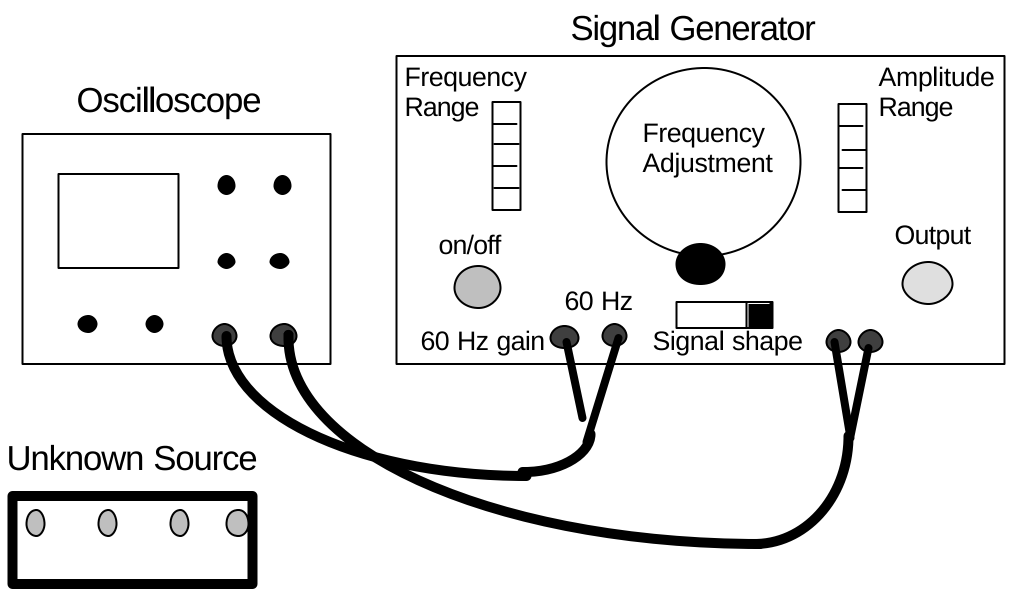
THE OSCILLOSCOPE

OBJECTIVES:

1) Explain the operation or effect of each control on a simple oscilloscope.
2) Display an unknown sinusoidal electrical signal on an oscilloscope and measure its amplitude and frequency.
3) Display a non-sinusoidal periodic electrical signal on an oscilloscope and sketch its time dependence.

APPARATUS:

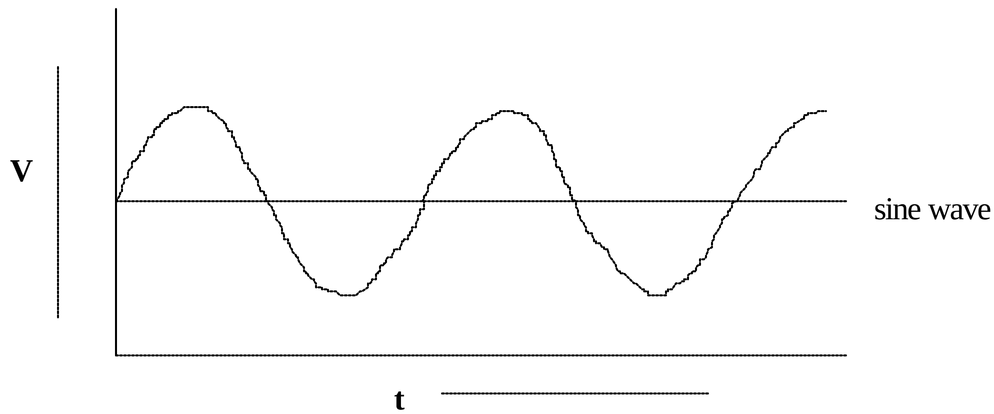


INTRODUCTION

To measure an electrical voltage you would use a voltmeter. But what happens if the electrical voltage you want to measure is varying rapidly in time? The voltmeter display may oscillate rapidly preventing you making a good reading, or it may display some average of the time varying voltage. In this case, an oscilloscope can be used to observe, and measure, the entire time-varying voltage, or "signal". The oscilloscope places an image of the time-varying signal on the screen of a cathode ray tube (CRT) allowing us to observe the shape of the signal and measure the voltage at different times. If the signal is periodic (it repeats itself over and over) as is often the case, we can also measure the frequency, the rate of repeating, of the signal.

