Measurements with an Oscilloscope

Goal: To learn how to make basic measurements of voltage and period using an oscilloscope.

Lab Preparation

This lab is an introduction to the use of the oscilloscope to measure time-dependent electrical signals. The oscilloscope is a widely used laboratory instrument for observing time-dependent electrical signals. It is, in essence, electronic "graph paper." While some may regard it as the domain of the electrical engineer or mad physicist, it finds wide use in a variety of engineering and laboratory settings wherever events occur too rapidly for the human hand to record or the eye to follow without some assistance.

The first encounter with an oscilloscope is often an intimidating event. Oscilloscopes first seem to have an infinite number of controls. In most circumstances the controls you need to use are few in number. Most people who use oscilloscopes regularly become familiar with the details of the equipment only with extensive use and practice. Be patient and carefully watch the effects of each control as you adjust the various knobs and switches. Remember, even experienced oscilloscope users encounter difficulties when faced with a new model. Just finding the power switch can be a challenge.

Equipment

Modern digital oscilloscopes measure the input signals at regular time intervals (the sampling rate) and pass those values on to the display electronics, so what one sees on the display is a snapshot of the signal. Important controls are grouped by function. The two most important groups are the horizontal controls and the vertical controls (Figure 1). The horizontal controls, or timebase settings, specify what total time interval the snapshot of the signal represents, or how much time one horizontal division on the screen represents. The vertical controls set the voltage scale for measured signals - how many volts one vertical division represents. The most common adjustments are made using the control knobs in the respective sections of the front panel. More options are provided through on-screen menus. A two-channel oscilloscope is also capable of displaying two different input signals simultaneously.

While the scope has some fancy built-in measurement capabilities, all measurements must be done by examining the displayed waveform and applying the horizontal and vertical scale settings to find amplitudes, periods, etc. For this lab we use just the basic features and build up the ability to interpret the waveforms in terms of the horizontal and vertical scales factors.

