth of 25 MHz.

If you are unfamiliar with the TELEQUIPMENT line, it would be well to take a few minutes to review the front panel controls. Most of the controls and operating modes are similar to those you find on TEKTRONIX instruments. The vertical consists of two channels with alternate, chopped and summing modes and each channel can be turned on or off independently by push buttons. Note also that you can select the trigger from channel 1, channel 2 or both.

Moving to the trigger mode section for A sweep you will see a couple of modes that may be unfamiliar—TV F and TV L. These are used when viewing composite video signals and permit you to trigger at the frame rate or the line rate. When not viewing television signals the normal mode of operation is to depress the INT and + slope buttons, leaving the top three buttons out. The LEVEL control selects the level at which triggering will occur and turning the control fully counterclockwise puts you in the AUTO triggering mode. Pulling out the Variable Time/CM control will give you a free running sweep.

The horizontal section is comprised of A and B sweeps. The A sweep is the main or delaying sweep, while B sweep serves as the delayed sweep. The sweep to be displayed is selected by two front panel push buttons. With both buttons out, only A sweep is displayed. The displayed sweep can be magnified by pulling out on the FINE position control. This is a 5X magnification of the center two centimeters of the display. With either the A intensified by B or B Delayed push button depressed, you must have A sweep running and the B sweep Variable Time/CM knob pulled to the Non-Gated Delay position to enable B sweep to run. (If you are feeding a trigger to B sweep the variable does not have to be in the Non-Gated Delay mode.)

Now that we're acquainted with the front-panel controls, let's make a quick check of the control settings before turning on the instrument. Depress both CH 1 and CH 2 push buttons to turn on both vertical channels and depress INT TRIG push button for channel 1. Make sure both horizontal DISPLAY buttons are out. (A common mistake is to have B Delayed push button depressed.) Set A sweep TIME/CM to .2 ms, pull out the VARIABLE knob and set the LEVEL control counterclockwise. The INT trigger mode button should be depressed. Set the ASTIG, FOCUS and BRILLIANCE controls to center position and you're ready to turn on the scope. You should have two traces on screen. If you only have one trace and CH 2 position control has no effect, check to see that either the CHOP or ALT button is depressed. The CH 2 position control does not function in the SUM mode.

It would be helpful at this point to apply a known signal to the vertical inputs and check out the various controls and operating modes. This will give you a quick picture of the condition of the instrument and often provide clues to circuits that may be in trouble.

A look inside

Now let's take a look inside the D67 and locate the adjustments we will be tweaking during calibration. The side panels are easily taken off by removing the two screws in the carrying handle and pulling the panels away and down from the instrument. Note that the transistors are mounted in sockets to facilitate servicing. The TIME/CM switches for A and B sweeps are
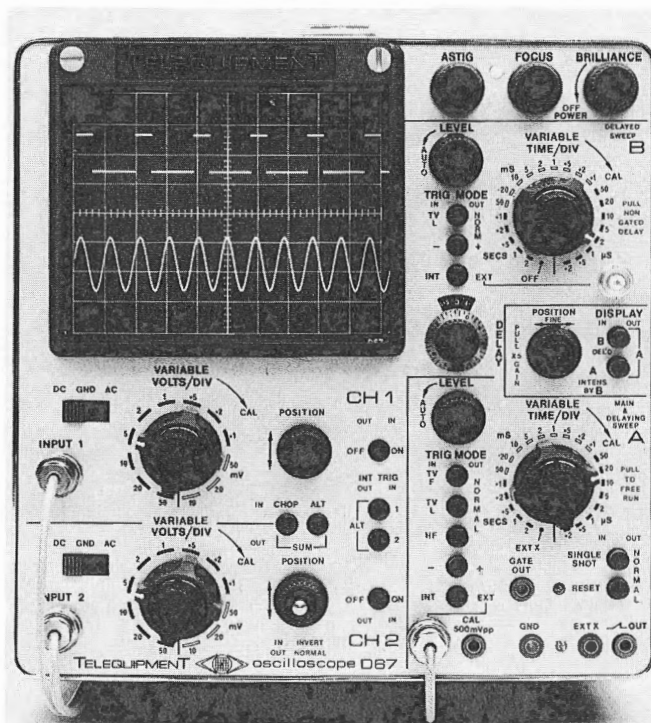
The D67 25 MHz oscilloscope.

convenient "landmarks" for locating the circuitry associated with the respective sweeps and you will find the adjustments marked on the printed circuit board by symbol number.

