INSTRUCTION MANUAL

TYPE 321

OSCILLOSCOPE

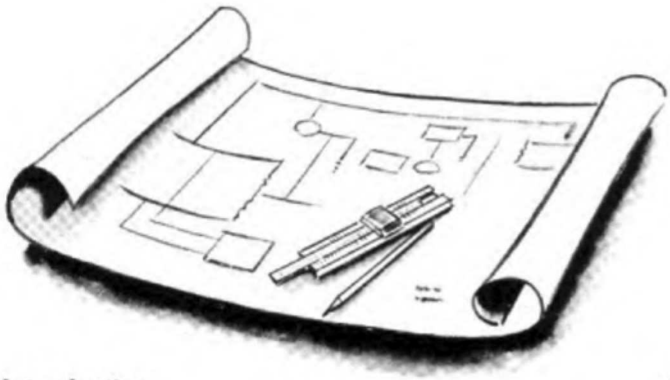
Tektronix, Inc.
S.W. Millikan Way ● P. O. Box 500 ● Beaverton, Oregon ● Phone MI 4-0161 ● Cables: Tektronix

Tektronix International A.G.
Terrassenweg 1A ● Zug, Switzerland ● PH. 042-49192 ● Cable: Tekintag, Zug Switzerland ● Telex 53.574

070-196

CONTENTS


TYPE 321 OSCILLOSCOPE
FOCUS
ASTIGMATISM
INTENSITY
SCALE ILLUM.
VERTICAL POSITION
HORIZONTAL POSITION
VERTICAL AMPLIFIER
VARIABLE VOLTS/DIV.
TIME BASE
VARIABLE TIME/DIV.
POWER ON
AC
DC
INPUT
DC BAL
CAL OUT 500 MV.
GND
STABILITY
TRIGGERING
INT.
EXT.
SLOPE
LEVEL
AUTO.
TEKTRONIX, INC.
PORTLAND, OREGON U.S.A.
SERIAL



SECTION 1

SPECIFICATIONS

Introduction

The Tektronix Type 321 is a transistorized, battery-operated portable oscilloscope. Its reliability, stability, light weight and small size makes it adaptable both as a field test oscilloscope and as a general purpose laboratory instrument.

Vertical Deflection System

Bandpass...DC to 5 mc.

Risetime . . . 0.07 μsecond.

Sensitivity . . . 0.01 v/div to 20 v/div in 11 calibrated steps, continuously variable from 0.01 v/div to 50 v/div.

Input Impedance . . . 40 pf paralleled by 1 megohm, 12 pf paralleled by 10 megohms when using P6003 (10X) probe.

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: 1 minor division vertical deflection.

External: 1.0 volts to 50 volts. Input impedance: 10 pf paralleled by 100 kilohms.

Sweep

Type...Miller Integrator.

Sweep Rates...0.5 μsec/div to 0.5 sec/div in 19 calibrated steps. Accurate 5-times sweep magnifier extends calibrated range to 0.1 μsec/div. Sweep time adjustable between steps and to 1 sec/div uncalibrated.

External Horizontal Input

Bandpass...DC to 1mc.

Sensitivity...1.5 v/div with sweep magnifier.

Input Impedance...20 pf paralleled by 100 kilohms.

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.

Cathode-Ray Tube

Type...Special Tektronix-manufactured T321. 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 1/4" 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 105 to 125 volts or 210 to 250 volts, rms, 50 to 800 cycles, single-phase ac.

Temperature Protection...Thermal cutout switch interrupts power if chassis temperature exceeds 120° F.

Optional...Built-in battery charger available as optional equipment.

Mechanical Specifications

Construction...Aluminum alloy chassis and cabinet.

Finish...Photo-etched anodized panel, blue vinyl-finish cabinet.

Dimensions...8 1/4" high, 5 3/4" wide, 16" deep.

Weight...13 1/2 lbs. without batteries; 16 lbs. with batteries.

Accessories

1...P6003 or P6022 Probe, 010-064

1...3-wire AC Power Cord, 161-015

1...3-wire Adapter, 103-013

1...3-wire DC Power Cord, 161-016

1...Green Filter, 378-521

2...Instruction Manuals

SECTION 2

PRELIMINARY INSTRUCTIONS

Power Requirements

The regulated power supplies in the Type 321 will operate from a 117-v or 234-v rms ac line, from an external dc source (11.5 to 35 volts), 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 (117 v or 234 v).

AC Operation

Unless tagged otherwise your instrument is connected at the factory for operation at 105 to 125 volts, 50 to 800 cycles ac (117 volts nominal). However, provisions are made for easy conversion to operate at 210 to 250 volts, 50 to 800 cycles (234 volts nominal). The power transformer T601 is provided with split input windings which are normally connected in parallel for 117-volt operation, but which can be connected in series for 234-volt operation.

The primary windings are marked 1, 2, 3 and 4. Terminals 1 and 3 are connected to one winding and terminals 2 and 4 are connected to the second winding. The ac input leads are connected to terminals 1 and 4 for both 117-volt and 234-volt operation, so these connections do not have to be changed when converting from one line voltage to the other.

When wired for 117-volt operation terminals 1 and 2 are joined by a bare bus wire, and terminals 3 and 4 are similarly joined, as shown in Fig. 2-1(a). To convert to 234-volt operation remove the bare bus wires between these terminals and substitute a single connecting wire between terminals 2 and 3, as shown in Fig. 2-1(b).

DC Operation

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 23-volt operation, the black (+) and white (—) leads are connected to the voltage source; for 22- to 35-volt operation, the green (+) and white (—) leads are connected to the voltage source.

Battery Operation

Operation from the internal battery source can be accomplished by using:

1. Ten size D flashlight cells (approximately ½ hour continuous ((more with intermittent)) operation), or
2. Ten rechargeable cells, 2.5 AH, (approximately 3 hours continuous operation), or

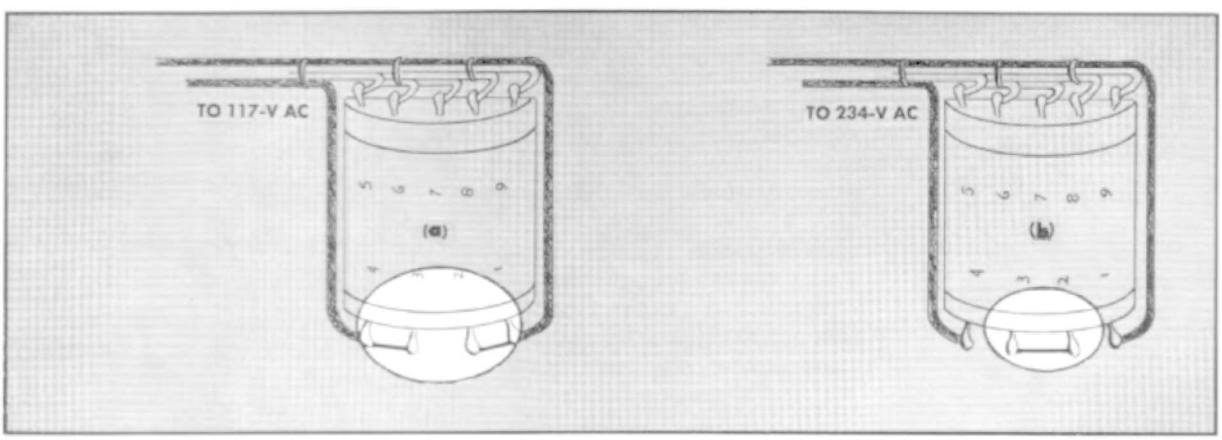


Fig. 2-1. (a) Transformer connection for operation from 105-125 volt ac line; (b) connections for operation from 210-250 volt ac line.

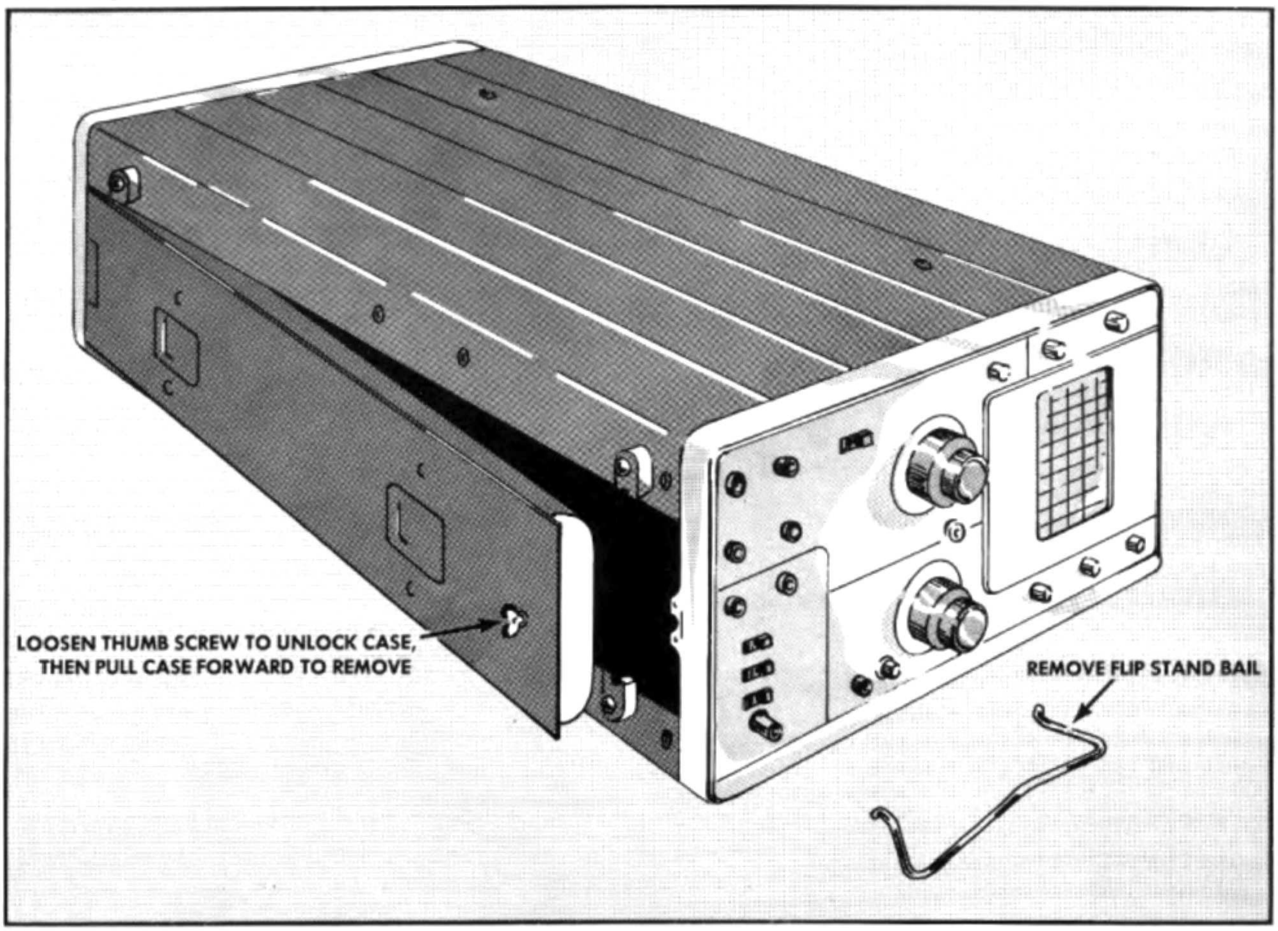


Fig. 2-2. Removing the battery case from the Type 321 Oscilloscope.

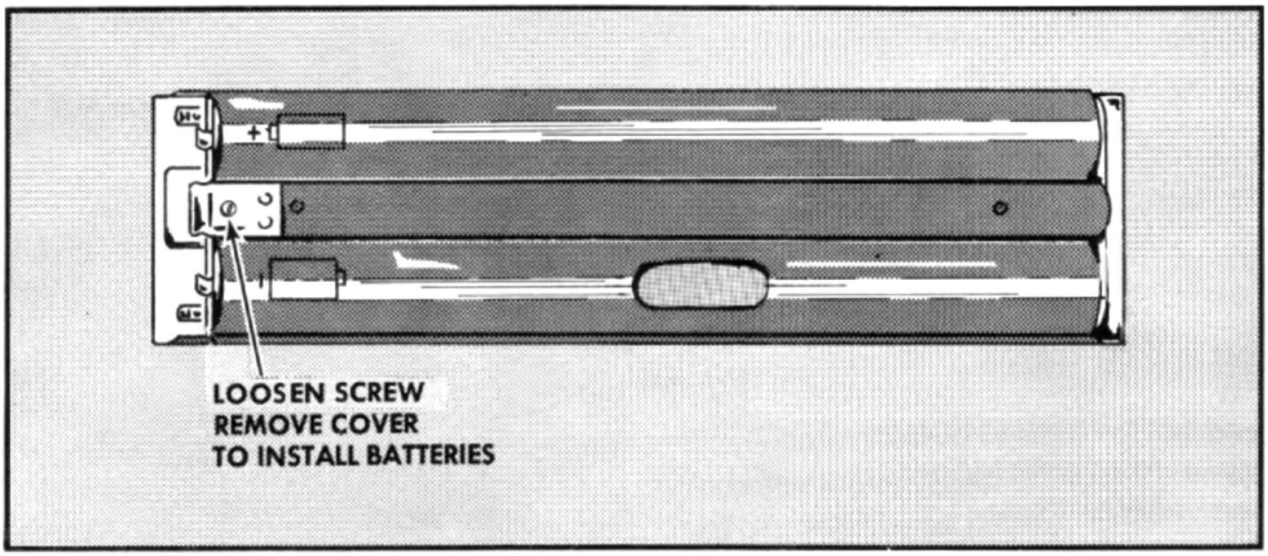


Fig. 2-3. Battery case illustrating correct polarity for installing batteries.

3. Ten rechargeable cells, 4 AH, (approximately 5 hours continuous operation). The 4-AH batteries make a more practical power supply for the Type 321, due to the longer "playing time".

A battery case is furnished with the Type 321. To install the cells, first remove the battery case as illustrated in Fig. 2-2. Then remove the cover shown in Fig. 2-3 and install five cells in each side.

CAUTION

Be sure to observe cell polarity indicated on the battery case.

Battery Charger

The Battery Charger will operate as long as the ac power cord is connected to an ac line. When the POWER switch is turned ON, a trickle charge of about 30 ma maintains the cells at their existing state of charge. When the POWER switch is turned off, the Charger is connected across the battery for full charge.

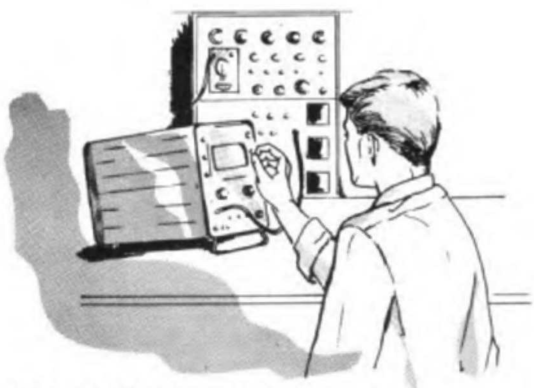
A Charger switch is provided to select the proper charging current for the type of battery being used in the Type 321. When dry cells are being used in the instrument, the switch should be set to the DRY CELL position. In this position, the charging circuit is opened up and no charging current flows. When 2.5-AH rechargeable cells are being used, the switch should be set in the 2.5 AH position. This provides a charging current of 200 ma through the battery. When 4-AH cells are being used, the switch should be set to the 4 AH position. This provides a charging current of 400 ma through the battery.

Preliminary Instructions — Type 321

The battery will withstand normal charging current for extended periods of time, however sixteen hours of charge should be adequate for either type of battery at the currents provided. Placing the Charging switch in the DRY CELL position, or removing the ac power from the Type 321, will stop the charging action.

Fuse Data

Use only the recommended fuses in the Type 321 Oscilloscope. The upper fuse (F601) is .25-amp 3AG Fast-Blo; the lower fuse (F621) is a 1.5-amp 3AG Fast-Blo. Neither fuse needs to be changed if the instrument is converted from one line voltage to the other (117 v and 234 v).



SECTION 3

OPERATING INSTRUCTIONS

General Information

The Type 321 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 321. 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 321 is shown in Fig. 3-1.

Intensity Control

Then INTENSITY control is used to adjust the trace brightness. This permits you to adjust the trace intensity to suit the ambient light conditions, and to adjust for 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 321 is accurately marked with 10 horizontal and 6 vertical divisions, with .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 rotating the control counterclockwise 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 321 Oscilloscope to position the trace or spot on the screen.

The HORIZONTAL POSITION control moves the trace to the right when it is rotated in the clockwise direction 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 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 when the control is rotated counterclockwise.

Intensity Modulation

The crt display of the Type 321 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.

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

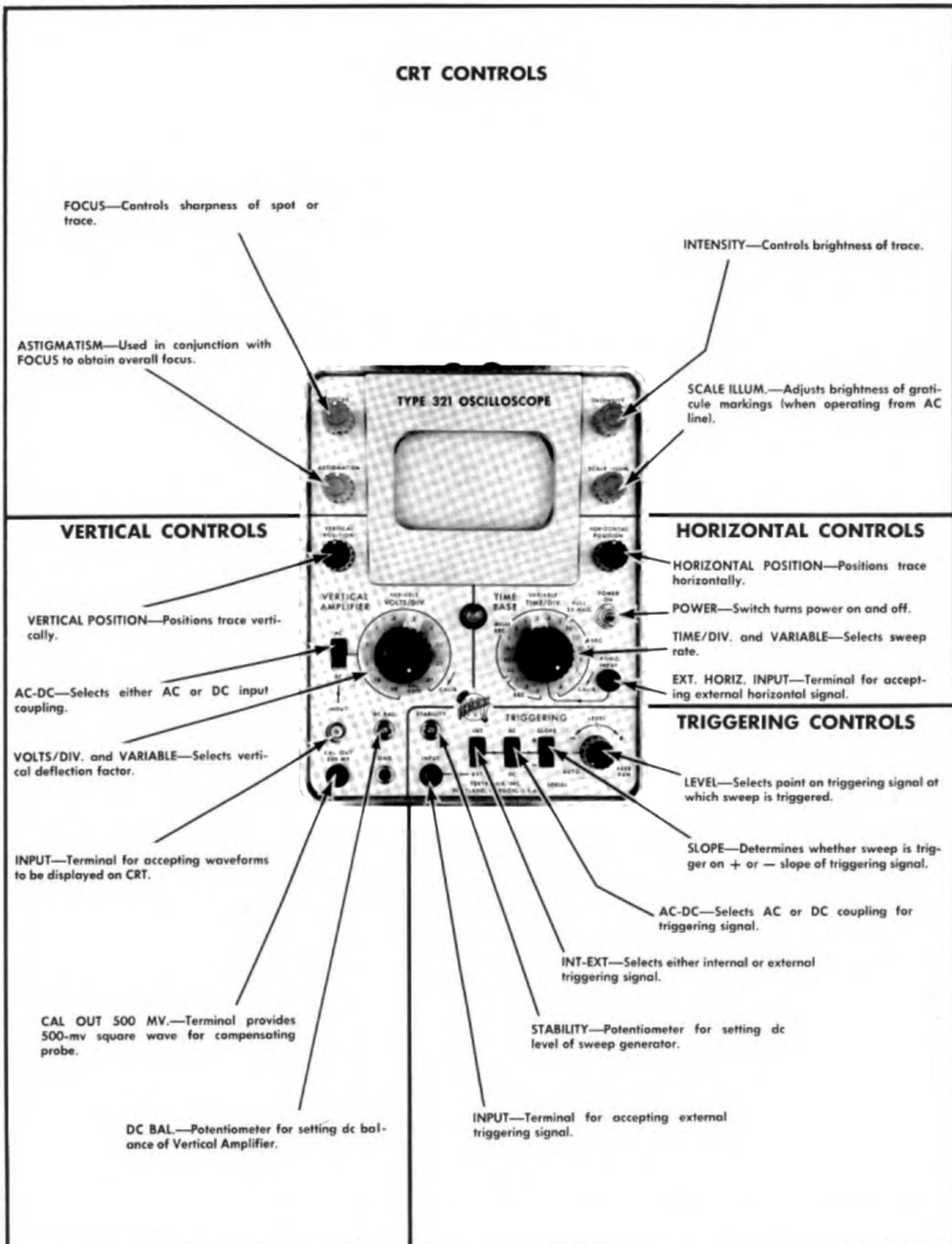


Fig. 3-1. Functions of the Type 321 Oscilloscope front-panel controls.

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 that 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 speed, 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.

The Time Base has 19 accurately calibrated sweep speeds ranging from .5 μsec/div to .5 sec/div. These calibrated sweep speeds are obtained when the VARIABLE TIME/DIV. control is fully clockwise in the CALIB. position. The VARIABLE control permits you to vary the sweep speed continuously between .5 μsec/div and approximately 2 sec/div. All sweep speeds obtained with the VARIABLE control in any position other than fully clockwise are uncalibrated.

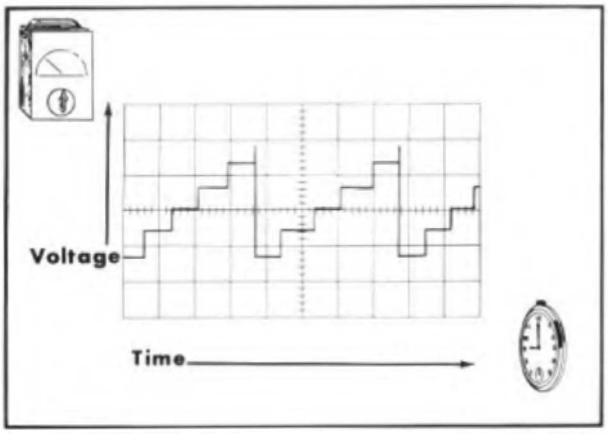


Fig. 3-2. The oscilloscope plots instantaneous voltage versus time, thereby serving both as a voltmeter and a timer.

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 5X MAG. switch in the on position (pull out the red VARIABLE TIME/DIV. knob; see Fig. 3-3). Any portion of the original unmagnified display can then be observed by rotating the HORIZONTAL POSITION control.

In magnified sweep operation, the sweep speed indicated by the position of the TIME/DIV. control must be divided by 5 to obtain the actual time required for the spot to move one division. For example, if the TIME/DIV. control 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.

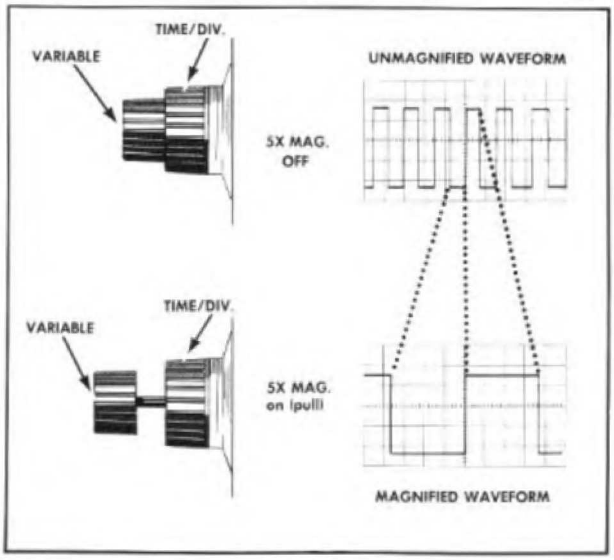


Fig. 3-3. Operation of the sweep magnifier.

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 an 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 1.5 volts/division with the 5X MAG. on.

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 at 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 321, 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.

Selecting the Triggering Source

In preparing the Type 321 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. Satisfatcory 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 trigggering 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.

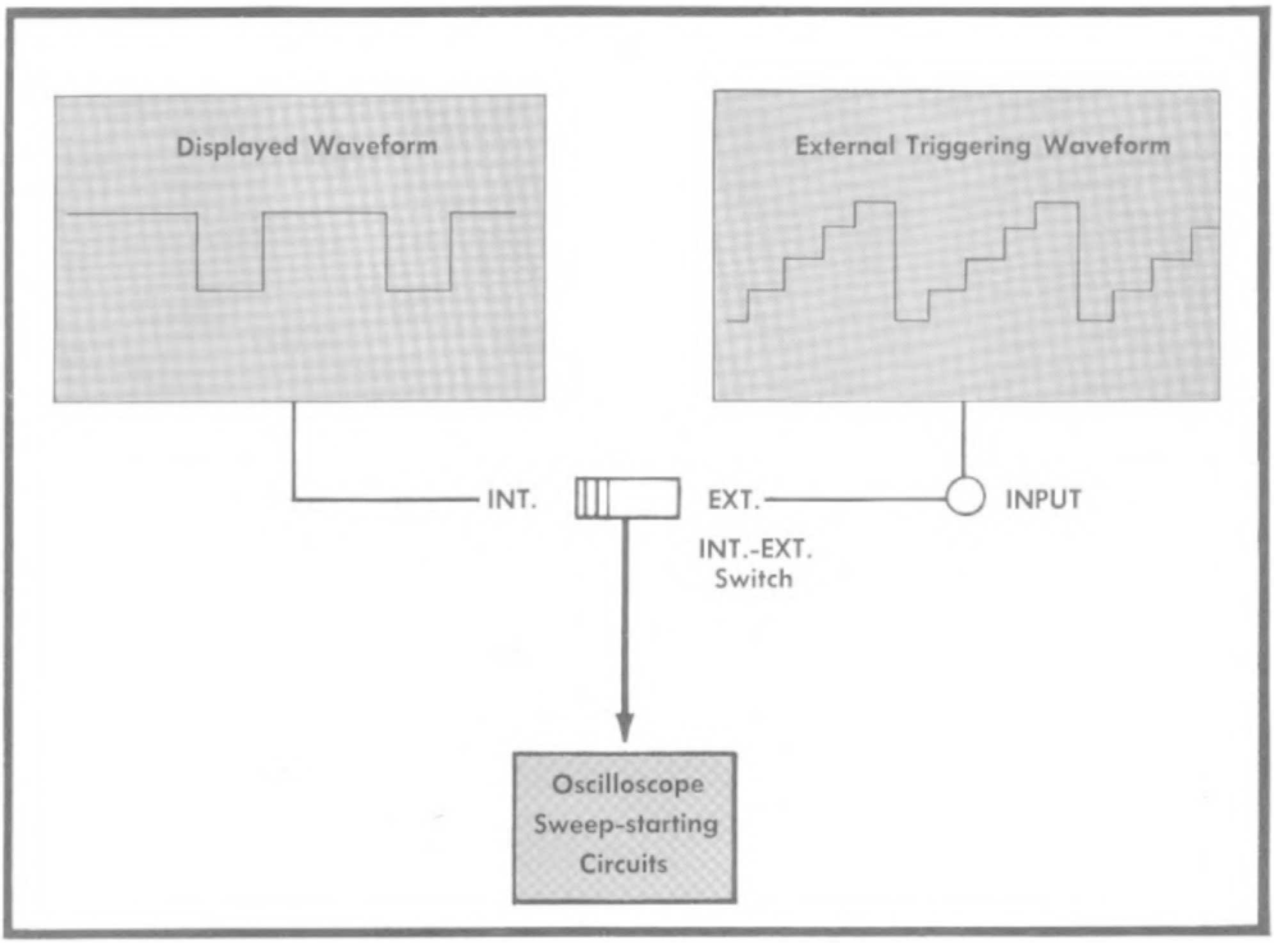


Fig. 3-4. The triggering signal is selected from two possible sources with the INT.-EXT. switch.

