THE OSCILLOSCOPE

OBJECTIVE: To become familiar with the operation of an oscilloscope.

THEORY:
An O-scope is essentially a Cathode Ray Tube (CRT) combined with appropriate circuitry so that it may be used as a voltmeter. From your lab on the CRT you may remember that a voltage applied to the horizontal plates of the CRT caused a vertical deflection of the electron beam. This deflection was proportional to the applied voltage. Therefore, the CRT can be used as a voltmeter to measure an unknown voltage applied to the horizontal plates. Calibration of the instrument is achieved by a grid of lines on the screen and by amplifying or attenuating the input signal so it fits the grid on the screen properly. An oscilloscope also contains a sweep generator that produces a time-varying voltage on the vertical plates of the CRT. This causes the electron beam to sweep horizontally across the screen. If the beam sweeps across the screen fast enough the sweeping dot on the screen appears as a line. The combined effect of time-varying vertical deflection and horizontal sweep is a Voltage vs Time plot on the screen. Therefore, when you turn the knobs on the O-scope that are marked VOLTS/DIV (VERTICAL DISPLAY) and TIME/DIV (HORIZONTAL DISPLAY) this amounts to setting up the vertical (voltage), and horizontal (time) axes, just as you would do if you plotted a voltage vs time graph on graph paper. The sweep generator also synchronizes the sweep voltage with the signal voltage. It can be run in the NORMAL (TRIGGERED) or AUTO mode. In the normal (triggered) mode no sweep is produced until the signal exceeds a certain selected value, and hence "triggers" the sweep from left to right. After completion of the sweep the beam returns to the left side and waits till the next sweep is triggered. In the auto mode, the sweep runs continuously at a pre-selected rate. In this lab exercise the O-scope will be run in the AUTO mode.

We will be analyzing AC sinusoidal voltage signals in this lab. Such a voltage signal is characterized by a voltage amplitude (V_M), a peak-to-peak voltage (V_{P-P}) which is twice the amplitude, a period (T) which is the time for one complete cycle, and a frequency (f) which is the number of cycles per second measured in Hertz. Period and frequency are reciprocals of one another, i.e. $f = 1/T$. Figure 1 shows such a voltage signal versus time.

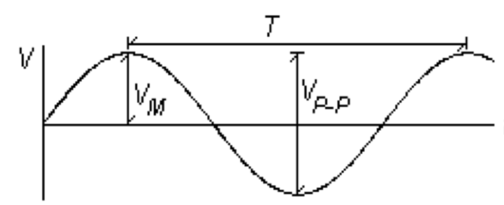

FIGURE 1

PROCEDURE:
1. Set up
Look at all the knobs and switches. There are two or three kinds of oscilloscopes, so we cannot tell you exactly where the particular knob or switch that you need will be. Please ask the instructor if you cannot find what you are looking for.
a) Set the sweep generator (Time/Division knob) to H IN or X-Y. Or push in the X-Y button.
b) Set the Volt/Division knob to 2 Volts per division.
c) Select to display ground (GND).
d) Turn on the O-scope. Focus the dot and turn the intensity down so that the dot on the screen is comfortably visible but not too bright (it may damage the screen otherwise).
e) Turn the VARIABLE knobs on the Time/Div and Volts/Div clockwise until you hear them click into position. This means that the O-scope is now calibrated.
f) Turn the POSITION knobs (VERTICAL and HORIZONTAL) to understand their function. Then adjust these controls to position the dot at the center of the screen.

2. Measurement of a DC voltage

Set up the simple circuit shown in Fig. 2 below using the PS (DC Power Supply) and the 10 Ohm resistor. Set the voltage of the PS at about 4 volts.

a) Measure the voltage across *R* using first the DMM.

b) On the O-scope, deselect GND and select DC and measure the voltage across *R*. Compare the two measured values.

c) Reverse the polarity of the voltage across *R* and observe what happens to the signal on the DMM and the O-scope.

