PRICE $2.00

CONAR

Model 251

Solid-State Oscilloscope

Operating Manual

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THE CONAR MODEL 251 OSCILLOSCOPE

The Model 251 Oscilloscope is a high-quality, general purpose oscilloscope that is well suited to many servicing and laboratory applications. The specifications for the Model 251 scope are given below.

SPECIFICATIONS

Vertical

Frequency response	dc to 5 MHz
Input impedance	1M paralleled by 30 pF
Attenuator	$\times 1$, $\times 10$, $\times 100$, CAL
Sensitivity	100 mV/cm

Horizontal

Frequency response	dc to 100 kHz
Input impedance	100 k-ohm
Sensitivity	0.25 V/cm

Time Base

Sweep	20 ms to 1 μs/cm
Trigger	Automatic
Trigger mode	Int, Ext, Line

CONTENTS

INTRODUCTION

The Model 251 oscilloscope is an instrument that you can be proud of. Remember though that the more you know about your scope, the better you can use it, and the more valuable it will be to you.

This manual contains valuable information about how an oscilloscope operates, how the individual circuits in the Model 251 operate, and how to use your oscilloscope to make certain measurements and observations. In addition, a maintenance section is included that will help you troubleshoot your scope should the need arise. A complete step-by-step alignment section is also provided in this manual.

Read this manual carefully and be sure you understand how your scope works and how to use it properly. Doing so will allow you to make maximum use of your scope.

PRINCIPLES OF OPERATION

Certain materials give off light when they are bombarded by electrons. This effect is known as fluorescence. Some materials continue to glow for a short period of time after the electron bombardment has ceased. This effect is called persistence.

Using one of these materials, we can coat a transparent screen, allow a thin beam of electrons to strike it, and produce a dot of light on the screen at the point of impact. Also, if we direct the beam so that it moves vertically in response to an applied voltage and horizontally at a constant speed, it will then produce a light trace on the screen. In other words, we have a graph of this applied voltage.

We can deflect (or bend) the beam of electrons by passing it between a pair of plates, as shown in Fig.1, and by applying a voltage to these plates. When one plate is positive and the other is negative, the beam will deflect toward the positive plate. This type of deflection is called electrostatic deflection. If two sets of plates are used, one set at right angles to the other, the spot can be moved both up and down (vertically) and right and left (horizontally) on the screen.

Now let's see how the image of an ac wave (such as the sine wave signal generated by an audio oscillator) can be produced. Applying such a signal across the vertical deflection plates of the crt will produce a vertical line. To produce the sine wave image, the spot must move at a constant speed from left to right. At the same time, the changing amplitude of the sine wave is causing the spot to move up and down.

To move the beam from left to right at a constant speed, a sawtooth voltage must be used. A typical sawtooth waveform is shown in Fig.2. At time 1, the voltage applied to the horizontal crt deflection plates is about -50 volts. At this instant, the spot is at the left edge of the screen. Between time 1 and time 2, the spot moves toward the center of the screen. At time 2, the applied voltage is zero. As a result, there is no deflection, and the beam is in the center of the screen. Between times 2 and 3, the applied voltage increases, and the spot is deflected from the center to the right edge of the screen. Finally, between times 3 and 4, the beam quickly moves back to the left edge of the screen (retrace). In other words, the waveform shown in Fig.2 causes one horizontal sweep across the face of the crt.

For the display on the crt screen to be stable, the signal applied to the horizontal deflection

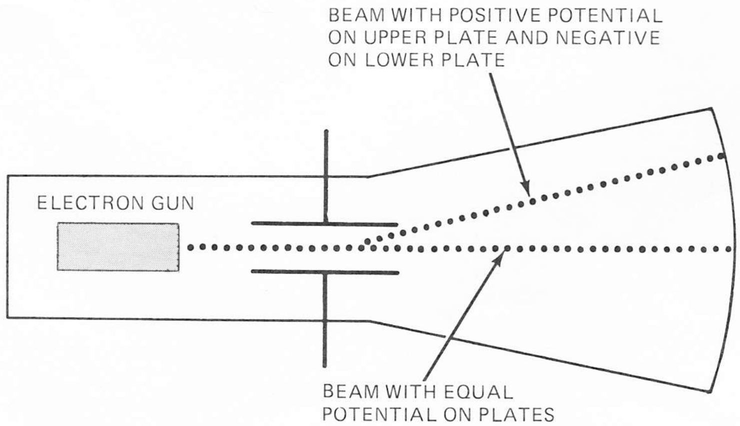


Figure 1. How deflection plates deflect the beam.

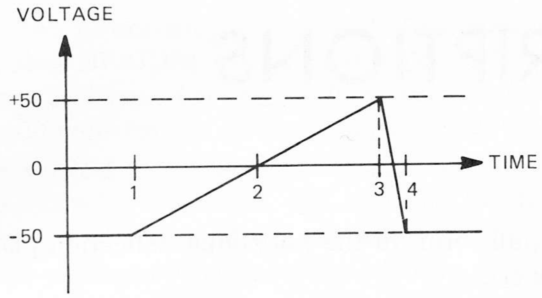


Figure 2. Sawtooth horizontal deflection voltage.

plates must be synchronized with the signal applied to the vertical deflection plates. To understand this concept, refer to Fig.3. The horizontal sawtooth voltage is moving the electron beam between time A and time B of the vertical signal. At time B, retrace takes place and the beam quickly moves back to the left of the screen. The horizontal signal now "waits" until the vertical signal gets to time C. At time C, the horizontal signal again starts moving the beam from the left to the right. Between C and D, the vertical waveform is the same as that between A and B; therefore, the crt will display this part of the vertical signal on the screen as shown.

The signal applied to the horizontal deflection plates is produced by a circuit called the sawtooth generator. As shown in Fig.3, the sawtooth generator is either in the sweep mode or the wait mode. In the sweep mode, the electron beam is moving. In the wait mode, the beam is at the left of the screen waiting for the vertical signal to reach zero voltage (note in Fig.3 that the sweep mode always starts as the vertical signal goes from negative to positive). Another circuit called the trigger generator is used to determine the point at which the vertical signal crosses zero (that is, goes from negative to positive). The output of the trigger generator is used to switch the sawtooth generator from the wait mode to the sweep mode.

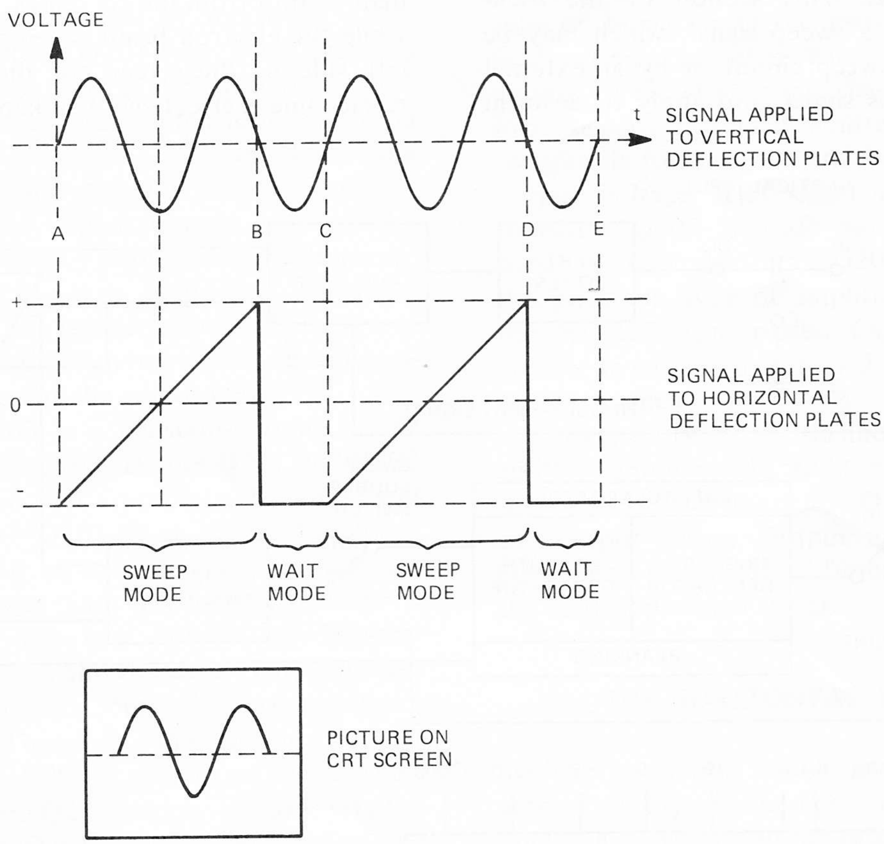


Figure 3. How the horizontal deflection sawtooth is synchronized to the vertical input signal to produce a stable display on the crt screen.

CIRCUIT DESCRIPTIONS

The circuitry of the Model 251 oscilloscope can be divided into four sections: the vertical amplifier, the horizontal amplifier, the sweep generator, and the power supply. Refer to the block diagram in Fig.4 as you read the following general description of how these sections fit together to form the complete oscilloscope.

The vertical amplifier receives the signal to be observed by the oscilloscope, amplifies the signal, and applies the signal, in push-pull form, to the vertical deflection plates of the cathode-ray tube (crt). A sample of the vertical signal is also made available to the sweep section for triggering.

The horizontal amplifier is very similar to the vertical amplifier, but the circuit is somewhat simplified because of the relaxed gain and bandwidth requirements. This section of the oscilloscope must take a sweep signal, which may be generated by the sweep circuit or by an external source, amplify this signal, and apply it, again in push-pull form, to the horizontal deflection plates of the crt.

The sweep generator section can be considered as three subsections: the trigger generator, the sawtooth generator, and the blanking subsections. The function of the trigger generator is to convert the trigger input signal into a pulse suitable for application to the sawtooth generator circuit. The purpose of the sawtooth generator is to generate a high-linearity sawtooth waveform for application to the horizontal amplifier.

At the end of each sweep, during the time that the sweep output voltage is rapidly falling toward its originating point, the blanking amplifier applies a large negative-going pulse to the grid of the crt. This negative-going pulse cuts off the beam. Thus, light output from the crt ceases. Since this happens while the electron beam is being swept back to the left side of the screen for the next sweep, the retrace line is effectively blanked.

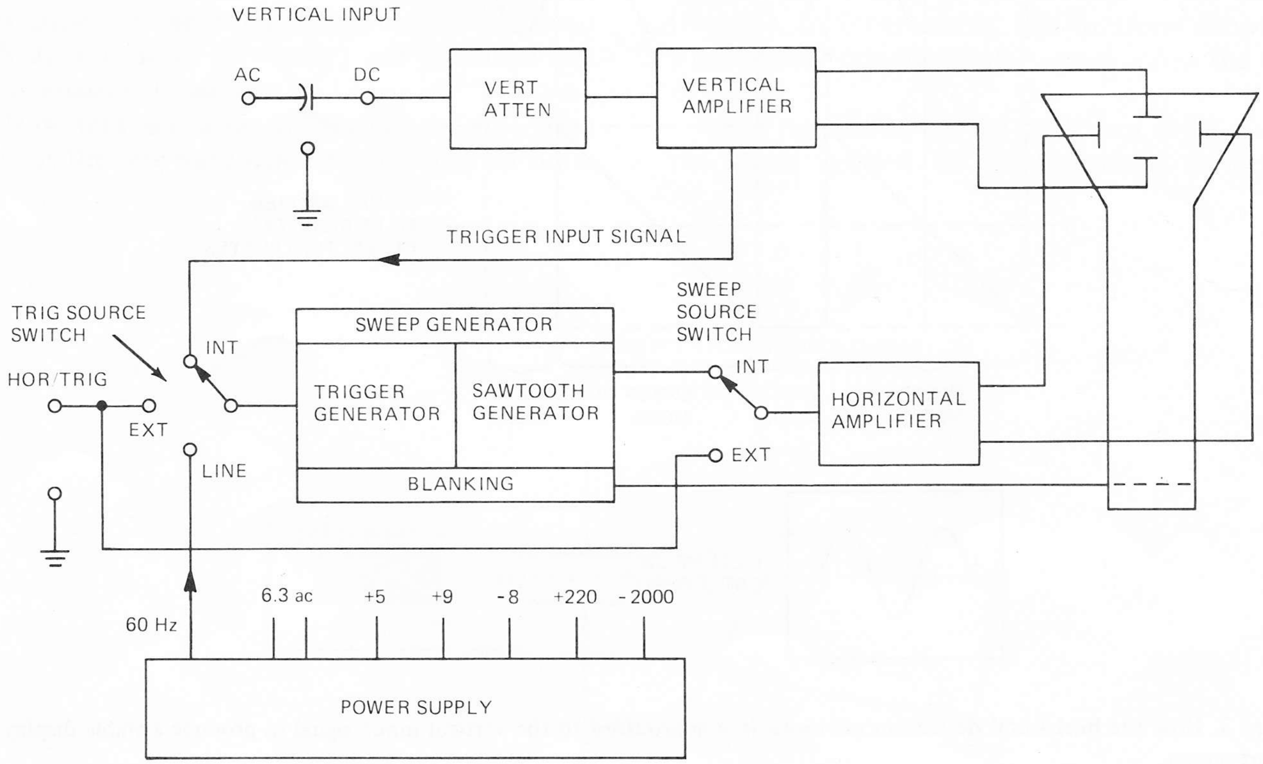


Figure 4. Simplified block diagram of the Model 251 oscilloscope.

