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Physics 536 Lab #1 - Introduction to Instruments

The purpose of the first lab session is to learn to use the equipment that will be needed for future experiments. Most of your time will be spent using the oscilloscope. If you do not have time to work with the power supply and the multi-meters, you should do those sections of this introduction in the second lab session before you start Experiment #1. A written report is not required for this lab.

1 General Laboratory Rules

- When you finish an experiment, put all components and equipment in their proper places. The Wires you have used are to be kept in the table drawers. You should memorize the resistor color code which is described in the text book. There is also a chart at the front of the lab to help you out.
- Turn off the equipment before you leave. In particular, the battery powered digital multi-meters should be left in the off position to avoid draining their battery.
- If you have not finished with an experiment, make arrangements with your lab instructor to leave your assembled circuit in a safe place.
- Take care not to blow up transistors, diodes or integrated circuits by turning off your power supply before making changes. Also, you should be sure that your power supply is set to provide the voltages described in the experiment instructions before you connect them to your circuit.
- Throw away any obviously bad resistors. If you suspect a diode or transistor to be bad, check it by using the simple conductance tests with the analog multi-meter. If, after performing the conductance tests, you believe a diode or transistor to be bad, put it in the small cardboard box labeled "bad diodes, transistors and chips". Suspected integrated circuits should also be placed there. Someone will double-check them later.

2 Oscilloscope

You should become familiar with the topics discussed in "XYZs of Oscilloscopes" which is available from the Tektronix web site:

`http://www.tek.com/Measurement/App_Notes/XYZs/`

which links to a PDF file that can be downloaded and viewed or printed. An older version called "The XYZs of Using a Scope" may also be of some use and is provided on-line at

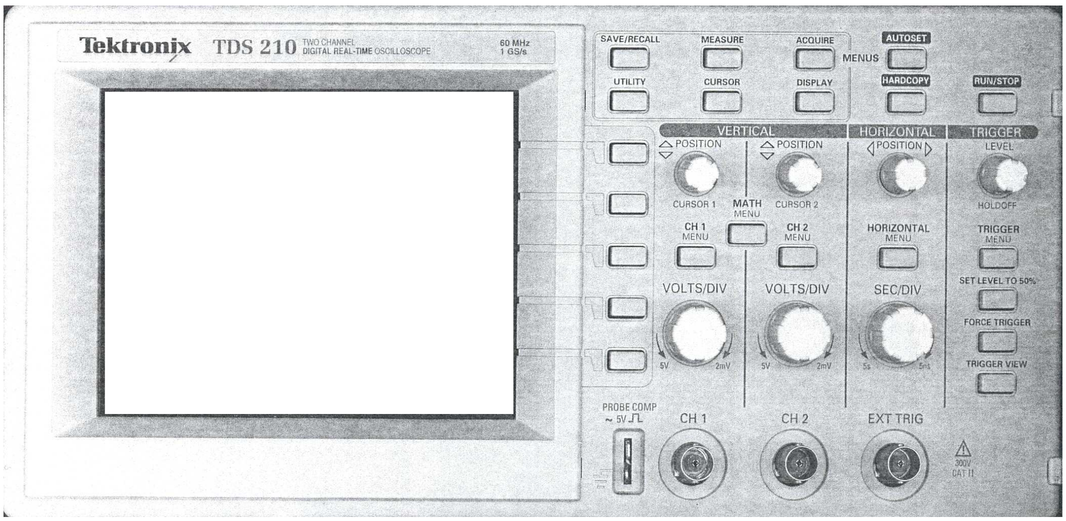
`http://www.physics.purdue.edu/~mjones/phys536/labs/OldTekPrimer.pdf`.

Although you will get practical experience using an oscilloscope by working through the instructions in this lab, you should become familiar with the information presented in these notes and re-read the relevant sections if there are features or capabilities of the oscilloscope that you find unclear. Which sections are applicable to the oscilloscopes used in the lab will be more clear after you have some experience using them.

The two main types of oscilloscopes are **analog** and **digital sampling** Oscilloscopes. Analog oscilloscopes usually have a cathode ray tube on which an electron beam is scanned, while digital oscilloscopes have a small monitor or liquid crystal display. The Tektronix primers describe both types of oscilloscopes, but in the Phys 536 lab we will use the Tektronix TDS 210 digital sampling oscilloscopes. Although Tektronix has discontinued this product line, the manual can be found at

`http://www.physics.purdue.edu/~mjones/phys536/labs/ttds200_series.pdf`.

