INSTRUCTION MANUAL

Serial Number ______

TYPE

321A

OSCILLOSCOPE

Tektronix, Inc.

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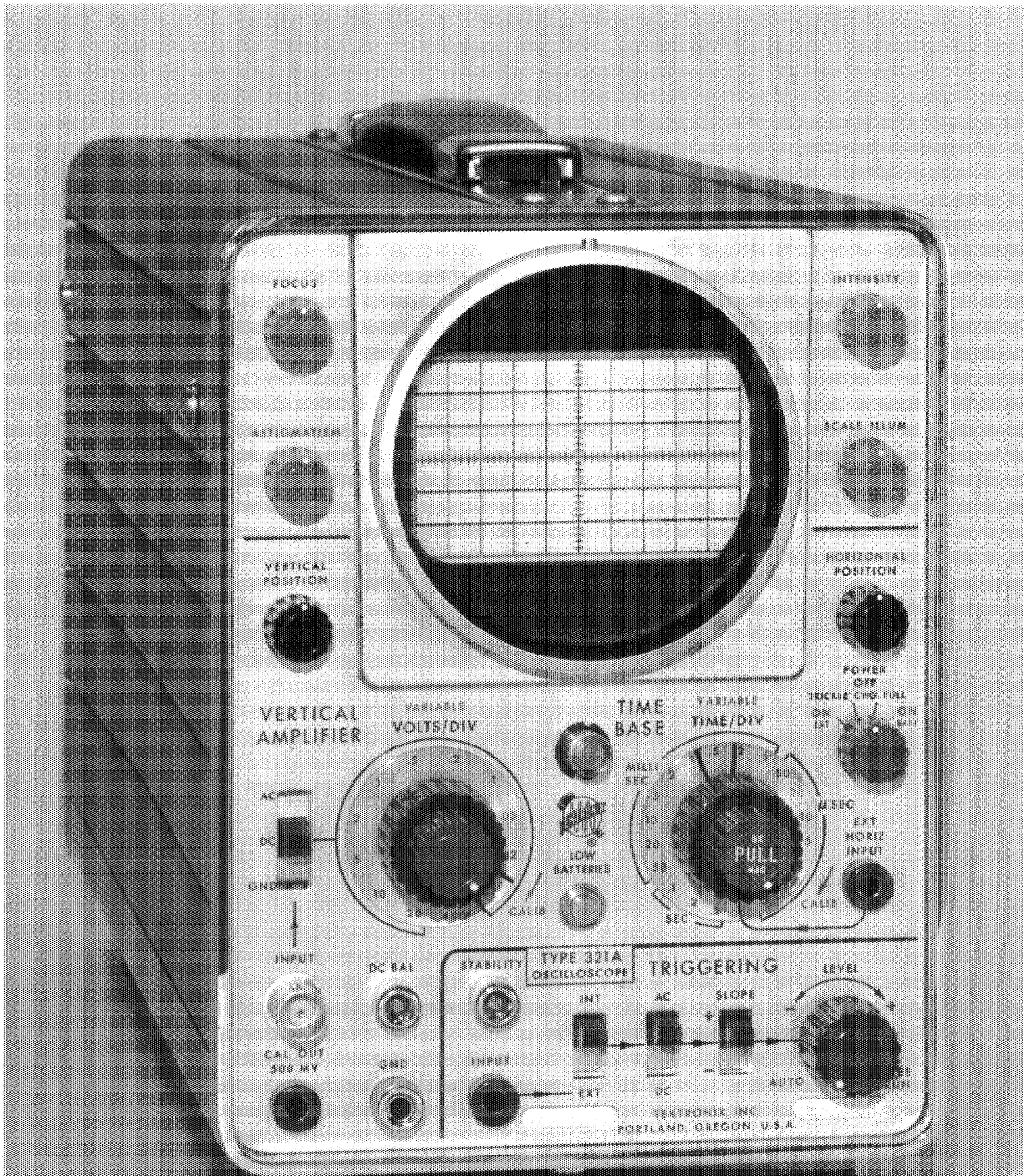

The Type 321A Oscilloscope.

SECTION 1
CHARACTERISTICS

Introduction

The Tektronix Type 321A is a high-performance, dc-to-6 mc, transistorized oscilloscope. Its light weight, small size and ability to operate from a variety of power sources make it a versatile field and laboratory instrument. The oscilloscope can operate from its internally-contained rechargeable battery pack, an external dc source or from a 115/230-volt 50-800 cycle ac line. Regulated power supplies in the instrument, accurate calibration, and precise linearity assure exact time and amplitude measurements despite normal voltage-source and power-supply-load changes that occur under actual operating conditions.

Operating temperature range derived from tests indicates optimum performance and reliability on its self-contained batteries from 0° to +40° C at altitudes up to 15,000 feet. Temperature range without batteries when operating from an external source is —15° C to +55° C. Non-operating temperature range is —55° C to +75° C without batteries and —40° C to +60° C with batteries at altitudes to 50,000 feet.

For the operator's convenience, a front-panel battery light indicates when the internal batteries are low. If external dc or ac operation is being used instead of the batteries, the light turns on if the external voltage source drops too low for proper power supply regulation.

A 4-position power switch on the front panel permits convenient selection of charging rate and/or power source.

Vertical Deflection System

Bandpass—Dc to at least 6 mc (3-db down) using dc coupling; using ac coupling, low-frequency 3-db down point is 2 cps typical from a 1-kc reference.

Sensitivity—0.01 v/div to 20 v/div in 11 calibrated steps; accuracy is within 3% of front-panel markings. Continuously variable from 0.01 v/div to about 50 v/div uncalibrated.

Input Impedance—35 pf nominal paralleled by 1 megohm (±1%), 8.2 pf nominal paralleled by 10 megohms (±2%) when using the P6006 10× Probe.

Maximum Allowable Input Voltage Rating—600 volts combined dc and peak ac; 600 volts (not 1200 volts) peak-to-peak ac.

Triggering

Type—Automatic, or amplitude-level selection using preset stability.

Mode—Ac-coupled or Dc-coupled.

Slope—Plus, from rising slope of triggering waveform, or minus from negative slope of triggering waveform.

Source—Internal from vertical signal, or external from triggering signal.

Signal Requirements—Internal: 0.2 major division vertical deflection at 1 kc increasing to 1 major division at 6 mc.

External: 1 volt peak-to-peak at 1 kc increasing to 3 volts peak-to-peak at 6 mc. Nominal input impedance: 5 pf paralleled by 100 kilohms (±20%).

Sweep

Type—Miller Integrator.

Sweep Rates—0.5 μsec/div to 0.5 sec/div in 19 calibrated steps. Accurate 5× sweep magnifier extends calibrated range to 0.1 μsec/div. Calibrated sweep-rate accuracy is ±3%. Sweep time adjustable between steps and to ≥1.5 sec/div uncalibrated.

External Horizontal Input

Bandpass—Dc to at least 1 mc (3-db down).

Deflection Factor—1 v/dv ±10% with 5× magnifier on.

Input Impedance—30 pf typical paralleled by 100 kilohms (±5%).

Amplitude Calibrator

Square Wave—Frequency about 2 kc.

Amplitude—500 mv peak-to-peak. Also 40 mv peak-to-peak internally coupled in CAL 4 DIV position of VOLTS/DIV switch. Peak-to-peak amplitude accuracy is ±3%.

Cathode-Ray Tube

Type—Special Tektronix-manufactured T3211. 3" flat-face, post-deflection accelerator. Low heater power.

Accelerating Potential—4 kv.

Z-Axis Modulation—External terminal permits RC coupling to crt grid.

Unblanking—Deflection unblanking.

Phosphor—Type P31 normally furnished; P1, P2, P7, and P11 phosphors optional. Other phosphors furnished on special order.

Graticule

Illumination—Variable edge lighting when operating from ac line.

Display Area—Marked in 6-vertical and 10-horizontal ¼" divisions.

Power Requirements

Source—Operates from 10 size D flashlight cells, or 10 size D rechargeable cells (approximately 3 hours using 2.5 ampere-hour cells; approximately 5 hours using 4 ampere-hour cells), or 11.5 to 35 volts dc (aircraft, auto, boat, etc.), or 103.5 to 126.5 volts or 207 to 253 volts, rms, 50 to 800 cycles, single-phase ac.

Power Consumption—Approximately 700 ma from internal batteries or external dc source; 20 watts nominal at 115-volt ac line.

Temperature Protection—Thermal cutout switch interrupts power if ambient temperature exceeds 131° F (55° C).

Built-in battery charger is standard equipment.

Environmental Capabilities

Vibration (operating)—0.025" peak-to-peak, 10 to 55 to 10 cps in 1 minute sweeps (4 G's) for 15 minutes on each axis. Three-minute vibration at resonance or 55 cps on each axis.

Shock (operating)—20 G's, ½ sine, 11-msec duration. Two shocks each direction along each of the three major axis: bottom, top, left side, right side, front and rear. Total of 12 shocks.

Shock (non-operating)—60 G's, ½ sine, 11-msec duration. One shock each direction along each of the three major axis; total of 6 shocks.

Humidity (non-operating)—Meets Mil-Std-202B, method 106A (except freezing and vibration) through 5 cycles (120 hours).

Transit (non-operating)—Meets National Safe Transit test when factory packaged. Vibration for one hour at slightly greater than one G. Eighteen-inch drop in any orientation.

Mechanical Specifications

Construction—Aluminum alloy chassis and cabinet.

Finish—Anodized panel, blue vinyl-finish cabinet.

Dimensions—8½" high, 5¾" wide, 16" deep overall.

ACCESSORIES

Information on accessories for use with this instrument is included at the rear of the mechanical parts list.

SECTION 3
OPERATING INSTRUCTIONS

General Information

The Type 321A Oscilloscope is an extremely versatile instrument, adaptable to a great number of applications. However, to make full use of the instrument, it is necessary that you understand completely the operation of each front-panel control. This portion of the manual is intended to provide you with the basic information you require. If you are familiar with other Tektronix oscilloscopes, you should have very little difficulty in understanding the operation of the Type 321A. The function of many controls is the same as the function of corresponding controls on other Tektronix instruments. A front-panel view of the Type 321A is shown in Fig. 3-1.

Intensity Control

The INTENSITY control is used to adjust the trace brightness. This permits adjustment of trace intensity to suit the ambient light conditions and changes in intensity caused by changes in the sweep triggering rate (sweep duty cycle). Clockwise rotation increases the intensity and counterclockwise rotation decreases the intensity.

Focus and Astigmatism Controls

The FOCUS and ASTIGMATISM controls operate in conjunction with each other to allow you to obtain a sharp, clearly defined spot or trace. To adjust these controls:

1. Adjust the INTENSITY control for the most pleasing level.
2. Set the ASTIGMATISM control to midscale.
3. Adjust the FOCUS control for sharpest detail.
4. Adjust the ASTIGMATISM control as necessary for best overall focus.

Graticule Illumination Control

The graticule used with the Type 321A is accurately marked with 10 horizontal and 6 vertical divisions, with 0.2-division markers on the centerlines. These graticule markings allow you to obtain time and voltage measurements from the oscilloscope screen.

Graticule illumination is adjusted by the SCALE ILLUM control, located just to the right of the oscilloscope screen. Rotating the control clockwise increases the brightness of the graticule markings and counterclockwise rotation decreases the brightness.

NOTE

The graticule is illuminated only when operating from an ac line. This permits longer operation when on batteries.

Positioning Controls

Two controls are used with the Type 321A Oscilloscope to position the trace or spot on the screen.

The HORIZONTAL POSITION control moves the trace to the right when it is rotated clockwise and to the left when it is rotated counterclockwise. This control has a positioning range of approximately 15 divisions with the sweep magnifier off, and approximately 75 divisions with the sweep magnifier on.

The HORIZONTAL POSITION control is a combination coarse/vernier type of control. Built-in blacklash between its two sections permits 30° of vernier adjustment for a given coarse setting. If a 30° range is exceeded, the coarse adjustment takes over to provide fast positioning of the trace.

The VERTICAL POSITION control has sufficient range to position the trace completely off the top or bottom of the screen, or to any intermediate point. The trace moves up when the control is rotated clockwise and down with the counterclockwise rotation.

Intensity Modulation

The crt display of the Type 321A Oscilloscope can be intensity modulated by an external signal to display additional information. This is accomplished by disconnecting the grounding bar from the CRT GRID connector at the rear of the instrument and connecting the external signal to this terminal. A negative signal of approximately 30 volts peak is required to cut off the beam from maximum intensity, less with lower intensity levels. Negative-going signals as low as 5 volts peak will accomplish intensity modulation.

HORIZONTAL DEFLECTION SYSTEM

Horizontal Sweep

The usual oscilloscope display is a graphical presentation of instantaneous voltage versus time. Voltage is represented by vertical deflection of the trace and time is represented by horizontal deflection. To obtain a useful display, the spot formed by the electron beam is deflected horizontally at a known rate, so that any horizontal distance on the screen represents a definite known period of time. The trace formed by the deflection of the spot across the screen is known as the horizontal sweep. Since the horizontal deflection of the spot bears a definite relationship to time, and provides the means for making time measurements from the screen, the horizontal sweep is also known as the time base. (See Fig. 3-2).

The rate at which the spot is deflected across the screen is accurately controlled by the setting of the TIME/DIV control. The setting of the TIME/DIV control determines the sweep rate, and thus the number of cycles displayed on the crt screen. The control is set to display the portion of the waveform you wish to observe.

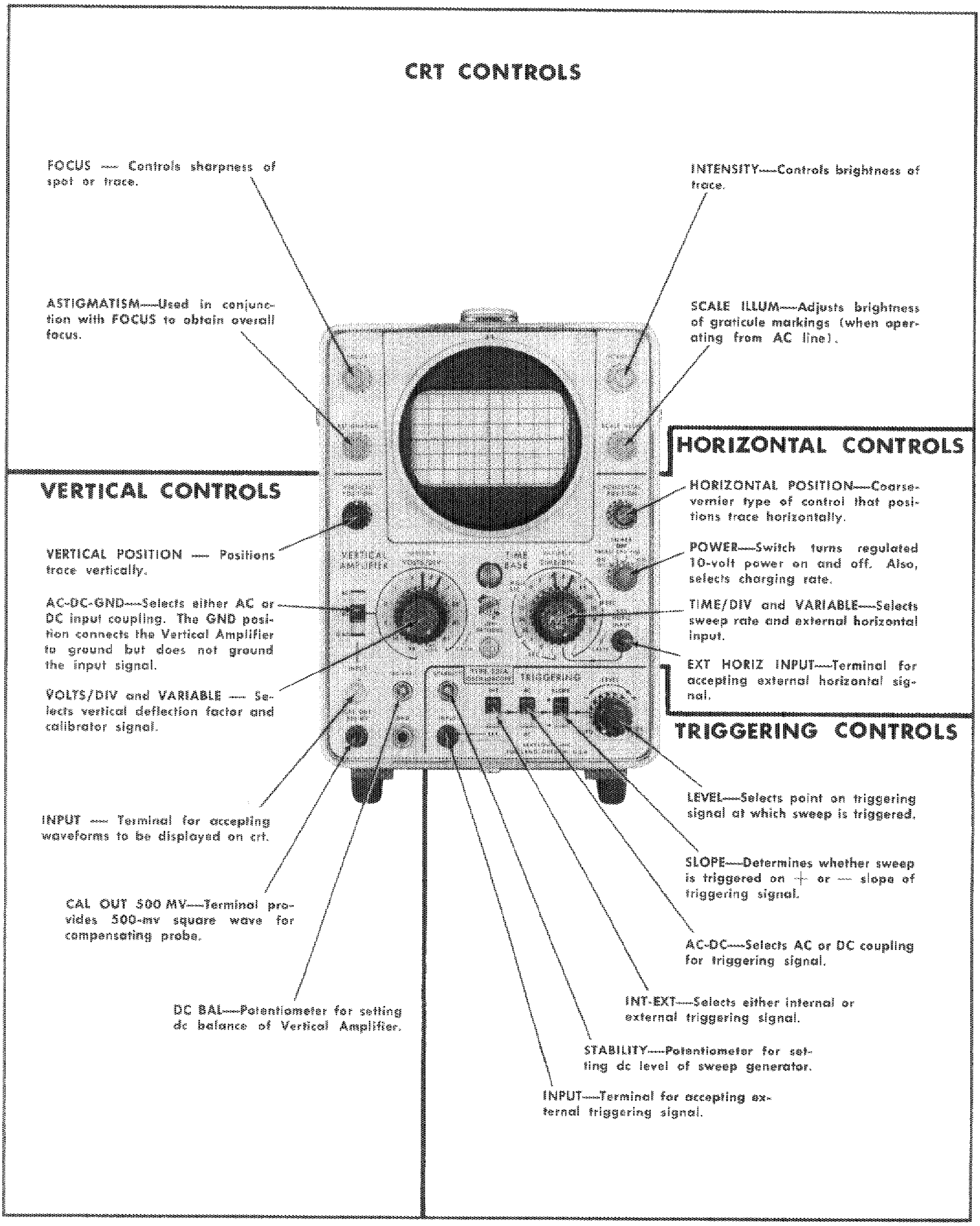

Fig. 3-1. Functions of the Type 321A Oscilloscope front-panel controls.