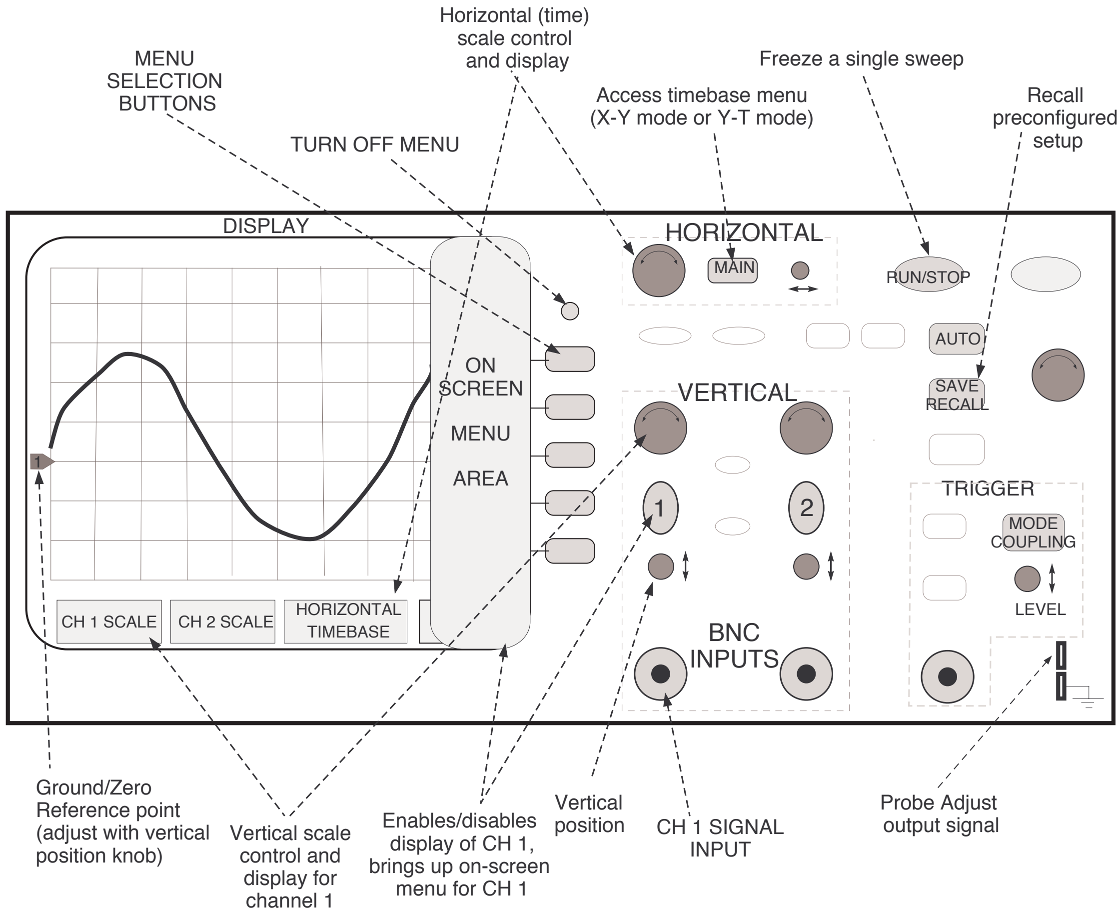

Figure 1: Main features on front panel of a digital oscilloscope

Important settings of the oscilloscope are presented at the bottom of the display area. In particular there will be the vertical scales or sensitivities (volts per division of the grid) for each channel and the horizontal or time base scale (in seconds per division). Other settings are changed by pressing one of the keys and working through on-screen menus.

Display of signals applied to channel 1 or channel 2 can be enabled and disabled by pressing the corresponding numbered keys in the vertical controls section. The vertical sensitivity or scale factor (volts/division) can be adjusted by the knob above the numbered key. The horizontal scale or timebase setting (seconds/division) is adjusted using the knob on the left of horizontal controls section.

The RUN/STOP button provides a way to freeze the display with the most recently collected data. This is useful if the signal is noisy or the display seems 'jumpy' and hard to see a good reproducible result.

On-screen menus can be closed and the full signal display restored using the small round button above the menu selection keys at the immediate right of the display.

Pressing the AUTO key causes the scope to adjust its horizontal and vertical settings to 'optimal' values for the input signals. Sometimes this works nicely; often it leads to settings that are completely inappropriate for the signals you are studying. If you use this button, you must always look at the vertical and horizontal settings at the bottom of the display area to see what the scope has selected, and then ask yourself if they are reasonable for what you are doing. If you use the AUTO key and don't see anything that makes sense, try returning to a known set of reasonable choices by recalling a pre-set configuration. To do this press SAVE/RECALL and select STORAGE SETUPS on the on-screen menu. Make sure that Setup no. 1 is selected and press the LOAD menu key followed by menu off button. This restores settings appropriate to the start of the experiment. Make adjustments manually from this point.

<u>Procedure</u>

I. <u>Basic controls.</u>
The first step in becoming familiar with the oscilloscope is to use it to observe a known signal and observe the effects of various controls. The oscilloscope provides an internally generated signal. This is normally used to calibrate special adapters used with the scope. For our purposes it provides a convenient signal with known frequency and amplitude.

Frequency is defined to be the number of cycles completed in 1 second and is routinely given the unit of hertz (Hz). A frequency of 60 Hz means 60 complete cycles are executed in one second. With oscilloscopes one measures the period of a signal: the time required to complete one full cycle, and then uses the relation between frequency f and period T to find the frequency of the signal: $f = 1/T$.

Use a coaxial cable with a BNC connector on one end to connect to the scope's channel 1 input and an alligator clip to connect to the upper PROBE ADJUST contact (see Figure 1). The convention with BNC cables is that the red lead is the inner conductor of the coaxial cable and BNC connector, while the black lead is the outer conductor, which is to be connected to the electrical ground. The outer conductor of the BNC input of the scope is tied to the scope's ground internally. The alligator-clip end of the ground wire (black) can be left floating (unconnected) for this part. Turn on the oscilloscope and hook up the signal from the PROBE ADJ to channel 1.