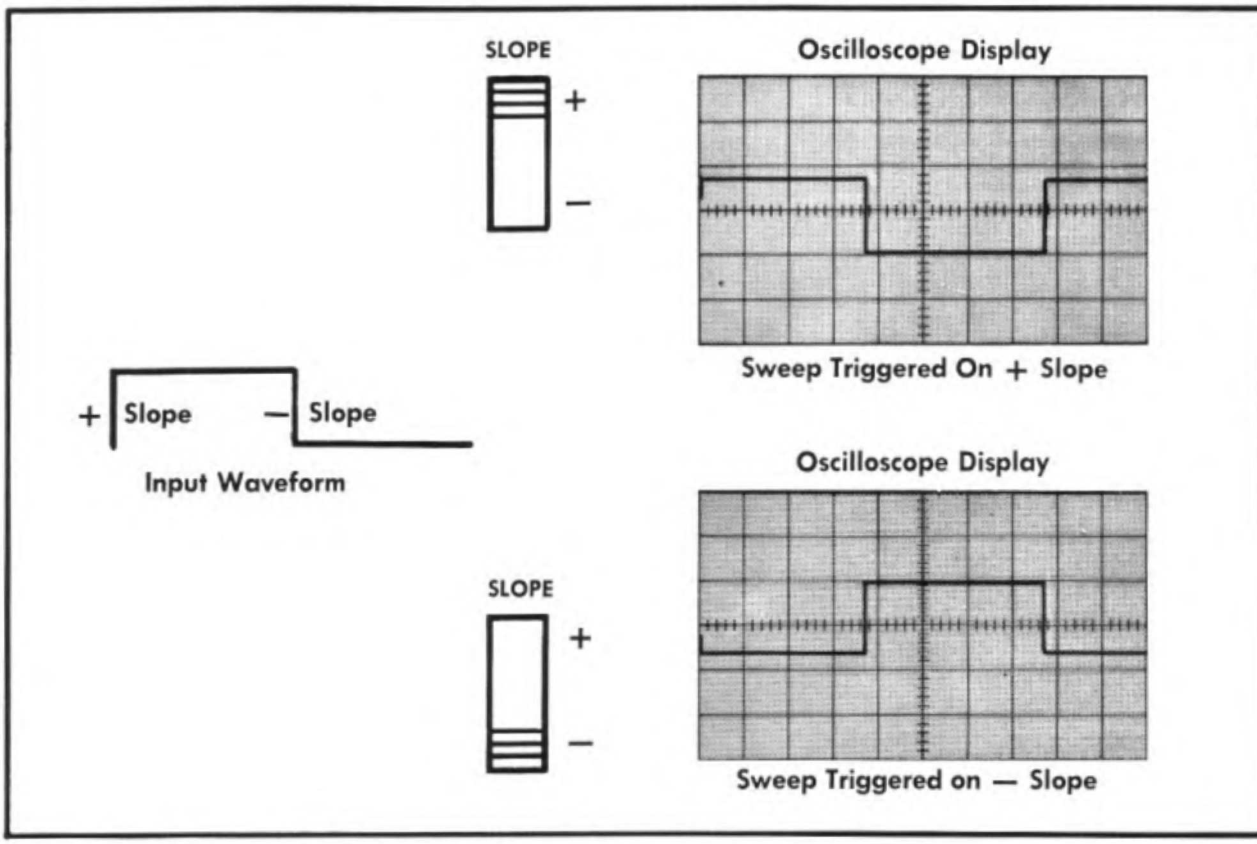


Fig. 3-5. Effects on the oscilloscope display produced by + and — settings of the SLOPE switch.

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.

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 also vary. 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 occurance 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. If you desire 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. 3-6).

FREE-RUNNING OPERATION

With the Type 321, 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 switch in the appropriate position. DC coupling applies both the ac and dc components of the input signal to the vertical amplifier circuit. This permits you to measure 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 ac coupling should be used. 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.

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 variable deflection factors between the fixed steps of the VOLTS/DIV. control.

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

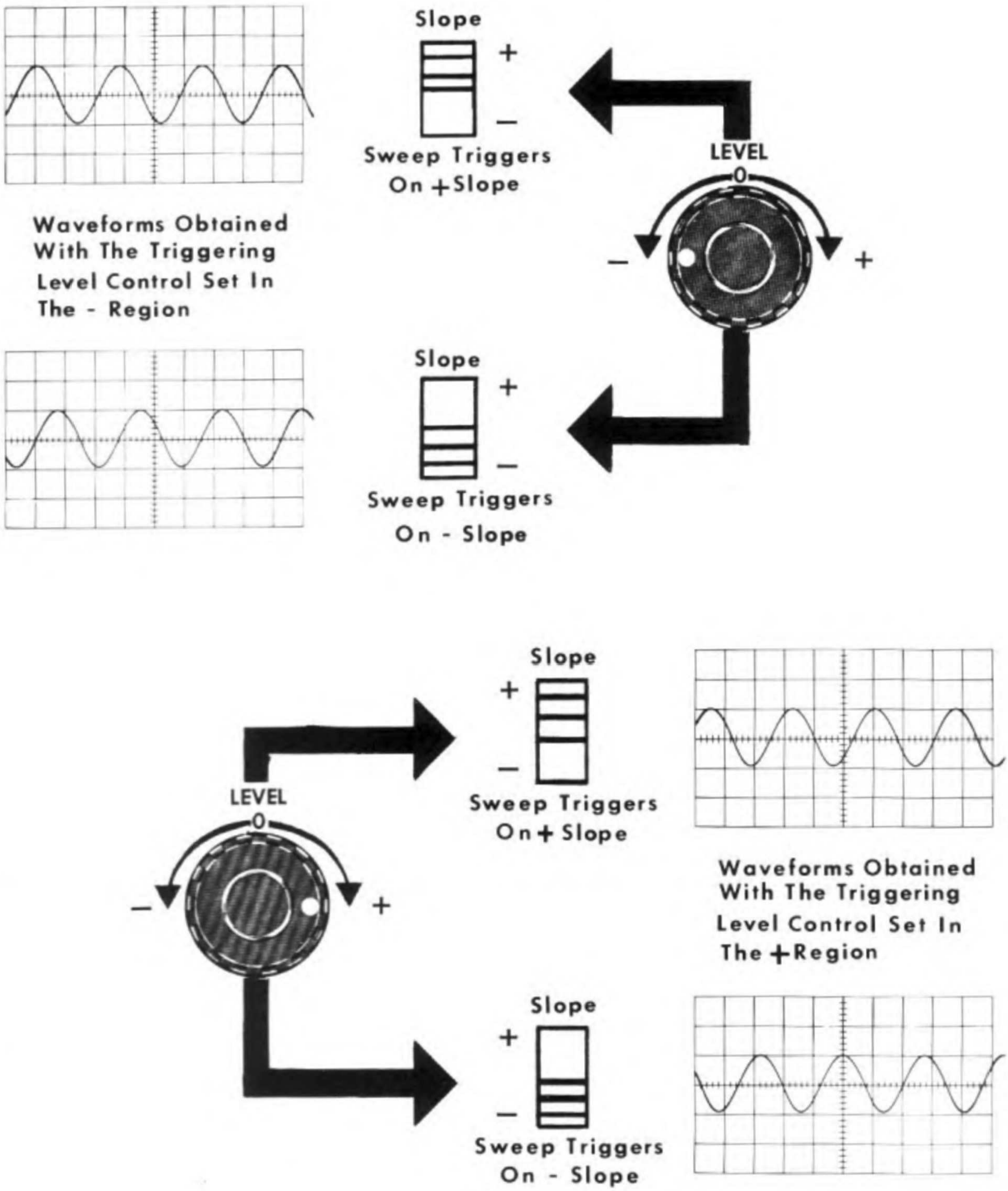


Fig. 3-6. Effects on the oscilloscope display produced by + and — settings of the LEVEL control.

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. With no signal connected to the INPUT connector, set the oscilloscope controls for a free-running trace.

2. 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 the 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 stray 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.

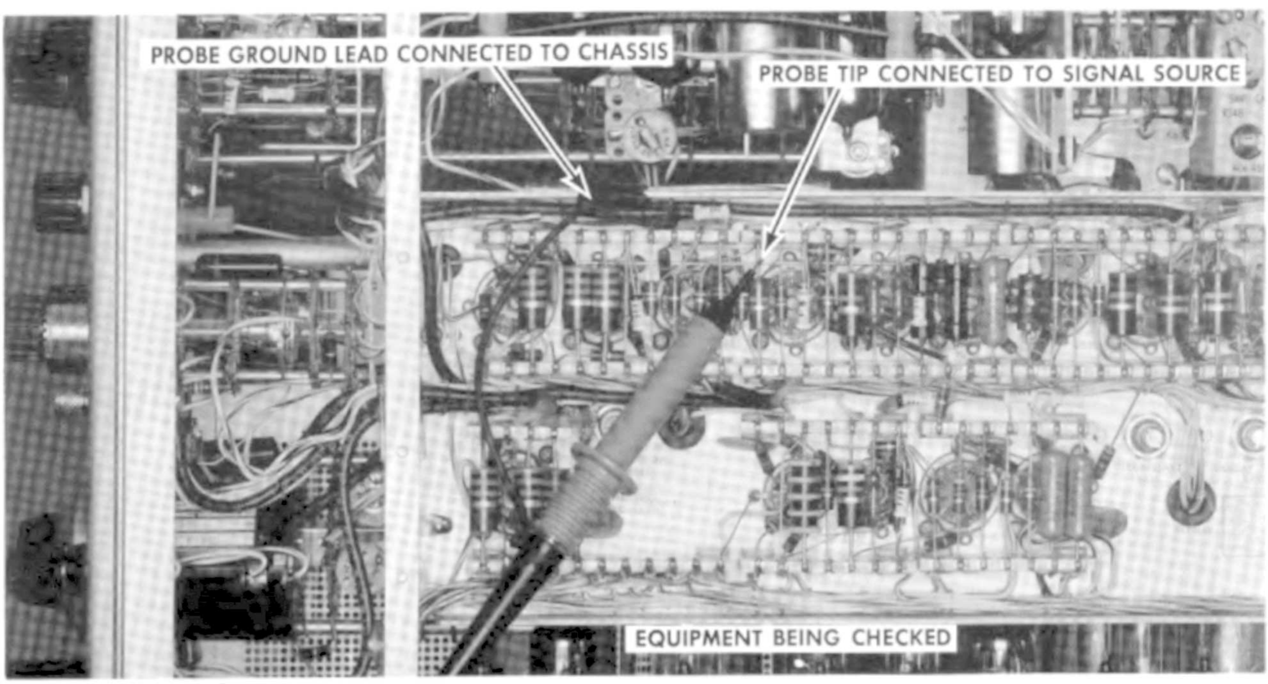


Fig. 3-7. Connecting a probe to the input signal source

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 which are 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. 3-7.

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 control, set the VOLTS/DIV. control to the .01 position and the LEVEL control to the AUTO. position. Set the SLOPE switch to + and 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. 3-8).

Voltage Measurements

The Type 321 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 type of voltage measurements, i.e., ac-component voltage measurements, and 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

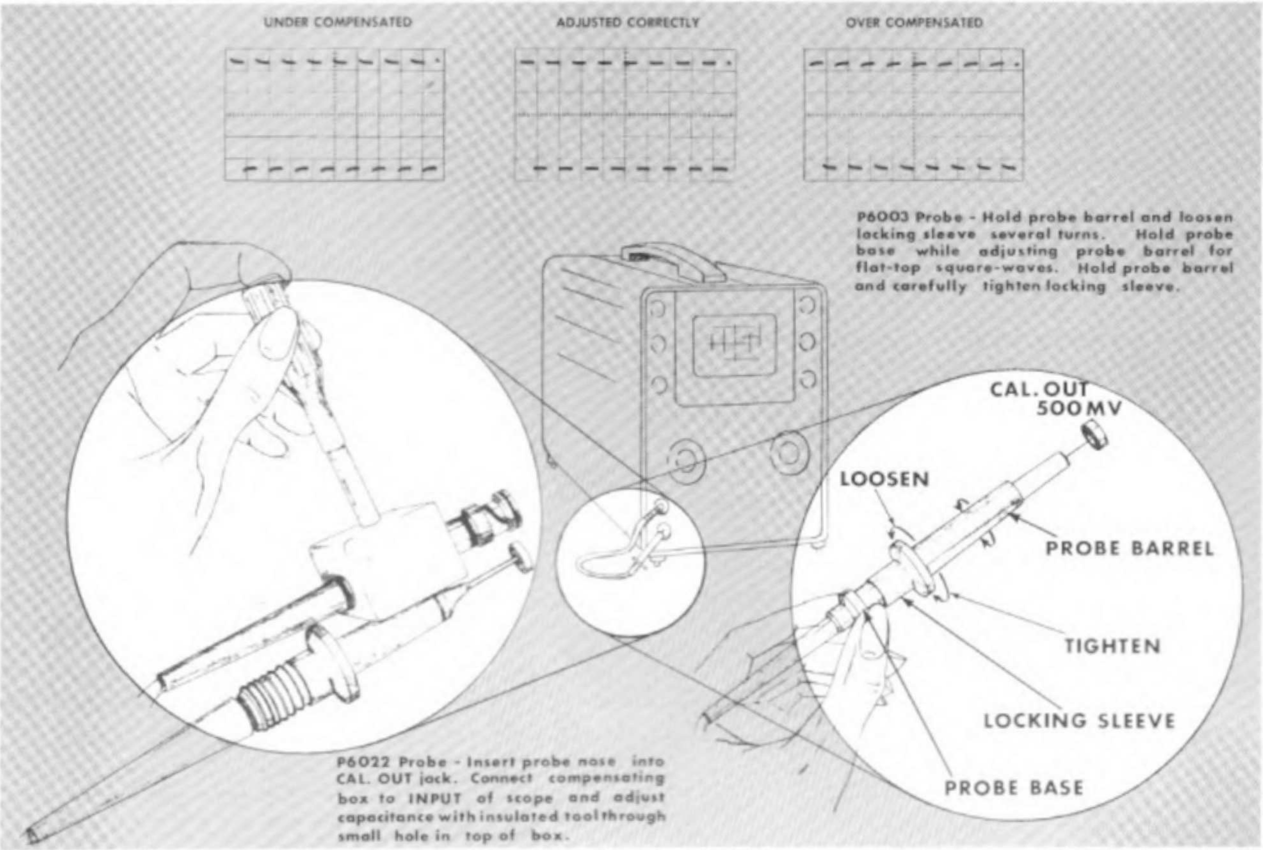


Fig. 3-8. The probe is adjusted to obtain an undistorted presentation of the calibrator square-wave.

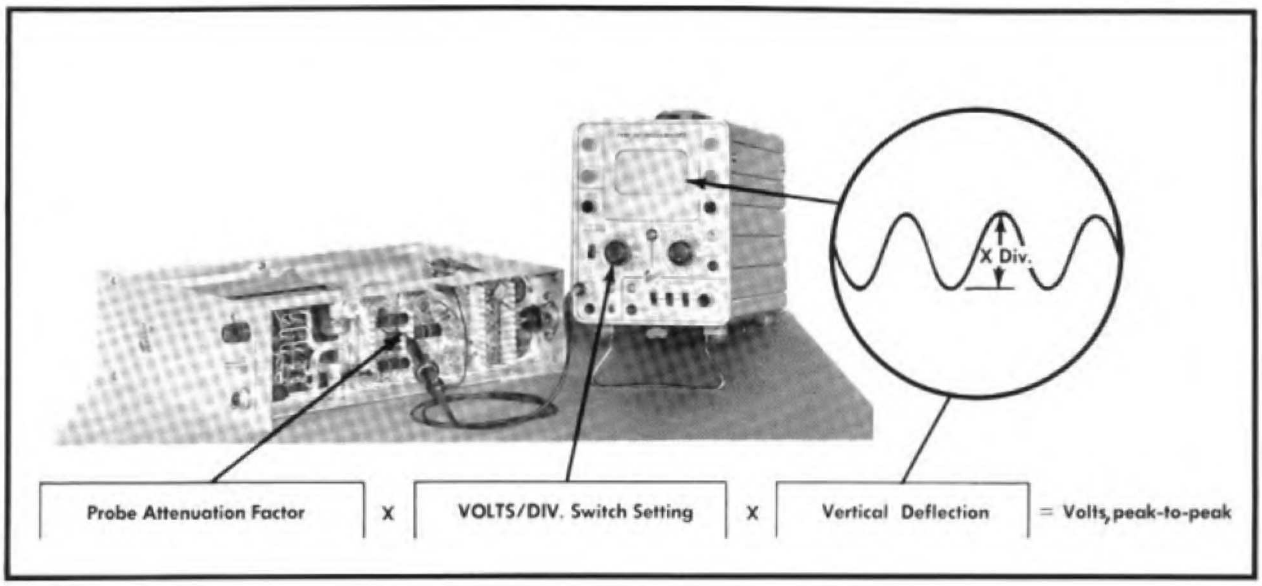


Fig. 3-9. Measuring the peak-to-peak ac voltage of an applied waveform.

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. position.

AC Component Voltage Measurement

To measure the ac component of a waveform, the AC-DC 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 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. 3-9).

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 P6003 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 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 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 instantaneous voltage measurement with respect to ground, perform the following steps (see Fig. 3-10).

1. To establish the voltage reference line, touch the probe tip to an oscilloscope ground (or if the reference line is to represent a voltage other than ground, then to a source of that voltage) and 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

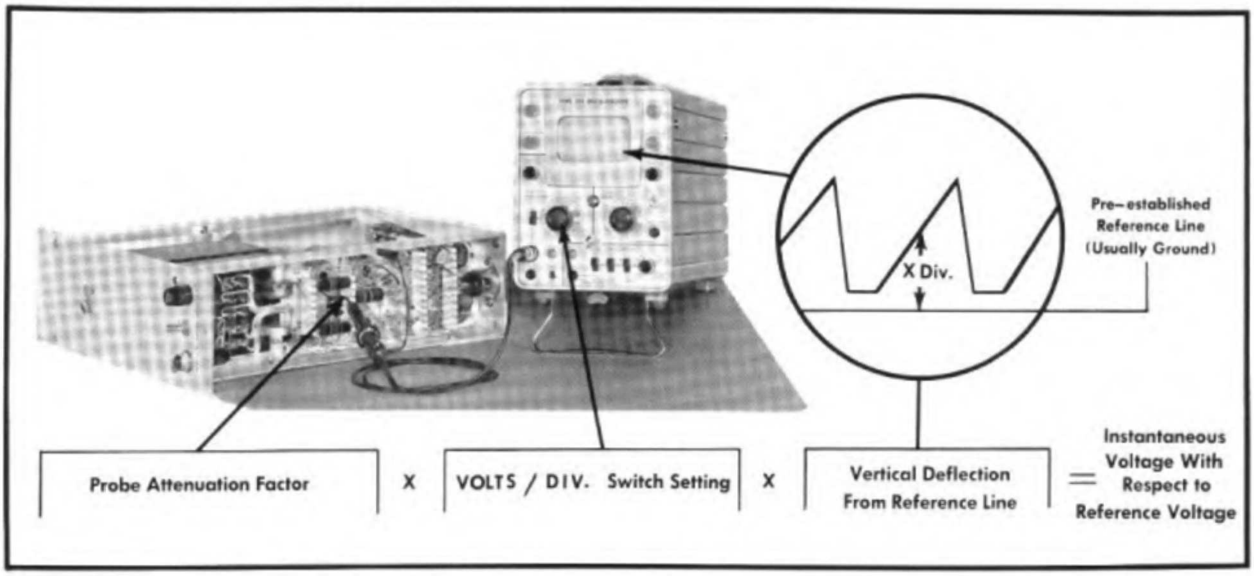


Fig. 3-10. Measuring the instantaneous voltage with respect to ground (or some other reference voltage).

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.)

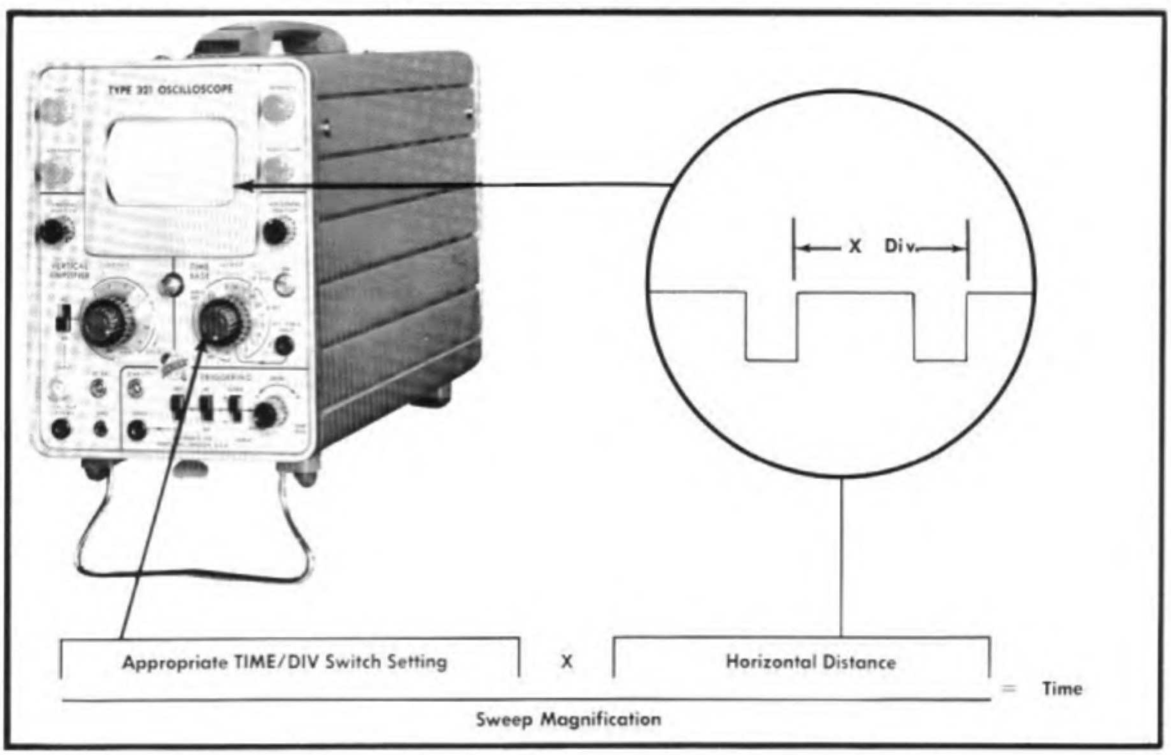


Fig. 3-11. Measuring time interval between events displayed on the oscilloscope screen.

2. Remove the probe tip from ground and connect it to the signal source. Adjust the LEVEL control for a stable display.

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 P6003 probe and a deflection factor of .2 volt per division. After setting the voltage reference line at the second from the bottom division of the graticule, you measure a distance of 3 divisions to the point you wish to check. In this case, then 3 divisions multiplied by .2 volts per division gives you an indicated .6 volts. 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 321 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. 3-11).

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

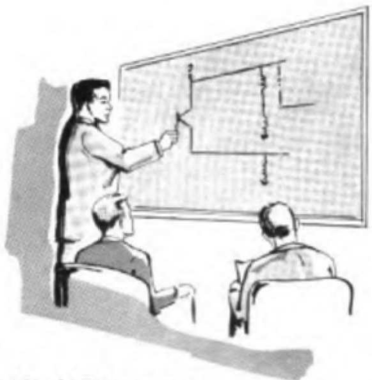
2. Multiply the distance measured by the setting of the TIME/DIV. control to obtain the apparent time interval. (The VARIABLE TIME/DIV. control must be in the CALIB. position).

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

For example, assume the TIME/DIV. switch setting is 1 MILLI SEC, the magnifier is on, and you measure a horizontal distance of 5 divisions 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 Measurement

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 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 (Parts List and Schematic Diagrams Booklet) shows the main sections of the Type 321 Oscilloscope. Wavefroms to be displayed are connected to the Vertical 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 Trigger 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 to the 5X 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 square wave, peak-to-peak, 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 turned full right to the CALIB. 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 321 will operate from a 117-v or a 234-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 (117 v or 234 v).

VERTICAL AMPLIFIER

Input Coupling

Input signals to the Vertical Amplifier can be either ac- or dc-coupled. When the AC-DC 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.

Input Circuit

The Vertical Amplifier requires an input signal of .01 volts, 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 .01 volt for each division of crt deflection when the VARIABLE knob is in the CALIB. 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 capacitance 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 capacitance so that it is the same value (approximately 40 pf) for all settings of the switch.

Input C.F.

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 E.F.