The power supply section of the oscilloscope supplies all of the operating voltages to the other three sections. The high-voltage supply develops -2000 volts for the crt electron gun, +220 volts for the vertical and horizontal output amplifiers and the blanking amplifier, 6.3 volts ac for the crt heater, and regulated +5, +9, and -8 volts for all other oscilloscope circuitry. In addition, one of the transformer windings also supplies a small ac voltage for use in the line trigger mode.

Now that you are familiar with the overall operation of the various sections of the oscilloscope, refer to Fig.17 on the insert sheet for the complete schematic diagram as we begin the detailed circuit description. We will start with the vertical amplifier.

THE VERTICAL AMPLIFIER

From the attenuator circuit, a portion of the input signal is coupled through resistor R201 and capacitor C201 to the gate of transistor Q201. Resistor R201 protects Q201 from being damaged in case a high voltage signal is applied to the vertical input while the attenuator switch is in one of its lower ranges. Q208 and Q209 are transistors connected to provide a zener action. Capacitor C201 improves the high-frequency response by forming a high-frequency path around R201.

Transistor Q201 is a field-effect transistor (FET) connected as a source follower. This type of transistor provides the high-impedance input necessary to prevent loading the circuit under test.

Transistor Q203 is a constant-current source for input transistor Q201. Diodes D201 and D202 each provide a 0.6 volt drop (total 1.2 volts) and hold the base of Q203 at a constant voltage. Because the circuit of transistor Q203 is basically an emitter follower and the emitter voltage is dependent upon the base voltage, the emitter voltage will also remain constant. This constant emitter voltage appears across the vertical-balance control, R207. Therefore, the current through R207 is constant. R207 is used to set the constant emitter voltage for Q203 which, in turn, sets the source voltage of Q201. R207 is adjusted so the source voltage of Q201 is zero when an input signal is not present.

A signal applied to the gate of Q201 will only cause voltage changes at the source because the current through Q201 is constant. These voltage variations are applied across the front panel vertical-gain control, R404. A portion of this signal is applied to the gate of source follower Q202.

Transistor Q210 forms a constant-current source for transistors Q204 and Q205. Because the emitter of each transistor is connected to this constant-current source, the current source serves as a common emitter resistance. R208, the vertical 100 V adjust trimmer, is used to set the operating point for the following stages. R208 is adjusted to make the collector of Q301 about 100 volts.

The output from source-follower transistor Q202 is amplified by Q204. A portion of the signal applied to the base of Q202 appears at its emitter. Because transistors Q204 and Q205 have a common emitter resistance, the signal present at the Q204 emitter is effectively coupled to the emitter of Q205.

Transistor Q205 functions as a common-base amplifier whose base is held constant by the front panel vertical position control, R403. This control positions the trace by applying a dc voltage to the base of transistor Q205, causing a dc imbalance in the vertical amplifier. When the collector output voltage of Q204 decreases, its emitter voltage will increase. An increased emitter voltage at Q205 reduces its forward bias and increases its collector output voltage. The signal at the collector of transistor Q205 is 180° out of phase with the signal at the collector of Q204. This signal forms the push-pull type of amplifier required to drive the crt deflection plates. Capacitor C202 is an emitter bypass capacitor used to boost the gain at high frequencies.

Driver transistors Q206 and Q207 are common-emitter amplifiers. In addition to providing gain, they also isolate transistors Q205 and Q204 from the output stages. Output amplifiers Q301 and Q302 again amplify the differential signal and drive the vertical plates of the crt.

THE HORIZONTAL AMPLIFIER

The horizontal input signal is coupled to the gate of Q211, and the horizontal position control applies a dc voltage to the gate of Q214. Q211 and Q214 form a differential amplifier, and Q216 is a constant-current source. With the horizontal position control centered and the horizontal input grounded, the horizontal balance pot, R230, is adjusted to produce equal voltages at the source terminals of Q211 and Q214. These signals are directly coupled to the bases of Q217 and Q218. Q217 and Q218 also form a differential amplifier, and the gain of this stage is controlled by R216, the horizontal gain control. Q215 is a constant-current source.

The Q217 and Q218 collector signals are directly coupled to the bases of Q220 and Q219 respectively. These transistors form another differential amplifier with their collectors directly connected to the crt horizontal deflection plates. R222, the horizontal 100 V adjust trimmer, operates in the same manner as the vertical 100 V adjust trimmer to set the collector voltages of Q219 and Q220 to 100 volts.

THE SWEEP GENERATOR

The Trigger Generator. The trigger input signal is coupled to the gate of Q107, and the source of Q107 is then coupled to the base of Q106. Q106 is biased just below cutoff. Therefore, as the signal at the Q107 source starts to increase, Q106 turns on and its collector voltage goes to almost 0 volts. This negative-going signal at the Q106 collector is used to trigger or start the horizontal electron beam motion from left to right.

The Sawtooth Generator. Figure 5 shows a simplified schematic of the sweep generator. Gates IC101A and IC101B form a flip-flop circuit. Initially, the voltage states at IC101-13, IC101-9, and IC101-8 are all high. The high state at IC101-8 turns on Q105, shorts out the timing capacitor, and holds the Q102 gate at almost 0 volts. The sweep balance trimmer, R101, is adjusted to make the Q102 source voltage about -0.4 volt when the gate is at 0 volts. The Q102 source voltage is connected to the horizontal amplifier input. A voltage of about -0.4 volt at the horizontal input positions the electron beam at the left edge of the screen.

Now let's see what happens when a trigger pulse arrives at IC101-13. The trigger pulse drives IC101-13 low, causing IC101-8 to go low. This action will turn off Q105 and let the timing capacitor charge through Q108, a constant-current source. As the timing capacitor charges, the Q102 gate voltage will increase causing the source voltage to follow this increase. Because this voltage is applied to the horizontal amplifier, the electron beam will begin to move from left to right across the screen. The speed with which the beam moves depends upon how fast the timing capacitor charges.

When the Q102 source voltage reaches about +0.4 volt, the beam will be at the right edge of the screen. At this point, the electron beam must quickly return (retrace) to the left of the screen. IC103, a voltage comparator, is used to determine when retrace should start. The Q102 source voltage is connected to IC103-5. When the voltage at IC103-5 exceeds the voltage at IC103-4 (about 0.4 volt), the voltage at IC103-10 goes low.

The low-going signal from IC103 goes to IC102-1. IC102A is a monostable multivibrator, also called a one-shot. A low-going pulse at IC102-1 causes IC102-4 to go low for a fixed amount of time. When IC102-4 goes low, IC101-9 also goes low causing IC101-8 to go high. Once this happens, Q105 will turn on and quickly discharge the timing capacitor causing the electron beam to return to the left of the screen. For a stable display, IC102-4 must stay low until the timing capacitor has fully discharged. If IC101-9 goes high before the timing capacitor is fully discharged, a trigger pulse at IC101-13 could start the trace before the beam has returned to the left of the screen. Note that as long as IC101-9 is low, IC101-8 will be high and trigger pulses at IC101-13 will not drive IC101-8 low. IC101-9 must be high before a trigger pulse will allow IC101-8 to go low.

Another one-shot, IC102B, is used to automatically trigger the sweep (about three times a second) if the trigger generator circuit fails to produce trigger pulses (for example, when there is no vertical input signal). When the trigger generator pulses stop, IC102-12 will go high (the normal output state at IC102-12 with no input pulses at IC102-9). A high at IC102-12 will turn on Q103, causing IC101-13 to go low. This low-going signal, as described above, will cause the sweep to start. Once the beam reaches the right edge of the screen, IC102-1 goes low, causing IC102-4 and IC102-9 to go low. At the instant IC102-9 goes low, IC102-12 will go low and Q103 will turn off, allowing IC101-13 to go high. If there are no trigger generator pulses after about 1/3 of a second, IC102-12 will go high, turning on Q103 and starting another sweep.

Note that as long as the trigger generator produces trigger pulses (at least one every 1/3 of a second), there will be pulses at IC102-9. In

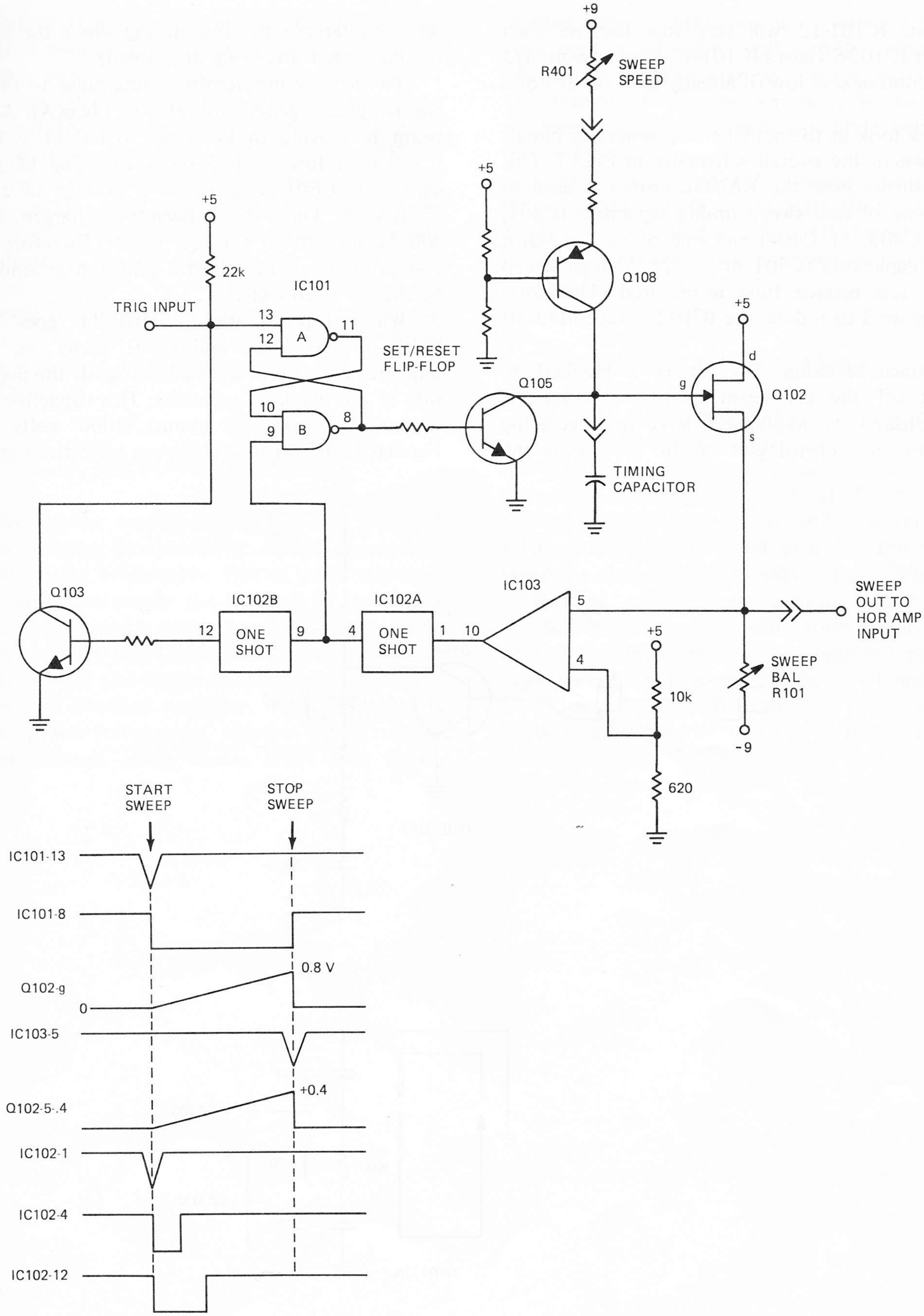


Figure 5. Simplified schematic of the sweep generator.

addition, IC101-12 will stay low because each pulse at IC102-9 causes IC101-12 to go low for 1/3 of a second or stay low (if already low) for 1/3 of a second.

Now look at the actual sweep generator circuit as shown in the overall schematic in Fig.17. This figure shows how the RANGE switch is used to select one of four sweep timing capacitors (C401, C402, C403, or C404) and one of two one-shot timing capacitors (C501 or C502). At high sweep speeds, less retrace time is required. Therefore, C502 is used to reduce the IC102A trace hold-off time.

Retrace Blanking. The retrace is blanked by cutting off the crt beam. Retrace blanking is accomplished by applying a large negative-going pulse to the control grid of the crt during the retrace interval (the time during which the sweep timing capacitor is being discharged).

To see how the negative-going pulse to the crt control grid is generated, refer to Fig.6(A). As the beam is moving to the right, IC101-11 is high, IC101-6 is low, and Q101 is off. The blanking capacitor, C601, charges to a voltage of about 2220 volts. Once this capacitor is charged, there will be no current through R601. Therefore, the voltage between the control grid and ground will be about - 2000 volts.

