

OBJECTIVE: To Study of C.R.O. Voltage measurement on C.R.O. Current measurement on C.R.O. Frequency measurement on C.R.O. Phase difference measurement on C.R.O.

APPARATUS REQUIRED: Cathode-ray oscilloscope, millimeter, and oscillator.

Theory

INTRODUCTION: The cathode-ray oscilloscope (CRO) is a common laboratory instrument that provides accurate time and amplitude measurements of voltage signals over a wide range of frequencies. Its reliability, stability, and ease of operation make it suitable as a general purpose laboratory instrument. The heart of the CRO is a cathode-ray tube shown schematically in Fig. 1.

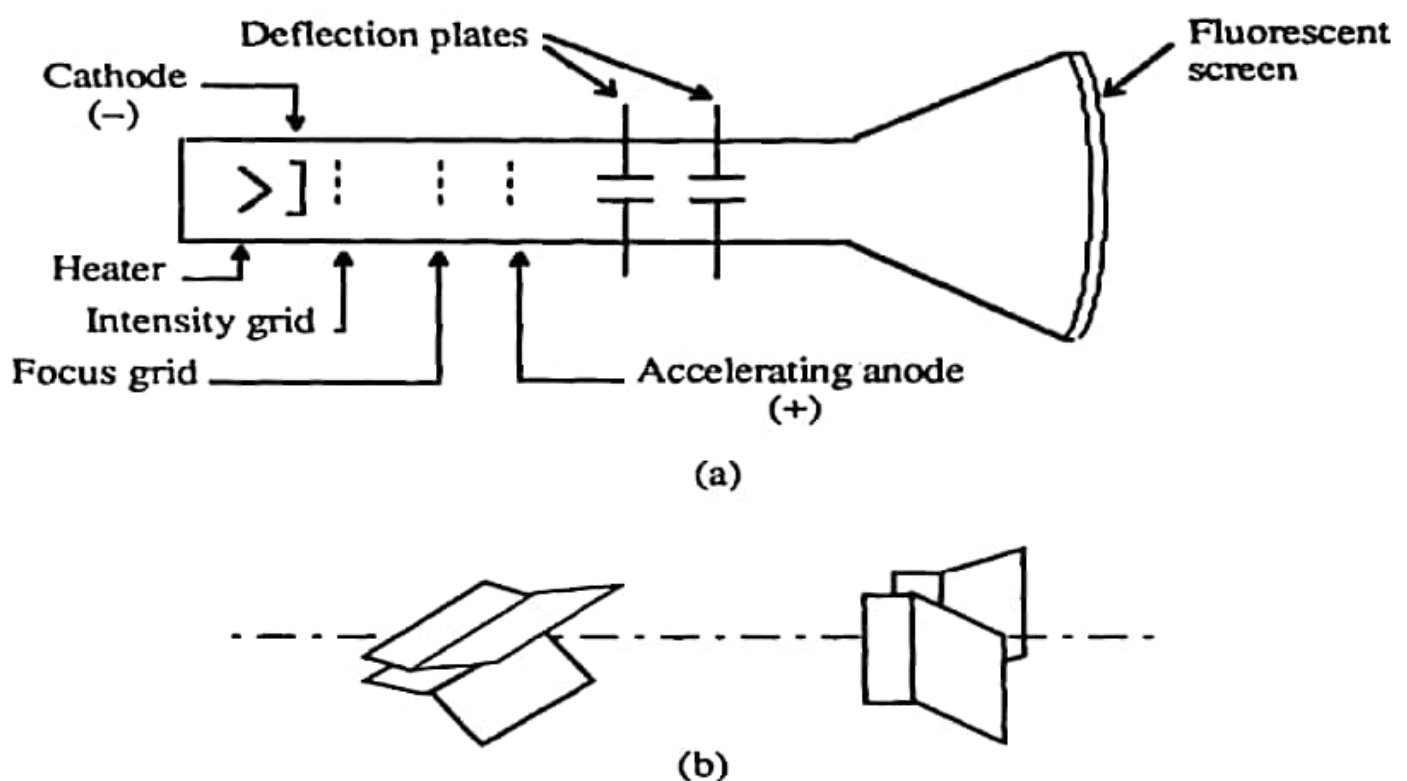


Figure 1. Cathode-ray tube: (a) schematic, (b) detail of the deflection plates.

