operating instructions
and typical applications

using your oscilloscope

type 535 A or type 545 A

MANUFACTURERS OF CATHODE-RAY OSCILLOSCOPES

USING YOUR OSCILLOSCOPE TYPE 535A OR TYPE 545A *INCLUDING TYPICAL APPLICATIONS*

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PART I

GETTING ACQUAINTED

WITH YOUR TYPE 535A OR TYPE 545A OSCILLOSCOPE

In order to help you begin using your new oscilloscope as soon as possible, we have outlined in this section some of the more frequently encountered oscilloscope operations.

The oscilloscope provides us with a means of actually looking at some voltage waveform we are interested in. To accomplish this, we feed this waveform into the INPUT or CHANNEL connector of the plug-in preamplifier. In most cases, we use the oscilloscope so that the display on the screen shows how the voltage of this waveform changes with time. For get-acquainted purposes, or to check the operation of the oscilloscope, we shall look at the square-wave signal generated by the AMPLITUDE CALIBRATOR which is built into the oscilloscope. For these purposes, we suggest the use of a Type A, Type B, Type K, or Type L Plug-In Preamplifier. Operating instructions for the plug-in preamplifier are given in the instruction manual for the preamplifier.

Note 1

In these instructions, CAPITALS indicate front-panel controls or control positions, or front-panel connectors.

Note 2

Note front-panel colors on your instrument. Black lettering goes with black knobs; red lettering goes with red knobs.

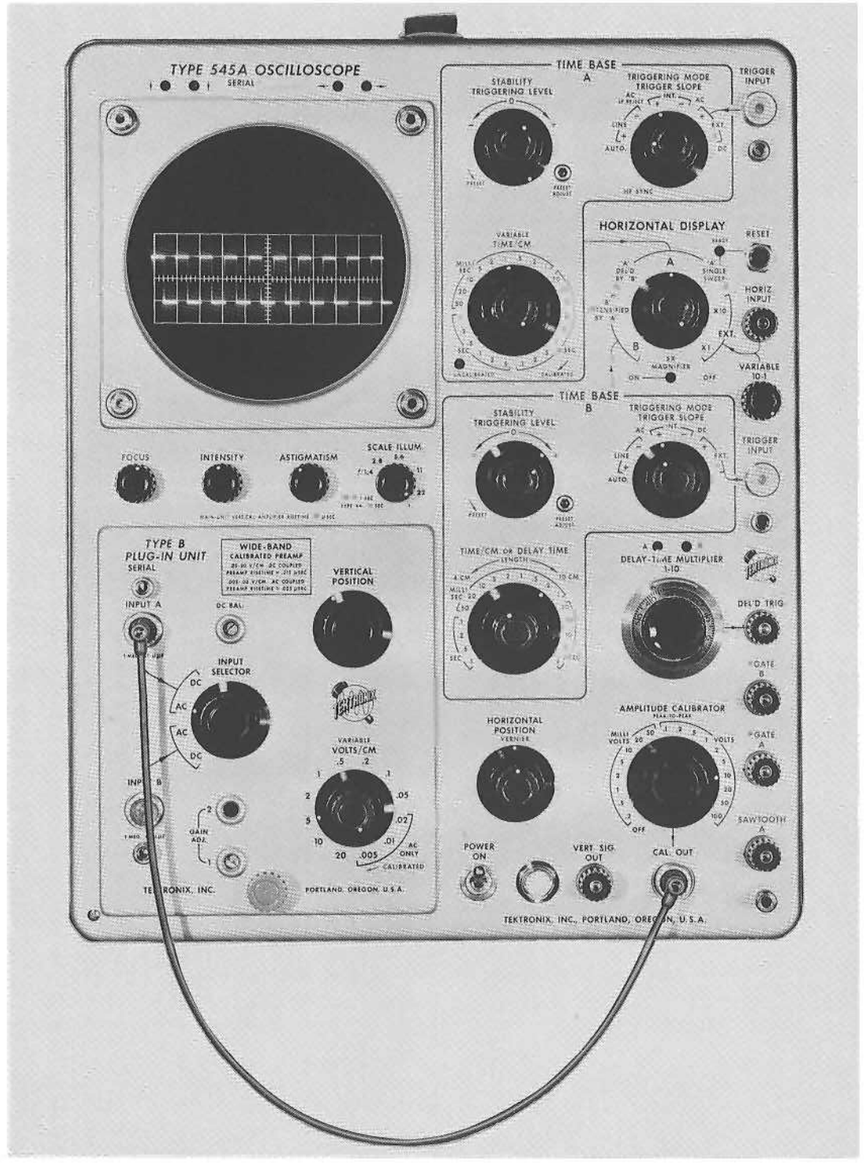

Fig. 1. Triggering in the AUTO. mode.

Triggering in the AUTO. Mode

Set the controls as follows (Fig. 1):

Horizontal Display:

HORIZONTAL DISPLAY	A
5X MAGNIFIER	OFF

Time Base A:

TRIGGERING MODE	AUTO.
TRIGGER SLOPE	+INT.
STABILITY	any position
TRIGGERING LEVEL	any position

(STABILITY and TRIGGERING LEVEL controls are inoperative in the AUTO. mode)

TIME/CM	1 MILLISEC
VARIABLE	CALIBRATED

Time Base B:

Time Base B controls are inoperative when the HORIZONTAL DISPLAY switch is in position A.

Plug-in Preamplifier:

INPUT or CHANNEL	A
AC-DC or INPUT SELECTOR	AC
VOLTS/CM	5
VARIABLE	CALIBRATED
VERTICAL POSITION	centered

Other Controls:

FOCUS	centered
INTENSITY	full left (counter-clockwise)
ASTIGMATISM	centered
SCALE ILLUM.	at convenient brightness
HORIZONTAL POSITION	centered
AMPLITUDE CALIBRATOR	10 VOLTS

Place the POWER switch in the ON position and allow the instrument to warm up. Time delay relays used in the Type 535A and Type 545A Oscilloscopes delay operation of the instrument for approximately 25 seconds after the POWER switch is turned ON to allow a brief tube-warm-up period. Turn the INTENSITY control to the right (clockwise) until a horizontal trace of useful brightness appears on the screen. Adjust the FOCUS and ASTIGMATISM controls for the sharpest trace. Connect a lead from the CAL. OUT connector to the INPUT or CHANNEL A connector on the plug-in preamplifier. The display on the screen should now be a square wave, 2 centimeters high. Slightly readjust the FOCUS, INTENSITY, and ASTIGMATISM controls so that the display has optimum sharpness and suitable brightness. Center the display on the graticule by means of the VERTICAL POSITION and HORIZONTAL POSITION controls.

You are now triggering in the AUTO. (automatic) mode. This is one of the most useful triggering modes because it provides a stable display of most waveforms with a minimum of adjustment. Turn the STABILITY and TRIGGERING LEVEL controls back and forth and notice that they have no effect on the display.

Remove the calibrator-signal lead from the INPUT or CHANNEL connector. Notice that the display now consists of a straight horizontal line. This trace indicates the line of "zero volts" with respect to ground, and serves as a desirable reference when you are testing equipment by moving a probe or other input connection from point to point in the equipment being tested. This reference trace in the absence of a triggering signal is not obtained when you are using triggering modes other than AUTO.

Now return the calibrator-signal connection to the INPUT or CHANNEL A connector.

Effect of the VERTICAL POSITION Control

Turn the VERTICAL POSITION control back and forth, and notice that this raises and lowers the display on the screen. Note especially that if you position the display off the graticule in either direction, one of the beam-position indicator lamps, located above the graticule, will indicate in which direction the display is positioned off the screen. This tells you which way to turn the VERTICAL POSITION control in order to get the trace back on the screen.

Now reset the VERTICAL POSITION control to return the display to the center of the screen.

Effect of the HORIZONTAL POSITION Controls

Turn the black HORIZONTAL POSITION control back and forth, and notice that the display moves to the left and to the right on the screen. Note especially that if you position the knob to the extreme left or right, one of the beam-position indicator lamps (located above the graticule) will indicate that the display is positioned off the screen to the left or right. This tells you which way to turn the HORIZONTAL POSITION control in order to get the trace back on the screen.

Turn the red VERNIER control back and forth, and note that this gives you a fine control of the horizontal position of the trace.

Now set the HORIZONTAL POSITION and VERNIER controls so that the trace is centered horizontally.

Effect of the AC-DC Switch

Set the AC-DC (or INPUT SELECTOR) switch on the plug-in preamplifier to DC. Notice the vertical shift in the position of the trace. This shift occurs because the output waveform from the AMPLITUDE CALIBRATOR has both an ac (square-wave) component and a dc component. When the AC-DC switch is in the AC position, the effect of the dc component is excluded from the display. When this switch is in the DC position, the display indicates both the ac and dc components of the waveform being observed. The dc component of the waveform causes the entire display to rise or fall on the screen.

Now reset the switch to AC.

Effect of the VOLTS/CM Controls

Turn the VOLTS/CM switch successively to positions both to the right and to the left of the 5 position. Notice that when you set the VOLTS/CM control to higher-numbered positions, the amount of vertical deflection produced on the screen by the AMPLITUDE CALIBRATOR waveform is reduced, and vice versa.

Reset the VOLTS/CM control to the 5 position.

Turn the red VARIABLE knob to the left. Notice that this reduces the amount of vertical deflection produced on the screen by the AMPLITUDE CALIBRATOR waveform. Now reset the VARIABLE control to the CALIBRATED position.

The above operations point up the fact that the VOLTS/CM switch and the VARIABLE knob provide control of the amount of deflection which results from feeding a waveform having a given peak-to-peak voltage into the INPUT or CHANNEL connector.

Effect of the TIME/CM Controls

Turn the black Time Base A TIME/CM switch successively to positions both to the right and to the left of the 1 MILLISEC position. Notice that the display expands or contracts horizontally as you turn this switch.

Reset the TIME/CM switch to the 1 MILLISEC position.

Turn the red VARIABLE knob to the left; note that this causes the UNCALIBRATED indicator lamp, located below and to the left of the control, to light. This control permits you to vary the sweep speed continuously between .1 microsecond and approximately 12 seconds per centimeter.

Effect of the 5X MAGNIFIER

Turn the red 5X MAGNIFIER switch to ON. This causes the 5X MAGNIFIER ON indicator lamp, located directly below the control, to light. Notice the resulting horizontal expansion of the trace. Turn this switch from OFF to ON and back several times. Observe that the portion of the waveform that occupies the middle two divisions of the graticule length when the switch is OFF is expanded to occupy the entire graticule length when the switch is ON.

With the 5X MAGNIFIER turned ON, turn the HORIZONTAL POSITION control through its range and notice that the display has been expanded beyond the limits of the graticule.

Now reset the 5X MAGNIFIER switch to OFF. With the HORIZONTAL POSITION control, return the display to the horizontal center of the graticule.

Effect of the TRIGGER SLOPE Control

Set the Time Base A TIME/CM control to 100 μSEC. Carefully observe the part of the display which appears at the left-hand end of the graticule. Notice that the trace begins during the rising portion of the square wave. That is, the sweep is **triggered** at a time when the **slope** of the wave is positive (Fig. 2a). This is because the TRIGGER SLOPE switch is set to +INT., rather than —INT.

Now turn the TRIGGER SLOPE control to —INT. Observe that the display appears to turn upside-down, so that it now begins during a falling portion of the square wave, at the left-hand end of the graticule. That is, the sweep is **triggered** at a time when the **slope** of the wave is negative (Fig. 2b).

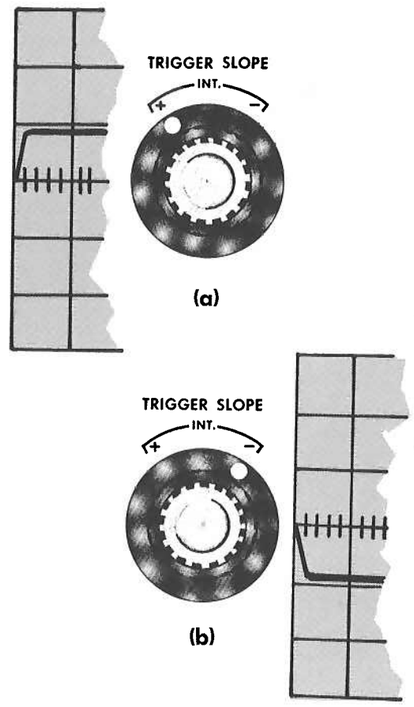

Fig. 2. Effect of the TRIGGER SLOPE control.

Turn the TRIGGER SLOPE switch back and forth several times between +INT. and —INT., observing the left-hand end of the display carefully to see how the sweep starts on either a rising or falling portion of the waveform.

The TRIGGER SLOPE switch also selects the source of the triggering signal. Thus far we have been triggering on the input signal; that is, we have been triggering **internally**. Other triggering sources will be discussed later.

Now return the TRIGGER SLOPE switch to the +INT. position.