What the Oscilloscope Does

The oscilloscope plots voltage as a function of time.



The voltage is on the vertical (y) axis and the time is on the horizontal (x) axis. A constant voltage shows up as a flat horizontal line. The scope has controls to make the x and y scales larger or smaller, similar to the scale selections on the digital voltmeter. These act like the controls for magnification on a microscope. They don't change the actual voltage any more than magnification makes a cell bigger; they just let us see small details more easily.

There are also controls to shift the center points of the voltage scales. These "offset" knobs are like the controls to move the stage of the microscope to look at different parts of a sample. You will learn about other adjustments in the course of the lab.

THE OSCILLOSCOPE EXPERIMENT

In this experiment you will familiarize yourself with the use of an oscilloscope. Using a Signal Generator you will produce various time varying voltages (Signals) which you will input into the oscilloscope for analysis. There are two main measurements that characterize any periodic AC signal. The first is the peak-to-peak voltage (V_{pp}), which is defined as the variation in voltage between the lowest and the highest voltages of the time-varying signal (see figure 2). The second is the frequency of the time-varying signal (f), defined by

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

where f is the frequency in Hz and T is the period in seconds.

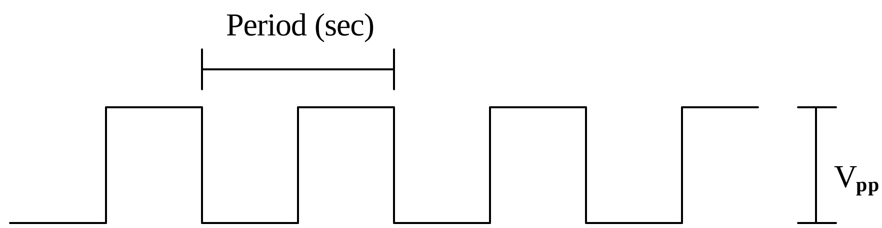
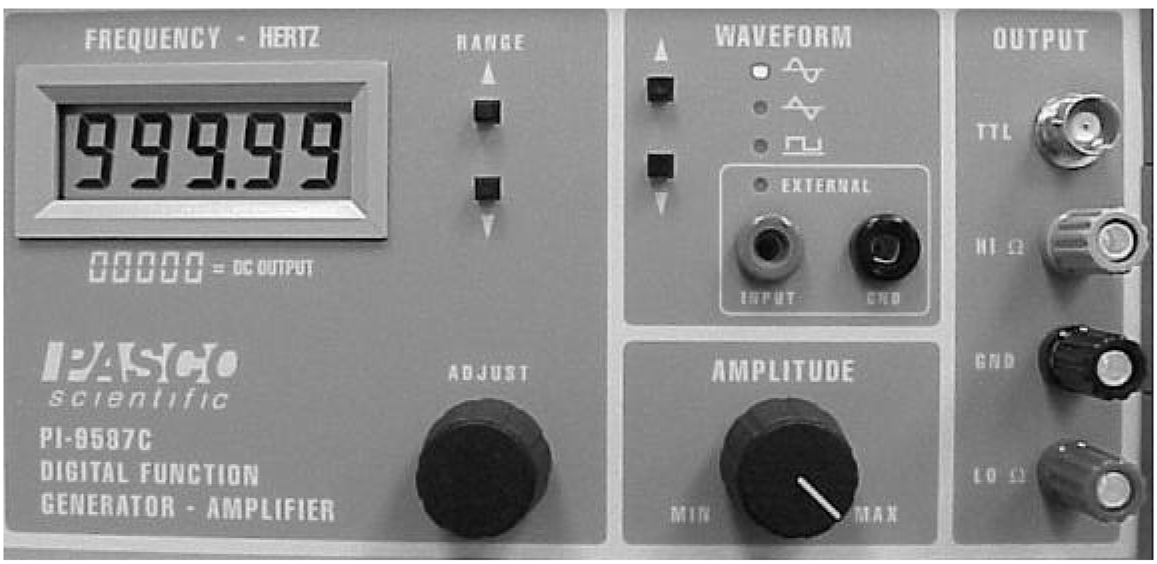


Figure 2

AC (derived from ALTERNATING CURRENT) indicates a voltage, the magnitude of which varies as a function of time. In contrast, DC (derived from DIRECT CURRENT) indicates a voltage whose magnitude is constant in time.