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 Amplifier 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 amplifier. 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 amplifier (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 GAIN ADJ. R468, an internal screwdriver-adjust potentiometer. Both controls vary the emitter degeneration and thus affect the gain of the stage. The GAIN ADJ. control is adjusted so that the amount of crt deflection agrees with setting of the VOLTS/DIV. switch when the VARIABLE control is turned full right to the CALIB. 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 volts and −10 volts. It is connected electrically so that as the voltage at one arm changes in the positive direction the voltage at the other arm changes in the negative direction. This causes the voltage at the base of Q483 to change in the opposite direction to the voltage at the base of Q493. The change in base voltage at the second E.F. (emitter-follower) stage will be reflected as a change in deflection voltage at the crt, since direct coupling is employed between these two points.

The Second E.F. state 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. There are two time-constant networks connected between the two emitters.

In instruments S/N 101-1880, one network consists of R507, R508, C507 and C508. This is an extremely short time-constant network (a fraction of a microsecond) and affects only fast-rise signals. The capacitive branch of this network offers less degeneration at high frequencies and thus improves the high-frequency response of the stage. The amount of high-frequency compensation can be adjusted by means of variable capacitor C508. On instruments S/N 1881 and up, an additional network has been added, consisting of diodes D506 and D507, connected back to back across R509 in series with 507. This additional network reduces compensation at the upper and lower deflection limits of the CRT by acting as an automatic gain control for signals at extremes of high and low amplitude.

The other time-constant network consists of R517, R518 and C518. This is a much longer time-constant network, and compensates for the thermal time-constant of the transistors. At dc and extremely low frequencies the impedance of C518 is so high that the effect of this network is negligible. Above this range, however, the impedance of C518 decreases and the shunting resistance of R517 and R518 decreases the degeneration slightly. R518, the LF COMP. control, is used to adjust the time-constant for optimum results.

The dc level of the Output Amplifier is established, in part, by the divider between the collector of the Input Amplifier and the base of the Second E.F. (R463 and R464 on one side and R473 and R474 on the other). These dividers help set the 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 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 Amplifier diagram) receives a sample of the vertical-output signal from the collector circuit of Q514. The amplified signal at the collector 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

The Trigger Multivibrator 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 reaches 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, which pulls down 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 will occur. Q35 will cut off and its collector voltage will rise. This will pull the base Q45 out of cutoff and Q45 will conduct. 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 voltage, 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 adjustable by means of the LEVEL control. With this configuration Q14-Q24 is an emitter-coupled 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. This eliminates Q14 from the amplifier circuit and Q24 becomes a collector-loaded amplifier. The output signal will therefore be 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 hysterisis of the Trigger Multivibrator is determined by the dividers in the base circuit of each transistor. The quiescent state of the Trigger-Input Amplifier is such that the collector voltage of Q24 is about in the center of the hysterisis 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 quiescent voltage at the collector of Q24, within the hysterisis 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) C30 is connected into the circuit; (b) the LEVEL control R17 is disconnected from 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 the FREE RUN position of the LEVEL control; in the latter position the Time-Base Generator free-runs).

The addition of C30 to the circuit causes the Trigger Multivibrator to free-run in the absence of a triggering signal. For example, assume the base of Q35 is just being driven into cutoff; the voltage at the collector of Q35 then starts to rise. The rise in collector voltage is coupled back to the base of Q35 through R32. However, the voltage at the base of Q35 cannot rise immediately, following the collector. The addition of C30 makes the time-constant such that it takes about 10 milliseconds for the voltage at the base to rise exponentially from its starting point, below cutoff, to a point where collector current can start.

As Q35 starts conducting its collector voltage drops. The base voltage will then start falling exponentially. When the base voltage falls below cutoff, the circuit will have completed one cycle of its approximately 50-cycle output.

With the circuit configuration just described, the sweep can be triggered with repetitive signals, over a wide range of frequencies, without readjustment. When not receiving triggers, the sweep continues at approximately a 50-cycle rate. Thus, in the absence of any triggering signal 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 collector 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 starts 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 linearily, and the voltage at the emitter of Q173 increases linearily (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 selected 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 +45v and +10 v, which varies the sweep rate over about a 4 to 1 range.

The SLOW SWP. ADJ. R167 is adjusted to regulate the current through Q163 so that no base current flows through R161 at slower sweep rates. The capacitor current is small at slow sweeps, and any base current other than that in R162 will affect the timing. R167 is adjustable to accommodate variations in transistors.

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 discharge 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 retrace 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 through 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 discharged 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 hysterisis 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 cutoff, however, that positive triggers can pull Q135 out of cutoff and force the multivibrator into its other state to initiate 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 the 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 the 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 321 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 unblanking 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 fore 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 across R338 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 321 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 117-v or a 234-v rms, 50-800 cycle ac line.

The ac rectifier is the conventional full-wave type, with a capacitor-input filter. The primary of the power transformer T601 has split input windings; these may be connected in parallel for operation from a 105-125 volt line, or in series for a 210-250 volt line.

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 23-v operation, the black (+) and white (—) leads are connected to the voltage source; for 22- to 35-v, the green (+) and white (—) leads are connected to the source.

Automatic Voltage Selection

The operation of the power-input circuit is unique in that if all three sources of power (ac, external dc or battery) are connected to the instrument, the one providing the highest voltage will automatically be connected to the Regulator. This is accomplished by the action of the "disconnect" diodes D620, D621 and D622.

For example, the ac rectifier is designed to provide a voltage of about 16 volts across C620 at normal line voltages. This will back-bias D621 by at least 2 volts (since the full-charge voltage of the batteries is about 14 volts) and disconnect the batteries from the circuit. And, if the voltage on the external dc bus is less than 16 volts, D622 will also be back-biased. However, should the voltage on the external dc bus exceed 16 volts, D620 will then be back-biased and the ac supply will be disconnected from the regulator circuit.

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 is furnished by the Zener diode D629. This diode provides a constant dc voltage of about +6.2 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 voltage across C620 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 321 is connected to a source of ac power and the POWER switch is turned off, 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 Charger switch is in the 2.5 AH position, 200 ma will flow through the battery. When the Charging switch is in the 4 AH position, 400 ma will flow through the battery. When the Charger switch is in the DRY CELL position, the circuit is opened up and no current will flow.

When the POWER switch is turned ON, R694 is inserted in series with R692 and/or R693 and the current is limited to about 30 ma, just enough to maintain the existing charge on the cells.

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 differences 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 trapezodial in shape; the secondary voltage is therefore a square wave. A full-wave rectifier with capacitor-input filters provides dc output voltages of —45, —10, +6.3, +10 and +45 volts. An additional half-wave rectifier circuit provides —720 volts for the crt gun.

A square wave 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 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 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.

SECTION 5

MAINTENANCE

PREVENTIVE MAINTENANCE

Recalibration

The Type 321 Oscilloscope is a stable instrument and will provide many hours of trouble-free operation. To insure the reliability of measurements obtained on the Type 321 however, we suggest its calibration be checked after each 500 hours of operation, or at least every six months if used intermittently. A check of the calibration also provides a means for checking the operation of each circuit. Minor operational deficiencies that are not apparent in normal use are often detected during a calibration check.

A complete step by step procedure for checking the calibration of the instrument is included in the Recalibration Procedure section of this manual.

Soldering Precautions

In the production of Tektronix instruments a special silver-bearing solder is used to establish a bond to the ceramic terminal strips. This bond may be broken by repeated use of ordinary tin-lead solder, or by excessive heating of the terminal strip with a soldering iron. However, occasional use of ordinary solder will not break the bond if too much heat is not applied.

In those shops responsible for the maintenance of several Tektronix instruments it is advisable to have a stock of solder containing about 3% silver. This type of solder is used frequently in printed-circuit work and is generally available. Or it can be purchased from Tektronix in one-pound rolls; order by part number 251-514.

REMOVAL AND REPLACEMENT OF PARTS

General Information

Procedures required for replacement of most parts in the Type 321 Oscilloscope are obvious. Detailed instructions for their removal are therefore not required. Other parts, however, can best be removed if a definite procedure is followed. Instructions for removal of some of these parts are contained in the following paragraphs. Because of the nature of the instrument, replacement of certain parts will require that you recalibrate portions of the oscilloscope to insure proper operation (refer to the Recalibration Procedure portion of this manual).

Removal of Panels

The panels of the Type 321 Oscilloscope are held in place by small screwhead fasteners. To remove the side panels, use a screwdriver to rotate the fasteners approximately two turns counterclockwise; then pull the upper portion of the panel outward from the carrying handles. Panels are replaced by reversing the order of their removal.

To remove the battery case, turn fastener at the front one-quarter turn and pull front end out for a short distance. Then slide the battery case forward to clear the clips at the rear end (see Fig. 2-2).

Replacement of the Cathode-Ray Tube

To remove the crt, first disconnect the tube socket and all leads connected to the neck of the tube. Loosen the tube clamp at the base of the crt and remove the graticule cover and graticule. Pull the crt straight out through the front panel. When the new crt is in place, the leads can be properly connected to the neck of the tube by following the color code information provided on the tube shield. After replacement of the crt, it will be necessary to check the calibration of the oscilloscope.

Replacement of Switches

Methods for removal of defective switches are, for the most part, obvious and only a normal amount of care is required. Single wafers are normally not replaced on the switches. If one wafer is defective the entire switch should be replaced. Switches can be ordered from Tektronix either wired or unwired, as desired.

REPLACEMENT PARTS

Standard Parts

Replacement parts can be obtained from Tektronix at current net prices. However, since most of the components are standard parts they can usually be purchased locally. Before ordering or purchasing parts, be sure to consult the Parts List to determine the tolerances required.

Selected Transistors

To obtain maximum reliability and performance, some of the transistors in the Type 321 are checked for certain characteristics. Specially selected transistors are identified with a part number beginning with 153-______.

These transistors are selected for certain collector-to-emitter breakdown voltages. For replacement purposes we suggest that you obtain these specially selected transistors from the local Tektronix field office.

Tektronix-Manufactured Parts

Tektronix manufactures almost all of the mechanical parts, and some of the electronic components, used in your instrument. When ordering mechanical parts, be sure to describe the part completely to prevent delays in filling your order.

The Tektronix-manufactured electronic components are so noted in the parts list. These components, as well as the mechanical parts, must be obtained from the factory or from the local Tektronix Field Engineering Office.

Parts Ordering Information

Each component in this instrument has a six-digit Tektronix part number. This number, together with a description of the part, will be found in the Parts List. To expedite filling your order be sure to include the following information when ordering parts:

1. A description of the part.
2. The part number.
3. The instrument type and serial number.

For example, a certain resistor should be ordered as follow: R650, a 470Ω, 1/4 watt, Fixed, Comp., resistor, tolerance 10%, part number 316-471 for a Type 321 Oscilloscope, serial number______. When parts are ordered in this manner we are able to fill the order promptly and delays that might result from transposed digits in the part number are avoided.

NOTE

Always include the instrument TYPE and SERIAL NUMBER in any correspondence concerning this instrument.

Since the production of this instrument some of the components may have been superceded with newer, improved components. If we receive an order for a component that has been superceded by a newer one, the new one will be shipped in place of the original. All Tektronix field offices have knowledge of these changes, and your local Field Engineer may call you if a change in your purchase order is necessary.

Replacement information notes sometimes accompany the new components to aid in thier installation.

TROUBLESHOOTING PROCEDURE

This section of the manual contains information for troubleshooting the Type 321 Oscilloscope. Before attempting to troubleshoot the instrument, however, make sure that any apparent trouble is actually due to a malfunction within the instrument and not due to improper control settings. Operating instructions for the Type 321, and general information concerning batteries and battery chargers, are contained in other sections of this manual.

The component number of each resistor, inductor, capacitor, transistor, vacuum tube, control and switch is shown on the circuit diagrams. The following chart lists the component numbers associated with each circuit.

All numbers less than 100	Time-Base Trigger
All 100 numbers	Time-Base Generator
All 300 numbers	Horizontal Amplifier
All 400 and 500 numbers	Vertical Amplifier
All 600 numbers	Regulator Circuit & Charger
All 700 numbers	Converter Circuit
All 800 numbers	CRT Circuit and Calibrator

CIRCUIT TROUBLESHOOTING

Although the Type 321 is a complex instrument, it can be thought of as consisting of seven main circuits, in addition to the calibrator circuit and battery charger. These are the

1. Regulator Circuit
2. Converter Circuit

3. CRT Circuit and High-Voltage Supply
4. Vertical Amplifier
5. Time-Base Trigger Circuit
6. Time-Base Generator
7. Horizontal Amplifier

The first circuit to check, for practically any type of trouble, is the 10-Volt Regulator Circuit. An improper output voltage from this supply will affect the operation of the entire instrument.

In some cases an improper voltage from the Converter may affect one circuit more than the others. In these cases, valuable time can be saved by checking the supply voltages first.

On the other hand, the crt display can often be used to isolate trouble to one particular circuit when trouble obviously exists in that circuit. If there is no vertical deflection, for example, when the intensity and horizontal deflection appear to be normal, it is apparent that an open condition exists in the Vertical Amplifier and this circuit should be investigated first.

The material that follows contains information for troubleshooting each circuit for troubles that may be caused by a defect in the circuit. A method is described, in some instances, for locating the stage in which the trouble may be originating; once the stage at fault is known, the components causing the trouble can be located by voltage and resistance measurements or by substitution. In certain other instances the information is more specific and the trouble can be traced to a particular component.

Circuit failure may be caused by transistor failure. If replacement of a defective transistor does not correct the trouble, then check the components associated with the transistors.

TROUBLESHOOTING THE REGULATOR CIRCUIT

Proper operation of every circuit in the Type 321 depends on proper operation of the Regulator circuit and the Converter. The DC voltages must remain within their specified tolerances for the instrument to retain its calibration.

Open Power Circuit (Dead Circuit)

With the AC 117V line (or 234V) connected, an increase in the SCALE ILLUM. control (cw) should brighten the graticule lights. If the graticule lights do not come on, check the source of power, power connection and the fuse F601. NOTE: Disconnect the power cord when working on the transformer T601 or associated circuits. If the fuse is blown, replace it with one of the proper value and reconnect the ac line cord. If the new fuse blows immediately, check the power transformer for shorted primary or secondary windings. Shorted rectifiers in the secondary circuit will also blow the fuse F601. Check for an open primary winding in the power transformer if the fuse is good.

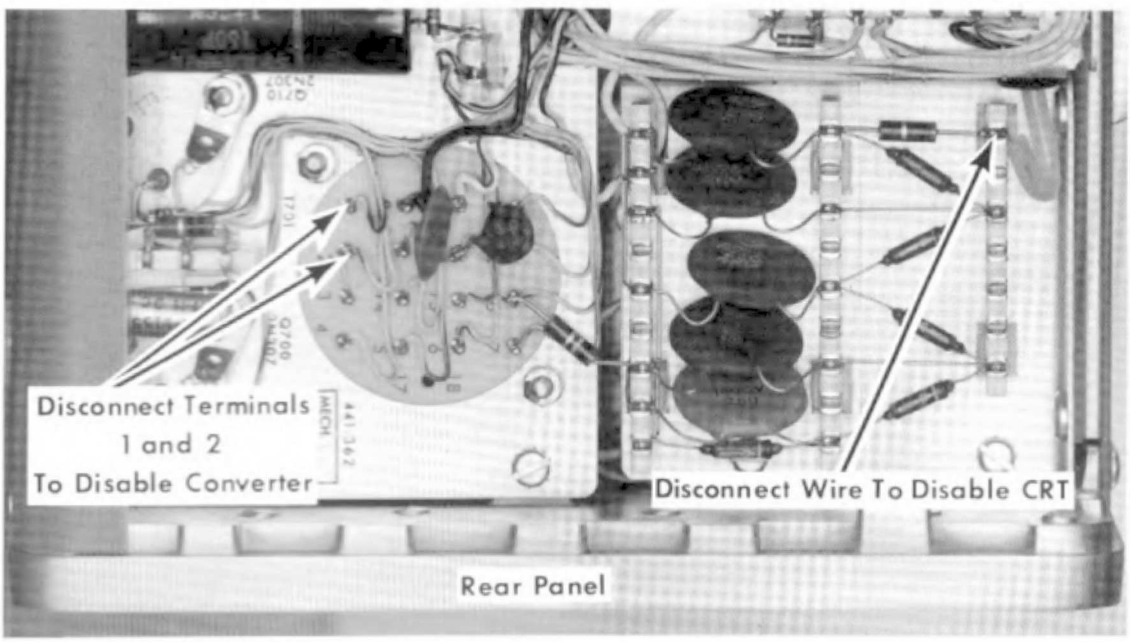


Fig. 5-1. Troubleshooting the Regulator Circuit.

Incorrect Voltage

With the POWER switch in the ON position, you should measure exactly 10 volts across C657; (see Fig. 6-1). If this voltage is not present, check for an open fuse F621 or thermal cutout switch TK621. (Resistance of the thermal cutout switch is about .1 Ω.) If the fuse is blown replace it with one of the proper value and turn the instrument on again. If the new fuse blows immediately, disconnect either the Converter circuit or the CRT circuit, or both, from the Regulator circuit to isolate the trouble (see Fig. 5-1). If the fuse continues to blow then the trouble lies in the Regulator circuit. If the Regulator circuit is free of trouble connect, one at a time, the Converter and the CRT circuit to locate the source of trouble. Once the circuit at fault is known, you can then troubleshoot within this circuit to locate the defective component(s). The Circuit Description of the circuit involved may prove useful when troubleshooting within a given circuit.

If varying the line voltage between 105 and 125 volts (or 210 and 250 volts for 234-v operation) varys the output of the 10-Volt Regulated supply, check for defective transistors in the Regulator circuit. The transistors Q700 and Q710 in the Converter circuit and the transistor Q800 in the CRT circuit may also affect the regulation of the 10-Volt Regulated supply.

TROUBLESHOOTING THE CONVERTER

The Converter voltages depend upon the operation of Q700 and Q710. These are the converter transistors and failure to operate will result in zero output.

Test points for checking the converter voltages are located on the right side of the oscilloscope (Fig. 6-2). If the converter transistors, Q700 and Q710, are inoperative, check to see if the regulated 10 volts are being applied across the converter transistors. Also check for shorted primary or secondary windings (T710). A short in any rectifier circuit will also cause the converter to be inoperative. If an improper voltage reading is obtained at any of the indicated points, check the 10V. ADJ. control R651 for correct setting.

TROUBLESHOOTING THE CRT CIRCUIT

The intensity, focus, geometry and calibration of the crt display depend on proper operation of the —720-volt supply and the high-voltage supply in the crt circuit. The —720 volts is dependent upon the converter for proper operation. For trouble in this supply refer to the converter troubleshooting procedure.

No Intensity

If the low-voltage power supply is operating normally, but no spot or trace is visible on the crt, the trouble could be a defective crt, a defect in the crt circuit including the —720-volt supply, an unbalanced condition in either or both of the deflection amplifiers, a defect in the Time-Base Generator circuit, or a defective unblanking circuit (to produce a spot or trace on the screen the crt must be unblanked).

To determine which circuit is at fault, turn the INTENSITY control full right. Set the LEVEL control to FREE RUN and the TIME/DIV. control to 1 MILLI SEC. Short the vertical deflection plates together (at the neck pins on the crt) with a screwdriver. Be extremely careful not to short either pin to the metal shield around the crt. Adjust the HORIZONTAL POSITION control and see if a spot or trace appears on the crt. If so, a state of unbalance in the vertical deflection system is indicated. (Refer to Troubleshooting the Vertical Amplifier).

If a spot or trace does not appear with the vertical deflection plates shorted, turn the instrument off and remove the leads that connect to the horizontal deflection plates. (Make sure that the metal clip on the end of each lead does not touch the chassis.) Turn the instrument back on and (after warmup) adjust the VERTICAL POSITION control. If a spot now appears on the crt, the Horizonal Amplifier is causing the trouble. If a spot does not appear, turn the instrument off and reconnect the leads to the horizontal deflection plates. Then turn the instrument back on and set the TIME/DIV. switch to the EXT. HORIZ. INPUT position. If a spot now appears on the crt, after warmup (it may be necessary to adjust the VERTICAL POSITION control), the Time-Base Generator is the circuit at fault. Refer to the appropriate troubleshooting section for trouble in either of these circuits.

If none of the previous checks indicates the source of the trouble, a defective crt or trouble in the high voltage circuit is indicated. Measurement of the high voltage can be made at the top end of R720 (Fig. 6-2). The voltage at this point should be approximately 3330 volts. If the voltage is present, a defective crt is indicated. Also a defective rectifier D714, D715, D717, D718 or D719, will cause the high voltage to be inoperative.

TROUBLESHOOTING THE VERTICAL AMPLIFIER

No Spot or Trace Visible on CRT

If all power supply voltages are normal, and the crt is known to be good, failure to obtain a spot or trace on the screen will be due to the Time-Base Generator and unblanking circuit or to improper positioning voltages. The latter condition is caused by a dc unbalance in either or both of the deflection amplifier circuits.

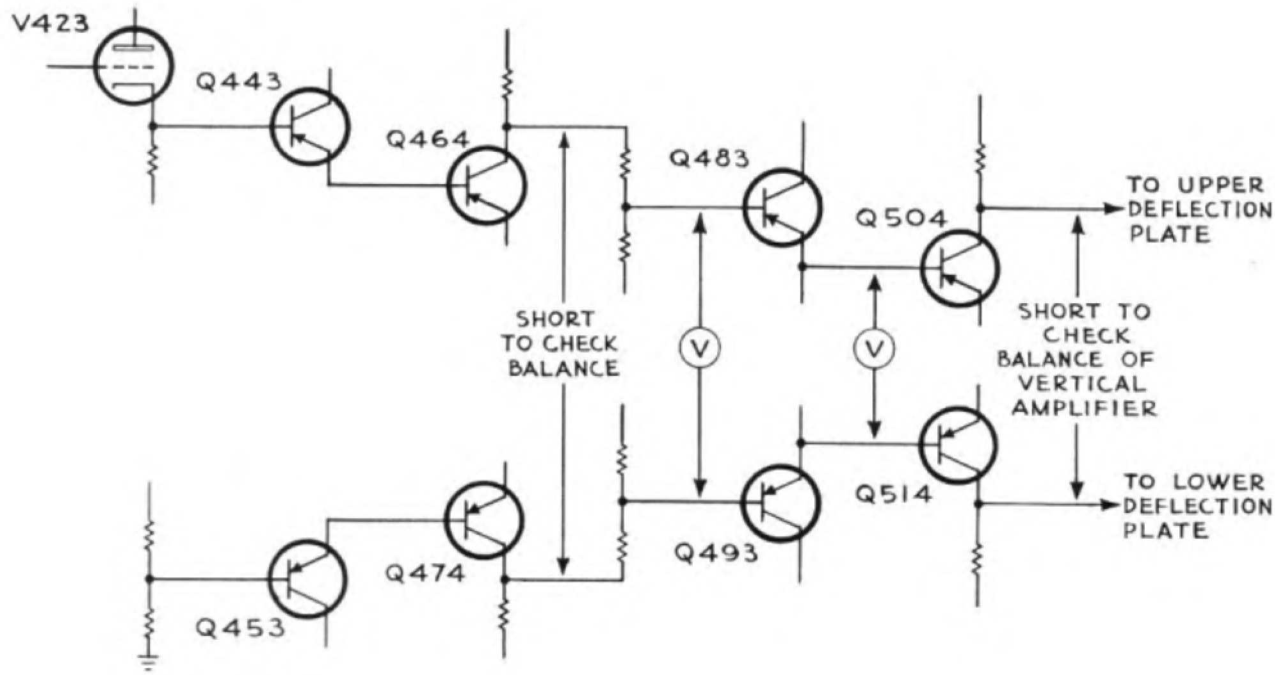


Fig. 5-2. Simplified diagram of the Vertical Amplifier showing test points for checking the balance of the amplifier.

To determine which circuit is at fault refer to Troubleshooting the Crt Circuit for the procedure to check the balance of the vertical and horizontal amplifier.

If it is determined that the vertical deflection circuit is unbalanced the next step is to check each stage for unbalance. Fig. 5-2 is a simplified diagram of the Vertical Amplifier showing test points for checking the balance of the amplifier. For this check it is convenient to have a short lead (about 8 or 10 inches) with a rubber-covered alligator clip on each end, and a voltmeter (5000 Ω per volt or better).

Connect the voltmeter between the base of Q504 and the base of Q514, and set the VERTICAL POSITION control to mid-position. A reading of less than 1 volt would indicate unbalance in the output stage (Q504, Q514). Check for defective transistors and associated circuit parts. A reading of 1 volt or more on the voltmeter indicates unbalance ahead (toward the input stage) of the voltmeter. Reconnect the voltmeter between the base of Q483 and Q493. A reading of less than 1 volt indicates unbalance in that stage. A reading of more than 1 volt indicates unbalance toward the input stage.

The next step is to connect together the collector of Q464 and the collector of Q474 with the shorting strap. If the trace appears on the crt (it may be necessary to adjust the VERTICAL POSITION control) the trouble lies either in one of the transistors or in some component ahead of this stage. From this point it is advisable to troubleshoot by substitution. Do not connect other points on opposite sides of the circuit together, as an improper voltage on one side could damage transistors on the other.

Insufficient or no Vertical Deflection

Insufficient vertical deflection indicates a change in the gain characteristics of the Vertical Amplifier. If there is only a slight deficiency in the deflection, as will usually be the case, the amplifier can generally be recalibrated for gain. Refer to the Recalibration Procedure for this. However, if the amplifier cannot be recalibrated, or if the decrease in gain is more pronounced, it will be necessary to check the transistors, tube and circuit components.

If there is no vertical deflection on the crt, an inoperative condition in the vertical deflection system is indicated. If the trace can be moved with the VERTICAL POSITION control, the trouble is originating ahead of the control in one of the input stages of the Vertical Amplifier (input c.f., input amplifier).

If the trace cannot be moved with the VERTICAL POSITION control, one of the stages following the control is inoperative. In either of the above cases the tube or transistor should first be replaced, then circuit components should be checked.