Check the power supplies

Before starting our calibration we should check the power supplies. There are three regulated supplies: +12 V, −12 V and +115 V. The high voltage is −1450 V with an unregulated +8.5 kV to the anode. Make sure the voltage selector plug on the back of the instrument is set to most nearly correspond with the actual line voltage. Then set the power supplies to their proper value in the following order: +12 V, −12 V, +115 V and −1450 V. The +8.5 kV should be checked but does not have an adjustment. Ripple on the low voltage supplies should be less than 10 mV and should be checked with the A sweep TIME/CM control in EXT X position.

A trigger set up

Since the triggering must be working properly to calibrate the rest of the instrument, it should be set up first. Set the D67 controls as follows:

A TIME/DIV to EXT X

B TIME/DIV to OFF

A and B LEVEL controls to AUTO (full ccw)

All push buttons to OUT

CH 1 and CH 2 inputs to GND

Connect a test oscilloscope with 10X probe to test point 124 located beneath the A TIME/DIV switch on printed circuit board PC75. Set the test scope vertical sensitivity to 5 mV/div and the sweep rate to 10 ms/div. The adjustments are R12 and R33 located just below the A TIME/DIV switch. Turn R33 fully counterclockwise and set R12 to the approximate center of the range in which an oscillation is observed on the test scope. (Note which direction you are turning R12 when the oscillation appears.) If you want to check the oscillation, speed up the test scope TIME/DIV and notice the frequency is about 1 MHz. Reset the test scope TIME/DIV to 10 ms. Every movement of R12 and R33 should now be very slight. Turn R33 clockwise until the oscillation just disappears. Turn R12 in the direction noted in parenthesis until the oscillation appears again. Then turn R33 clockwise slightly until the oscillation again disappears. Repeat these two steps until a triangular waveform of about 20 to 40 Hz appears. Carefully adjust R12 and R33 until the waveform is a symmetrical triangle approximately 70 to 75 mV peak-to-peak in amplitude and at a frequency between 20-40 Hz. The ideal frequency is 30 Hz. (See Fig. 1)
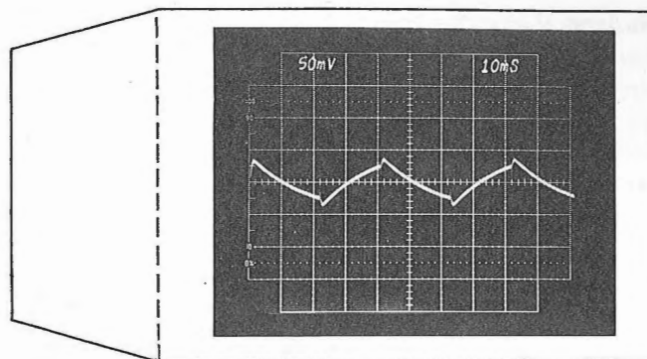

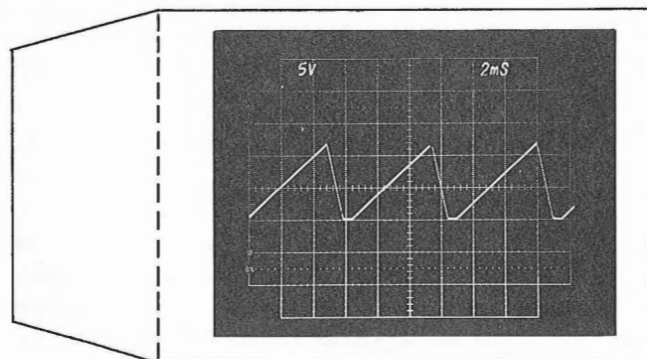Fig 1. Typical waveform at TP124 when R12 and R33 are properly adjusted.

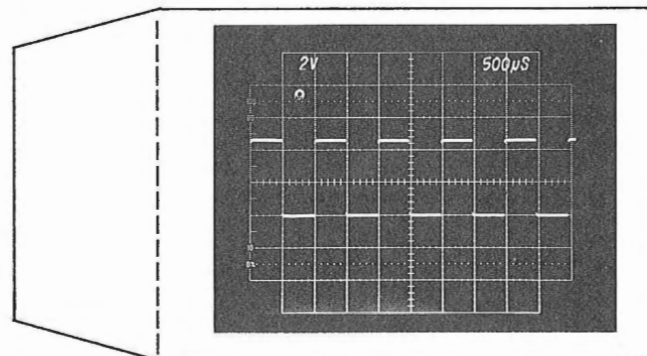Fig. 2. Front-panel sawtooth output with proper holdoff adjustment.

