OPERATION

This section of the Manual explains the function of each control, switch, and connector; describes how to correlate between time/cm and frequency; and provides operational examples.

NORMAL OPERATING CHARACTERISTICS

The following information is provided to help answer possible questions you may have about the operation of your Oscilloscope.

- Several minutes may be required for the trace to stabilize when the Oscilloscope is first turned on, especially on the more sensitive voltage ranges.
- Random noise on the input signal may cause false triggering, especially on the most sensitive voltage ranges.
- A baseline will automatically appear after a short pause when the TRIGGERING AUTO/NORMAL switch is placed in the AUTO position or when the input signal is disconnected when automatic triggering is used.

USING A 10-MILLIVOLT OSCILLOSCOPE

When you use an Oscilloscope as sensitive as this, you must use special care to make reliable measurements. Keep the following points in mind when you measure very low level signals.

- Placement of the ground clip may be critical if the signal source ground carries an appreciable current. Voltage differences of several millivolts from one side of a chassis or ground foil to the other are common. Place the ground clip at the point that gives the least error. This is usually nearest the signal source. You may have to move the ground clip when you measure different points.
- Stray 60 Hz pickup may be hard to eliminate, especially in high impedance circuits. Be sure to use shielded test cables. Shield the signal source if necessary.
- Wideband measurements in the millivolt region are more difficult because of the inherent noise (shot noise and thermal noise) generated by electronic components. This may appear as a widening of the baseline or the baseline appearing out of focus. Noise on the baseline that appears as "hash" or "spikes" may be caused by the electromagnetic pickup of man-made noise such as ignition noise, appliance noise, etc. Noise of any kind may cause erratic triggering.

ALTERNATE PRIMARY VOLTAGES

In the United States 120 VAC line voltage is most often used, while in other countries 240 VAC line voltage is more common. If you intend to operate the Oscilloscope on 240 volts, perform the following steps. Otherwise, proceed to "Operation and Applications." NOTE: Electrical regulations in some areas require a special line cord and/or plug for 240-volt operation. Replace them if necessary.

( ) Make sure the line cord is unplugged.

( ) Remove the cabinet from the Oscilloscope.

( ) Shift the 120/240 slide switch to the 240 position. This switch is located near the rear of the chassis, between the CRT and power transformer.

( ) Remove the 1/2-ampere slow-blow fuse and install a 1/4-ampere slow-blow fuse (not furnished). The fuse block is located on the bottom side of the chassis.

( ) Reinstall the cabinet.

OPERATION AND APPLICATIONS

Refer to Pictorial 6-1 (Illustration Booklet, Page 23) for the location and explanation of the front panel controls and switches.

OPERATIONAL EXAMPLE

The following example will help you become more familiar with the control functions, especially the sweep and trigger controls.

Connect a 1 kHz sine wave source to the Y1 vertical INPUT connector. Set the TRIGGERING switches to Y1, AC, (+), and NORMAL. Set the Y1 INPUT switch to AC and the VERTICAL MODE switch to Y1.

Turn the TRIG LEVEL control to its center of rotation. Adjust the VOLTS/CM switch to obtain a trace 3 or 4 centimeters high. Adjust the HORIZ POS control so the left edge of the trace is just inside the left margin of the graticule. Set the TIME/CM switch to display a few cycles of the waveform. Adjust the Y1 POS control to center the trace vertically.

Now carefully readjust the TRIG LEVEL control and observe how the left edge (starting point) of the sweep moves upward as the control is turned clockwise, and downward as the control is turned counterclockwise. See A on Pictorial 8-1 (Illustration Booklet, Page 25).

Switch the TRIGGERING +/− switch to the "−" position, and note that the TRIG LEVEL control has the same effect except that the sweep start point is on the negative slope of the waveform.