TROUBLESHOOTING THE HORIZONTAL AMPLIFIER

No Spot or Trace on the CRT

To determine that the Horizontal Amplifier is in a state of dc unbalance, turn the instrument off and remove the leads that connect to the horizontal deflection plates. (Make sure that the metal clips on the end of each lead do not touch the chassis.) Turn the instrument back on and (after warmup), adjust the VERTICAL POSITION control. If a spot now appears on the crt, the trouble lies in either the Horizontal Amplifier or the Time-Base Generator. To determine which circuit is at fault, reconnect the leads to the horizontal deflection plates and turn the TIME/DIV. control to EXT. position. If the spot now appears, the Horizontal Amplifier is in balance and the trouble is being caused by an inoperative condition in the Time-Base Generator (refer to Troubleshooting the Time-Base Generator).

If no spot appeared on the crt with the TIME/DIV. control in the EXT. position, the Horizontal Amplifier is causing the trouble. The procedure for troubleshooting the Horizontal Amplifier, to locate the defective stage, is similar to that explained for troubleshooting the Vertical Amplifier for unbalance. A voltmeter (5000 Ω per volt or better) is used to determine which stage is unbalanced. Fig. 5-3 is a simplified diagram of the Horizontal Amplifier showing test points for checking the balance of the amplifier. Connect the voltmeter between the base of Q334 and the base of Q344. Set the HORIZONTAL POSITION control to mid-position. A reading of 1.5 volts or over will indicate an unbalance in the first stage (Q313, Q323). A reading of less than 1.5 volts will indicate an unbalance condition in the output stage (Q334, Q344). When the stage at fault is determined, check for defective transistors and components associated with that stage.

Insufficient or No Horizontal Deflection

If the gain of the Horizontal Amplifier decreases, the trace will not extend from the left to the right side of the graticule. In addition, the timing will no longer correspond to the calibrated value indicated by the TIME/DIV. switch.

If the change is slight, as indicated by improper timing and a slightly decreased sweep, the amplifier can usually be recalibrated. Since the gain of the Horizontal Amplifier regulates the timing of the sweep, care must be taken to insure that the gain adjustments are accurately made. Be sure to refer to the Recalibration Procedure if it is necessary to adjust the gain of the Horizontal Amplifier.

If there is no horizontal deflection on the crt the circuit at fault could be the Horizontal Amplifier or the Time-Base Generator.

The operation of the Time-Base Generator can be checked by measuring the voltage at the emitter of Q173. Set the TIME/DIV. control to .1 SEC and the LEVEL control to FREE RUN. Connect a voltmeter between the emitter of Q173 (Fig. 5-4) and ground. If the voltage varies between zero and —20 volts, as the Miller circuit runs down and back, the Time-Base Generator is operating properly and the trouble lies in the Horizontal Amplifier.

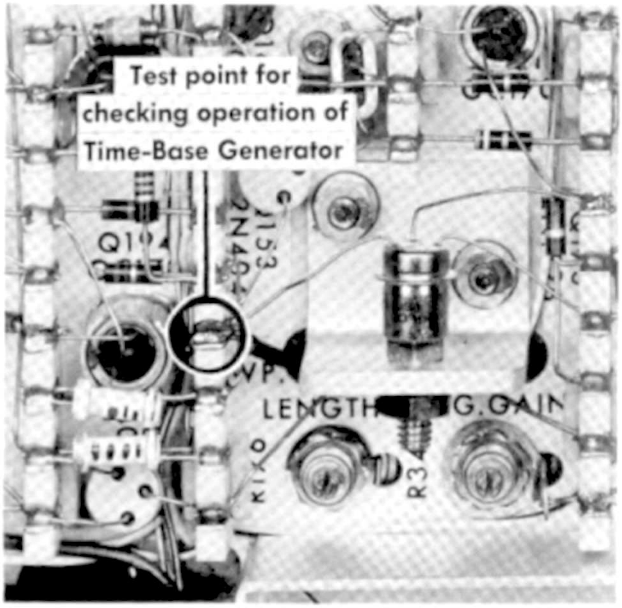


Fig. 5-4. Checking the operation of the Time-Base Generator by measuring the voltage at the emitter of Q173.

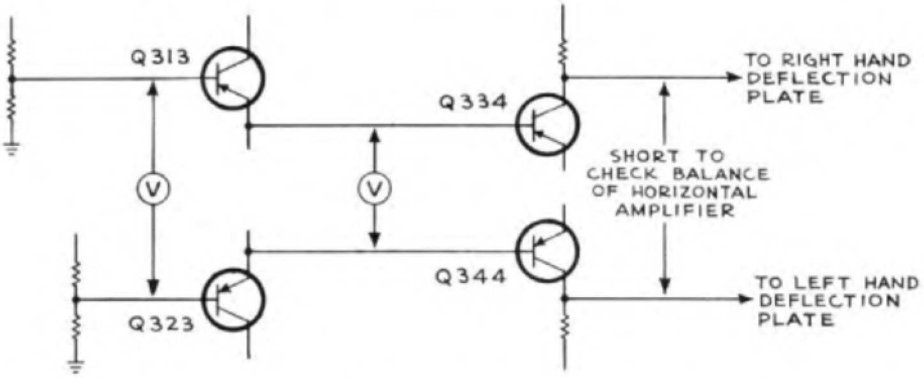


Fig. 5-3. Simplified diagram of the Horizontal Amplifier showing test points for checking the balance of the amplifier.

When the trouble has been isolated to either the Time-Base Generator (refer to troubleshooting the Time-Base Generator) or the Horizontal Amplifier, a check of the transistors and circuits components should be made.

If there is some horizontal deflection on the crt, but not enough to cover the ten-division length of the graticule, the trouble will either be due to insufficient output from the Time-Base Generator, or to insufficient gain in the Horizontal Amplifier.

The Time-Base Generator can be checked in the same manner as described previously. That is, by measuring for a 20-volt variation at the emitter of Q173, at a slow sweep rate. If this reading is not obtained, the Time-Base Generator is at fault, and its circuitry can be investigated. The SWP. LENGTH control (R176) is very important and its setting should be checked first. For the proper adjustment of this control, refer to the Recalibration Procedure.

If the voltmeter indicates the proper reading (Fig. 5-4) the Horizontal Amplifier will be the circuit at fault. Check for defective transistors and circuit components.

TROUBLESHOOTING THE TIME-BASE TRIGGER

Improper Triggering

If the waveform you are observing cannot be triggered (locked into position) properly, the trouble can be: (1) misadjustment of the STABILITY control, (2) the trigger-pickoff circuit (trigger amplifier Q524) in the Vertical Amplifier, (3) Time-Base Generator, or (4) the Time-Base Trigger circuit.

Refer to the Recalibration Procedure for misadjustment of the STABILITY control. The operation of the trigger pick-off circuit can be checked as follows: connect an external triggering signal (preferably the signal input waveform) to the (TRIGGERING) INPUT connector. Set the INT.-EXT. switch to the EXT. position. Check to see if the waveform can now be triggered. If so, the trigger pickoff stage Q524 is at fault; it is not passing the internal signal that develops the triggering pulse.

If the waveform cannot be triggered in either the INT. or EXT. position, some circuit in the Time-Base Trigger or the Time-Base Generator is not operating properly.

If the sweep can be turned off and on with the LEVEL control, the sweep generator is capable of being triggered. This indicates the Time-Base Trigger is not functioning properly. Check for defective transistors and circuit components.

TROUBLESHOOTING THE TIME-BASE GENERATOR

No Horizontal Sweep

It is important that you understand the operation of the Time-Base Generator before proceeding with any extensive investigation of the circuit. For this reason we suggest that you thoroughly study that portion of the Circuit Description that pertains to this circuit.

If the Time-Base Generator is not producing a sawtooth sweep when the LEVEL control is in the FREE RUN position, some defect is rendering the circuit inoperative. The timing components (R160-C160) and the hold-off capacitor (C180) can be checked by rotating the TIME/DIV. switch through its range. If a trace appears in some positions of the switch, the trouble will lie in the components associated with the inoperative position(s) of the switch.

If no trace appears in any position of the TIME/DIV. switch, the generator is "hung up" either at the low end or at the high end of the sweep. Set the TIME/DIV. switch to .5 MILLI SEC and measure the voltage at the emitter of Q173. If this voltage is very close to zero, the circuit is hung up at the low end of the sawtooth; that is, the sweep cannot get started. In this case, voltage readings at key points in the circuit may help to isolate the source of trouble. Connect the voltmeter to the base of Q135 and turn the LEVEL control just slightly to the left, away from the FREE RUN position. Then vary the setting of the STABILITY potentiometer. The voltage at the base of Q135 should vary between about —2 volts and about —10 volts. Voltages outside of this range indicate trouble in the stability-control circuit... R111, R131, D111, D131. Also, check transistors Q135 and Q183, and R181 in the emitter circuit of Q183.

The operation of the Sweep-Gating Multivibrator can be checked by connecting the voltmeter to the collector of Q145 (base of Q153) and varying the setting of the STABILITY potentiometer. If no trouble exists in the multivibrator circuit, it will be forced from one stable state to the other as the STABILITY control is varied from one end of its range to the other. This will cause the collector voltage of Q145 (and the base voltage of Q153) to vary about .5 to .75 volt above and below zero. Normal operation of the gating transistor Q153 is indicated by a voltage change at its emitter equal to about one-half the voltage change at its base.

If the voltage range at the emitter of Q153 appears to be normal, the hang-up is occurring in the Miller Circuit. A check of the voltages, at the points indicated on the circuit diagram, may indicate the source of the trouble. If not, check by substitution transistors Q161, Q163 and Q173, and diode D153.

If the voltage at the emitter of Q173 is from —20 to about —35 volts, the circuit is hung up at the high (most negative) end of the sawtooth. This indicates that the discharge path of the Timing Capacitor C160 is blocked. Since the Timing Capacitor discharges through Q153, R153 and D153, these components should be checked first. Then check the action of the Sweep-Gating Multivibrator by the method mentioned previously. If the multivibrator is locked up so that Q145 is conducting, Q153 will be back-biased and will block the discharge path.

Improper Triggering

If the sweep cannot be triggered properly, the gating pulse from the Multivibrator (Q135-Q145) is not turning the diode D153 off and on properly. The start of the gating pulse, which turns the diode off and starts the sweep, is initiated by the triggering pulse at the base of Q135. The end of the gating pulse, which turns the diode on and initiates the retrace, is controlled by the hold-off waveform at the base of Q135. The main component to check, in addition to the transistors, is the differentiating capacitor C131.

TROUBLESHOOTING THE CALIBRATOR

Insufficient or No Calibrator Output

The Converter circuit supplies the signal to the Calibrator cirucit. To check the Calibrator, turn the VOLTS/DIV. control to the CAL. 4 DIV. position. Set the LEVEL control to the AUTO. position. There should now be displayed on the crt 4 vertical divisions of Calibrator signal. If not, and the Vertical Amplifier is known to be working, check for a defective transistor Q874 and associated circuit components. For adjustment of the CAL ADJ. control refer to the Recalibration Procedure. The CAL. ADJ. control will compensate for slight changes in the calibrator output. If the change is more pronounced, the transistor Q874 should be checked.

SECTION 6

RECALIBRATION

The following equipment is required for a full recalibration of the Type 321 Oscilloscope.

1. DC voltmeter (sensitivity at least 5000 Ω/v) calibrated for an accuracy of at least 1% at 10, 45 and 720 volts. Be sure the meter is accurate; few portable meters have comparable accuracy, particularly after a period of use.
2. Accurate rms-reading ac voltmeter, 0-150 volts (0-250 or 0-300 volts for 234-volt operation).
3. Variable autotransformer (powerstat, variac, etc) having a rating of at least 1 ampere.
4. Time-Mark Generator, Tektronix Type 180 or Type 180A or equivalent. Time-mark generator must have markers at 1 μsec, 10 μsec, 100 μsec, 1 msec, 5 msec, 10 msec, 100 msec and 500 msec, with an accuracy of at least 1%.
5. Square-Wave Generator, Tektronix Type 105 or equivalent. If a Tektronix Type 105 is not available, it will be necessary to substitute a generator with the following specifications; (1) output frequencies of approximately 1 kc and 100 kc; (2) risetime no more than 0.02 microsecond; and (3) output amplitude variable from 18 millivolts to 40 volts (including the use of attenuator pads).
6. Constant-amplitude signal generator, Tektronix Type 190 or 190A or equivalent. If a Tektronix Type 190 or 190A is not available, it will be necessary to substitute a generator that provides a 50-millivolt signal variable in frequency from 500 kc to over 5 mc. The signal amplitude must remain constant (50 mv) over the entire frequency range.
7. Test oscilloscope, accurately calibrated for vertical gain at 500 millivolts.
8. Low-capacitance recalibration tool; part number 003-000.

ADJUSTMENT PROCEDURE

Preliminary

Remove the side covers from the Type 321. Set up the front-panel controls as follows:

INTENSITY	full left (ccw)
TRIGGERING LEVEL	FREE RUN (full right)
SLOPE	+
AC-DC	AC
INT.-EXT.	INT.
TIME/DIV.	1 MILLI SEC
VARIABLE	CALIB. (full right)
5X MAG.	in
VOLTS/DIV.	1
VARIABLE	CALIB. (full right)
AC-DC	DC

Note: For those controls not listed, their adjustment is not pertinent to this part of the procedure and the controls may be left in any position. Adjustment of these controls will be made at the appropriate time in the following procedure.

Connect the Type 321 to the autotransformer, and turn on all equipment. Set the output of the autotransformer to the design center voltage for which your instrument is wired (117 or 234 v).

If the instrument fails to calibrate in any of the following steps, refer to the Troubleshooting Procedure section of the manual for information concerning the circuit involved.

POWER SUPPLY, CALIBRATOR AND CRT CIRCUIT

(1) 10-Volt Adjust

Connect a voltmeter across the 10-volt regulated supply at the points shown in Fig. 6-1. Adjust the 10 VOLT ADJ. (R651) for a reading of exactly 10 volts. Use a voltmeter you know to be accurate. Check the regulation of the supply by varying the line voltage between 105 and 125 volts (or 210 and 250 volts). The voltage should remain constant over this range.

Disconnect the common or ground lead of the voltmeter and reconnect it to the chassis. Then check the following voltages (see Fig. 6-2): +45 v, +10 v, +6.3 v, —10 v, —45 v and —720 v. The ± 45 volts should be within 5% of rated value. All other voltages should be within 10% of rated value.

(2) Calibrator

Connect the test oscilloscope to the CAL. OUT 500 MV terminal on the front panel. Adjust the CAL. ADJ. control (R884) for exactly 500 mv on the test oscilloscope. Use an oscilloscope you know to be accurate.

(3) CRT Alignment

Turn up the INTENSITY control until a trace is visible (it may be necessary to adjust the vertical positioning control) and adjust FOCUS and ASTIGMATISM for sharpest trace (narrowest trace width). Position the trace directly behind the center graticule line. If the trace and graticule line do not coincide over the length of the graticule, loosen the crt base clamp and rotate the tube. When the trace and the graticule line are in coincidence, push the tube forward so that it rests snugly against the graticule. Then tighten the crt base clamp. Recheck the alignment after tightening the clamp to be sure it didn't move while the clamp was being tightened.

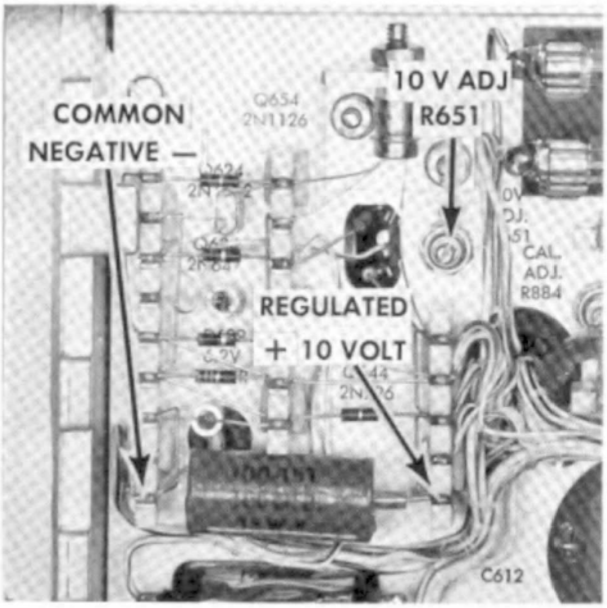


Fig. 6-1. Test points for checking the output of the 10-Volt Regulated Supply.

(4) CRT Geometry

Position the trace to the top graticule line. If any curvature is present in the trace, adjust the GEOM. ADJ. control R861 for minimum curvature. Then position the trace to the bottom graticule line and repeat the adjustment, if necessary. A compromise setting of the GEOM ADJ. control may be necessary for best overall linearity.

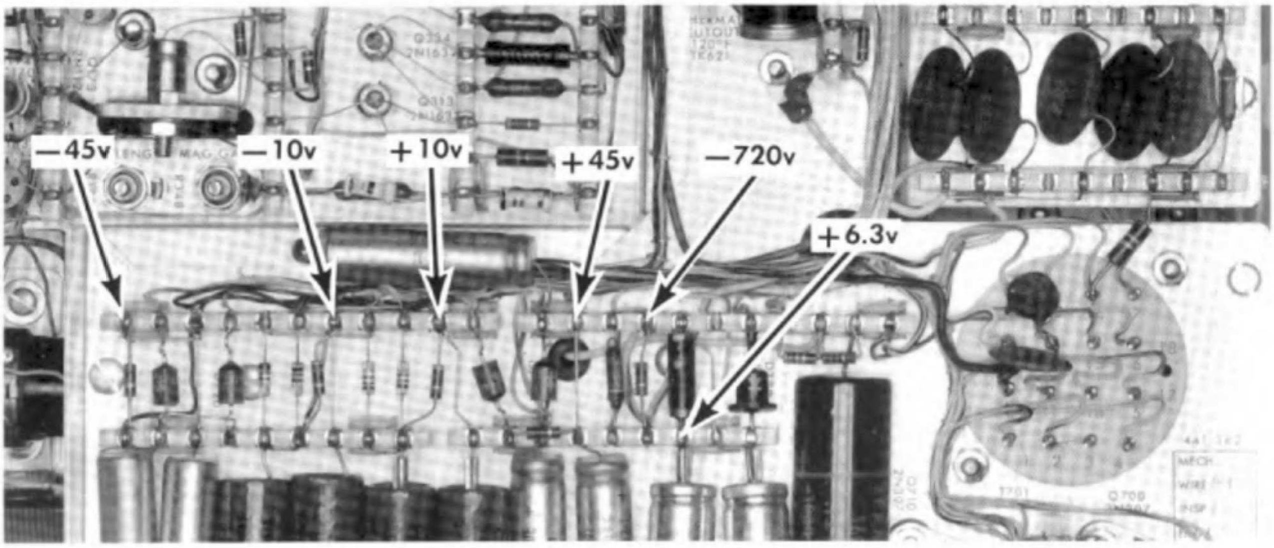


Fig. 6-2. Test points for checking the converter output voltages.

TRIGGERING CIRCUIT

(5) Stability Adjust

Reposition the trace to the center of the screen, and set the (TRIGGERING) LEVEL control to the AUTO. position (full left). Then set the STABILITY control (screwdriver adjustment, front panel) to its full left position (ccw). Next, advance the STABILITY control to the right until a trace is just visible on the crt. Then, advance the STABILITY control further right until the trace just brightens. (This is an extremely small range and the control must be adjusted very carefully.) Finally, back off the control and set it midway between visibility and brightness.

VERTICAL AMPLIFIER

Set up front-panel controls as follows:

TRIGGERING	
LEVEL	AUTO.
SLOPE	+
INT.-EXT.	INT.
AC-DC	AC
TIME/DIV.	1 MILLI SEC
VARIABLE	CALIB. (full right)
VOLTS/DIV.	1 VOLT
VARIABLE	CALIB. (full right)
AC-DC	DC

(6) DC BAL. Adjust

Center the trace vertically on the crt. Rotate the (Vertical) VARIABLE control; if any vertical displacement of the trace is apparent, adjust the DC BAL. control (screwdriver adjust, front panel) until the trace remains stationary as the VARIABLE control is rotated. Be sure to return the VARIABLE control to the CALIB. position after completing the adjustment.

(7) Low Frequency Compensation

Set the VOLTS/DIV. control to .5 and position the trace near the bottom line of the graticule. Connect an ohmmeter, set to the R x 1 scale, between the Vertical INPUT connector and the chassis. The voltage at the INPUT connector is zero, so there is no danger of damaging the meter. If the polarity of the ohmmeter leads is correct, and if a $1\frac{1}{2}$-volt cell is used on the R x 1 scale, the trace should jump toward the upper line of the graticule. If the trace is deflected off the screen it may be necessary to reverse the ohmmeter leads, increase the setting of the VOLTS/DIV. control, or both. When the proper polarity for the ohmmeter leads has been established, find a setting for the VOLTS/DIV. control (if other than .5) where the trace is visible on the crt with the ohmmeter both connected and disconnected.

Alternately connect the lead to the INPUT connector and disconnect it, observing the trace as it comes to rest. If there is any vertical drift to the trace, as it comes to rest in either position, adjust the LF COMP. control (R518) for minimum drift. This is a very slow drift and must be observed for a few seconds to determine the amount and direction.

(8) Vertical Amplifier Gain

Set the VOLTS/DIV. control to the CAL. 4 DIV. position. There should be displayed on the crt approximately 4 divisions of signal. Adjust the GAIN ADJ. control (R468) for exactly 4 divisions of vertical deflection. As an extra check to the gain setting, set the VOLTS/DIV. control to .1 and connect a test lead from the CAL. OUT 500 MV connector to the INPUT connector. You should now have 5 divisions of signal.

(9) Probe and VOLTS/DIV. Attenuator Adjustments

Connect the cable of the P6003 Probe to the (Vertical Amplifier) INPUT connector of the Type 321, and set the VOLTS/DIV. control to .01. Compensate the probe according to the instructions presented on page 3-9 and illustrated in Fig. 3-8 (Operating Instructions).

After compensating the probe, connect the probe tip to the OUTPUT connector on the Type 105 (or equivalent) Square-Wave Generator and connect the ground clip to any convenient ground point on the generator. Adjust the Type 105 to supply a 1-kilocycle square wave. Throughout this step, adjust the OUTPUT AMPLITUDE control of the Type 105 as required for about 4 major divisions of vertical deflection. With the VOLTS/DIV. control in the .02 position, use the VARIABLE control to decrease the amplitude to 4 divisions. In all the other VOLTS/DIV. positions, the VARIABLE control should be in the CALIB. position (maximum output of the Type 105 will give a deflection of slightly more than 1 division in the 10 position of the VOLTS/DIV. control.)

In each of the following VOLTS/DIV. positions, adjust the two capacitors in each position for best square-wave response. C418C, C416C, C414C, C412C and C410C affect the leading edge and corner of the square wave (see Fig. 6-3. C418A, C416A, C414A, C412A and C410A affect the over all level of the square-wave (see Fig. 6-4).

VOLTS/DIV.	ADJUST
.02	C418A, C418C
.05	C416A, C416C
.1	C414A, C414C
1	C412A, C412C
10	C410A, C410C

Fig. 6-5 shows location of the attenuator capacitors.

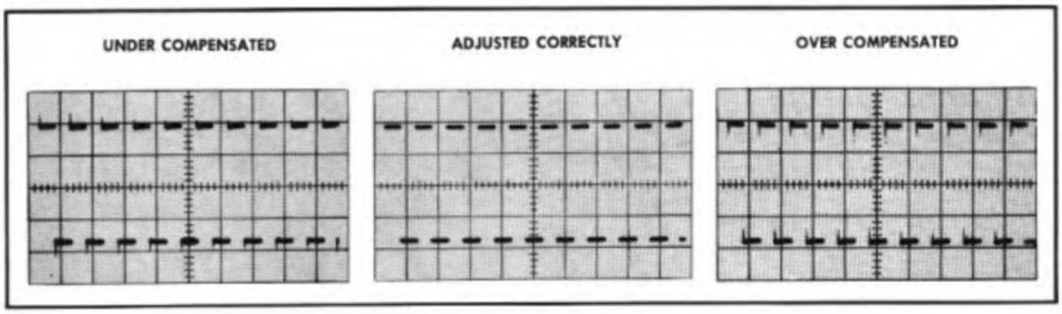


Fig. 6-3. Compensating the Attenuator high-frequency response.

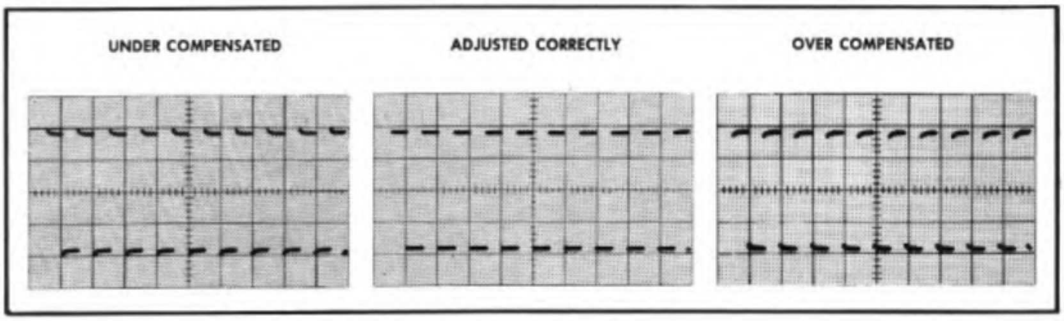


Fig. 6-4. Standardizing the input capacitance.

(10) C508-High Frequency Adjust

Reset the Type 105 for an output frequency of 100 kc. Set the VOLTS/DIV. control to the .01 position and display 4 major divisions of signal. Set the TIME/DIV. to the 2 μSEC position, and adjust C508 for best square-wave response.

(11) Check Bandwith of Vertical Amplifier

Connect the output cable from the Constant-Amplitude Signal Generator to the INPUT connector of the Type 321. Set up the front panel controls as follows:

TRIGGERING LEVEL	FREE RUN
TIME/DIV.	1 MILLI SEC
VARIABLE	CALIB.
VOLTS/DIV.	.01
VARIABLE	CALIB.

