

MEASUREMENTS OF VARYING VOLTAGES

Measurements of varying voltages are commonly done with an oscilloscope. The oscilloscope displays a plot (graph) of voltage versus times. This is done by deflecting a stream of electrons (which has been accelerated from the back of the instrument to the front) both horizontally and vertically before it strikes a fluorescent screen. The amount of vertical deflection is determined by the voltage under study; the horizontal deflection is proportional to the time elapsed since the sweep began. The oscilloscope always responds to voltage, but these voltages are often characteristic of other phenomena. For example, a microphone changes the variations in air pressure associated with the sound to changes in voltage that can then be observed with the oscilloscope.

The oscilloscopes you will use in this lab all have common features. Each is a triggered dual-trace D.C. coupled scope. Dual trace means that two traces, or beams, can be viewed simultaneously. Each input voltage goes into its own amplifier and is displayed on the screen independently of the other. Triggered means that the electrons sweeping across the screen begin their journey from the left side only when "told to" or "triggered." There are several ways to trigger the beam. For many, but not all, of our uses, the beam will be triggered by the input voltage. If the triggering adjustment is not set correctly, the pattern will drift across the screen and will not be "locked in." (You will probably find this adjustment a bit of a mystery. Don't worry--ask your instructor if adjustments are needed.) D.C. coupled means that any input voltage, including a constant voltage, causes a deflection. (In A.C. coupling, only variations cause a deflection; the average of the display is zero).

About the only thing you can do to hurt a scope is to leave a bright dot at one place on the screen for a long time. Also, avoid putting a sharp pencil or pen on the screen as this scratches the surface.

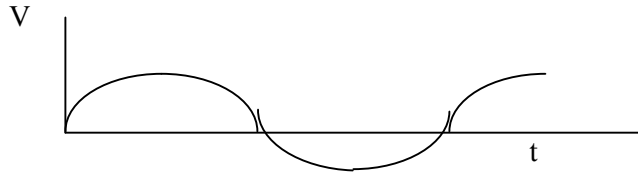
1. Spend some time studying the front panel of the scope. There is a myriad of switches and knobs. Locate the following important ones:
 - a) On-Off (or A.C. on)
 - b) Intensity or brightness
 - c) Focus
 - d) Vertical Gain, in volts/div (one for each channel)
 - e) Horizontal Sweep rate, in time/div
 - f) D.C. - A.C. input switch

Be sure you understand the marking on the vertical and horizontal controls. Each must be set to the CAL position before the marked values will be accurate.

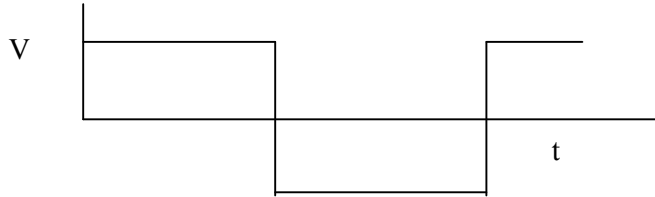
2. Turn on the scope. After a minute or so, you should have a focused line centered on the screen. Turn the sweep rate to its slowest value. Watch the dot move across the screen. Now step-by-step, increase the speed of the electron beam's travel across the screen. The spot will develop a comet-like tail which finally seems to turn into a continuous line. Remember that this line is an illusion caused by the persistent glowing of the phosphor after being hit by the electrons. There is still a dot of electrons moving across, now very rapidly. Continue to increase the sweep rate. The line will get very dim at the highest rates because the time spent at any place on the screen decreases.
3. Set the vertical gain to .5V/Div and the input to D.C. Read the voltage of a 1.5 volt battery on the oscilloscope. Try it with the opposite polarity of the battery by reversing the leads. What would happen if the gain were changed to 1V/Div? Try it and find out if what you expect indeed happens. Now set the INPUT to AC and try to measure the battery. What happens?

4. A signal generator produces a voltage which varies with time. The type of variation is characterized by a plot of the voltage versus times.