When retrace starts, IC101-11 goes low, IC101-6 goes high, and Q101 turns on. This sequence of action essentially grounds the positive side of the blanking capacitor. This capacitor now discharges down to about -2000 volts [see Fig.6(B)]. To do this, electrons leave the negative

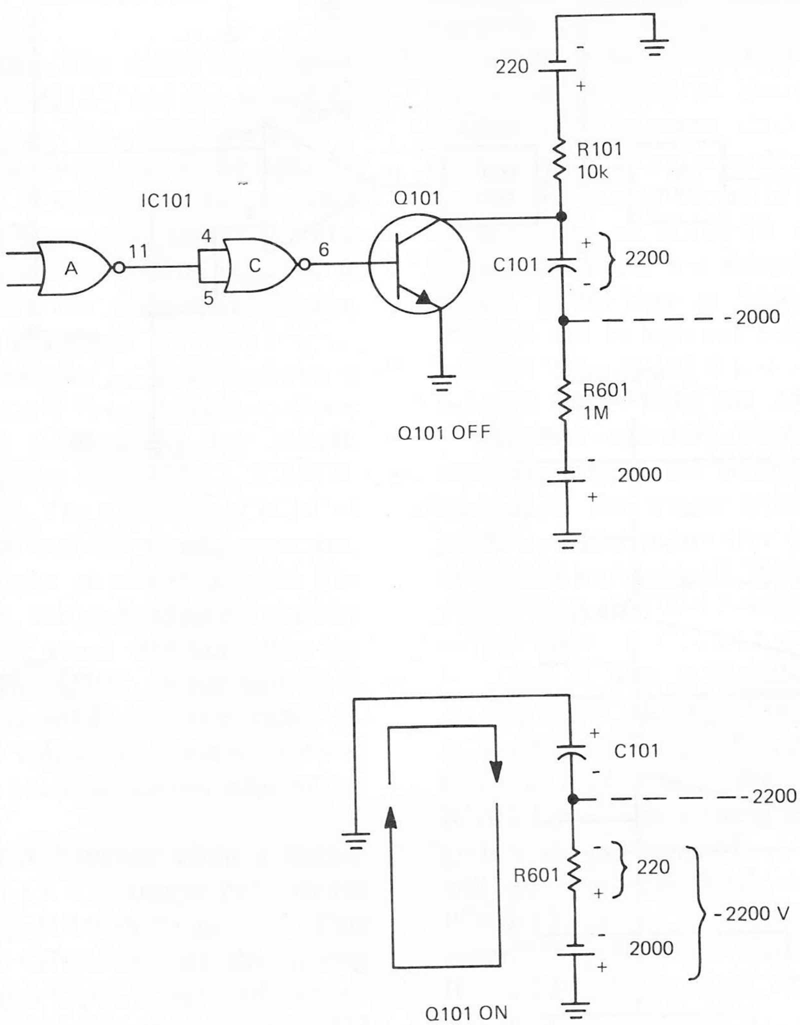


Figure 6. How the retrace blanking circuit works.

side of C601 and go through R601, through the -2000 V supply, through Q101, and back to the positive side of C601. At the instant that Q101 turns on, the current through R601 causes a voltage drop of about 220 volts across this resistor. Because this voltage is in series with the - 2000 V supply, the voltage at the control grid (with respect to ground) is - 2220 volts at the instant Q101 turns on. As C601 discharges, the voltage across R601 will decrease. As this happens, the voltage at the control grid returns to about - 2000 volts, and the crt beam is no longer cut off. When the next sweep starts, Q101 will turn off, and C601 will charge again such that the voltage across it will be about 2220 volts.

THE POWER SUPPLY

The power supply furnishes seven different output voltages to operate the crt and the various circuits in the oscilloscope. One of these outputs is 6.3 volts ac to supply the filament of the crt. A standard full-wave rectifier circuit, using the silicon rectifiers D301 and D302, provides +200 volts dc to the vertical and horizontal output stages and to the retrace blanking amplifier. An 800 V winding on the power transformer, together with a voltage-doubler circuit using diodes D601 and D602, provide about - 2000 volts dc to operate the crt. This negative voltage is applied to the cathode and grids of the crt. The intensity control, R405, varies the strength of the electron beam in the crt by changing the effective grid-to-cathode voltage in the electron gun.

Diodes D305 and D306 supply the positive input voltage to both the +5 V (IC301) and the +9 V (IC302) regulated supplies. Diodes D303 and D304 supply the negative input voltage to the - 8 V regulated supply (IC303).

THE CALIBRATION CIRCUIT

IC101D, C102, and R116 form an oscillator. The output of this oscillator (IC101-3) is a square wave with an amplitude of about 4 volts peak-to-peak and a frequency of about 1 kHz. Q104 buffers the oscillator output, and resistors R108, R109, and R110 are used to divide this voltage down to about 0.1 volt peak-to-peak. When the VERTICAL ATTEN switch is in the CAL position, the 0.1 V peak-to-peak calibration signal is connected directly to the vertical amplifier input. The next section in this manual called "Using Your Oscilloscope" explains how you can use this calibration signal to measure voltage and frequency.

USING YOUR OSCILLOSCOPE

OBSERVING SIGNALS

To observe a signal with your oscilloscope, the signal must be applied between the vertical input (dc or ac) and the ground input. That is, you must have a connection to the vertical input from the point in the circuit where you wish to observe the signal. In all cases, you must have a test lead connecting the ground of the oscilloscope to the ground of the circuit under test.

The TRIG SOURCE switch and the HOR/TRIG INPUT switch should normally be in the INT position. The waveform can be centered with the vertical and horizontal position controls, and the RANGE and SWEEP SPEED controls should be used to adjust the amount of the waveform you wish to display. The ATTEN and GAIN controls can be used to adjust the amplitude of the waveform.

If, for example, you want to look at a television composite video signal (output of the first video amp), apply that signal between the ac input and ground, and set up your oscilloscope as shown in Fig.7. Place both the HOR/TRIG INPUT switch and the TRIG SOURCE switch in the INT position. Set the RANGE switch to Step 3 (from the left), set the ATTEN switch to ×10, and adjust the GAIN control to produce about 4 cm of vertical deflection. Center the trace with the position controls, and adjust the SWEEP SPEED control to show about two cycles of the signal. Your display should look similar to that shown in Fig.8. This is referred to as viewing the composite video signal at the horizontal rate. The negative-going pulse displayed is the horizontal sync pulse.

In addition to horizontal sync pulses, there are also vertical sync pulses in the composite video waveform. Because there are about 260 horizontal

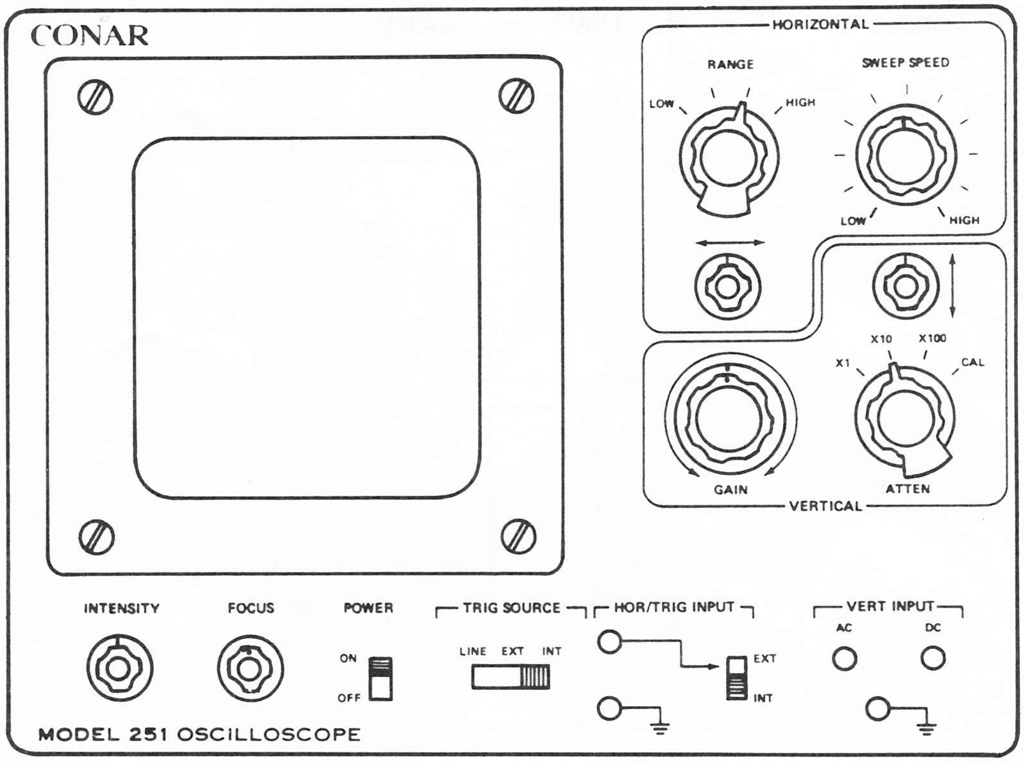


Figure 7. How the oscilloscope controls are set to view television signals at the horizontal rate.

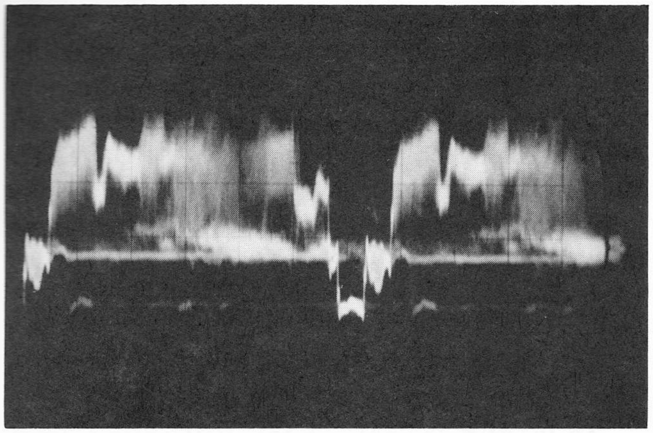


Figure 8. Composite video (horizontal rate).

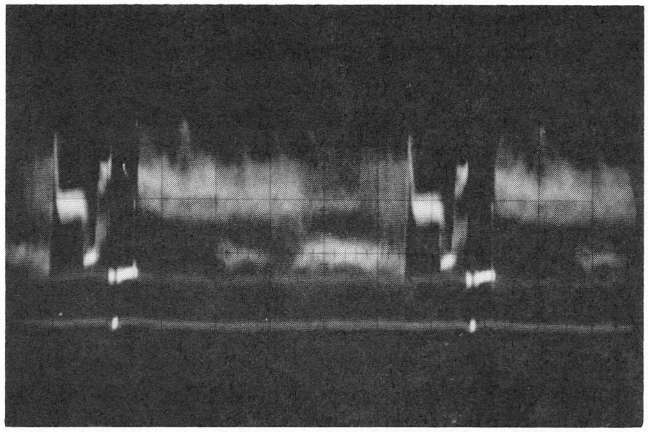


Figure 10. Composite video (vertical rate).

sync pulses between each vertical sync pulse, to see the vertical pulse the sweep speed must be much slower than the speed used to view the horizontal pulses. To slow the sweep speed, move the RANGE switch to Step 1 (fully counterclockwise), move the TRIG SOURCE switch to the LINE position, and adjust the SPEED control to show about two vertical sync pulses. Your scope controls should be set as shown in Fig.9. Your waveform will drift slowly and should be similar to the one shown in Fig.10. Watching the waveform in this manner is referred to as viewing the composite video signal at the vertical rate.

The reason your waveform will drift slowly across the screen is because the LINE trigger causes 60 sweeps each second while the actual vertical frequency generated by the television station is between 59 and 60 Hz. In other words, the sweep does not start at exactly the same point of each composite video cycle.

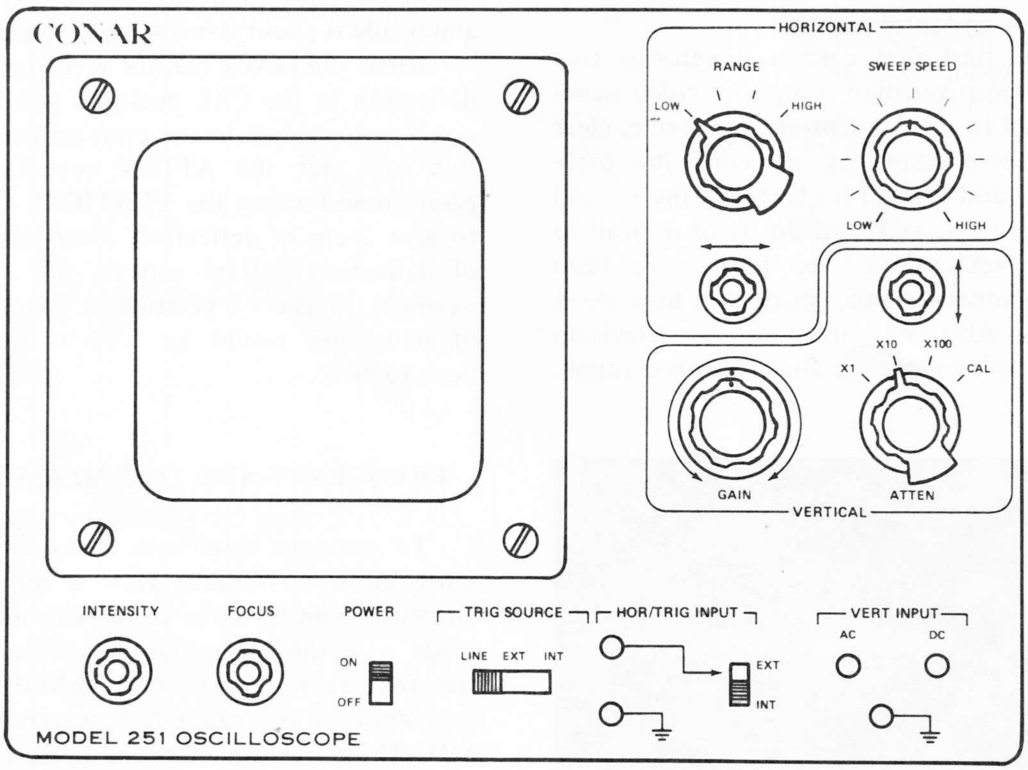


Figure 9. How the oscilloscope controls are set to view television signals at the vertical rate.