Set the frequency controls on the Signal Generator for an output frequency of 500 kc, and adjust the amplitude controls for a vertical deflection of exactly 4 major divisions. Position the display on the crt (with the VERTICAL POSITION control) so that the deflection extends over the middle 4 divisions.

Then increase the output frequency of the Signal Generator to 5 megacycles. (Make sure the VOLTS/DIV. and VARIABLE controls are set to .01 and CALIBRATED, respectively.) The deflection should be at least 2.9 major divisions at 5 mc. If not, refer to the Maintenance Section for information concerning the circuit involved.

TIME-BASE GENERATOR AND HORIZONTAL AMPLIFIER

Set up the front panel controls as follows:

TIME/DIV.	1 MILLI SEC
*VARIABLE	CALIB. (full right)
5X MAG	In
TRIGGERING LEVEL	AUTO.
INT.-EXT.	INT.
AC-DC	AC
SLOPE	+
VARIABLE (vertical)	CALIB. (full right)

Set up the following controls on the Type 321 for best presentation: VOLTS/DIV., VERTICAL POSITION, HORIZONTAL POSITION, FOCUS, INTENSITY, ASTIGMATISM and SCALE ILLUM.

*Be sure the VARIABLE TIME/DIV. control is in the CALIB. position (full right).

(12) Horizontal Amplifier Gain

Apply 1-millisecond markers from the Time-Mark Generator to the INPUT connector of the Type 321. Adjust the HORIZ. GAIN control (R338) for one marker per division. (Use

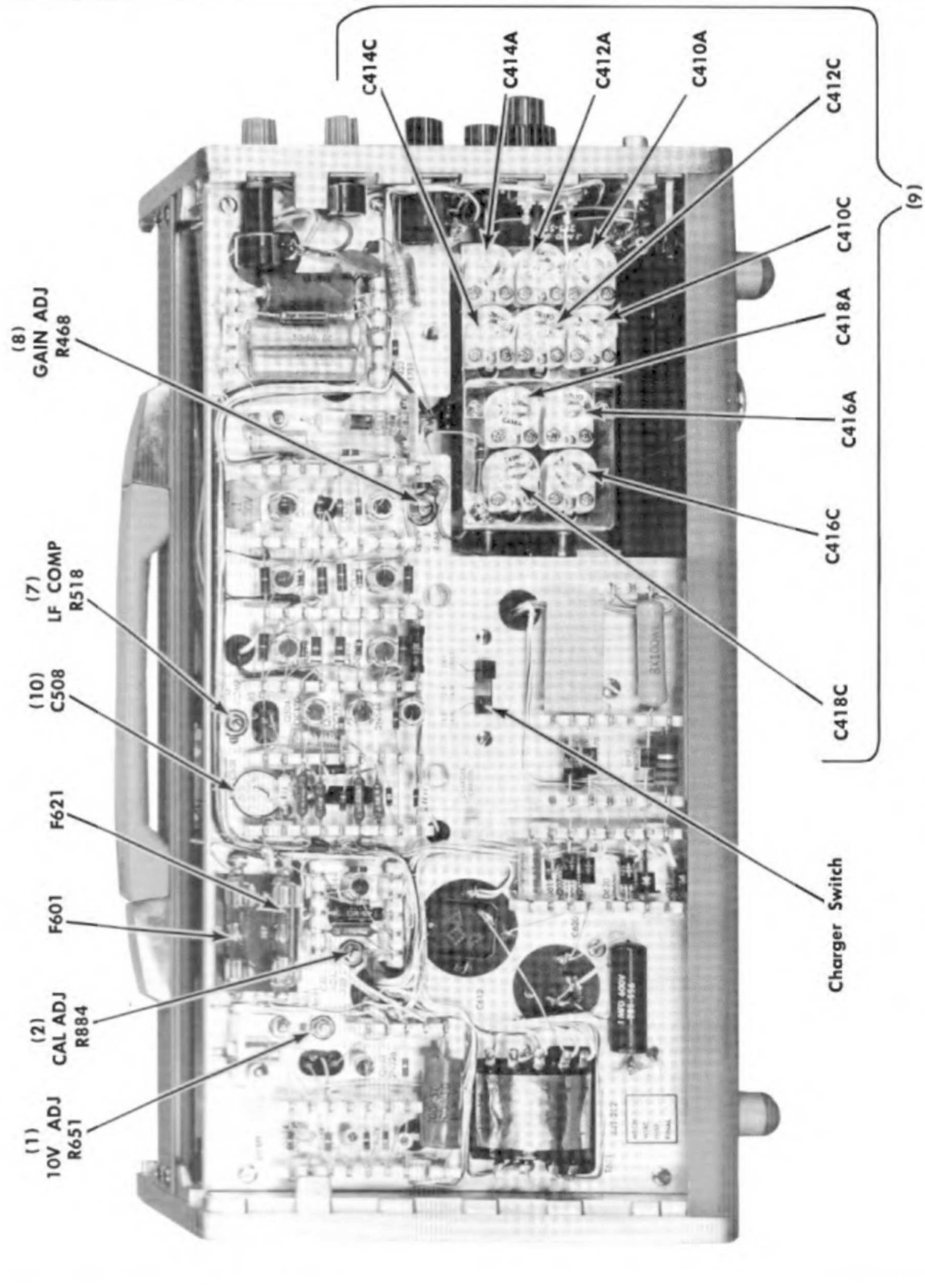


Fig. 6-5. Left-side view of the Type 321 Oscilloscope. The numbers in parenthesis refer to steps in the Recalibration Procedure.

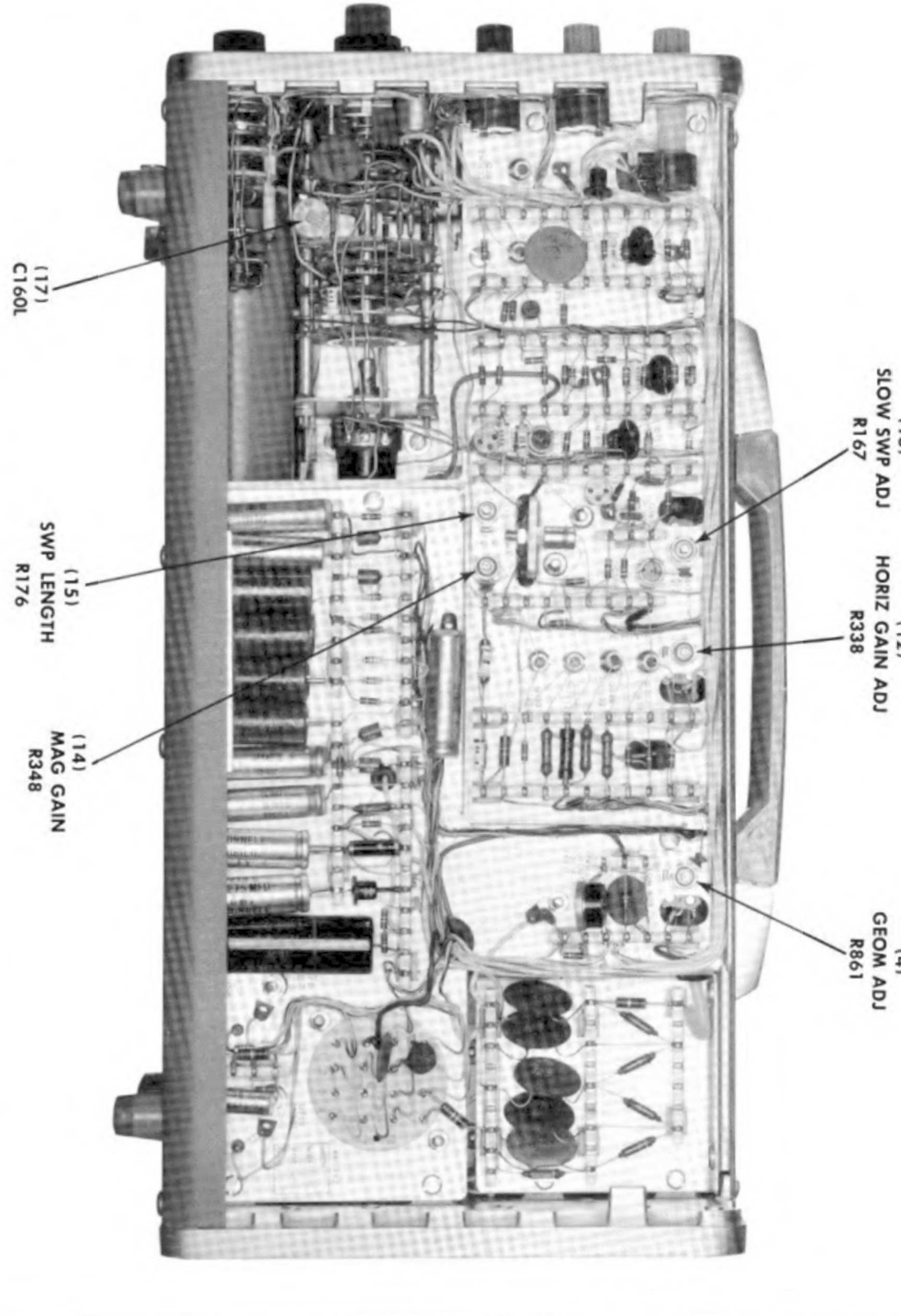


Fig. 6-6. Right-side view of the Type 321 Oscilloscope. The numbers in parenthesis refer to steps in the Recalibration Procedure.

the HORIZ. POSITION control to align the markers with the graticule lines). The circuit must calibrate between the 1- and 9-division graticule lines in steps (12), (13), (14).

(13) Slow Sweep Adjust

Set the TIME/DIV. control to the .5 SEC position. Apply 500-millisecond markers from the Time-Mark Generator. Adjust the SLOW SWP. ADJ. (R167) for one marker per division. Recheck steps (12) and (13) as there is interaction between these two controls.

(14) Magnifier Gain

Apply 100-microsecond markers from the Time-Mark Generator to the INPUT connector. Pull the (TIME BASE) VARIABLE control to the 5X MAG. position. Set the TIME/DIV. control to the 1 MILLI SEC position. Adjust the MAG. GAIN control (R348) for two markers per division.

(15) Sweep Length

Apply 1-millisecond markers from the Time-Mark Generator to the INPUT connector. Push the 5X MAG. control In. Adjust the SWP. LENGTH control (R176) for a sweep length of 10.5 divisions.

(16) Check Sweep Timing: .5 Seconds/Div. to 1-Microsecond/Div.

Table 6-1 lists the time markers to be applied for the indicated setting of the TIME/DIV. switch, and the number of markers per division to be observed for each setting. There are no adjustments to be made in this step; this is a check on the accuracy of the components that make up R160 and C160 in the indicated range of sweep rates.

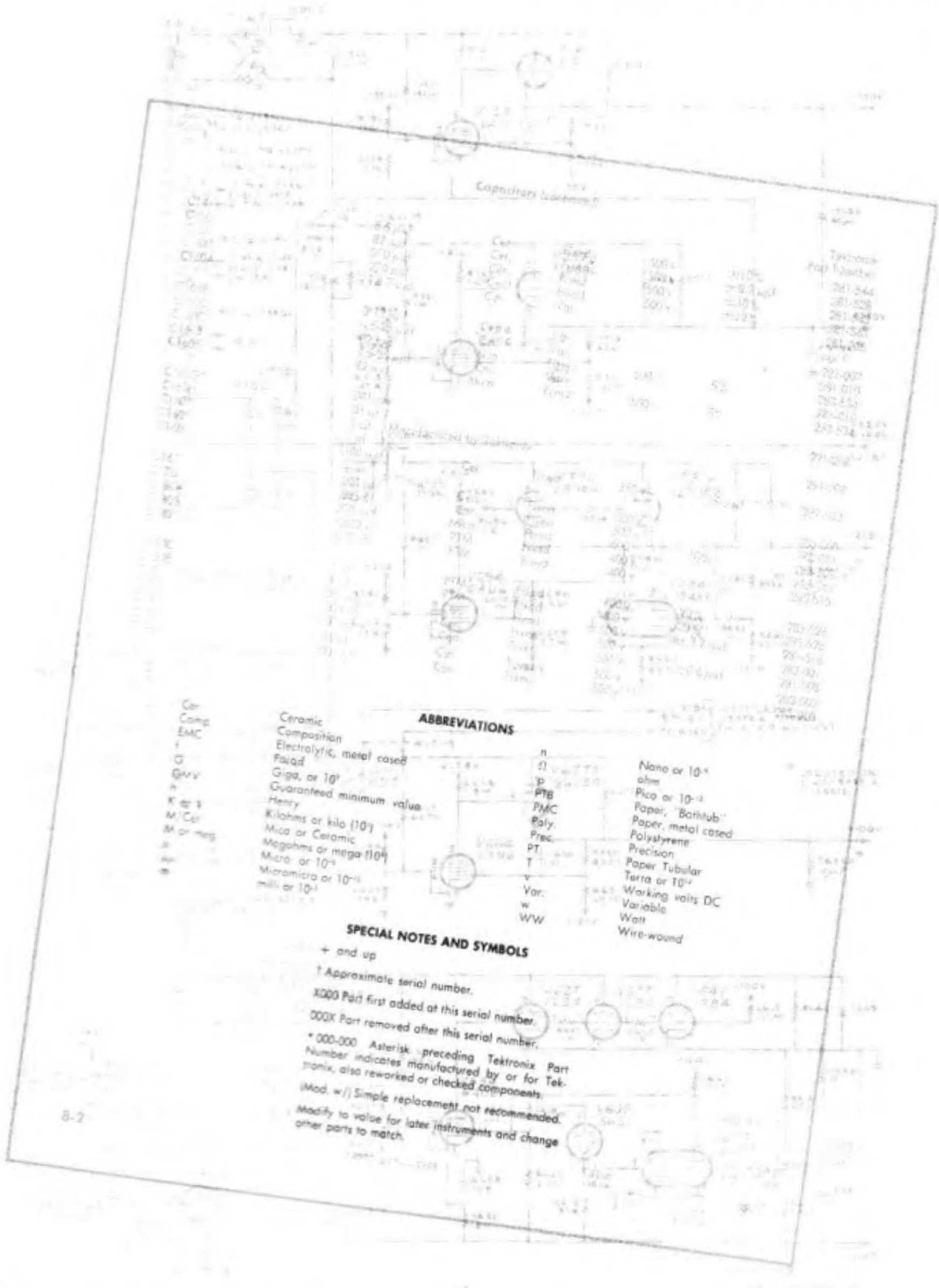
TABLE 6-1

TIME/DIV.	TIME MARKERS	OBSERVE
1 μsec	1 μsec	1 marker/div
10 μsec	10 μsec	1 marker/div
.1 MILLI SEC	100 μsec	1 marker/div
1 MILLI SEC	1 msec	1 marker/div
2 MILLI SEC	1 msec	2 marker/div
5 MILLI SEC	5 msec	1 marker/div
10 MILLI SEC	10 msec	1 marker/div
.1 SEC	100 msec	1 marker/div
.2 SEC	100 msec	2 marker/div
.5 SEC	500 msec	1 marker/div

(17) Adjust Sweep Timing and Linearity: .5 μsec/div.

Apply 1-μsec markers from the Time-Mark Generator to the INPUT connector. Set the TIME/DIV. control to .5 μSEC. Check to see that the VARIABLE TIME/DIV. control is in the CALIB. position. Adjust the (TRIGGERING) LEVEL control as required to obtain a stable display. Adjust C160L for 1 marker per 2 divisions. Timing should be made between the 1- and 9-division graticule lines.

PARTS LIST *and* DIAGRAMS



MANUFACTURERS OF CATHODE-RAY OSCILLOSCOPES

PARTS LIST

Bulbs

			Tektronix Part Number
B424	X1810-up	Neon, NE2	150-002
B601		Incandescent, #47	150-001
B602		Incandescent, #47	150-001
B845		Neon, NE2 Pilot Light	150-020

Capacitors

C2		4.7 μμf	Cer.	Fixed	500 v	±1 μμf	281-501
C8		.1 μf	Cer.	Fixed	500 v		Use 283-008
C20		.01 μf	Cer.	Fixed	150 v		283-003
C30		2.2 μf	Cer.	Fixed			283-019
C37	101-1809	47 μμf	Cer.	Fixed	500 v	±9.4 μμf	281-518
C37	1810-up	120 μμf	Cer.	Fixed	500 v		281-550
C131		47 μμf	Cer.	Fixed	500 v		281-518
C141		150 μμf	Cer.	Fixed	500 v	±30 μμf	281-524
C160A		10 μf	Mylar	Fixed			*291-028
C160C		1 μf			Timing Series		*291-027
C160E		.1 μf					
C160G		.01 μf					
C160J		.001 μf					
C160K	X2020-up	Selected Nominal Value 15μμf					281-509
C160L	101-719	7-45 μμf	Cer.	Var.			281-012
C160L	720-up	8-50 μμf	Cer.	Var.			281-022
C160M	101-719	470 μμf	Cer.	Fixed		±94 μμf	281-525
C160M	720-up	470 μμf	Cer.	Fixed	500 v	±10%	281-580
C163		.01 μf	Cer.	Fixed	150 v		283-003
C180A		2 μf			20 v		290-121
C180C		.2 μf	Cer.	Fixed	25 v		283-026
C180E		.02 μf	Cer.	Fixed	50 v		283-027
C180G		.0022 μf	Cer.	Fixed	50 v		283-028
C181		150 μμf	Cer.	Fixed	500 v	±30 μμf	281-524
C193		470 μμf	Cer.	Fixed		±94 μμf	281-525
C300		10 μμf	Cer.	Fixed	500 v	±1 μμf	281-504
C311		5.6 μμf	Cer.	Fixed	500 v	±10%	281-544
C312		68 μμf	Cer.	Fixed	500 v	±10%	281-549
C325		.01 μf	Cer.	Fixed	150 v		283-003
C401		.1 μf	PTM	Fixed	600 v		*285-556
C410A		7-45 μμf	Cer.	Var.			281-012
C410C		1.5-7 μμf	Cer.	Var.			281-005
C410E		1000 μμf	Cer.	Fixed	500 v	±100 μμf	281-536
C410F		1000 μμf	Cer.	Fixed	500 v	±100 μμf	281-536
C412A		4.5-25 μμf	Cer.	Var.			281-010
C412C		1.5-7 μμf	Cer.	Var.			281-005
C412E		270 μμf	Cer.	Fixed	500 v	±10%	281-543
C414A		4.5-25 μμf	Cer.	Var.			Use 281-010
C414C		3-12 μμf	Cer.	Var.			281-007
C414E		47 μμf	Cer.	Fixed	500 v	±9.4 μμf	281-518
C416A		3-12 μμf	Cer.	Var.			281-007
C416C		3-12 μμf	Cer.	Var.			281-007
C418A		1.5-7 μμf	Cer.	Var.			281-005
C418C		4.5-25 μμf	Cer.	Var.			281-010
C422		3.3 μμf	Cer.	Fixed	500 v	±.25 μμf	281-534

Capacitors *(continued)*

							Tektronix Part Number
C423	101-1809	.01 μf	Cer.	Fixed	150 v		283-003
C423	1810-up	.0033 μf	Cer.	Fixed	500 v		283-041
C430	101-719X	10 μf		Fixed	15 v		290-106
C436	101-719	10 μf		Fixed	15 v		290-106
C436	720-up	100 μf		Fixed	6 v		290-105
C442		.1 μf	Cer.	Fixed	50 v		283-009
C507		120 μμf	Cer.	Fixed		10%	281-550
C508		7-45 μμf	Cer.	Var.			281-012
C518		10 μf		Fixed	15 v		290-106
C522		150 μμf	Cer.	Fixed	500 v	±30 μμf	281-524
C612		2000 μf	EMC	Fixed	30 v		290-087
C620		2 x 100 μf	EMC	Fixed	50 v		290-119
C621		.1 μf	PTM	Fixed	600 v		285-556
C657		100 μf	EMT	Fixed	15 v		290-099
C660		500 μf	EMT	Fixed	25 v		290-116
C700	101-2619X	10 μf		Fixed	15 v		290-106
C701		.005 μf	Cer.	Fixed	500 v		283-001
C707		.001 μf	Cer.	Fixed	500 v		283-000
C714	X720-up	.005 μf	Cer.	Fixed	4000 v		283-034
C715	X720-up	.005 μf	Cer.	Fixed	4000 v		283-034
C716	X720-up	.02 μf	Cer.	Fixed	1400 v		283-022
C717	X720-up	.005 μf	Cer.	Fixed	4000 v		283-034
C718		.01 μf	Cer.	Fixed	1000 v		283-013
C719		.1 μf	PTM	Fixed	1000 v		285-575
C720	X720-up	.005 μf	Cer.	Fixed	4000 v		283-034
C724	X720-up	.001 μf	Cer.	Fixed	500 v		283-000
C730		50 μf	EMT	Fixed	50 v		290-117
C731		50 μf	EMT	Fixed	50 v		290-117
C734		50 μf	EMT	Fixed	50 v		290-117
C735		50 μf	EMT	Fixed	50 v		290-117
C738		100 μf	EMT	Fixed	15 v		290-099
C739		100 μf	EMT	Fixed	15 v		290-099
C742		275 μf	EMT	Fixed	6 v		290-020
C743		275 μf	EMT	Fixed	6 v		290-020
C745		100 μf		Fixed	6 v		290-105
C750		100 μf	EMT	Fixed	15 v		290-099
C751		100 μf	EMT	Fixed	15 v		290-099
C753		100 μf	EMT	Fixed	6 v		290-105
C756		50 μf	EMT	Fixed	50 v		290-117
C757		50 μf	EMT	Fixed	50 v		290-117
C800	101-719X	.22 μf	Cer.	Fixed	3 v		283-020
C836	101-719X	.001 μf	Cer.	Fixed	5000 v		283-021
C851		.01 μf	Cer.	Fixed	150 v		283-003
C852		.02 μf	Cer.	Fixed	1400 v		Use 283-022
C854		.01 μf	Cer.	Fixed	1000 v		283-013
C864		.01 μf	Cer.	Fixed	150 v		283-003
C874		10 μf		Fixed	15 v		290-106

Fuses

F601	¼ amp, Fast-Blo 3AG	159-028
F621	1-½ amp, Fast-Blo 3AG	159-016

Inductors

			Tektronix Part Number
L743		40 μh	108-200
L745		40 μh	108-200

Resistors

R2		100 k	¼ w	Fixed	Comp.	10%	316-104
R15		10 k	¼ w	Fixed	Comp.	10%	316-103
R17		100 k		Var.	Comp.	10%	311-173
R19		15 k	¼ w	Fixed	Comp.	10%	316-153
R20		10 k	¼ w	Fixed	Comp.	10%	316-103
R23		47 k	¼ w	Fixed	Comp.	10%	316-473
R24		1.2 k	¼ w	Fixed	Comp.	10%	316-122
R32		100 k	¼ w	Fixed	Comp.	10%	316-104
R33		820 k	¼ w	Fixed	Comp.	10%	316-824
R35	101-1809	3.3 k	¼ w	Fixed	Comp.	10%	316-332
R35	1810-up	3.9 k	¼ w	Fixed	Comp.	5%	315-392
R37	101-1809	27 k	¼ w	Fixed	Comp.	10%	316-273
R37	1810-up	15 k	¼ w	Fixed	Comp.	5%	315-153
R38	101-1809	3.9 k	¼ w	Fixed	Comp.	10%	316-392
R38	1810-up	2.2 k	¼ w	Fixed	Comp.	5%	315-222
R43		2.2 k	¼ w	Fixed	Comp.	10%	316-222
R46		22 k	¼ w	Fixed	Comp.	10%	316-223
R111		50 k		Var.	Comp.		311-154
R131		3.9 k	¼ w	Fixed	Comp.	10%	316-392
R133	101-1124	560 Ω	¼ w	Fixed	Comp.	10%	316-561
R133	1125-up	820 Ω	¼ w	Fixed	Comp.	10%	316-821
R134	101-1124	1.2 k	¼ w	Fixed	Comp.	10%	316-122
R134	1125-up	1 k	¼ w	Fixed	Comp.	10%	316-102
R135		10 k	¼ w	Fixed	Comp.	10%	316-103
R141		39 k	¼ w	Fixed	Comp.	10%	316-393
R143		180 k	¼ w	Fixed	Comp.	10%	316-184
R144		39 k	¼ w	Fixed	Comp.	10%	316-393
R147		2.2 k	¼ w	Fixed	Comp.	10%	316-222
R148		33 k	¼ w	Fixed	Comp.	10%	316-333
R151		1 k	¼ w	Fixed	Comp.	10%	316-102
R152		27 k	¼ w	Fixed	Comp.	10%	316-273
R153	101-1386	100 Ω	¼ w	Fixed	Comp.	10%	316-101
R153	1387-up	47 Ω	¼ w	Fixed	Comp.	10%	316-470
R160A		1.13 M	⅛ w	Fixed	Prec.	1%	318-021
R160C		453 k	⅛ w	Fixed	Prec.	1%	318-022
R160E		226 k	⅛ w	Fixed	Prec.	1%	318-023
R160G		113 k	⅛ w	Fixed	Prec.	1%	318-024
R160J		45.3 k	⅛ w	Fixed	Prec.	1%	318-025
R160L		22.6 k	¼ w	Fixed	Prec.	1%	319-013
R160R	X720-up	22 k	¼ w	Fixed	Comp.	10%	316-223
R160S	X720-up	27 k	¼ w	Fixed	Comp.	10%	316-273
R160T	X720-up	47 k	¼ w	Fixed	Comp.	10%	316-473
R160U	X720-up	22 k	¼ w	Fixed	Comp.	10%	316-223
R160V		20 k		Var.	Comp.		311-166
R160Z		47 k	¼ w	Fixed	Comp.	10%	316-473