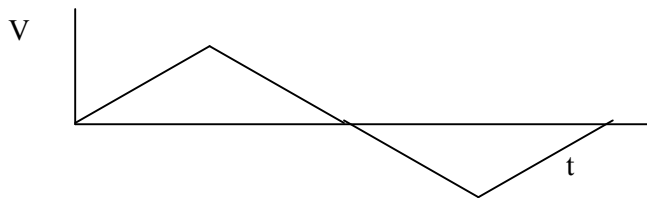
The plot may look like a sine wave



a square wave

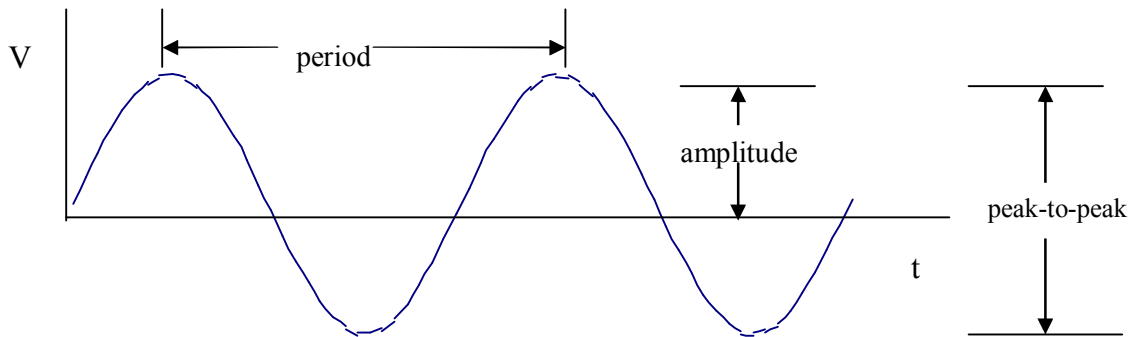


a triangular wave



or some other form.

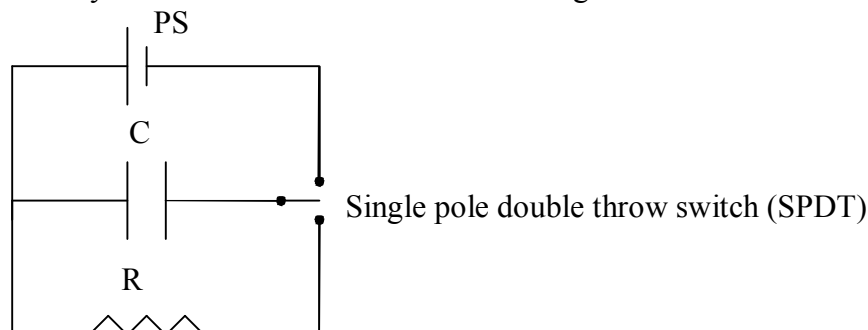
The frequency of the signal is the repetition rate of the regular pattern (frequency is the inverse of the period, which is the time between adjacent peaks). The amplitude of the signal is the maximum voltage of the signal (half the peak-to-peak value). (See the figure below).