In order to investigate how the oscilloscope works, we will need to give it an input signal of some kind. To accomplish this, we will be using a signal generator like the one pictured below.



Pasco Signal Generator

It is important to understand the function of all of the dials and switches on the signal generator. The digital read out (upper left) displays the frequency that the signal generator is currently set to. This readout is in Hertz (Hz). The RANGE buttons (immediately next to this display) will move the decimal in the read out left or right. This means that by pressing the button once, we can change the frequency by a factor of ten. In the example pictured, one press of the button would change the frequency from over 999 Hz to over 9,999 HZ or over 99 Hz, depending on which direction we move the decimal. This will allow us to generate a large number of different frequencies quickly and easily. This only moves the decimal, it does not change the numbers that are displayed. If we wish to make a different numerical value, we need to turn the knob immediately below that, marked ADJUST. This adjustment works in a rather unique way. If the knob is turned *quickly* the numbers change quickly. If we turn the knob *slowly*, the digits change slowly. So, with our frequency set at 999.99 Hz, as in the example above, if we wish to set it to 999.48 Hz, we could turn the know slowly. If we wanted to set it to a 188.34 Hz, we could turn the knob the same amount, but just turn faster and the digits change faster. It may seem a little bit awkward at first, but it gives us access to a large range of frequencies very accurately.

In the middle of the signal generator, at the top is a setting labeled WAVEFORM. By changing this setting, we can create smooth sine curves, square waves or triangular waves. The led will light up next to the type of wave selected.

Below that is a knob labeled AMPLITUDE. By rotating this knob, we can change the amplitude or height of our wave. This amplitude will be measured using the oscilloscope.

On the far right hand side is where we connect the cables to take the signal to the oscilloscope or circuit that we happen to be using. We will use the two pegs at the bottom (the red and black ones) to connect banana plugs to a cable that has a BNC connector on the other end (the BNC connector is the round metal one that will connect to the "input" on the oscilloscope, see page 7).

How the Oscilloscope Works

An oscilloscope contains a cathode ray tube (CRT), in which the deflection of an electron beam that falls onto a phosphor screen is directly proportional to the voltage applied across a pair of parallel deflection plates. A measurement of this deflection yields a measurement of the applied voltage. The oscilloscope can be used to measure and display rapidly varying electrical phenomena. The oscilloscope is made up of the five subsystems shown in Fig. 3:

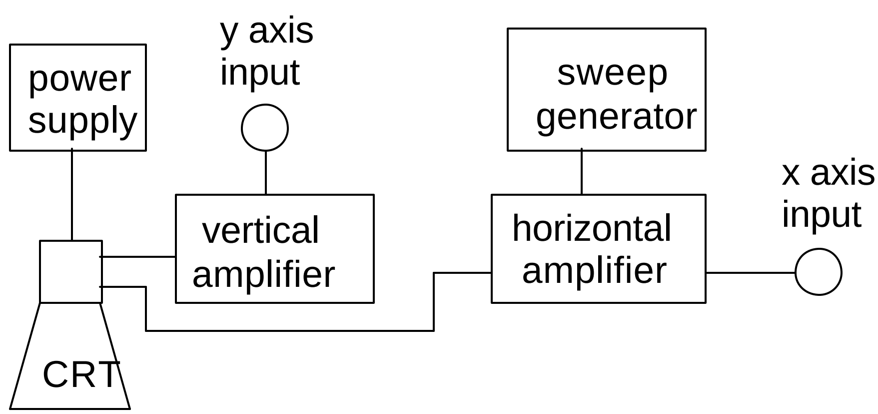


Figure 3

A CRT containing an electron gun, deflection plates and an image screen is shown in fig.4.

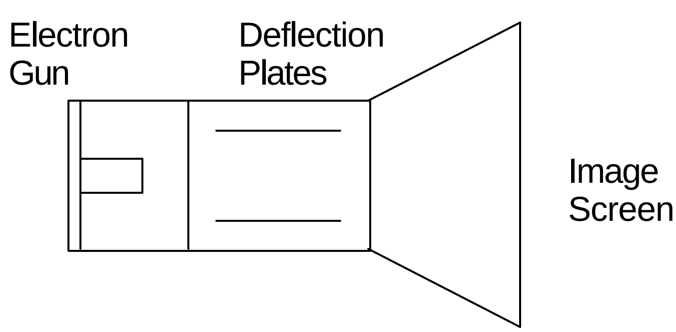


Figure 4

A vertical amplifier is connected to the y-axis plates. It serves to amplify the input signal to the y-plates so that the CRT can show an appreciable vertical displacement for a small input voltage. The horizontal amplifier serves the same purpose for the x-plates and the horizontal display. A sweep generator is used to make the beam move in the x-direction with a constant (but adjustable) speed. This allows the oscilloscope to display the y-input signal as a function of time.