There is no fixed rule for setting the TRIG LEVEL control, as no two waveforms are alike. For example, assume that you want to examine the "spike" on waveform B of Pictorial 8-1. By adjusting the TRIG LEVEL control so the sweep starts just before the spike, as in C in Pictorial 8-1, and decreasing the time required for one complete sweep by changing the position of the TIME/CM switch, the spike can be spread out across a large area of the screen for closer observation, as shown in D of Pictorial 8-1.

By reading the TIME/CM switch, you can determine the duration of the spike. This feature is also useful to observe distortion in circuits using square wave signals.

The TIME/CM switch should be set to display the desired waveform or portion of a waveform. Occasionally it may also be necessary to use the VARIABLE. However, the sweep time is not calibrated when the VARIABLE is used. Refer to the formula or the "TIME/CM FREQUENCY Correlation Chart" on Page 96 to determine unknown frequencies or sweep times when you use the calibrated positions of the TIME/CM switch.

The TRIGGERING Y1/Y2/EXT/LINE switch permits you to choose between internal or external triggering signals. The internal trigger is derived from the Y1 or Y2 vertical input signal, or the power line signal. The EXT (external) trigger position allows the sweep to be triggered from external sources, such as TV horizontal or vertical sync pulses, that are not necessarily related to the vertical input signal.

When the TRIGGERING AUTO/NORMAL switch is in the AUTO position, a sweep appears on the screen even in the absence of a signal. The AUTO position is useful for simple waveforms with frequencies from about 40 cycles and upward. This switch position is also useful for signals that are too weak to trigger the sweep circuits in the normal position.

The TRIGGERING AC/DC/TV switch will normally be on the AC position except when you use very low frequency or DC signals as a trigger source, or when you use the TV setting to filter out the horizontal sync signal when you view a composite waveform.

Dual-Trace Operation

Signal source: Sine wave — square wave generator capable of in-phase, simultaneous, sine wave and square wave output, 1kHz, 1volt.

Connect the sine wave signal to the Y1 INPUT and the square wave signal to the Y2 INPUT.

Set both the Y1 and Y2 VOLTS/CM switches at 1 V and both INPUT switches at AC; then set the following switches as indicated:

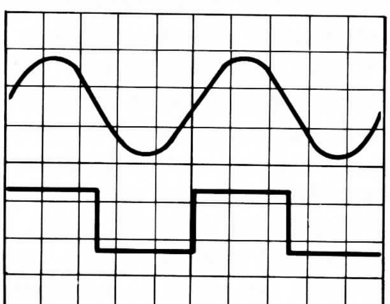
Y1, Y2, CHOP, ALT	ALT
TRIGGERING	Y1, AC, plus (+), AUTO
LEVEL	Center of rotation
TIME/CM	200 μS

Adjust the Y1 and Y2 POSITION controls so the two waveforms are separated on the CRT. The display will be similar to that shown in Pictorial 8-2.

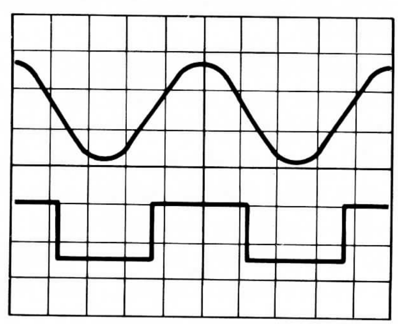
NOTE: In dual trace operation, use the ALT mode when operating at sweep speeds greater than 200 μS, and use the CHOP mode at the slower sweep speeds.

Turn the LEVEL control so triggering occurs at the peak of the sine wave as in Pictorial 8-3. Note that this is at the midpoint of the positive portion of the square wave.