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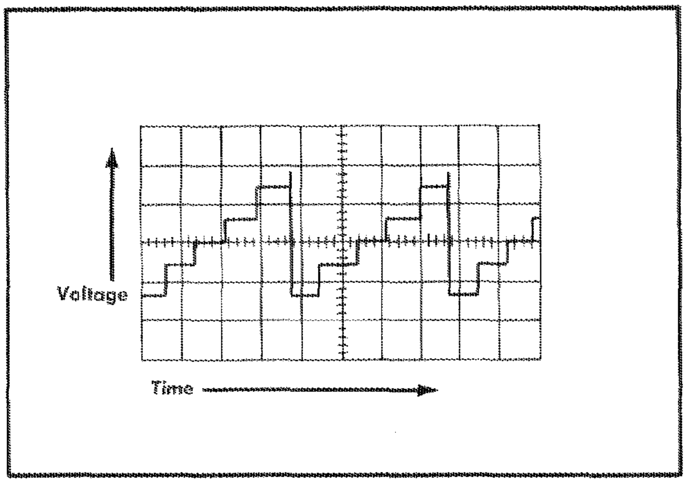

Fig. 3-2. The oscilloscope plots instantaneous voltage versus time, thereby serving both as a voltmeter and a timer.

The Time Base has 19 accurately calibrated sweep rates ranging from .5 μsec/div to .5 sec/div. These calibrated sweep rates are obtained when the VARIABLE (TIME/DIV) control is fully clockwise in the CALIB position. The TIME/DIV switch selects the calibrated sweep rates and can be rotated 360° since there are no mechanical stops. The VARIABLE control permits you to vary the sweep rate continuously between .5 μsec/div and approximately 1.5 sec/div. All sweep rates obtained with the VARIABLE control in any position other than fully clockwise are uncalibrated.

Sweep Magnifier

*The sweep magnifier allows you to expand any two-*division portion of the displayed waveform to the full ten-division width of the graticule. This is accomplished by first using the HORIZONTAL POSITION control to move the portion of the display you wish to expand to the center of the graticule, then placing the 5× MAG switch in the "on" position (pull out the red VARIABLE TIME/DIV knob; see Fig. 3-3). Any portion of the display magnified by the horizontal sweep can then be observed by rotating the HORIZONTAL POSITION control.

In magnified sweep operation, the sweep rate indicated by the position of the TIME/DIV switch must be divided by 5 to obtain the actual time required for the spot to move one division. For example, if the TIME/DIV switch is set to 5 MILLI SEC, the actual time per division is 5 milliseconds divided by 5, or 1 millisecond per division. The actual time-per-division must be used for all time measurements.

External Horizontal Input

For special applications you can deflect the trace horizontally with some externally derived waveform rather than by means of the internal sweep sawtooth. This allows you to use the oscilloscope to plot one function versus another.

To use the external horizontal input, connect the externally derived waveform to the EXT HORIZ INPUT connector and place the TIME/DIV switch in the EXT position. The horizontal deflection factor is approximately 1 volt/division with the 5× MAG on.

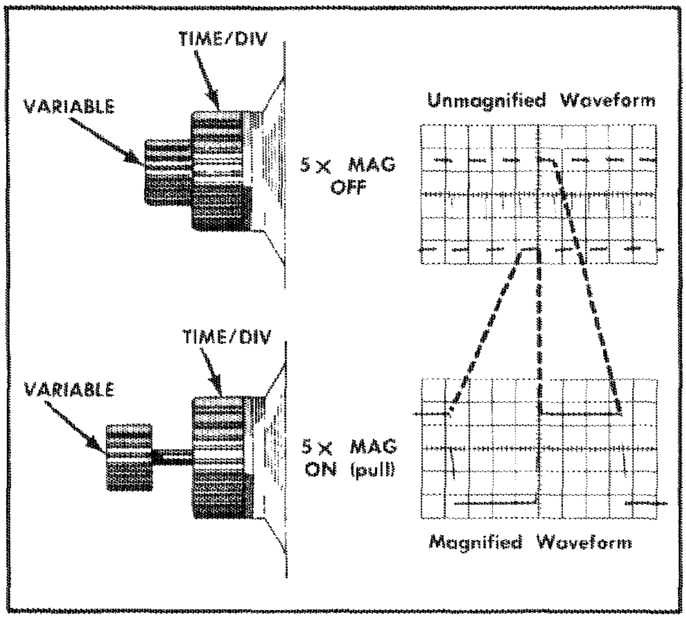

Fig. 3-3. Operation of the sweep magnifier.

Sweep Triggering

The oscilloscope display is formed by the repetitive sweep of the spot across the oscilloscope screen. If the sweeps are allowed to occur at random, or a rate unrelated to the input waveform, the displayed waveform will be traced out at a *different point on the screen with each sweep. This will* either cause the waveform to drift across the screen or to be indistinguishable.

In most cases it is desirable for repetitive waveforms to appear stationary on the oscilloscope screen so that the characteristics of the waveform can be examined in detail. As a necessary condition for this type of display, the start of the sweep must bear a definite, fixed-time relationship to the observed waveform. This means that each sweep must start at the same time, relative to some point on the observed waveform. In the Type 321A, this is accomplished by starting or triggering the sweep with the displayed waveform, or with another waveform bearing a definite time relationship to the displayed 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 source.

Selecting the Triggering Source

In preparing the Type 321A Oscilloscope for triggered operation of the sweep, it is first necessary to select the triggering signal source which will provide the best display for the particular application. The sweep can be triggered by the displayed waveform, or by an externally derived waveform. This selection is made by the setting of the INT-EXT switch (see Fig. 3-4). Each type of triggering has certain advantages for some applications.

Triggering from the displayed waveform is the method most commonly used. The displayed waveform is selected when the INT-EXT switch is in the INT position. Internal triggering is convenient since no external triggering connections are required. Satisfactory results are obtained in most applications.

To trigger the sweep from some external waveform, connect the triggering waveform to the (TRIGGERING) INPUT connector and place the INT-EXT switch in the EXT position. (External triggering provides definite advantages over internal triggering in certain cases.) With external triggering, the triggering signal usually remains constant in amplitude and shape. It is thereby possible to observe the shaping and amplification of a signal in an external circuit without resetting the oscilloscope triggering controls for each observation. Also, time and phase relationships between the waveforms at different points in the circuit can be seen. If, for example, the external triggering signal is derived from the waveform at the input to a circuit, the time relationship and phase of the waveforms at each point in the circuit are compared to the input signal by the display presented on the oscilloscope screen.

Selecting the Triggering Slope

The horizontal sweep can be triggered on either the rising or falling portion of the triggering waveform. When the SLOPE switch is in the + position, the sweep is triggered on the rising portion of the triggering waveform; when the SLOPE switch is in the — position, the sweep is triggered on the falling portion of the waveform (see Fig. 3-5).

In many applications the triggering slope is not important since triggering on either slope will provide a display suitable to the application.

Selecting the Triggering Mode

Automatic Mode

Automatic triggering is obtained by rotating the (TRIGGERING) LEVEL control fully counterclockwise to the AUTO position.

This mode allows triggering at the average voltage point of the applied waveform. Also, the sweep runs at approximately a 50-cycle rate when no triggering signals are applied; this produces a reference trace or baseline on the screen. Automatic triggering can be used with both internal and external triggering signals, but for most waveforms it is useful only for triggering at frequencies above 50 cycles. Automatic triggering saves considerable time in observing a series of waveforms since it is not necessary to reset the triggering level for each observation. For this reason it is the mode that is normally used. Other modes are generally used only for special applications, or where stable triggering is not attainable in the automatic mode.

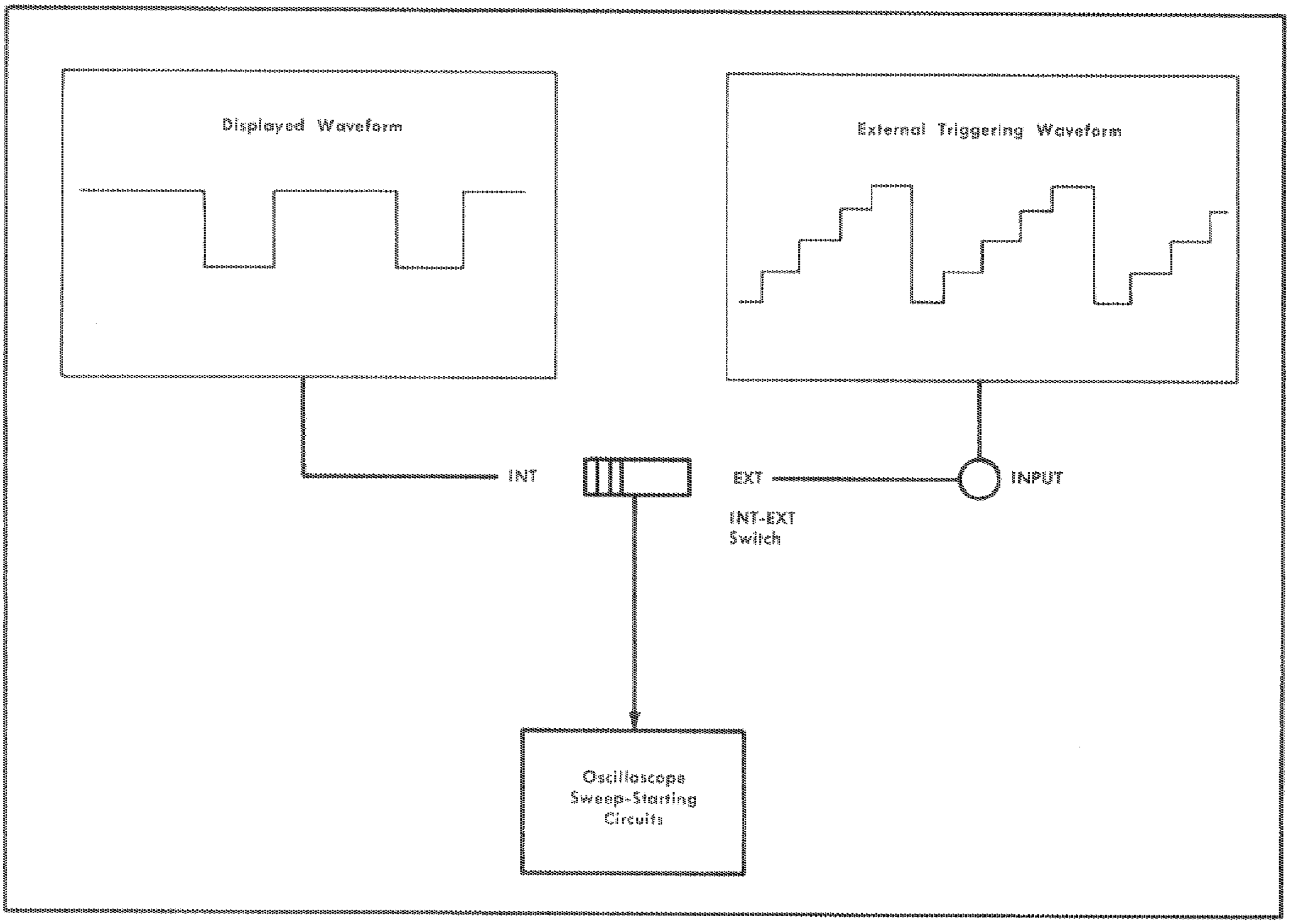

Fig. 3-4 The triggering signal is selected from two possible sources with the INT-EXT switch.

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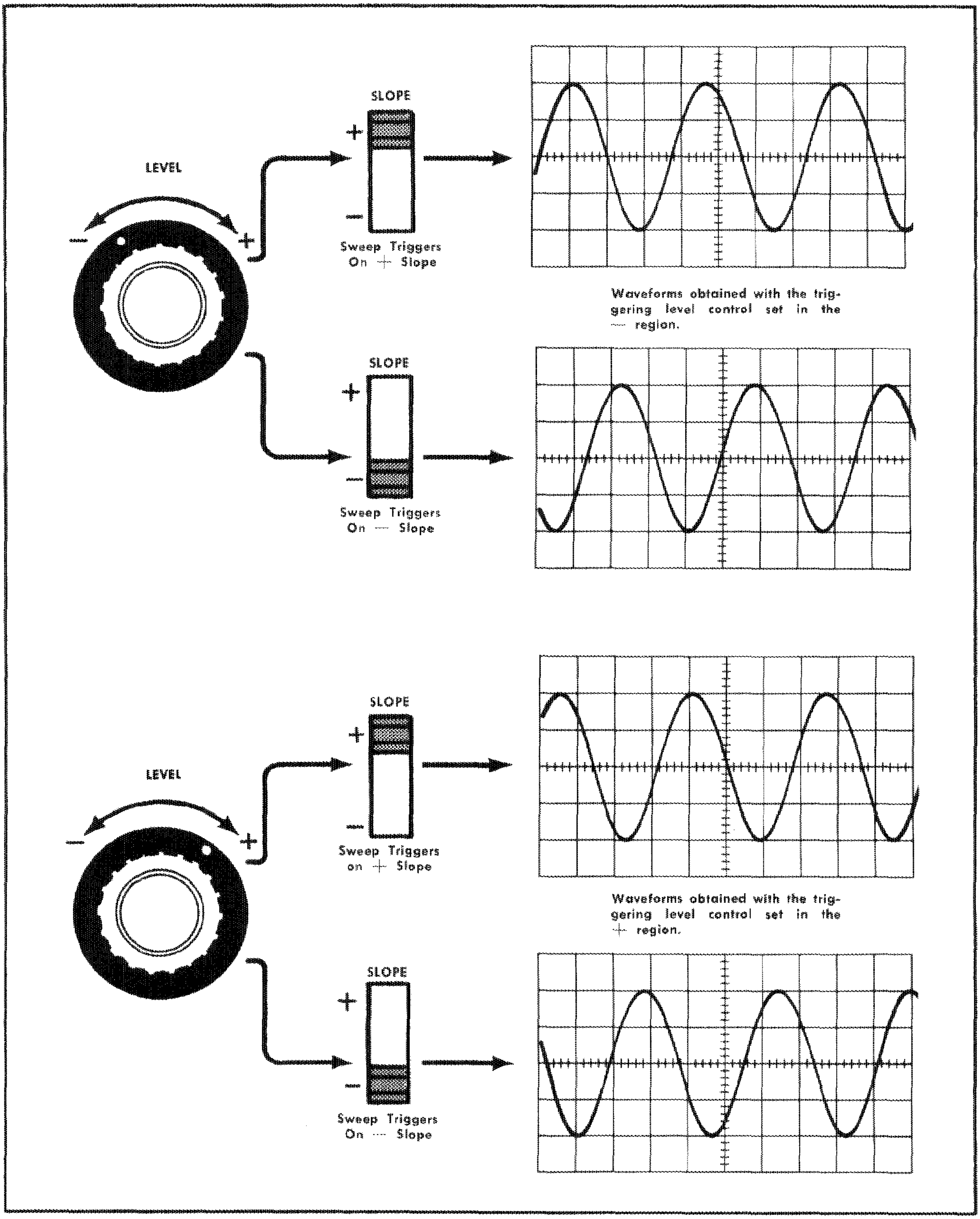

Fig. 3-5. Effects on the oscilloscope display produced by + and — settings of the SLOPE and LEVEL controls.

Ac Mode

Ac-mode triggering is obtained by setting the AC-DC switch to the AC position. This mode provides stable triggering on virtually all types of waveforms. As a general rule, however, the ac mode is unsatisfactory for triggering with low amplitude waveforms at frequencies below approximately 15 cycles. This figure will vary depending upon the amplitude and shape of the triggering waveform and should not therefore be set as an absolute standard. Triggering at frequencies below 15 cycles can be accomplished when higher amplitude triggering signals are used.

In the ac mode, the triggering point depends on the average voltage level of the triggering signals. If the triggering signals occur at random, the average voltage level will vary causing the triggering point to vary also. This shift of the triggering point may be enough so that it is impossible to maintain a stable display. In such cases you should use the dc mode.

Dc Mode

Dc mode triggering is obtained by setting the AC-DC switch to the DC position. This mode of triggering is particularly useful in triggering from waveforms which are not adaptable to the ac mode, such as random pulse trains or very low-frequency waveforms. Random pulse trains pose a special problem in the ac mode since the random occurrence of the input waveforms causes the average voltage level to shift. This in turn may cause the triggering level to shift to an unstable point. This problem is not encountered in the dc mode since the triggering point is determined only by instantaneous voltages.

In the dc mode, when the triggering signal is obtained from the Vertical Amplifier, varying the VERTICAL POSITION control will change the triggering point. For this reason, you may find it necessary to readjust the LEVEL control when you change the vertical position of the trace. To eliminate this effect, you can use the ac mode provided the triggering signal is otherwise suitable for this mode of operation. In the dc mode, the dc level of the external triggering signals will also effect the triggering point. Generally, when the triggering signal is small compared to its dc level, the ac mode should be used.

How to Set the Triggering Level

In the ac and dc triggering modes, the LEVEL control determines the voltage level on the triggering waveform at which the sweep is triggered. Using this control, the sweep can be continuously triggered at any point on the waveform so long as the slope of the waveform is great enough to provide stable triggering. In the dc mode, the sweep cannot be triggered with any degree of stability at the top of a square wave, for example, because the time that the voltage remains constant is comparatively long. As a result, the sweep triggers at random points along the top of the square wave, producing considerable trace jitter.