2.1 Exercise 1: Introduction to the Oscilloscope



Although it is usually possible to initialize the oscilloscope into a configuration that will be reasonably close to what you want by pushing the AUTOSET button, it is more useful to explicitly configure it to suit your needs so that you know exactly what conditions are used to acquire waveforms.

1. Turn on the oscilloscope. The power button is located on top.
2. Connect the probe to the CH 1 input and clip the probe to the top (ungrounded) PROBE COMP connection.
3. Adjust the vertical POSITION knob for channel 1 until the message at the bottom of the screen reads `CH1 vertical position 0.00 divs`.
4. Push the CH 1 MENU button and select Coupling=`DC`, BW Limit=`OFF`, Volts/Div=`Coarse`, Probe=`1X`.
5. Adjust the VOLTS/DIV knob for channel 1 until the text at the *bottom* of the screen reads `CH1 200mV`.
6. Push the CH 1 MENU button and select `DC coupling` by pushing the appropriate menu button.
7. Adjust the horizontal POSITION knob until the text at the *top* of the screen reads `M Pos:  0.000s`.
8. Adjust the horizontal SEC/DIV knob until the text at the *bottom* of the screen reads `M 250` μ`s`.
9. Push the CH 1 MENU button until the trace for channel 1 is displayed.

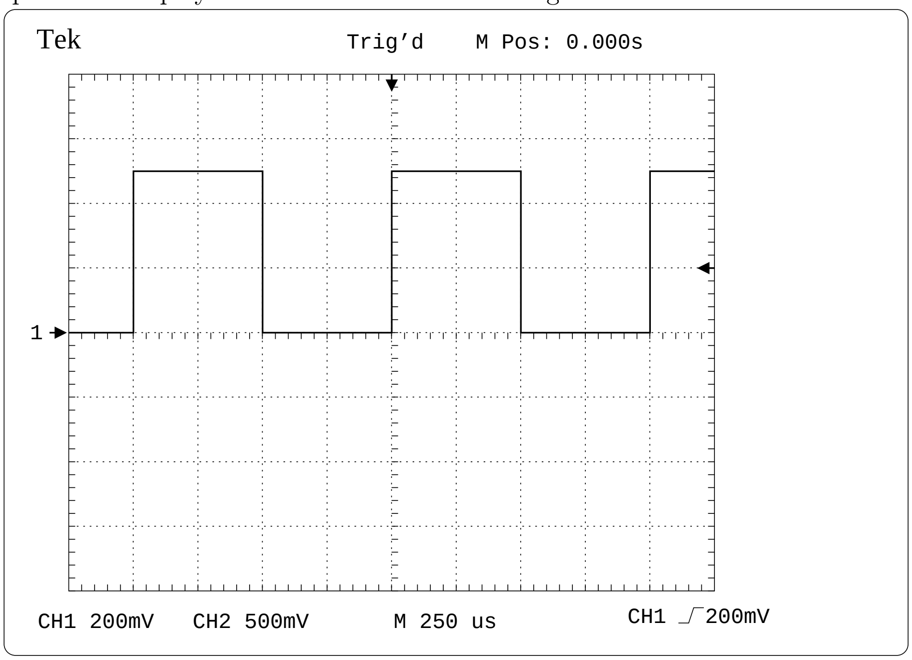
At this point you might see some type of activity on the screen for the trace corresponding to channel 1. Next, the oscilloscope should be configured to trigger on the input waveform in a useful way.

1. Push the TRIGGER MENU button and select `Edge`, Slope=`Rising` slope, Source=`CH1`, Mode=`Normal`, Coupling=`DC`. Note that you can check the trigger configuration at any time by pushing and holding the TRIGGER VIEW button.

2. Adjust the trigger LEVEL knob until the text at the *bottom right* corner of the screen reads `CH1 / 200mV`.

3. If the display says • `Stop` at the top, push the RUN/STOP button until it says `Trig'd`.

At this point the display should resemble the following:



From this information one can determine that the input to channel 1 is a square wave with a period of (4 div) × (250 μs/div) = 1 ms and an amplitude of (2.5 div) × (200 mV/div) = 0.5 V. At this point you can notice several important pieces of information and examine the behavior of the knobs and buttons:

1. The arrow at the top of the screen indicates the time at which the trigger condition was satisfied. In this case, the oscilloscope triggers when the slope of the waveform is rising, and crosses the threshold of 200 mV. The waveform to the left of the arrow shows the state of the signal *before* the trigger condition was satisfied and the waveform to the right of the arrow shows the signal after the trigger condition was satisfied.