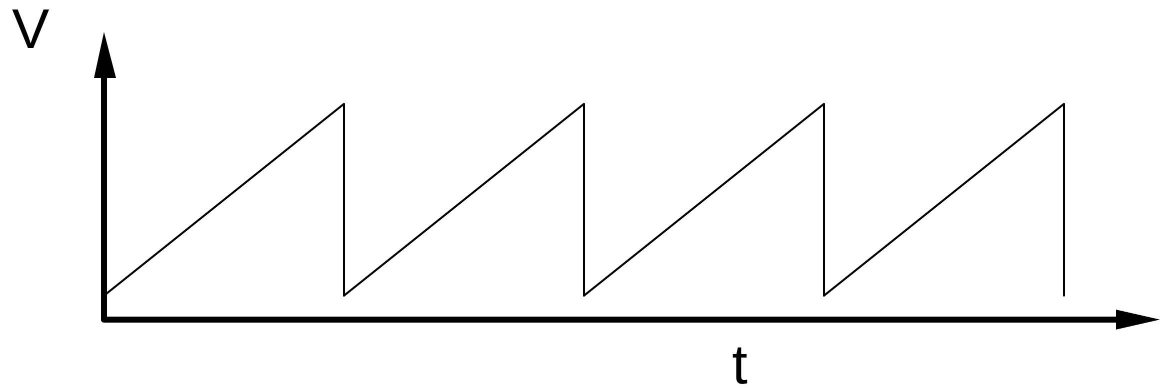


Figure 5

The sweep generator functions as follows. Whenever a periodic, time-varying signal is supplied to the x-plates, the charge on the plate's changes with time, which in turn changes the electric field between the plates. The result is that the beam is swept back and forth at the frequency of this time-varying signal. Because both the screen phosphor and the eye retina have some finite retention time, the moving spot looks like a line at frequencies over about 15 Hz. The sweep generator actually supplies a voltage form called a ramp signal (fig. 5) to the x-axis plates. The voltage first increases linearly in time and then drops to zero very quickly. During the voltage rise, the trace moves to the right at a constant rate. During the drop the beam spot is abruptly restored to its original position. The rate at which the beam sweeps across the screen can be selected by the time base selector knob and is calibrated in time/cm.

Partners ______________________ Name_____________________

______________________ Section___________________

It is extremely important that you learn how to operate the oscilloscope since it will be used extensively in three other experiments this semester!

NOTE: 1 millisecond = 1 ms = 1 x 10^{-3} sec
1 microsecond = 1 ? s = 1 x 10^{-6} sec
1 millivolt = 1 mV = 1 x 10^{-3} volts
1 microvolt = 1 ? V = 1 x 10^{-6} volts

PROCEDURE:

1. **Returning the Phillips PM3335 Oscilloscope to Mid-Range or Nominal Conditions.**
   a) First disconnect all input cables to your oscilloscope except the rear power cable.

   b) Find the following controls and set their nominal values:
   (In the following, LCD refers to the Liquid Crystal Display screen to the right of the main screen.)

Control	Setting	Notes
INPUTS	DISCONNECTED	
POWER	ON	(switch in, LCD light on)
INTENS(ITY)	MID-RANGE	
FOCUS	MID-RANGE	
ILLUM(INATION)	OFF	(knob fully anti clockwise)
DIGITAL MEMORY	ON	(check LCD for "Digital Memory")
Y-POS(ITION)	MID-RANGE	(both knobs: A and B channels)
X-POS(ITION)	MID-RANGE	
VAR(IABLE)	**CAL**	**(fully clockwise, all three knobs)**
HOLD OFF	MIN(IMUM)	(fully clockwise)
TRIG(GER) LEVEL	MID-RANGE	
LOCK	OFF	(button, check LCD for no "Locked")

   c) Now press the AUTO SET button. This will automatically reset the internal electronics of the oscilloscope to reasonable nominal settings. Your oscilloscope should now display a horizontal line across the screen. If not, go back and recheck that each control is in the nominal position. If the horizontal line still does not appear ask your instructor for help. If you ever get lost later in the lab, you can return to the nominal settings. (The AUTO SET button does not necessarily give you the *best* configuration for your particular measurement, it gives *nominal* settings which are a good starting point. You will then use manual adjustments to customize the setup.)