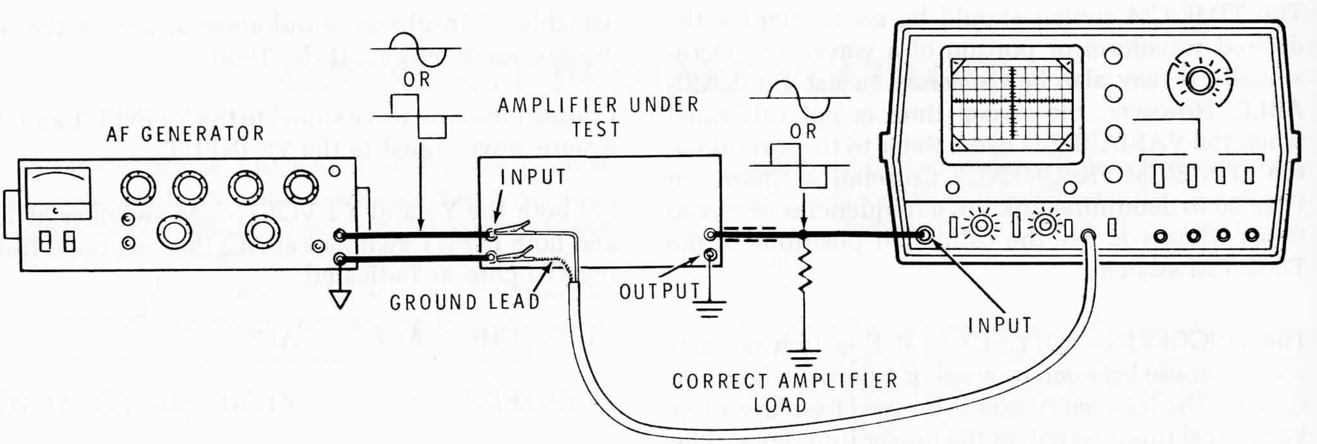
Return the LEVEL control to the center of rotation and the waveforms will again appear in their generated phase relationship.



PICTORIAL 8-2



PICTORIAL 8-3



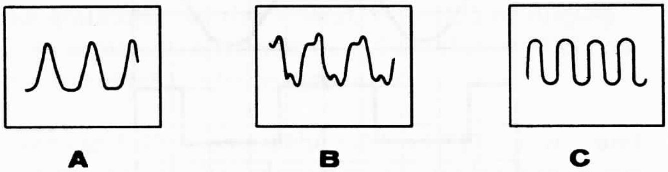
PICTORIAL 8-4

AUDIO AMPLIFIER CIRCUITS

You can observe frequency response, distortion, and gain in an audio amplifier by observing its output waveform when a sine wave or a square wave is applied to either amplifier input.

Pictorial 8-4 shows a typical setup for checking an audio amplifier. The audio generator injects either a low distortion sine wave or square wave signal into the input of the amplifier. The amplifier's output terminates in the proper load for the amplifier, and the oscilloscope is connected across the load and the output of the generator. Use the Y2 TRIGGERING position (if necessary) to synchronize the display.

The waveform produced by the audio generator will not be changed as it passes through properly operating circuits of a high-fidelity amplifier. However, if any circuit is not operating properly, the output waveform will be distorted. The two traces can be compared directly.



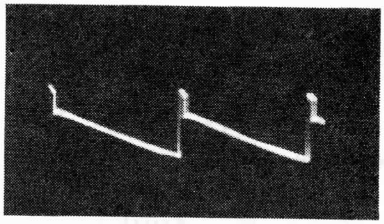
PICTORIAL 8-5

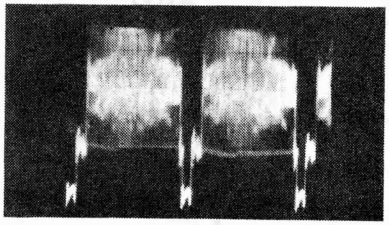
Pictorial 8-5, Part A, shows a sine wave with a serious flattening of one peak. This represents about 10% harmonic distortion, which could be caused by an improperly biased stage or a defective tube or transistor, and is a particularly objectionable amplifier fault. Pictorial 8-5, Part C, shows a flattening of both peaks, which usually indicates an overdriven stage somewhere in the amplifier.