Triggering in the AC Mode

After completing the previous operations, see that the following Time Base A controls are set as indicated (Fig. 3):

TRIGGERING MODE	AC
TRIGGER SLOPE	+INT.
STABILITY	PRESET (turn left until internal switch is actuated)
TRIGGERING LEVEL	full right (clockwise) or full left (counter-clockwise)

There now should be no trace on the screen.

Slowly turn the TRIGGERING LEVEL control toward the 0 position until the trace reappears; adjust this control for a stable display of the AMPLITUDE CALIBRATOR waveform. We say that triggering is now being effected in the AC mode.

Next, slowly turn the TRIGGERING LEVEL control back and forth several times throughout its range from —, through 0, to +. Carefully observe the left-hand end of the display while you do this. Note that there is a certain part of the range of this control that provides a display; settings too far toward the — or + marks on the panel result in no display.

If the INTENSITY control is sufficiently advanced, you can also observe that in the part of the range of the Time Base A TRIGGERING LEVEL control where you get a display, the TRIGGERING LEVEL control determines the height or "level" of the point on the waveform where the display starts. If you set the TRIGGERING LEVEL control more toward the — portion of its range, the display starts on the lower part of the waveform (Fig. 4a). If you set the TRIGGERING LEVEL control more toward the + portion of its range, the display starts on the higher part of the waveform (Fig. 4b). (Incidentally, you might even get the display to start on the lower "flat" portion of the waveform, because this part, as generated by the calibrator, has a slight upward slope.) Since the TRIGGER SLOPE control is set to +INT., the display in each case starts on the rising part of the waveform (where its slope is positive).

Now reduce the AMPLITUDE CALIBRATOR control setting to 5 VOLTS. Repeat the observations of the preceding paragraph. Note that the vertical deflection you observe on the display is reduced to one-half its former value. Particularly, notice also that the range over which the TRIGGERING LEVEL control is effective in producing a display is reduced. This re-

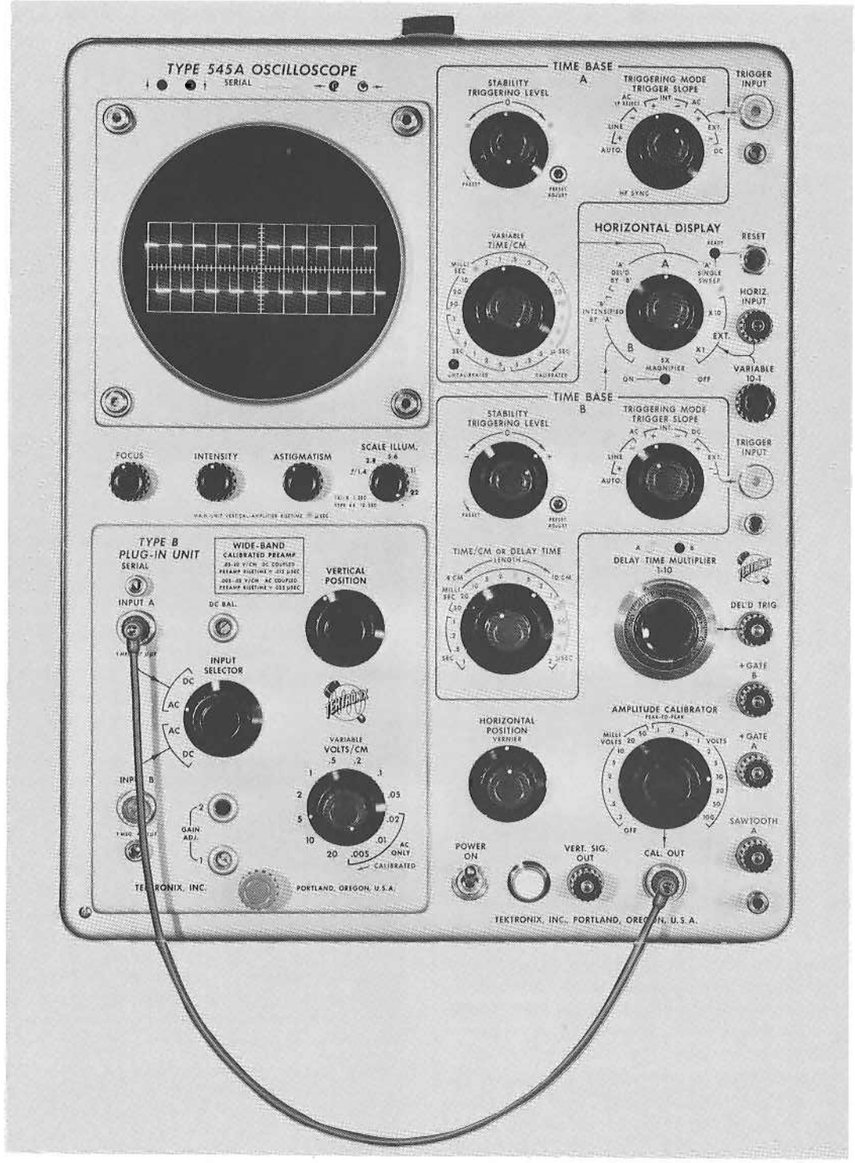

Fig. 3. Triggering in the AC mode.

duction in effective range of the TRIGGERING LEVEL control is caused by the smaller triggering signal derived internally from the displayed waveform.

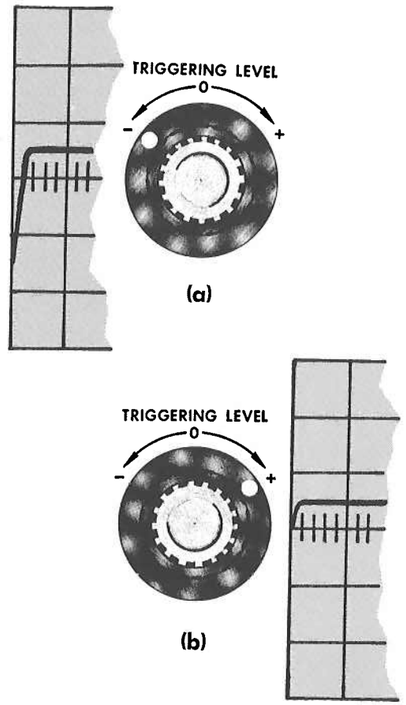

Fig. 4. Effect of the TRIGGERING LEVEL control when the TRIGGER SLOPE control is in the + position.

Now turn the AMPLITUDE CALIBRATOR control back to 10 VOLTS.

Turn the TRIGGER SLOPE control to —INT., so that the waveform appears upside-down; that is, it starts on the falling portion of the waveform. Repeat the observations of the previous paragraph, and note that you can still control the height of the point where the trace starts by means of the TRIGGERING LEVEL control (Fig. 5a, b). (You might even get the display to start on the upper "flat" portion of the waveform, because this part, as generated by the calibrator, has a slight downward slope.)

Reset the black TRIGGER SLOPE control to +INT. Now turn the VERTICAL POSITION control back and forth, so that the display is moved up and down on the graticule. Observe the left-hand end of the display while you do this. Notice that, for a fixed setting of the TRIGGERING LEVEL control, the trace always starts at a given point on the waveform, regardless of the setting of the VERTICAL POSITION control.

For most waveforms, setting the STABILITY control in the PRESET position is all the adjustment that is required. Operation of this control, other than that just described, will be explained later.

These brief statements can be made to compare the AC and the AUTO. modes of triggering:

1. It is necessary to adjust the TRIGGERING LEVEL and STABILITY controls when you use the AC (or AC LF REJECT) mode of triggering, but not when you use the AUTO. mode.

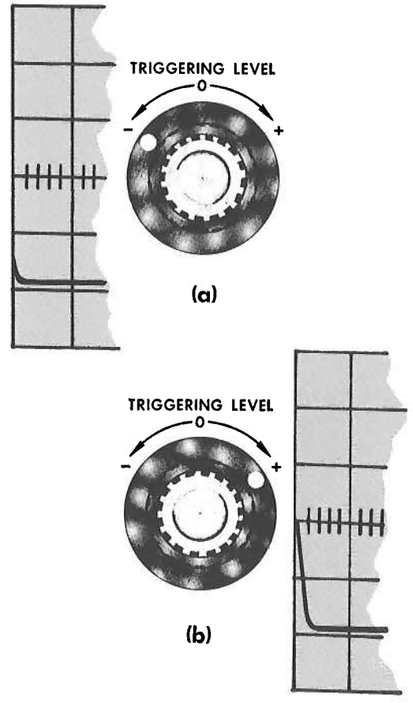

Fig. 5. Effect of the TRIGGERING LEVEL control when the TRIGGER SLOPE control is in the — position.

2. When you use the AUTO. mode, you get a horizontal reference trace on the screen, even when no input signal is used. This will be especially useful when you are testing equipment by moving the input connection from one point to another in the equipment. When you use the AC mode, no trace appears when there is no input signal.

3. In the AC mode, the TRIGGERING LEVEL control provides control of the height or "level" at which the trace starts on the waveform being observed. This is not true in the case of the AUTO. mode.

4. The AUTO. mode is useful when you are looking at periodic waveforms. The AC mode is useful both for periodic waveforms and for waveforms which occur only once or at random intervals.

NOTE: For most uses, the AC mode is preferable to the AC LF REJECT mode. Use of the AC LF REJECT mode is described in the "Operating Instructions" section.

Triggering in the DC Mode

After completing the previous operation, use the VERTICAL POSITION control to center the display vertically on the screen. Set the TRIGGERING LEVEL control for a stable display with the control located as close as possible to 0.

Turn the TRIGGERING MODE switch to DC (Fig. 6). If necessary, readjust the TRIGGERING LEVEL control for a stable display. You are now triggering the sweep in the DC mode.

Slowly turn the TRIGGERING LEVEL control back and forth several times throughout its range from —, through 0, to +. Carefully observe the left-hand end of the display while you do this. Note that the results are very much like those you obtained when you used the AC mode.

Turn the TRIGGER SLOPE switch to —INT., and repeat the above operation. Again, note that the results are similar to those you obtained when you used the AC mode. Return the TRIGGER SLOPE switch to +INT.

Now turn the VERTICAL POSITION control back and forth so that the display is moved up and down on the graticule. Observe the left-hand end of the display while you do this. Notice that, for a given setting of the TRIGGERING LEVEL control, the trace starts at a given point on the graticule, regardless of the setting of the VERTICAL POSITION control. (If you position the trace too high or too low, so that the waveform does not include this starting point, the trace disappears.)

The four comments at the close of the section on the AC triggering mode apply also to triggering in the DC mode. The following statements can be made to compare the DC and AC modes of triggering:

1. When you use the DC mode, the trace always starts at a given point on the **graticule**, for a given TRIGGERING LEVEL setting (regardless of the VERTICAL POSITION setting). But when you use the AC mode, the trace always starts at a given point on the **waveform**, for a given TRIGGERING LEVEL setting (regardless of the VERTICAL POSITION setting).
2. The DC mode is especially useful for viewing waveforms which change slowly.

TIME BASE B

With the HORIZONTAL DISPLAY switch in the B position, Time Base B may be displayed on the oscilloscope screen instead of Time Base A. Within the limitations imposed by differences in control function or range, all operations with the available triggering modes of Time Base B are identical to those of Time Base A. Time Base B has three triggering modes while Time Base A has five. Not available for Time Base B are the HF SYNC and AC LF REJECT triggering modes. In addition, Time Base B has 18 accurately calibrated sweep speeds while Time Base A has 24. These 18 available sweep speeds vary from 2 microseconds to 1 second per centimeter. The red LENGTH control adjusts the sweep length between approximately 4 and 10 centimeters.

