# LAB 2
## Circuit Tools and Voltage Waveforms

### OBJECTIVES

1. Become familiar with a DC power supply and setting the output voltage.
2. Learn how to measure voltages & currents using a Digital Multimeter.
3. Explore the voltage and current measurements in a simple series circuit.
4. Learn to use a function generator to create time-varying voltage patterns, and to control the amplitude, frequency, and waveform of these patterns.
5. Learn to measure and record these rapidly varying voltages using Capstone.

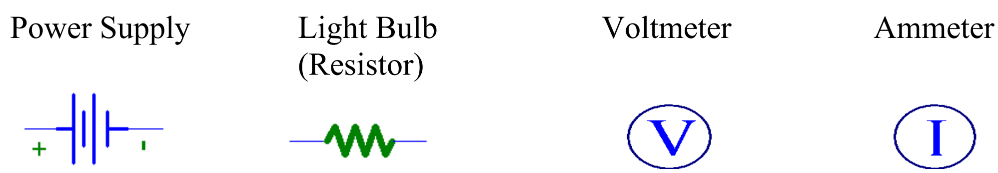
### EQUIPMENT

DC power supply, digital multimeter (DMM), conducting wires, light bulbs, function generator, Capstone software (with Voltage Sensor hardware).

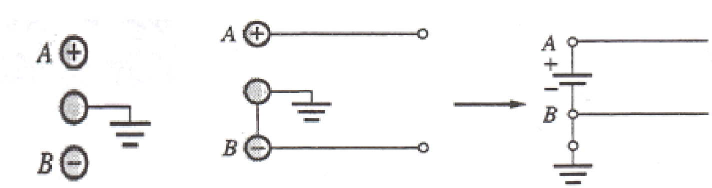
### THEORY

The purpose of this laboratory exercise is to acquaint you with the equipment, so ***do not rush***. Don't let one individual make all the measurements. You must become comfortable with the instruments if you expect to do well in future labs.

**Circuit Symbols:**

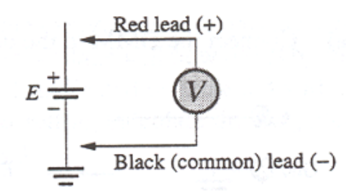



Our DC power supplies have three terminals, labeled as shown in the figure below:




The main job of the power supply is to maintain a set voltage difference between the high-voltage (red, or +) terminal and the low-voltage (black, or "-") terminal. The third, green terminal, is connected to the "ground" of the power grid, which is usually considered "zero volts". Often, you will wire the black and green terminals together, meaning that black also represents room ground.

When using a voltmeter (including a DMM on its "voltage" setting) to measure the voltage difference between two points, the voltmeter should connected in "parallel" (across) the element being measured, as shown in the figure below:




The value shown on the meter will be:

*Voltmeter Reading = (Voltage at Red Lead) - (Voltage at Black Lead)*

That is, if the leads are connected as shown in the figure, the reading will be positive. If the leads were reversed, the reading would be negative. Thus, if you don't *know* which of two points is at a higher voltage, the meter can tell you.

Ammeters (the current setting on the DMM) are always connected in "series" with the branch in which the current is being measured, normally requiring that the circuit be broken and the meter inserted. Think of the current as being shunted *through* the meter:

For an ammeter, a positive reading means that current (positive charge) is flowing *in* the red lead, through the meter, and *out* the black lead. A negative reading means the current is flowing the opposite direction.

A Function Generator provides a voltage which varies with time as a sinusoidal, square, or triangular waveforms. Function Generators have dials to adjust both the frequency and amplitude of their waveform, but often the amplitude dial has no gradation markings. The only way to know the peak-to-peak amplitude of the signal you are producing is to measure it, either with a multimeter (on its AC voltage setting) or with an oscilloscope (or Capstone). The Function Generator's controls can then increase or decrease the amplitude to a desired value.

## PROCEDURE

### Part 1: Using the DMM to measure voltage differences

The first voltage source you investigate will be a common 9-volt battery.

(a) Set a digital multimeter to measure voltage. This will mean the black lead is plugged into the "COM" port, the red lead to the "V" port, and the main dial to "V" with a straight (rather than wavy) line over it.

*Can you predict what the meter will read if you touch its leads to the two terminals of the battery?* ***(Answer this -- and any other "prediction" questions in labs -- before you proceed!)***

Actually touch the leads to the terminals. *Was your prediction correct?*

(b) *What do you predict will happen if you reverse those two leads? What actually happens?*

**Part 2: Using the DC Power Supply as a voltage source**

(a) *Record the min/max output voltage and current specs written below the negative terminal.* These, unsurprisingly, tell you the range of different voltages and currents your supply can provide.

Find your power supply's positive (red) and negative (black) output terminals and check that the negative (black) is connected to the ground (green)

(b) Identify the coarse and fine voltage adjustment knobs – these will be the controls you use most often. The current adjust knobs and the "hi/lo" amps switch are used only to set an upper limit on the current to protect the circuit that will be tested in our experiment. For now, crank the current knobs all the way to the right, so the power supply is "willing" to provide the full current you recorded in part (a).