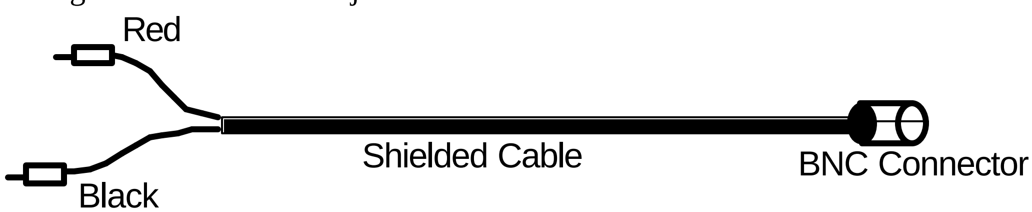
2. Adjustments

a) Adjust the FOCUS and INTENSITY controls for a sharp and reasonably bright line.
b) Rotate the Y POS knob associated with the A-Channel (top knob) and move the horizontal line up and down on the screen. Set the line in the middle of the screen.
c) Set the display to Channel B: keep pressing the A/B button until you see "B" (and no "A") indicated on the LCD. You can now adjust the Y POS knob of the B-Channel. Set the line in the middle of the screen.
d) Set the display to both Channel A and B simultaneously: "A" and "B" indicated on the LCD.
e) Rotate the Y POS knobs for both channels A and B. Notice that the signal moves up and down on the screen and note the independence of the two controls. Reset both to the center of the screen and then set the display for Channel A only.

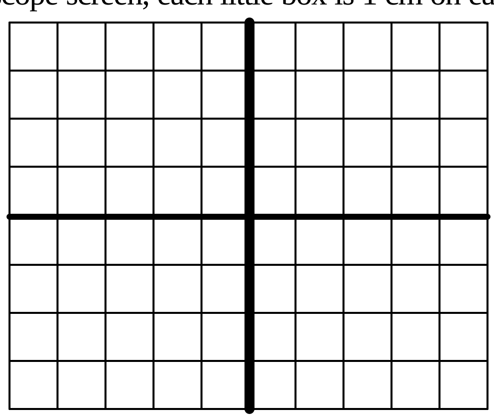
3. View the input signal from the signal generator (set to 60Hz)

The Signal Generator produces a "Signal" which is simply an electrical voltage which varies over time. We will be using sine-wave signals in this lab, i.e., the voltage varies in time like a sine-wave, oscillating between a positive and a negative voltage with some frequency. The "output" signal from the generator becomes the "input" signal to the oscilloscope when the cable is connected.

a) Attach the output of the SIGNAL GENERATOR to the channel A input of the oscilloscope using a cable with "banana jacks" on one end and a "BNC Connector" on the other end:



b) Turn the SIGNAL GENERATOR on using the switch on the back of the unit. Set it to 60Hz. Press the AUTO SET button on the oscilloscope.
c) Sketch the signal you see on the screen. Label what both the horizontal and vertical axis represent.
(On the oscilloscope screen, each little box is 1 cm on each side.)



d) Rotate the X POS control and observe its effects. Position the 60 Hz signal so that the left most edge of the trace begins at the left edge of the screen.

Q: What is the effect of the HORIZONTAL POSITION control on the trace?

4. Digital vs. Analog

This oscilloscope can be operated in "digital" or "analog" mode. Pressing the DIGITAL MEMORY button toggles it between digital and analog modes. In analog mode the trace on the screen comes directly from the input voltage (after some amplification/de amplification). The *voltage* of the input signal is given by the *vertical* displacement of the trace on the screen. To measure the voltage in analog mode you have to know the sensitivity of the scope setting (set by the raising-lowering switch marked "A") and measure the height of the trace on the screen. The voltage is then given by V (Volts) = Sensitivity (Volts/cm) x Height (cm). The wonders of modern science have made it a bit easier for you though. In *digital* mode the oscilloscope automatically "digitizes" the input voltage: it quickly (up to 40 million times per second) reads the input signal and stores the value, in Volts, in its electronic memory. The contents of the memory are then displayed on the screen (only at 100,000 times per second or less though). To read the voltage of your input signal you simply have to read off the value from the screen using some screen cursors. This will be described later.

a) Place it in analog mode (check "DIGITAL MEMORY" is gone from the LCD).