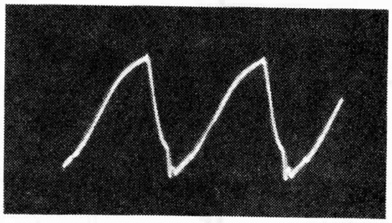
While a sine wave signal will tell a lot about an amplifier, a square wave gives an additional indication of amplifier performance with respect to frequency response, amplitude distortion, and phase shift. The square wave generator must produce a clean waveform with straight sides, sharp corners, and flat horizontal lines, as shown in Pictorial 8-6, (Illustration Booklet, Page 25) Part A.

When a low frequency square wave signal is fed into the input of an amplifier, its output waveform will be a faithfully reproduced square wave if its frequency response is good and if little amplitude or phase distortion occurs in its circuits. The shape of the leading edge of an output waveform, as shown in Pictorial 8-6, Part B, indicates poor high frequency response. This may be caused by amplitude distortion (clipping), or phase shift, or both.

The slope of the flat portion of the waveform, as shown in Pictorial 8-6, Part C, indicates poor low frequency response.







PICTORIAL 8-7

TELEVISION RECEIVER CIRCUITS

An oscilloscope can also be used to service television receivers. There are two methods of using the oscilloscope in TV service work. One is the point-to-point probing to study components of a transmitted television signal and their