You can use the same method to set the LEVEL control for either the ac or dc mode. After selecting the triggering slope, rotate the LEVEL control fully counterclockwise to the AUTO position. Then rotate the LEVEL control clockwise until the sweep no longer triggers. Continue to rotate the control in the clockwise direction until the sweep again triggers and a stable display is obtained. Further rotation of the control in the clockwise direction causes the sweep to trigger at more positive points on the triggering waveform. In the fully clockwise direction the trace will free run (Fig. 3-5).

FREE-RUNNING OPERATION

With the Type 321A, you can get a periodic, free-running sweep, independent of any external triggering or synchronizing signal, by rotating the LEVEL control fully clockwise to the FREE RUN position. This permits you to observe the trace without an input signal. This trace can then be used to position the sweep or to establish a voltage reference line. The difference between the traces produced in the AUTO position and the FREE RUN position is the repetition rate. The repetition rate in the FREE RUN position is dependent upon the setting of the timing switch. The repetition rate in the AUTO position is fixed at approximately 50 cycles. At the faster sweep rates, the trace in the AUTO position will appear to be dim. In the FREE RUN position the trace intensity remains essentially constant for all sweep rates.

VERTICAL DEFLECTION SYSTEM

Input Coupling

Input signals to the Vertical Amplifier can be either ac- or dc-coupled by placing the AC-DC-GND switch in the appropriate AC or DC position. Dc coupling applies both the ac and dc components of the input signal to the vertical amplifier circuit. This permits measurement of the dc voltage level as well as the amplitude of the ac component. It is sometimes neither necessary nor desirable to display the dc component, however, and in such cases as coupling should be used. This is accomplished by setting the AC-DC-GND switch to AC. With ac coupling, a capacitor is placed in series with the input connector to block the dc component while allowing the ac component to be displayed.

Placing the AC-DC-GND switch to the GND position grounds the input circuit of the vertical amplifier to provide a dc zero reference. In this position the switch internally disconnects, but does not ground, the applied signal to the input connector. Thus, the GND position eliminates the usual need for externally grounding the (Vertical Amplifier) INPUT connector of the Type 321A or the probe tip to establish a ground reference.

Deflection Factor

The electrical waveform to be observed is applied to the (Vertical Amplifier) INPUT connector. The waveform is then applied through the vertical-deflection system to cause the spot to be deflected vertically to trace out the waveform on the screen of the crt. The VOLTS/DIV switch controls the vertical deflection factor in accurately calibrated steps. The VARIABLE control provides uncalibrated variable deflection factors between the fixed steps of the VOLTS/DIV switch. The VARIABLE control has 360° rotation range and a detent position when the control is set to CALIB.

NOTE

To make the deflection factor equal to that indicated by the VOLTS/DIV switch, set the VARIABLE control to the CALIB detent position.

Dc Balance Adjustment

The need for adjustment of the DC BAL control is indicated by a vertical shift in the position of the trace as the VARIABLE (VOLTS/DIV) control is rotated. This adjustment should be made as follows:

1. Set the AC-DC-GND switch to GND.
2. Set the oscilloscope controls for a free-running trace.
3. Rotate the VARIABLE (VOLTS/DIV) control back and forth, and adjust the DC BAL control simultaneously until the trace position is no longer affected by rotation of the VARIABLE control.

Input Signal Connections

Certain precautions must be observed when you are connecting the oscilloscope to an input signal source. This is to insure that accurate information is obtained from the oscilloscope display. This is particularly true when you are observing low-level signals, or waveforms containing high- or extremely low-frequency components. For applications where you are observing low-level signals, shielded cables should be used whenever possible, with the shield connected to the chassis of both the oscilloscope and the signal source. Unshielded input leads are generally unsatisfactory due to their tendency to pick up stary signals which produce erroneous oscilloscope displays. Regardless of the type of input used, the leads should be kept as short as possible.

Distortion of the input waveform may result if:

1. Very low-frequency input signals are ac-coupled to the oscilloscope.
2. High-frequency waveforms are not properly terminated.
3. The input waveform contains high-frequency components which exceed the bandpass of the oscilloscope.

You must be aware of the limitations of the instrument.

In analyzing the displayed waveform, you must consider the loading effect of the oscilloscope on the input signal source. In most cases this loading effect is negligible; however, in some applications loading caused by the oscilloscope may materially alter the results obtained. In such cases you may wish to reduce the amount of loading to a negligible amount through the use of a probe.

Use of Probes

Occasionally connecting the input of an oscilloscope to a signal source loads the source sufficiently to adversely affect both the operation of the source and the waveform displayed on the oscilloscope. In such cases an attenuator probe may be used to decrease both the capacitive and resistive loading caused by the oscilloscope to a negligible value.

In addition to providing isolation of the oscilloscope from the signal source, an attenuator probe also decreases the amplitude of the displayed waveform by the attenuation factor of the probe. Use of the probe allows you to increase the vertical-deflection factors of the oscilloscope to observe large-amplitude signals beyond the normal limits of the oscilloscope. Signal amplitudes, however, must be limited to the maximum allowable value of the probe used. When making amplitude measurements with an attenuator probe, be sure to multiply the observed amplitude by the attenuation of the probe.

If the waveform being displayed has rapidly rising or falling voltages, it is generally necessary to clip the probe ground lead to the chassis of the equipment being tested. Select a ground point near the point of measurement, as shown in Fig. 3-6.

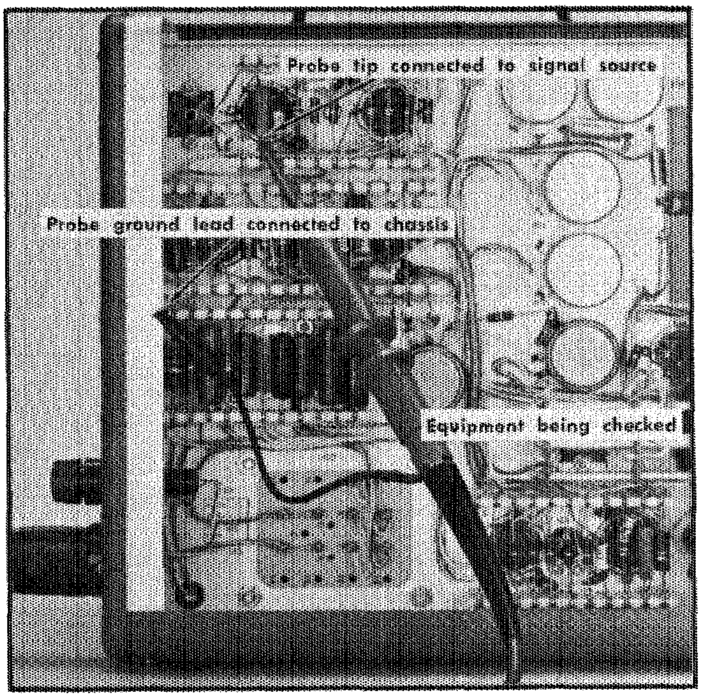

Fig. 3-6. Connecting a probe to the input signal source.

Before using a probe you must check (and adjust if necessary) the compensation of the probe to prevent distortion of the applied waveform. The probe is compensated by adjusting the control located in the body of the probe. Adjustment of the probe compensates for variations in input capacitance from one instrument to another. To insure the accuracy of pulse and transient measurements, this adjustment should be checked frequently.

To adjust the probe compensation, set the VOLTS/DIV control to the .01 position and the LEVEL control to the AUTO position. Set the SLOPE switch to + and the INT-EXT switch to INT. Connect the probe tip to the CAL OUT 500 MV connector. Set the TIME/DIV switch to .5 MILLI SEC and adjust the probe to obtain flat tops on the displayed square waveform (see Fig. 3-7.)

Voltage Measurements

The Type 321A Oscilloscope can be used to measure the voltage of the input waveform by using the calibrated vertical-deflection factors of the oscilloscope. The method used for all voltage measurements is basically the same although the actual techniques vary somewhat depending on the types of voltage measurements, i.e., ac-component voltage measurements, or instantaneous voltage measurements with respect to some reference potential. Many waveforms contain both ac and dc voltage components, and it is often necessary to measure one or both of these components.

When making voltage measurements, you should display the waveform over as large a vertical portion of the screen as possible for maximum accuracy. Also, it is important that you do not include the width of the trace in your measurements. You should consistently make all measurements from one side of the trace. If the bottom side of the trace is used for one reading, it should be used for all succeeding readings. The VARIABLE (VOLTS/DIV) control must be in the CALIB detent position.

Ac Component Voltage Measurements

To measure the ac component of a waveform, the AC-DC-GND switch should be set to the AC position. In this position only the ac components of the input waveform are displayed on the oscilloscope screen. However, when the ac component of the input waveform is very low in frequency, it will be necessary for you to make voltage measurements with the AC-DC-GND switch in the DC position.

To make a peak-to-peak voltage measurement on the ac component of a waveform, perform the following steps (see Fig. 3-8).

1. With the aid of the graticule, measure the vertical distance in divisions from the positive peak to the negative peak.
2. Multiply the setting of the VOLTS/DIV control by the distance measured to obtain the indicated voltage.
3. Multiply the indicated voltage by the attenuation factor of the probe you are using to obtain the true peak-to-peak voltage.

As an example of this method, assume that using the P6006 Probe and a deflection factor of 1 volt per division, you measure a vertical distance between peaks of 4 divisions. In this case, then, 4 divisions multiplied by 1 volt per division gives you an indicated voltage of 4 volts peak-to-peak. The indicated voltage multiplied by the probe's attenuation factor of 10 then gives you the true peak-to-peak amplitude of 40 volts.

When sinusoidal waveforms are measured, the peak-to-peak voltage obtained can be converted to peak, rms, or average voltage through use of standard conversion factors.

Instantaneous Voltage Measurements

The method used to measure instantaneous voltages is virtually identical to the method described previously for the measurement of the ac components of a waveform. However, for instantaneous voltage measurements the AC-DC-GND switch must be placed in the DC position. Also, since instantaneous voltages are measured with respect to some potential (usually ground), a reference line must be established on the oscilloscope screen which corresponds to that potential. If, for example, voltage measurements are to be made with respect to +100 volts, the reference line would correspond to +100 volts. In the following procedure a method is presented for establishing this reference line at ground, since measurements with respect to ground are the

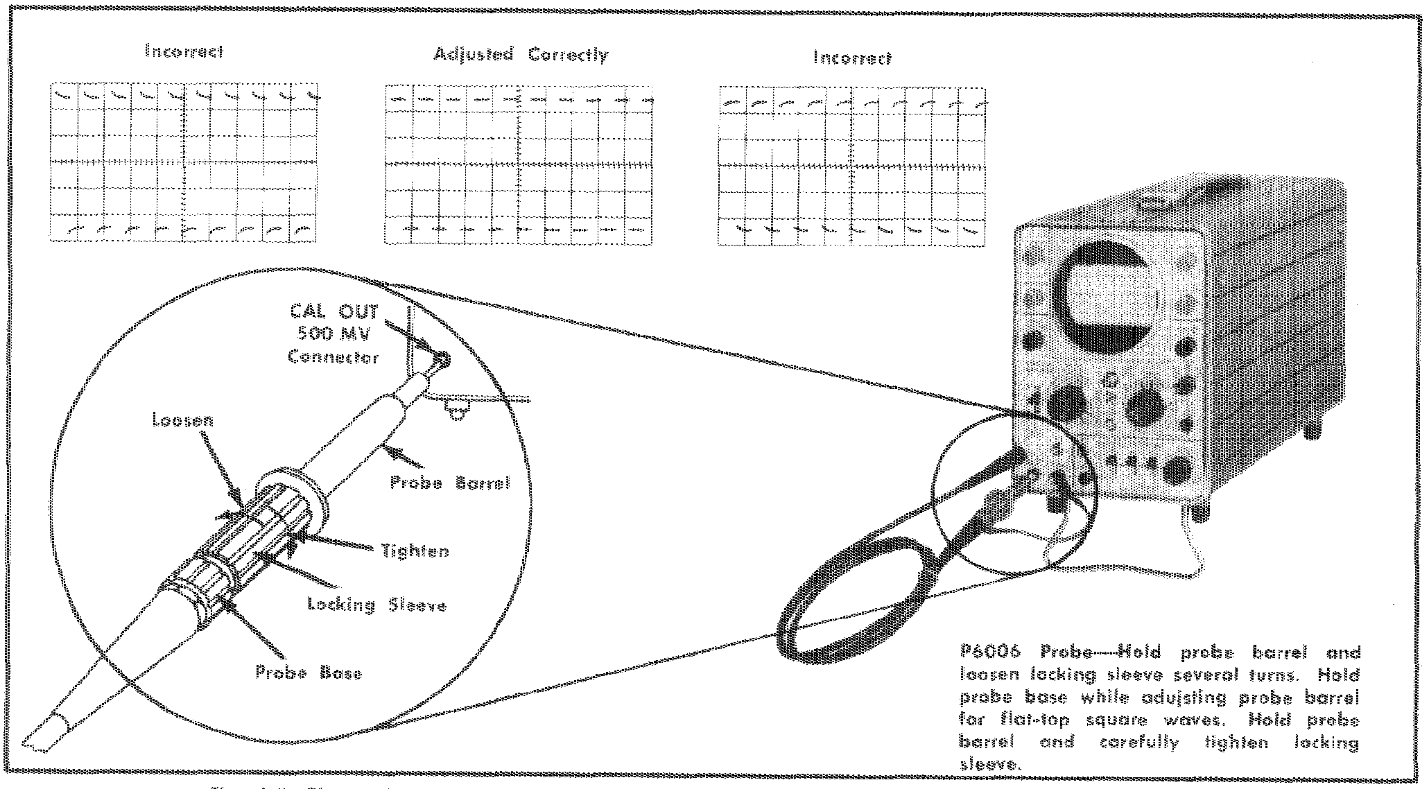

Fig. 3-7. The probe is adjusted to obtain an undistorted presentation of the calibrator squarewave.

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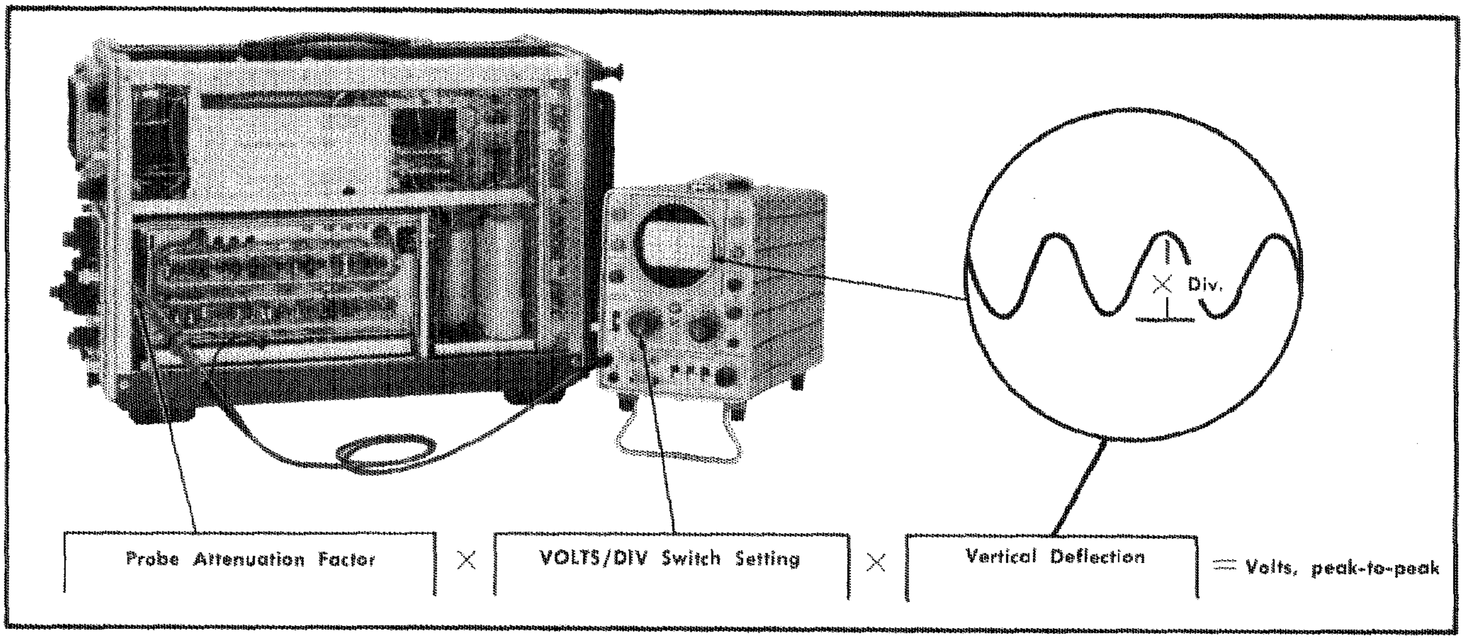

Fig. 3-8. Measuring the peak-to-peak ac voltage of an applied waveform.

most common type. The same general method may be used to measure voltage with respect to any other potential, however, so long as that potential is used to establish the reference line.

To obtain an intantaneous voltage measurement with respect to ground, or some other voltage, perform the following steps (see Fig. 3-9).

1. To establish a ground reference line, set the AC-DC-GND switch to GND. Or, to establish a reference line which represents a voltage other than ground, touch the probe tip to the voltage and leave the AC-DC-GND switch at DC. Then adjust the oscilloscope controls to obtain a free-running sweep. Vertically position the trace to a convenient point on the oscilloscope screen. This point will depend on the polarity and amplitude of the input signal, but should always be chosen so that the trace lies along one of the major divisions of the graticule. The graticule division corresponding to the position of the trace is the voltage reference line and all voltage measurements must be made with respect to this line. (Do not adjust the VERTICAL POSITION control after the reference line has been established.)