Q: How does the trace change on going from digital to analog?

b) During the next part, it is easiest to leave it in analog mode.

5. Signal Triggering (Digital mode **off**)

The trigger is the starting gun for the trace: the trace on the screen only begins when the oscilloscope detects a trigger signal. On the P-P setting the trigger is a "threshold voltage" from the input signal. When the input signal exceeds this voltage the starting gun fires.

a) Check that you can see "P-P" on the LCD screen. If you can't, push the TRIG COUPL button a few times until you can see it. With the left-hand end of the trace in sight, Rotate the TRIG(GER) LEVEL control slowly in each direction and observe its effects on the vertical starting point of the signal.

Q: How does the starting voltage of the trace change when you move the TRIG LEVEL knob? (Hint: Move the trace slightly to the right using the X-POS knob. Stare at just the beginning part of the signal.)

b) Place the trigger setting on DC by pressing the TRIG COUPL button a few times until you see DC on the LCD. ("DC" should appear close to the position where "P-P" was previously). Rotate the TRIG(GER) LEVEL knob all the way to the right.

Q: What happens when the TRIG LEVEL knob is rotated all the way to the right on the "DC" setting?

Q: Why do we need a trigger? What would the screen trace look like if there was no trigger and the trace could start at any time?

c) Slowly rotate the TRIG LEVEL knob back until the trace just becomes stable (visible and not "rolling" left or right).

Q: What is the threshold voltage (vertical position of the start of the trace) compared to the peak voltage of your signal?

Q: Why did the trace become unstable when you rotated the TRIG LEVEL knob further to the right?

d) Set the TRIG COUPL button back to P-P and adjust the TRIG LEVEL knob so that the signal starts on the horizontal axis. The vertical position should still be in adjustment, if not, re-adjust it using Y POS. Move the trace back to the left using the X-POS knob. [**Hint for the future**: If you have trouble triggering on a signal, try using a higher voltage sensitivity (smaller V/cm).]

6. Peak-to-Peak Voltage Measurement (Turn the digital memory back **on)**

a) Press AUTO SET. Make sure the A-Channel sensitivity is set at 1V (check the LCD). If not, adjust it to 1V using the raising-lowering switch marked "A" on the oscilloscope. Adjust the amplitude of the input signal from the signal generator, using the AMPLITUDE knob at lower left of the signal generator, until the trace is 4 cm from top to bottom.

b) Inspect the main screen. If there is no writing at the bottom of the screen, press one of the blue keys below the screen (these are called the "soft-keys") to make the writing appear. If there is some writing and one of the soft-keys has RETURN written above it, keep pressing it until it no longer says RETURN above it. This means that you were at a lower menu level and we want to start at the highest level.

You should see:

CURSORS SETTINGS TEXT OFF

c) We will use these soft-keys to move screen cursors to read off voltages from the screen. Press the CURSORS soft-key. Press MODE to set up the cursors we want. Toggle the V-CURS and T-CURS soft-keys until the horizontal cursor lines are on and the vertical cursor lines are off. Press RETURN.

d) Press V-CTL to control the Voltage, cursors. The V cursors measure voltage, which is displayed as the vertical (y) axis on the screen. They appear as horizontal lines on the screen, representing a constant voltage level. Move the top one down to the peak positive voltage of your signal, and move the bottom one up to the peak negative voltage. The value of the Peak-to-Peak voltage, Vpp, is displayed at the top of the screen. Record the voltage.

V_{pp} for the calibration signal = __________±__________V

Uncertainty estimation: use 2 clicks, or two linewidths, or remeasure a few times.

e) Using the sensitivity adjustment, you can change the height of the trace on the screen without changing the actual input voltage. Change the volts/cm sensitivity of the oscilloscope screen to "2 V" using the raising-lowering button marked "A". ***Remember to reset the cursor!*** Readjust the cursors whenever you change the sensitivity or time base and whenever you start looking at a new input signal or the cursors will not match the features you are trying to measure. Notice the change in the height of the signal. You can estimate the height of the signal both before and after the change by counting the little boxes which are each 1 cm square.