Turn on and test the power supply. Note that whenever power is on, either a green or a red indicator light will light up: *green* indicates normal (constant voltage) operation and *red* indicates the current limit has been reached.

Use the coarse and fine adjust knobs to set the output voltage to 9 volts. Now use your multimeter to measure the voltage difference between the red and black terminals. *Does the DC Power Supply seem to behave exactly like the 9-volt battery you used before? If not, in ways is it different?*

The biggest advantage your DC supply has over a battery is that its voltage is not fixed. Mess with the course and fine voltage adjust knobs. *How does the voltage gauge on the face of the meter react? How do the readings on your multimeter react?*

(d) Your power supply contains built-in limits to protect against excessive current, which could damage both the supply itself and whatever circuit it is powering. To see these built-in safety features at work, "short" across the output terminals with a wire. (**NOTE: never "short" any unprotected power supply, including those 9-volt batteries from before!)** *How do the readings on the supply itself, and on your multimeter (still set to read voltage), change? Do you see or hear anything else at the moment you close the short circuit?*

Use a second multimeter (or the same one, if multimeters are scarce) to measure DC current. This will mean the black lead is plugged into the "COM" port, the red lead to the "10 A" port, and the main dial to "Amps".

To use the multimeter to measure the current flowing through that "short" wire on your power supply, you will need to break the circuit temporarily, and wire the leads so that the current flows through the multimeter. *How does the reading on the multimeter compare to the readings on the power supply's gauges?*

This is a good time to learn how those current-limit knobs work. Normally, they do not set the amount of current flowing through the power supply; instead, they set that safety "cutoff" value for current. However, when you short the supply, as you're doing now, it

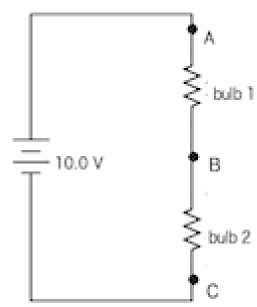
WILL give whatever maximum safe current you've set. Play with the fine and course current-limit knobs. *How does the current measured by your multimeter change?*

Adjust the current limit to 0.6 A and then remove the short from the terminal points. You have now set the upper current limit; leave it there for the remainder of this lab. Also, set the output voltage to 10.0 volts, and leave it there for the time being.

## Part 3: Measuring Voltage and Current in a Simple Circuit

In this section, the current and voltage of a DC series circuit will be determined by direct measurement using a DMM.

(a) Construct the circuit below using a DC power supply (set to 10.0 volts, and 0.60 Amps max current), and two light bulbs.




*Do the bulbs light? (If not, figure out what's wrong before continuing.)*

(b) You are going to use your DMM as before, to measure the voltage between the following three pairs of points: A and B, B and C, and A and C. *Before you make any measurements, do you predict any particular relationship between these three readings? Make the measurement. Were your predictions correct?*

(c) Now you are going to use your other DMM, as before, to measure the *current* passing through point A, the current through point B, and the current through point C. (Remember, current is trickier to measure than voltage -- you have to break the circuit and shunt the current *through* your meter.)

*Before you make the measurement, which do you predict will be greatest: the current through A, through B, or through C?*

*Now, make the actual measurements. Did they come out as you expected? Why or why not?*

## Part 4: Capstone Data Acquisition System

**Important**: Capstone can be damaged by voltages above ±12 V – ***do not*** *turn the power supply voltage above 10* V *when using Capstone.*

(a) Use Capstone's Voltage Sensor to measure the constant 10.0 V output of your power supply with a Digits and a Table display. Record at least a few seconds of data and display the data in a list. *Is noise present in the voltage reading?* Click the Statistics button (marked with a sigma) to display statistics and check both mean and standard deviation in the associated drop-down list. *Record both the mean and the standard deviation in your lab notebook.*

## Part 5: Function Generator & Capstone's Oscilloscope

(a) Connect Capstone's Voltage Sensor to the Function Generator and setup Capstone to display the voltage across the Function Generator using the scope display.

Set the Function Generator to produce a sine waveform with a frequency of 500 Hz and a peak-to-peak (*p-p*) voltage of 10 V. To set a voltage of 10-V (*p-p*) with Capstone's Scope, adjust the amplitude of the waveform on the Function Generator and use Capstone's Smart Tool as a guide.

*Use the Coordinate/Delta Tool to measure and record (1) the period T and (2) the peak-to-peak voltage V.*

*Determine the frequency from the period measurement. How well does it match the frequency given by the Function Generator?*

(b) To explore the capabilities of the Function Generator and the effect it has on the voltage waveforms, change the following variables of the Function Generator:

- Frequency (adjust)
- Voltage (amplitude)
- Voltage waveform

*Describe in words and sketch the effect that each variable has on the voltage waveform.*