2. By adjusting the horizontal POSITION knob, you can examine any part of the waveform after the trigger is satisfied, or any part of the waveform up to 1 ms before the trigger.

3. By adjusting the SEC/DIV knob, you can change the horizontal scale and the interval of time that is displayed.

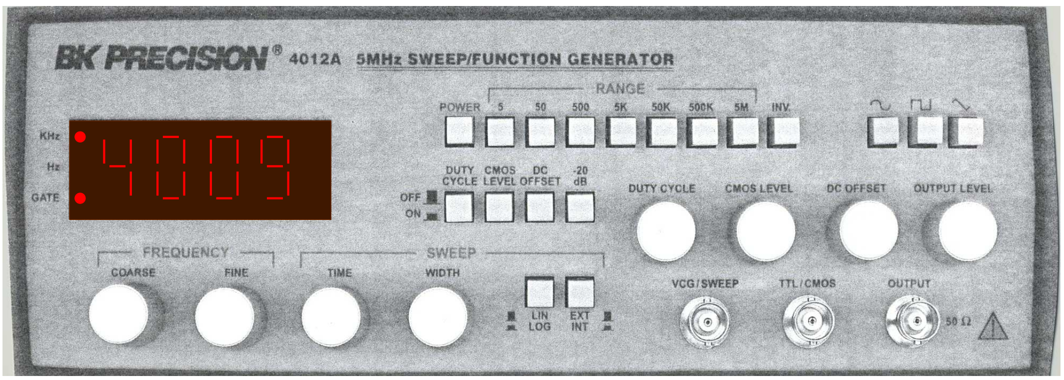
4. By adjusting the VOLTS/DIV knob, you can select the vertical scale of the channel being displayed.

5. By adjusting the vertical POSITION knob you can select where the waveform will be displayed on the screen.

6. By pushing the TRIGGER MENU button and selecting Slope=`Falling` you will see the waveform triggered on the falling edge.

7. If you adjust the TRIGGER LEVEL so that it is < 0 V or > 0.5 V, the input signal will no longer satisfy the trigger condition. No new waveform is displayed and the oscilloscope will indicate that it is waiting for a trigger by displaying `Ready` at the top of the screen.

3 Function Generator



The BK Precision 4012A 5 MHz function generator will be used to produce input signals to several circuits that you will build. Its basic functionality allow you to produce a square, sine or triangle wave of variable amplitude with frequencies up to 5 MHz. Other controls allow you to change the DC offset and to sweep the of the output signal over a range of frequencies.

3.1 Exercise 2: Introduction to the Function Generator

This exercise will give you more experience using the oscilloscope and will allow you to verify that you understand the signals produced by the function generator.

1. Turn on the function generator. Select the sine wave output function, turn off the DUTY CYCLE, CMOS LEVEL, DC OFFSET and -20 dB functions and select EXT for the SWEEP source.

2. Turn the OUTPUT LEVEL knob all the way counter-clockwise to produce an output signal with minimal amplitude.

3. Connect the OUTPUT to channel 1 of the oscilloscope.

4. Set the RANGE to 5 kHz and adjust the COARSE and FINE frequency knobs until a number close to 2500 Hz is displayed.

5. Set the horizontal SEC/DIV to 250 μs/div and the vertical VOLTS/DIV on channel 1 to 500 mV/div.

6. Set the scope to trigger on channel 1 with a positive slope and a threshold close to zero volts. You should see a sine wave displayed on the oscilloscope.

7. Adjust the horizontal POSITION knob to line up one of the peaks with one of the major divisions on the screen. Count how many divisions, $N_{\rm div}$, there are between this peak and the

n^{th} subsequent peak, where would n probably be about 4 or 5. Calculate the frequency of the signal using

$$f = \frac{n}{N_{div} \times (250\ \mu\text{s/div})} \tag{1}$$

and compare this frequency with the number displayed on the function generator.

8. Push the MEASURE button on the oscilloscope and select `Source` at the top of the menu. Then push the next menu button to select CH1 as the measurement source. Next, select the `Type` of measurement and push the next menu button to select `Freq`. The measured frequency of the signal on channel 1 should be displayed. Compare this with the value you calculated previously and displayed on the function generator.

9. Select `CH1 Pk-Pk` as the second measurement source. Compare the measured peak-to-peak voltage with the waveform displayed on the oscilloscope. In this way, determine the amplitudes of the largest and smallest signals that can be produced with the signal generator by adjusting the OUTPUT LEVEL knob.