effect on receiver circuits. The other method uses the signal from a sweep generator and is used primarily for the alignment of a receiver. These two methods will be treated separately in the following paragraphs.

Point-to-Point Signal Tracing

Most television maufacturers supply service information that shows correct oscilloscope patterns at various points in the receiver. These patterns are generally of the composite video signal or synchronizing signals that are received from a television transmitter, or generated within the receiver. Some of these patterns are shown in Pictorial 8-7, with the signal frequency indicated for each pattern. No special equipment is required for observing these patterns on your Oscilloscope, except a demodulator probe to detect modulation envelopes in the IF or RF amplifier sections.

Pictorial 8-8 is a simplified block diagram of a typical television receiver. It shows various stages and points for connecting the Oscilloscope probe. The letters at each test point indicate the type of probe to use, and the setting of the Oscilloscope's sweep speed. These letters are defined in the following chart.

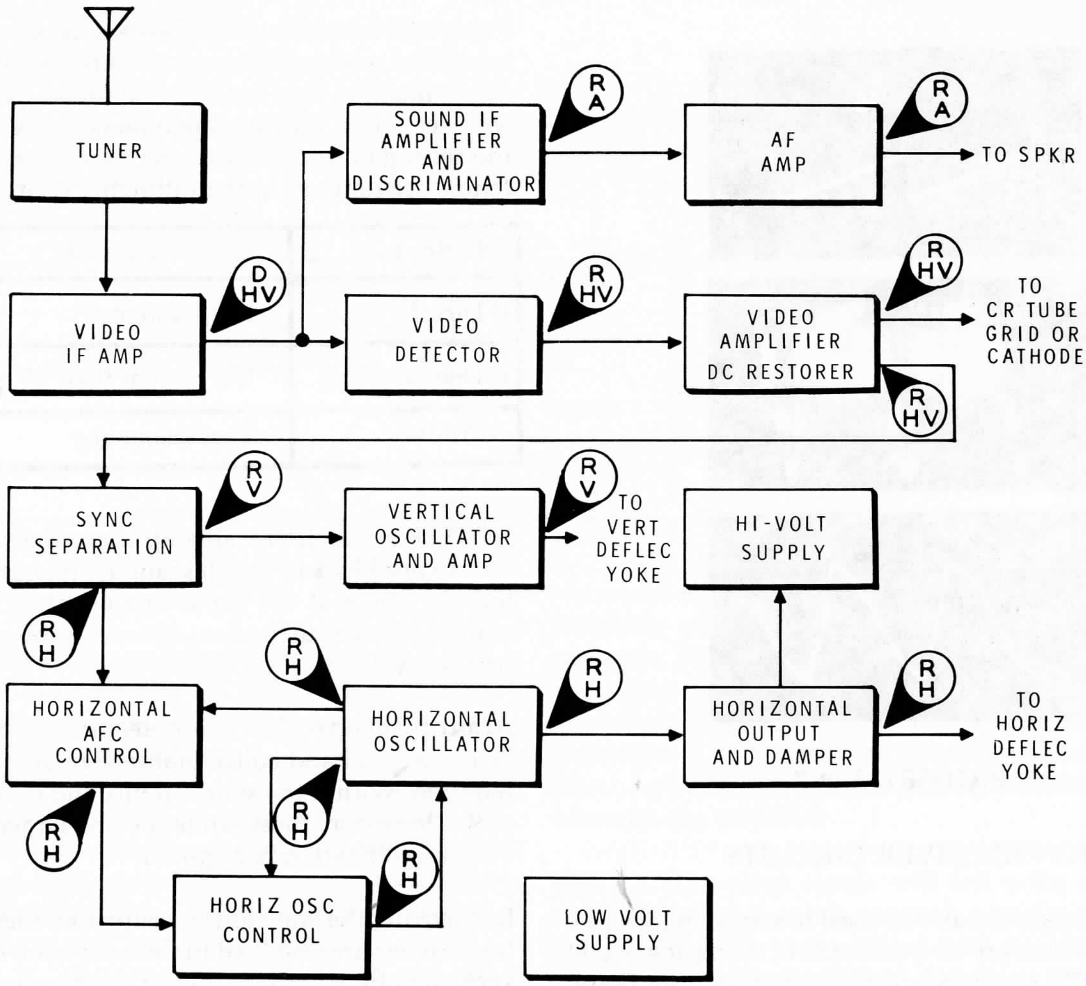
PROBE	SWEEP SPEED
R Direct	H 20 μs/cm
D Demodulator	V 2 ms/cm (use TV trigger)
A Audio	Test frequency