The cathode ray is a beam of electrons which are emitted by the heated cathode (negative electrode) and accelerated toward the fluorescent screen. The assembly of the cathode, intensity grid, focus grid, and accelerating anode (positive electrode) is called an *electron gun*. Its purpose is to generate the electron beam and control its intensity and focus. Between the electron gun and the fluorescent screen are two pair of metal plates - one oriented to provide horizontal deflection of the beam and one pair

oriented to give vertical deflection to the beam. These plates are thus referred to as the *horizontal* and *vertical deflection plates*. The combination of these two deflections allows the beam to reach any portion of the fluorescent screen. Wherever the electron beam hits the screen, the phosphor is excited and light is emitted from that point. This conversion of electron energy into light allows us to write with points or lines of light on an otherwise darkened screen. In the most common use of the oscilloscope the signal to be studied is first amplified and then applied to the vertical (deflection) plates to deflect the beam vertically and at the same time a voltage that increases linearly with time is applied to the horizontal (deflection) plates thus causing the beam to be deflected horizontally at a uniform (constant) rate. The signal applied to the vertical plates is thus displayed on the screen as a function of time. The horizontal axis serves as a uniform time scale. The linear deflection or sweep of the beam horizontally is accomplished by use of a *sweep generator* that is incorporated in the oscilloscope circuitry. The voltage output of such a generator is that of a sawtooth wave as shown in Fig. 2. Application of one cycle of this voltage difference, which increases linearly with time, to the horizontal plates causes the beam to be deflected linearly with time across the tube face. When the voltage suddenly falls to zero, as at points (a) (b) (c), etc., the end of each sweep - the beam flies back to its initial position. The horizontal deflection of the beam is repeated periodically, the frequency of this periodicity is adjustable by external controls.

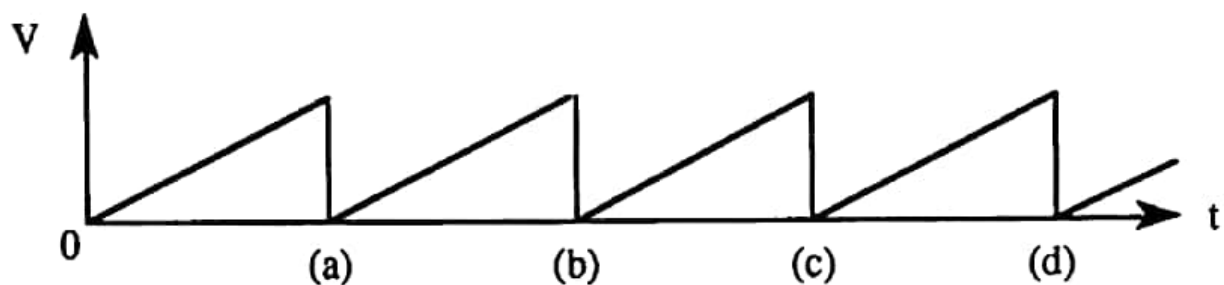


Figure. 2. Voltage difference V between horizontal plates as a function of time t .

To obtain steady traces on the tube face, an internal number of cycles of the unknown signal that is applied to the vertical plates must be associated with each cycle of the sweep generator. Thus, with such a matching of synchronization of the two deflections, the pattern on the tube face repeats itself and hence appears to remain stationary. The persistence of vision in the human eye and of the glow of the fluorescent screen aids in producing a stationary pattern. In addition, the electron beam is cut off (blanked) during fly back so that the retrace sweep is not observed.