							Tektronix Part Number
R161		150 Ω	¼ w	Fixed	Comp.	10%	316-151
R162		1.2 M	¼ w	Fixed	Comp.	10%	316-125
R163		220 Ω	¼ w	Fixed	Comp.	10%	316-221
R165		3.9 k	¼ w	Fixed	Comp.	10%	316-392
R166		4.7 k	¼ w	Fixed	Comp.	10%	316-472
R167		50 k		Var.	Comp.		311-154
R169		12 k	¼ w	Fixed	Comp.	10%	316-123
R174		68 k	¼ w	Fixed	Comp.	10%	316-683
R176		50 k		Var.	Comp.		311-154
R178		3.9 k	¼ w	Fixed	Comp.	10%	316-392
R181		100 k	¼ w	Fixed	Comp.	10%	316-104
R182		18 k	¼ w	Fixed	Comp.	10%	316-183
R183		18 k	¼ w	Fixed	Comp.	10%	316-183
R190		10 k	¼ w	Fixed	Comp.	10%	316-103
R193		150 Ω	¼ w	Fixed	Comp.	10%	316-151
R194		22 k	¼ w	Fixed	Comp.	10%	316-223
R196		330 Ω	¼ w	Fixed	Comp.	10%	316-331
R197		33 k	¼ w	Fixed	Comp.	10%	316-333
R198		22 k	¼ w	Fixed	Comp.	10%	316-223
R199		18 k	¼ w	Fixed	Comp.	10%	316-183
R300		68 k	¼ w	Fixed	Comp.	10%	316-683
R311		25 k	⅛ w	Fixed	Prec.	1%	318-012
R312		3.92 k	½ w	Fixed	Prec.	1%	309-270
R316		22 k	½ w	Fixed	Comp.	5%	301-223
R317		4.7 k	¼ w	Fixed	Comp.	10%	316-472
R321		20 k		Var.	Comp.	10%	311-170
R323		18 k	¼ w	Fixed	Comp.	10%	316-183
R325		3.9 k	¼ w	Fixed	Comp.	10%	316-392
R327		4.7 k	¼ w	Fixed	Comp.	10%	316-472
R333		7.3 k	½ w	Fixed	Prec.	1%	309-120
R336		18 k	½ w	Fixed	Prec.	1%	309-036
R338		1 k		Var.	Comp.	10%	311-155
R343	101-209	7.3 k	½ w	Fixed	Prec.	1%	309-120
R343	210-up	8.25 k	½ w	Fixed	Prec.	1%	309-314
R346		18 k	½ w	Fixed	Prec.	1%	309-036
R348		200 Ω	.5 w	Var.	Comp.	10%	311-158
R410C		1 M	½ w	Fixed	Prec.	1%	309-014
R410E		1 k	½ w	Fixed	Prec.	1%	309-115
R412C		990 k	½ w	Fixed	Prec.	1%	309-013
R412E		10.1 k	½ w	Fixed	Prec.	1%	309-034
R414C		900 k	½ w	Fixed	Prec.	1%	309-111
R414E		111 k	½ w	Fixed	Prec.	1%	309-046
R416C		800 k	½ w	Fixed	Prec.	1%	309-110
R416E		250 k	½ w	Fixed	Prec.	1%	309-109
R418C		500 k	½ w	Fixed	Prec.	1%	309-003
R418E		1 M	½ w	Fixed	Prec.	1%	309-014
R420		47 Ω	¼ w	Fixed	Comp.	10%	316-470
R422		1 M	½ w	Fixed	Prec.	1%	309-014
R423	101-1809	100 k	¼ w	Fixed	Comp.	10%	316-104
R423	1810-up	390 k	¼ w	Fixed	Comp.	10%	316-394
R424		47 Ω	¼ w	Fixed	Comp.	10%	316-470
R427		10 k	¼ w	Fixed	Comp.	10%	316-103
R430	101-379	220 Ω	¼ w	Fixed	Comp.	10%	316-221
R430	380-719	10 k	¼ w	Fixed	Comp.	10%	316-103
R430	720-up	22 k	¼ w	Fixed	Comp.	10%	316-223
R432		2.5 k	0.5 w	Var.	Comp.	±20%	311-086
R433	101-719	4.7 k	¼ w	Fixed	Comp.	10%	316-472

							Tektronix Part Number
R433	720-up	560 Ω	¼ w	Fixed	Comp.	10%	316-561
R434	101-719	4.7 k	¼ w	Fixed	Comp.	10%	316-472
R434	720-up	12 k	¼ w	Fixed	Comp.	10%	316-123
R436	101-719	820 Ω	¼ w	Fixed	Comp.	10%	316-821
R436	720-up	560 Ω	¼ w	Fixed	Comp.	10%	316-561
R437	X720-up	18 k	¼ w	Fixed	Comp.	10%	316-183
R443		4.7 k	¼ w	Fixed	Comp.	10%	316-472
R453		4.7 k	¼ w	Fixed	Comp.	10%	316-472
R454	X720-up	47 Ω	¼ w	Fixed	Comp.	10%	316-470
R462		1.2 k	½ w	Fixed	Comp.	5%	301-122
R463		1.5 k	½ w	Fixed	Comp.	5%	301-152
R464		3.9 k	½ w	Fixed	Comp.	5%	301-392
R466		2.7 k	½ w	Fixed	Comp.	5%	301-272
R467		47 Ω	¼ w	Fixed	Comp.	10%	316-470
R468		200 Ω	.5 w	Var.	Comp.	10%	311-158
R472		1.2 k	½ w	Fixed	Comp.	5%	301-122
R473		1.5 k	½ w	Fixed	Comp.	5%	301-152
R474		3.9 k	½ w	Fixed	Comp.	5%	301-392
R476		2.7 k	½ w	Fixed	Comp.	5%	301-272
R477		120 Ω	¼ w	Fixed	Comp.	10%	316-121
R478		270 Ω		Var.	WW		Use *311-286
R480		2 x 20 k		Var.	Comp.		311-163
R481		12 k	¼ w	Fixed	Comp.	10%	316-123
R483		4.7 k	¼ w	Fixed	Comp.	10%	316-472
R491		12 k	¼ w	Fixed	Comp.	10%	316-123
R493		4.7 k	¼ w	Fixed	Comp.	10%	316-472
R502		5 k	½ w	Fixed	Prec.	1%	309-159
R506		2.63 k	½ w	Fixed	Prec.	1%	309-230
R507	101-1880	330 Ω	½ w	Fixed	Comp.	5%	301-331
R507	1881-up	240 Ω	¼ w	Fixed	Comp.	5%	315-241
R508		100 Ω	¼ w	Fixed	Comp.	10%	316-101
R509	X1881-up	82 Ω	¼ w	Fixed	Comp.	5%	315-820
R512		5 k	½ w	Fixed	Prec.	1%	309-159
R516		2.63 k	½ w	Fixed	Prec.	1%	309-230
R517		4.7 k	¼ w	Fixed	Comp.	10%	316-472
R518		10 k		Var.	Comp.	10%	311-153
R520		100 k	¼ w	Fixed	Comp.	10%	316-104
R521		6.8 k	¼ w	Fixed	Comp.	10%	316-682
R522		1.8 k	¼ w	Fixed	Comp.	10%	316-182
R524		10 k	½ w	Fixed	Prec.	1%	309-100
R602		100 Ω		Var.	Comp.	±50%	311-165
R610	101-719	13 Ω	10 w	Fixed	WW	5%	308-158
R610	720-up	10 Ω	10 w	Fixed	WW	5%	308-175
R621	101-719X	33 k	¼ w	Fixed	Comp.	10%	316-333
R622	101-349	2.2 k	¼ w	Fixed	Comp.	10%	316-222
R622	350-up	1 k	¼ w	Fixed	Comp	10%	316-102
R624		560 Ω	¼ w	Fixed	Comp.	10%	316-561
R631		1.8 k	¼ w	Fixed	Comp.	10%	316-182
R634	101-719X	82 Ω	¼ w	Fixed	Comp.	10%	316-820
R635	X360-719	150 Ω	2 w	Fixed	Comp.	10%	306-151
R635	720-up	40 Ω	10 w	Fixed	WW	5%	308-012
R644	X720-up	47 Ω	¼ w	Fixed	Comp.	10%	316-470

Resistors *(continued)*

							Tektronix Part Number
R650	101-349	470 Ω	¼ w	Fixed	Comp.	10%	316-471
R650	350-up	1 k	¼ w	Fixed	Comp	10%	316-102
R651		1 k		Var.	Comp.	10%	311-155
R652		1.8 k	¼ w	Fixed	Comp.	10%	316-182
R692		100 Ω	8 w	Fixed	WW	5%	308-110
R693		117 Ω	8 w	Fixed	WW	5%	308-174
R694		680 Ω	2 w	Fixed	Comp.	10%	306-681
R700		330 Ω	¼ w	Fixed	Comp.	10%	316-331
R701	X720-up	10 Ω	½ w	Fixed	Comp.	10%	302-100
R707		22 k	¼ w	Fixed	Comp.	10%	316-223
R714	X720-up	100 k	½ w	Fixed	Comp.	10%	302-104
R718		1 M	¼ w	Fixed	Comp.	10%	316-105
R720	X720-up	1 meg	½ w	Fixed	Comp.	10%	302-105
R731		100 Ω	¼ w	Fixed	Comp.	10%	316-101
R735		470 Ω	¼ w	Fixed	Comp.	10%	316-471
R739		47 Ω	¼ w	Fixed	Comp.	10%	316-470
R751		47 Ω	¼ w	Fixed	Comp.	10%	316-470
R753		220 Ω	¼ w	Fixed	Comp.	10%	316-221
R757		100 Ω	¼ w	Fixed	Comp.	10%	316-101
R800	101-719X	6.8 k	¼ w	Fixed	Comp.	10%	316-682
R841		3.3 M	¼ w	Fixed	Comp.	10%	316-335
R842		2 M		Var.	Comp.	20%	311-167
R844		1 M		Var.	Comp.	20%	311-168
R845		470 k	¼ w	Fixed	Comp.	10%	316-474
R846		33 k	¼ w	Fixed	Comp.	10%	316-333
R851		100 k	¼ w	Fixed	Comp.	10%	316-104
R854		1 M	½ w	Fixed	Comp.	10%	302-105
R861		100 k		Var.	Comp.	10%	311-157
R864		100 k		Var.	Comp.	10%	311-176
R871		100 k	¼ w	Fixed	Comp.	10%	316-104
R874		150 Ω	¼ w	Fixed	Comp.	10%	316-151
R881		2.2 k	¼ w	Fixed	Comp.	10%	316-222
R882		6.8 k	½ w	Fixed	Comp.	5%	301-682
R884	101-379	1 k		Var.	Comp.	10%	311-155
R884	380-up	2.5 k		Var.	Comp.	20%	311-120
R886		570 Ω	½ w	Fixed	Prec.	1%	309-081
R888		49.5 k	½ w	Fixed	Prec.	1%	309-215

Switches

			wired	unwired
SW2		INT.-EXT.		260-145
SW8		AC-DC		260-145
SW15		SLOPE		260-212
SW17		TRIGGERING LEVEL	*262-250	*260-296
SW160	101-719	TIME/DIV.	*262-248	*260-294
SW160	720-up	TIME/DIV.	*262-395	*260-376
SW401		INPUT		260-145
SW410		VOLTS/DIV.	*262-480	*260-295
SW621		POWER ON		*260-307
SW692		BATTERY CHARGER ON		*260-251

Thermal Cutout

			Tektronix Part Number
TK621		120° F ±5° Open; 105° ±5° Close	*260-293

Transformers

T601		POWER TRANSFORMER	*120-152
T701	101-719	REGULATOR TRANSFORMER	*120-153
T701	720-up	REGULATOR TRANSFORMER	*120-210
T801	101-719X	H.V. OSCILLATOR TRANSFORMER	*120-151

Diodes

Even though the diodes may be different in physical size, they are direct electrical replacements for the diodes in your instrument.

D111		T12G Germanium Diode	152-008
D131		T12G Germanium Diode	152-008
D153		Silicon Diode	152-017
D194		T12G Germanium Diode	152-008
D482	X479-up	T12G Germanium Diode	152-008
D506	X1881-up	Germanium Diode	152-075
D507	X1881-up	Germanium Diode	152-075
D610		Silicon Diode	152-066
D611		Silicon Diode	152-066
D620		Silicon Diode	152-066
D621		Silicon Diode	152-001
D622		Silicon Diode	152-001
D629		Zener Diode	152-016
D660		Silicon Diode	152-066
D661		Silicon Diode	152-066
D692		Silicon Diode	152-066
D700	101-2619	T12G Germanium Diode	152-008
D700	2620-up	IN91 Germanium Diode	152-001
D710		T12G Germanium Diode	152-008
D711		T12G Germanium Diode	152-008
D712		T12G Germanium Diode	152-008
D713		T12G Germanium Diode	152-008
D714	X720-up	Silicon Diode	152-002
D715	X720-up	Silicon Diode	152-002
D716		Silicon Diode	152-002
D717	X720-up	Silicon Diode	152-002
D718	X720-up	Silicon Diode	152-002
D719	X720-up	Silicon Diode	152-002
D720		Silicon Diode	152-066
D721		Silicon Diode	152-066
D724		Silicon Diode	152-066
D726		Silicon Diode	152-066
D728		Silicon Diode	152-001
D882		T12G Germanium Diode	152-008

Transistors

Q14	101-719	2N544	replace with 050-038
Q14	720-up	2N1632	151-048
Q24	101-719	2N544	replace with 050-038
Q24	720-up	2N1632	151-048
Q35		2N169A	151-033

Transistors *(continued)*

				Tektronix Part Number
Q45		2N169A		151-033
Q135		2N169A		151-033
Q145		2N169A		151-033
Q153	101-1386	2N404		151-010
Q153	1387-up	2N1997		151-078
Q161		OC170		*153-501
Q163		J509/2N1592		151-035
Q173		2N671/2N1126		151-012
Q183		2N404		151-010
Q194		OC170		*153-501
Q199		2N226		151-025
Q313	101-719	2N544		replace with 050-038
Q313	720-up	2N1632		151-048
Q323	101-719	2N544		replace with 050-038
Q323	720-up	2N1632		151-048
Q334		2N1632 Selected		Use *153-516
Q344		2N1632 Selected		Use *153-516
Q443		OC170		151-015
Q453	101-719	2N544		replace with 050-038
Q453	720-up	2N1632		151-048
Q464		OC170		151-015
Q474		OC170		151-015
Q483		OC170		151-015
Q493		OC170		151-015
Q504		OC170		*153-501
Q514		OC170		*153-501
Q524	101-719	2N544		replace with 050-038
Q524	720-up	2N1632		151-048
Q624		2N1102		151-026
Q634		2N647		151-030
Q644	101-719X	2N226		151-025
Q654		2N671/2N1126		151-012
Q657		2N250		151-018
Q700		2N307	Selected pair	*153-510
Q710		2N307		
Q800	101-719X	2N250		151-018
Q874	101-719	2N544		replace with 050-038
Q874	720-up	2N1632		151-048

Vacuum Tubes

V423	101-719	5718	154-053
V423	720-up	7586	154-306
V832	101-719X	5642	154-051
V859		T321P31	*154-347

Type 321
Mechanical Parts List

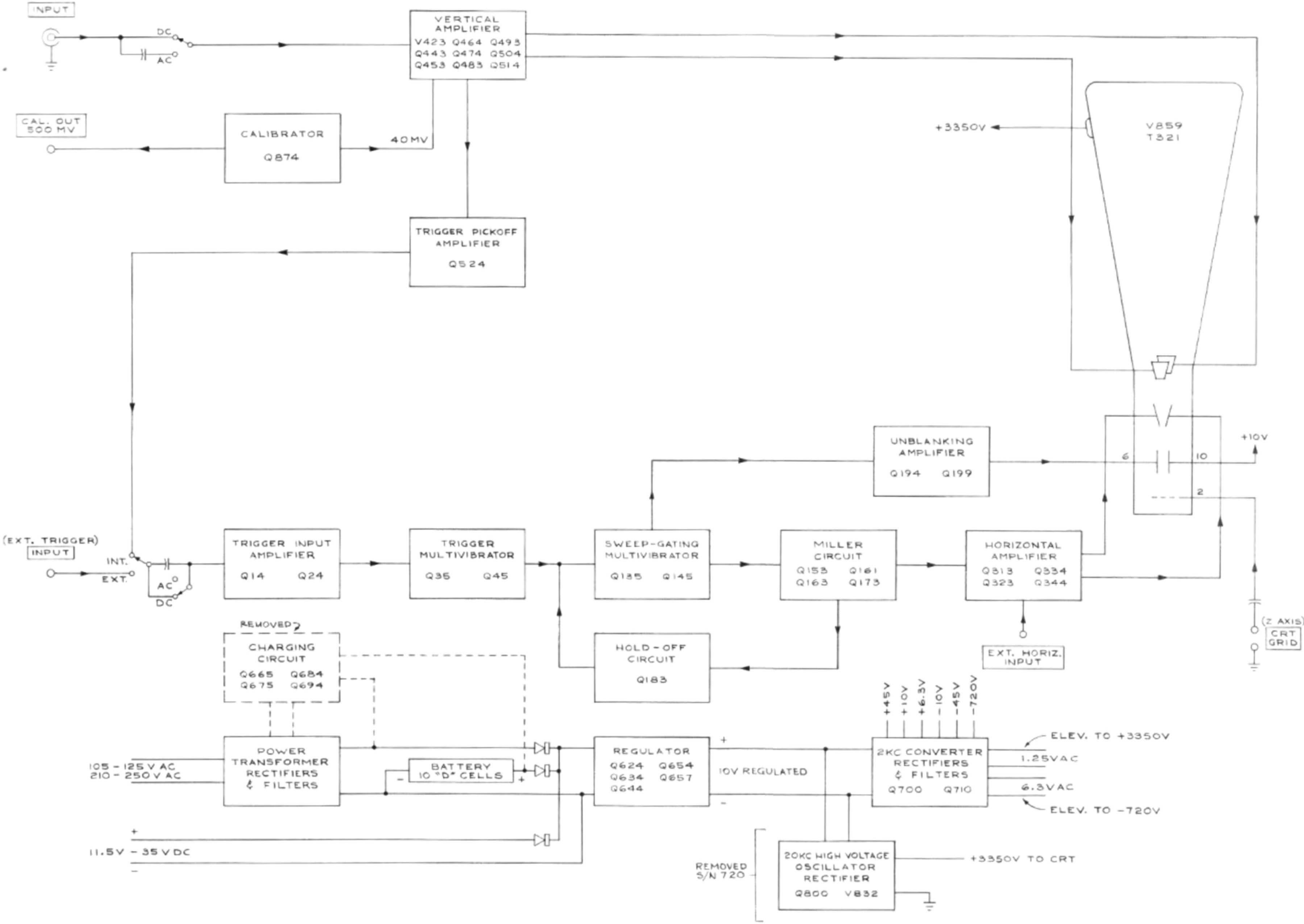
	Tektronix Part Number
BAR, HANDLE ASS'Y CHANNEL TOP SUPPORT	381-146
BAR, TIE ASS'Y FOR BATTERY BOX	381-158
BATTERY BOX ASS'Y	650-426
BRACKET, ATTEN. SWITCH	406-523
BRACKET, HEAT SINK	406-524
BRACKET, CAPACITOR MTG.	406-529
BRACKET, TIME/CM SWITCH	406-534
BRACKET, THERMISTOR MTG.	406-535
BRACKET, TRANSFORMER MTG. SN 720-up	406-685
BUSHING, BANANA JACK	358-054
BUSHING, POT MTG.	358-075
CABINET SIDE	387-008
CABLE, HV poly	175-012
CABLE, COAX 50 Ω	175-068
CABLE HARNESS, POWER SN 101-719	179-375
CABLE HARNESS, HORIZ. AMP.	179-376
CABLE HARNESS, CHARGER	179-377
CABLE HARNESS, TIMING SWITCH	179-380
CABLE HARNESS, POWER SN 720-up	179-501
CABLE HARNESS, POWER TRANSFORMER SN 720-up	179-502
CERAMIC STRIP 3/4 x 2 notches, clip-mounted	124-086
CERAMIC STRIP 3/4 x 4 notches, clip-mounted	124-088
CERAMIC STRIP 7/16 x 3 notches, clip-mounted	124-092
CERAMIC STRIP 7/16 x 5 notches, clip-mounted	124-093
CERAMIC STRIP 7/16 x 7 notches, clip-mounted	124-094
CERAMIC STRIP 7/16 x 9 notches, clip-mounted	124-095
CERAMIC STRIP 3/4 x 1 notches, clip-mounted	124-100
CERAMIC STRIP 7/16 x 11 notches, clip-mounted	124-106
CHASSIS, HORIZ. AMP. SN 101-719	441-281
CHASSIS, POWER & VA SN 101-719	441-282
CHASSIS, CHARGER	441-284
CHASSIS, POWER & VA SN 720-up	441-361
CHASSIS, HORIZ. AMP. SN 720-up	441-362
CLAMP, CABLE 1/8" plastic	343-001
CLAMP, CABLE 7/8" plastic	343-009
CLAMP, CABLE .037 x 1 7/16 w/2 mtg. straps	343-038

	Tektronix Part Number
CLAMP, TRANSISTOR MTG.	343-044
CLAMP, TRANSISTOR MTG. 1/4" ID x 1/4 SN 720-up	343-068
CONNECTOR, TERMINAL FEED THRU	131-025
CONNECTOR, COAX, CHASSIS MT.	131-106
COUPLING, POT	376-014
COVER, TRANSISTOR	200-196
COVER, CAPACITOR	200-213
CRT PIN CONNECTOR	131-049
CRT BRUSH CONNECTOR	131-073
CRT ANODE LEAD ASS'Y 12" SN 720-up	131-084
CRT ANODE LEAD ASS'Y 15 1/2" SN 101-719	131-135
CRT SOCKET	136-082
CRT ANODE CAP, black poly	200-110
CRT ANODE COVER 1 3/16 OD	200-197
CRT SHIELD	337-336
CRT SHIELD GROMMET	348-030
CRT ROTATING RING	354-095
EYELET, TAPERED BARREL	210-601
FASTENER, RECEPTACLE	214-127
FELT STRIP 1/8 x 1 x 4 1/16	124-109
FELT STRIP 1/8 x 1 x 2 3/8	124-115
FOOT, RUBBER w/steel insert	348-025
FOOT, FLIP STAND PIVOT BLOCK, LEFT	348-026
FOOT, FLIP STAND PIVOT BLOCK, RIGHT	348-027
FRAME, BOTTOM RAIL	426-078
FUSE HOLDER	352-025
GROMMET, RUBBER 1/4"	348-002
GROMMET, RUBBER 5/16"	348-003
GROMMET, RUBBER 1/2"	348-005
GROMMET, RUBBER 5/8"	348-012
GRATICULE LIGHT SOCKET	136-035
GRATICULE COVER	200-214
GRATICULE	331-055
GRATICULE LIGHT FILTER, GREEN	378-521
KNOB, SMALL BLACK 1/4" insert hole	366-033
KNOB, ASS'Y FOR SMALL RED SHELL	366-081

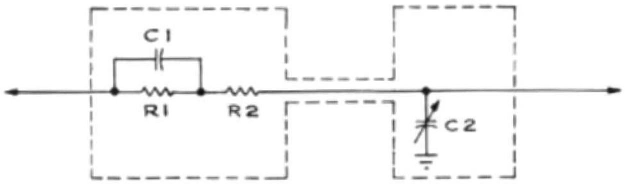
	Tektronix Part Number
KNOB, SMALL GREY ASS'Y	366-083
KNOB, SMALL BLACK ASS'Y	366-085
KNOB, ASS'Y FOR SMALL BLACK SHELL	366-087
LOCKWASHER #2 INT	210-001
LOCKWASHER #4 INT	210-004
LOCKWASHER #6 INT	210-006
LOCKWASHER #8 INT	210-008
LOCKWASHER 1/4 INT	210-011
LOCKWASHER POT INT	210-012
LUG, SOLDER SE 4	210-201
LUG, SOLDER SE 6 w/2 wire holes	210-202
LUG, SOLDER SE 6 long	210-203
LUG, SOLDER DE6	210-204
LUG, SOLDER 1/4" hole	210-223
NUT, HEX 2-56 x 3/16	210-405
NUT, HEX 4-40 x 3/16	210-406
NUT, HEX 6-32 x 1/4	210-407
NUT, HEX 8-32 x 5/16	210-409
NUT, HEX 3/8-32 x 1/2	210-413
NUT, HEX 10-24 x 3/8 square	210-416
NUT, KEP 6-32 x 5/16	210-457
NUT, HEX 1/4-32 x 3/8 x 3/32	210-465
NUT, INSERT, Nylon Rear Casting	210-241
NUT, HEX 5-10 watt resistor mtg.	210-478
PANEL, FRONT	333-566
PANEL SERIAL NUMBER INSERT TAG	334-679
PLATE, FIBER CAPACITOR MTG.	386-252
PLATE, MICA, TRANSISTOR INSULATOR SN 101-1332	386-978
PLATE, INSULATING, HD Anodized Alum. SN 1333-up	387-345
PLATE, MICA .875 x 1.125 x .002	387-004
PLATE, ALUM., REAR CASTING	387-005
PLATE, VERT. BULK HEAD SN 101-719	387-015
PLATE, VERT. BULK HEAD SN 720-up	387-378
PLATE, REAR BATTERY BOX ASS'Y	387-022
PLATE, FRONT BATTERY BOX ASS'Y	387-023
PLATE, ALUM., FRONT CASTING	387-100
PLATE, BOTTOM, BATTERY BOX	387-247
PLUG, TWIN BANANA 3/4" apart	134-012
POST, TERMINAL TRANSISTOR MTG.	129-049