When viewing the composite video signal at the vertical rate, by careful adjustment of the SPEED control, you may be able to achieve a stable display. At this point, the TRIG SOURCE switch should be in the INT position. The problem here is that the trigger generator cannot tell the difference between horizontal and vertical sync pulses. For a stable display, the scope must trigger at the vertical rate only.

When viewing waveforms at slow sweep speeds (that is, with the RANGE switch in the fully counterclockwise position), the display may appear to "flicker." This situation is normal and is caused by the slowness of the beam moving across the screen and the persistence of the crt screen coating. As the beam moves from the left to the right, the image "dies out" before the slow-moving beam returns to "refresh" the image.

When using the INT trigger mode, the GAIN control must be adjusted to produce at least 1 cm of vertical deflection to ensure that the sawtooth generator will be triggered by the vertical signal. With less with 1 cm of vertical deflection, the sawtooth generator will automatically trigger at about three sweeps per second. The auto trigger mode will not normally produce a stable display. Also, at higher sweep speeds, you may not be able to see the auto trigger sweeps because the beam is moving quickly and infrequently.

You may find that certain waveforms (for example, the positive-going composite video signal shown in Fig.11) may not produce a stable, clear display. In these cases, try reversing the oscilloscope input and ground leads (move the ground lead to the ac or dc jack and the ac or dc lead to the ground jack). Once the leads have been reversed, remember that the image you now see is upside down. Also, be sure that the television chassis and the oscilloscope chassis do *not* touch.

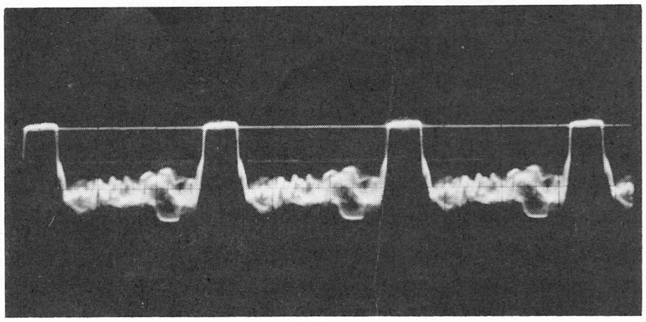


Figure 11. Positive-going composite video.

The composite video signal may also be viewed at either the horizontal or vertical rate by using the TRIG SOURCE switch in the EXT position and connecting an external signal (for example, from the television oscillator circuits) to the HOR/TRIG INPUT switch. For further information concerning this mode of operation, refer to a later section of this manual called "Using the External Trigger."

VOLTAGE MEASUREMENTS

To measure the peak-to-peak voltage of a signal connected to the oscilloscope (dc or ac input), first set the ATTEN switch to the CAL position. Then, set the RANGE switch to Step 1 (fully counterclockwise) and adjust the VERTICAL GAIN control to give 1 cm of deflection. Because the calibration signal is 0.1 volt peak-to-peak, each centimeter (cm) of deflection is 0.1 volt in the $\times 1$ ATTEN position. In the $\times 10$ position, each centimeter of deflection is 1 volt, and in the $\times 100$ position, each centimeter of deflection is 10 volts.

For example, if a signal of unknown amplitude causes 3 cm of deflection when using the $\times 10$ position, the amplitude is about 3 volts peak-to-peak. As another example, if a signal causes 4 cm of deflection when using the $\times 1$ range, the amplitude is about 0.4 volt peak-to-peak.

When the GAIN control is set to give 1 cm of deflection in the CAL position, you may find the signal is too small to see even on the $\times 1$ scale. In this case, set the ATTEN switch to the CAL position and adjust the VERTICAL GAIN control to give 2 cm of deflection. Now, each centimeter of deflection is 0.05 volt on the $\times 1$ scale. For example, in the $\times 1$ position, a waveform of 3 cm of deflection would be 0.05×3 or 0.15 volt peak-to-peak.

FREQUENCY AND TIME MEASUREMENTS

To measure time with the oscilloscope, you must know how much time is required for the electron beam to move 1 cm. This measurement is made with the calibration waveform on either of the first two steps of the RANGE switch. The frequency of the calibration waveform is about 1 kHz. Thus, the time for one cycle (1/f) is 0.001 second or 1 millisecond (ms). With this information, you can determine the time required for the beam to move 1 cm by using the following procedure:

(1) Put the ATTEN switch in the CAL position ( )

(2) Count the number of centimeters (horizontally) for one cycle . . . . ( )

(3) Divide the result of (2) into 1 ms . . . . ( )

In formula form:

$$T = \frac{1 \times 10^{-3}}{C} \quad \text{or} \quad \frac{0.001}{C}$$

where

T = Time for beam to move 1 cm.
C = Number of centimeters (horizontally) for 1 cycle of the calibration waveform.

For example, if in the CAL position one cycle is 4 cm as shown in Fig.12, the time it takes for the beam to move 1 cm is:

$$T = \frac{1 \times 10^{-3}}{4} = \frac{1}{4} \times 10^{-3}$$

$$= 0.25 \times 10^{-3} = 0.25 \text{ ms}$$

$$= 250\,\mu\text{s}$$

Note that 10^{-3} second = 1 ms = 1000 μs.

Now you can measure the time for one cycle and the frequency of an input waveform using the following procedure:

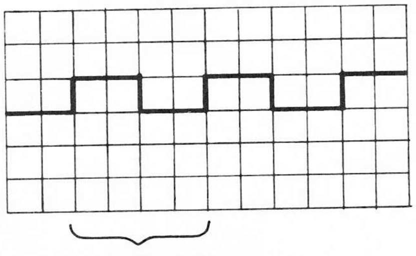


Figure 12. Time calibration example.

(1) Move the ATTEN switch to the ×1, ×10, or ×100 position – depending on the amplitude of the input waveform. Do *not* move the RANGE or SPEED controls. If either is moved, you must recompute T . . . . ( )

(2) Count the number of centimeters taken for one cycle . . . . ( )

(3) Multiply the result of (2) by the time required for the beam to move 1 cm . . . . ( )

(4) Divide the result of (3) into 1 to get the frequency . . . . ( )

In formula form:

$$f = \frac{1}{N \times T}$$

where

f = Frequency in hertz.
N = Number of centimeters for 1 cycle (horizontally) of the input waveform.
T = Time required for the beam to move 1 cm.

For example, if one cycle of an input waveform is 3 cm when the beam speed is calibrated at 250 μs for 1 cm (as described above), then the frequency is:

$$f = \frac{1}{N \times T}$$

$$f = \frac{1}{3 \times 250\,\mu\text{s}} = \frac{1}{0.75\text{ ms}}$$

$$= \frac{1}{0.75 \times 10^{-3}} = 1.33 \times 10^{3}$$

$$= 1.33 \text{ kHz} = 1330 \text{ Hz}$$

If a composite video waveform source is available, you may use it to measure time on the higher sweep speeds, because the time between horizontal sync pulses is about 64 μs. For example, if the RANGE and SPEED controls are adjusted such that the horizontal sync pulses are 4 cm apart,

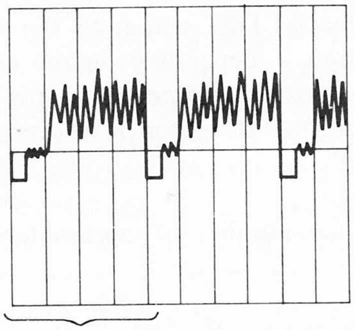


Figure 13. Using a composite video (horizontal rate) waveform to calibrate the time base.

as shown in Fig.13, the beam takes about 16 μs (64 μs/4) to move 1 cm. If a composite video source is not available, a calibrated frequency generator may be used for this purpose.

USING THE EXTERNAL TRIGGER

In most cases, a sample of the input signal is used to generate the sweep trigger pulses. This is called internal trigger (INT). However, if the input waveform has more than a single pulse in each cycle, the trigger generator might allow any of these pulses to trigger the sweep. Because a stable waveform display requires a trigger pulse at exactly the same point for each cycle of the wave, extra trigger pulses can distort or blur the display.

To overcome this problem, an external signal of one pulse per cycle (if available) can be connected to the trigger generator rather than the input signal. This procedure is called using external trigger (EXT). Figure 14 shows how the controls should be adjusted for this type of operation. Note that the TRIG SOURCE switch is in the EXT position and the HOR/TRIG INPUT switch is in the INT position.

In a television, low amplitude pulses in the horizontal and vertical circuits can often be used as external trigger signals to provide a more stable display of the television waveforms.

When using an external trigger input, the external trigger signal should be only a few volts peak-to-peak. If you want to use larger trigger signals, you should connect a 1 megohm (M) trimmer like that shown in Fig.15 to reduce the amplitude of the trigger pulse to an acceptable level.

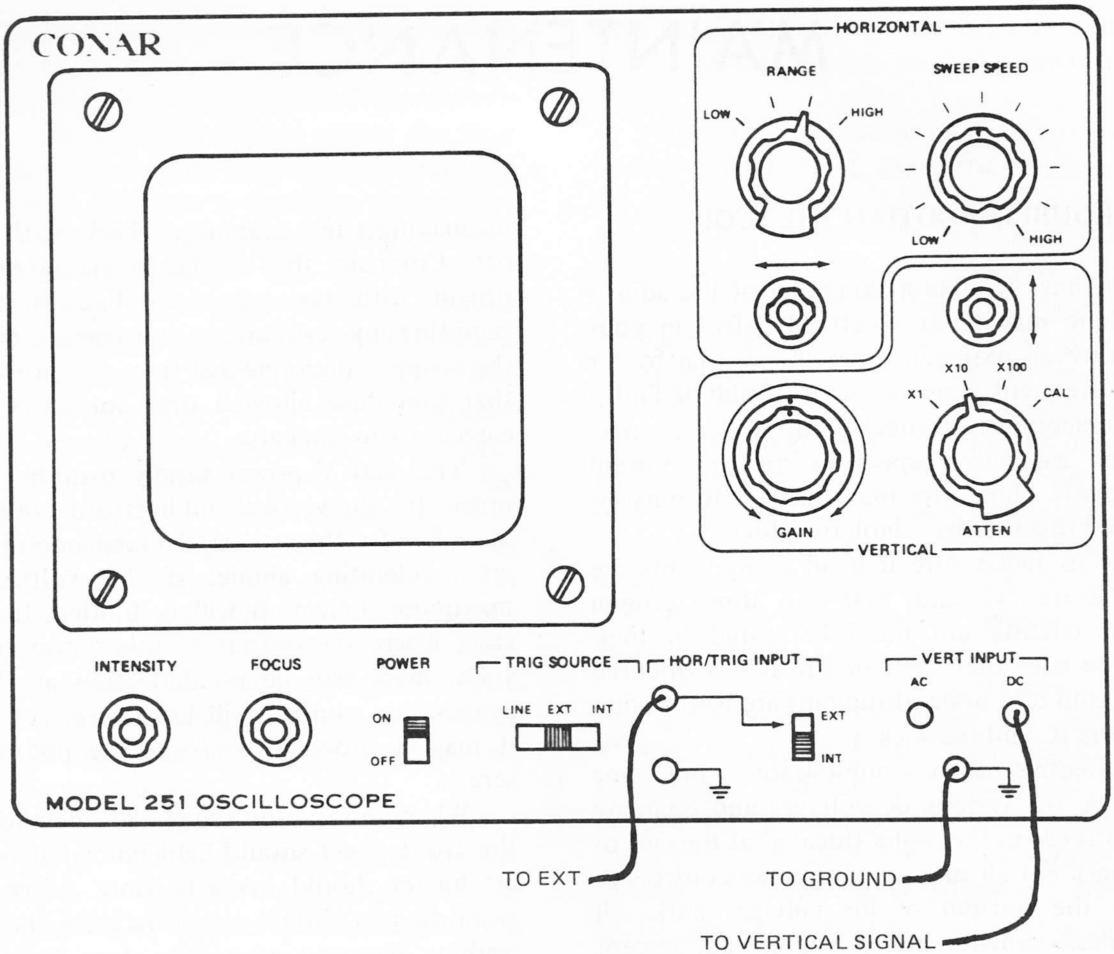


Figure 14. Using an external trigger.

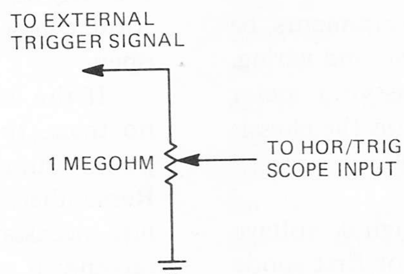


Figure 15. Using external trigger signals larger than a few volts peak-to-peak.

MAINTENANCE

TROUBLESHOOTING THE SCOPE

If you have trouble making any of the adjustments, there may be an electrical defect in your scope. However, experience has shown that by far the most frequent cause of such trouble is faulty solder connections. Recheck your solder connections very carefully, especially on the printed circuit boards. Make sure that adjacent IC pins are not shorted together by a blob of solder.