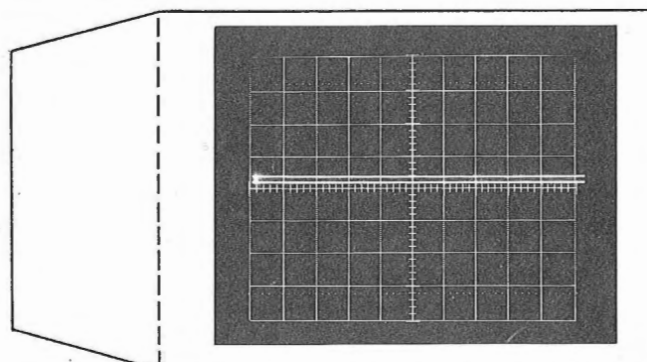Fig. 3. Typical waveform at TP125 when R62 and R82 are properly adjusted.

Fig. 4. Appearance of trace while setting sweep B stability and holdoff. Bright spot is caused by disconnecting link from TP153.

Horizontal amplifier balance

Before setting the hold off, the horizontal amplifier should be balanced. Set the A TIME/DIV switch to EXT X position. Connect a DC voltmeter across the collectors of TR277 and TR278 and adjust horizontal position and FINE controls for a meter reading of 0. Now put the negative lead to ground and the positive lead to the collector of TR278 and adjust R297 for a reading of approximately 53 V. Pull out the FINE position control for X5 horizontal gain, and center the spot with the position controls. Push in FINE and recenter the spot with R292. Repeat these last three steps until there is no spot movement and the amplifier is balanced.

Setting A holdoff time

The next step is to set the holdoff time. Set the A TIME/DIV switch to .5 ms and pull the A VARIABLE control out. The variable control should be fully clockwise. Check to see that the horizontal FINE control is pushed in. You should now have a free-running trace on screen. Adjust R109 on PC75 for a trace length of 10.2 divisions. Now observe the front-panel sawtooth output waveform with your test oscilloscope and adjust R113 to make the duration of holdoff equal to the duration of flyback; that is, the horizontal portion of the waveform equal to the negative going portion. (See Fig. 2)

Setting A stability

Apply a 1 kHz squarewave signal to CH 1 input of the D67 and set the controls as follows:

CH 1 input to AC

VOLTS/CM to 10 mV

CH 1 push button ON

INT TRIG push button 1 IN

TRIG MODE to INT

Adjust the 1 kHz signal for one division of deflection. Set R125, located on PC75, fully counterclockwise and watching the trace, turn R125 clockwise slowly until the display locks in. Pull out A VARIABLE to make sure the sweep free runs. If not, turn R125 clockwise slightly until it does free run. Push A VARIABLE back in and recheck for a locked-in display. R109, R113 and R125 interact so this procedure should be rechecked and set until the holdoff, trace length and stability are correct. Now depress the SINGLE SHOT push button and note that a single sweep occurs each time the RESET button is depressed.

Setting A timing

The next step is to set A sweep timing. Apply .1 ms time marks to CH 1 input and adjust the controls for a stable display.

Set A TIME/DIV to .2 ms

Adjust R143 for 2 markers per division

Pull out FINE position control

Adjust R285 for 2 markers per 5 divisions

Push in FINE position control

Apply 1 μs markers to CH 1 input

Set A TIME/DIV to .2 μs

Adjust C219A on TIME/DIV switch for 1 marker per 5 divisions

B trigger set up

Before setting up the B trigger you need to turn off the scope and unplug the link from TP153 located near the top middle of PC75. Turn the scope back on and set the controls as follows:

A TIME/DIV to EXT X

B TIME/DIV to OFF

Both LEVEL controls to AUTO

B TRIG MODE to INT and + slope

DELAY dial to 5.0

CH 1 VOLTS/CM to 10 mV

INT TRIG to CH 1

Apply a 1 kHz squarewave to CH 1 input and adjust the squarewave for a .2 division display. Connect the test scope probe to test point 125 located just behind the B TIME/DIV switch on PC75. Adjust R62 and R82 in the same manner as was done in setting up A trigger, the difference being, the signal on the test scope should be a 1 kHz squarewave of about 4 V peak-to-peak. (See Fig. 3)

Setting B stability and holdoff

With the A TIME/DIV still in EXT X, set B TIME/DIV to .5 ms and pull out B VARIABLE control. A trace should now be seen with an amplitude of about .2 divisions. You will note a bright dot appears on the front of the trace (Fig. 4) . This is normal until the wire link is put back on TP153. If a trace is not displayed, adjust R179 until a trace appears.

Connect the probe of the test oscilloscope to the collector of TR165 and observe a sawtooth waveform of approximately 36 V. Adjust R168 for a holdoff equal to the flyback or negative slope. Adjust R165 for 10.2 div of trace length. Push in B VARIABLE control, and set R179 for a locked-in trace; then pull out B VARIABLE and make sure the trace free runs. R179, R168, and R165 interact so this procedure should also be rechecked and set until holdoff, trace length, and stability are correct.