A. Observe the pattern displayed on the scope. Try adjusting the vertical scale control and the vertical position for channel 1 and note the results. Try adjusting the time-base (horizontal) scale control and the horizontal position as well.
B. For a time base (horizontal) setting of 500μs/div and a vertical setting of 2.0V/div carefully sketch the waveform displayed.
C. <u>Determine the amplitude of the wave.</u> To determine the amplitude of the wave, first measure the amplitude of the wave in divisions by using the waveform on your screen (measuring the total vertical height and dividing by 2 is best way to do this). After the amplitude is found in divisions, calculate the amplitude in volts by using the vertical setting on the oscilloscope.
D. <u>Determine the frequency of the wave.</u> To determine the frequency of the wave you will first need to find the period of the wave. Recall the period of a wave is the time for one complete cycle. Similar to finding amplitude, you can find the period in divisions and then convert to seconds using the time base setting. Once the period is found determine the frequency.
E. Repeat parts B through D for a time base setting of 500μs/div and a vertical setting of 1.0V/div.
F. Repeat parts B through D for a time base setting of 200μs/div and a vertical setting of 1.0V/div.

II. Determination of an “unknown” frequency.

Sound is a periodic variation in the pressure and density of air (or other gases or liquids). A tuning fork produces a fairly pure sinusoidal pressure variation (if not struck overly hard) at a well-defined frequency. A microphone or speaker can be used to convert the pressure variations of the sound wave into a varying voltage that can be measured with an oscilloscope. Devices such as the speaker or microphone that convert mechanical variations into electrical variations are called transducers.

A. Connect the scope, the microphone, and the microphone amplifier box to observe a sound wave. Plug the microphone in to the amplifier box and run a coaxial cable from the amplifier box into channel 1 on the oscilloscope. Make sure the microphone amplifier box is plugged in.

   Hit a tuning fork with a rubber mallet and put it next to the microphone. You will most likely have to adjust the vertical and horizontal sensitivities to get a wave on the screen. By hitting the RUN/STOP button you can capture a waveform on the screen for closer inspection.

B. Determining the frequency of the tuning fork. Before determining the frequency of the tuning fork. Answer the following questions with your lab partners.

   1. To achieve the greatest precision in finding the frequency $f = 1/T$, does it make any difference to set the scope to display approximately one complete cycle across the screen and measure the period directly for one cycle, or set the scope to display several complete cycles and measure the time for N cycles, dividing the measured time by N to find the period of one cycle?

   2. Is it better to choose as a reference point for your measurements the top (or bottom) of the waveform or the point where the waveform crosses zero?

   Once you've answered these questions, calculate the frequency of your tuning fork (show all of your work). Make a sketch to scale of the observed waveform for your tuning fork.

   Compare the frequency you have measured with the one stamped on the tuning fork.

C. Measure the frequency of a different tuning fork and compare to the frequency stamped on the tuning fork. You do not need to make a sketch.

III. Phase measurements.

Two signals may have the same frequency, but reach their maxima (or minima) at different times. Such signals are said to differ in phase. Figure 2 shows a typical display of two signals out of phase. The period of the waveforms is T and signal 2 reaches its maximum by an amount of time Δt after signal 1.