2. If ground reference was established, set the AC-DC-GND switch to DC; if a reference line other than ground was established, remove the probe tip from this voltage and connect it to the signal source. Adjust the LEVEL control for a stable display.

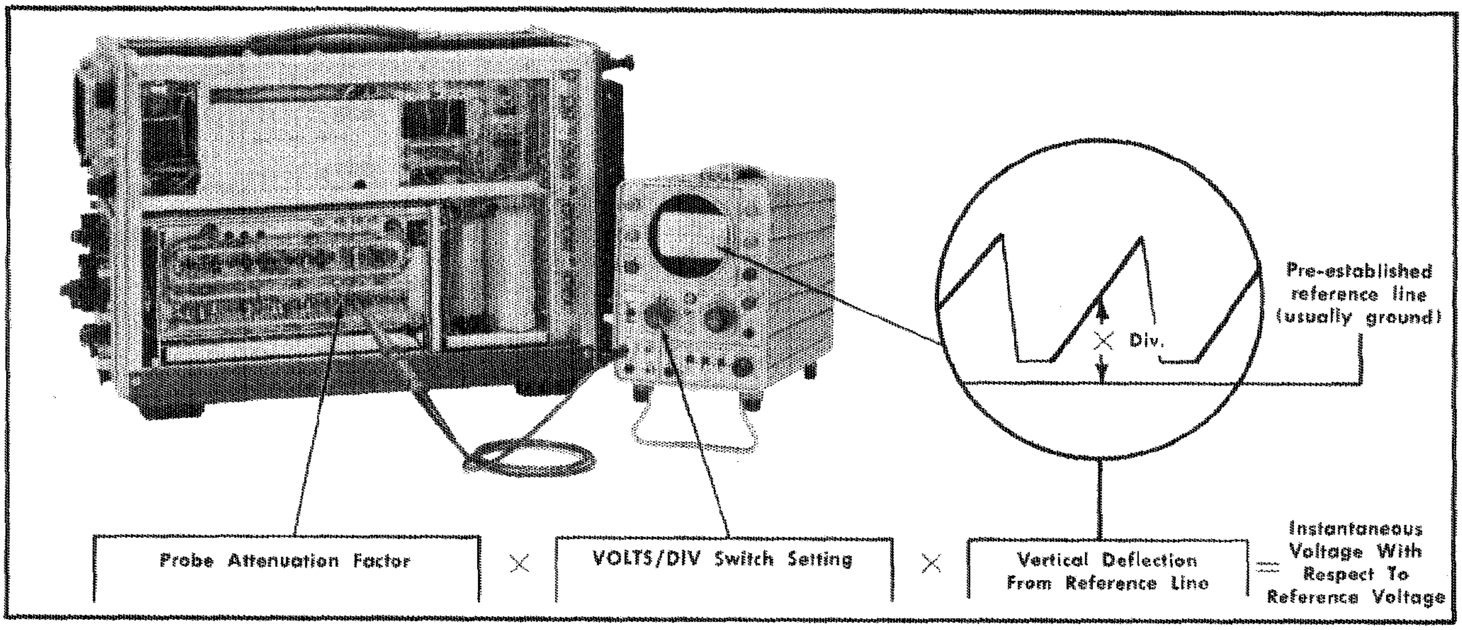

Fig. 3-9. Measuring the instantaneous voltage with respect to ground (or some other reference voltage).

3. Measure the vertical distance in divisions from the desired point on the waveform to the voltage reference line.

4. Multiply the setting of the VOLTS/DIV control by the distance measured to obtain the indicated voltage.

5. Multiply the indicated voltage by the attenuation factor of the probe you are using to obtain the actual voltage with respect to ground (or other reference voltage).

As an example of this method, assume you are using the P6006 Probe and a deflection factor of 0.2 volt per division. After setting the voltage reference line at the second from bottom division of the graticule, you measure a distance of 3 divisions to the point you wish to check. In this case, 3 divisions multiplied by 0.2 volt per division gives you an indicated 0.6 volt. Since the voltage point is above the voltage reference line the polarity is indicated to be positive. The indicated voltage multiplied by the probe attenuation factor of 10 then gives you the actual voltage of +6 volts.

Time Measurements

The calibrated sweep of the Type 321A Oscilloscope causes any horizontal distance on the screen to represent a definite known interval of time. Using this feature you can accurately measure the time lapse between two events displayed on the oscilloscope screen. One method which produces sufficient accuracy for most applications is as follows (see Fig. 3-10).

1. Measure the horizontal distance between the two displayed events whose time interval you wish to find.

2. Multiply the distance measured by the setting of the TIME/DIV control to obtain the apparent time interval. (The VARIABLE TIME/DIV control must in the CALIB position.)

NOTE

Divide the apparent time interval by 5 if the magnifier is on.

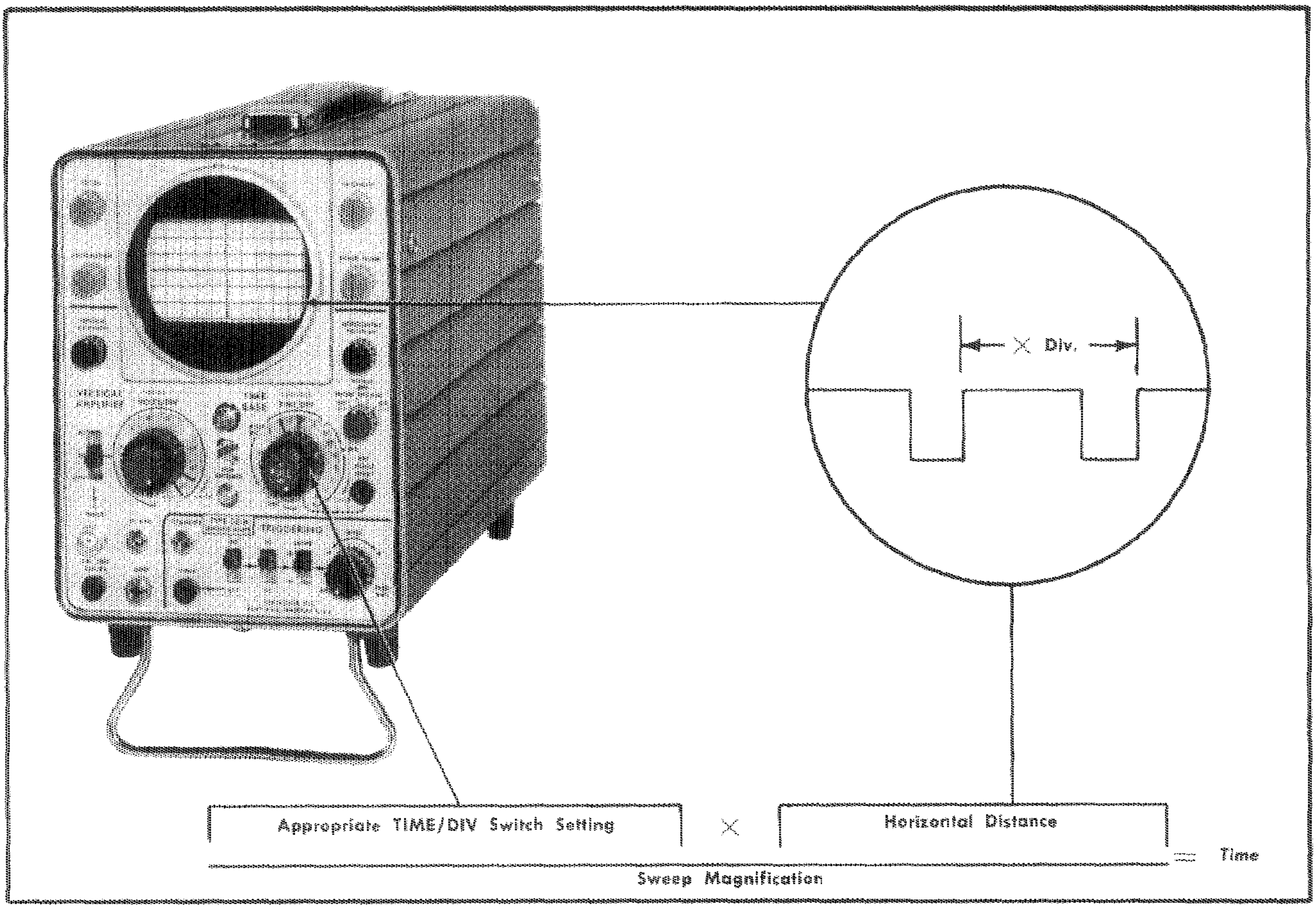

Fig. 3-10. Measuring the interval between events displayed on the oscilloscope screen.

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For example, assume the TIME/DIV switch setting is 1 MILLI SEC, the magnifier is on, and you measure a horizontal distance of 5 division between events. In this example, then, 5 divisions multiplied by 1 millisecond per division gives you an apparent time interval of 5 milliseconds. The apparent time divided by 5 then gives you the actual time interval of 1 millisecond.

Frequency Measurements

The frequency of a periodically recurrent waveform can be determined if the time interval (period) of one complete cycle of the waveform is known. This time interval can be measured by means of the the procedure described in the preceding paragraph. The frequency of a waveform is the reciprocal of its time interval, i.e., $f = 1/t$.

SECTION 4
CIRCUIT DESCRIPTION

Block Diagram

The block diagram in Section 7 of this manual shows the main sections of the Type 321A Oscilloscope. Waveforms to be displayed are connected to the Vertical Amplifier INPUT terminal, located on the front panel of the instrument. Large signals are attenuated the desired amount (up to 2000 times) in the attenuator networks. The signal is then amplified in the Vertical Amplifier and fed push-pull to the vertical deflection plates of the crt.

A trigger-pickoff circuit in the Vertical Amplifier applies a sample of the input signal to the Time-Base Trigger circuit. This sample signal is instrumental in starting the horizontal sweep. An external triggering signal connected to the Triggering INPUT terminal may also be used for this purpose.

Signals of widely varying shapes and amplitudes may be applied to the Time-Base Trigger circuit. This circuit in turn produces constant-amplitude output pulses which are used to start the horizontal sweep at the proper time to insure a stable display of the vertical-input waveform.

The output pulses from the Time-Base Trigger circuit are applied to the Time-Base Generator to initiate the sawtooth horizontal-sweep waveform. The sawtooth waveform is then amplified in the Horizontal Amplifier and applied push-pull to the horizontal deflection plates of the crt. For X-Y applications of the instrument an externally-generated signal can be applied to the EXT HORIZ INPUT terminal. The external signal is then amplified by the Horizontal Amplifier and applied to the horizontal deflection plates of the crt.

The gain of the Horizontal Amplifier can be increased five times by pulling the (Time Base) VARIABLE control outward to the 5× MAG position.

The Calibrator produces a square wave output of constant amplitude which can be used to check the gain of the Vertical Amplifier and compensate the probe. A 40-mv peak-to-peak square wave, is coupled internally to the Vertical Amplifier when the VOLTS/DIV switch is set to the CAL 4 DIV position. If the gain of the amplifier is properly adjusted, this will produce a deflection of exactly 4 divisions when the (Vertical Amplifier) VARIABLE control is set to the CALIB detent position. A square wave having a peak-to-peak amplitude of 500 mv is available at the CAL OUT terminal on the front panel of the instrument; this waveform can be used to compensate the probe.

The regulated power supplies in the Type 321A will operate from a 115-v or a 230-v rms ac line, from an external dc source (11.5 v to 35 v), or from a "battery pack" consisting of either 10 size D flashlight cells or 10 size D rechargeable cells. A built-in battery charger charges the "rechargeable" cells when the instrument is connected to an ac source (115 v or 230 v).

VERTICAL AMPLIFIER

Input Coupling

Input signals to the Vertical Amplifier can be either ac-coupled, dc-coupled, or internally disconnected. When the AC-DC-GND switch SW401 (see Vertical Amplifier circuit diagram) is in the DC position, input signals are directly coupled to the VOLTS/DIV switch. In the AC position input signals are coupled through a blocking capacitor C401. In the GND position the signal path is opened and the input circuit is grounded.

Input Circuit

The Vertical Amplifier requires an input signal of 0.01 volt, peak-to-peak, to produce 1 division of calibrated deflection on the crt. To satisfy this condition, yet make the instrument applicable to a wide range of input voltages, a precision attenuation network is incorporated into the vertical deflection system.

When the VOLTS/DIV switch (SW410) is in the .01 position, the signal is coupled "straight through" (without attenuation) to the grid of V423. For all other settings of the VOLTS/DIV switch (except CAL 4 DIV) the Attenuators are switched into the input circuit, either singly or in tandem pairs, so that the input signal voltage to the Vertical Amplifier is always 0.01 volts for each division of crt deflection when the VARIABLE knob is in the CALIB detent position.

The Attenuators are frequency-compensated voltage dividers. For dc and low-frequency signals they are resistance dividers, and the degree of attenuation is determined by the resistance values. The impedance of the capacitors, at dc and low frequencies, is so high that their effect in the circuit is negligible. As the frequency of the input signals increases, however, the impedance of the capacitors decreases and their effect in the circuit becomes more pronounced. For high-frequency signals the impedance of the capacitors is so low, compared to the resistance in the circuit, that the Attenuators become capacitive reactance dividers.

In addition to providing the proper degree of attenuation, the resistance values in the Attenuators are chosen to provide the same input resistance (1 megohm) regardless of the setting of the VOLTS/DIV switch. Moreover, the variable capacitor at the input to each network provides a means for adjusting the input time constant so that it is the same value (nominally 35 pf × 1 meg) for all settings of the switch.

Input Cathode Follower

A nuvistor, V423, is used as a cathode-follower input stage. This stage presents a high-impedance, low-capacitance load to the input circuit and isolates the input circuit from the main amplifier. R422 is the 1-megohm input resistor. This resistor becomes a part of each attenuation network when the VOLTS/DIV switch is turned away from the .01 position. R423, bypassed by C423, prevents the grid of V423 from drawing excessive current (in the event the stage is overdriven) when dc input coupling is used. R424 is a parasitic suppressor.

Input Emitter Follower

An emitter-follower stage Q443 couples the Input C.F. to the Input Amplifier. The output impedance of Q443 is very nearly equal to the output impedance of V423 divided by the β of Q443. This stage thus provides the necessary low-impedance drive (approximately 20 Ω) for the base of Q464, one-half of the Input Amplifer stage. The opposite emitter-follower Q453 couples a dc voltage, adjustable by means of the DC BAL control, to the base of Q474 (the other half of the Input Amplifier stage). The purpose of this dc voltage will be discussed in the following section.

Input Amplifier

The Input Amplifier consists of Q464 and Q474 connected as an emitter-coupled paraphase amplifer. In addition to amplifying the signal, this stage converts the single-ended input at the base of Q464 to a push-pull output signal between the two collector circuits. Q474 operates essentially as a grounded-base amplifer (grounded through the low output impedance of Q453); the input signal to Q474 is developed across the impedance in its emitter circuit.

There are two gain controls located in the common emitter circuit of the Input Amplifier. One is the front-panel VARIABLE control R478; the other is the VERT GAIN R468, an internal screwdriver-adjust potentiometer. Both controls vary the emitter degeneration and thus affect the gain of the stage. The VERT GAIN control is adjusted so that the amount of crt deflection agrees with the setting of the VOLTS/DIV switch when the VARIABLE control is turned to the CALIB detent position.

The DC BAL control R432 is used to adjust the dc level of Q474 so that its emitter will be at the same voltage as the emitter of Q464 when no input signal is applied to the instrument. With the emitters at the same voltage there will be no current through the VARIABLE control. With this configuration an adjustment of the VARIABLE control will not affect the dc level in the collector circuit of the Input Amplifier and will therefore not affect the positioning of the beam.

Vertical Positioning

The VERTICAL POSITION control is a dual control, connected between —10 and +10 volts. It is connected electrically so that as the voltage at one arm changes in the direction toward —10 volts the voltage at the other arm changes in the positive direction. This causes the voltage at the emitter of Q464 to change in the opposite direction to the voltage at the emitter of Q474. The change in emitter voltages in the Input Amplifier stage Q464/Q474 will be reflected as a change in deflection voltage at the crt, since direct coupling is employed between these two points.

Second Amplifier

The Second Amplifier stage Q484/Q494 provides a high-impedance, low-capacitance load for the Input Amplifier, and provides a low-impedance drive for the base of the Output Amplifier.

Output Amplifier

The Output Amplifier Q504/Q514 is a conventional collector-loaded, push-pull amplifier to drive the vertical deflection plates of the crt. A transistor, Q519, sets the emitter current for Q504 and Q514. There are two time-constant networks connected between the two emitters.

One network consists of diodes D505 and D506, connected back to back across R505 in series with R504. This network reduces the emitter-to-emitter impedance when the trace is positioned to the top or bottom of the graticule. Thus the gain of the stage is increased at the upper and lower deflection limits to offset crt compression. As a result, the displayed waveform will not change in amplitude regardless of trace location.

The other network consists of R506, C506, C507, and C508. This is an extremely short time-constant network (a fraction of a microsecond) and affects only fast-rise signals. The capacitive branches of this network offer less degeneration at high frequencies and thus improve the high-frequency response of the stage. The amount of high-frequency compensation can be adjusted by means of variable capacitor C506.