Check to make sure that all components are installed correctly, and that the three plug-in integrated circuits are properly seated in their sockets. Be sure that each of the ICs is oriented correctly, and that none of the pins are bent under, between the IC and the socket.

One effective way of troubleshooting the scope is to check the various dc voltages and compare them with those in the tables (located at the end of the manual). Set all of the front panel controls as shown at the bottom of the voltage chart. All voltage measurements are shown in dc, except where indicated. You should allow a ±20% variation in your voltage measurements because of component tolerance and meter accuracy.

CAUTION: In taking voltage measurements, be sure to keep your hands off the chassis and wiring. In addition, watch where you place your meter probe. There are dangerous voltages on the chassis and on the intensity and focus controls.

Do not attempt to measure the high dc voltage applied to the cathode, heater, grid, or first anode of the crt unless it is absolutely necessary to do so. If you are going to measure the high dc voltages, you must use a high-voltage probe with your tvom. Instead of measuring these voltages, however, we suggest that you measure the voltage at the low end of the focus control (terminal 3); this voltage should be about - 700 volts. If so, you know that the high ac and dc voltages are correct. Therefore, there is little need to measure the output from the high-voltage supply.

If the voltage at terminal 3 of the focus control is incorrect, you can probably locate the trouble by making a few ohmmeter checks *with the power off*. Compare the resistance measurements you obtain with the schematic diagram. Before attempting any resistance measurements, be sure that the scope is disconnected from the power line and that you have allowed time for all of the filter capacitors to discharge.

The 220 V power supply furnishes operating power for the vertical and horizontal output stages as well as for the retrace blanking amplifier and the crt accelerating anode. If this voltage is low, maximum deflection will be limited. In the worst case, where the output of this power supply is 0 volts, there will be no deflection at all and the astigmatism control will have no effect. However, it may be possible to focus the dot on the crt screen.

When you turn on the power, the pilot lamp on the front panel should light immediately, and the crt heater should begin to glow. After about 15 seconds, you should see a trace on the screen. If nothing happens when you turn on the power switch, the fuse could be open, the scope could be connected to a dead ac outlet, or the power transformer primary circuit could be miswired. If the crt heater does not light, the power transformer may be miswired, or the crt heater may be open.

If the crt heater operates normally but there is no trace, the problem could be in one of the dc power supplies or in the deflection amplifiers. Remember, the lack of a trace on the screen does not necessarily mean that the high voltage is missing; it could be that the trace is there but is being deflected offscreen by an unbalanced amplifier. Because all of the deflection amplifiers are direct coupled, the problem could be anywhere from the output stages back to the vertical and horizontal input jacks. A thorough check of the dc voltages of the amplifiers should isolate this type of problem.

If you have trouble with the +5, +9, or - 8 V power supplies, the problem could involve a defective component (such as a diode, a regulator, or a capacitor) or a shorted load. To determine the problem, turn off the oscilloscope, remove the

Hor/Vert module and the sweep module, turn on the power, and recheck the +5, +9, and -8 V supplies. If the removal of these modules corrects the voltage, the problem involves either the Hor/Vert module or the sweep module. If the removal of these boards does not correct the voltage, the components on the power module should be tested and replaced as necessary.

If all of the power supply voltages are normal and there is no trace on the screen, the problem is probably in either the vertical or the horizontal deflection amplifier. The easiest way to troubleshoot these amplifiers is with another oscilloscope. That is, inject a signal at the input of the oscilloscope and with the other oscilloscope follow it through the various stages to see where it is lost or distorted. If you do not have access to another oscilloscope you can use the following troubleshooting procedures to locate the problem. Note that these procedures are only a guide to help you identify the section causing the problem. You may use your own procedure or vary the procedure we have given if you so desire.

Sometimes you will find it necessary to remove a part (or parts) from a circuit board during the troubleshooting procedure. Removal should be done with the aid of a solder-pulling device or a solder wick. Either of these instruments can be used to remove solder quickly without damaging the foil pads on the circuit boards. They can be purchased at most electronic supply stores and in some hardware stores. Both tools are valuable servicing devices that you can use often.

TROUBLESHOOTING THE VERTICAL AMPLIFIER

STEP 1: With terminal 201 grounded, measure the Q201 source voltage as you vary the vertical-balance trimmer, R207. This voltage should vary from above 0 volts (positive) to below 0 volts (negative). If this happens, set the voltage to exactly 0 volts and move directly to Step 2. If you do not obtain the correct results, continue with the following discussion.

Discussion of Step 1: If you cannot adjust the Q201 source voltage as described, first check to be sure that the Q201 drain voltage is +9 volts and that one side of R207 is at -8 volts. If either voltage is wrong, trace the voltage path back to the power supply to find the trouble. Next, be sure that the Q201 gate is at 0 volts. A problem here should be traced back to the ground at terminal 201.

A wiring error at terminal 203 could prevent normal operation of the vertical-balance control. To isolate this possibility, remove the wire at terminal 203 and recheck the voltage variation at the source of Q201. If removing the wire at terminal 203 corrects the Q201 source voltage problem, carefully check the wiring involving terminals 203 and 204, and R404 (the vertical-gain control). Use your ohmmeter to check this wiring and be sure to turn off the scope before you make any ohmmeter checks. Check the wiring because one of the shielded cables connected to R404 could be shorted. A short in one of these cables would cause the Q201 source voltage to measure 0 volts and *not* change as the vertical-balance trimmer is adjusted.

A defect at Q210 could also cause a problem at the Q201 source. Note that the Q203 base is directly connected to the Q210 base. To see if Q210 is involved, remove it. With Q210 out of the circuit, the vertical-balance trimmer should still cause the Q201 source voltage to vary as described in Step 1. If removing Q210 corrects the problem, Q210 or a component in the Q210 circuit may be defective.

If removing Q210 does not correct the problem, check the Q203 base and emitter voltages. Although the exact voltages will vary, you should find a voltage drop of about 0.6 to 0.7 volt between emitter and base. Table I (located at the end of the manual) lists typical voltages you can expect to find. If your Q203 voltages are not correct, first check to be sure that D201 and D202 are correctly installed with the cathode end as marked on the circuit board. In addition, be sure that you have +9 volts on one side of R204.

After checking D201 and D202, remove Q203. Q210 should also be isolated. With Q203 removed, measure the voltage between D202 and R204. This measurement should be about -6.4 volts. If you measure about +9 volts, either D201 or D202 is open and must be replaced. If you measure about -8 volts, D201 and D202 are both shorted. If one diode is shorted, you will measure about -7.4 volts. With Q203 removed and the power off, you can test R207 with an ohmmeter.

Assuming the tests described above do not isolate the problem, first Q203 and then Q201 should be replaced with new transistors.

STEP 2: Measure the voltage at terminal 206 as you vary the front panel vertical position control. This voltage should vary from about 0.75 to 0.85 volt. If this variation is correct, move directly to Step 3.

Discussion of Step 2: If your voltage variation at terminal 206 is not correct, turn off the power and check the resistance between terminal 206 and pin 2 of R403. Your reading should be 0 ohms. Any other reading could indicate a wiring error between pin 2 of R403 and terminal 206. Also, be sure that R407 is 620 ohms, R501 is 6.8 kilohms, and R403 is 100 ohms. Finally, check to be sure that one side of R501 measures +9 volts and one side of R407 is grounded (0 volts).

STEP 3: With terminal 201 still grounded, measure the voltage at the Q202 source as you vary the vertical centering trimmer, R202. Note that R403 is the front panel vertical position control and R202 is the vertical centering trimmer located on the Hor/Vert module. The Q202 source voltage should vary above and below the voltage you measured at terminal 206 with the vertical position control centered. If this voltage variation is correct, move directly to Step 4.

Discussion of Step 3: To investigate a problem at the Q202 source, first check the Q202 drain voltage (+9 volts) and the Q202 gate voltage (0 volts). Next, check for a wiring problem at terminal 204. Be sure that R202 is a 1 kilohm trimmer and that one side of R202 is grounded. Test with an ohmmeter.

Because a defective Q204 could load the source of Q202, remove Q204 and measure the Q202 source voltage as you adjust R202. If removing Q204 corrects the Q202 source voltage, Q204 or a component in the Q204 circuit could be defective. If removing Q204 does not correct the Q202 source voltage, replace Q202 with a new transistor.

STEP 4: With terminal 201 still grounded, the vertical position control centered, and R202 adjusted such that the Q202 source voltage equals the voltage at terminal 206, measure the voltages at the collector of Q204 and the collector of Q205. These voltages should be about equal and both values should increase or decrease simultaneously as the vertical 100 V adjust trimmer, R208, is rotated. These voltages should also appear at the bases of Q207 and Q206. If these results are correct, move directly to Step 5.

Discussion of Step 4: A problem at this point could indicate a defective Q210, Q204, Q205, Q207, Q206, or R208. If your voltage measurements do not suggest which of these components might be causing the problem, remove Q206 and Q207. With these transistors out of the circuit, the collectors of Q204 and Q205 should still adjust as described in Step 4. If removing Q206 and Q207 does not correct the Q204 and Q205 collector voltages, measure the Q210 base and emitter voltages. Although these voltages will depend on the position of the vertical 100 V adjust trimmer, you should always have about a 0.6 or 0.7 volt drop between the base and emitter. If your Q210 voltages are not correct, be sure that one side of R208 measures -8 volts and that R208 is a 500 ohm trim pot.

If the checks described do not isolate the problem, check to be sure that one side of R210 is at +9 volts and that one side of R211 is at +9 volts. Then, one at a time, replace Q210, Q204, and Q205 with new transistors.

STEP 5: With all controls adjusted as described at the start of Step 4 and terminal 201 still grounded, measure the voltages at the collector of Q206 (terminal 207) and at the collector of Q207 (terminal 208). These voltages should be about equal (within 20 volts of each other) and both should increase or decrease as the vertical 100 V adjust trimmer (R208) is rotated. These voltages should also appear at the bases of Q201 (terminal 303) and Q302 (terminal 316). If these results are correct, move directly to Step 6.

Discussion of Step 5: A problem at this point could involve a defective Q206, Q207, Q301, or Q302. Disconnecting the wires at terminals 207 and 208 will isolate Q301 and Q302. With Q301 and Q302 isolated, you should be able to adjust the Q206 and Q207 collector voltages as described in Step 5.

If isolating Q301 and Q302 does not help, be sure that one side of R212 is at +9 volts, one side of R209 is at +9 volts, one side of R215 is grounded, and one side of R203 is grounded. Finally, replace Q206 and Q207 with new transistors.

STEP 6: Without changing any controls and with terminal 201 still grounded, measure the collector voltages at Q301 (terminal 314) and Q302 (terminal 315). These voltages should also be about equal and both should increase or decrease as you rotate the vertical 100 V adjust trimmer. The 100 V adjust trimmer should be set to give the Q301 collector about 100 volts. If these results are correct, move directly to Step 7.

Discussion of Step 6: A problem at this point could involve Q301, Q302, a wiring error at either terminal 314 or 315, or a problem with the collector power source.

STEP 7: Without changing any controls and with terminal 201 still grounded, measure the Q301 and Q302 collector voltages as you adjust the front panel vertical position control, R403. As R403 is adjusted from the center position to the fully clockwise position, the Q301 collector voltage should decrease and the Q302 collector voltage should increase. Although the amount of voltage change will vary, if the Q301 collector is initially at about 100 volts, clockwise adjustment of R403 should cause this voltage to decrease by about 20 to 40 volts to between 60 and 80 volts. When R403 is adjusted counterclockwise, the Q301 collector should increase to between 120 and 140 volts.

Next, move the HOR/TRIG INPUT switch to the EXT position. Assuming your horizontal amplifier is working correctly, you should see a dot on the screen and you should be able to center that dot with the horizontal and vertical position controls. You may also need to adjust the FOCUS and INTENSITY controls.

Discussion of Step 7: If the Q301 and Q302 collector voltages do not vary as described, first check the Q204 and Q205 collector voltages as you adjust the front panel vertical position control. As you move this control clockwise from midposition, the Q204 collector voltage should decrease slightly and the Q205 collector voltage should increase slightly. Moving the vertical position control counterclockwise from midposition should cause the voltages on these collectors to change in opposite directions. Next, check the voltage change by using the vertical position control at the collectors of Q206 and Q207. As the Q206 collector voltage increases, the Q207 collector voltage should decrease. If your results for a particular stage are incorrect, carefully check the components associated with this section of the circuit.

STEP 8: Remove the ground from terminal 201, set the front panel GAIN control to the fully counterclockwise position, set the VERTICAL ATTEN switch to the ×10 position, and use a test lead to connect +5 volts from terminal 115 to the dc input jack. With +5 volts at the input, you should have about 0.5 volt at terminal 201, because the vertical attenuation circuit divides the +5 V input voltage by a factor of 10. You should also have about 0.5 volt at terminal 203 (the Q201 source). Next, advance the front panel VERTICAL GAIN control. As you adjust this control clockwise, the Q202 source voltage should increase by about 0.5 volt.

Assuming the Q202 source voltage is correct, measure the Q301 collector voltage (terminal 314) as you advance the front panel VERTICAL GAIN control. This voltage should decrease. Next, measure the Q302 collector voltage (terminal 315) as you advance the front panel VERTICAL GAIN control. This voltage should increase.