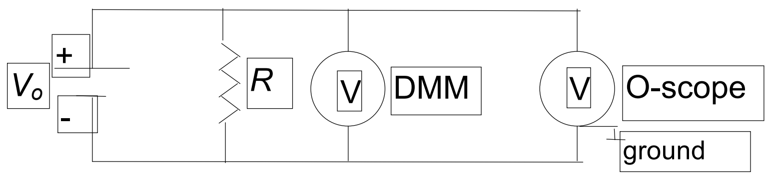

FIGURE 2

3. Measurement of an AC voltage

a) Locate the Sine-Square Wave Generator (SSG) but do not turn it on. Connect the OUTPUT terminals of the SSG to the DMM and the VOLTAGE input terminals of the O-scope as shown in Fig. 3. Make sure that the negative side of the SSG is connected to the ground terminal of the O-scope. Set the SINE/SQUARE selector switch on the SSG to SINE. Select the highest possible LEVEL range. Turn the OUTPUT VOLTAGE all the way down to zero. Using the FREQUENCY MULTIPLIER (or FREQUENCY RANGE selector) and the FREQUENCY dial, set the frequency to 100 Hz. Select AC for both the DMM and the O-scope.

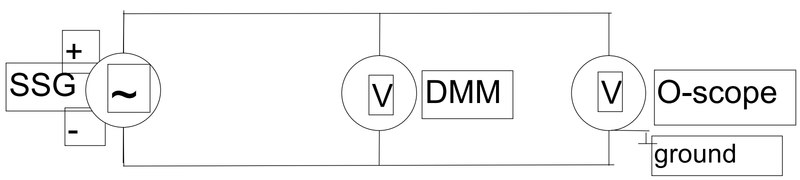

FIGURE 3

b) Now turn on the SSG and increase the OUTPUT VOLTAGE to some value. You should see a vertical line on the O-scope. Why?

c) Measure the peak to peak voltage (V_{P-P}) of the voltage signal using the O-scope. Divide this value by two to get the amplitude of the voltage (V_M).

d) Record the voltage measured by the DMM. This should be the rms voltage which is related to the voltage amplitude by $V_{rms} = V_M / \sqrt{2}$. Calculate the rms voltage and compare to the value from the DMM.

e) Now take the sweep generator off of H IN or X-Y and start to increase the Time/Div knob. You should see a sine wave signal displayed. Why? Obtain a stable sine wave with at least one period displayed. You may have to adjust the TRIGGER LEVEL to stabilized the signal.

f) Measure the period of the signal. Recall that the period is the time required for one cycle as illustrated in Fig. 1. Using this value of *T*, calculate the frequency *f* of the signal. Is this value close to 100 Hz? It may not agree exactly since the frequency knob of the SSG may not be calibrated perfectly.

g) IF TIME ALLOWS, disconnect the SSG from the circuit and replace it with the transformer. Use the two far output terminals on the transformer. Determine the rms voltage and frequency of the output voltage signal from the transformer. What should the frequency be? Is this a step-up or step-down transformer?

4. Square wave voltage applied to an RC circuit

a) Build the circuit shown in Fig. 4 below where *R* is supplied by a decade resistance box set at 1000 Ω, and *C* is supplied by a decade capacitance box set at 2 μF.

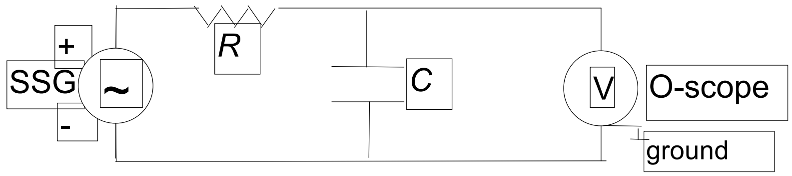

FIGURE 4

b) Set the SINE/SQUARE switch on the SSG to SQUARE, and the frequency to 100 Hz. Observe the time variation of the capacitor voltage and explain it.

c) Vary the frequency and the capacitance, and observe the effect of this on the capacitor voltage. Also, observe the effect of changing the resistance *R* on the capacitor voltage.

d) Describe how the capacitance of a capacitor could be measured using this circuit and the signal displayed on the O-scope.

5. Lissajous Figures (*IF TIME ALLOWS*)

a) Connect the sinusoidal output of the SSG to the O-scope inputs. Connect the output of the transformer to the either the H IN or X inputs OR to the other channel of the O-scope if you're using a dual channel scope. Set the TIME/DIV knob on the O-scope to H IN or X-Y or select X-Y.

b) Vary the amplitude and frequency of the SSG signal and observe the O-scope display. The figures you are generating are called "Lissajous figures". You are sending one time-varying voltage signal to the horizontal plates and the other time-varying voltage signal to the vertical plates.

c) If the two source frequencies are identical, you should get a stationary ellipse (or a circle if the two voltage amplitudes are identical). Try this.

d) What kind of figure will you get if one frequency is twice the other frequency? ...three times the other frequency? ...one and a half times the other frequency?