

EXPERIMENT 4: INTRODUCTION TO OSCILLOSCOPE

The oscilloscope is one of the most useful electronic test instruments, useful in a variety of physics, engineering and science applications. A variety of data, electronic or mechanical, may be displayed as a function of time, or plotted vs other variables.

ADVANCE STUDY ASSIGNMENT

1. If a linearly increasing voltage (say from 0 to 5.0 V) is applied to the horizontal deflection plates, and repeated at a frequency of 2 Hz (2 times a second), describe the appearance of the beam on the face of the CRT, assuming no voltage is applied to the vertical plates.
2. If now a sinusoidally varying voltage ($V = V_m \sin \omega t$; recall $x = x_m \sin \omega t$ in description of simple harmonic motion in Chapter 14) is applied to the vertical deflection plates, at the same time as the horizontal plates have a linearly varying voltage applied, describe what you would see.

BACKGROUND

The basis of the oscilloscope is a CRT such as we used in a recent experiment, with horizontal and vertical deflection plates, to which are applied voltages relating to quantities of interest. In addition to the connections for supply and deflection voltages a typical oscilloscope has controls to change the frequency and magnitude of deflections displayed, controls to manipulate the position of the beam, sometimes to display more than one trace and other controls to make the device more useful. Originally, oscilloscopes were dedicated devices. Now, as in our lab, it is common to use a computer with an interface box to serve as an oscilloscope. The computer monitor takes the place of the CRT and a software program simulates or reproduces all the controls of the oscilloscope.

In addition to the exercises prescribed in the procedures below, you should practice until you feel comfortable with the various controls of the oscilloscope.

PROCEDURE A

1. As usual, be sure to turn on the Pasco interface box before turning on the computer. Then, double-click on Data Studio. Plug in the Voltage Sensor to Channel A. On Data Studio, select and double-click on Voltage Sensor (for Analog Channel A in Experiment Setup window). Drag the icon for Oscilloscope (or “Scope”, in Display window) onto the words Voltage Sensor under Analog Channel A in Experiment Setup window.
2. For the first use of the oscilloscope, you are to use an old Signal Generator, SG (a beige box with green front, which the Power Amplifier now replaces for most purposes, as the computer does the old oscilloscopes). Turn the SG on, and wait for it to warm up (it uses vacuum tubes which take several minutes to warm up.)
3. Either turn the SG controls to Sine Wave, or plug into the Sine Wave output of the SG. Dial the output to the middle of the range options available, and set the frequency to 250 HZ. Note that there may be more than one scale, depending on the frequency range you select. Be sure to read the correct scale.
4. Connect the voltage sensor to the output of the SG, observing the proper polarity (+ to +, - to -).

5. Click Start on the Data Studio window, and note the appearance of the oscilloscope window. Compare this with your prediction in ASA 2. Try adjusting the output of the SG (both frequency and amplitude), and observe what effect this has on the display. It may be the display is too big or too small to be seen conveniently. Try clicking on the black arrows on the oscilloscope window to the right of the graph-like scope display. These two up or down arrows change the scale of the oscilloscope as it displays voltage. The default setting is 1V/div, and you can adjust between a range of 0.001 V/div to 5.0 V/div. Observe the appearance of the trace on the oscilloscope as you step through the range of available settings. By this means, you can display very small to moderately large voltages on the oscilloscope.
6. Now look at the arrows and numbers immediately below the graph-like scope display. The two buttons change the display from 1000 ms/div (or 1 s/div) to 0.02 ms/div. Observe the effect on the display as you step through the range here. Select a value so that you have two or three complete sine waves displayed. Because the signal generators are old, the display may be unstable.
7. Experiment with the buttons at the top of the Scope display window. In particular, note the single trace button (the one with the red number 1), which is useful for stopping the display. Click start button again after turning the single trace off to reactivate the scope window. The first button on the oscilloscope window is called the smart tool (it looks like an x-y graph with red letters xy) and is useful for reading values on the oscilloscope. Use the mouse (and the hand cursor) to move the dotted axes. Note you can move the whole axis system or only the x-axis or only the y-axis, depending where you click the hand cursor. For accurate readings, it may be most useful to move only the x- or y- axis, rather than move both. Note also that the x-axis values (which are actually time values) are only positive – that is, the 0 point is at the left end, not in the center as we might expect.
8. Adjust the SG to maximum output (without distorting the sine wave), and adjust the vertical display of the oscilloscope so the sine wave is filling as much of the vertical display as possible. Adjust the horizontal display so you have two or three complete sine waves displayed. Read the maximum and minimum (negative maximum) voltages of the display twice, once by reading blocks on the oscilloscope window, and once by using the smart tool. Record both sets of readings on Data Table A. Record both the number of divisions and the corresponding voltage for the first set of readings (e.g., if the top of the sine wave is exactly half way between the third and the fourth block you would record 3.5 div; if the scale is 2.0 V/div, you would record the voltage as 7.0 V. Note the proper use of significant figures for the second set of readings. The six significant figures the smart tool may give you are not all really significant.)
9. Now record the time of the positive maximum of the first sine wave on your display, again by two methods: by reading blocks with the correct division scale, and by using the smart tool. Again record on Data Table A, and record both blocks and corresponding time for the first method. Record also the divisions and time of the next maximum. Now find the difference. The time difference is the period of the sine wave. Record T in Data Table A.
10. Now calculate the frequency of the sine wave, using the smart tool data, as the reciprocal of the period, T. Compare with the frequency the SG is set to, and calculate the percent difference. Note that this illustrates one important ability of the oscilloscope, to find the (possibly unknown) frequency of a repetitive phenomenon.
11. Next notice the small arrows, with a single digit between them, labeled offset, for vertical display. Click these, and notice the effect on the display, to move the signal up or down. Generally, this is kept at 0, but occasionally, we may want to adjust the position of a display.

