Physics 4700 Experiment 1

Instrumentation and Resistor Circuits

Power supply:

A power supply is supposed to have two terminals, positive and negative outputs. However, the power supplies in the lab have three terminals, positive, negative, and ground. To use a power supply to provide a positive output voltage, connect the negative terminal to the ground terminal using the shorting bar attached to the power supply. This effectively reduces the number of terminals to two as you would naively expect for a power supply. For a power supply to provide a negative output voltage, connect the positive terminal to ground using the shorting bar. Measure the power supply voltage and current with a **multimeter** instead of using the reading on the supply if a more precise value is needed.

Ground:

It is important to keep all the ground wires (terminals) connect together at one location. If you connect two locations in a circuit to ground, the two locations will be at the same potential (zero Volt) and there would be no current flowing between them. To avoid accidentally grounding a signal, use **red** wires for signal and **black** for ground. If a red wire is connected directly to a black wire, the signal is grounded, i.e. no signal.

0) Study the operation of the oscilloscope, multimeter, power supplies, and wave generator. For the oscilloscope you should try to understand the function of all the knobs or buttons on the front panel. Some buttons may have several functions and some of the functions will not be relevant for this class. Try to follow the examples in the instruction manual.

1) Verify Ohm's law by measuring and then plotting voltage vs. current for a resistor. Measure the voltage and current simultaneously by using both the handheld and desktop multimeters. Fit your graph(s) to extract the measured resistance using the formula,

$$V = V_{offset} + IR$$

where V_{offset} is the voltage offset of the multimeter. What should the V_{offset} be for an ideal multimeter? Use a resistor of your choice. Take at least five data points for each resistor. Do the slope and intercept from your fit consistent with the expectations? Repeat the measurement with a resistor of a much higher value (e.g. 10-100X) than your previous choice. Use a DC power supply for the circuit.

2) Measure the DC resistance (R_m) of your multimeter when it is used to measure voltage, i.e. on voltage scale. This can be done using a voltage divider, which consists of two resistors in series with one of them being the multimeter internal resistor. Draw the circuit diagram and **show** that the DC resistance is given by

$$R_m = RV_m / (V - V_m)$$

where V_m is the voltage reading on the multimeter and V is the power supply voltage which should be measured with another multimeter in order to achieve the precision needed to provide a decent measurement of the DC resistance. Look up R_m in the manual of the multimeter (e.g. from the web) so that you can choose a R such that you have good sensitivity to the measurement of R_m. How does your measurement of the multimeter's resistance compare to the specs of the meter?
Note: Prove the formula first before measuring R_m so that you construct the proper circuit.

3) The RMS (Root Mean Square) value of a voltage (or current) is defined as

$$V_{RMS} = \sqrt{\frac{1}{\tau}\int_0^{\tau} V^2 dt}$$

Show that $V_{RMS} = V_0/\sqrt{2}$ for a sine wave voltage, $V = V_0 \sin\omega t$. Don't use program such as Mathematica or Maple for the proof as it only demonstrates that you know how to use the program rather than how to do the integration. This result is only valid for a sine wave voltage. If the input is a sine wave riding on a DC offset, you must use the original formula to compute the RMS voltage.
Note: The multimeter only measures the RMS value of a voltage or current.

4) This exercise is intended to make you familiar with some of the very useful functions of the oscilloscope. Send a 1 kHz sine wave with an amplitude of 0.5 V and DC offset of 0.5 V into the scope. Use **DC coupling** between the scope and the function generator (See the instruction manual for definitions of DC and AC couplings. Push the CH1 or CH2 MENU button to select the desirable coupling from the menu.)
a) Calculate the expected RMS voltage.
b) Use the scope to capture the sine wave with time stamp.
c) Use the "MEASURE" button to measure the following quantities: mean, RMS voltage, peak-to-peak voltage, period, and frequency. Do the measured quantities agree with the expectations?
d) Use the "CURSOR" button to position the two cursors to measure the peak-to-peak voltage and period. Do the measured quantities agree with the expectations?
e) Measure the RMS voltage with an **AC coupling** between the scope and the function generator. Does the measured RMS voltage agree with the expectation?

5) Repeat part 1) using a 10 Hz (or as low frequency as practical) sine wave. Repeat measurements using a much higher (e.g. 1 kHz) frequency sine wave. You should collect four (= 2 x 2) sets of data. Fit your data to a straight line and compare the extracted slope and intercept of each fit to the expectations. Any frequency dependence for R?
Note: Use a multimeter for the current measurement and an oscilliscope for the voltage measurement. All of our multimeters measure current and voltage over a limited frequency range. Check the spec sheet for your meter's usable frequency range.

6) Design and build a circuit with the following specs:

a) four or more different resistors

b) resistors in series and parallel

c) circuit draws between 10 and 50 milliamps when connected to 5 V DC.

Calculate and measure the voltage drop and current through each element in the circuit, with measuements and theoretical expectations summarized in a table.

7) Use the oscilloscope to check the frequency calibration of your function generator. Start at about 10 Hz and go up to the highest frequency available. Present your results in a log-log plot. Fit the plot to a straight line,

$$f = f_{offset} + cf_0$$

How is your measured c compared to the value expected for an ideal function generator? Is the extracted f_{offset} consistent with the expectation for an ideal function generator?

Optional Advanced Experiment (10 point)

1) Measure the input impedance of your oscilloscope. Determine the effective values of R and C and compare with the scope's specs. Use a resistor divider to measure R and a capacitor divider to measure C. Include in the report the two formulas used in the calculation.