10. Depress the -20 dB button on the signal generator and measure the determine the maximum and minimum peak-to-peak voltages that can be produced.

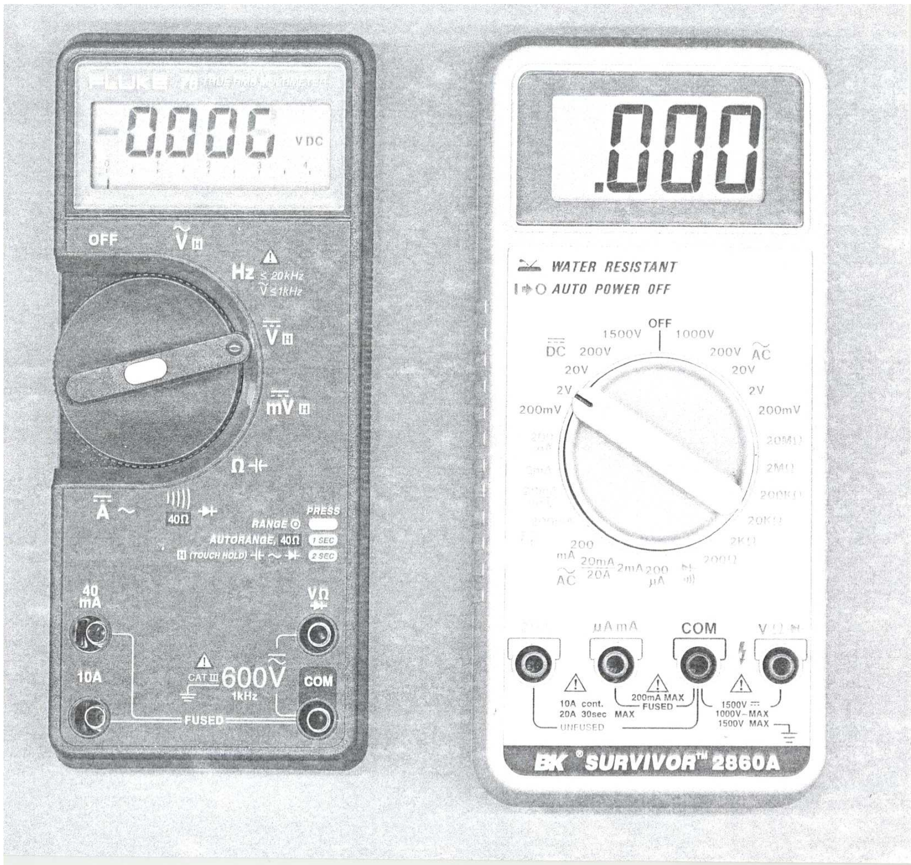
11. Depress the DC OFFSET button and adjust the DC OFFSET knob. You will probably have to increase the TRIGGER LEVEL to allow the oscilloscope to trigger on the signal. Verify that you can control the DC OFFSET of the signal with these controls.

12. On the oscilloscope, select the CH1 MENU and select `Coupling=AC`. After possibly adjusting the trigger threshold, you should find that any DC offset on the input signal is now removed. AC coupling is sometimes useful, but does not necessarily accurately represent the input waveform in cases where the DC offset is important. Normally you should use DC coupling and adjust the vertical gain, position and trigger threshold as needed to accurately measure the waveform.

4 Multi-meters

Multi-meters are used to measure voltage, current or resistance. Some can be used to measure capacitance or temperature, when used with an appropriate transducer. Battery powered multi-meters are useful for quickly checking voltages in a circuit, while the AC powered multi-meters are more appropriate when making repeated precise measurements. In general, it is unwise to trust the calibration of a meter with which you are unfamiliar. Therefore, before attempting to make accurate measurements, you should be prepared to verify that a meter is functioning as expected by either measuring a known standard, or by comparison with another meter or an oscilloscope.

4.1 Battery powered meters



There are several types of battery-powered multi-meters that can be found in the Physics 536 lab. Some, like the Fluke 76 multi-meter have auto-range capabilities, while others like the BK 2860A require selecting an appropriate measurement range manually. Both types of meters have a black common jack but separate jacks for measuring voltage/resistance and current.

4.2 AC powered meters

For more precise measurements of voltage, current, resistance or frequency, the Fluke 45 Dual Display multi-meter should be used. Although providing more precision, these meters are more expensive and less portable, but are well suited for making repetitive measurements once a circuit has been set up and is working.