Finally, move the HOR/TRIG INPUT switch to the EXT position. Assuming that the horizontal amplifier is working correctly, you should see a dot on the screen, and as you advance the VERTICAL GAIN control, the dot should move upward. Although your voltages may differ slightly, the Q301 and Q302 collector voltages should change about 10 volts for each vertical centimeter of deflection. For example, suppose the Q301 collector is at 100 volts with the dot at the center of the screen. If you advance the GAIN control until the dot moves up 3 centimeters, the Q301 collector voltage should decrease by approximately 30 volts (10 volts × 3 cm) to 70 volts. This completes the testing of the vertical amplifier.

Discussion of Step 8: If you do not measure about 0.5 volt at terminal 201, you may have a wiring error on the VERTICAL ATTEN switch or a defective S404. You can check the wiring and switch with your ohmmeter. If you do not measure the correct voltage at terminal 203, check the Q201 gate voltage. This voltage should be about 0.5 volt. A problem here could indicate that Q208 or Q209 is shorted.

If the voltage at the source of Q202 does not increase as the GAIN control is advanced, use your ohmmeter to check the wiring between terminals 203 and 204. A shorted shielded cable could be the source of the problem or a defective R404.

If you have a problem with the Q301 or Q302 collector voltages, start at the collector of Q204 and the collector of Q205. As the front panel GAIN control is advanced, the Q204 collector voltage should decrease slightly (for example, from about 7.5 to about 7.1 volts), and the Q205 collector voltage should increase slightly (from about 7.5 to about 7.8 volts).

Assuming transistors Q204 and Q205 are working correctly, measure the Q206 and Q207 collector voltages as the GAIN control is advanced. In this case, the Q207 collector voltage should increase (from about 4.2 to about 8 volts), and the Q206 collector voltage should decrease (from about 4.2 to about 1.2 volts). Keep in mind that the voltages that you measure may be different. However, the Q207 collector voltage should increase and the Q206 collector voltage should decrease by about the same amount. If the voltages involved with a particular transistor are not correct, carefully inspect and test the components associated with the particular circuit.

TROUBLESHOOTING THE CALIBRATION OSCILLATOR

If no waveform appears in the CAL position, first check the voltage at IC101-3 (about 2.2 volts) and at the Q104 collector (also about 2.2 volts). If either voltage is wrong, IC101D, C102, or Q104 could be defective. Also, be sure that R116 is 470 ohms and R121 is 22k-ohms.

At terminals 112 and 201 you should measure about 0.05 volt (the ATTEN switch must be in CAL position). If you measure a voltage at terminal 112 but not at terminal 201, turn off the power and use your ohmmeter to measure the resistance between terminals 112 and 201. You should measure 0 ohms. If you do not, check the wiring between these terminals.

TROUBLESHOOTING THE HORIZONTAL AMPLIFIER

STEP 1:

(1) Place the HOR/TRIG INPUT switch in the EXT position . . . . ( )

(2) Connect a test lead from the HOR/TRIG INPUT jack (front panel) to chassis ground . . . ( )

(3) Apply power and measure the voltage at terminal 211 (0 volts) . . . . ( )

(4) Measure the voltage at terminal 213 as you rotate the horizontal position control. This voltage should vary from slightly negative to about +1 volt . . . . ( )

(5) Center the horizontal and vertical position controls . . . . ( )

(6) Measure the voltages at the Q211 source and the Q214 source as you rotate the horizontal balance trimmer (R230). As one voltage increases, the other should decrease. Set R230 so that the Q211 source voltage equals the Q214 source voltage. If your results are correct, move directly to Step 2. If you do not get the correct results, continue with the following discussion . . . . . . ( )

Discussion of Step 1: If you do not measure 0 volts at terminal 211, use your ohmmeter to measure the resistance between the HOR/TRIG INPUT jack and terminal 211. Be sure to turn off the power when you make ohmmeter measurements. You should measure 0 ohms. If you do not measure 0 ohms, trace the wiring between the HOR/TRIG INPUT jack and terminal 211. Pay close attention to the HOR/TRIG INPUT switch (S403).

If the voltage at terminal 213 is wrong, first be sure one side of R502 is at +9 volts and that one side of R225 is at - 8 volts. Next, be sure you have 0 ohms between one side of R402 and terminal 214. As another test, disconnect the wire at terminal 213 and check the voltage at R402 – pin 2 as you rotate R402. The voltage should vary from slightly negative to about +1 volt. If removing the wire at terminal 213 corrects the voltage, Q214, the components associated with Q214, or the etches involved may be bridged or broken.

If the Q211 and Q214 source voltages do not adjust as described, first be sure you have +9 volts at both the drain of Q211 and the drain of Q214. Also, one side of R221 should be at - 8 volts. As a next step, check the Q216 base voltage. It should be about - 3.7 volts. Then check the Q216 emitter voltage. It should be about - 4.3 volts. If the base voltage is wrong, first be sure one side of R224 is at - 8 volts, that R224 and R223 are both 1 kilohm, and that C204 is not shorted. Next, remove Q215 and recheck the Q216 base voltage. If removing Q215 corrects the base voltage, Q215 should be replaced with a new transistor. On the other hand, if removing Q215 does not correct the Q216 base voltage, remove Q216 and measure the voltage at the junction of R223 and R224. Note that R223 and R224 establish the base voltage for Q215 and Q216. If removing Q216 produces the correct Q216 base voltage at the junction of R223 and R224, Q216 should be replaced with a new transistor.

Assuming you have the correct voltage on Q216 but incorrect voltages at Q211 and Q214, remove Q217 and Q218 one at a time. After removing each transistor, recheck the Q211 and Q214 source voltages. If removing Q217 or Q218 corrects these voltages, the transistor that corrected the problem when removed should be replaced with a new one. Finally, if removing Q217 and Q218 does not help, Q211 and Q214 should be replaced with new transistors.

STEP 2: With the HOR/TRIG INPUT jack still grounded, measure the Q217 and Q218 collector voltages as you vary the horizontal 100 V adjust trimmer (R222). The collector voltages should be about equal and both should increase or decrease as R222 is adjusted. The horizontal gain trimmer (R216) should be centered. If your Step 2 results are correct, move directly to Step 3.

Discussion of Step 2: If the Q217 and Q218 collector voltages are not correct, first check to be sure that the Q214 source voltage appears at the Q217 base, and the Q211 source voltage appears at the Q218 base. Next, be sure that one side of both R217 and R220 is at +9 volts and that one side of R222 is at -8 volts.

As a next step, check the base voltage of Q214 (about -3.7 volts) and the Q215 emitter voltage (about -4.3 volts). A problem here could indicate that Q215 is defective.

Assuming that Q215 is operating correctly, next remove Q219 and Q220. With these transistors out of the circuit, the Q217 and Q218 collectors should still vary as R222 is adjusted. If this does not happen, carefully check the components and the etches associated with Q217 and Q218. If a component problem is not found, Q217 and Q218 should be replaced with new transistors.

STEP 3: With the HOR/TRIG INPUT jack still grounded, measure the Q219 and Q220 collector voltages as you vary the horizontal 100 V adjust trimmer (R222). These collector voltages should also be about equal (within 20 volts of each other) and both should increase or decrease as R222 is adjusted. If this happens, set R222 such that the Q219 collector voltage is about 100 volts. Then, move directly to Step 4.

Discussion of Step 3: If the collector voltages of Q219 and Q220 are not correct, first check the wiring at terminals 209 and 210. Also, be sure that the transistors are correctly installed. Assuming you do not find an installation, component, etch, or wiring problem, Q219 and Q220 should be replaced with new transistors.

STEP 4: Remove the ground from the HOR/TRIG INPUT jack, connect a test lead from +5 volts (terminal 115) to the dc vertical input jack, place the VERTICAL ATTEN switch in the ×10 position, connect another test lead from terminal 204 to the HOR/TRIG INPUT jack, and place the HOR/TRIG INPUT switch in the EXT position. Figure 16 shows the connections described above. Basically, Q201 and R404 are used to generate an adjustable (0 - 0.5 volt) voltage source. This adjustable voltage (adjusted by the VERTICAL GAIN control, R404) is connected to the input of the horizontal amplifier. After connecting the two test leads, measure the voltage at terminal 204 as you rotate R404. This voltage should vary from about 0 to 0.5 volt. If this does not happen, refer to the vertical amplifier troubleshooting procedure.

If you have the correct voltage variation at terminal 204, next measure the voltage at the gate of Q211 as you adjust R404. This voltage should also change from 0 to about 0.5 volt. Next, check the voltage variations at the Q211 and Q214 sources as you adjust R404. As you advance R404, the Q211 source voltage should increase and the Q214 source voltage should decrease.

Next, measure the Q217 and Q218 collector voltages as you advance R404. The Q217 collector voltage should increase and the Q218 collector voltage should decrease. Finally, measure the Q219 and Q220 collector voltages as you advance R404. The Q219 collector voltage should increase and the Q220 collector voltage should decrease.

Discussion of Step 4: If the gate voltage of Q211 does not vary as R404 is adjusted, first check the resistance between terminals 204 and 211. You should read 0 ohms. If not, use Fig.16 or the overall schematic in Fig.17 to trace the circuit. If

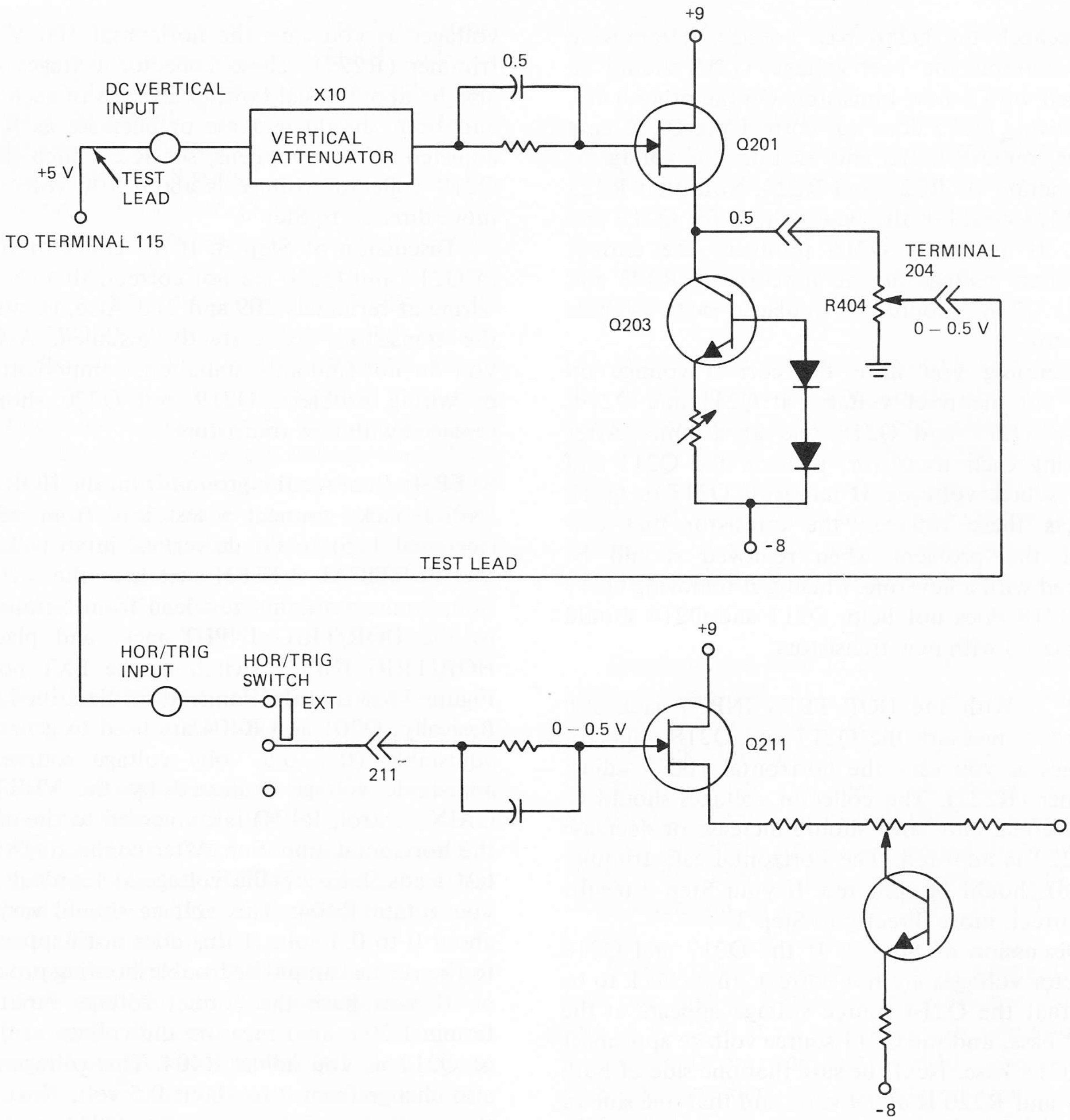


Figure 16. Connections for Step 4 of the horizontal troubleshooting procedure.

you do read 0 ohms, remove Q212 and again check for a voltage variation at the Q211 gate. If removing either Q212 or Q213 corrects the problem, the transistor may be defective and should be replaced. A defective Q211 could also prevent the normal voltage variation at the gate of Q211. Assuming you have the correct Q211 gate voltages but the wrong source voltage variation, Q211 should be replaced. If you find a problem at the collector of Q217, Q218, Q219, or Q220, carefully check the components and etches in the circuit involved.