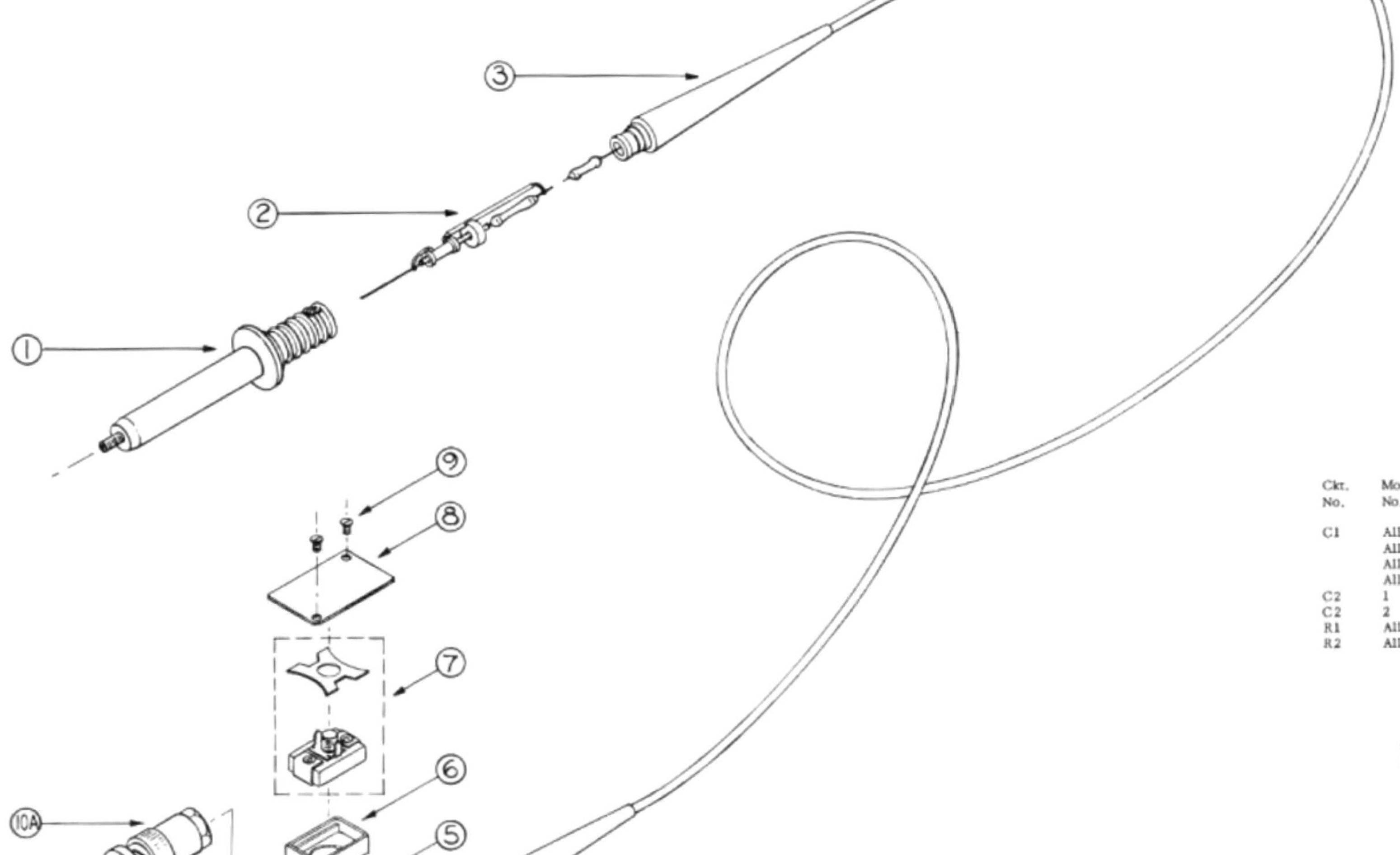
	Tektronix Part Number
POWER CORD ADAPTER 3- to 2-wire	103-013
POWER CORD AC w/female connector & male plug	161-015
POWER CORD DC w/female connector	161-016
POWER RECEPTACLE BOARD ASS'Y	392-129
ROD, EXTENSION $4^{31}/_{32}$	384-197
ROD, HEX, NYLON, 1/4"	255-037
ROD, NYLON 1/4 x 1 1/16	385-139
SCREW 4-40 x 3/16 BHS	211-007
SCREW 4-40 x 1/4 BHS	211-008
SCREW 4-40 x 1 1/4 RHS	211-021
SCREW 2-56 x 3/16 RHS	211-022
SCREW 4-40 x 1/4 FHS	211-023
SCREW 2-56 x 1/4 FHS	211-030
SCREW 4-40 x 1 5/8 BHB	211-052
SCREW 6-32 x 3/16 BHS SN 720-up	211-503
SCREW 6-32 x 1/4 BHS	211-504
SCREW 6-32 x 5/16 BHS	211-507
SCREW 6-32 x 3/8 BHS	211-510
SCREW 6-32 x 1/2 BHS	211-511
SCREW 6-32 x 5/16 Pan HS w/lockwasher	211-534
SCREW 6-32 x 1 1/4 Truss HS Phillps	211-545
SCREW 6-32 x 1 1/2 RHS Phillips	211-553
SCREW 6-32 x 1/4 Truss HS Phillips	211-565
SCREW 1-24 x 5/8 RHS	212-513
SCREW, SET 4-40 x 3/16 HSS Allen	213-022
SCREW, THREAD CUTTING, 4-40 x 5/16 Phillips	213-034
SCREW, THREAD CUTTING, 4-40 x 1/4 Phillips	213-035
SCREW, THREAD CUTTING, 4-40 x 5 1/16 PHILLIPS	213-045
SHIELD, ATTEN. BOTTOM	337-331
SHIELD, ATTEN. TOP	337-332
SHIELD, CONVERTER	337-343
SHIELD, HORIZ. & VERT.	337-344
SHIELD, BATTERY BOX	337-346
SHIELD, HV, PLEXIGLASS SN 720-up	337-425
SHIELD, 1 5/8 x 2 7/8 SN 720-up	337-426
SOCKET, SUBMINIATURE	136-078
SOCKET, BANANA JACK ASSEMBLY, BLACK	136-106
SOCKET, BANANA JACK ASSEMBLY, RED	136-107
SOCKET, 5-pin NU-VISTOR SN 720-up	136-101
SPACER, 5/32 NYLON for ceramic strip	361-007

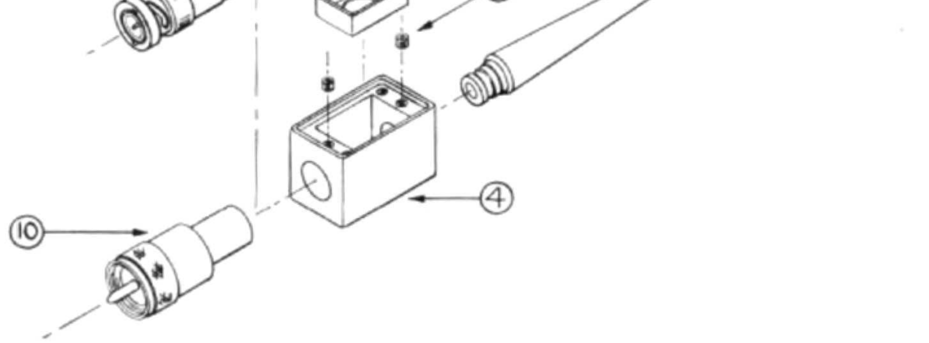
	Tektronix Part Number
SPACER, 3/8 NYLON for ceramic strip	361-009
SPACER, BATTERY TUBE	361-016
STAND, BAIL FLIP	348-024
TAG, VOLTAGE RATING 105-125 V	334-649
TUBE, BATTERY, GREY FIBER	166-157
TUBE, BATTERY, GREY FIBER w/cutout	166-158
TUBING, PLASTIC, CLEAR #7	162-012
TUBING, PLASTIC, BLACK #20	162-504
WASHER, 5S x 9/32 x .025	210-801
WASHER, 6L x 3/8 x .032	210-803
WASHER, FIBER #6 shouldered	210-811
WASHER, FIBER #10	210-812
WASHER, STEEL .390 ID x 9/16 OD x .020	210-840
WASHER, INSULATING, BLACK, shouldered	210-895
WASHER, INSULATING, RED, shouldered	210-898
WASHER, BAKELITE, TRANSISTOR MTG.	210-900
WASHER, #14 .265 x 7/16 x .050	210-905
WIRE #22 SOLID WHITE	175-522
WIRE #26 SOLID WHITE, NYLON	175-528
WIRE #26 STRANDED	175-546
WIRE #26 SOLID WHITE, POLY VINYL	175-573
WIRE #20 STRANDED WHITE SN 720-up	175-512
WIRE #22 STRANDED WHITE SN 720-up	175-527
WIRE #24 SOLID RED SN 720-up	175-572
WIRE #26 SOLID BLACK SN 720-up	175-574
WIRE 5/32 wide, flat shield	176-047


INPUT
DC
AC
VERTICAL AMPLIFIER
V423 Q464 Q493
Q443 Q474 Q504
Q453 Q483 Q514
CAL. OUT 500 MV
CALIBRATOR
Q874
40MV
TRIGGER PICKOFF AMPLIFIER
Q524
+3350V
V859
T321
+10V
6
10
2
UNBLANKING AMPLIFIER
Q194 Q199
(EXT. TRIGGER) INPUT
INT.
EXT.
AC
DC
TRIGGER INPUT AMPLIFIER
Q14 Q24
TRIGGER MULTIVIBRATOR
Q35 Q45
SWEEP-GATING MULTIVIBRATOR
Q135 Q145
MILLER CIRCUIT
Q153 Q161
Q163 Q173
HORIZONTAL AMPLIFIER
Q313 Q334
Q323 Q344
(Z AXIS) CRT GRID
EXT. HORIZ. INPUT
REMOVED?
CHARGING CIRCUIT
Q665 Q684
Q675 Q694
HOLD-OFF CIRCUIT
Q183
+45V +10V +6.3V -10V -45V -720V
105 - 125 V AC
210 - 250 V AC
POWER TRANSFORMER RECTIFIERS & FILTERS
BATTERY 10 "D" CELLS
REGULATOR
Q624 Q654
Q634 Q657
Q644
10V REGULATED
2KC CONVERTER RECTIFIERS & FILTERS
Q700 Q710
ELEV. TO +3350V
1.25VAC
6.3VAC
ELEV. TO -720V
11.5V - 35VDC
REMOVED S/N 720
20KC HIGH VOLTAGE OSCILLATOR RECTIFIER
Q800 V832
+3350V TO CRT

MRH
9-13-62







PROBES THIS SHEET COVERS

P6017

43 inches	Tektronix Part No.	010-038
6 ft.		010-056
9 ft.		010-057
12 ft.		010-058

P6022

43 inches	Tektronix Part No.	010-064
6 ft.		010-066
9 ft.		010-067
12 ft.		010-068

TABLE I ELECTRICAL PARTS

Ckt. No.	Model No.	Cable Length	Value	Description	Tektronix Part No.
C1	All	43 inches	11µµf	Cer. Fixed 500v +or- 5%	281-576
	All	6 ft.	14µµf		281-577
	All	9 ft.	18µµf		281-578
	All	12 ft.	21µµf		281-579
C2	1	All Lengths	8-50µµf	Cer. Var. 500v	281-013
C2	2	All Lengths	5-80µµf	Mica Var. 500v	281-062
R1	All	All Lengths	9 meg	1/2 w Fixed Prec. 2%	309-232
R2	All	All Lengths		Selected for proper cable termination. Furnished with cable.	

NOTE

On the underside of the lid for the Compensation Box is the Model Number. If the probe shows no number it will be Model Number One.

TABLE II MECHANICAL PARTS

Item No.	Probe Type	Model No.	Cable Length	Part Title	Tektronix Part No.
1	P6017/P6022	All	All Lengths	Probe Body	204-054
2	P6017/P6022	All	43 inches	Attenuation Assembly	011-038
			6 ft.		011-037
			9 ft.		011-039
			12 ft.		011-040
3	P6017/P6022	All	43 inches	Cable Assembly	175-143
			6 ft.		175-185
			9 ft.		175-186
			12 ft.		175-187
4	P6017/P6022	1	All Lengths	Compensator Box	202-051
		2			202-068
5	P6017/P6022	All	All Lengths	Allen Set Screws 4-40 x 3/32	213-075
6	P6017/P6022	2 only	All Lengths	Positioning Insulator	200-098
7	P6017/P6022	1	All Lengths	Compensating Capacitor	281-013
		2		Compensating Capacitor and Spring Clip Assembly	281-059
8	P6017/P6022	All	All Lengths	Plate Cover	200-248
9	P6017/P6022	All	All Lengths	Thread Cutting Screw 4-40 x 1/4	213-035
10A	P6017	All	All Lengths	Connector, UHF	131-058
10	P6022	All	All Lengths	Connector, BNC	131-186

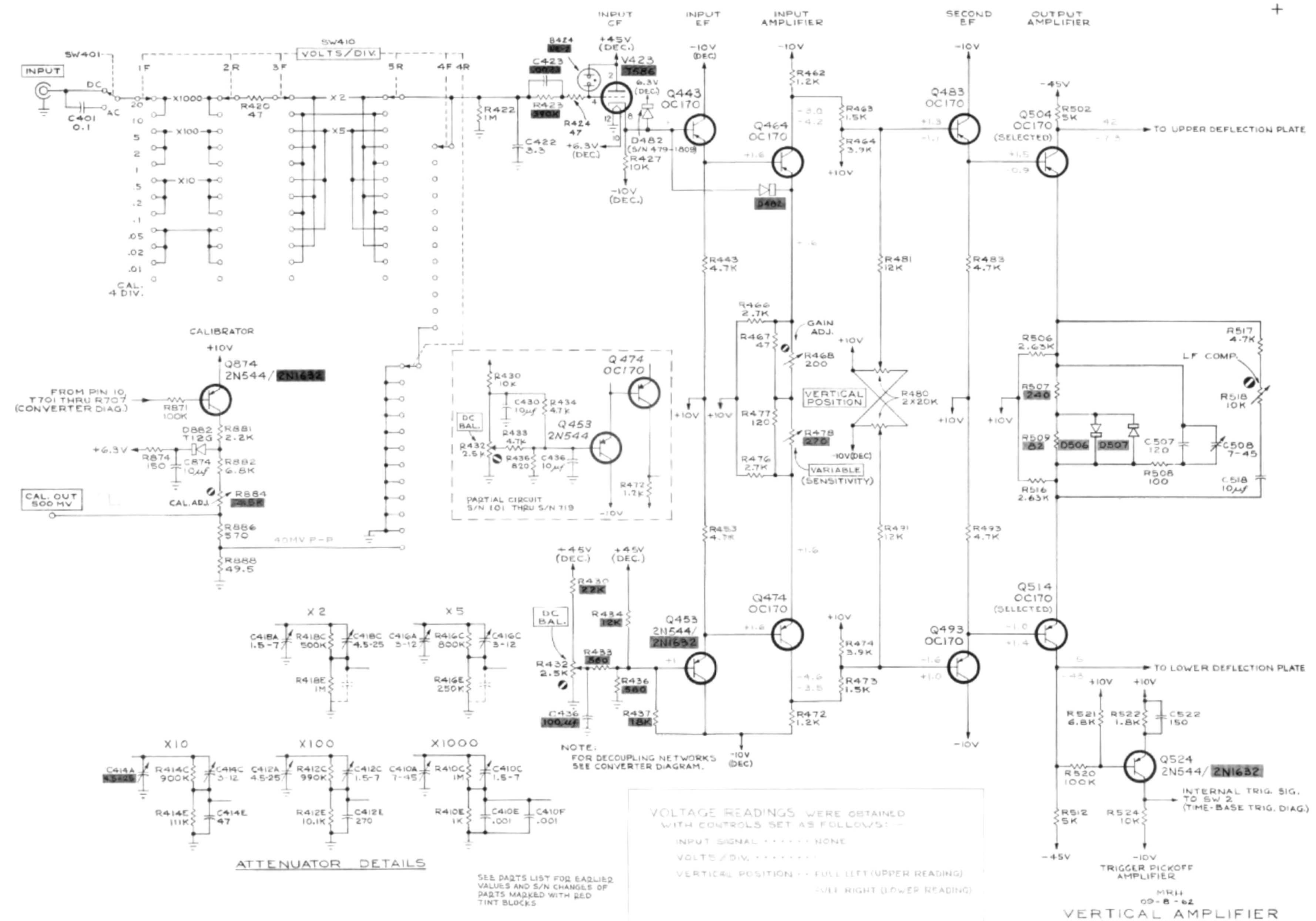
Accessories Supplied with Probe

Mini-gator Clip	344-046
Banana Plug	134-013
Probe Holder	352-024
Hook Tip	206-105
Spring Tip	206-060
Pincer Tip	013-027
12 inch Ground Strap	175-125

Accessories That May be Purchased

BNC to Probe Adaptor	013-020
Spring Tip without Shank	206-061
Pinjack Tip, Insulated	206-054
Insert Tip	206-052
Pinjack Tip	206-045
Straight Tip	206-104
BNC Tip	206-015
5 inch Ground Strap	175-124
18 inch Ground Strap	175-184

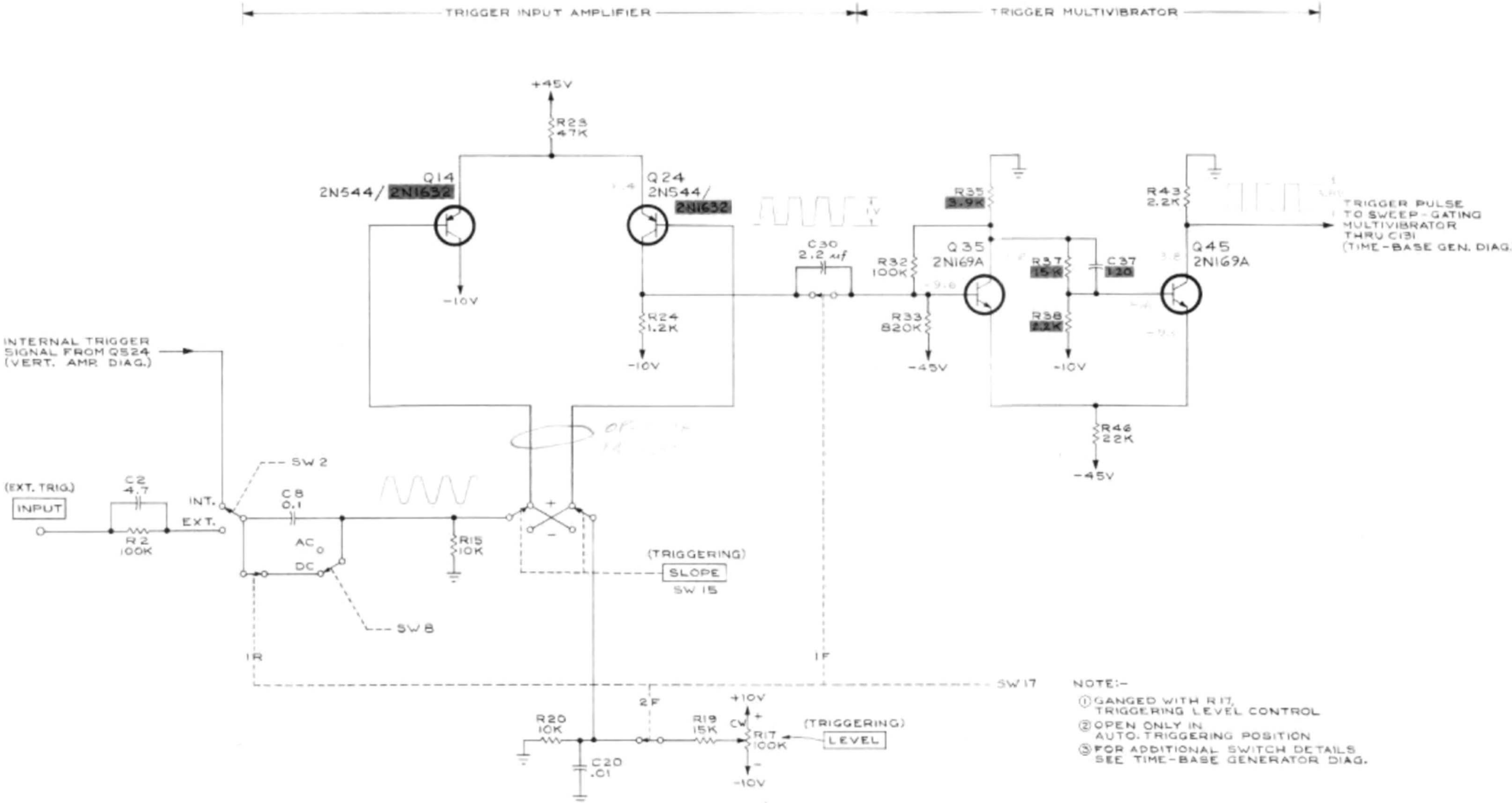
MRH



MRH
09-8-62

VERTICAL AMPLIFIER & CALIBRATOR

CIRCUIT NUMBERS
400 THRU 525
871 THRU 889



WAVEFORMS AND VOLTAGE READINGS

WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:-

WAVEFORMS

INPUT SIGNAL	500~ SINEWAVE, 3V P-P
TRIGGER SOURCE	INT.
TRIGGER SLOPE	+
TRIGGER LEVEL	AUTO
TIME/DIV.	0.5 m SEC
VARIABLE (TIME/DIV.)	CALIB.
MAG.	OFF

VOLTAGE READINGS

TRIGGER SLOPE	+
INPUT SIGNAL	NONE
TRIGGER LEVEL	CLOCKWISE, BUT NOT SWITCHED TO FREE RUN

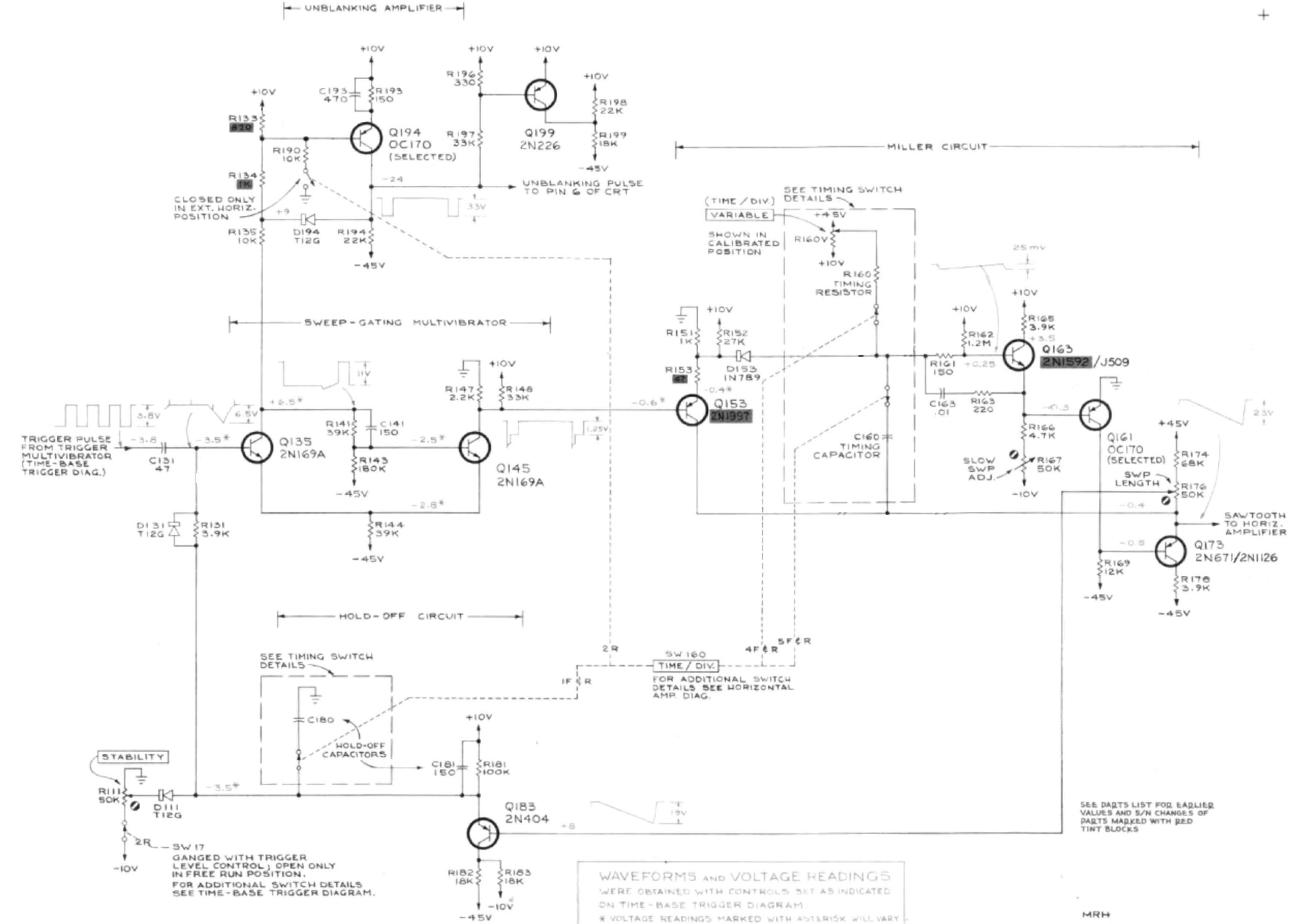
SEE PARTS LIST FOR EARLIER VALUES AND S/N CHANGES OF PARTS MARKED WITH RED TINT BLOCKS