4.3 Exercise 3: Measuring AC voltages

When measuring AC voltage with a multi-meter, be aware that the voltage that is displayed is an estimate of the RMS voltage. For sinusoidal voltage sources, the RMS voltage is related to the amplitude of the wave and to the peak-to-peak voltage by

$$V_{\mathrm{RMS}} = \frac{1}{\sqrt{2}}A \tag{2}$$

$$A = \frac{1}{2}V_{\mathrm{P-P}}. \tag{3}$$

However, not all types of meter measure the RMS voltage with high accuracy:

1. Set up the function generator to produce a sinusoidal signal with a frequency of about 100 Hz and with an amplitude of about 2 volts peak-to-peak.

2. Verify that the function generator is producing such a signal by examining the waveform on the oscilloscope.

3. Measure the frequency and peak-to-peak voltage using the oscilloscope.

4. Using the MEASURE menu, set up the oscilloscope to measure the RMS voltage by selecting the `Cyc RMS` measurement type.

5. Verify that the RMS voltage is *approximately* equal to $V_{\mathrm{P-P}}/\sqrt{2} = 0.707 \times V_{\mathrm{P-P}}$. Can you think of any reason that the measured relationship between RMS and P-P voltage might deviate from this relation?

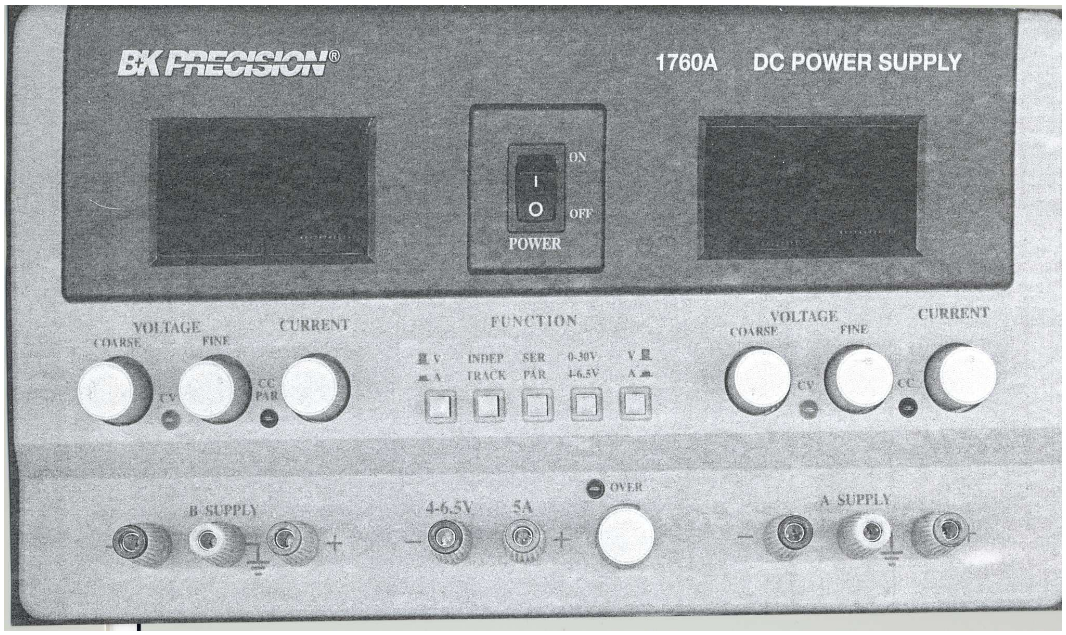
6. Measure the RMS voltage using a multi-meter and compare the measurement with the value obtained using the oscilloscope.

7. Repeat this comparison using a signal with a frequency of 10 kHz.

8. Repeat these comparisons using a battery powered multi-meter and a Fluke 45 meter. Try to figure out how to get the Fluke 45 meter to measure RMS voltage and frequency simultaneously on its dual displays.

From this exercise you should have learned that although digital multi-meters are useful test instruments, the oscilloscope is a much better instrument for making measurements that are accurate and well defined.

5 DC Power Supply



You will most likely use the BK Precision 1760A DC power supply for most of the experiments in the Physics 536 lab. This power supply provides three adjustable DC output voltages with internal current limiting and short circuit protection. The manual is available from the BK Precision web site at the following URL:

`http://www.bkprecision.com/products/docs/manuals/1760A_manual.pdf`.