Delayed Sweep Operation

With the Type 535A or Type 545A Oscilloscopes the start of the horizontal sweep can be

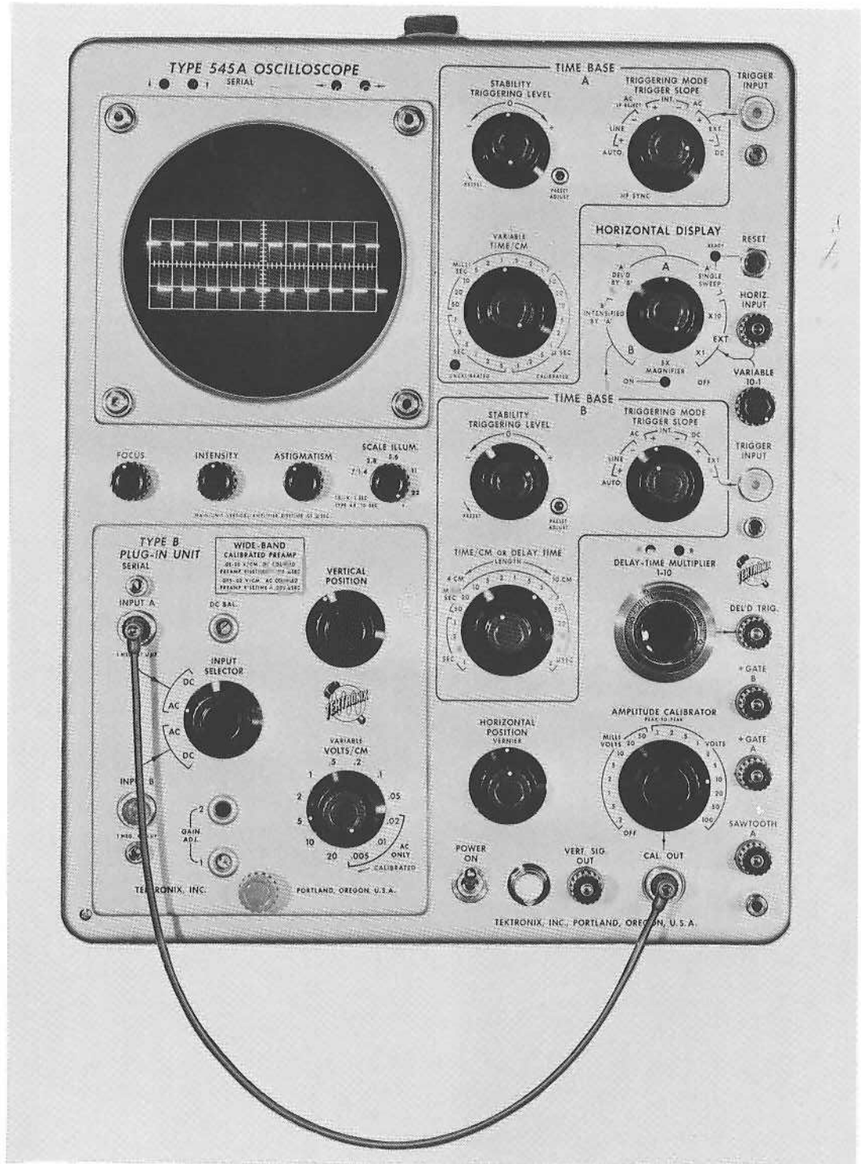

Fig. 6. Triggering in the DC mode.

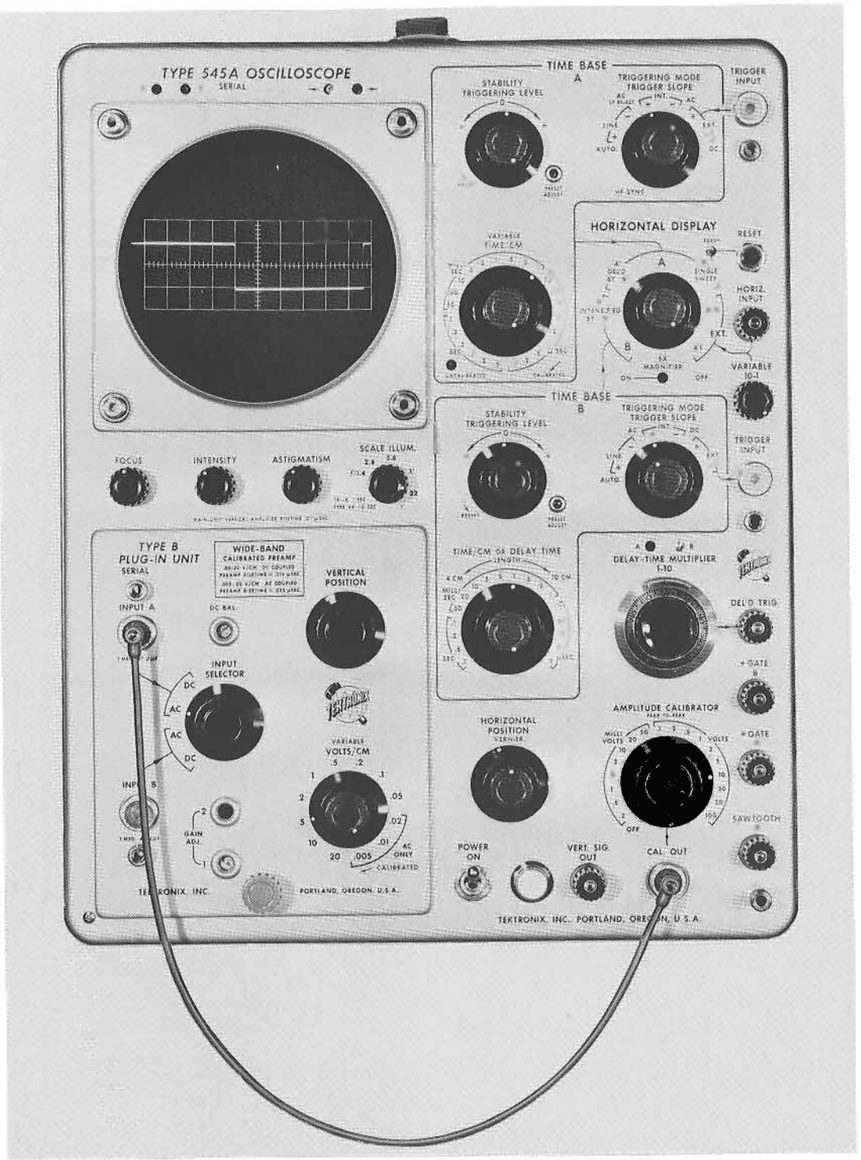

Fig. 7. 'A' DEL'D BY 'B'

delayed for a period of from 1 microsecond to 10 seconds after application of the triggering waveform. This is done through simultaneous use of Time Base A and Time Base B. In this application Time Base B is used to provide the accurate time delay while Time Base A presents a normal horizontal sweep at the end of the delay period. The duration of the sweep delay is controlled by the Time Base B TIME/CM OR DELAY TIME switch and the DELAY-TIME MULTIPLIER control. Set the controls as follows (Fig. 7):

Horizontal Display:

HORIZONTAL DISPLAY	'A' DEL'D BY 'B'
5X MAGNIFIER	OFF

Time Base A:

TRIGGERING MODE	AC or DC
TRIGGER SLOPE	+INT.
STABILITY	full right
TRIGGERING LEVEL	any position
TIME/CM	100 μSEC
VARIABLE	CALIBRATED

Time Base B:

TRIGGERING MODE	AC
TRIGGER SLOPE	+INT.
STABILITY	adjust for stable display
TRIGGERING LEVEL	adjust for stable display
TIME/CM OR DELAY TIME	1 MILLISEC
LENGTH	10 CM
DELAY-TIME MULTIPLIER	6.50

Plug-in Preamplifier:

INPUT or CHANNEL	A
AC-DC or INPUT SELECTOR	AC
VOLTS/CM	5
VARIABLE	CALIBRATED
VERTICAL POSITION	centered

Other Controls:

AMPLITUDE CALIBRATOR	10 VOLTS

Connect a lead from the CAL. OUT connector to the INPUT or CHANNEL A connector on the plug-in preamplifier.

The amount of delay occurring from application of the triggering waveform until the sweep runs is indicated directly by the settings of the TIME/CM OR DELAY TIME switch and the DELAY-TIME MULTIPLIER control. The settings of the two controls are multiplied together to obtain the actual delay time. If the TIME/CM OR DELAY TIME switch is set at 1 MILLISEC and the vernier dial of the DELAY-TIME MULTIPLIER control indicates 6.50, the delay time is 6.50 milliseconds. When the Time Base A STABILITY control is in the fully clockwise position, the horizontal sweep starts immediately at the completion of the delay period at a rate determined by the settings of the Time Base A TIME/CM controls. Now turn the HORIZONTAL DISPLAY switch to the 'B' INTENSIFIED BY 'A' position (Fig. 8).

That portion of the display between 6.5 centimeters and 7.5 centimeters along the graticule length should now be brighter than the rest of the display (this increased brightness can be seen only when the intensity control is not turned too far to the right). The start of this brightened portion indicates the start of the delayed sweep and the length of the brightened portion indicates the delayed sweep duration. The start of the brightened portion can be positioned left or right with the DELAY-TIME MULTIPLIER control. The length of the brightened portion can be adjusted with the Time Base A TIME/CM controls. Using these controls, it is possible to include any portion of the displayed waveform in the brightened area. Turn the HORIZONTAL DISPLAY switch back to the 'A' DEL'D BY 'B' position. Observe that the portion of the original display that was brightened will now be expanded to fill the entire graticule length.

Now turn the DELAY-TIME MULTIPLIER slowly back and forth over the range from 1.00 to 10.00, meanwhile switching the HORIZONTAL DISPLAY control back and forth between 'B' INTENSIFIED BY 'A' and 'A' DEL'D BY 'B'. Note that in each case the portion of the waveform that is brightened when the HORIZONTAL DISPLAY switch is in the 'B' INTENSIFIED BY 'A' position is displayed across the entire graticule length when the HORIZONTAL DISPLAY switch is in the 'A' DEL'D BY 'B' position. Since you set the Time Base A TIME/CM control for a sweep rate 10 times as fast as the setting of the

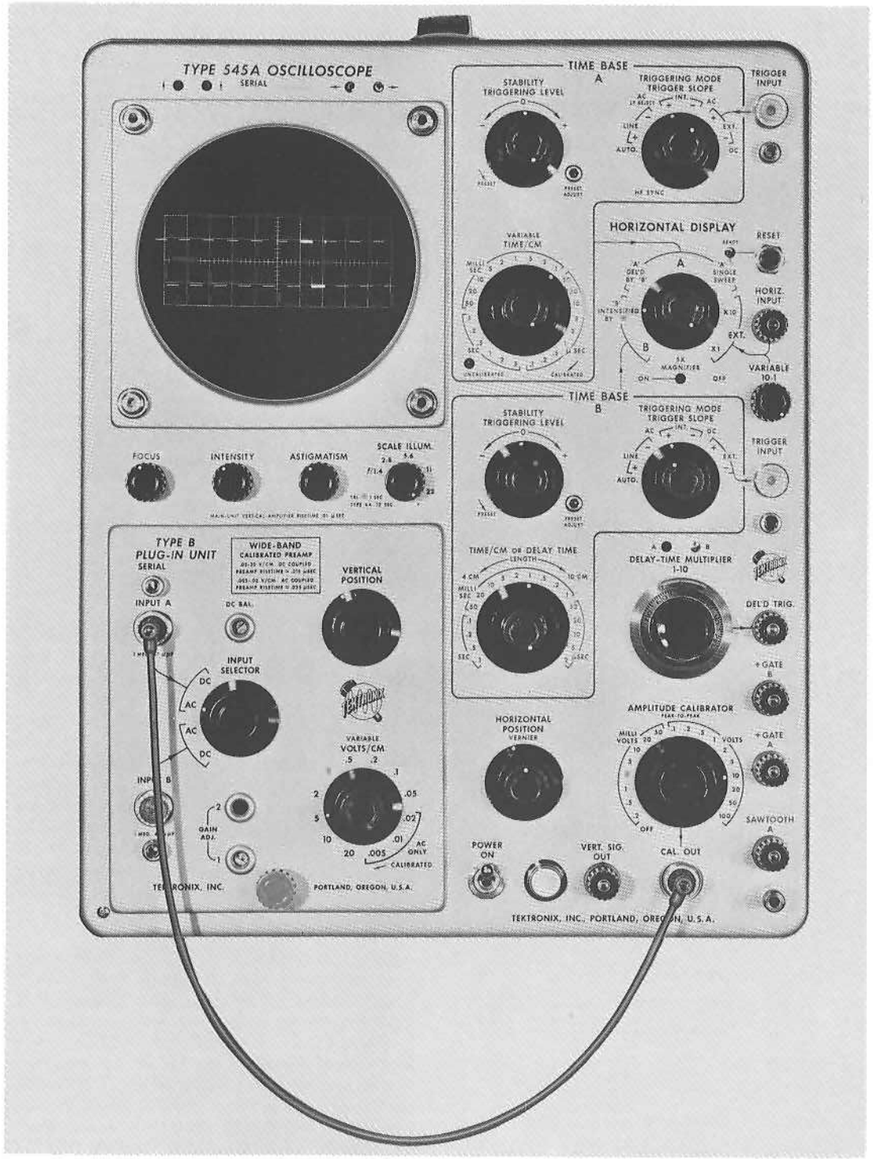

Fig. 8. 'B' INTENSIFIED BY 'A'

Time Base B TIME/CM OR DELAY TIME control, the waveform is magnified 10 times as compared with the display presented when the HORIZONTAL DISPLAY switch is in the 'B' INTENSIFIED BY 'A' position.

Now set the Time Base A TIME/CM control to 10 μSEC. Set the HORIZONTAL DISPLAY switch to 'B' INTENSIFIED BY 'A'. Note that a much shorter portion (1 millimeter) of the display is brightened. Now turn the DELAY-TIME MULTIPLIER control slowly back and forth between 1.00 and 10.00, at the same time switching the HORIZONTAL DISPLAY switch back and forth between the 'B' INTENSIFIED BY 'A' and 'A' DEL'D BY 'B' positions. Again note that the portion of the waveform that is brightened when the HORIZONTAL DISPLAY switch is in the 'B' INTENSIFIED BY 'A' position is displayed across the entire graticule length when the HORIZONTAL DISPLAY switch is in the 'A' DEL'D BY 'B' position. Here, the magnification is 100 times, since the Time Base A TIME/CM control is set for a rate 100 times as fast as the setting of the Time Base B TIME/CM OR DELAY TIME control.