The dc level of the Output Amplifier is established, in part, by the divider in the base circuit of the Second Amplifier (R479 and R482 on one side and R489 and R492 on the other). These dividers help set dc level of Q504 and Q514 so that the maximum swing in collector voltage can be obtained.

TRIGGERING

Time-Base Trigger

The Time-Base Trigger circuit consists of a Trigger Input Amplifier stage Q14/Q24 and a rectangular-pulse Trigger Multivibrator Q35/Q45. The main function of the trigger circuitry is to produce a positive-going rectangular pulse at the collector of Q45 whose repetition rate is the same as that of the triggering signal. The positive step is then differentiated to produce a very sharp positive spike (trigger) which is used to trigger or start the sweep.

Triggering Signals

The triggering-input signal, from which the rectangular output is produced, may be obtained from an external source through the (Triggering) INPUT terminal, or it may be obtained from the Vertical Amplifier. When the INT-EXT switch SW2 is in the EXT position, the input circuit is arranged to receive external signals. In the INT position, the signal is received internally from the Vertical Amplifier. A Trigger-Pickoff stage Q524 (shown on the Vertical Ampilfier diagram) receives a sample of the vertical-output signal from the collector circuit of Q514. The signal at the emitter of Q524, which is in phase with the vertical input signal at the grid of V423, is then coupled to the Time-Base Trigger circuit.

When the AC-DC switch SW8 is in the AC position trigger input signals are ac-coupled through C8; in the DC position C8 is bypassed with a direct connection.

Trigger Multivibrator

When the (Triggering) LEVEL control is set between AUTO and FREE RUN for triggered operation, the Trigger Multivibrator Q35/Q45 is a bistable Schmitt Circuit. It is forced from one of its stable states into the other by the triggering signal applied to the base of Q35. In the first stable state (ready to receive a signal) Q35 is cut off and its collector voltage is up (near ground). This holds up the base of Q45, since the two circuits are dc-coupled, and Q45 conducts. With Q45 conducting its collector voltage is down; hence no output is being produced.

A positive-going signal is required at the base of Q35 to force the multivibrator into its second stable state to produce the positive step at the collector of Q45. However, since the signal at the base of Q35 is an amplification of the triggering signal, it contains both positive- and negative-going portions.

The positive-going portion of the triggering signal will drive the base of Q35 in the positive direction. When the base voltage is just out of cutoff, Q35 starts conducting and its emitter voltage will rise, following the base. This pulls up the emitter of Q45, since the two emitters are strapped together.

At the same time the collector voltage of Q35 starts to drop, carrying with it the base voltage of Q45. With the base of Q45 down and its emitter up, Q45 cuts off. As Q45 cuts off its collector voltage rises, creating a positive step at the output. This transition occurs very rapidly, regardless of how slowly the base signal of Q35 may rise.

When the signal at the base of Q35 starts in the negative direction just the opposite chain of events occurs. Q35 cuts off and its collector voltage rises. This pulls the base of Q45 out of cutoff and Q45 conducts. As Q45 conducts its collector voltage drops; this completes the positive step-voltage output from the Trigger Multivibrator circuit.

Trigger-Input Amplifier

Although the output of the Trigger Multivibrator is always a positive step votlage, the start of the step may be initiated by either the rising (positive-going) or falling (negative-going) portion of the triggering signal. The amplified triggering signal is always taken from the collector of Q24, but the base of either transistor (Q14 or Q24) can be connected to the input circuit. When the SLOPE switch SW15 is in the + position the base of Q14 is connected to the input circuit and the base of Q24 is connected to a bias source adjusable by means of the LEVEL control. With this configuration Q14/Q24 is a differential amplifier and the signal at the collector of Q24 is in phase with the signal at the base of Q14. A positive-going signal at the input will therefore produce a positive-going signal at the base of Q35 and, as explained previously, this is the action that initiates the sweep. The sweep will therefore start on the positive slope (rising portion) of the triggering signal when the SLOPE switch is in the + position.

When it is desired to trigger the sweep on the falling or negative-going portion of the triggering signal, the signal at the base of Q35 must be opposite in polarity to the signal at the input circuit. This is accomplished by placing the SLOPE switch in the — position. With this arrangement the base of Q24 is connected to the input circuit and the base of Q14 is connected to the bias source. The configuration is still a differential amplifier and gain is the same as before, but the output signal is now opposite in polarity to the base signal.

Triggering Level

The setting of the (Triggering) LEVEL control determines the point (instantaneous voltage) on the triggering signal at which the sweep is started. This is accomplished as follows:

The quiescent state of the Trigger-Input Amplifier is such that the collector voltage of Q24 is about in the center of the hysteresis of the multivibrator. An adjustment of the LEVEL control will vary the bias on the transistor to which it is connected. This in turn will vary the dc level at the collector of Q24 to within the hysteresis range of the multivibrator. By adjusting the LEVEL control, the operator can select the point on the waveform at which he wishes to trigger the sweep.

Automatic Triggering

The sweep can be triggered automatically, instead of manually, by turning the LEVEL control full left to the AUTO position. In the AUTO position SW17 is opened, which alters the circuit configuration as follows: (a) the switch end of R38 is disconnected from the —10-volt decoupled supply to provide feedback from the collector of Q45 to its base; (b) the LEVEL control R17 is disconnected from the circuit; and (c) all triggering-input signals are ac-coupled through C8 regardless of the setting of the AC-DC switch.

In the automatic (AUTO) triggering mode, the Trigger Multivibrator is converted from a bistable configuration to a recurrent (free-running) configuration. (This is not to be confused with FREE RUN position of the LEVEL control; in the latter position the Time-Base Generator free runs).

The charging and discharging action of C30, fed to the base of Q45 and driving it, sets the Trigger Multivibrator recurrent rate at about 50 cps when no signal or low-amplitude signal is applied to the base of Q35. When a signal of sufficient amplitude to overcome the hysteresis of Q35 is applied, then the repetition rate of the applied signal (if it is higher than 50 cps) takes over and controls the switching rate of the multivibrator circuit.

Assume no signal is applied to the base of Q35 for example. Also, assume that Q35 has just turned off and Q45 has turned on. Under these conditions, for the first half cycle (duration is about 10 msec), C30 is charging to the voltage set by divider R33, R34, and the collector of Q45. As C30 charges, it is driving Q45 base toward cut off. Q35 emitter, through direct coupling to the emitter of Q45, is moving in a direction which will eventually turn Q35 on; the base of Q35 meanwhile is set at a fixed level by Q24 collector. After about 10-msec charging time, C30 cuts off Q45 and Q35 turns on.

Now, for the next half cycle C30 is discharging toward the voltage set by divider resistors R32, R43, R33, and R34. As C30 is discharging, C30 is driving Q45 toward its forward bias point. After about 10 msec discharging time, C30 discharges sufficiently to drive Q45 into conduction and C35 cuts off. This completes one cycle of the 50-cps output of the multivibrator.

As mentioned earlier, when a signal of sufficient amplitude is applied to the base of Q35 and the repetition rate of the signal is higher than 50 cps, the signal drives the base of Q35 and controls the switching rate of the Trigger Multivibrator. Capacitor C30 under these conditions has negligible effect on controlling the multivibrator action.

With this configuration just described, the sweep can be triggered with repetitive signals, over a wide range of frequencies, without readjustment. When no signal is applied to the base of Q35, the sweep continues at approximately a 50-cycle rate because the Trigger Multivibrator provides the trigger signal which triggers the Time-Base Generator. Thus, the sweep generates a base line which indicates that the instrument is ready to display any signal (within the voltage and frequency limits of the instrument) that might be connected to the vertical deflection system.

SWEEP GENERATION

Time-Base Generator

The positive-going pulses produced by the Time-Base Trigger circuit are differentiated in the base circuit of Q135. The sharp positive spikes produced by the differentiation process are used to start the sweep; the negative spikes are not used.

The Time-Base Generator consists of three main circuits . . . a bistable Sweep-Gating Multivibrator, a Miller Integrator Circuit, and a Hold-Off Circuit. Transistors Q135 and Q145 make up the Sweep-Gating Multivibrator. In the stable state immediately following a sweep Q135 is nonconducting and Q145 is conducting.

The essential components in the Miller Circuit are the Miller transistors Q161 and Q163, the emitter-follower Q173, the gating transistor Q153, the "disconnect" diode D153, the Timing Capacitor C160, and the Timing Resistor R160. The Hold-Off Circuit consists mainly of the emitter-follower Q183 and the Hold-Off Capacitors C180 and C181.

In the quiescent state the gating transistor Q153 is held in conduction (by the conducting multivibrator transistor Q145) and its emitter voltage is negative. This holds the cathode of D153 negative and forces the diode to conduct. In this state the low forward impedance of Q153 and D153 shunts the Timing Capacitor and prevents it from charging. This action also clamps the Miller Circuit in such a way that the emitter-followers Q163 and Q173 conduct very little and the amplifier Q161 conducts heavily.

Sweep Generation

The next positive trigger to arrive at the base of Q135 will force the Sweep-Gating Multivibrator into its second stable state in which Q145 is cut off. The rise in voltage at the collecor of Q145 pulls up the base of Q153 and this stage cuts off. The rise in voltage at the emitter of Q153 then back-biases D153 and the diode stops conducting. This action unclamps the Miller Circuit and permits it to seek its own voltages.

The base of Q163 then starts positive, since it is connected through the Timing Resistor to the +45-volt bus (when the VARIABLE control is in the CALIB position). The emitter of Q163 and the base of Q161 also start positive, following the base of Q163. The collector of Q161 then starts negative, carrying with it the base and emitter of Q173. This causes the voltage at the lower side of the Timing Capacitor to increase in the negative direction which in turn pulls down the base of Q163 and prevents it from going positive. The gain of the Miller Circuit is such that the feedback network maintains the voltage at the base of Q163 virtually constant (within about one-tenth of a volt).

The Timing Capacitor then start charging with current through the Timing Resistor and the emitter-follower Q173. Since the voltage at the base of Q163 remains essentially constant, the voltage across the Timing Resistor, and hence the charging current through it, remains essentially constant. The Timing Capacitor therefore charges linearly, and the voltage at the emitter of Q173 increases linearly (in the negative direction). Any departure from a linear increase in the voltage at this point will produce a change in the voltage at the base of Q163 in a direction to correct for the error.

The linear increase in voltage at the emitter of Q173 is used as the sweep time base. Timing Capacitor C160 and Timing Resistor R160 are selected by the setting of the TIME/DIV switch SW160. The Timing Resistor determines the current that charges the Timing Capacitor. By means of the TIME/DIV switch, both the size of the capacitor being charged and the charging current can be selceted to cover a wide range of sweep speeds. The setting of the TIME/DIV switch therefore determines the speed at which the spot moves across the crt.

If uncalibrated sweep rates are desired the VARIABLE control R160V can be turned away from the CALIB position. This connects the Timing Resistor to a voltage adjustable between +45 v and +10 v, which varies the sweep rate over about a 4 to 1 range.

Retrace

The length of the sweep—the distance the spot moves across the crt—is determined by the setting of the SWP LENGTH control R176. As the sweep voltage increases negatively at the emitter of Q173 there will be a linear increase in voltage at the arm of R176 and at the base of Q183. This will pull down the voltage at the emitter of Q183 and at the base of Q135. When the voltage at the base of Q135 falls to cutoff, the Sweep-Gating Multivibrator will rapidly revert to its original state with Q135 cut off and Q145 conducting. The voltage at the collector of Q145 will then drop, carrying with it the base of Q153. This will gate on Q153 and the diode D153 and provide a discarge path for C160.

The resistance through which C160 discharges (R153 and the forward resistance of Q153 and D153) is much less than that through which it charges (R160, R178, and the forward resistance of Q173). The capacitor current during discharge will therefore be much larger than during charge, and the Miller transistors will return rapidly to their quiescent state. This produces the retace portion of the sweep sawtooth, during which time the crt beam returns rapidly to its starting point.

Hold-Off

The Hold-Off Circuit prevents the Time-Base Generator from being triggered during the retrace interval. In addition, the hold-off allows a finite time for the sweep circuits to regain a state of equilibrium after the completion of a sweep.

During the trace portion of the sweep sawtooth the Hold-Off Capacitors C180-C181 charge through Q183 as a result of the drop in voltage at the emitter of Q183. This pulls the base of Q135 negative until Q135 cuts off. As explained previously, this is the action that initiates the retrace.

At the start of the retrace C180 and C181 start discharging thorugh R181. The time-constant of this circuit is such that during the retrace, and for a short period after the completion of the retrace, the base of Q135 is held far enough below cutoff that positive triggers cannot switch the Sweep-Gating Multivibrator. When the Hold-Off Capacitors have discharge to a predetermined voltage (established by the setting of the STABILITY control) the effect of the hold-off is removed. This returns the Sweep-Gating Multivibrator to its quiescent state in which it can be triggered by the next positive trigger to arrive at the base of Q135.

Stability Control

The STABILITY control R111 regulates the dc level at the base of Q135 within the hysteresis of the Sweep-Gating Multivibrator. When this control is properly adjusted, the base of Q135 is held just negative enough that Q135 is back-biased and nonconducting; this prevents the circuit from free running. The base voltage must be sufficiently close to cut-off so that positive triggers can pull Q135 out of cutoff and force the multivibrator into its other state to initate the sweep.

During the trace portion of the sweep sawtooth, when the Hold-Off Capacitors are charging, the emitter of Q183 is forced negative. When the emitter of Q183 is more negative than the arm of the STABILITY control diode D111 is back biased; this disconnects the STABILITY control from the Multivibrator circuit.

During the retrace portion of the sweep sawtooth the Hold-Off Capacitors discharge. When the voltage at the emitter of Q183 rises to the voltage at the arm of the STABILITY control diode D111 conducts and clamps the Hold-Off Circuit at this voltage. With the base of Q135 clamped in this manner, a sweep can only be produced when a positive trigger pulls Q135 out of cutoff.

However, should a free-running trace be desired, the (Triggering) LEVEL control can be turned full right to the FREE RUN position. This opens switch SW17 and forces the arm of the STABILITY control to ground potential. This permits the base of Q135 to rise to cutoff immediately upon removal of the hold-off voltage, at which point the next sweep is initiated.

Unblanking

The crt in the Type 321A contains a second set of horizontal deflection plates (pins 6 and 10; see diagram for Crt Circuit). Pin 10 is connected to +10 volts; pin 6 is connected to the Unblanking Amplifier (shown on the Time-Base Generator diagram). In the interval between sweeps, pin 6 rests at about —20 volts; the crt beam is therefore deflected off the screen and is not visible.

When a positive trigger switches the Sweep Gating Multivibrator to start a sweep, the negative gate at the collector of Q135 is coupled to the base of Q194. This results in a 30-volt positive gate at the collector of Q194, which in turn is fed to pin 6 of the crt. The 30-volt positive gate, whose start and duration are coincident with the start and duration of the sweep, pulls pin 6 of the crt up to +10 volts, the same as pin 10. This deflects the crt beam back into the range of visibility for the trace portion of the sweep sawtooth.

Transistor Q199 is connected as a load-stabilizer. Q199 conducts when Q194 is nonconducting. When Q194 conducts, during sweep time, Q199 is nonconducting. This circuit prevents the switching of Q194 from changing the load on the power supply, and therefore prevents crosstalk to the Vertical Amplifier.

HORIZONTAL AMPLIFIER

Input Circuit

The Horizontal Amplifier consists of an emitter-follower input stage Q313 and an emitter-coupled paraphase amplifier Q334/Q344. For all sweep-time settings of the TIME/DIV switch, the negative-going sweep sawtooth produced by the Miller Circuit is coupled to the Input E.F. Q313 via the frequency-compensated voltage divider R311-R312. In the EXT HORIZ INPUT setting of the switch, Q313 receives its signal from the EXT HORIZ INPUT connector. This setting of the switch also produces the following results: (1) The Time-Base Generator is rendered inoperative; (2) The emitter of Q194 (Unblanking circuit) is clamped at about +10 volts, thus removing the blanking potential at pin 6 of the crt.

Emitter-follower Q323 balances the Horizontal Amplifier for dc potentials. This stage also couples the positioning voltage from the HORIZONTAL POSITION control R321 to the amplifier circuit.

Output Amplifier

Q334 and Q344 are connected as an emitter-coupled paraphase amplifier to provide the push-pull drive for the horizontal deflection plates of the crt. The setting of the HORIZ GAIN control R338 determines the emitter degeneration and thus sets the gain of the stage. A second gain control R348 (MAG GAIN) is connected in the emitter circuit when the VARIABLE timing control is pulled out to close SW348. This action decreases the degeneration and increases the gain 5 times to provide 5X sweep magnification.

REGULATOR CIRCUIT

Power Sources

The function of the Regulator circuit in the Type 321A is to provide a regulated 10 volts dc for the converter-type power supply. The Regulator is designed to operate from a self-contained battery pack, from an external 11.5-v to 35-v dc source, or from either a 115-v or a 230-v rms, 50-800 cycle ac line.

To operate from the internal batteries only, the POWER switch SW621 is set to BATT ON. The POWER switch connects the internal batteries directly to the Regulator circuit via TK621 and F621. TK621 is a thermal cutout switch that opens if the ambient temperature of the Type 321A rises to about 131° F (±5°) and closes when the chassis temperature drops to 120° F (±8°). Normally, for internal battery mode of operation other voltage sources are not connected to the Type 321A at this time.

