Using an Oscilloscope

The oscilloscope is used to measure a voltage that changes in time. It has two probes, like a voltmeter. You put these probes on either side of the thing that you want to measure the voltage across. (Another way of saying the same thing: if you want to know the electric potential difference between two points, put one probe at each point.) The oscilloscope screen gives you a graph of voltage versus time.

Your oscilloscope is a 2-channel instrument. This means that you can measure two voltages at once if you want to. We will only use channel 1.

1 Initial Setup

1. Turn on the oscilloscope.

2. You should have a cable with a connector at one end and a pair of alligator clips (one red, one black) on the other end. Connect this cable to the channel 1 input of the oscilloscope. (The channel 1 input is at the lower left.)

3. Clip the red and black alligator clips to each other. This gives an electric potential difference of zero between the probe leads. You should see a horizontal line on the screen. Find the vertical position adjustment knob. This knob just slides the image on the screen up and down. Adjust it so that the horizontal line is nicely centered at $y = 0$ on the screen.

   You can play with the horizontal adjustment knob too if you want to, but it's not very exciting with a horizontal line.

4. Locate the three little knobs that are marked "cal", and make sure each one is turned all the way to the right. These "cal" knobs should click into place.

2 Lab Bench AC Supply

1. Connect the probes to the low voltage lab bench AC supply. It doesn't matter which probe goes to which supply jack. Turn the AC supply knob to somewhere in the middle.

2. Locate the knob that says "VOLTS/DIV". Turn it to different positions. What does this knob do?

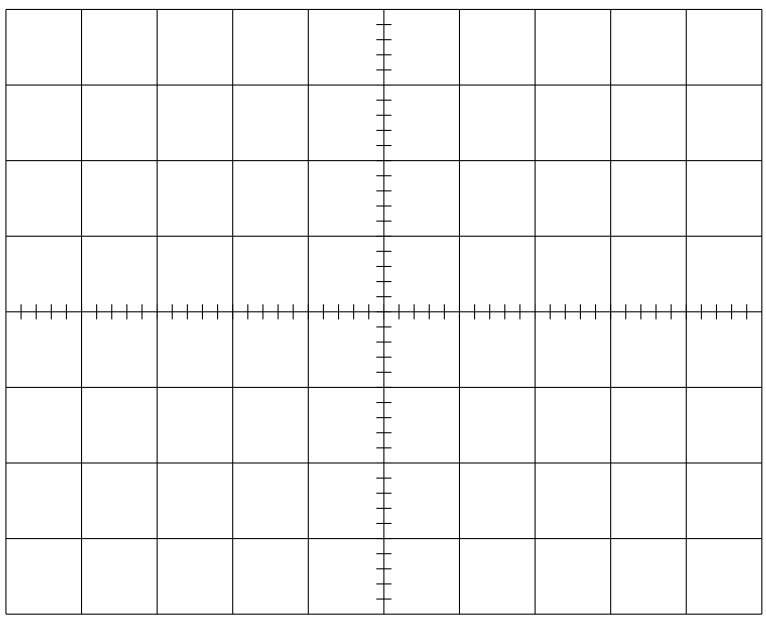
3. Locate the knob that says "SEC/DIV". Turn it to different positions. What does this knob do?

4. Adjust the VOLTS/DIV and SEC/DIV knobs so that the image fits on the screen vertically and you see a few cycles of the sinusoidal image. Record the VOLTS/DIV and SEC/DIV settings that you are using

below.

VOLT/DIV	
SEC/DIV	

5. Draw a picture of what's on the screen.



6. The amplitude of the sinusoidal voltage is the maximum voltage obtained. (Do not confuse the amplitude with the "peak-to-peak" voltage, which is the difference between the maximum and minimum (most negative) voltages in the cycle. The amplitude is one half of the peak-to-peak voltage.) Record the amplitude of the voltage oscillation below.