Now reset the Time Base A TIME/CM control to 100 μSEC.

Note that if the Time Base A triggering controls are set to provide for normal triggering (STABILITY control not in the fully clockwise position), the delay time is not continuously variable and is dependent not only on the settings of the Time Base B TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control, but on the occurrence of the Time Base A triggering waveform as well.

Delayed Trigger Operation

Set the HORIZONTAL DISPLAY switch to the 'B' INTENSIFIED BY 'A' position. Set the TIME/CM OR DELAY TIME control to 1 MILLISEC. Adjust the Time Base B controls for a stable display of the AMPLITUDE CALIBRATOR signal. Now set the DELAY-TIME MULTIPLIER control to 6.50.

Turn the Time Base A TRIGGER SLOPE switch to AUTO. and the TIME/CM control to 100 μSEC.

The first AMPLITUDE CALIBRATOR square-wave cycle appearing to the right of the 6.5-centimeter point on the graticule length should appear brighter than the rest of the display. Now turn the HORIZONTAL DISPLAY switch to 'A' DEL'D BY 'B', and the part of the display that was brightened will now appear displayed across the entire graticule length.

Notice these differences between the present operation and the operation previously described—"Delayed Sweep Operation":

1. In the delayed sweep operation, the portion of the display that is brightened when the HORIZONTAL DISPLAY switch is in the 'B' INTENSIFIED BY 'A' position begins at a point on the graticule length that is determined by the setting of the DELAY-TIME MULTIPLIER. This brightened portion will be displayed over the graticule length when you turn the HORIZONTAL DISPLAY switch to the 'A' DEL'D BY 'B' position.

2. But in the present delayed trigger operation, the portion of the waveform that is brightened when the HORIZONTAL DISPLAY switch is in the 'B' INTENSIFIED BY 'A' position begins with the first leading edge of the waveform **after** that point on the graticule length determined by the DELAY-TIME MULTIPLIER setting. This, too, is the portion that is displayed across the entire graticule length when you turn the HORIZONTAL DISPLAY switch to 'A' DEL'D BY 'B'. With the HORIZONTAL DISPLAY switch at 'B' INTENSIFIED BY 'A', turn the DELAY-TIME MULTIPLIER control back and forth over its range from 1.00 to 10.00. Notice that the brightened portion of the waveform does not progress smoothly across the graticule as it did when you used the delayed sweep operation. Here, the brightened portion remains stationary until you turn the DELAY-TIME MULTIPLIER so far that the brightened portion starts at an earlier or later edge of the waveform.

At any time you can turn the HORIZONTAL DISPLAY switch to 'A' DEL'D BY 'B' and view the brightened portion of the waveform expanded over the entire graticule length. (Here, the display will in all cases be identical, because all cycles of the calibrator square wave are similar.)

Now turn the Time Base A TRIGGER SLOPE control to —INT. With the HORIZONTAL DISPLAY switch at 'B' INTENSIFIED BY 'A', repeat the above operation with the DELAY-TIME MULTIPLIER control. Observe that this operation is similar to the one previous, except that now the brightened portion of the waveform starts on a falling edge rather than on a leading edge of the waveform.

NOTE: Although the operations described here under "Delayed Sweep Operation" and "Delayed Trigger Operation" make Time Base B function to provide a very versatile and accurate magnifier, there are other important applications of Time Base B. Some of these are discussed later under "Operating Instructions."

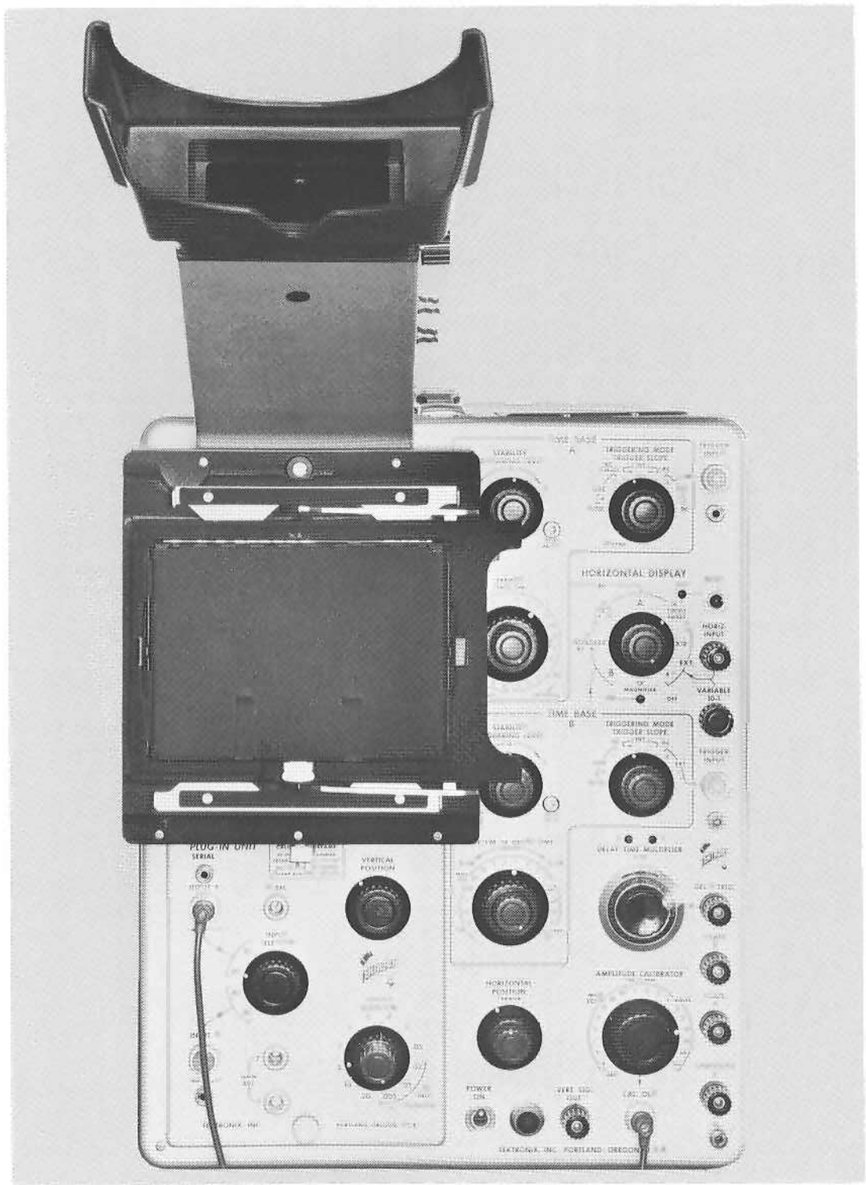

Fig. 9. 'A' SINGLE SWEEP

SINGLE SWEEP OPERATION

The Type 535A and Type 545A Oscilloscopes permit you to obtain a single-sweep presentation and to eliminate all subsequent sweeps so that information is clearly recorded without the confusion resulting from multiple traces. In applications where the displayed waveform is not repetitive or varies in amplitude, shape, or time interval, a repetitive sweep produces a jumbled display. A single-sweep presentation is obtained by setting the front-panel controls as follows (Fig. 9):

Horizontal Display:

HORIZONTAL DISPLAY	'A' SINGLE SWEEP
5X MAGNIFIER	OFF

Time Base A:

TRIGGERING MODE	AC
TRIGGER SLOPE	+INT.
STABILITY	full right
TRIGGERING LEVEL	any position
TIME/CM	100 μSEC
VARIABLE	CALIBRATED

Time Base B:

Time Base B controls are inoperative when the HORIZONTAL DISPLAY switch is in the 'A' SINGLE SWEEP position.

Plug-In Preamplifier:

INPUT or CHANNEL	A
AC-DC or INPUT SELECTOR	AC
VOLTS/CM	5
VARIABLE	CALIBRATED
VERTICAL POSITION	centered

Other Controls:

AMPLITUDE CALIBRATOR 10 VOLTS

Connect a lead from the CAL. OUT connector to the INPUT or CHANNEL A connector of the plug-in preamplifier.

If you now operate the RESET push-button, you should get a single trace across the screen, displaying the AMPLITUDE CALIBRATOR square wave. Each time you operate the RESET button, you should get another single trace.

When the STABILITY control is set fully clockwise or the TRIGGERING MODE switch is in the AUTO. position, a single sweep runs immediately each time the RESET button is depressed. However, if Time Base A is set for triggered operation with the TRIGGERING MODE switch in other than the AUTO. or HF SYNC positions, the single sweep does not occur when the RESET button is depressed unless a triggering signal is applied to Time Base A. Instead the READY lamp lights to indicate that the sweep is ready to be triggered. When a triggering signal occurs, the single sweep runs and the READY light goes out. Each time the RESET button is depressed the procedure is repeated.

PART II

OPERATING INSTRUCTIONS

INCLUDING TYPICAL APPLICATIONS

This section includes the information in the "Getting Acquainted" section, in condensed form for easy reference. You will also find instructions on other applications of your oscilloscope.

HORIZONTAL-DEFLECTION SYSTEM

TIME BASE A
TRIGGERED OPERATION

For many uses of your oscilloscope, you will need to get a stable display of some recurrent waveform. To accomplish this, you can operate the oscilloscope so that each horizontal sweep of the spot across the screen starts at a given point on the waveform you are looking at. This is called "triggered" operation. For present purposes, then, we can refer to the starting of the horizontal sweep at the left-hand end of the graticule as "triggering" the sweep.

Triggered operation is also useful in looking at a waveform which occurs only once, or which occurs at random intervals.

For any of the above uses, the oscilloscope can alternatively be used in such a way that each horizontal sweep of the spot is triggered by some waveform other than the one you are observing, but which has a time relationship to the observed waveform.

The waveform used to start the horizontal sweep is called a "triggering signal" (whether it is the waveform being observed, or some other waveform). The following instructions tell you how to select the triggering signal. They also contain information on triggering according to various modes, depending upon the nature of the triggering signal.

How to Select the Triggering Signal

1. To trigger Time Base A from the waveform being observed, set the black TRIGGER SLOPE switch to +INT. or to —INT.
2. To trigger the sweep from the power-line voltage waveform, as in the case where you are observing a waveform which has a time relationship to the power-line wave, set the black TRIGGER SLOPE switch to +LINE or to —LINE.
3. To trigger the sweep from some externally derived waveform which has a time relationship to the observed waveform, connect the source of triggering waveform to the TRIGGER INPUT connector. Set the black TRIGGER SLOPE switch to +EXT. or to —EXT.

If you want the start of the display, at the left-hand end of the graticule, to occur at a time when the triggering signal is rising (has a positive slope), use the +INT., the +LINE or the +EXT. position of the black TRIGGER SLOPE switch, as described above. If you want the start of the display to occur when the triggering signal is falling (has a negative slope), use the —INT., the —LINE or the —EXT. position of the black TRIGGER SLOPE switch.

AUTO. Mode

This is an especially useful triggering mode, providing automatic triggering from periodic signals in the range from about 60 cycles to 2 megacycles.

1. Select the desired triggering signal.
2. Set the Time Base A TIME/CM switch for a sweep rate suited to the waveform being observed.
3. Set the HORIZONTAL DISPLAY switch to position A, and set the red TRIGGERING MODE switch to AUTO.

AC Mode

This mode is useful for triggering either from transients, or from periodic signals in the range from about 60 cycles to 5 megacycles.

1. Select the desired triggering signal.
2. Set the controls as follows:

HORIZONTAL DISPLAY	A
TRIGGERING MODE	AC
TRIGGERING LEVEL	full right or full left
STABILITY	PRESET

3. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.
4. Turn the TRIGGERING LEVEL control slowly toward the 0 position until the trace begins at the desired point on the waveform being observed.

DC Mode

In the DC mode, triggering can be effected from periodic signals in the range from dc to 5 megacycles, or from transients. This mode is especially useful with triggering signals that change slowly.

Another application of the DC triggering mode is to attain a stable display of a random-pulse train. The average voltage of this type of signal depends upon the duration of each pulse, the amplitude of each pulse, and the spacing between successive pulses. Therefore, the average voltage applied to the triggering circuits

will fluctuate. This can result in unstable triggering if the AC or AC LF REJECT mode is used. When the DC mode is used, however, the triggering circuits are sensitive to only the instantaneous applied voltage. Thus the sweep is initiated when any single pulse rises to a voltage selected by the TRIGGERING LEVEL control.

Operating instructions are similar to those given above for the AC mode, except that you set the red TRIGGERING MODE switch to DC.

AC LF REJECT Mode

In the AC LF REJECT mode, triggering can be effected from periodic signals in the range from 10 kilocycles to 5 megacycles. Characteristics are similar to those of the AC mode, except that low-frequency components of the triggering signal are rejected.

For most uses, the AC mode is preferable to AC LF REJECT. AC LF REJECT is principally for use with the Type CA Dual-Trace Plug-In Unit.

Aside from this use, AC LF REJECT may reduce jitter due to hum in the triggering signal. Operating instructions are similar to those given above for the AC mode, except that you set the red TRIGGERING MODE switch to AC LF REJECT.