Operation from an external dc source is accomplished by connecting the special pigtail-type dc power cord in the proper manner. For 11.5- to 20-v operation, the black (+) and white (—) leads are connected to the voltage source; for 20- and 35-v operation, the green (+) and white (—) leads are connected to the source. The ac line cord is not used during this mode of operation. To turn on the Type 321A the POWER switch is set to EXT ON. The switch connects the dc source to the regulator circuit. Diode D620 is normally back-biased to keep T601 disconnected since the T601 secondary portion of the circuit is not used at this time.

For ac line operation the ac power cord is connected to the ac line and line power is applied through F601 to the T601 primary winding. The primary of power transformer T601 has split input windings; these may be connected in parallel for operation from a 103.5-126.5 volt line, or in series for a 207-253 volt line.

Graticule lights and an ac rectifier are connected to the secondary windings of T601. The ac rectifier is a conventional full-wave type, with a capacitor-input filter. When the POWER switch is set to EXT ON, the output of the ac rectifier is applied through D620, the POWER switch, TR621 and F621 to the Regulator circuit. At nominal line voltages the ac rectifier provides a voltage of about 14.5 volts across C696.

Voltage Regulation

The Regulator circuit is designed to respond both to changes in supply voltage and to changes in loading. Reference voltage for the Regulator circuit is furnished by Zener diode D629. This diode provides a constant dc voltage of about +5.1 volts (with respect to the common negative bus) at the base of Q624, one-half of a difference amplifier. The base voltage for the other half of the difference amplifier, Q634, is obtained from a divider R650, R651, and R652. The 10 V ADJ control R651 determines the percentage of total voltage that appears at the base of Q634 and thus determines the total voltage across the divider. This control is adjusted so that the output is exactly 10 volts.

The regulation of the output, in the presence of line-voltage or load changes, is accomplished by varying the impedance of Q657 in a direction to compensate for the change. For example, assume the output voltage tends to decrease. This will lower the base voltage of Q634 and alter the current distribution through the difference amplifier. That is, the current through Q634 will decrease and the current through Q624 will increase.

The resultant drop in voltage at the collector of Q624 will pull down the base and emitter of Q654. This action drives the base of Q657 toward its collector, which increases the current through Q657 and lowers its impedance.

The unregulated voltage is equal to the output voltage plus the drop across Q657. The decrease in impedance of Q657 lowers its emitter-to-collector voltage, which causes the output voltage to increase to its proper value.

If the output voltage tends to increase, just the opposite will occur. The base voltage of Q634 will increase, more current will flow through Q634 and less current will flow through Q624. The rise in voltage at the collector of Q624 will pull up the base and emitter of Q654, and the base of Q657. This decreases the current through Q657 and increases its impedance.

As the impedance of Q657 increases its voltage drop increases. This in turn lowers the output voltage to its proper value.

Battery Charger

When the Type 321A is connected to a source of ac power and the POWER switch is turned to TRICKLE or FULL, the rectified output of T601 is sufficient to cause a back current through the 12-volt battery, resulting in a charging of the cells (if rechargeable cells are used). The resistive network of R692, R693, and the internal resistance of the cells determine the amount of charging current which will flow. When the POWER switch is set to FULL and the Charger switch is in the LOW position, 200 ma will flow through the battery at nominal line voltage. When the Charging switch is in the HIGH position, 360 ma will flow through the battery. When the Charger switch is in the DRY CELLS position, the circuit is opened up and no current will flow.

When the POWER switch is turned to TRICKLE, R694 is inserted in series with R692 and/or R693 and the current is limited to about 40 ma, just enough to maintain the existing charge on the cells.

Low-Batteries Light

Transistor Q614 and associated circuitry constitute the low-batteries warning-light system. The emitter of Q614 is held constant by the 10-volt regulated supply, the base is controlled by a voltage dividing network consisting of R695, R696, and R697. The network connects across the unregulated supply voltage. The LOW BATTERIES B699) light is connected in the collector circuit of Q614.

Under normal conditions when the internal batteries provide a voltage of more than 11.5 volts (±0.2 v), transistor Q614 is cut off and the LOW BATTERIES light is off. However, if the unregulated voltage drops to about 11.5 volts or less due to low batteries, Q614 base-emitter junction forward biases and Q614 conducts, thus turning on the light.

As a secondary function of this circuitry, the LOW BATTERIES light acts as a warning light for either of these conditions: (1) If the Type 321A is operated from a low external ac line source or (2) from a low external dc source. If either condition causes the unregulated voltage to fall to about 11.5 volts, or lower, Q614 will conduct and turn on the LOW BATTERIES light.

Diode D614 is a protection diode for Q614. Normally the diode is forward-biased to limit the reverse-bias voltage across the base-emitter junction of Q614 during cut off. When the unregulated voltage drops to about 11.5 volts or lower, D614 reverse biases and Q614 base-emitter junction becomes forward-biased to turn on the light.

CONVERTER

The regulated 10 volts output of the Regulator circuit is applied to the Converter transistors Q700-Q710. Both transistors are biased in the forward direction when power is applied, but because of slight difference in characteristics one will start conducting before the other. Current flowing in the collector circuit of the conducting transistor will then induce a voltage into the base windings (terminals 5, 6, and 7) of transformer T701. The polarity of the base voltages induced will be such that the conducting transistor will conduct more, and the nonconducting transistor will be driven into cutoff.

The buildup of current in the conducting transistor will continue until the transformer saturates. At saturation the induced voltage in the base windings will start decaying and the conducting transistor will accordingly conduct less. The collapsing field will then induce voltages of the opposite polarity in the base windings. This will drive the transistor that had been conducting into cutoff, and turn on the transistor that had previously been cut off. The circuit will then produce a secondary voltage of the opposite polarity. The repetition rate of the circuit is about 2 kc.

The transistor current, flowing in the primary circuit of T701, is somewhat trapezoidal in shape; the secondary voltage is therefore nearly a square wave. A full-wave rectifier with capacitor-input filters provides dc output voltages of —47.5, —45, —10, +5.8, +10, and +45 volts. An additional half-wave rectifier circuit provides —720 volts for the crt gun.

An ac signal of approximately 100 volts, peak-to-peak, is coupled from terminal 10 of T701 to the Calibrator circuit (shown on the Vertical Amplifier and Calibrator diagram). The 100-volt ac signal square wave is clipped in Q874 and divided down to provide the 500-millivolt external signal available at the CAL OUT 500 MV terminal, and the 40-millivolt square wave internally coupled to the Vertical Amplifier in the CAL 4 DIV position of the VOLTS/DIV switch.

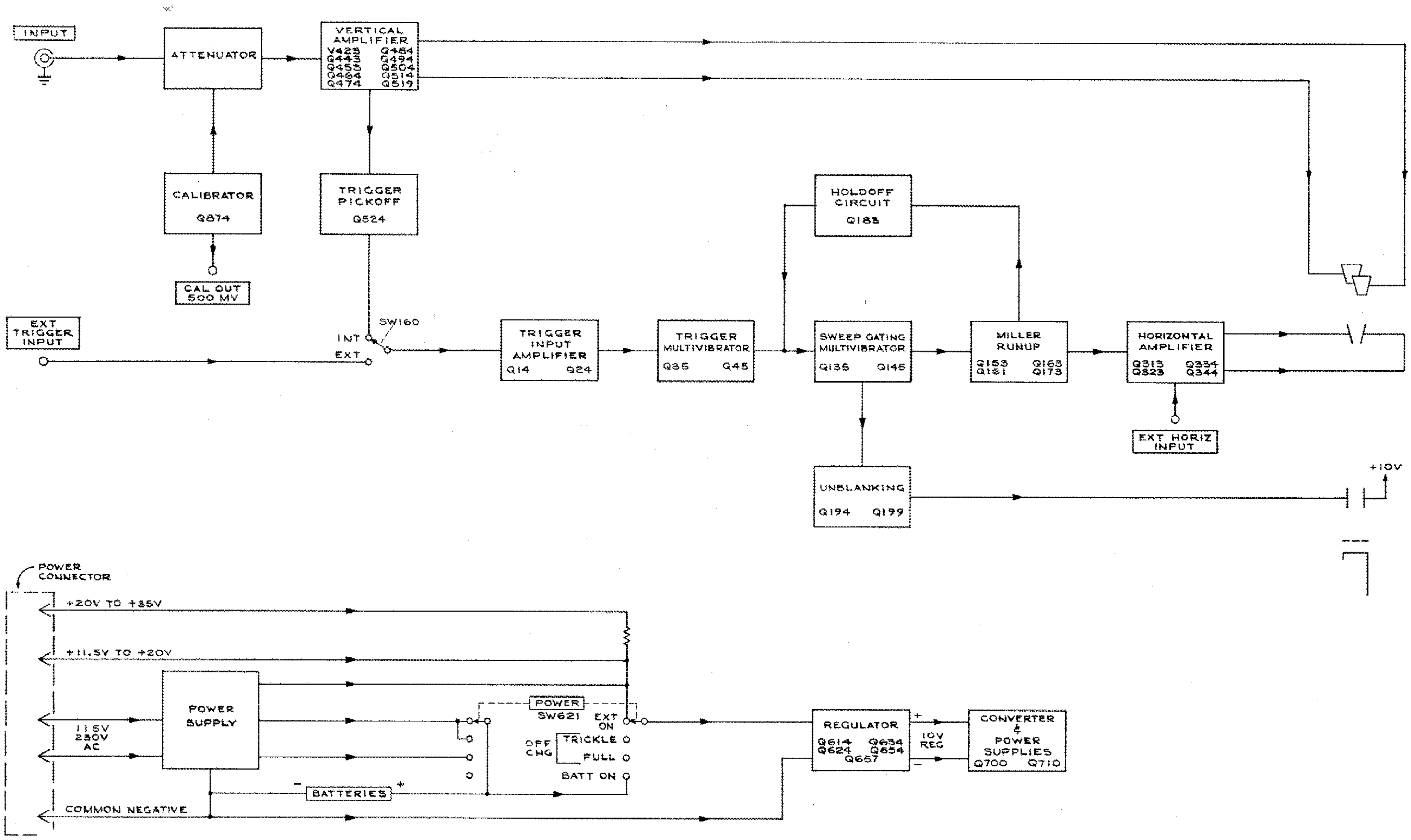
CRT CIRCUIT

Crt Control Circuits

The INTENSITY control R844, part of a divider connected between —720 volts and ground, varies the crt grid-to-cathode voltage to regulate the beam current. The FOCUS control R842 varies the voltage at the focusing anode to set the second cross-over point right at the crt screen. The ASTIGMATISM control R864 varies the voltage at the astigmatism anode to focus the spot in both dimensions simultaneously. The GEOM ADJ R861 varies the field the beam encounters as it emerges from the deflection system to control the linearity at the extremes of deflection.

High Voltage Supply

A pentupler, starting with the voltage at Terminal 16 of T701, builds up a potential of 3350 volts for the post-deflection accelerator in the crt. This provides an accelerating potential of approximately 4 KV, since the cathode voltage is about —670 volts.

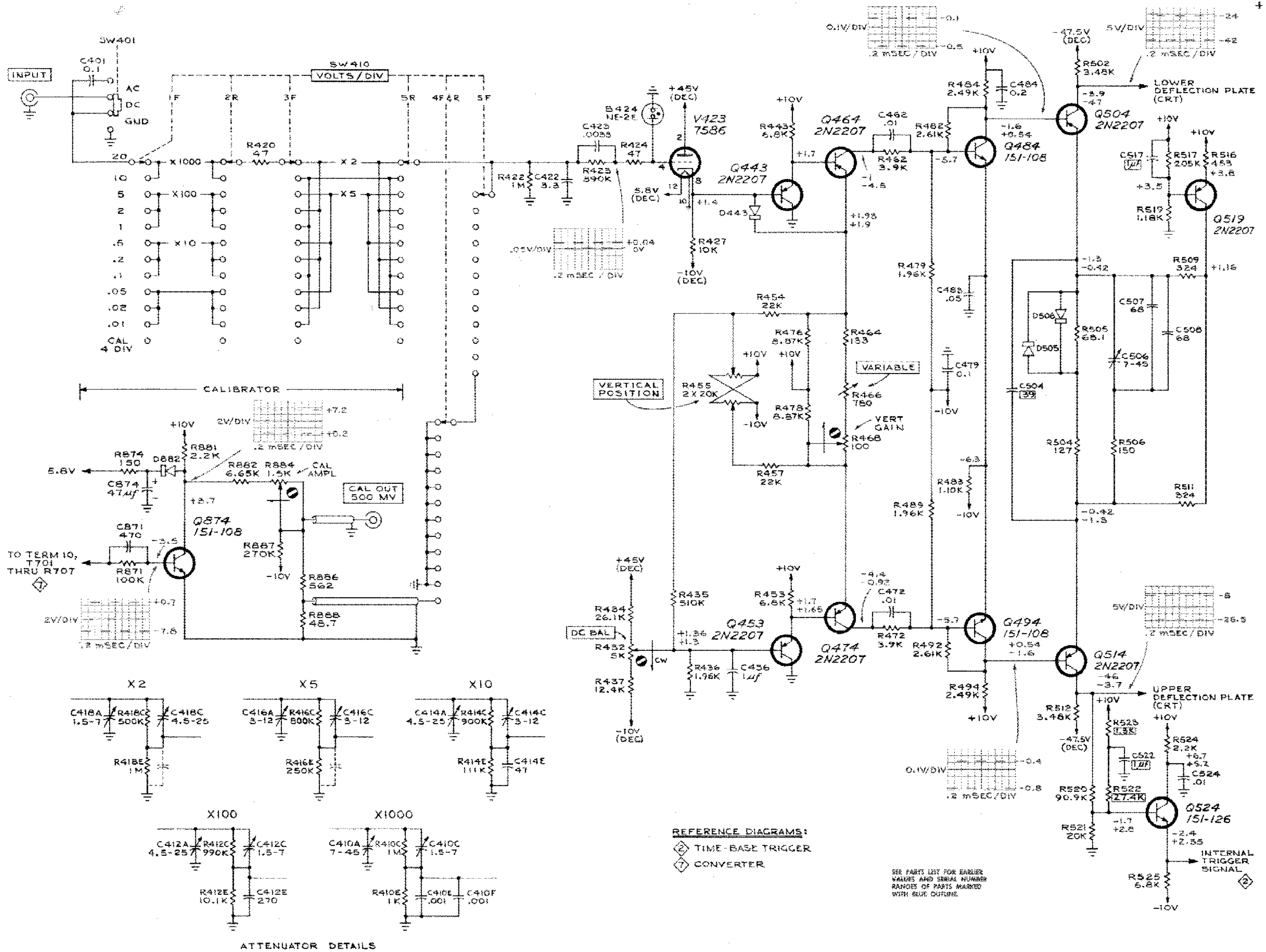


TYPE 321A OSCILLOSCOPE

A

MRH
564

BLOCK DIAGRAM



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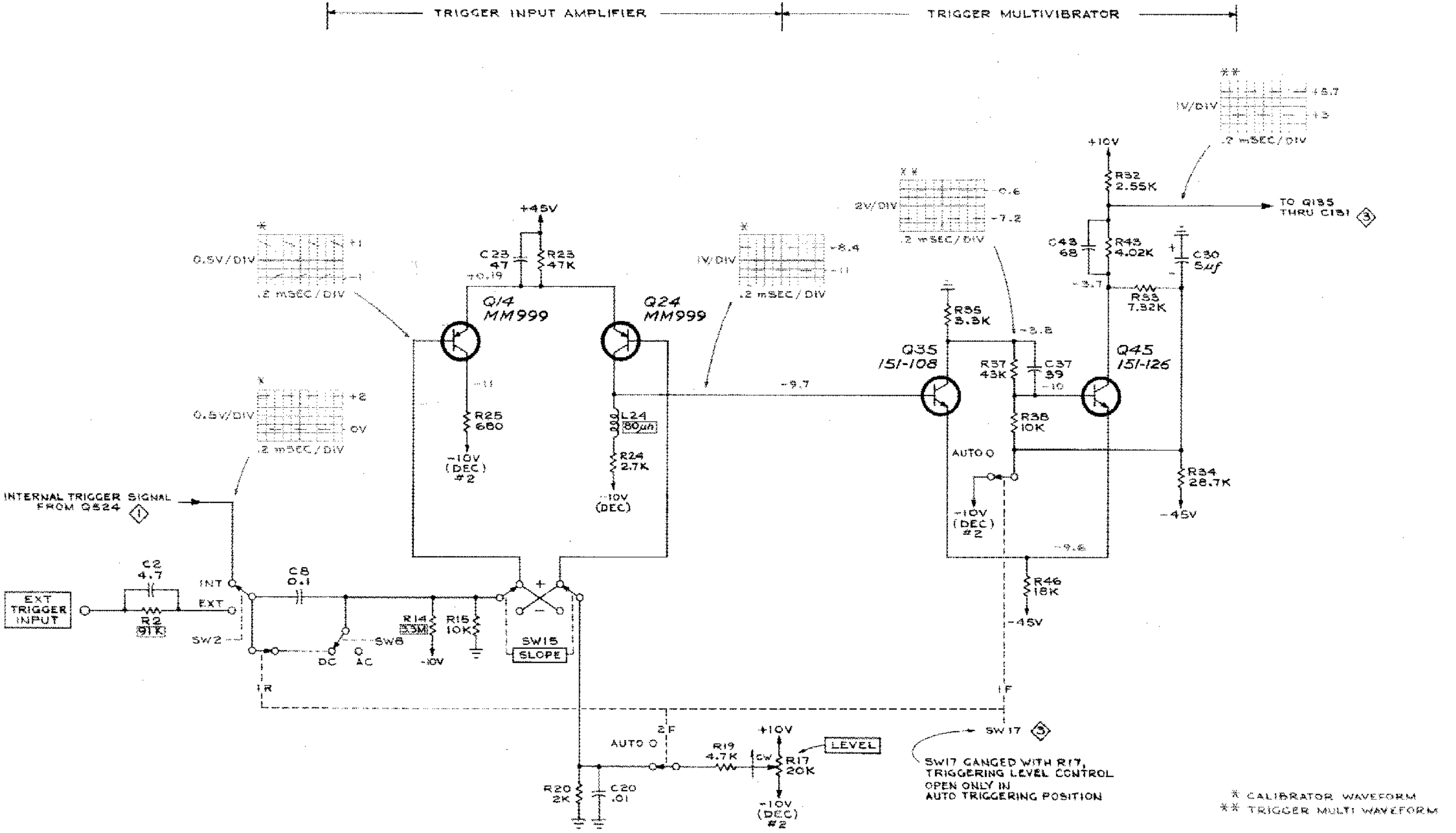
TYPE 321A OSCILLOSCOPE