Voltage Amplitude	

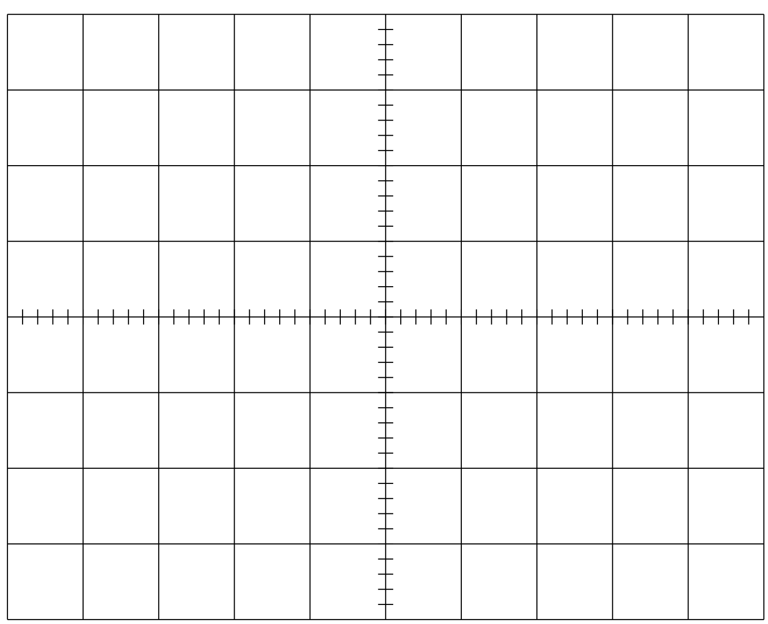
7. Record the period of the voltage oscillation, the frequency (in Hz), and the angular frequency (in rad/s).

Period T	
Frequency f	
Angular frequency ω	

3 Lab Bench DC Supply

1. Connect the probes to the lab bench DC supply. Connect black to black and red to red. Keep the knob in the same middle location that you used in the previous part.

2. Draw a picture of what's on the screen. (It should be a horizontal line.)



3. Record the VOLTS/DIV setting that you are using below.

VOLT/DIV	

4. Record the voltage measured with the oscilloscope.

Voltage from DC supply (oscilloscope)	

5. Measure the DC supply voltage with a voltmeter.

Voltage from DC supply (voltmeter)	

The measurements from the oscilloscope and the voltmeter should agree reasonably well.

4 Lab Bench AC Supply revisited

1. Use the multimeter to measure the AC supply voltage and record the result below.

Voltage from AC supply (multimeter)	

This multimeter measurement should not agree so well with the voltage amplitude that you measured with the oscilloscope. The reason is that the multimeter measures RMS (root-mean-square) voltage, and not voltage amplitude.

5 RMS Voltage

Let us try to understand the relationship between RMS voltage and voltage amplitude. Suppose that a voltage $V(t)$ oscillates sinusoidally in time, and is given by

$$V(t) = V_0 \cos \omega t,$$

where V_0 is the voltage amplitude and ω is the angular frequency. The RMS voltage is the root of the mean of the square of this function. Let's look at it step-by-step.

1. Write down an expression for $V(t)^2$.

2. The mean of the square is given by integrating $V(t)^2$ over one period (from $t = 0$ to $t = T$) and dividing by the period. In other words, the mean of the square is given by

$$\frac{1}{T} \int_0^T V(t)^2 dt.$$

Substitute your expression for $V(t)^2$ and do this integral. You can look up the integral in a table if you want to, or the following trigonometric identity may help.

$$\cos^2 x = \frac{1}{2} + \frac{1}{2} \cos 2x$$

You should get a result that depends only on V_0 and not on T or ω.

3. Finally take the square root of your result from the previous part. This is the RMS voltage, V_{RMS}. Write an expression for V_{RMS} in terms of the voltage amplitude V_0.

4. Calculate V_{RMS} using for V_0 the voltage amplitude of the AC supply measured previously with the oscilloscope. Compare this with the multimeter measurement.

6 Wall Outlet Voltage

We will measure the wall outlet voltage with the oscilloscope. Before we do this, there are two additional issues we need to talk about.