Dual-Trace Operation, With Type CA Plug-In Unit

This section describes use of the ALTERNATE sweeps mode of the Type CA. For further information on use of the Type CA, refer to the Instruction Manual for that unit.

In the present use, waveforms fed to CHANNEL A and to CHANNEL B connectors on the Type CA are displayed alternately (Fig. 10).

1. Select the desired triggering signal.
2. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.
3. Set the other controls as follows:

HORIZONTAL DISPLAY	A
TRIGGERING MODE	AC LF REJECT*
TRIGGERING LEVEL	full right or full left
STABILITY	PRESET
MODE (on Type CA)	ALTERNATE

4. Turn the TRIGGERING LEVEL control toward the 0 position for a stable display of the input signals. For further information on triggering in this mode see the Instruction Manual for the Type CA.

***It may be preferable to use AC if one (or both) of the signals displayed is of low frequency.**

How to Use the Time Base A STABILITY Control

You might wish, in a few particularly difficult triggering applications, to use a setting of the STABILITY control other than the one available in the PRESET position. You can do this if you are using triggered operation in either the AC, the AC LF REJECT, or the DC mode.

1. Start with the STABILITY control turned full right. Use other control settings as given in the above instructions for the desired triggering mode.
2. Turn the STABILITY control left until the trace disappears, then two or three degrees farther left.
3. Turn the TRIGGERING LEVEL control slowly toward the 0 position until the trace begins at the desired point on the waveform being observed.
4. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.

SYNCHRONIZED OPERATION

HF SYNC Mode

When you use the HF SYNC mode, you get a recurrent horizontal sweep which can be synchronized, by means of the STABILITY control, with waveforms in the range from 5 megacycles to 15 megacycles.

When using the HF SYNC mode, you will usually want to synchronize the horizontal sweep with the waveform being displayed. To do this, set the controls as outlined in Step 1, below. If, however, you want to synchronize the sweep with some external waveform, connect the source of this waveform to the TRIGGER INPUT connector and set the TRIGGER SLOPE switch to +EXT. or —EXT.

1. Set controls as follows:

HORIZONTAL DISPLAY	A
TRIGGER SLOPE	+INT. or —INT.
TRIGGERING MODE	HF SYNC
STABILITY	full right

2. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.
3. Turn the STABILITY control slowly to the left until you get a stable display of the waveform being observed.

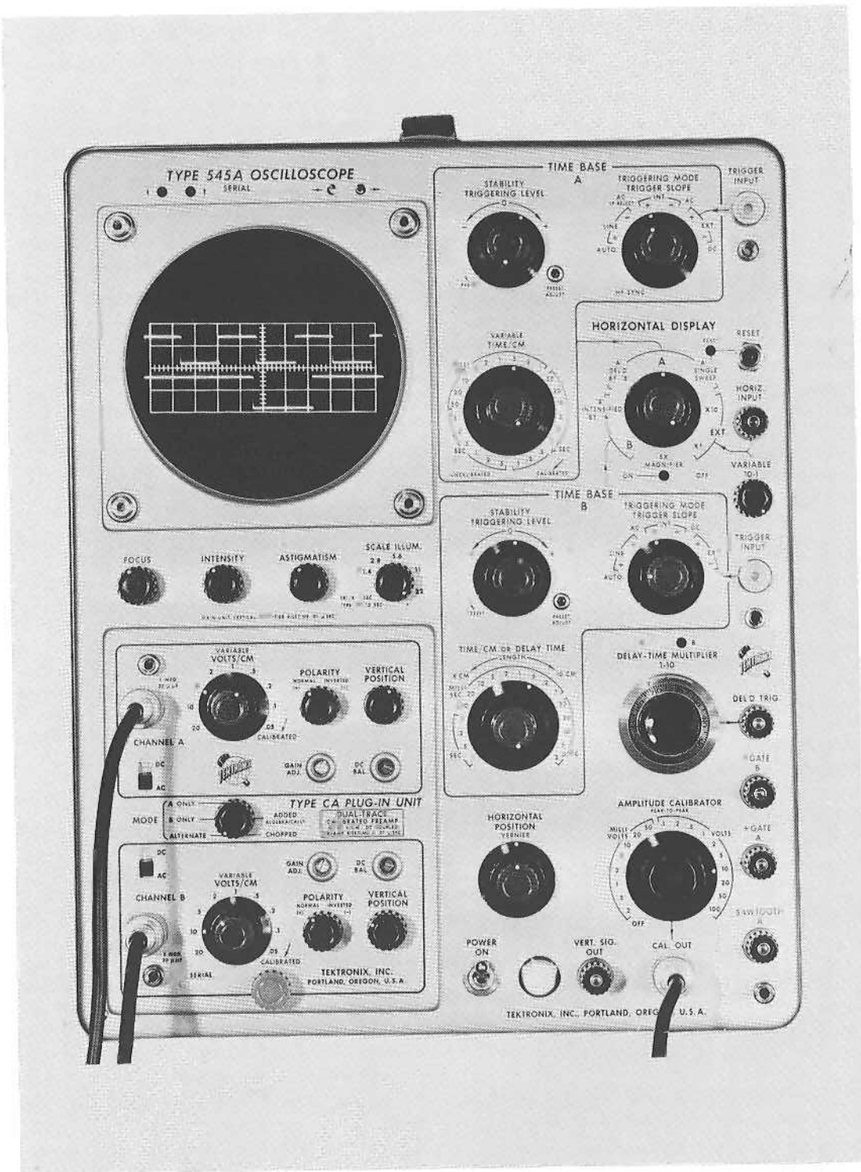

Fig. 10. Dual-Trace Operation.

FREE-RUNNING OPERATION

You can get a periodic, free-running sweep, independent of any external triggering or synchronizing signal.

As an application of free-running operation you can actuate the system under investigation by means of a signal from either the +GATE A or the SAWTOOTH A connector. (See section entitled "Output Waveforms".) The signals from these connectors have a starting time and a duration corresponding to the starting time and the duration of the horizontal sweep of the cathode-ray-tube spot. Note that this reverses the usual situation where the oscilloscope sweep is timed to the waveform under investigation. Here, the system being investigated is timed to the oscilloscope sweep. Thus a stable display is presented of the waveform resulting from actuating the system under investigation.

1. Use no input to the TRIGGER INPUT connector.
2. Set the controls as follows:

HORIZONTAL DISPLAY	A
TRIGGER SLOPE	+INT., —INT., +EXT., or —EXT.
TRIGGERING MODE	AC or DC
STABILITY	full right
TRIGGERING LEVEL	any position

3. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.

Alternatively, you can get a free-running sweep at a fixed repetition rate of approximately 50 cycles, using the AUTO. mode:

1. Use no input to the TRIGGER INPUT connector.
2. Set the controls as follows:

HORIZONTAL DISPLAY	A
TRIGGER SLOPE	+INT., —INT., +EXT., or —EXT.
TRIGGERING MODE	AUTO.

DELAYED TRIGGERS FROM TIME BASE A

Delayed positive-going triggering signals are available from the DEL'D TRIG. connector. You can use these triggering signals to actuate equipment external to the oscilloscope. When the HORIZONTAL DISPLAY switch is set to A, these triggering signals appear after a predetermined delay time following the triggering of Time Base A. The duration of this delay time is equal to the product of the settings of the Time Base A TIME/CM control and the DELAY-TIME MULTIPLIER control.

SINGLE SWEEPS

Manual Operation

1. Set the controls as follows:

HORIZONTAL DISPLAY	'A' SINGLE SWEEP
TRIGGERING MODE	AC
STABILITY	full right
TRIGGERING LEVEL	any position

2. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.
3. Push the RESET button. You should get a single trace across the screen, displaying the waveform applied to the INPUT or CHANNEL connector.

Typical application No. 1

This operation is useful in photographing recurrent phenomena when succeeding waves are similar but not necessarily identical—for example, in certain biological work. After you have made the adjustments as given above, prepare your camera to receive the picture. Open the camera shutter, and immediately push the RESET button once; then close the camera shutter. The resulting picture will show a typical waveform, without blurring from succeeding waveforms that may not be exactly identical to the waveform photographed.

Typical application No. 2

You can use the manual single-sweep operation to photograph the result of an action which is initiated when you operate the RESET push-button. First make the adjustments described in Steps 1, 2 and 3 above. Connect the +GATE A connector to controlling circuits for the action to be initiated. (This connector supplies a positive-going rectangular waveform of 20 to 30 volts amplitude starting when the RESET push-button is operated and the horizontal sweep begins.) Prepare your camera to receive the picture. Connect the output of the transducer or other signal source to the INPUT or CHANNEL connector. Open the camera shutter and immediately push the RESET push-button once; then close the camera shutter. The resulting picture will show the response of the transducer to the desired action. (See also separate publication FIP-3, "Notes on the Practical Photography of Oscilloscope Displays," available from Tektronix.)

Triggered Operation

1. Set the HORIZONTAL DISPLAY switch to position A.
2. Set the Time Base A TIME/CM control for a rate suited to the waveform being observed.
3. Adjust the Time Base A controls for triggering on the desired triggering signal according to the AC or the DC mode as previously described.
4. Set the HORIZONTAL DISPLAY switch to 'A' SINGLE SWEEP. Operate the RESET push-button. The READY lamp should now be lighted.
5. Connect the source of the expected signal to the INPUT or CHANNEL connector.
6. When the triggering signal is received, a single sweep will occur. Following this, the READY lamp will be extinguished. An additional single sweep will occur each time (A) the RESET push-button is operated and (B), following this, a triggering signal is received.

Typical application

This operation is useful in photographing a phenomenon that can occur at an unknown time or at a time when the operator is absent. After making the adjustments described in Steps 1 through 5 above, prepare your camera to receive the picture. Make sure that the READY lamp is lighted. Open the camera shutter. When the READY lamp is extinguished, close the camera shutter. If any triggering signals are received after the first, they will not cause additional traces on the oscilloscope screen, so that your picture is protected against further exposures. (See also separate publication FIP-3, "Notes on the Practical Photography of Oscilloscope Displays," available from Tektronix.)

TIME BASE B

Triggered Operation

When the HORIZONTAL DISPLAY switch is placed in position B, Time Base B is displayed on the oscilloscope screen instead of Time Base A. All operations with the available triggering modes and sweep speeds of Time Base B are identical to those of Time Base A.

DELAYING SWEEP

How to Obtain a Delayed Sweep

Through simultaneous use of Time Base A and Time Base B, the start of the horizontal sweep can be delayed for a period of from 1 microsecond to 10 seconds after application of the triggering waveform. In order to obtain a delayed sweep, set the controls as follows:

Horizontal Display:

HORIZONTAL DISPLAY	'B' INTENSIFIED BY 'A'
5X MAGNIFIER	OFF

Time Base A:

TRIGGERING MODE	AC or DC
TRIGGER SLOPE	+INT.
STABILITY	full right
TRIGGERING LEVEL	any position

Time Base B:

TRIGGERING MODE	AC
TRIGGER SLOPE	+INT.
STABILITY	adjust for stable display
TRIGGERING LEVEL	adjust for stable display
LENGTH	10 CM

Set the Time Base B TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control so that the product of their settings is equal to the desired delay time between the triggering of Time Base B and the beginning of the display to be presented by means of Time Base B.

Set the Time Base A TIME/CM control for a sweep rate suited to the waveform being observed. This rate is typically faster than that for which you set the Time Base B TIME/CM OR DELAY TIME control.

When the waveform to be displayed is periodic:

Connect the source of signal to be displayed to the INPUT or CHANNEL connector. If the INTENSITY control is sufficiently advanced, you should see an unstable presentation of the displayed waveform. Turn the Time Base B STABILITY control slowly to the left until the display disappears, then two or three degrees farther to the left. Then turn the Time Base B TRIGGERING LEVEL control slowly toward 0 until the trace begins at the desired point on the Time Base B triggering signal. If the INTENSITY control is set correctly, you should see a brightened portion of the trace. The length of this brightened portion is controlled by means of the Time Base A TIME/CM controls, and the position of this brightened portion is controlled by means of the DELAY-TIME MULTIPLIER control. When you turn the HORIZONTAL DISPLAY control to 'A' DEL'D BY 'B', the brightened portion is displayed across the entire graticule length.

If you set the HORIZONTAL DISPLAY switch to 'B' INTENSIFIED BY 'A' and then turn the LENGTH control to the left until the trace ends just after the brightened portion of the display, you can improve the duty factor and therefore the average brightness of the display presented when you turn the HORIZONTAL DISPLAY switch to 'A' DEL'D BY 'B'.

When the waveform to be displayed occurs only once:

Set the HORIZONTAL DISPLAY switch to the 'B' INTENSIFIED BY 'A' position. Adjust the Time Base B STABILITY and TRIGGERING LEVEL controls so that Time Base B will trigger at the desired point on the Time Base B triggering signal. (You might want to display the AMPLITUDE CALIBRATOR waveform by means of Time Base B in making these adjustments.) Then connect the source of signal to be displayed to the INPUT or CHANNEL connector. Now turn the HORIZONTAL DISPLAY switch to 'A' DEL'D BY 'B'. Time Base A is held "locked out" or inoperative until a predetermined delay time has elapsed after the triggering of Time Base B. This delay time is equal to the product of the settings of the TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control. After this delay time has elapsed, Time Base A presents a display of the waveform under observation.