NOTE: Satisfactory results in Steps 1 through 3 indicate that Q217, Q218, Q219, and Q220 are probably good. Therefore, a problem in this step would suggest one of the other components may be defective.

TROUBLESHOOTING THE SAWTOOTH GENERATOR

To investigate a problem with the sawtooth generator, follow the steps listed in the order given.

STEP 1:

(1) Put the POWER switch in the OFF position ( )

(2) Put the RANGE switch and the SPEED control in their fully counterclockwise positions ( )

(3) Place the TRIG SOURCE switch in the EXT position and the HOR/TRIG INPUT switch in the INT position .... ( )

(4) Remove IC102 .... ( )

(5) Put the POWER switch in the ON position ( )

(6) Momentarily ground IC101-9 .... ( )

At this time, IC101-13 and IC101-8 should be high. The collector of Q105 and the gate of Q102 should be at almost 0 volts. The source of Q102 and IC103-5 should be about -0.3 volt (you may need to adjust R101). IC103-4 should be about +0.25 volt, and IC103-10 should be high. If these voltages are correct, move directly to Step 2. If they are not, continue with the discussion below.

Discussion of Step 1: If IC101-13 is not high, Q106 or Q103 could be shorted, or IC101 could be defective. If removing IC102 causes IC101-13 to go high, IC102 should be replaced. If removing either transistor corrects the IC101-13 voltage, the transistor should be replaced. Finally, if removing IC102, Q103, and Q106 does not correct the IC101-13 voltage, check for continuity from IC101-13 through R119 to +5 volts.

If IC101-13 is high but IC101-8 is low, be sure IC102 has been removed and try momentarily grounding IC101-9 again. Next, check the supply voltage to IC101 at pin 14 to be sure you have +5 volts. Check to be sure you have exactly 0 volts at IC101-7. A problem with either voltage should be traced back to the power supply.

If you have the correct voltage at IC101-14 and IC101-7 but not at IC101-8, check the IC101-8 voltage as you ground IC101-9. When IC101-9 is low (grounded), IC101-8 should be high. Because IC101-8 is also connected to IC101-12, IC101-12 should also be high. With both IC101-12 and IC101-13 high, IC101-11 should be low, holding IC101-10 low. When the ground on IC101-9 is removed, the low at IC101-10 should hold IC101-8 high. If these voltages are not correct, IC101 may be defective; there may be a solder bridge involving the IC101 etches; or the wrong resistor may be installed at R111.

If your IC101 voltages are correct but the Q105 collector voltage is wrong, the problem could involve Q105, the wiring from terminal 103 to the timing capacitor, Q102, or Q108. When IC101-8 is high, the base of Q105 should be about 0.6 volt and should forward bias (turn on) Q105. With the base of Q105 at about 0.6 volt, the resistance from the Q105 collector to the emitter will be almost zero causing about 0 volts at the collector.

A problem with the voltage at the source of Q102 could involve the wiring to terminal 102, R101, or Q102. First, be sure you have +5 volts at the Q102 drain and -8 volts on one side of R101. To check for a wiring problem at terminal 102, remove the wire from this terminal. You should still have about -0.3 volt (adjustable by R101).

The voltage at IC103-5 should be the same as the voltage at the source of Q102, and the voltage at IC103-4 depends on R104 and R105. One side of R105 should be at +5 volts and one side of R104 should be at ground.

Assume that the voltages at IC103-4 and IC103-5 are correct. To investigate a problem at IC103-10, check the supply voltages at IC103-12 (+5 volts), IC103-6 (-8 volts), and IC103-9 (ground). If the supply and input voltages are correct, a low voltage at IC103-10 could mean that IC103 is defective or that the etch at IC103-10 is accidentally bridged to ground.

STEP 2 With IC102 still removed, momentarily ground IC101-13. After grounding IC101-13, IC101-8 should be low; the Q105 collector, Q102 gate, Q102 source, and IC103-5 should be high; and IC103-10 should be low. IC103-4 should remain at about +0.25 volt. If these results are correct, move directly to Step 3.

Discussion of Step 2: If IC101-8 does not go low when IC101-13 is grounded, check the voltage at IC101-11 while grounding IC101-13. A low at IC101-13 should make IC101-11 go high. Because IC101-11 is connected to IC101-10, IC101-10 should also be high. At this time, IC101-9 is floating (remember that IC102 has been removed). Because a floating input is seen as a high and IC101-10 is high, IC101-8 should be low. This input is connected to IC101-12 and should hold IC101-11 high after the ground on IC101-13 is removed. Assuming the supply voltages to IC101 are correct (+5 volts at IC101-14 and ground at IC101-7), the most likely problem would be a defective IC101 or a solder bridge in the IC101 etches.

STEP 3: With IC102 still removed, momentarily ground IC101-9. IC101-8 should now be high; the Q105 collector and Q102 gate should be low; the Q102 source should be about −0.3 volt; and IC103-10 should be high. Note that these are the same voltages you measured in Step 1. When the sawtooth generator is working properly, a low-going signal at IC101-13 will start the sweep, and a low-going signal at IC101-9 will stop the sweep. If your Step 3 results are correct, move directly to Step 4.

Discussion of Step 3: If grounding IC101-9 does not cause IC101-8 to go high, study the section called "Discussion of Step 1."

STEP 4: With IC102 still removed, use a short jumper wire to connect IC102-1 to IC102-4. This connection may be made by carefully inserting a section of regular hookup wire into the IC sockets. Next, use clip leads or tack solder to connect a 25 μF to 100 μF capacitor (exact value is not critical) in parallel with C401. This extra capacitor will be called C_x. Be careful to connect the positive (+) terminal of C_x to the positive terminal of C401. Capacitor C_x will slow the charge time so that you can watch the sweep voltages change with a voltmeter. Be sure the RANGE and SPEED controls are still in the fully counterclockwise position.

With C_x installed, connect your voltmeter to terminal 103 (initially should be low) and momentarily ground IC101-13. After grounding IC101-13, you should see the voltage at terminal 103 slowly increase as C401 – in parallel with C_x – charges. When this voltage reaches about +0.6 volt, it should quickly drop to about 0 volts and stay low.

To test the SPEED control, move it to mid-position and again momentarily ground IC101-13 as you watch the voltage at terminal 103. Now, this voltage should increase faster – to about +0.6 volt – and then quickly drop to a low voltage.

Assuming your results are correct at terminal 103, move your meter to terminal 102 (use 3 V range) and adjust the meter zero control to center the needle without voltage applied. If you do not have a meter that can be adjusted for center zero operation, you can adjust the needle up scale from zero to observe the following change. At terminal 103, the needle should deflect to the left of center indicating a negative voltage (about −0.3 volt). Next, momentarily ground IC101-13 and the voltage at terminal 102 should slowly increase to about +0.25 volt and then quickly return to the initial voltage. With the HOR/TRIG INPUT switch in the INT position, you should see the same voltage change at terminal 211 when IC101-13 is grounded. You should also see a dot move slowly across the crt screen when IC101-13 is momentarily grounded (assuming no problems with the vertical and horizontal amplifiers). If your results are correct, move directly to Step 5.

Discussion of Step 4: If you do not see a change in the voltage at terminal 103, there is a possibility that the voltage increased and then decreased so quickly that the meter could not react in time. To test for this possibility, remove the IC102-1 to IC102-4 jumper and ground IC101-13. If the voltage at terminal 103 increases now, C401 and C_x are charging too fast. To investigate this problem, first be sure that the RANGE and SPEED controls are both fully counterclockwise and that C_x is in parallel with C401 (C401 is the 10 μF capacitor on the front panel).

A problem with Q108 or Q102 could cause the voltage at terminal 103 to increase too quickly. To investigate this possibility, compare the Q108 and Q102 voltages with those in Table I. To help isolate the problem, remove Q102 and momentarily ground IC101-13. With Q102 isolated, grounding IC101-13 should still cause the voltage at terminal 103 to increase slowly. If removing Q102 causes the voltage at terminal 103 to increase slowly, Q102 should be replaced with a new transistor. If removing Q102 does not correct the voltage, Q108 should be replaced with a new transistor.

NOTE: With the jumper between IC102-1 and IC102-4 removed, you will need to ground IC101-9 (to reset IC101) before momentarily grounding IC101-13.

If you have the correct voltage variation at terminal 102 but not at terminal 211, use your ohmmeter to check continuity between terminals 102 and 211. Look for a wiring error at terminal 102, terminal 211, or the HOR/TRIG INPUT switch.

If you have the correct voltage variation at terminal 211, but the dot does not sweep slowly across the screen, the problem may involve the horizontal amplifier.

STEP 5: Remove the jumper between IC102-1 and IC102-4, and install IC102. Capacitor C_x (in parallel with C401) should still be installed. With your meter at terminal 102 and with the zero control adjusted as described in Step 4, you should see the voltage slowly increase, quickly decrease, and then repeat this cycle. If you can successfully complete Steps 1 through 5, your sawtooth generator should be fully operational. When testing of the sawtooth generator is completed, remove C_x.

Discussion of Step 5: If you do not have a voltage variation at terminal 102, there could be any one of several problems. For example, either section A or B of IC102 could be defective; supply voltage has not been applied at IC102-3, -10, -11, -20 (+5 volts) and IC102-8 (ground); C106, C505, and C506 could be defective; a wiring error may have occurred from terminals 105 and 106 to C505 and C506; or Q103 could be defective.

To help isolate the problem, try grounding IC101-13 as you watch the voltage at terminal 102. If momentarily grounding IC101-13 causes the voltage at terminal 102 to increase and decrease once, IC102A is probably working correctly but IC102B, Q103, or C106 may be defective. If grounding IC101-13 causes the voltage at terminal 102 to increase but not return to -0.3 volt, IC102A may be defective.

With IC102 installed and when power is applied, IC102-12 will be high (turning on Q103), making IC101-13 low and IC101-8 low (turning off Q105). When Q105 is off, the timing capacitor can charge through Q108. While the capacitor is charging, IC102-4 should be high, holding IC101-9 high until the voltage at IC103-5 exceeds the voltage at IC103-4. When this happens, IC103-10 should go low, making IC102-4, IC102-9, IC102-12, and IC101-9 all go low. The low at IC101-9 will cause IC101-8 to go high (turning on Q105). Q105 will then allow the timing capacitor to discharge quickly.

After the timing capacitor has discharged, IC102A will time out, causing IC102-4 and IC101-9 to go high. About 1/3 of a second after IC102-4 goes high, IC102B will time out, causing IC102-12 to go high. This action causes IC101-13 to go low and then the cycle repeats itself. With C_x installed, you can watch the sawtooth generator voltages with your voltmeter to help identify the problem. Once you have completed your testing, be sure to remove C_x.

TESTING THE TRIGGER GENERATOR WITH ANOTHER OSCILLOSCOPE

If you have access to another oscilloscope, the following procedure may help to troubleshoot the trigger generator.

STEP 1:

(1) Put the ATTEN switch in the CAL position ( )

(2) Advance the VERTICAL GAIN control to the fully clockwise position . . . . ( )

(3) Place the TRIG SOURCE switch in the INT position . . . . ( )

(4) Put the POWER switch in the ON position ( )

(5) Connect the vertical input of the other oscilloscope to terminal 116. You should see a square wave, assuming that the vertical amplifier is working correctly . . . . ( )

(6) Move the vertical input of the other oscilloscope to the gate of Q107. You should see a square wave . . . . ( )

(7) Move the vertical input of the other oscilloscope to the source of Q107. You should see a square wave . . . . ( )

(8) Move the vertical input of the other oscilloscope to the base of Q106. You should see a square wave . . . . ( )

(9) Finally, move the vertical input of the other oscilloscope to the collector of Q106. You should now see negative-going pulses . . . . ( )

Discussion of Step 1: If you do not see a square wave signal at terminal 116, first be sure that a square wave signal is present at terminal 317. If there is no signal at terminal 317, disconnect the wire at terminal 317 and recheck for a waveform at terminal 317. If there is still no waveform, something is wrong with the vertical deflection amplifier and you should refer to the vertical troubleshooting procedure. If disconnecting the wire at terminal 317 produces a waveform at terminal 317, carefully check the wiring between terminal 317 and terminal 116. Pay special attention to the TRIG SOURCE switch, S402.

If you have a square wave at terminal 317 but not at terminal 116, measure the resistance between terminals 317 and 116. You should measure 0 ohms. If you do not find 0 ohms, trace the wiring from terminal 317 through the TRIG SOURCE switch to terminal 116.

If you do not have a square wave at the Q107 gate, remove Q107 and check for a signal at the junction of C104 and R120. If there is still no signal, C104 may be open; R120 is not 1 megohm; or there may be an etch problem.

If you have a signal at the Q107 gate but not at the source, first be sure that the Q107 drain is at +5 volts and that one side of R122 is at -8 volts. Assuming these checks do not indicate a problem, either Q107 or C105 may be defective. If you have a signal at the Q107 source but not at the Q106 base, C105 or Q106 could be defective.

If you have a signal at the base of Q106 but not at the collector, first check the dc voltage at the Q106 base. With no trigger signal (switch the TRIG SOURCE switch to EXT for this measurement) at terminal 116, you should measure about 0.4 volt at the base of Q106. If this voltage is wrong, check R118 and R117. Be sure that one side of R117 is at +5 volts and that one side of R118 is at 0 volts or ground. If the Q106 base voltage is correct, Q106 should be replaced.