NOTE: For simplicity, all amplifier stages are shown within one block of the diagram in Pictorial 8-8. Tests may be made at the input or output of individual amplifier stages using the indicated probe and sweep frequency.

At any point up to the video detector, the voltages will be quite small and considerable vertical gain will be required. Within the sync circuits and deflection circuits, however, these voltages are larger and very little amplification is required.

In checking the waveforms, remember that two basic frequencies are involved in the television signal. The vertical or field frequency is 60 Hz. Any investigation of the circuit except within the horizontal oscillator, its differentiator network, and the horizontal amplifier stages, can generally be made using a sweep speed of 2 ms/cm. In order to study the horizontal pulse shape or the operation of the horizontal deflection system, it is generally necessary to operate the sweep generator at 20 μs/cm. This sweep rate will show the waveform of about three lines of the signal.

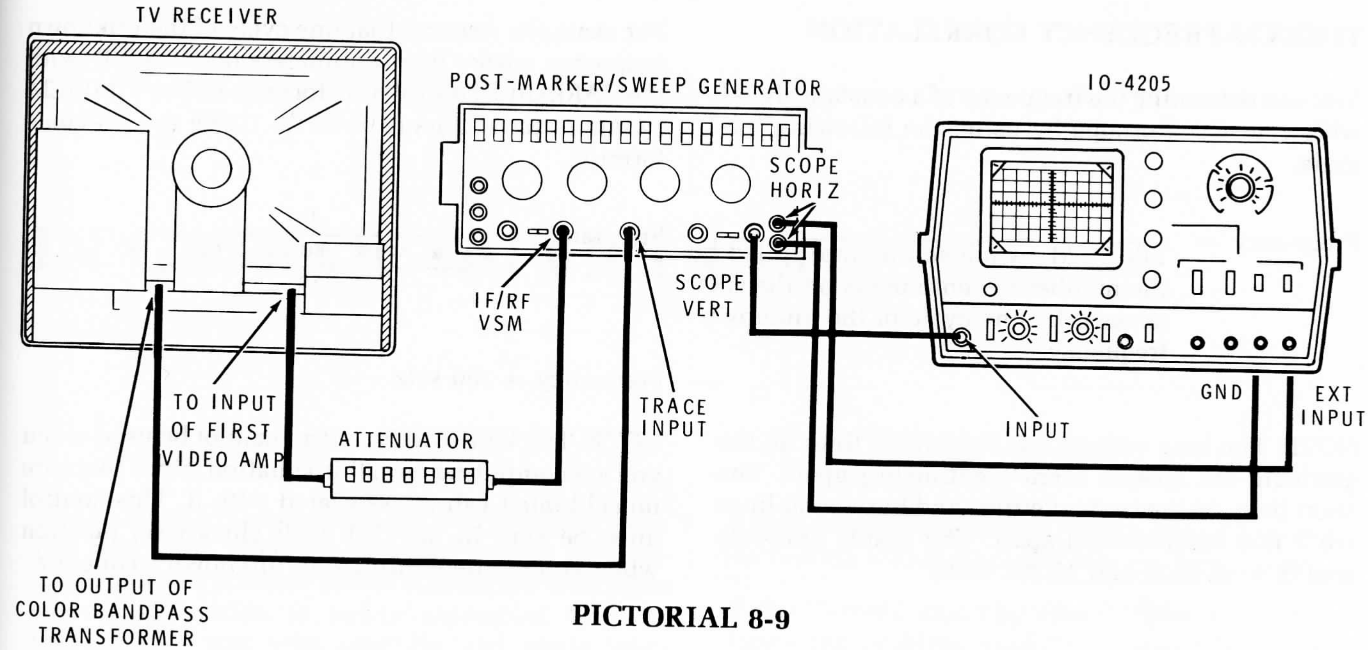
The point-to-point signal tracing method of analysis is most helpful in going through a receiver, since faulty receiver operation is generally caused by the loss of all or a significant portion of the picture information and pulses at some stage within the receiver. With a basic understanding of the function of each part of the signal and with a knowledge of what the signal actually looks like at any part of the receiver, it is a comparatively simple matter to isolate the defective portion and the particular component causing the failure.



PICTORIAL 8-8

Bear in mind that a phase shift of 180 degrees takes place in some circuits of a receiver. Therefore, the pattern displayed on the Oscilloscope screen may be inverted in some cases. The pattern or form of the wave should not be changed however.

Video amplifier response can be measured in exactly the same manner described for testing an audio amplifier, and again a square wave signal is the most efficient method to use. Because a video amplifier must pass signals as low as 20 Hz and as high as 4 or 5 MHz, a more comprehensive test is required. Usually a 60 Hz check is made to cover low and medium frequency characteristics. A second check at 25 kHz covers the high frequency portion of the response curve. Again, such tests require accuracy on the part of the Oscilloscope. The signal tracing technique can be used in these tests also. The square wave generator is fed directly into the first video amplifier stage. Very low signal input will be required. Then the Oscilloscope is connected to various stages, starting near the output end and working back until any distortion is isolated. Patterns such as Pictorial 8-6, Part B, (Illustration Booklet, Page 25) are responsible for poor picture detail or fuzziness, while the distortion of the waveform shown in Pictorial 8-6, Part C, can cause shading of the picture from top to bottom.