Typical application No. 1

The operation described above under the heading "When the waveform to be displayed is periodic" provides a very versatile magnifier, so that you can accurately select the portion of the waveform to be magnified and the amount of magnification. The amount of magnification is determined by the ratio of the TIME/CM OR DELAY TIME control setting to the Time Base A TIME/CM control setting.

Using this method, you can very accurately measure the time interval between two displayed events. Observe the magnified display with the HORIZONTAL DISPLAY switch in the 'A' DEL'D BY 'B' position. Find the difference between the DELAY-TIME MULTIPLIER settings that successively place the two events directly under a given graticule line. Multiply this difference by the Time Base B TIME/CM OR DELAY TIME setting. The result is the time difference between the two events.

Typical application No. 2

The operation described above under the heading "When the waveform to be displayed occurs only once" allows you to photograph any part of a transient waveform occurring at any desired time after Time Base B is triggered. For example, you can arrange to initiate an experimental action by operating an external push-button. Let the impulse from this push-button also trigger Time Base B. Then Time Base A will display a selected part of the resulting waveform occurring after a predetermined delay time. The amount of delay is determined by the product of the TIME/CM OR DELAY TIME setting and the DELAY-TIME MULTIPLIER setting. The duration of the display is chosen by setting the Time Base A TIME/CM controls.

How to Obtain a Delayed Trigger

1. Select the Time Base A triggering signal as described under the heading "Time Base A."
2. Set the Time Base A TIME/CM controls for a sweep rate suited to the waveform being observed. (This rate is typically faster than that for which you will set the Time Base B TIME/CM OR DELAY TIME control, as described in Step 6.)
3. For most uses, you can set the TRIGGER SLOPE switch to +INT. or —INT., and set the TRIGGERING MODE switch to AUTO. (Alternatively, you can use the Time Base A TRIGGERING MODE switch in either the AC or DC position, rather than AUTO. To do this, set the HORIZONTAL DISPLAY switch to the A position, and set the Time Base A TRIGGERING MODE, TRIGGERING LEVEL, and STABILITY controls for triggering at the desired point on the triggering signal, as described under the heading "Time Base A".)
4. Turn the HORIZONTAL DISPLAY switch to 'B' INTENSIFIED BY 'A'. Select the Time Base B triggering signal as previously described.
5. Set the Time Base B STABILITY and LENGTH controls full right. Set the Time Base B TRIGGERING LEVEL control full right or full left.
6. Set the Time Base B TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control so that the product of their settings is the amount of delay time you want to elapse between the triggering of Time Base B and the time when Time Base A becomes susceptible to triggering.

When the waveform to be displayed is periodic:

Connect the source of signal to be displayed to the INPUT or CHANNEL connector. If the INTENSITY control is sufficiently advanced, you should see an unstable presentation of the displayed waveform. Turn the Time Base B STABILITY control slowly to the left until the trace disappears, then two or three degrees farther to the left. Then turn the Time Base B TRIGGERING LEVEL control slowly toward the 0 position until the trace begins at the desired point on the Time Base B triggering signal. If the INTENSITY control is set correctly, you should see a brightened portion of the trace. This brightened portion starts with the first Time Base A triggering signal received after that point on the graticule determined by the DELAY-TIME MULTIPLIER setting. In other words, the brightened portion starts with the first Time Base A triggering signal received after (1) Time Base B has been triggered and also after (2) the horizontal motion of the trace caused by Time Base B has gone on for a "delay" time equal to the product of the TIME/CM OR DELAY TIME setting and the DELAY-TIME MULTIPLIER setting. The length of the brightened portion is controlled by the Time Base A TIME/CM controls. When you turn the HORIZONTAL DISPLAY control to 'A' DEL'D BY 'B', the brightened portion is displayed across the entire graticule length.

When the waveform to be displayed occurs only once:

After completing Step 6 above, adjust the Time Base B STABILITY and TRIGGERING LEVEL controls so that Time Base B will trigger at the desired point on the Time Base B triggering signal. (You might want to display the AMPLITUDE CALIBRATOR waveform by means of Time Base B in making these adjustments.) Then connect the source of signal to be displayed to the INPUT or CHANNEL connector. Now turn the HORIZONTAL DISPLAY switch to 'A' DEL'D BY 'B'. Time Base A is held "locked out" or inoperative until a predetermined delay time has elapsed after the triggering of Time Base B. This delay time is equal to the product of the settings of the TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control. After this delay time has elapsed, the first succeeding triggering signal that arrives will cause Time Base A to present a single display of the waveform under observation.

DELAYED TRIGGERS FROM TIME BASE B

Delayed positive-going triggering signals are available from the DEL'D TRIG. connector. You can use these triggering signals to actuate equipment external to the oscilloscope. When the HORIZONTAL DISPLAY switch is set to 'B' INTENSIFIED BY 'A' or to 'A' DEL'D BY 'B', these triggering signals appear after a predetermined delay time following the triggering of Time Base B. The duration of this delay time is equal to the product of the settings of the TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control.

5X MAGNIFIER

To expand a particular part of the display horizontally, first use the HORIZONTAL POSITION control to position that part of the display so that it falls near the vertical center line of the graticule. Then turn the 5X MAGNIFIER switch to ON. That part of the display which occupied the middle two centimeters of the graticule will now be expanded to fill the graticule horizontally. Each major graticule division will now have a time value one-fifth of the value indicated by the TIME/CM switch.

EXTERNAL HORIZONTAL SWEEP

You might need to effect horizontal deflection of the spot across the screen by means of some externally derived waveform, rather than by means of Time Base A or Time Base B. To accomplish this, connect the source of this waveform to the HORIZ. INPUT connector. Turn the HORIZONTAL DISPLAY switch to either EXT. position. The horizontal deflection factor is continuously variable from approximately .2 to approximately 15 volts per centimeter with the VARIABLE 10-1 control and the HORIZONTAL DISPLAY switch.

If you are using an externally derived sine wave for horizontal deflection, and if the frequency of this sine wave exceeds 240 kilocycles, you will have to limit the amount of horizontal deflection in order to avoid distortion of the display due to overloading of the horizontal-deflection system.

OUTPUT WAVEFORMS

A sawtooth waveform is available at the SAWTOOTH A connector on the front panel. This positive-going waveform starts at about zero volts and rises linearly to a peak amplitude of about 150 volts. The start of the rising part of the sawtooth is determined in the same way as the start of the Time Base A sweep. That is, the rising part of the sawtooth can be initiated by a triggering or synchronizing signal applied to Time Base A. Or the sawtooth can be generated in a periodic, free-running manner, without regard to any triggering or synchronizing signal (see "Free-Running Operation"). The rate at which the sawtooth rises is controlled by the Time Base A TIME/CM controls. The duration of the positive portion of the waveform corresponds to the duration of the left-to-right trace of Time Base A.

A rectangular waveform is available at the +GATE A connector on the front panel. This waveform starts at zero volts and rises to a peak amplitude of 20 to 30 volts. Its starting time and duration correspond to the starting time and duration of the positive-going part of the sawtooth available at the SAWTOOTH A connector discussed above.

A rectangular waveform is available at the +GATE B connector on the front panel. This waveform starts at zero volts and rises to a peak amplitude of about 20 volts. Its starting time is determined in the same way as the start of the Time Base B sweep. That is, the positive part of the waveform can be initiated by a triggering signal to Time Base B when the Time Base B STABILITY and TRIGGERING LEVEL controls are adjusted for triggered operation of Time Base B. Or the rectangular waveform can be generated in a periodic, free-running manner, without regard to any triggering signal if the Time Base B STABILITY control is turned full right. The duration of the positive portion of the waveform corresponds to the duration of the left-to-right trace of Time Base B.

For information on the triggering signals available at the DEL'D TRIG. connector, see sections on "Delayed Triggers from Time Base A", and "Delayed Triggers from Time Base B."

RATE-GENERATOR FEATURE

While you are using Time Base A to display a waveform from some source, you can at the same time use Time Base B to perform these two simultaneous functions:

1. To actuate or trigger the source of the waveform being displayed.
2. To trigger Time Base A so that the display will be stable.*

The steps in this operation are as follows:

1. Turn the Time Base B STABILITY control full right. Set the Time Base B repetition rate to the desired value. In general, when the Time Base B LENGTH control is turned full right, this repetition rate in cycles per second will be one-tenth the reciprocal of the setting in seconds of the TIME/CM OR DELAY TIME control. You can make a precise determination of the repetition rate as follows:
   a. Connect the probe cable to the INPUT or CHANNEL connector of the plug-in preamplifier, and connect the probe tip to the +GATE B connector.
   b. Set the HORIZONTAL DISPLAY switch to position A. Set the Time Base A controls to display the +GATE B waveform (using the AUTO. or the AC mode, as described previously under "Time Base A—Triggered Operation").
   c. The repetition rate of the +GATE B waveform is approximately equal to the reciprocal of the product of the settings of the Time Base A TIME/CM control and the horizontal distance in centimeters on the graticule occupied by one cycle of the waveform. The Time Base B LENGTH control provides a fine control of the repetition rate.
2. Disconnect the probe tip from the +GATE B connector. Connect the +GATE B connector to the Time Base A TRIGGER INPUT connector. Also connect the +GATE B connector so that the leading edge of its output will trigger or actuate the source of the waveform to be observed.

(NOTE: Alternatively, you can use the output from the DEL'D TRIGGER connector to actuate the source of the waveform to be observed. In this case the source of the waveform to be observed will be actuated **after** Time Base A is triggered. The delay time involved will be equal to the product of the settings of the TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control.)

3. Feed the waveform to be observed into the INPUT or CHANNEL connector of the plug-in preamplifier.
4. Set the Time Base A TRIGGER SLOPE control to +EXT. Set the Time Base A TRIGGERING MODE, STABILITY and TRIGGERING LEVEL controls for triggering in the AC or in the AUTO. mode as described previously under "Time Base A—Triggered Operation." If the repetition rate is greater than about 60 cycles per second, the AUTO. mode will generally be satisfactory.

*This arrangement corresponds to that which is often called a "synchroscope."

SUPERPOSITION OF WAVEFORMS

This operation is useful when you want to compare the first waveform in a recurrent wave train with a later waveform in the train.

1. Connect the VERT. SIG. OUT connector to the Time Base B TRIGGER INPUT connector. Connect a capacitor of about 100 $\mu\mu f$ capacitance between the +GATE B connector and the DEL'D TRIG. connector.

2. Set the HORIZONTAL DISPLAY switch to 'B' INTENSIFIED BY 'A'. Connect the source of the wave train to the INPUT or CHANNEL connector of the plug-in preamplifier. Adjust the controls according to instructions given previously under the heading "How to Obtain a Delayed Sweep." Turn the DELAY-TIME MULTIPLIER control to a setting in the upper part of its range.

Adjust the Time Base B TIME/CM OR DELAY TIME control so that the desired number of waveforms is displayed.

3. You should now observe two brightened portions of the display—one at the start of the display at the left-hand end of the graticule, and the other at a later point along the graticule. Set the Time Base A TIME/CM control so that the left-hand brightened portion includes the first waveform in the train. With the DELAY-TIME MULTIPLIER, move the second brightened area so that it includes the waveform you want to compare with the first waveform in the train.

4. Set the HORIZONTAL DISPLAY switch to 'A' DEL'D BY 'B'. The display should now present both the first waveform in the train and the other waveform that was brightened in the preceding step. You can now use the DELAY-TIME MULTIPLIER to superimpose these two waveforms for precise comparison. The resulting reading of the DELAY-TIME MULTIPLIER, multiplied by the TIME/CM OR DELAY TIME setting, indicates the delay time between the waveforms being compared. You can also now observe any jitter in the second waveform with respect to the first.

(NOTE: For the above method to function, there must be a time interval between the end of the first waveform and the beginning of the waveform being compared with the first waveform. Depending upon the TIME/CM OR DELAY TIME setting, this interval must be at least 10 to 20 microseconds.)

PHASE-ANGLE MEASUREMENTS

This operation is useful in determining the phase displacement between two identical waveforms of the same frequency (for example, two sine waves). The useful frequency range is from a few cycles to about 5 megacycles. For frequencies in the range from 1 to 5 megacycles, the effective resolution of the readings is reduced by a factor of 5. Use the Type CA Plug-In Preamplifier.

1. Connect the source of the reference waveform to the CHANNEL A connector of the plug-in preamplifier and to the Time Base A TRIGGER INPUT connector.