- a) Turn on the signal generator. Make sure it is set for sine output. Set the scope input to A.C. Connect the oscilloscope cable to the output of the generator. You may have to vary the sweep speed (**horizontal on the scope**) to spread the pattern enough to make a frequency measurement and you may need to vary the **vertical gain on the scope** to make it fit nicely vertically on the screen. If you have trouble getting a stable pattern, see your instructor. As you are making these changes in gain and sweep speed, the pattern will change; are the characteristics of the input signal changing? Based on your measurements **with the scope**, what are the period, frequency, amplitude and p-p voltage of the signal you have?
- b) Now connect a small speaker to the output of the signal generator and leave the scope also connected to the output. Now the same signal that the oscilloscope looks at is driving the speaker, converting it to sound waves of the same frequency. Do you hear the tone? (If you don't, don't panic yet).
- c) Find the controls **on the signal generator** which would change the frequency of the signal. You should be able to observe on the oscilloscope when you have found the right control. Now find the control **on the signal generator** which would vary the amplitude of the signal. Again, you should be able to observe on the scope when you have the right control. Adjust these until you can hear a tone; large enough amplitude (loud enough) and a frequency you are sensitive to. Change the signal frequency and notice the effect it has on the display and the pitch of the tone. Make sure you understand how the display changes as you go from low to high frequency and vice versa. In going over the range of audible frequencies, you may have to change the sweep rate of the oscilloscope. When you do, make sure you understand that the display looks different because of a scale change and not necessarily a change in frequency of the signal. Find the highest and lowest frequencies you can hear.
- d) Now try to use your speaker as a microphone. In (b) and (c) you supplied a varying voltage to the speaker and that caused the speaker to vibrate. Suppose you cause the speaker to vibrate (by tapping it or "hitting" it with sound waves). Would it output a voltage? **Disconnect** the speaker from the signal generator so that **only** the speaker is now connected to the input of the oscilloscope. See if you can detect any voltage output from the speaker as you tap it or talk into it. (You may need to increase the sensitive by changing the vertical gain of the scope.)

Activity 2: RC Circuits- Exponential Decay.

This activity uses a circuit similar to the following:



The switch is first thrown so that the power supply is attached to the capacitor. The capacitor is charged until the voltage across it equals that of the source (which is nearly instantaneous). The switch is thrown the other way so that the power supply is disconnected and the resistor is attached. This gives a path for the capacitor to discharge. Since the rate at which the charge leaves the capacitor is proportional to the amount of charge on the capacitor, this discharge is exponential. As discussed in class and chapter 28, the time constant $\tau=RC$.

1. First charge and discharge the capacitor while watching the voltage across the capacitor with a multimeter. To do this assemble the circuit and connect a multimeter across the capacitor. Flip the switch to the power supply and observe the charging of the capacitor. When fully charged, flip the switch to the resistor and observe the “decay” in the potential difference across the capacitor.
2. Collecting the data by hand is tedious. Instead we will use the computer to collect the voltage across the capacitor at equally spaced times.
 - a. Turn on the interface box.
 - b. Connect the leads of the “voltage probe” across the capacitor. (Leave the multimeter attached, too.)
 - c. Start ‘Data Studio’. (It is on the desktop)
 - d. Select Create Experiment.
 - e. The voltage probe is plugged into the interface box but you must tell the computer that this is so. Click on port A and select “Voltage probe”.
 - f. To create a graph of your data drag a graph from the “Displays” window up to the voltage probe in the “Data” window.
 - g. Click on START and observe the voltage reading in the digital display on the screen as you flip the switch first to the power supply and then to the resistor and a graph of the voltage as a function of time. STOP taking data when the capacitor is discharged. The values on the screen should be about the same as those shown on the multimeter.
 - h. Repeat if necessary.

3. Analyze the data:
- Fit the data to a “Natural Exponential Fit”. The fit equation is $y=A*\exp(-x*C)+B$ where A, B, and C are fit parameters. Note that the fit parameter “C” is *not* capacitance.
 - Not all of your data corresponds to exponential decay. You will need to select only the data that corresponds to the time during which the voltage is decaying exponentially. Do this by highlighting the relevant data.
 - Write the fit equation below in terms of your physical variables, V and t:

- How do you interpret the fit parameters A and C physically? Use the results of your fit to determine the time constant τ .

- Now reading from your graph, what is the time it takes for the voltage to be decreased by one-half (a “half-life”)?

- How does this value compare to the “theoretical” value? Half life is related to the time constant through $T_{1/2}=0.693 \tau$.

- Graphing your data so that it looks like a straight line is useful. We expect that the data should be an exponential curve, but as a final check graph the natural log of your data. To do this click the “Calculate” button near the start button. In the definition box enter “ $y=\ln(x)$ ” and define the x variable as “Data Measurement”. Graph the results of this calculation and fit it with a straight line (over the same period of time as in the last fit). How do you interpret the slope and what is the value you find?

- Print both of your graphs.