CRO Operation: A simplified block diagram of a typical oscilloscope is shown in Fig. 3. In general, the instrument is operated in the following manner. The signal to be displayed is amplified by the vertical amplifier and applied to the vertical deflection plates of the CRT. A portion of the signal in the vertical amplifier is applied to the **sweep trigger** as a triggering signal. The sweep trigger then generates a pulse coincident with a selected point in the cycle of the triggering signal. This pulse turns on the sweep generator, initiating the sawtooth wave form. The sawtooth wave is amplified by the horizontal amplifier and applied to the horizontal deflection plates. Usually, additional provisions signal are made for applying an external triggering

signal or utilizing the 60 Hz line for triggering. Also the sweep generator may be bypassed and an external signal applied directly to the horizontal amplifier.

CRO Controls

The controls available on most oscilloscopes provide a wide range of operating conditions and thus make the instrument especially versatile. Since many of these controls are common to most oscilloscopes a brief description of them follows.

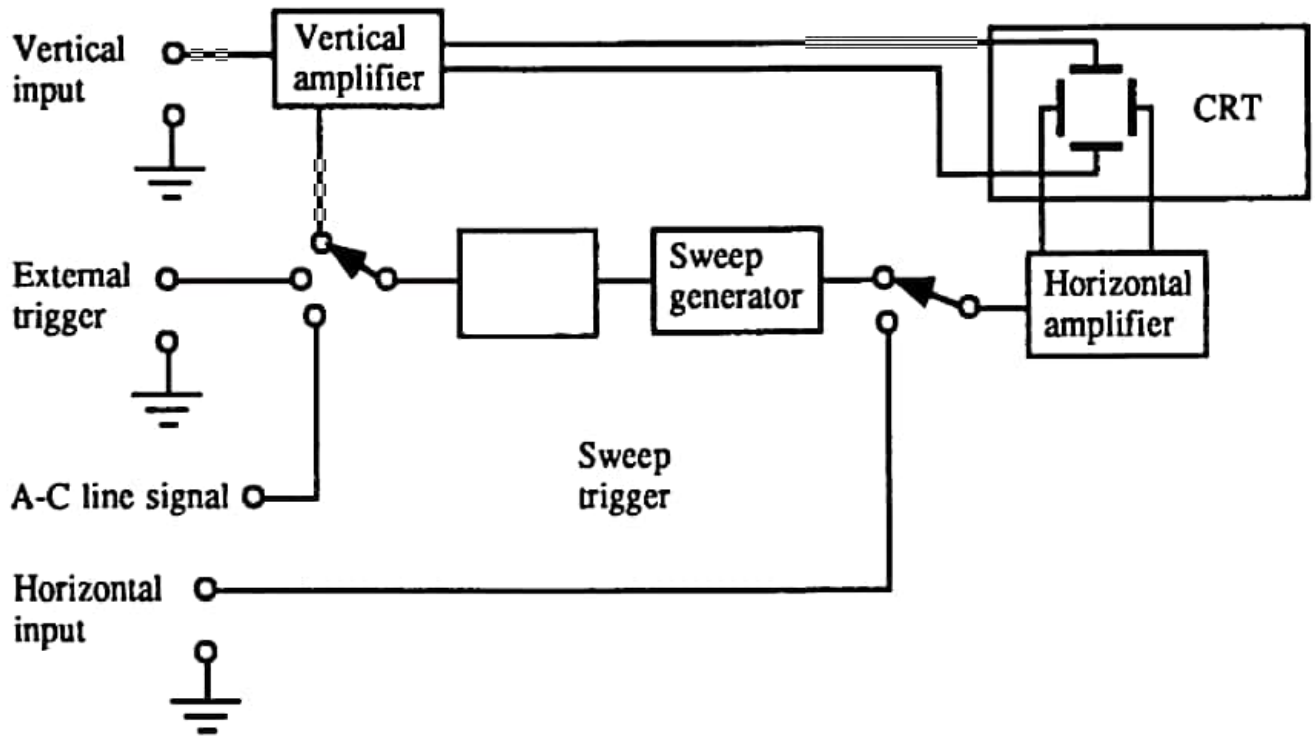


Figure 3. Block diagram of a typical oscilloscope.