2. Set the controls as follows:

Horizontal Display:

HORIZONTAL DISPLAY	A
5X MAGNIFIER	OFF*

Time Base A:

TRIGGERING MODE	AC
TRIGGER SLOPE	—EXT.
TRIGGERING LEVEL	full right or full left
STABILITY	PRESET

Plug-In Preamplifier:

MODE	A ONLY
AC-DC switches	both at AC or both at DC‡
NORMAL-INVERTED switches	both at NORMAL

3. Turn the Time Base A TRIGGERING LEVEL control slowly toward 0 until you get a stable display of the reference waveform. Set the Time Base A TIME/CM control so that this display includes several cycles of the waveform.

4. Using the CHANNEL A VERTICAL POSITION control, keep the trace centered vertically while you adjust the CHANNEL A VOLTS/CM and VARIABLE controls so that the peak-to-peak vertical deflection caused by the reference waveform is precisely 6 centimeters in the case of the Type 535A, or precisely 4 centimeters in the case of the Type 545A.

5. Keeping the display centered vertically, adjust the Time Base A TRIGGERING LEVEL control so that the start (left-hand end) of the displayed waveform appears precisely at the horizontal center-line of the graticule. With the HORIZONTAL POSITION control, position the left-hand end of the waveform precisely to the left-hand vertical graticule line. Set the Time Base A TIME/CM and red VARIABLE controls so that the display includes precisely 1 cycle of the waveform displayed over the 10-centimeter graticule length. In succeeding steps, do not retouch the Time Base A or Channel A controls.

*For frequencies in the range from 1 to 5 megacycles, turn the 5X MAGNIFIER ON.

‡For low-frequency waveforms, use the DC position.

6. Apply the second waveform to the CHANNEL B connector. Turn the MODE switch of the plug-in preamplifier to B ONLY. You should now see a stable display of the second waveform. Using the CHANNEL B VERTICAL POSITION control, keep the trace centered vertically while you adjust the CHANNEL B VOLTS/CM and VARIABLE controls so that the peak-to-peak vertical deflection caused by the waveform is precisely 6 centimeters in the case of the Type 535A, or precisely 4 centimeters in the case of the Type 545A.

7. Turn the MODE control on the plug-in preamplifier to ALTERNATE. You should now see a stable display that includes both the reference waveform and the second waveform whose phase relation you want to measure with respect to the reference waveform.

8. Locate the EXTERNAL CRT CATHODE connector on the back of the oscilloscope. Disconnect the jumper between the EXTERNAL CRT CATHODE connector and the GND connector. Then:

a. If the Time Base A sweep rate is faster than about 10 microseconds per centimeter, connect a test lead from the EXTERNAL CRT CATHODE connector to the DEL'D TRIG. connector; or, if the Time Base A sweep rate is slower than about 10 microseconds per centimeter, connect a test lead from the EXTERNAL CRT CATHODE connector to the +GATE B connector.

b. Connect the DEL'D TRIG. connector to the Time Base B TRIGGER INPUT connector. Turn the TIME/CM OR DELAY TIME control for a Time Base B sweep rate roughly 10 times as fast as the Time Base A sweep rate (unless the Time Base A sweep rate is so fast as to prevent such a setting; in the latter case, set the TIME/CM OR DELAY TIME control to 2 μSEC). Turn the Time Base B TRIGGERING LEVEL control full left. Turn the INTENSITY control slowly toward the left until the trace brightness is at a minimum useful value. Slowly turn the Time Base B STABILITY control to the left until the trace just reappears or abruptly dims. Turn the INTENSITY control slowly to the right until the trace just reappears or abruptly brightens. Slowly turn the Time Base B TRIGGERING LEVEL control to the right until a stable blanked-out portion appears in the display.

9. A portion of each of the displayed waveforms should now be blanked out, and you should be able to position this blanked-out portion horizontally by means of the DELAY-TIME MULTIPLIER control. Position the start (left-hand end) of the blanked-out portion of the display precisely to the point where the reference waveform crosses the horizontal center-line of the graticule, and record the setting of the DELAY-TIME MULTIPLIER control. Position the start of the blanked-out portion of the display precisely to the point where the other waveform crosses the horizontal center-line of the graticule, and record the new setting of the DELAY-TIME MULTIPLIER. If the 5X MAGNIFIER has been turned OFF during the preceding operations, multiply the difference between the two DELAY-TIME MULTIPLIER settings by 0.36 degree. If the 5X MAGNIFIER has been turned ON during the preceding operations (for frequencies between 1 and 5 megacycles), multiply the difference between the two DELAY-TIME MULTIPLIER settings by 1.8 degrees. The result in either case is the phase difference between the two displayed waveforms.

Always replace the jumper between the EXTERNAL CRT CATHODE and GND connectors when you have completed your measurements. This maintains the initial part of the display at its normal brightness on fast sweeps.

JITTER REDUCTION

Suppose we want to display a waveform having either or both of these characteristics:

1. The desired waveform has appreciable amplitude jitter—that is, there is present, in addition to the desired waveform, a periodic waveform of lower frequency.
2. The frequency of the desired waveform jitters at a periodic rate lower than the frequency of the desired waveform.

If a source of the jitter signal alone is available (for example, if the jitter signal is the power-line waveform), you can markedly decrease or often almost eliminate the jitter in the display by the following operation.

1. Apply the source of jitter signal to the Time Base B TRIGGER INPUT connector. Set the HORIZONTAL DISPLAY switch to 'B' INTENSIFIED BY 'A'. Apply the jitter

signal to the INPUT or CHANNEL connector. Turn the VOLTS/CM control and the TIME/CM OR DELAY TIME control to settings suited to the jitter signal. Adjust the Time Base B STABILITY and TRIGGERING LEVEL controls for a stable display of the jitter signal. Now turn the TIME/CM OR DELAY TIME control to 2 μSEC, and turn the DELAY-TIME MULTIPLIER to 1.0.

2. Apply the desired signal, in place of the jitter signal, to the INPUT or CHANNEL connector. Leave the jitter signal connected to the Time Base B TRIGGER INPUT connector. Turn the HORIZONTAL DISPLAY switch to 'A' DEL'D BY 'B'. Turn the VOLTS/CM control and the Time Base A TIME/CM control to settings suited to the desired signal. Select the Time Base A triggering signal (for example, +INT. or —INT.), and adjust Time Base A for triggering in the AC or AC LF REJECT mode.

The resulting display should be comparatively jitter-free.

VERTICAL-DEFLECTION SYSTEM

INPUT COUPLING

It is sometimes neither necessary nor desirable to display the dc component of the input waveform. A capacitor placed in series with the INPUT or CHANNEL connector will block this dc component, but at the same time, will allow the ac component to be displayed. This is done when the INPUT SELECTOR switch or the AC-DC switch on the plug-in preamplifier is placed in the AC position.

DEFLECTION FACTOR

The VOLTS/CM switch controls the vertical deflection factor in accurately calibrated steps. The VARIABLE control provides fine adjustment of the deflection factor.

NOTE: To make the deflection factor equal to that indicated by the VOLTS/CM switch, set the VARIABLE control to the CALIBRATED position.

CONNECTING THE OSCILLOSCOPE TO THE SIGNAL SOURCE

Here are some precautions you should observe in connecting your oscilloscope to the source of signals to be displayed, or to a source of triggering signals.

1. Avoid errors in readings due to stray electric or magnetic coupling between circuits, particularly in the lead connected to the INPUT or CHANNEL connector. In general, unshielded leads of appreciable length are unsuited to this use. This is true even in the audio-frequency range, except possibly when making measurements on low-impedance circuits of very low frequencies. When shielded leads are used, the shields should be grounded to the oscilloscope chassis and to the chassis of the equipment being tested. Coaxial cables are recommended for many purposes.

2. In broadband applications, it might be necessary to terminate a coaxial cable with a resistor or an attenuating pad presenting a resistance equal to the characteristic impedance of the cable. This is to prevent resonance effects or ringing (high-frequency damped oscillation). It becomes more necessary to terminate the cable properly as the length of the cable is increased. The termination is generally placed at the oscilloscope end of the cable, although many sources require an additional termination at the source end of the cable as well. Refer to the accessories section of your Tektronix catalog for a listing of cables, terminating resistors and pads.

3. As nearly as possible, simulate actual operating conditions in the equipment being tested. For example, the equipment should work into a load impedance equal to that which it will see in actual use.

4. Consider the effect of loading upon the signal source due to the input circuit of the oscilloscope. The input circuit can be represented by a resistance shunted by a capacitance. Effective values of resistance and capacitance are indicated on the preamplifier panel. You should remember, however, that with a few feet of cable in the input circuit the loading capacitance on the circuit under investigation might be as high as 100 micromicrofarads or more. In some cases, the effects of these resistive and capacitive loads are not negligible, and to minimize them, you might want to use a probe in the manner described in the next section.

USE OF PROBES

An attenuator probe lessens both capacitive and resistive loading, at the same time reducing sensitivity. The attenuation introduced by the probe permits measurement of signal voltages in excess of those that can be accommodated by the preamplifier alone. When making amplitude measurements with an attenuator probe, be sure to multiply the observed amplitude by the attenuation of the probe (marked on probe).

The probe furnished with the oscilloscope has an attenuation ratio of 10 to 1. The maximum voltage that may be applied to the probe is 600 volts. Voltages in excess of this value (either dc volts or peak ac volts) may cause damage to components inside the probe body.

To preserve the waveform of the signal being displayed, it is generally necessary to clip the probe lead to the chassis of the equipment being tested. Select a ground point near the probe-input connection.

Before using the probe, always check its adjustment

An adjustable capacitor in the probe body compensates for variations in input capacitance from one instrument to another. To insure accuracy in pulse and transient measurements, check this adjustment frequently. To make this adjustment, set the AMPLITUDE CALIBRATOR controls for an output signal of suitable amplitude. Touch the probe tip to the oscilloscope CAL. OUT connector and adjust the oscilloscope controls to display several cycles of the waveform. Adjust the probe capacitor for a flat top on the calibrator square wave, as shown in the right-hand picture of Fig. 11.

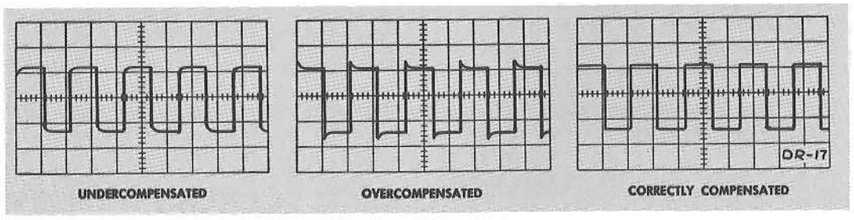

Fig. 11. Probe Adjustments.

We describe here two categories of voltage measurements with the oscilloscope: (1) measurement of the peak-to-peak voltage of a displayed waveform and (2) measurement of the peak voltage of a waveform with respect to a reference voltage. The specific examples that follow are intended to show the general procedure. These examples can be modified to suit any particular application.

How to Measure Peak-to-Peak Voltages

Suppose a given waveform produces the trace shown in Fig. 12 when a 10X probe is used and when the controls are set as follows:

AC-DC or INPUT SELECTOR	AC
VOLTS/CM	.1
VARIABLE	CALIBRATED

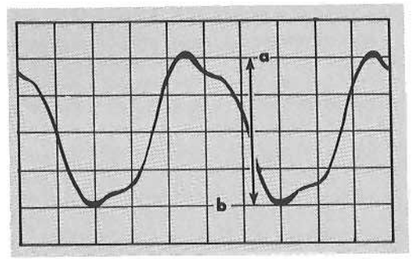

Fig. 12. Measuring peak-to-peak voltages.

The first step in measuring the peak-to-peak voltage of this waveform is to measure the amount of vertical deflection. The vertical distance from point *a*, the positive peak, to point *b*, the negative peak, is 4 centimeters. Multiply this figure by the VOLTS/CM setting, .1, and the result is .4 volt. This figure represents the voltage present at the INPUT or CHANNEL connector of the oscilloscope. Multiply this result by 10—the attenuation ratio of the probe. This gives 4 volts as the peak-to-peak voltage of the displayed waveform.

How to Measure a Peak Waveform Voltage With Respect to Ground

Set the AC-DC or INPUT SELECTOR switch to DC, and set the VARIABLE control to CALIBRATED. Adjust the oscilloscope for a free-running trace. Touch the probe tip to the oscilloscope ground terminal. Use the VERTICAL POSITION control to set the trace to a convenient position, such as *b*, in Fig. 13. Next, disconnect the probe tip from the ground terminal and connect it to the waveform source without disturbing the VERTICAL POSITION control. Adjust the oscilloscope controls for a stable display. Observe the vertical distance between the peak waveform voltage *a*, and the original trace position *b*. If this distance is inconveniently large or small, reset the VOLTS/CM switch to a more suitable position and repeat the above procedure.

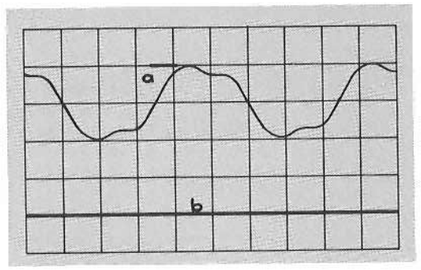

Fig. 13. Measuring a peak voltage with respect to ground.