C

VERTICAL AMPLIFIER & CALIBRATOR ⟨1⟩



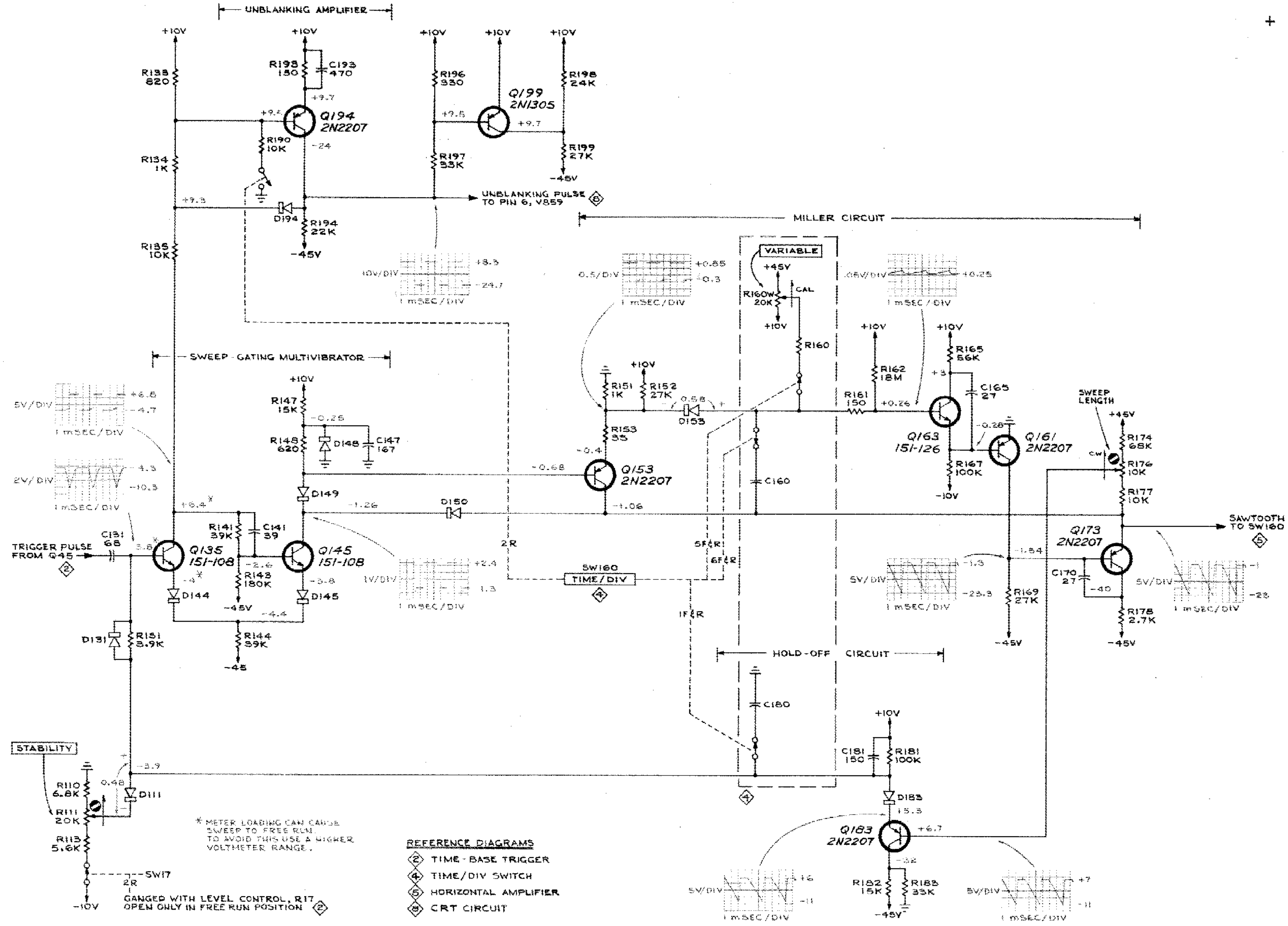
* CALIBRATOR WAVEFORM
** TRIGGER MULTI WAVEFORM

REFERENCE DIAGRAMS:

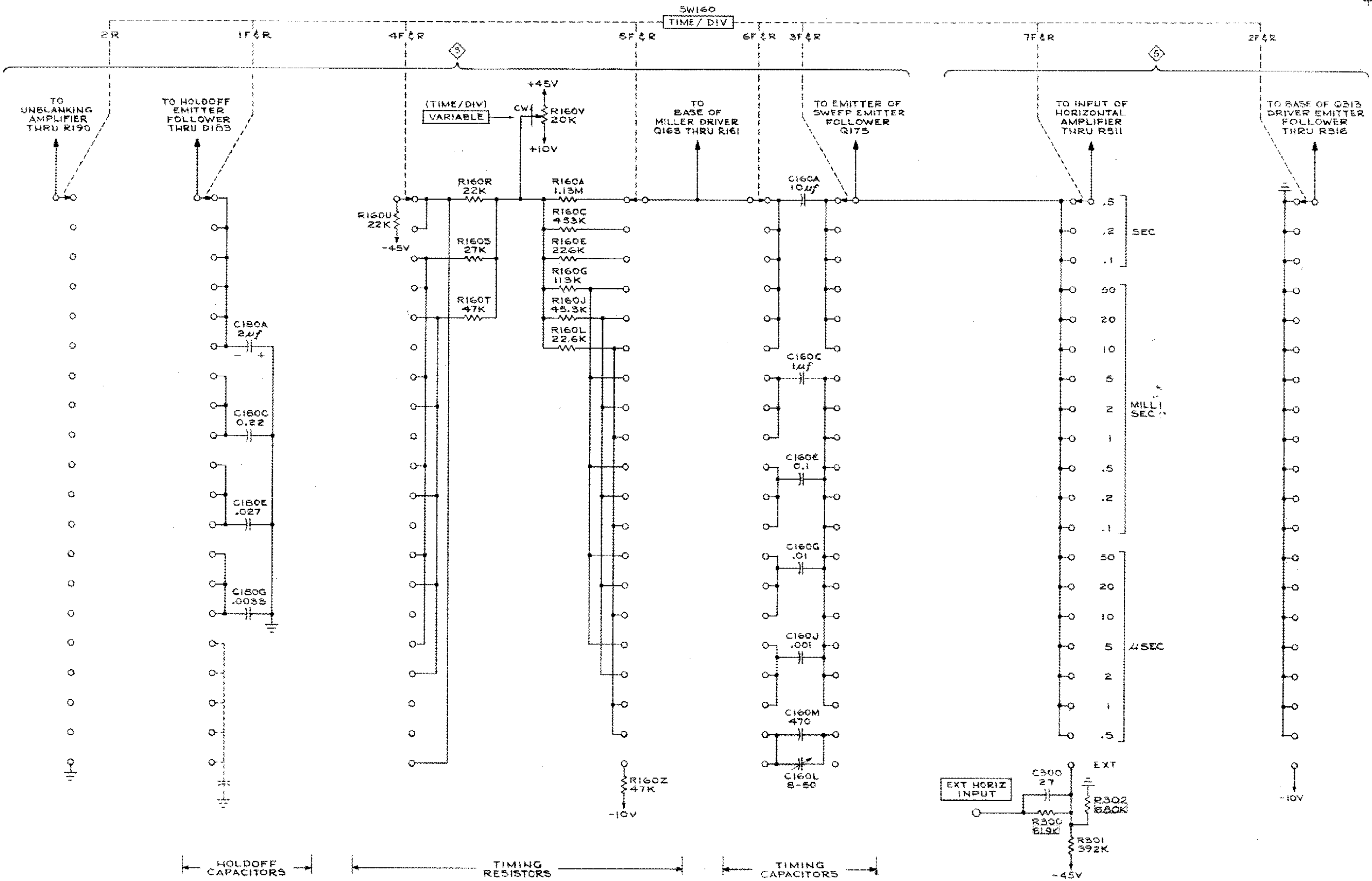
1 VERTICAL AMPLIFIER & CALIBRATOR

3 TIME-BASE GENERATOR

MRH
1164


UNBLANKING AMPLIFIER
+10V
R133 820
R134 1K
R135 10K
R198 150
C193 470
Q194 2N2207
R190 10K
D194
R194 22K
-45V
R196 330
R197 33K
Q199 2N1305
R198 24K
R199 27K
UNBLANKING PULSE TO PIN 6, V859 ⑥
MILLER CIRCUIT
VARIABLE
+45V
R160W 20K
CAL
R160
SWEEP-GATING MULTIVIBRATOR
R147 15K
R148 620
D148
C147 167
D149
D150
R151 1K
R152 27K
D153
R153 33
Q153 2N2207
R161 150
R162 18M
R165 56K
C165 27
Q163 151-126
Q161 2N2207
R167 100K
-10V
SWEEP LENGTH
R174 68K
R176 10K
R177 10K
SAWTOOTH TO SW160 ⑤
Q173 2N2207
C170 27
R169 27K
R178 2.7K
TRIGGER PULSE FROM Q45 ②
C131 68
Q135 151-108
Q145 151-108
R141 39K
C141 39
R143 180K
D144
D145
R144 39K
-45
D131
R131 8.9K
SW160 TIME/DIV ④
C160
HOLD-OFF CIRCUIT
C180
+10V
C181 150
R181 100K
D183
Q183 2N2207
R182 15K
R183 33K
STABILITY
R110 6.8K
R111 20K
R113 5.6K
D111
SW17
GANGED WITH LEVEL CONTROL, R17 OPEN ONLY IN FREE RUN POSITION ②
* METER LOADING CAN CAUSE SWEEP TO FREE RUN. TO AVOID THIS USE A HIGHER VOLTMETER RANGE.
REFERENCE DIAGRAMS
② TIME-BASE TRIGGER
④ TIME/DIV SWITCH
⑤ HORIZONTAL AMPLIFIER
⑥ CRT CIRCUIT
1 mSEC/DIV

MRH
464



MRH
465

REFERENCE DIAGRAMS

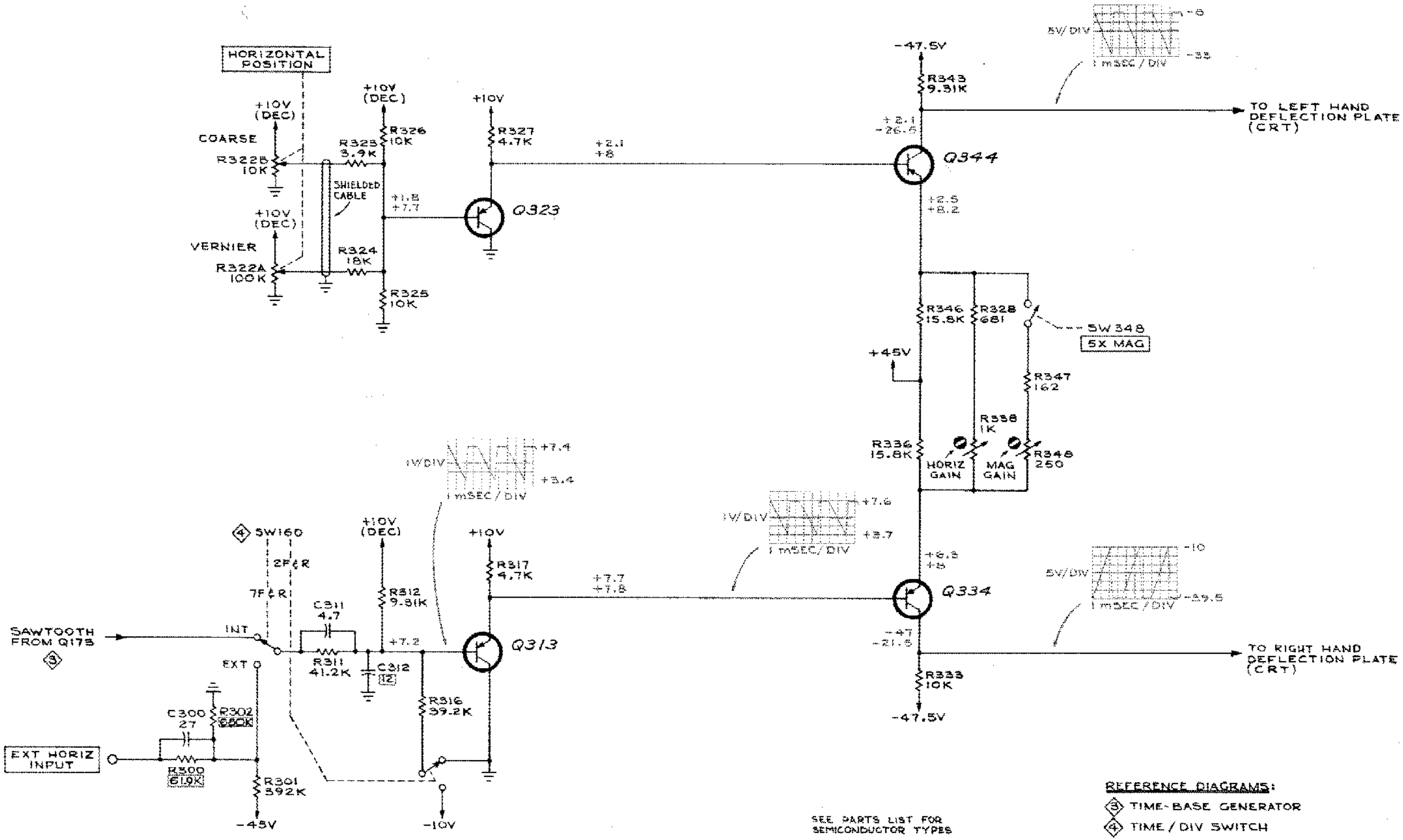
③ TIME-BASE GENERATOR

⑤ HORIZONTAL AMPLIFIER

TYPE 321A OSCILLOSCOPE

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

TIME / DIV SWITCH ④



SEE PARTS LIST FOR SEMICONDUCTOR TYPES

REFERENCE DIAGRAMS:

③ TIME-BASE GENERATOR

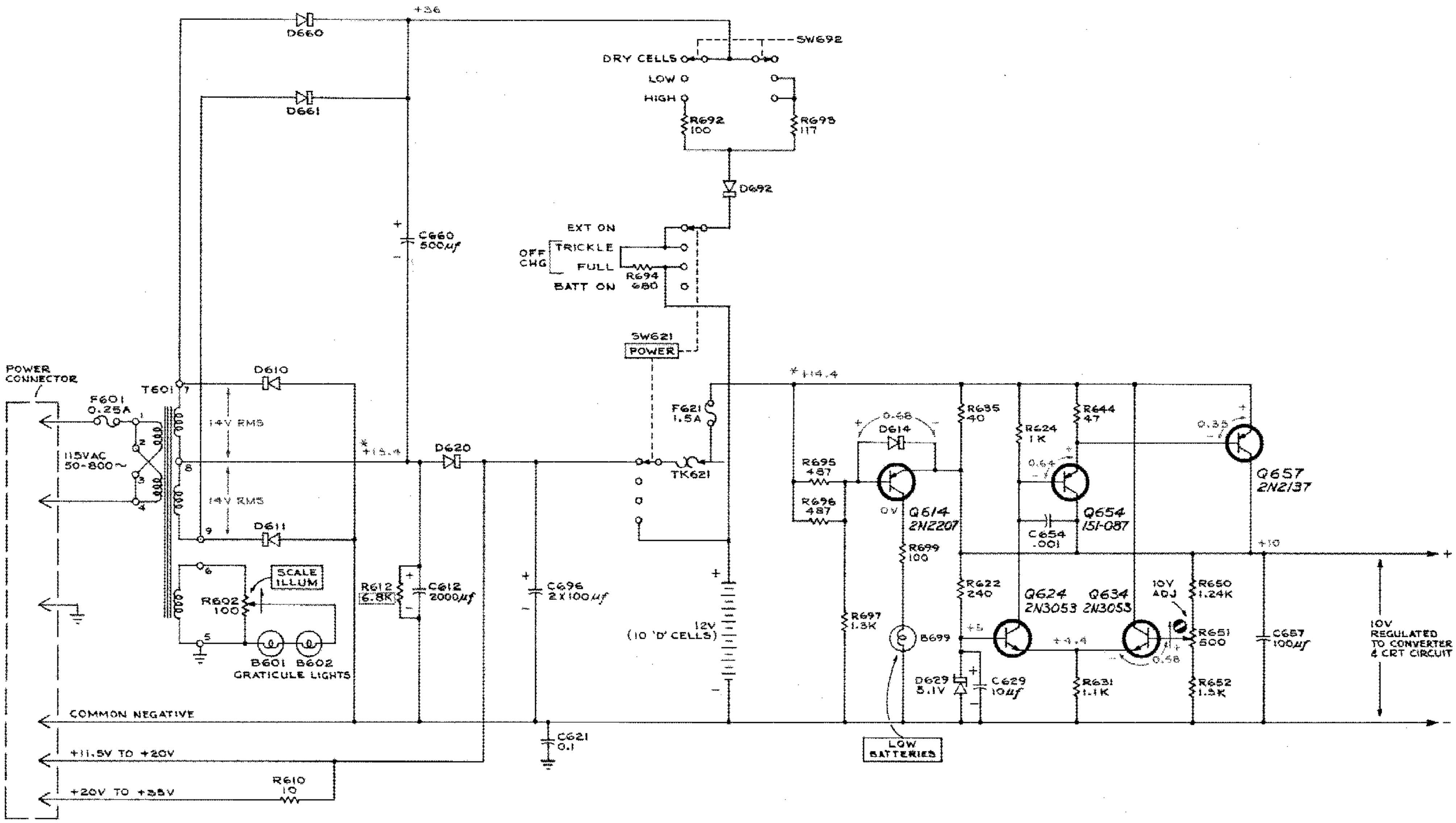
④ TIME / DIV SWITCH

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

TYPE 321A OSCILLOSCOPE

MRH
965

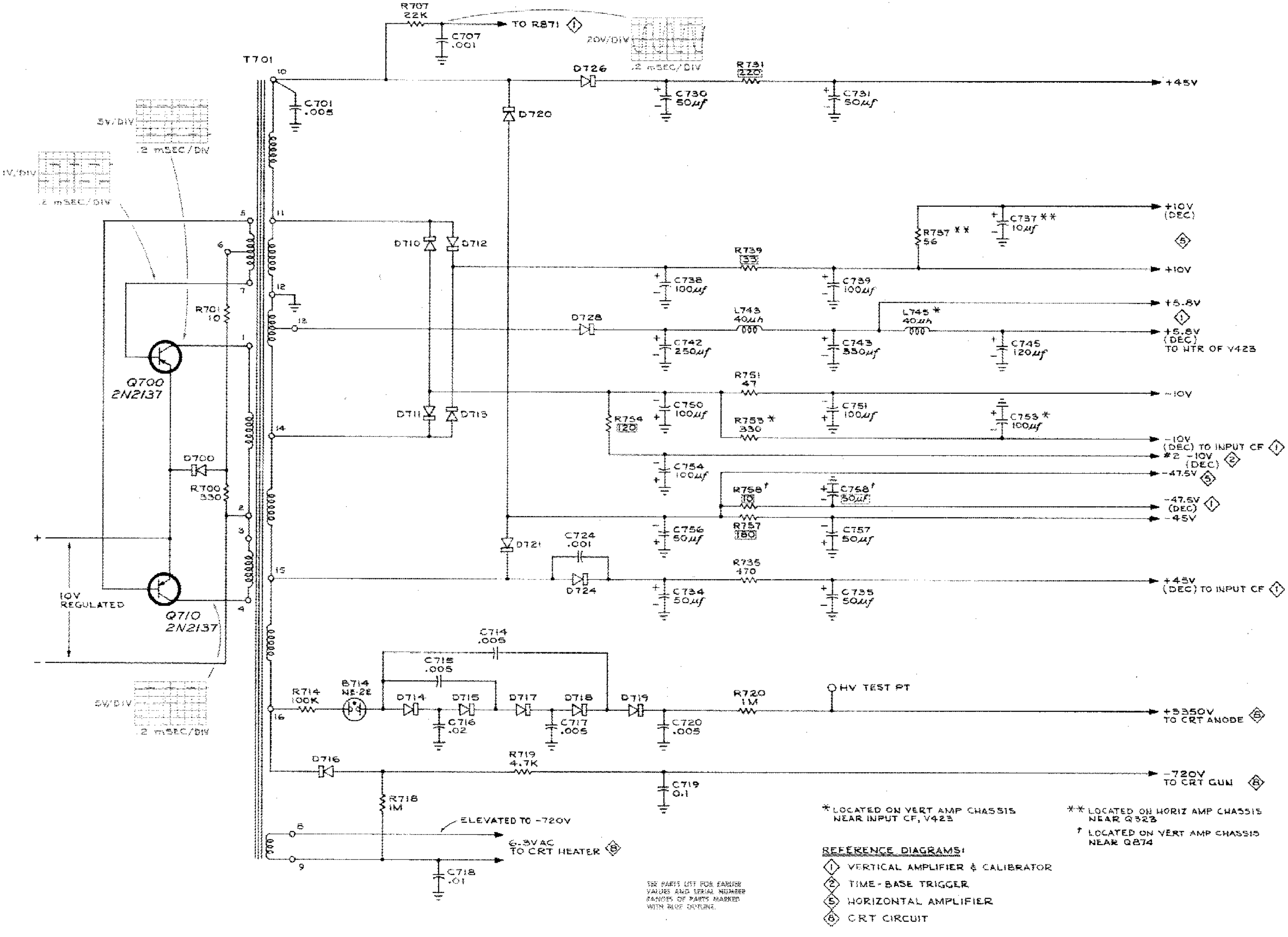
HORIZONTAL AMPLIFIER ⑤

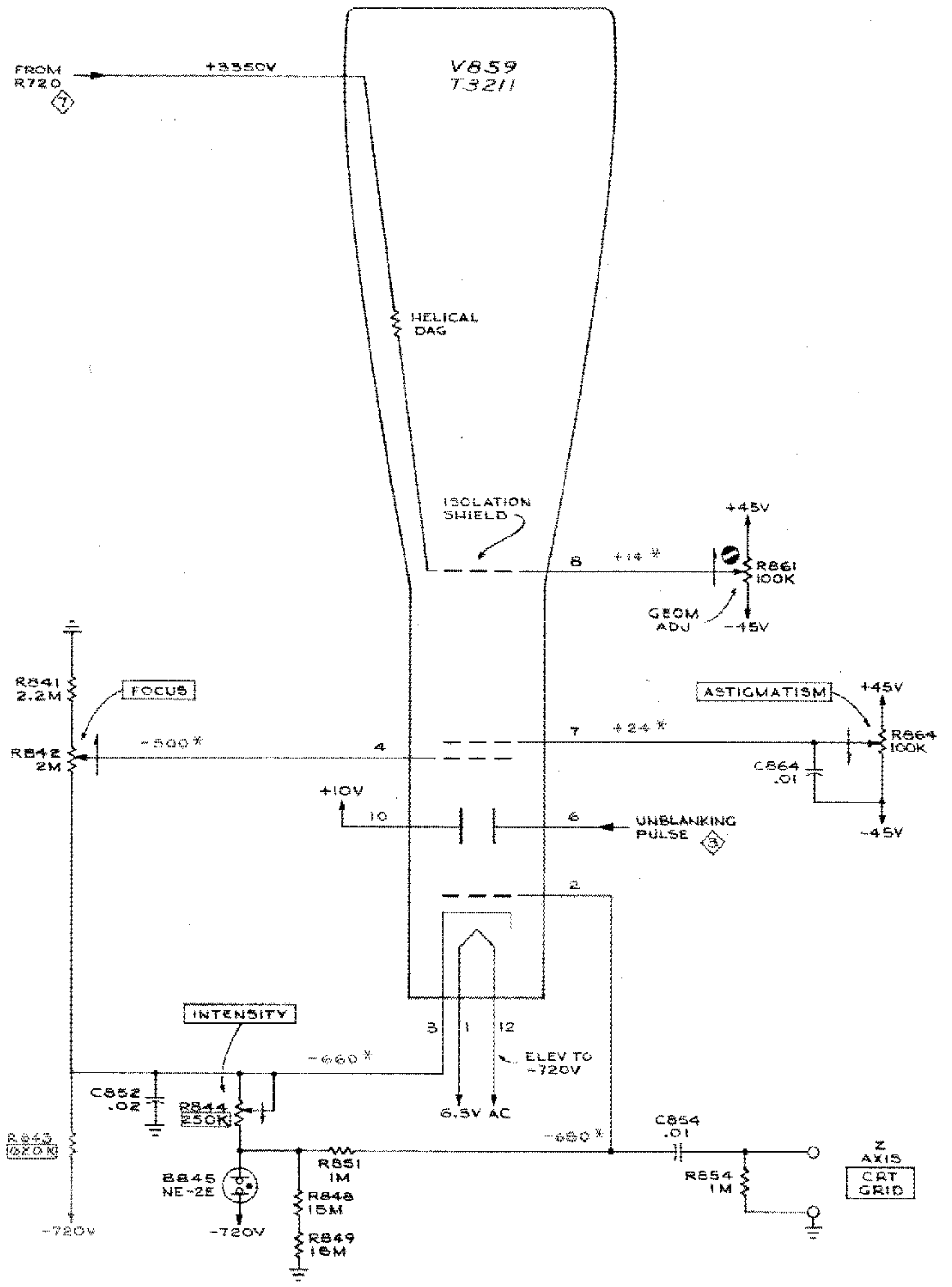


* VARIES WITH LINE VOLTAGE

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED

MRH
864


T701
R707
22K
C707
.001
TO R871 ①
20V/DIV
.2 mSEC/DIV
C701
.005
D726
R731
120
+45V
C730
50μf
C731
50μf
D720
5V/DIV
.2 mSEC/DIV
1V/DIV
.2 mSEC/DIV
+10V
(DEC)
R737 **
56
C737 **
10μf
⑤
D710
D712
R739
33
+10V
C738
100μf
C739
100μf
R701
10
+5.8V
①
D728
L743
40μh
L745 *
40μh
+5.8V
(DEC)
TO HTR OF V423
C742
250μf
C743
330μf
C745
120μf
Q700
2N2137
R751
47
-10V
D711
D713
R754
120
C750
100μf
C751
100μf
R753 *
330
C753 *
100μf
-10V
(DEC) TO INPUT CF ①
#2 -10V
(DEC) ②
D700
C754
100μf
-47.5V ⑤
R700
330
R758 †
10
C758 †
50μf
-47.5V ①
(DEC)
-45V
R757
180
C756
50μf
C757
50μf
D721
C724
.001
10V
REGULATED
R735
470
D724
+45V
(DEC) TO INPUT CF ①
C734
50μf
C735
50μf
Q710
2N2137
C714
.005
C715
.005
5V/DIV
.2 mSEC/DIV
R714
100K
B714
NE-2E
D714
D715
D717
D718
D719
HV TEST PT
R720
1M
+3350V
TO CRT ANODE ⑥
C716
.02
C717
.005
C720
.005
D716
R719
4.7K
-720V
TO CRT GUN ⑥
C719
0.1
R718
1M
ELEVATED TO -720V
6.3VAC
TO CRT HEATER ⑥
C718
.01
* LOCATED ON VERT AMP CHASSIS
NEAR INPUT CF, V423
** LOCATED ON HORIZ AMP CHASSIS
NEAR Q323
† LOCATED ON VERT AMP CHASSIS
NEAR Q874
REFERENCE DIAGRAMS:
① VERTICAL AMPLIFIER & CALIBRATOR
② TIME-BASE TRIGGER
⑤ HORIZONTAL AMPLIFIER
⑥ CRT CIRCUIT
MRH
1164



* DEPENDENT ON CONTROL SETTING & METER LOADING

REFERENCE DIAGRAMS
3 TIME-BASE GENERATOR
7 CONVERTER

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

MRH
1265

CRT CIRCUIT 8

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages. If it does not, your manual is correct as printed.

PARTS LIST CORRECTION

CHANGE TO:

R410C	323-0481-01	1 MΩ	1/2 W	1/2%
R410E	323-0193-01	1 kΩ	1/2 W	1/2%
R412C	323-0614-01	990 kΩ	1/2 W	1/2%
R412E	322-1289-01	10.1 kΩ	1/2 W	1/2%
R414C	323-0611-01	900 kΩ	1/2 W	1/2%
R414E	323-1389-01	111 kΩ	1/2 W	1/2%
R416C	323-0620-01	800 kΩ	1/2 W	1/2%
R416E	322-0614-01	250 kΩ	1/4 W	1/2%
R418C	322-0610-01	500 kΩ	1/4 W	1/2%
R418E	323-0481-01	1 MΩ	1/2 W	1/2%
R422	323-0481-01	1 MΩ	1/2 W	1/2%

TYPE 321A TENT SN 3030

PARTS LIST CORRECTION

CHANGE TO:

C160M	283-0148-00	470 pF	Cer	5%

MECHANICAL PARTS LIST CORRECTION

Page 7-14, STANDARD ACCESSORIES,

Change REF. NO. 1 to read:

010-0203-00	1	PROBE, package, P6012

TYPE 321A TENT SN 3290

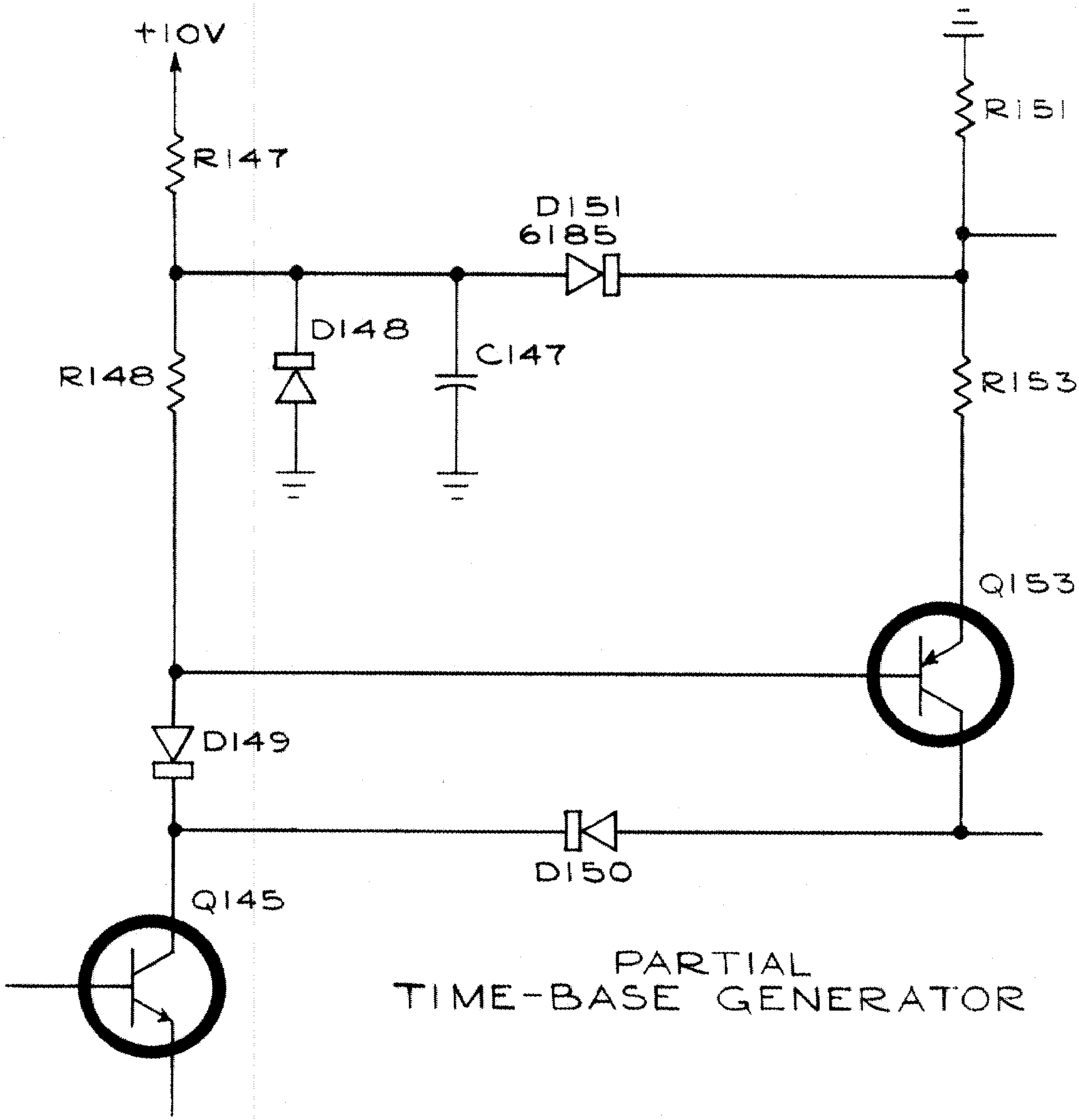
PARTS LIST CORRECTION

ADD:

D151	152-0185-00	Silicon	6185	
R160K	316-0186-00	18 meg	1/4 w	10 %

SCHEMATIC CORRECTION

R160K is added in parallel with R160J.



PARTIAL
TIME-BASE GENERATOR

M11,715/167