Q: What is the result of changing the sensitivity of the meter from the 1V/division setting to the 2V/division setting?

Change in the height of the signal = ______________________

New V_{pp} reading from the cursors = __________±__________V

Q: Did the peak-to-peak voltage change when you changed the oscilloscope from the 1V setting to the 2V setting?

Q: What would you have to do to change the input voltage?

Q: When you use this instrument to measure an unknown voltage, how would you decide which setting (for voltage and time base) to use? How could you optimize the setting of the oscilloscope to obtain the most accurate measurement? (Hint: Compare the error in the voltage readings in the present and previous sensitivity settings.)

f) The VAR knob varies the sensitivity in a continuous way, which cannot be interpreted by the electronics. Move the channel A VAR knob away from the full-right CAL position.

Q: How does the trace on the screen change when you move the VAR knob away from the CAL position?

Q: What does the voltage readout at the top of the screen say when the scope is in this condition?

Q: What does the voltage sensitivity on the LCD say?

Q: Can this setting be used to measure volts accurately? Why?

g) Return the sensitivity of the A-Channel back to 1 V/cm. **Make sure you return the VAR knob fully back to the CAL position**.

7. Frequency Measurement:

Next, we wish to determine how rapidly the signal is varying in time. Time is measured as a horizontal distance on the screen. The sine-wave signal is cyclic: it repeats itself. <u>The time it takes to make one cycle is called the period of the signal</u>. It has units of seconds. The inverse of this quantity is the fequency. Whereas the period is the number of seconds per cycle, the frequency is the number of cycles per second (units of 1/seconds). The unit of frequency is Hertz (Hz). One Hertz equals one cycle per second.

Frequency (Hz) = 1/Period (sec.)

a) To measure time we need the T-cursors (T stands for time). Time is displayed as the x-axis on the screen, so a constant time is marked by the T cursor as a vertical line. Return to the top-level menu using the RETURN soft-key. Press MODE and toggle the T-CURSOR to *on*. Hit RETURN, then hit T-CTL to move the time-cursors to the left and right. The length of the cycle can be measured by positioning the T-cursors on equivalent points on the trace, for example, on two adjacent peaks or two adjacent valleys. The period and the frequency can both be read off from the top of the screen.

Frequency = ________________

Period = ____________________

b) You can change the *time* sensitivity of the oscilloscope by varying the raising-lowering button labeled TB (stands for "Time base"). The Time Base is sensitivity in Time/Division shown on the screen. Record, then change, the time base; *readjust* the T cursor position so they again mark one cycle of the signal.

Old Time Base: _________________ New Time Base: _________________

Frequency = ___________________

Period = ______________________

Q: What is changed when the Time Base is put on a different setting?

Q: Does changing the Time Base setting change the Period of the signal?

8. The Signal Generator

Next, we wish to view other periodic signals by connecting the signal generator to the oscilloscope. The signal generator produces voltage signals of different frequencies and peak-to-peak voltages. In order to use the signal generator effectively, we will first have to learn something about its operation. Set the knobs on the signal generator initially as indicated below:

FREQUENCY = 60.000
WAVEFORM = smooth sine wave
AMPLITUDE = Approximately the Middle

a) Set Channel A to the correct sensitivity and time base, on the scope, so that you see a sinusoidal signal taking up most of the screen.

Q: What happens to the trace shape, size, or frequency when the frequency ADJUST is changed?

Sketch the trace before and after the Frequency Selector dial is moved. These need not be exact representations and you may change the scale (time base and voltage sensitivity) if you are unable to reasonable sketch the trace.

BEFORE: AFTER:

Volt/Div:___________ Volt/Div:__________

Time/Div:___________ Time/Div:__________

Q: What happens to the trace when the RANGE setting is changed?

Sketch the trace before and after you changed the RANGE setting.

BEFORE: AFTER:

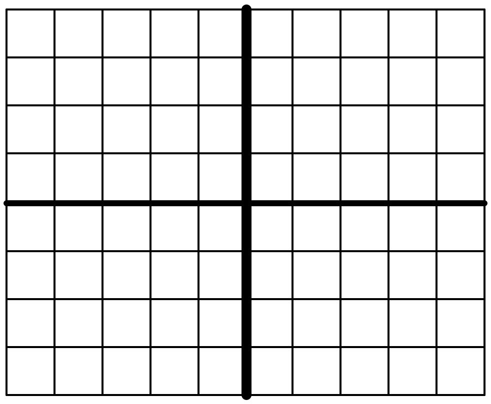
Volt/Div:___________ Volt/Div:__________

Time/Div:___________ Time/Div:__________

Q: What happens (to the signal shape, amplitude or frequency) to the trace when the AMPLITUDE knob is moved?