As an example, suppose the vertical distance betwen *a* and *b* is 4 centimeters when a 10X probe is used and when the VOLTS/CM switch is set at .1. Multiply the distance between *a* and *b* (4 cm) by the VOLTS/CM setting (.1 v/cm) and by the probe attenuation ratio (10). This shows the peak voltage of the waveform with respect to ground to be 4 volts.

In measuring signal amplitudes, it is important to remember that the width of the trace may be an appreciable part of the over-all measurement. This is particularly true when you are measuring signals of small amplitude or when stray-signal pickup has broadened the trace. Notice in Fig. 12 that points *a* and *b* correspond to the bottom side of the trace itself. The measurement would be just as accurate if points *a* and *b* correspond to the top side of the trace or to its center.

Calibrator

A primary use of the voltage AMPLITUDE CALIBRATOR is to provide a signal for checking the calibration of the vertical-deflection system, and for adjusting probes.

The AMPLITUDE CALIBRATOR provides a source of square waves of known amplitude at 1000 cycles ±about 30%. The output impedance varies with output-voltage setting, but is as high as 5,000 ohms. Be sure the load impedance you connect to the CAL. OUT connector is not so low as to change the ouput voltage.

Trace-Brightness Modulation

To couple markers or other signals into the crt cathode for trace-brightness modulation, disconnect the ground strap at the rear of the instrument and apply the signal between the EXTERNAL CRT CATHODE binding post and GND.

Always replace the ground strap when you are not using this feature. This maintains the initial part of the trace at its normal brightness on fast sweeps.

Graticule Illumination

The graticule lighting control, labeled SCALE ILLUM., can be adjusted to suit the lighting conditions of the room. The graticule can be mounted in either of two positions, rotated 180 degrees from each other. In one position the illumination is colored red and, in the other position, white. The white will reproduce well photographically.

A green light filter is supplied which can be used for increased contrast. Normally this filter should be mounted next to the crt screen so it does not block the light from the graticule lines.

Direct Connection to CRT Vertical-Deflection Plates

The two pins on the left-hand side of the crt neck are for connections to the vertical-deflection plates. The DP-52 Deflection-Plate Connector provides a convenient means for making direct connections to the vertical-deflection plates. With this device, front-panel control of the crt beam position is retained. To order this Deflection-Plate Connector, specify Part No. 013-007.

If you wish to devise your own system of connections to the vertical-deflection plates, you can get an unwired plastic plate and mounting bracket by ordering Part No. 013-008. You can drill holes in the plate for mounting coaxial connectors or other components. Unless dc coupling is required, connect coupling capacitors in series with the leads to the vertical-deflection plates, and connect 1-megohm resistors from the vertical-deflection plates to the leads from the delay line. With these connections, the plates are maintained at their proper operating potential, and vertical-positioning control is retained for the front-panel VERTICAL POSITION control. If you use another method of connections, maintain the average dc potential on the vertical-deflection plates at +300 volts to avoid distortion. If you use a different potential, you can minimize the distortion by readjusting the internal GEOM. ADJ. control at the rear of the sweep chassis.

OPERATING DESCRIPTIONS OF CONTROLS AND CONNECTORS

HORIZONTAL DISPLAY	Seven-position switch. In the A, 'A' DEL'D BY 'B', and 'A' SINGLE SWEEP positions, the output of Time Base A is connected to the sweep-amplifier input. In the B, and 'B' INTENSIFIED BY 'A' positions, the output of Time Base B is connected to the sweep-amplifier input. (In the 'A' DEL'D BY 'B' and the 'B' INTENSIFIED BY 'A' positions, Time Base A is held inoperative—"locked out"—until after a delay time following triggering of Time Base B.) In the EXT. positions, the HORIZ. INPUT connector is connected to the sweep-amplifier input.
5X MAGNIFIER	When the red 5X MAGNIFIER switch is turned from the OFF position to the ON position, that part of the display which occupied the middle two divisions of the graticule is expanded to fill the graticule horizontally.

Time Base A TRIGGERING MODE — Five-position switch (red control) selects one of the four types of triggering (AUTO., AC LF REJECT, AC, or DC), or synchronized operation (HF SYNC).

Time Base A TRIGGER SLOPE — Black TRIGGER SLOPE switch selects Time Base A triggering signal—the signal being displayed (+INT. or —INT.), some signal fed into the TRIGGER INPUT connector (+EXT. or —EXT.), or the power-line wave (+LINE or —LINE). In the +INT., +EXT., and +LINE positions, triggering occurs during the voltage rise of the triggering waveform. In the —INT., —EXT., and —LINE positions, triggering occurs during the voltage fall of the triggering waveform.

Time Base A STABILITY — Red STABILITY control adjusts Time Base A for triggered or for free-running operation. When the Time Base A TRIGGERING MODE switch is in the AC, DC or AC LF REJECT position, the Time Base A STABILITY control can generally be used in its PRESET position. This control serves as the synchronizing control when the TRIGGERING MODE switch is in the HF SYNC position. The Time Base A STABILITY control is disabled when the Time Base A TRIGGERING MODE switch is in the AUTO. position.

Time Base A TRIGGERING LEVEL — Black TRIGGERING LEVEL control determines at what voltage on the input triggering signal the horizontal trace will start. This control is disabled when the Time Base A TRIGGERING MODE switch is in the AUTO. or HF SYNC positions.

Time Base A TIME/CM — Twenty-four-position switch (black control) to select the Time Base A sweep rate.

Time Base A VARIABLE — Red VARIABLE knob is an uncalibrated control which permits the sweep speeds to be varied continuously.

Time Base A TRIGGER INPUT — Coaxial connector for accepting an external triggering signal for the Time Base A generator when the Time Base A TRIGGER SLOPE switch is in the +EXT. or the —EXT. position.

Time Base B TRIGGERING MODE — Three-position switch (red control) selects one of three types of triggering (AUTO., AC, or DC).

Time Base B TRIGGER SLOPE — Black TRIGGER SLOPE switch selects Time Base B triggering signal.

Time Base B STABILITY — Red control adjusts the Time Base B generator for triggered or free-running operation. When the Time Base B TRIGGERING MODE switch is in the AC or DC position, the Time Base B STABILITY control can generally be used in its PRESET position. The Time Base B STABILITY control is disabled when the Time Base B TRIGGERING MODE switch is in the AUTO. position.

Time Base B TRIGGERING LEVEL — Black control determines at what voltage on the Time Base B input triggering signal the Time Base B sweep will start. This control is disabled when the Time Base B TRIGGERING MODE switch is in the AUTO. position.

Time Base B TIME/CM OR DELAY TIME — Eighteen-position switch which controls the Time Base B sweep rate.

Time Base B LENGTH — Sweep-length control permits improvement of duty factor when HORIZONTAL DISPLAY switch is placed in 'A' DEL'D BY 'B' position. Normally will be set full right.

Time Base B TRIGGER INPUT — Coaxial connector for accepting an external triggering signal for the Time Base B generator when the Time Base B TRIGGER SLOPE switch is in the +EXT. or the —EXT. position.

DELAY-TIME MULTIPLIER 1-10 — Ten-turn control. When the HORIZONTAL DISPLAY switch is in the 'B' INTENSIFIED BY 'A' or the 'A' DEL'D BY 'B' positions, Time Base A is held inoperative until after a delay time following the triggering of Time Base B. This delay time is the product of the settings of the TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control.

AMPLITUDE CALIBRATOR — Black switch selects any one of 18 calibrator square-wave output amplitudes; also turns calibrator OFF.

CAL. OUT — Coaxial connector for supplying square-wave output voltage from AMPLITUDE CALIBRATOR.

HORIZONTAL POSITION — Black knob positions trace horizontally.

VERNIER — Red knob provides fine control of horizontal position of trace.

RESET — Push-button which produces manually-controlled single sweeps, or which arms Time Base A for triggered single sweeps.

HORIZ. INPUT — When the HORIZONTAL DISPLAY switch is in the EXT. positions, this connector accepts external horizontal-deflection waveforms.

VARIABLE 10-1 — Black knob controls the gain of the horizontal amplifier for external horizontal input signals, providing continuous coverage from X1 to X100.

DEL'D TRIG. — Connector supplying delayed positive-going triggering signals. When the HORIZONTAL DISPLAY switch is in the A position, the output triggering signal occurs following the start of the Time Base A sweep, after a delay equal to the product of the settings of the Time Base A TIME/CM control and the DELAY-TIME MULTIPLIER control. When the HORIZONTAL DISPLAY switch is in the 'A' DEL'D BY 'B' or in the 'B' INTENSIFIED BY 'A' position, the output triggering signal occurs following the start of the Time Base B sweep, after a delay equal to the product of the settings of the TIME/CM OR DELAY TIME control and the DELAY-TIME MULTIPLIER control.

+GATE B — Connector supplying a positive-going rectangular wave having a maximum value of 20 to 30 volts. Its positive portion coincides with the left-to-right trace of Time Base B.

+GATE A — Connector supplying a positive-going rectangular wave having a maximum value of 20 to 30 volts. Its starting time and duration correspond to the starting time and duration of the positive-going part of the sawtooth available at the SAWTOOTH A connector.

SAWTOOTH A — Connector supplying a positive-going sawtooth having a peak value of about +150 volts. The rising part of the sawtooth coincides with the left-to-right trace of Time Base A. The rate at which the sawtooth rises is controlled by the Time Base A TIME/CM switch and by the red VARIABLE control.

VERT. SIG. OUT — Supplies sample of waveform being displayed vertically on oscilloscope. About 2 volts peak-to-peak for each centimeter of vertical deflection.

Beam-position indicators	Indicator lamps marked with arrows. The arrow nearest the illuminated indicator shows which way the beam is off the screen if it cannot be seen.
EXTERNAL CRT CATHODE	Connector at rear of cabinet for accepting beam-intensity-modulation voltage. Capacitively coupled. This connector should be jumpered to the GND connector when not in use.
INPUT or CHANNEL (plug-in unit)	Connector for accepting waveforms to be displayed vertically on the oscilloscope screen.
VOLTS/CM (plug-in unit)	Switch provides fixed calibrated vertical-deflection factors when the VARIABLE control of the plug-in unit is set to the CALIBRATED position.
VARIABLE (plug-in unit)	Provides continuously variable (uncalibrated) vertical-deflection factors between those provided on the VOLTS/CM switch.
VERTICAL POSITION (plug-in unit)	Positions trace vertically.

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V

TEKTRONIX FIELD SERVICES

Tektronix Customers are urged to take advantage of the many field services available to them through Tektronix Field-Engineering Offices, Engineering Representatives, and Overseas Engineering Organizations. Some of these services are described below.

Ordering—There are many types of oscilloscopes, each designed for a specific application area. Your Field Engineer can help you select the one best suited to your present and future needs, and he will be happy to arrange a demonstration of the instrument ....in your application if you so desire.

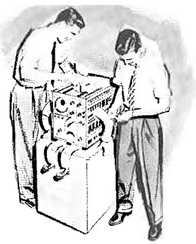
If you are a Purchasing Agent or Buyer, your Field Engineer or his secretary can help you with information on prices, terms, shipping estimates, and best method of transportation on instruments, accessories, and replacement parts.

Operation—Your Tektronix Oscilloscope can be most useful to you when you are familiar with all control functions. Your Field Engineer will be glad to demonstrate the use of your instrument in various applications to help you become more familiar with its operation. If your instrument is to be used by several engineers, your Field Engineer will be happy to conduct informal classes on its operation in your laboratory.

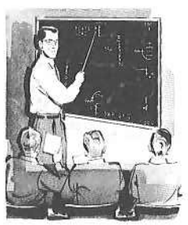
Applications—Perhaps the answers you need in a specific application can be obtained faster and easier through use of your Tektronix Oscilloscope. Your Field Engineer can help you find out, and if use of your oscilloscope is indicated, help you with procedures. He may also be able to suggest many time-saving uses for your oscilloscope in routine checks and measurements.

If you are responsible for the maintenance of a large quantity of Tektronix Instruments, ask your Field Engineer about the free factory training course in maintenance and calibration.

Instrument Reconditioning—An older Tektronix Oscilloscope, properly reconditioned, can give you many additional years of service. Your Field Engineer will gladly explain the advantages and limitations of instrument reconditioning, and make the necessary arrangements if you decide in favor of it.



Nearly all major repair and recalibration jobs can be performed at a nearby Field Maintenance Center. Ask your Field Engineer about this at-cost service to Tektronix customers.



Maintenance—Tektronix willingly assumes much of the responsibility for continued efficient operation of the instruments it manufactures. If you should experience a stubborn maintenance problem, your Field Engineer will gladly help you isolate the cause. Often a telephone discussion with him will help you get your instrument back into operation with minimum delay. If yours is a large laboratory, your Field Engineer can be of service to your maintenance engineers by conducting informal classes on test and calibration procedures, trouble-shooting techniques, and general maintenance.

Communications—Your Field Engineer is a valuable communication link between you and the factory. He knows the exact person to contact in each circumstance, and he can reach that person fast and easily. Let him help speed your communications with the factory on any problem related to your Tektronix Instruments.

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