ALIGNMENT PROCEDURE

(1) Set all trimmers on both the HOR/VERT module and the SWEEP/TRIG module to mid-position . . . . ( )

(2) Center the vertical and horizontal position controls on the front panel . . . . ( )

(3) Place the HOR/TRIG INPUT control in the EXT position and the RANGE switch in the LOW position . . . . ( )

(4) Put the ATTEN control in the × 10 position ( )

(5) Move the POWER switch to the ON position and again check the dc supply voltages: terminal 312 (4 to 6 volts), terminal 313 (8 to 10 volts), terminal 318 (-7 to -9 volts), terminal 319 (approximately 150 to 200 volts), and terminal 320 (approximately 200 volts) . . . . ( )

(6) Set your voltmeter to measure a maximum voltage of about 100 volts dc. Assuming your voltages are within normal limits, adjust the HOR BAL trimmer to obtain equal collector voltages at Q219 and Q220. As you adjust the HOR BAL trimmer, the collector voltage at either Q219 or Q220 will increase. As this happens, the collector voltage at the other transistor will decrease . . . ( )

(7) After adjusting the HOR BAL trimmer, adjust the HOR 100 V ADJ trimmer to obtain a collector voltage at Q219 of about 100 volts . . . . ( )

(8) Set your voltmeter to read a maximum voltage of 1 volt dc. Then set the front panel GAIN control to midposition and adjust the VERT BAL trimmer for 0 volts at terminal 204 . . . . ( )

(9) Measure the voltage at terminal 206 and note this voltage in the margin . . . . ( )

(10) Adjust the VERT POS trimmer to give the same voltage at the base of Q204 as you measured in Step 9 at terminal 206 (noted in margin) . . ( )

(11) Set your voltmeter to read a maximum voltage of 300 volts dc. Adjust the VERT 100 V ADJ trimmer to obtain a collector voltage at Q301 of about 100 volts . . . . ( )

(12) At this point you should have a dot on the screen. You may need to adjust the front panel INTENSITY and FOCUS controls. Use the front panel vertical and horizontal position controls to center the dot . . . . ( )

(13) Now switch the front panel HOR/TRIG INPUT switch to the INT position. You should now have a short horizontal line. The line may appear to "flash" or move. This is due to the slow sweep speed being used. Now, use the SWEEP BAL trimmer (on the SWEEP/TRIG module) to center this line horizontally . . . . ( )

(14) Move the RANGE switch to the LOW (full counterclockwise) position. Adjust the HOR GAIN trimmer (on the HOR/VERT module) so that the horizontal line expands to the full graticule. You may need to slightly adjust the SWEEP BAL trimmer to keep the trace centered . . . . ( )

(15) Switch the front panel ATTEN switch to the CAL position and advance the front panel GAIN control to the fully clockwise position. You should now see a rectangular wave on the screen. Adjust the SWEEP SPEED control for about three of four cycles of the CAL rectangular wave. While watching this display, adjust the ASTIG trimmer on the SWEEP/TRIG module for best focus . . ( )

(16) If your display is tilted, turn off the power and loosen the two nuts on the crt clamps slightly until you can rotate the crt easily. Turn the power on and grasp the wide front part to the crt with your hand. Rotate it until the display is level. Then turn off the power and retighten the nuts on the clamps until the crt is held securely . . . . ( )

TABLE I
SEMICONDUCTOR VOLTAGE CHART

Transistor	e/s	b/g	c/d
Q101	0	3.5	175
Q102	-0.3	0	5.0
Q103	0	0	5.0
Q104	0	0.26	0.7
Q105	0	0.6	0
Q106	0	0.4	4.8
Q107	-0.2	0	5.0
Q108	3.5	2.9	0
Q201	0	0	9.0
Q202	0	0.7	9.0
Q203	-7.0	-6.4	0
Q204	0.1	0.7	7.5
Q205	0.1	0.7	7.5
Q206	8.1	7.5	4.2
Q207	8.1	7.5	4.2
Q208	0	X	0
Q209	0	X	0
Q210	-7.0	-6.4	0
Q211	0.36	0	9.0
Q212	0	X	0
Q213	0	X	0
Q214	0.38	0	9.0
Q215	-4.3	-3.8	-1.4
Q216	-4.3	-3.6	-1.0
Q217	-0.22	0.36	4.2
Q218	-0.24	0.36	4.2
Q219	3.6	4.2	100
Q220	3.6	4.2	100
Q301	3.6	4.2	100
Q302	3.6	4.2	100

Pin	IC101	IC102	IC103
1	1.3	H	X
2	1.3	5.0	X
3	1.1	5.0	X
4	L	H	0.25
5	H	X	-0.3
6	H	1.6	-8.0
7	0	1.3	X
8	H	0	X
9	H	H	0
10	L	5.0	H
11	L	5.0	X
12	H	H	5.0
13	H	X	X
14	5.0	1.6	X
15	X	1.4	X
16	X	5.0	X

NOTES

1 H = LOGIC HIGH (ABOVE 2 VOLTS)

L = LOGIC LOW (BELOW 1 VOLT)

X = VOLTAGE NOT IMPORTANT

2 VERTICAL INPUT GROUNDED

HOR/TRIG SWITCH IN INT POSITION

TRIG SOURCE SWITCH IN INT POSITION

RANGE SWITCH FULL COUNTERCLOCKWISE

SPEED CONTROL FULL COUNTERCLOCKWISE

GAIN CONTROL FULL COUNTERCLOCKWISE

VERTICAL ATTEN SWITCH IN X10

TRACE CENTERED

3 ACTUAL VOLTAGES MAY DIFFER FROM LISTED VOLTAGES BECAUSE OF COMPONENT TOLERANCES. USE THESE VOLTAGES ONLY AS A GUIDE.

* NOMINAL VALUES. ACTUAL VOLTAGES MAY VARY AS MUCH AS 20%.

TABLE II

CIRCUIT BOARD TERMINAL VOLTAGE CHART

Terminal	Voltage
101	-8.0
102	-1.3
103	0
104	5.0
105	1.4
106	1.6
107	175
108	0
109	107
110	205
111	8.0
112	0.05
113	0
114	-8.0
115	5.0
116	4.0

Terminal	Voltage
201	0
202	0
203	0
204	0
205	X
206	0.7
207	4.2
208	4.2
209	100
210	100
211	0
212	0
213	0.4
214	0.04
215	9.0
216	-8.0

Terminal	Voltage
301	2.7 ac
302	14.0
303	4.2
304	11 ac
305	11 ac
306	0
307	-14.0
308	210
309	186 ac
310	186 ac
311	0
312	5.0
313	9.0
314	100
315	100
316	4.2
317	3.6
318	-8.0
319	170
320	207

NOTES

1 X MEANS VOLTAGE NOT IMPORTANT.

2 CONTROLS ADJUSTED AS STATED IN TABLE 1.

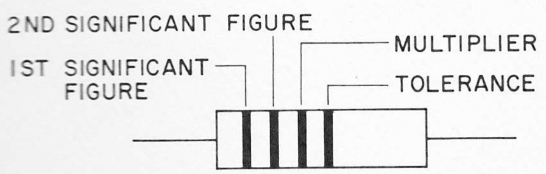
3 VOLTAGES MAY DIFFER FROM THIS TABLE BECAUSE OF COMPONENT TOLERANCES.

RESISTOR AND CAPACITOR COLOR CODES

JAN and EIA stand for the two common color codes (Joint Army-Navy and Electronics Industries Association). The two codes are the same except as indicated. We have not indicated temperature coefficients or characteristics of capacitors, because they are not necessary for identifying your parts.

COLOR	SIG. FIG.	MULTIPLIER	RESIS.	TOLERANCE: CERAMIC CAPACITORS 10 MMF OR LESS	TOLERANCE: CERAMIC CAPACITORS OVER 10 MMF	TOLERANCE: MICA CAPACITORS (As below, or ± 1 mmf, whichever is larger)	TOLERANCE: PAPER CAP
Black	0	1		± 2.0 MMF	± 20%	± 20%	20%
Brown	1	10		± 1.0 MMF	± 1%	± 1%	
Red	2	100			± 2%	± 2%	
Orange	3	1000			± 2.5%	± 2.5%	
Yellow	4	10,000					
Green	5	100,000		± 0.5 MMF	± 5%	± 5% (EIA)	5%
Blue	6	1,000,000					
Violet	7	10,000,000					
Gray	8			± 0.25 MMF			
White	9			± 1.0 MMF	± 10%		10%
Gold		.1	± 5%			5% (JAN)	5%
Silver		.01	± 10%			10%	10%
No color			± 20%				20%

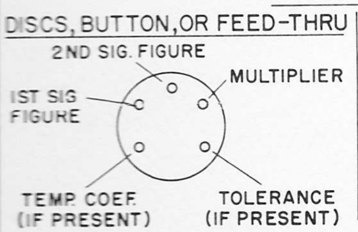
RESISTORS — RESISTANCE GIVEN IN OHMS

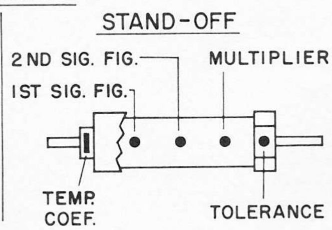


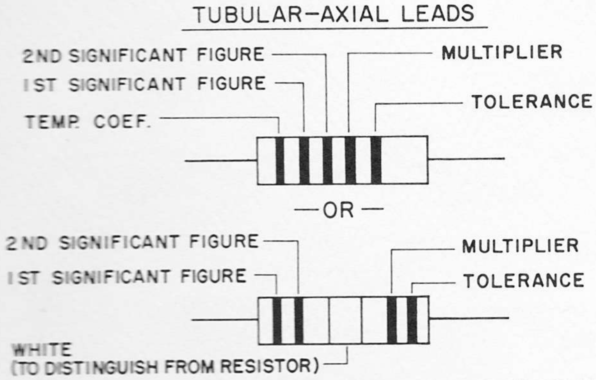
Black body = composition, non-insulated.
Colored body = composition, insulated.
Double width band for 1st sig. figure indicates wire-wound.

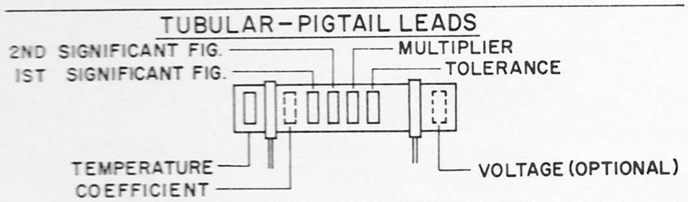
CAPACITORS — CAPACITY GIVEN IN MMF

CERAMIC



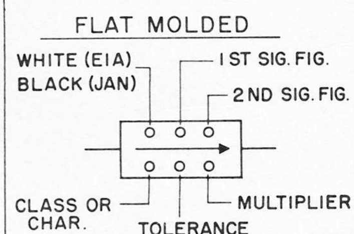


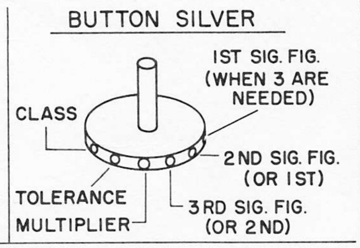




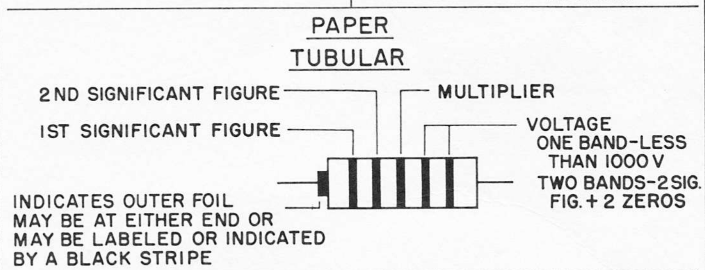
MICA

CLASS OR CHARACTERISTIC REFERS TO Q FACTOR, TEMPERATURE COEFFICIENT, AND PRODUCTION TEST REQUIREMENTS

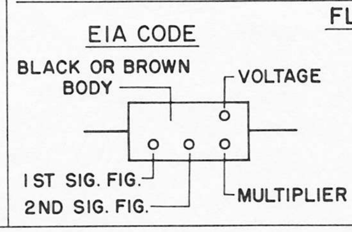


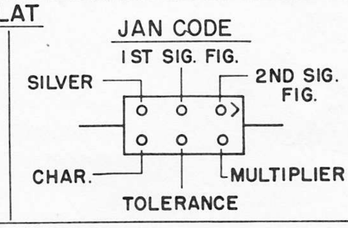


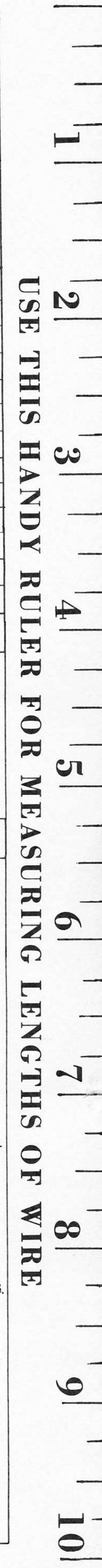
PAPER



FLAT







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