Setting B timing

You can use the same procedure for B timing as was used for A with the exception that R186 is the adjustment for the .2 ms timing and C219B for the .2 μs timing. There is no adjustment for X5 on the B sweep. When timing is completed, turn off the scope and replace the wire link on TP153.

After replacing the link set A TIME/DIV to .1 ms and B TIME/DIV to 20 s. Depress the A intens by B DISPLAY push button and check for proper operation of the A intensified and B delayed modes of operation. This concludes the sweep calibration procedure.

The vertical section

Calibration of the vertical section is relatively easy and the manual procedure is adequate so we will not cover it here. However, there is one item of interest that should be mentioned. If CH 1 and CH 2 have unequal inputs and the SUM mode is selected, the sum of the two inputs will be seen on the crt. If the INVERT switch on CH 2 is depressed, then the difference of the two signals will be displayed, thus acting as a differential amplifier. Remember that in the SUM mode only CH 1 position control will position the trace.

Some service hints

There are two different versions of the D67. One has printed circuit boards that are soldered through to the outside; the other is soldered from the back side only.

If you are removing parts or doing any soldering on the latter version, it would be advisable to do so from the back of the board. This is the side with the circuit runs on it and the crt should probably be removed for accessibility. When soldering on these boards it is important to avoid applying excessive heat for long periods. Excessive heat will damage the runs and lift pads and eyelets away from connections.

The crt is removed by taking off the back panel (4 screws), unplugging the crt socket and removing the three mounting screws on the left hand side of the crt shield as viewed from the front of the scope. Disconnect the neck pins and the anode lead, and slide the crt and shield assembly toward the back until the crt clears the front panel. It can now be removed by pulling it to the left and forward.

A note of caution is in order when troubleshooting the unblanking circuit. This circuit is elevated to −1450 V and it is easy to short out several transistors when probing around with your test scope leads. Using an isolation capacitor of approximately .01 μf, 3-5000 V rating at the tip of your test probe will limit the possibility of shorting.