TYPE 321 OSCILLOSCOPE

MRH
09-8-62

TIME-BASE TRIGGER

CIRCUIT NUMBERS 1 THRU 49



SEE PARTS LIST FOR EARLIER VALUES AND S/N CHANGES OF PARTS MARKED WITH RED TINT BLOCKS

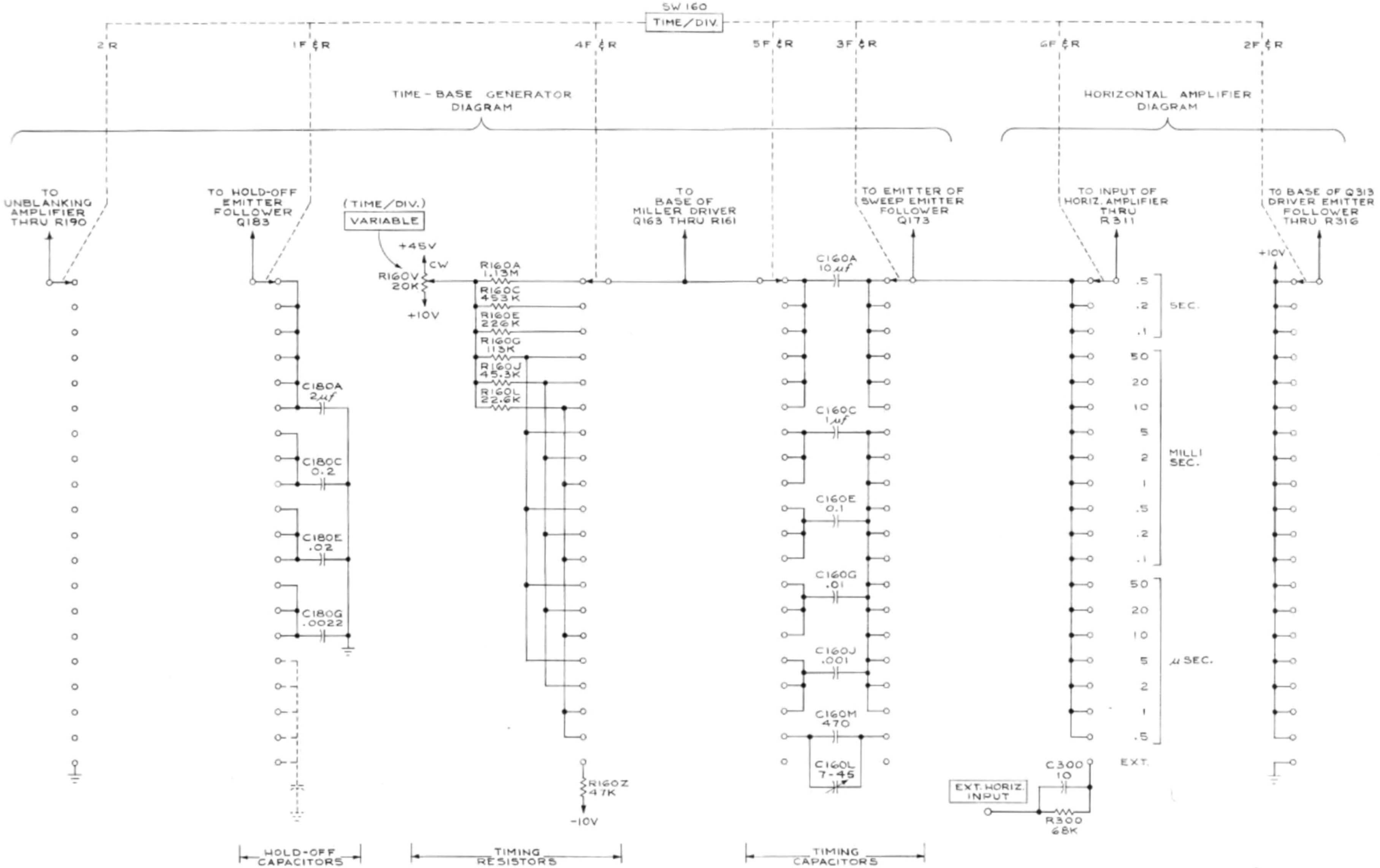
WAVEFORMS AND VOLTAGE READINGS
WERE OBTAINED WITH CONTROLS SET AS INDICATED ON TIME-BASE TRIGGER DIAGRAM
✱ VOLTAGE READINGS MARKED WITH ASTERISK WILL VARY WITH SETTING OF STABILITY CONTROL

MRH
9-31-62

TYPE 321 OSCILLOSCOPE

TIME-BASE GENERATOR

CIRCUIT NUMBERS 110 THRU 199



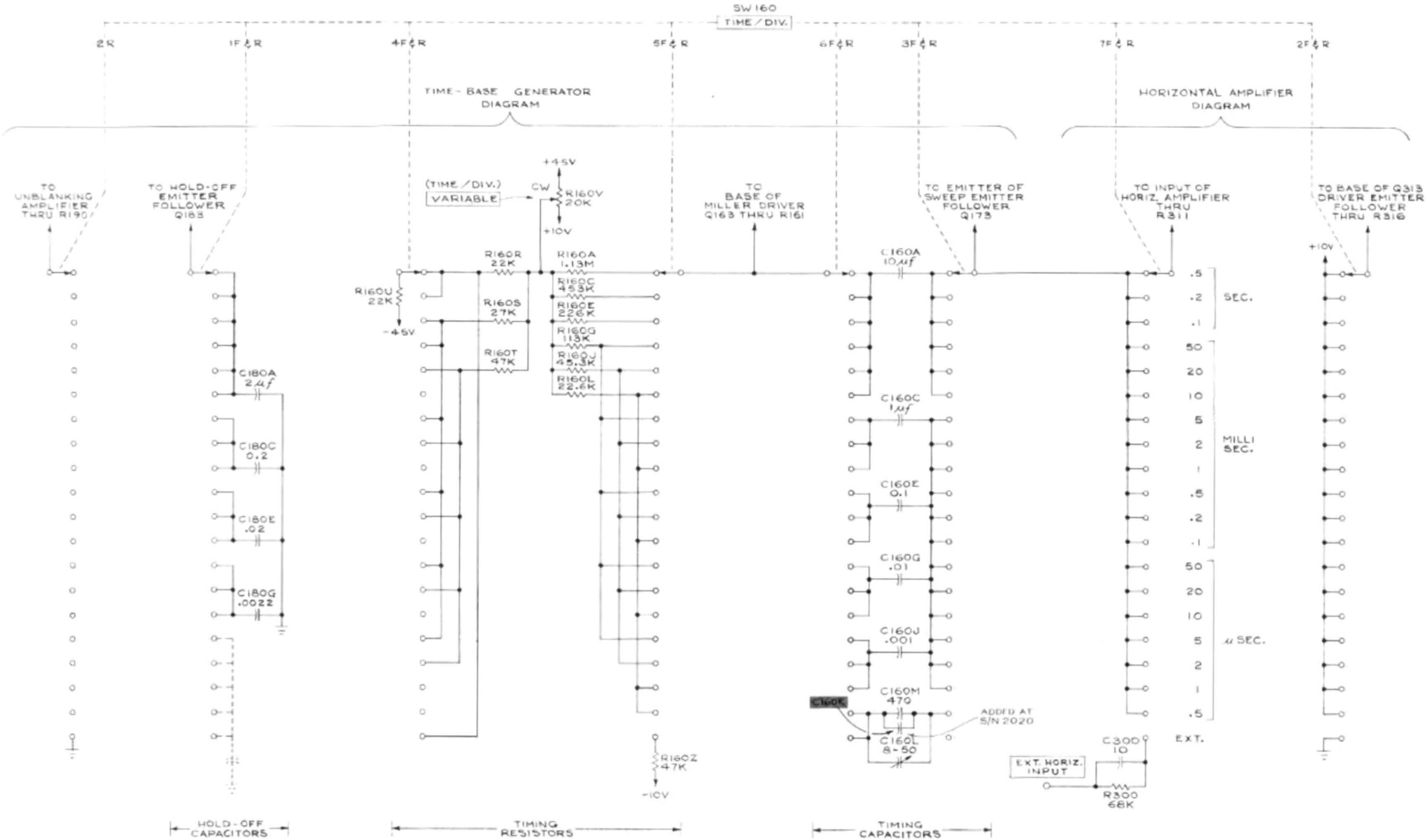
MRH
10-15-59

TYPE 321 OSCILLOSCOPE

A1

TIME/DIV. SWITCH

S/N 101 TO 719



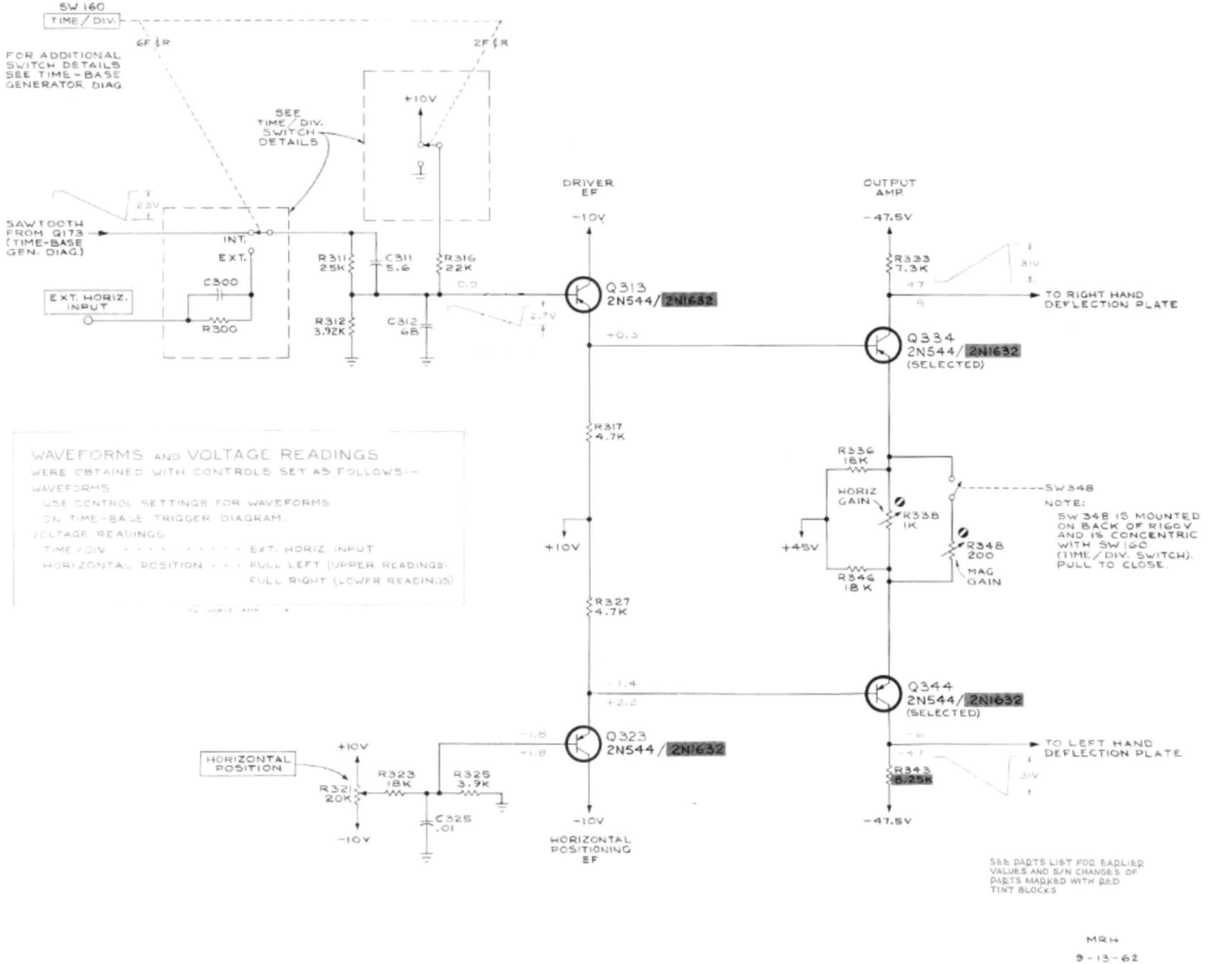
SEE PARTS LIST FOR EARLIER VALUES AND S/N CHANGES OF PARTS MARKED WITH RED TINT BLOCKS

MKH
9-10-62

TYPE 321 OSCILLOSCOPE

D_1

TIME / DIV. SWITCH
S/N 720 & UP

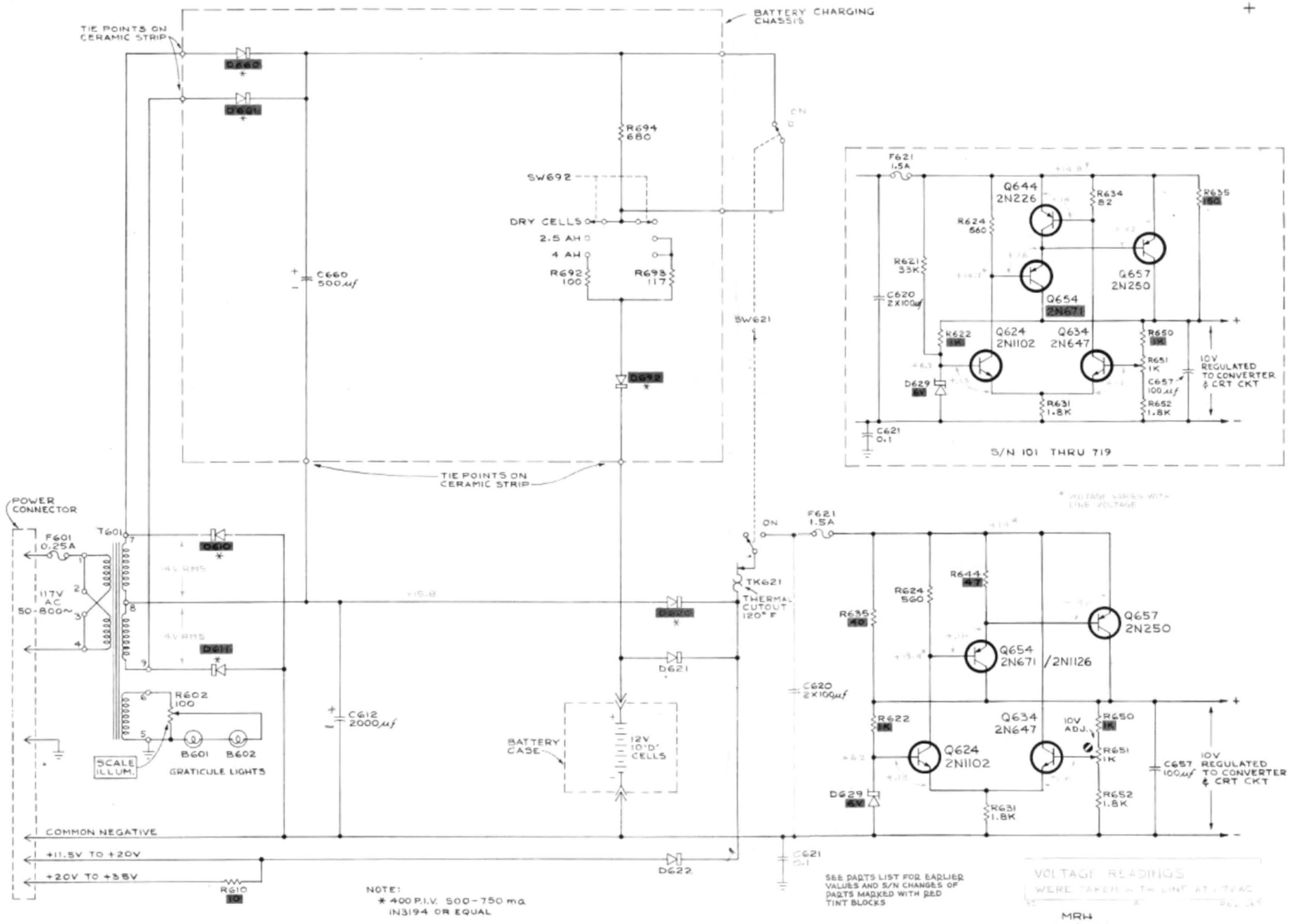


TYPE 321 OSCILLOSCOPE

B3

HORIZONTAL AMPLIFIER

CIRCUIT NUMBERS 300 THRU 349

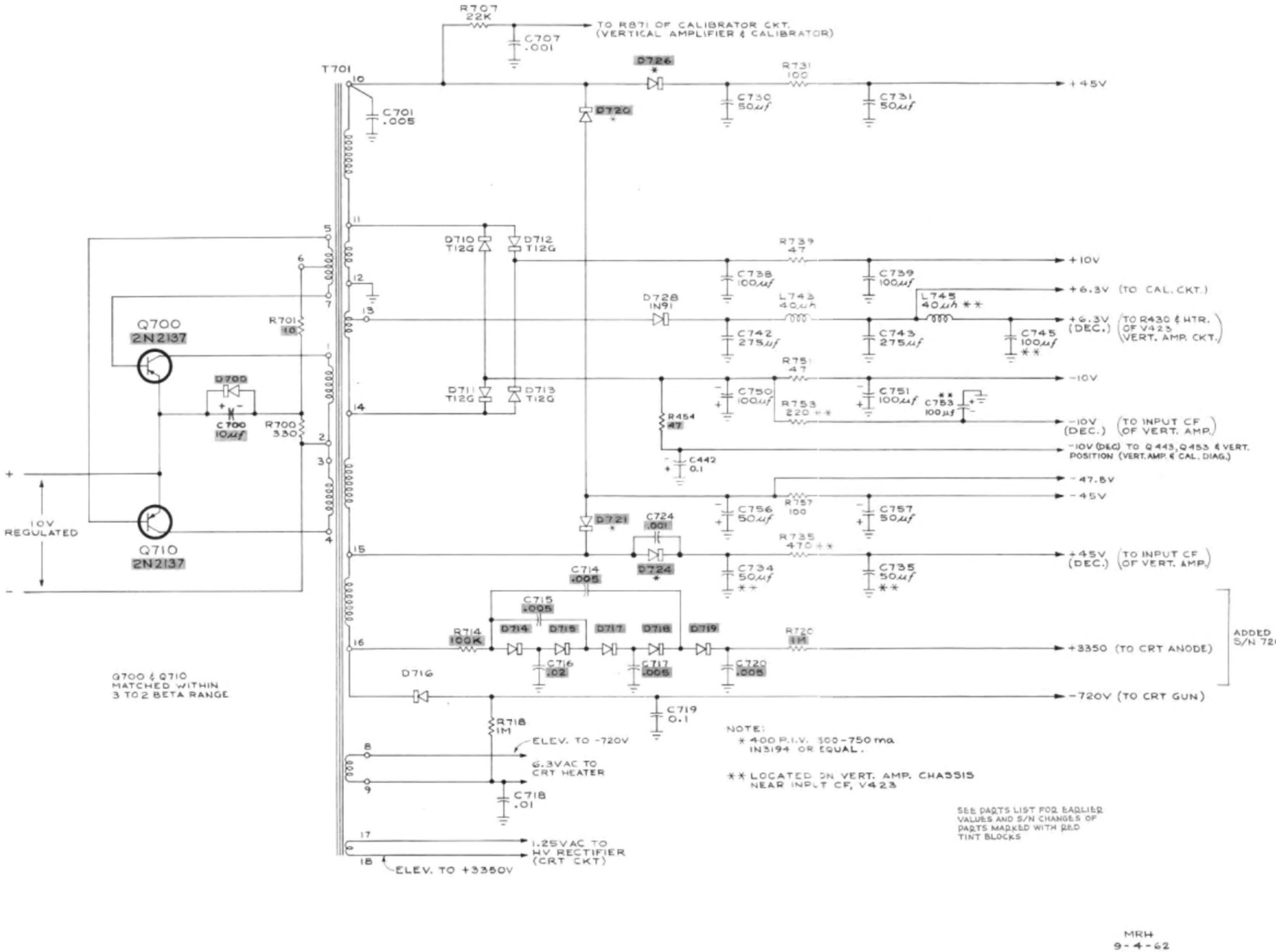


MRH
9-4-62

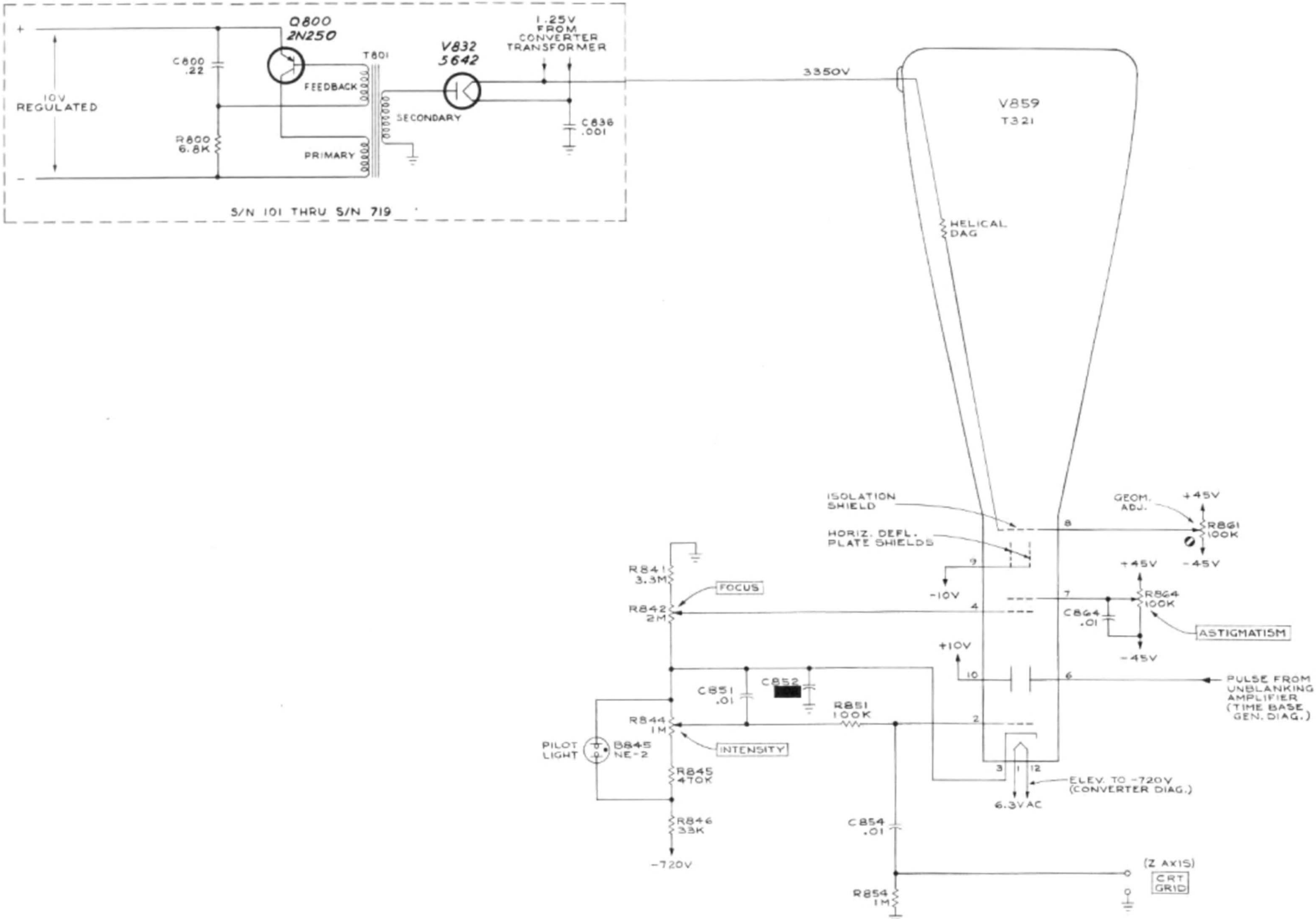
TYPE 321 OSCILLOSCOPE

REGULATOR CIRCUIT

CIRCUIT NUMBERS 600 THRU 699


R707 22K
C707 .001
TO R871 OF CALIBRATOR CKT. (VERTICAL AMPLIFIER & CALIBRATOR)
T701
D726 *
R731 100
+45V
C701 .005
D720 *
C730 50µf
C731 50µf
D710 T12G
D712 T12G
R739 47
+10V
C738 100µf
C739 100µf
+6.3V (TO CAL. CKT.)
D728 1N91
L743 40µh
L745 40µh **
+6.3V (DEC.) (TO R430 & HTR. OF V423 VERT. AMP. CKT.)
C742 275µf
C743 275µf
C745 100µf **
Q700 2N2137
R701 10
D700
C700 10µf
R700 330
D711 T12G
D713 T12G
R751 47
-10V
C750 100µf
C751 100µf
C753 ** 100µf
R753 220 **
-10V (DEC.) (TO INPUT CF OF VERT. AMP.)
R454 47
C442 0.1
-10V (DEC) TO Q443, Q453 & VERT. POSITION (VERT. AMP. & CAL. DIAG.)
-47.8V
-45V
10V REGULATED
C756 50µf
R757 100
C757 50µf
D721 *
C724 .001
R735 470 **
Q710 2N2137
+45V (DEC.) (TO INPUT CF OF VERT. AMP.)
D724 *
C734 50µf **
C735 50µf **
C714 .005
C715 .005
ADDED S/N 720
R714 100K
D714 D715 D717 D718 D719
R720 1M
+3350 (TO CRT ANODE)
C716 .02
C717 .005
C720 .005
Q700 & Q710 MATCHED WITHIN 3 TO 2 BETA RANGE
D716
-720V (TO CRT GUN)
C719 0.1
R718 1M
ELEV. TO -720V
6.3VAC TO CRT HEATER
C718 .01
NOTE:
* 400 P.I.V. 300-750 ma 1N3194 OR EQUAL.
** LOCATED ON VERT. AMP. CHASSIS NEAR INPUT CF, V423
SEE PARTS LIST FOR EARLIER VALUES AND S/N CHANGES OF PARTS MARKED WITH RED TINT BLOCKS
1.25VAC TO HV RECTIFIER (CRT CKT)
ELEV. TO +3350V
MRH 9-4-62
CONVERTER
CIRCUIT NUMBERS 700 THRU 759

F1



SEE PARTS LIST FOR EARLIER VALUES AND S/N CHANGES OF PARTS MARKED WITH RED TINT BLOCKS

MRH
9-13-62

TYPE 321 OSCILLOSCOPE

C_2

CRT CIRCUIT

CIRCUIT NUMBERS 800 THRU 869

TYPE 321 (6)
Mod 6112 Tent. S/N 2900

R321	Change to	20K	Pot	.2w	311-345
R480	Change to	2-20K	Pot	.2w	311-346
R602	Change to	100Ω	Pot	1.5w	311-344
R842	Change to	2M	Pot	HV insulated	311-349
R844	Change to	1M	Pot	HV insulated	311-348
R864	Change to	100K	Pot	.2w	311-347
R1180	Change to	100K	Pot	.2w	311-347
R2180	Change to	100K	Pot	.2w	311-347

TYPE 321 (45)
MOD 6168 - Tent S/N 2620

Q700	Change to	2N2137	151-101
Q710	Change to	2N2137	151-101