Sketch the trace before and after the AMPLITUDE knob is moved.

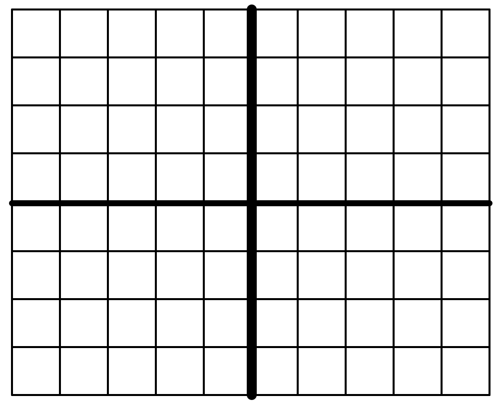
BEFORE:



Volt/Div:___________

Time/Div:___________

AFTER:



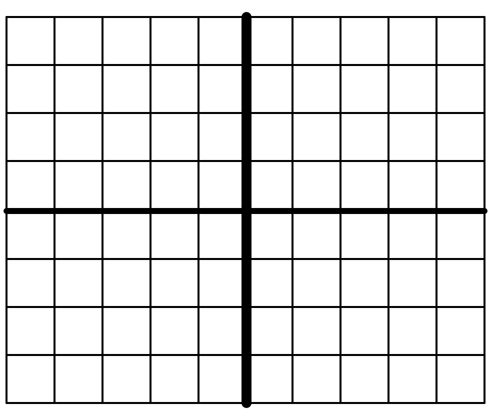
Volt/Div:__________

Time/Div:__________

Q: What happens to the trace when the WAVEFORM setting is changed?

Sketch the trace before and after the WAVEFORM setting is changed.

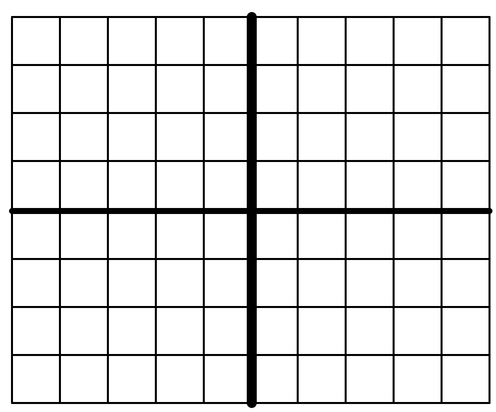
BEFORE:



Volt/Div:___________

Time/Div:___________

AFTER:



Volt/Div:__________

Time/Div:__________

b) Indicate the function of each knob on the signal generator.

ADJUST dial:

RANGE setting:

AMPLITUDE knob:

WAVEFORM setting:

9. Measurement of Signal Generator Signals:

Obtain a sinusoidal signal from the signal generator and display it on the scope. Set the frequency of the signal to the first value given in the table below. Calculate the frequency and the peak-to-peak voltage for each signal, using the oscilloscope. The results that you obtain on the scope may be more accurate since this is the actual signal that is being produced rather than the signal that we hope is being produced. Compare your results with the dial setting on the generator. Complete the measurements for the four frequencies in the table and comment on your results.

Frequency on Dial (Hz)	Vpp (Volts)	Period (Sec.)	Measured Frequency (Hz)
75			
2000			
8000			
25000			

Q: What is the percent difference in the output frequency of the signal generator for the selected frequencies of 25,000 Hz and 75 Hz? Show your calculations. (See page 10 of the Introduction if you need to.)

% for 25,000 Hz = __________%

% for 75 Hz = ______________%

10. Measurement of an Unknown Sinusoidal Signal:

Measure the frequency and V_{pp} for the mystery signal from the white box. Here you will connect the output of on unknown box directly to the oscilloscope. You will not need the signal generator. Be sure to turn on the power supply connected to the unknown box.

White Box I.D. = ___________

V_{pp} = _______________±____________ Volts

Frequency = ___________±___________ Hz