5.1 Exercise 3: Power Supply Configurations

1. Make sure the supply outputs are not connected to anything and turn on the power supply.
2. Enable the INDEP function so that both the A and B supplies are independent.
3. Enable the V and 0-30V functions to display the voltage of the A and B supplies.
4. Turn the CURRENT limit knobs all the way counter-clockwise.
5. Turn the COARSE and FINE voltage knobs all the way counter-clockwise to set the output of both A and B supplies to zero.

The CURRENT knob can be adjusted to limit the current that the supply will provide. If the current drawn from the supply is less than this limit, then the power supply acts as a *constant voltage* supply and the green CV LED is lit. If a circuit would cause a current larger than the limit to flow, the output voltage will be reduced to value that provides only the limiting current and the red CC LED will be lit to indicate that the supply is in *constant current* mode.

1. Connect a small valued resistor between the - and + outputs of supply A.
2. Turn the CURRENT knob to approximately mid-range, to set the current limit to approximately 1 Ampere, which is 50% of the maximum current the supply will provide. With zero volts, no current is drawn and the CV LED will be lit.

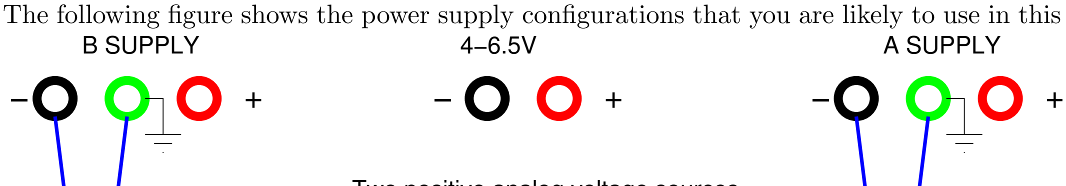
3. Slowly increase the A supply output voltage until the red CC LED lights and the supply switches to constant current mode. Notice that increasing the voltage knob no longer changes the voltage displayed on the readout.
4. Depress the left-most function button to display the current being provided by supply A.
5. Turning the CURRENT limit knob counter-clockwise will decrease the current provided by the supply, while turning it clockwise will increase the current limit and allow the supply to switch back to the constant voltage mode.

For most of the circuits you will analyze in this lab, you should set the current limit to a conservative value of less than 50%. Only if your circuit really does require more than 1 A, should it be necessary to increase the current limit. In this way, finding the supply in an unexpected CC state will most likely indicate that the circuit you are analyzing has been connected incorrectly.

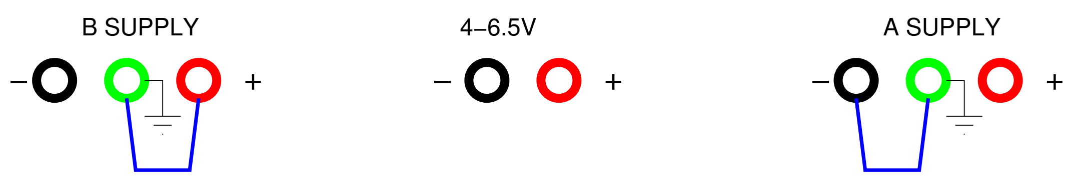
5.2 Bipolar Power Supply Configurations

The black and red terminals of the A and B supply outputs provide a *potential difference* but the absolute voltage of either terminal is undefined. Thus, either terminal can be tied to the green terminal, which is defined to be ground potential, or zero volts. The potential difference, provided by the supply, and the assignment of one point in the circuit to be zero volts, fully defines the voltages of all other terminals.

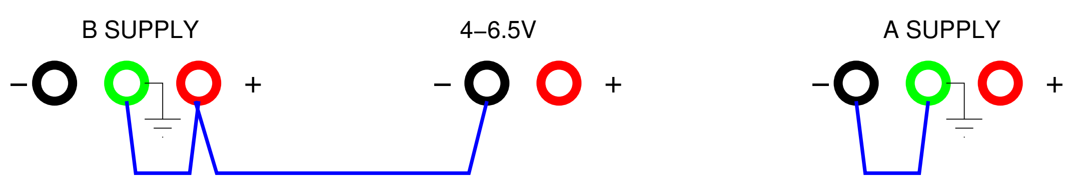
The following figure shows the power supply configurations that you are likely to use in this lab.



Two positive analog voltage sources



Two bipolar analog voltage sources



Two bipolar analog voltage sources and one positive digital voltage source