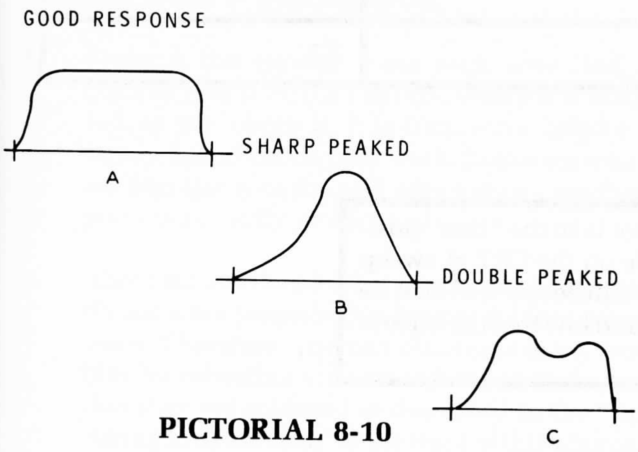


PICTORIAL 8-9

Receiver Alignment

Alignment of television RF and IF circuits requires the use of an alignment sweep generator as well as the Oscilloscope. This sweep generator supplies an RF signal that sweeps across all the frequencies of a television channel or IF amplifier 60 times a second. The sweep generator also supplies 60 Hz sweep voltage to the Horizontal input of the Oscilloscope. Pictorial 8-9 shows a typical setup for the alignment of a television receiver.

The exact procedure for alignment differs with various receivers and with different sweep generators. Maufacturer's service data usually includes alignment procedures and correct response waveforms.



PICTORIAL 8-10

Pictorial 8-10, Part A, shows a typical response curve for a properly aligned receiver. Notice that the top part of the waveform is essentially flat, and tapers sharply at both ends. The waveform shown in Part B of Pictorial 8-10 might result if the IF stages of the receiver were aligned too sharply or all at the same frequency. This would produce a narrow bandwidth and seriously affect picture quality. A misalignment of one or more IF stages would produce a waveform like that shown in Pictorial 8-10, Part C, which would also reduce picture quality.

AC VOLTAGE MEASUREMENTS

Because of its characteristics, the oscilloscope is particularly suited to the measurement of AC voltages. In some television circuits, it is imperative that such measurements be made accurately with respect to wave shape, so that the conventional rms-indicating AC voltmeter is no longer adequate. Most television service bulletins specify peak-to-peak voltages which appear at various points of the circuit.

The following relationships exist for sine wave AC voltages:

rms × 1.414 = Peak Voltage
rms × 2.828 = Peak-to-Peak Voltage
Peak Voltage × .707 = rms Voltage
Peak-to-Peak Voltage × 0.3535 = rms Voltage

TIME/CM-FREQUENCY CORRELATION

You can determine the frequency of a constant signal with your Oscilloscope by using the following formula.

$$\text{Frequency} = \frac{1}{\text{TIME/CM switch setting multiplied by the number of centimeters on the CRT covered by one cycle of the unknown frequency.}}$$

NOTE: The long vertical and horizontal lines on the graticule are spaced 1 cm (centimeter) apart. The short lines on the center vertical and horizontal lines are 2 mm (millimeters) apart. The usable graticule area is 8 cm high and 10 cm wide.

For example: Assume that one cycle of the unknown frequency covers five centimeters on the CRT (with the VARIABLE control full clockwise). The TIME/CM switch is set at 2 μs (2×10^{-6}). Using the previous formula.

$$\text{Frequency} = \frac{1}{\dfrac{2 \times 10^{-6}\ \text{sec} \times 5\ \text{cm}}{\text{cm}}}$$

Frequency = 100 kHz.

NOTE: The VARIABLE control cannot be used when you are computing with this equation, since there are no calibrated values associated with it. This control must be kept in the CAL (full clockwise) position when you are determining an unknown frequency.

TIME/CM-FREQUENCY CORRELATION CHART

TIME/CM SWITCH	TIME FOR 1 CM SWEEP	FREQUENCY (Hz) FOR 1 CYCLE/10-CM (full screen width)	FREQUENCY (Hz) FOR 5 CYCLES/10 CM (full screen width)
.2 μs	.2 μ sec	500,000	2500,000
.2 μs	2 μ sec	50,000	250,000
20 μs	20 μ sec	5,000	25,000
200 μs	200 μ sec	500	2500
2 ms	2 m sec	50	250
20 ms	20 m sec	5	25
200 ms	200 m sec	.5	2.5

NOTE: When the trigger selector is in the "line" position, a trace may not be visible on the CRT at sweep speeds above 20 μsec. The Oscilloscope will still be triggered, but the refresh rate is so low that the trace is dim.