CATHODE-RAY TUBE

Power and Scale Illumination: Turns instrument on and controls illumination of the graticule.

Focus: Focus the spot or trace on the screen.

Intensity: Regulates the brightness of the spot or trace.

VERTICAL AMPLIFIER SECTION

Position: Controls vertical positioning of oscilloscope display.

Sensitivity: Selects the sensitivity of the vertical amplifier in calibrated steps.

Variable Sensitivity: Provides a continuous range of sensitivities between the calibrated steps. Normally the sensitivity is calibrated only when the variable knob is in the fully clockwise position.

AC-DC-GND: Selects desired coupling (ac or dc) for incoming signal applied to vertical amplifier, or grounds the amplifier input. Selecting dc couples the input directly to the amplifier; selecting ac send the signal through a capacitor before going to the amplifier thus blocking any constant component.

HORIZONTAL-SWEEP SECTION

Sweep time/cm: Selects desired sweep rate from calibrated steps or admits external signal to horizontal amplifier.

Sweep time/cm Variable: Provides continuously variable sweep rates. Calibrated position is fully clockwise.

Position: Controls horizontal position of trace on screen.

Horizontal Variable: Controls the attenuation (reduction) of signal applied to horizontal amplifier through Ext. Horiz. Connector.

TRIGGER

The trigger selects the timing of the beginning of the horizontal sweep.

Slope: Selects whether triggering occurs on an increasing (+) or decreasing (-) portion of trigger signal.

Coupling: Selects whether triggering occurs at a specific dc or ac level.

Source: Selects the source of the triggering signal.

INT - (internal) - from signal on vertical amplifier

EXT - (external) - from an external signal inserted at the **EXT.**

TRIG. INPUT. LINE - 60 cycle trigger

Level: Selects the voltage point on the triggering signal at which sweep is triggered. It also allows automatic (auto) triggering or allows sweep to run free (free run).

CONNECTIONS FOR THE OSCILLOSCOPE

Vertical Input: A pair of jacks for connecting the signal under study to the Y (or vertical) amplifier. The lower jack is grounded to the case.

Horizontal Input: A pair of jacks for connecting an external signal to the horizontal amplifier. The lower terminal is grounded to the case of the oscilloscope.

External Trigger Input: Input connector for external trigger signal.

Cal. Out: Provides amplitude calibrated square waves of 25 and 500 millivolts for use in calibrating the gain of the amplifiers.

Accuracy of the vertical deflection is + 3%. Sensitivity is variable.

Horizontal sweep should be accurate to within 3%. Range of sweep is variable.

Operating Instructions: Before plugging the oscilloscope into a wall receptacle, set the controls as follows:

- (a) Power switch at off
- (b) Intensity fully counter clockwise
- (c) Vertical centering in the center of range
- (d) Horizontal centering in the center of range
- (e) Vertical at 0.2
- (f) Sweep times 1

Plug line cord into a standard ac wall receptacle (nominally 118 V). Turn power on. Do not advance the Intensity Control. Allow the scope to warm up for approximately two minutes, then turn the Intensity Control until the beam is visible on the screen.

PROCEDURE:

I. Set the signal generator to a frequency of 1000 cycles per second. Connect the output from the generator to the vertical input of the oscilloscope. Establish a steady trace of this input signal on the scope. Adjust (play with) *all* of the scope and signal generator controls until you become familiar with the function of each. The purpose for such "playing" is to allow the student to become so familiar with the oscilloscope that it becomes an aid (tool) in making measurements in other experiments and not as a formidable obstacle. Note: If the vertical gain is set too low, it may not be possible to obtain a steady trace.