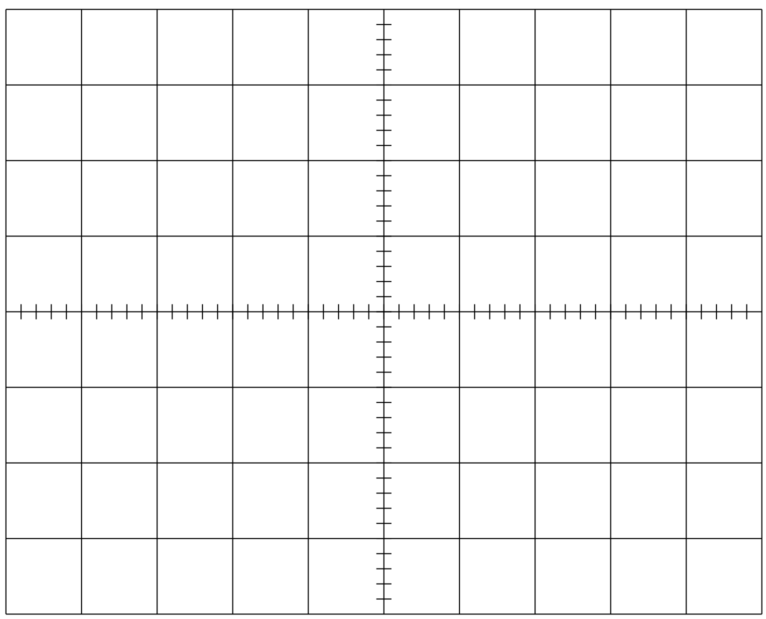
The first issue has to do with grounding. This building, like most modern buildings with electricity, has a ground system. A ground system is a collection of wires that are all connected to each other and to a big metal pipe that is driven into the ground. Sometimes a water pipe is used for this pipe. (The pipe in the ground is not intended to carry current.) On a 3-prong electrical plug, the third prong is connected to this ground system. When such a ground system exists, we call the electric potential of the ground system zero volts (where a ground system does not exist, we are free to call any place we want zero volts). The oscilloscope is grounded by the third prong of the power cord, and this third prong is electrically connected to the black (alligator clip) probe that we have been using. This means that the black probe is *already* connected to zero volts.

Some voltage supplies use the ground system of the building (every wall outlet does) and some do not (batteries do not). The "neutral" side (larger prong) of a wall outlet is connected to the ground system (but by different wires than the ones used for the round third prongs. The AC and DC bench supplies do not use the building ground system. (None of the bench supply jacks are connected to the building ground system.) When measuring voltage on a system that is not connected to the building ground system, the act of attaching the black alligator clip to something makes the potential of that thing the same zero volts that the ground system has. So, this is what we did for the AC and DC bench supplies.

On the other hand, when we go to measure the voltage provided by a wall outlet, we want to measure the voltage with respect to the ground system. But the oscilloscope is already connected to ground. So, to measure the voltage provided by the wall outlet, we only need to connect a single wire from the "hot" side of the outlet to the oscilloscope. We only need one wire to measure voltage because we are measuring with respect to a common ground. The second wire is already connected for us through the third prong of the power plug.

The second issue has to do with the high voltage of the wall outlet. The oscilloscope can not handle an input voltage of more than about 40 V. The wall outlet voltage is higher than that. So, we use a "10X probe". This probe measures voltage and sends one tenth of the measured voltage to the oscilloscope, so that we need to multiply what we read on the oscilloscope by ten to get the correct value.

1. Connect the 10X probe to channel 1 of the oscilloscope. Put the probe in the "hot" side of a wall outlet. (The hot side is the short prong.)
2. Adjust the VOLTS/DIV and SEC/DIV so that the picture fits nicely on the screen.
3. Make a picture of what you see on the screen.



4. Record the voltage amplitude, period, and frequency.

Voltage Amplitude	
Period T	
Frequency f	

5. Use a multimeter to measure the RMS voltage of the wall outlet.

RMS Voltage	

6. Are the voltage amplitude (measured with the oscilloscope) and the RMS voltage (measured with the multimeter) related in the correct way? Explain.

7 Questions

1. It may seem that RMS voltage is a complicated mess, and you may wonder why the multimeter measures RMS voltage rather than, say, average voltage. Explain why a measurement of average voltage for an AC voltage source is not very useful.