Cleaning of the D67 should be done with compressed air and a soft brush. It is not recommended that you wash the instrument.
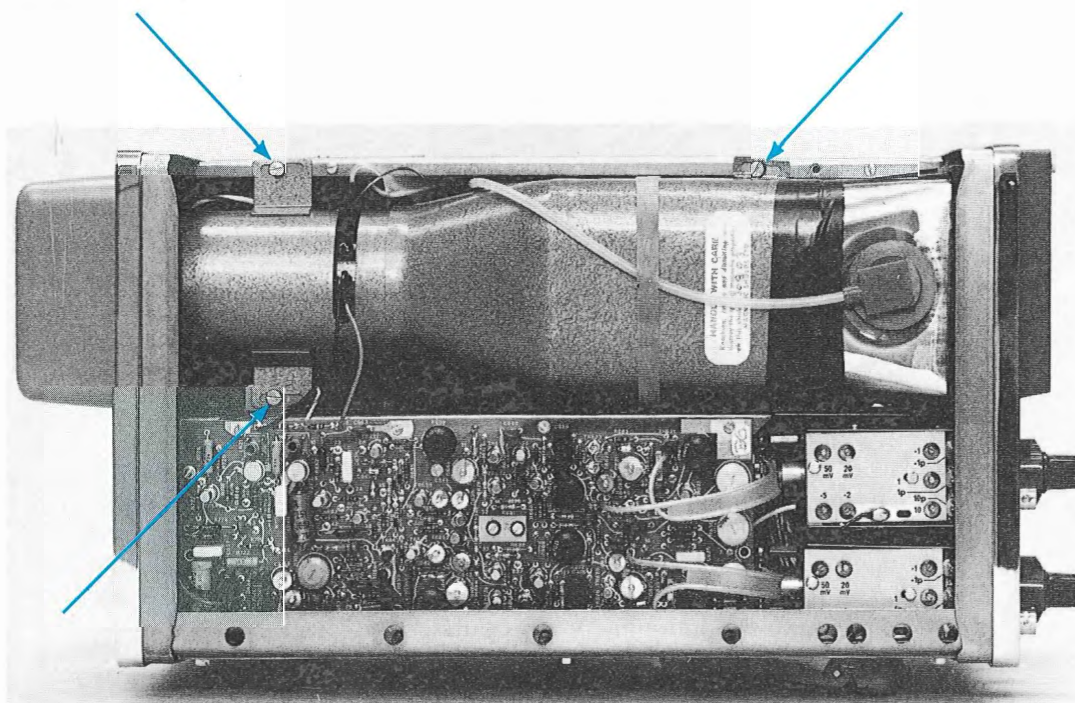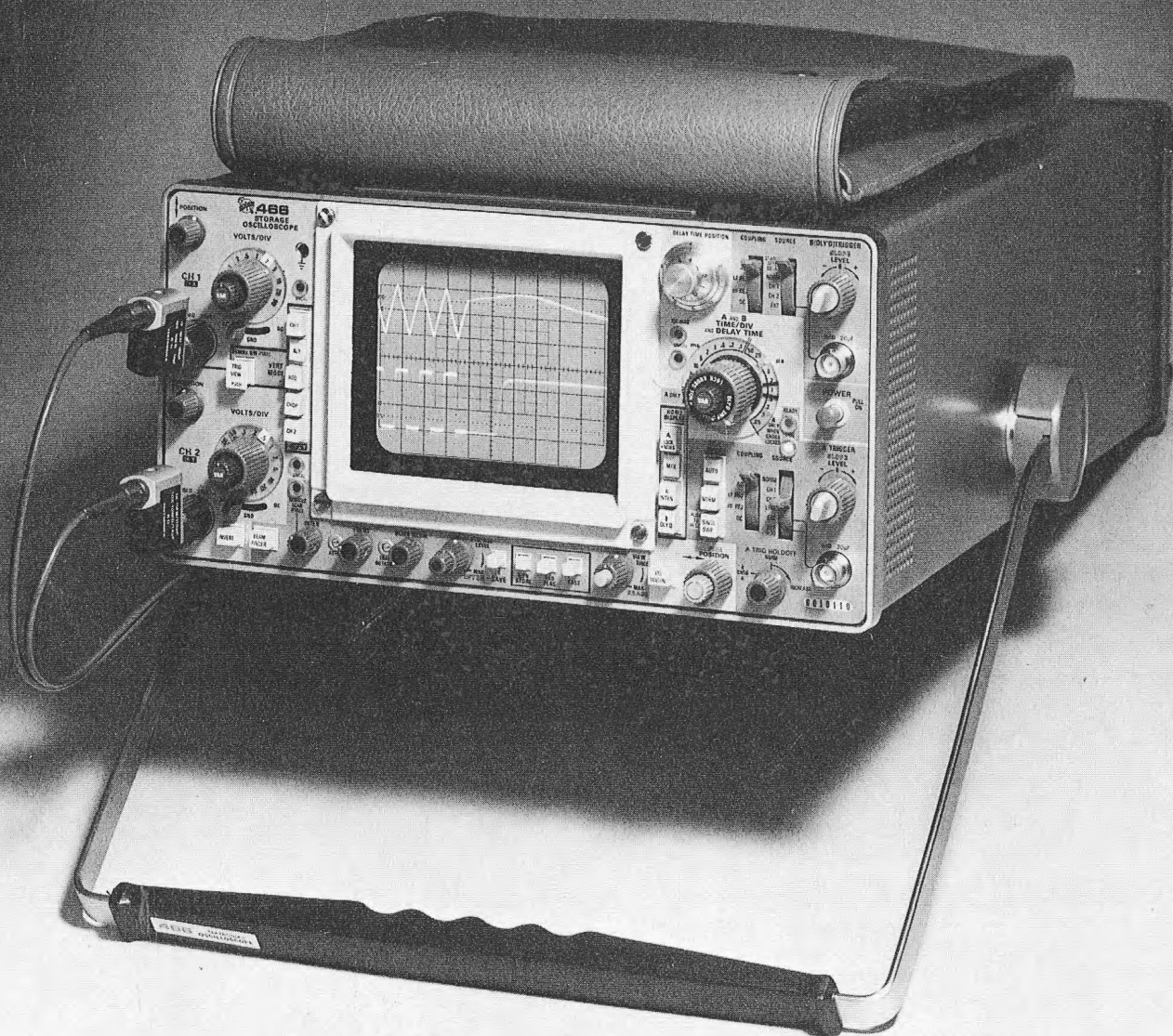

Fig. 5. Arrows indicate three mounting screws holding crt shield.

1350 cm/µs
Storage Portable

The TEKTRONIX 466 Storage Portable Oscilloscope adds fast-writing storage to the operating convenience and many features of the popular 465 portable. Storage modes include variable persistence, fast and save. With dual trace vertical, DC to 100 MHz bandwidth, delaying sweep and fast storage, the 466 packs unequalled measurement performance in a ready-to-travel package weighing just thirty pounds.

A-2939