II. Measurements of Voltage: Consider the circuit in Fig. 4(a). The signal generator is used to produce a 1000 hertz sine wave. The AC voltmeter and the leads to the vertical input of the oscilloscope are connected across the generator's output. By adjusting the Horizontal Sweep time/cm and trigger, a steady trace of the sine wave may be displayed on the screen. The trace represents a plot of voltage vs. time, where the vertical deflection of the trace about the line of symmetry CD is proportional to the magnitude of the voltage at any instant of time.

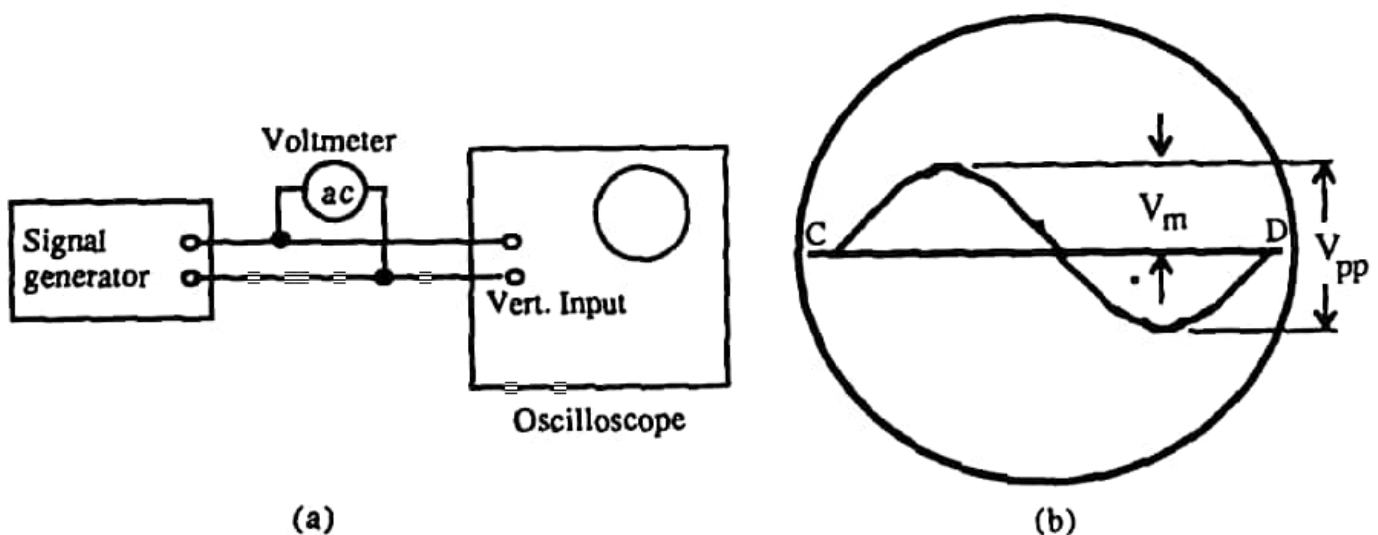


Figure 4 (a) Circuit for procedure II. (b) Trace seen on scope.

To determine the size of the voltage signal appearing at the output of terminals of the signal generator, an AC (Alternating Current) voltmeter is connected in parallel across these terminals (Fig. 4a). The AC voltmeter is designed to read the dc "effective value" of the voltage. This effective value is also known as the "Root Mean Square value" (RMS) value of the voltage. The peak or maximum voltage seen on the scope face

(Fig. 4b) is V_m volts and is represented by the distance from the symmetry line CD to the maximum deflection. The relationship between the magnitude of the peak voltage displayed on the scope and the effective or RMS voltage (V_{RMS}) read on the AC voltmeter is

$$V_{RMS} = 0.707 V_m \text{ (for a sine or cosine wave).}$$

Thus

$$V_m = \frac{V_{RMS}}{0.707}$$

Agreement is expected between the voltage reading of the multimeter and that of the oscilloscope. For a symmetric wave (sine or cosine) the value of V_m may be taken as 1/2 the peak to peak signal V_{pp}

The variable sensitivity control a signal may be used to adjust the display to fill a convenient range of the scope face. In this position, the trace is no longer calibrated so that you can not just read the size of the signal by counting the number of divisions and multiplying by the scale factor. However, you can figure out what the new calibration is and use it as long as the variable control remains unchanged.