PROCEDURE B

12. Now add a second Voltage Sensor to Channel B, both physically and on the Data Studio Window. Also plug in the Power Amplifier to Channel C, and select and click on the power amplifier icon on the sensor window of the Experiment Setup window. It may be useful to move the Signal Generator window, which controls the Power Amplifier, to a lower portion of the Data Studio window, so it does not become hidden under another window.
13. Set the Power Amplifier frequency to 125 Hz and output voltage (also called amplitude) to 3.0 V using the Power Amplifier (also called Signal Generator) window. These settings are made by clicking on the + or – buttons below the amplitude and frequency windows on the SG window. You can also highlight the values with the mouse and type over them. You can also use the arrows to change the step value when you use the + and – buttons. Practice with all of these controls. Be sure the waveform is set to sine wave.
14. Connect the Channel B Voltage Sensor to the Power Amplifier. Turn the Power Amplifier on, both on the back of the box, and with the button on the SG window on Data Studio. Drag the icon for Scope onto the words “voltage sensor” for Channel B, and observe the oscilloscope display, after clicking start. Change the frequency, amplitude and wave type, and observe the change on the display.
15. Now set the frequency of the Power Amplifier to 250 Hz. Repeat Procedure 10, recording results in Data Table B. Comment on differences between accuracy of the two data table readings for frequencies below Data Table B. Is there a significant difference, and if so, why?
16. Next we want to use the oscilloscope in x-y mode, which means eliminating the time on the horizontal input, and applying voltages to both the horizontal and vertical inputs. To do this, click on and drag the “Voltage, Ch A” words (in the Data window at the left of the Data Studio window) onto the time display at the bottom of “Scope 2”. You should then see “Voltage, Ch A” as the horizontal axis of the oscilloscope, and “Voltage, Ch B” as the vertical axis. Observe the trace on the oscilloscope when you click Start. If the trace is moving, try adjusting the frequency of the Power Amplifier in 0.1 V steps, to see if you can stop the motion. Once the motion has stopped, or nearly stopped, draw the shape of the trace in the space provided on Data Table B. Also in the space explain the shape of the curve..
17. Now change the frequency of the SG, first to 500 Hz, then to 1000 Hz, while watching the oscilloscope. Draw what you see. (You may want to adjust the SG a little, by 0.1 V steps, or even .01 V steps off the assigned frequencies, to get a stationary trace to draw. You are looking for loop patterns.)
18. Return the SG to 250 Hz, and change the Power Amplifier to 500, 1000 and 1250 Hz. Again, you may need to adjust the Power Amplifier frequency slightly. You do not need to draw what you see, but explain below the graphs for Procedure 17 what you see.

QUESTIONS

1. Suppose you could measure the voltages applied to the horizontal deflecting plates of a CRT (cathode ray tube) when it is functioning as an oscilloscope as in Procedure 5, with the scale set at 5 ms/div. If the voltage reads 0 at $t = 0$ s, and 4.0 V at $t = 5$ ms, what would the voltage on the deflecting plates read at $t = 2.5$ ms? At 1.0 ms?
2. Why was it necessary to adjust the frequency of the Power Amplifier to obtain a stationary trace?

3. Explain why, when the frequencies applied to both inputs of the oscilloscope were equal (each at 250 Hz) the trace moved slowly from straight line to a circle.

DATA TABLE A

USING: SCALE SMART TOOL USING: SCALE SMART TOOL


| | DIV | V(V) | V(V) | | DIV | t(ms) | t(ms) |
|----------------|--------|------|------|-----------------------|-----|-------|-------|
| Max voltage | | | | Location of first max | | | |
| Min voltage | | | | Location of sec max | | | |
| Vertical scale | V/div | | | Difference (T) | | | |
| Hor. scale | ms/div | | | Frequency (f) | | | |
| | | | | Percent difference | | | |

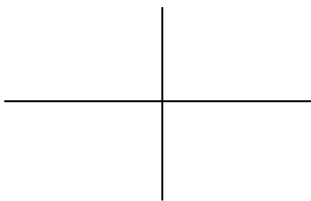
DATA TABLE B

USING SMART TOOL USING: SMART TOOL

| | V(V) | | t(ms) |
|-------------|------|-----------------------|-------|
| Max voltage | | Location of first max | |
| Min voltage | | Location of sec max | |
| | | Difference (T) | |
| | | Frequency (f) | |

COMMENT ON DATA TABLE B ACCURACY (COMPARED TO DATA TABLE A):

PROCEDURE 16 TRACE (Label the frequencies applied to each axis.)



PROCEDURE 17 TRACE (Label with frequencies)

PROCEDURE 17 TRACE (Label...)