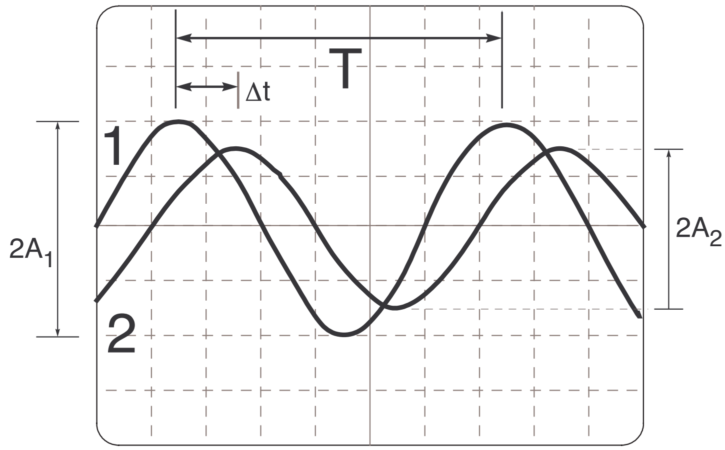

Figure 2

A. Hooking up the Circuit. You have an AC voltage source in the form of a small transformer that plugs into a standard wall socket and a phase shifter "black box" (a box that contains unknown components and labeled "Low Pass RC Filter") that will cause the waves to differ in phase. Use the provided connectors (BNC tees, coaxial cables, etc.) to connect the voltage source to both the small metal box's input BNC connector and channel 1 of the scope. Use channel 2 of the scope to observe the output of the box (you will need to turn on channel 2). See Figure 3 to help set this circuit up.

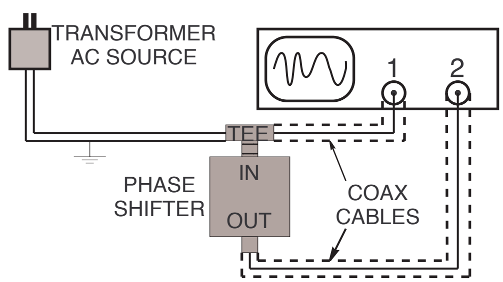

Figure 3

B. Use the Oscilloscope to help determine the amplitudes and frequency of the two signals.

C. Make a careful sketch of the display from which you made your measurements.

D. Use the Oscilloscope to carefully determine Δt. Clearly display your calculations.

IV. X-Y mode and Lissajous figures.

No introduction to the oscilloscope would be complete without some exotic (and often confusing) displays in the form of Lissajous figures. For this part, the horizontal axis of the scope is controlled by the voltage applied to channel 1 (X) and the vertical axis is controlled by the input to channel 2 (Y).

Getting into X-Y mode (CH1 determines X and CH2 determines Y) requires accessing an on-screen menu. Press the MAIN/DELAYED key in the Horizontal section of the controls to bring up the on-screen menu for time-base settings. Then press the Time Base menu key until it displays Time Base X-Y. Follow the same procedure to restore normal operation via Time Base Y-T. NOTE: You will need to adjust the timebase setting (seconds/div) whenever coming back to Y-T mode from X-Y.

A. Hook-up the output of the function generator to channel 2 (use the output 50 Ω) and connect the transformer to channel 1. The function generator provides a signal of variable frequency and amplitude while the transformer provides a steady 60 Hz signal.

   Switch the scope out of X-Y mode and adjust the amplitude and frequency controls of the generator to produce a signal of about 60 Hz (put the function generator scale on 100), with approximately the same amplitude as the AC signal attached to channel 1. Once this is done, hop back to X-Y mode. Slight adjustments of the frequency of the function generator should produce a pattern that seems to "rotate" slowly. Adjust the function generator to make the pattern change as slowly as possible and sketch the pattern. (RUN/STOP is helpful in freezing the display, again.)

B. Try frequencies of 30 Hz, 90 Hz, 120 Hz and 180 Hz on the function generator. Again adjust the frequency control to achieve a (nearly) stationary display and sketch for each case.

C. Try find one additional Lissajous figure by adjusting the function generator. Make a sketch and record what frequency was used. How does this frequency relate to the other frequencies that were used?

Before you leave: Restore your scope to a reasonable set of default settings for the next lab: press SAVE/RECALL, then select STORAGE SETUPS on the on-screen menu. Make sure that Setup no. 1 is selected, and press the LOAD menu key, followed by menu off button. This restores settings appropriate to the start of the experiment.

***When finished with your lab clean up your lab station. Make sure you put all of your wires away.**