Caution: The mathematical prescription given for RMS signals is valid only for sinusoidal signals. The meter will not indicate the correct voltage when used to measure non-sinusoidal signals.

III. Frequency Measurements: When the horizontal sweep voltage is applied, voltage measurements can still be taken from the vertical deflection. Moreover, the signal is displayed as a function of time. If the time base (i.e. sweep) is calibrated, such measurements as pulse duration or signal period can be made. *Frequencies* can then be determined as reciprocal of the periods.

Set the oscillator to 1000 Hz. Display the signal on the CRO and measure the period of the oscillations. Use the horizontal distance between two points such as C to D in Fig. 4b.

Set the horizontal gain so that only one complete wave form is displayed.

Then reset the horizontal until 5 waves are seen. Keep the time base control in a calibrated position. Measure the distance (and hence time) for 5 complete cycles and calculate the frequency from this measurement. Compare your result with the value determined above.

Repeat your measurements for other frequencies of 150 Hz, 5 kHz, 50 kHz as set on the signal generator.

IV. Lissajous Figures: When sine-wave signals of different frequencies are input to the horizontal and vertical amplifiers a stationary pattern is formed on the CRT when the ratio of the two frequencies is an integral fraction such as 1/2, 2/3, 4/3, 1/5, etc. These stationary patterns are known as *Lissajous figures* and can be used for comparison

measurement of frequencies.

Use two oscillators to generate some simple Lissajous figures like those shown in Fig. 5. You will find it difficult to maintain the Lissajous figures in a fixed configuration because the two oscillators are not phase and frequency locked. Their frequencies and phase drift slowly causing the two different signals to change slightly with respect to each other.

V. Testing what you have learned: Your instructor will provide you with a small oscillator circuit. Examine the input to the circuit and output of the circuit using your oscilloscope. Measure such quantities as the voltage and frequency of the signals. Specify if they are sinusoidal or of some other wave character. If square wave, measure the frequency of the wave. Also, for square waves, measure the on time (when the voltage is high) and off time (when it is low).

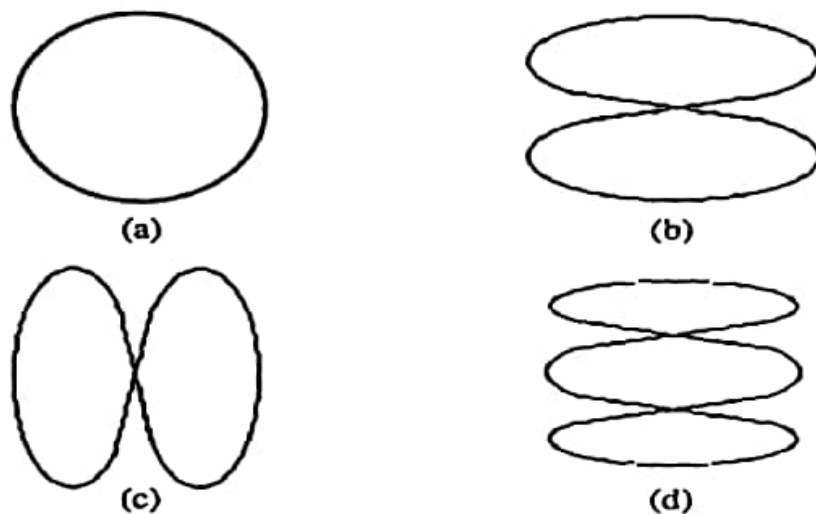


Figure 5. Lissajous figures for horizontal-to-vertical frequency ratios of: (a) 1:1, (b) 2:1, (c) 1:2, and (d) 3:1.

Result:- Study is completed

Precautions: 1. Operate cro carefully
2. Take all reading carefully
3. Use correct power supply