Introduction

This lab familiarizes you with the basics of instrumentation. The lab introduces you to resistors, capacitors, diodes and light emitting diodes (LEDs). You will have an opportunity to build and test electronic circuits and in the process get acquainted with the different laboratory equipments such as breadboard, oscilloscope, multimeter, and other systems you plan to use in your career as an electrical/biomedical engineer.

Resistors and capacitors are circuit elements that impede current flow. Ohm's law is $v = iR$, and says that the voltage across something is equal to the current through that thing times its resistance (or impedance). Current can be direct current (dc), which has a frequency of 0 Hz, or it can be alternating current (ac) with a frequency of >0 to ∞ Hz. Resistors impede current flow the same amount for any frequency. Their value of impedance is always R Ω (ohms). The impedance of a capacitor is dependent on the frequency of current through it. Its value of impedance is $1/(j\omega C)$, where C is the capacitance value expressed in farads (F) and $\omega = 2\pi f$ is the frequency in radians/s whereas f is the frequency in cycles/s (Hz). Because a capacitor's impedance varies with frequency, we can use it to make a filter. A filter is a circuit that minimizes unwanted frequencies. Filters built with resistors and capacitors are called passive filters.

We will study half-wave rectification using diode. Rectifiers are circuits that convert an ac voltage into a dc voltage. We will determine the voltage required to light the LED and the current and voltage to start a dc motor.

Electric current can stimulate the nerve and muscles and cause a tingling sensation or a shock. The amount of current required to cause a shock increases with frequency. We will estimate the threshold for perception of current by passing current through the arm at different frequencies.

Before the lab: Read material about electronics from J. G. Webster (ed.), *Bioinstrumentation*, Chapter 2 at the course page http://ecow.engr.wisc.edu/cgi-bin/get/bme/310/webster/

More detailed information is in Horowitz, P. and W. Hill, *The Art of Electronics*, 2nd ed. Cambridge: Cambridge University Press, 1998.

Laboratory Equipment

1. Resistors, capacitors, op amps
2. Bread board
3. HP 33120A signal generator
4. HP 54600B oscilloscope
5. HP 34401A digital multimeter
6. HP E3630A dc power supply

Procedure

A. Lab Equipment
1.   Turn on dc power supply and digital multimeter (DMM).
2.   Adjust the power supply to 15 V using the knob labeled 20 V.

3.   Press the DC V button on the DMM. Plug one end of one cable into the COM port on the power supply and the other end into the GND port on the DMM. Plug one end of the other cable into the +20 V port on the power supply and the other end into the top right port of the DMM. Record the voltage and verify that the voltage displayed is close to +15 V.
4.   Remove the cable from the +20 V port on the power supply and plug it into the – 20 V port. Record the voltage and verify that the voltage displayed on the DMM is close to –15 V.
5.   Turn dc power supply off.
6.   Unplug both cables from the dc power supply.
7.   Press the 2Ω button on the DMM. This will allow us to measure resistance.
8.   Measure the resistances of the resistors in front of you and record their values.
9.   Turn on the oscilloscope and waveform generator.
10.   Connect probe 1 to the waveform generator. Make sure channel 1 is selected on the oscilloscope. Press the AUTO-SCALE button.
11.   Press the VOLTAGE button on the oscilloscope and then press the button at the bottom of the display under V P-P. Record the peak-to-peak voltage of the waveform on the screen.
12.   Press the TIME button on the oscilloscope and then press the button at the bottom of the display under FREQ. Record the frequency of the waveform on the display.
13.   Verify that the voltage and frequency shown on the oscilloscope are the same as shown by the waveform generator.
14.   Change the frequency and voltage of the waveform generator by pressing the FREQUENCY and AMPLITUDE buttons, respectively, and adjusting the knob accordingly. The values can also be changed by keying in the actual numerical values desired. Record the effects of changing the frequency and amplitude of the waveform.

B. Measuring voltage and current
15.   Connect the circuit as shown in Figure 1.
16.   Use Ohm's law to calculate the voltage across the resistor and the current passing through the resistor.
17.   Connect the ammeter and voltmeter as shown in the Figure# to measure the voltage across the resistor and the current passing through the resistor.
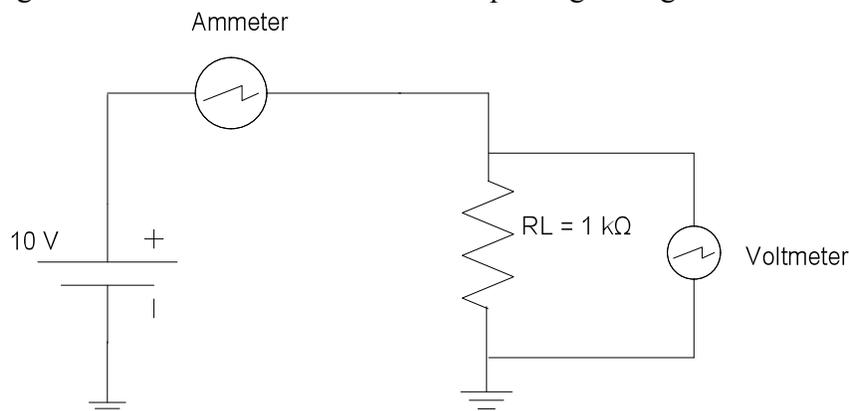

Figure 1 Measurement of current and voltage

C. Half-wave rectification
18.   Connect the circuit as shown in Figure 2.
19.   Use a signal generator and set the voltage to 0.1 V and frequency of 20 Hz. Observe the voltage across the R_L on the oscilloscope and record the value/output waveform.
20.   Increase the voltage in step of 0.1 V till 2 V and record the value/waveform.
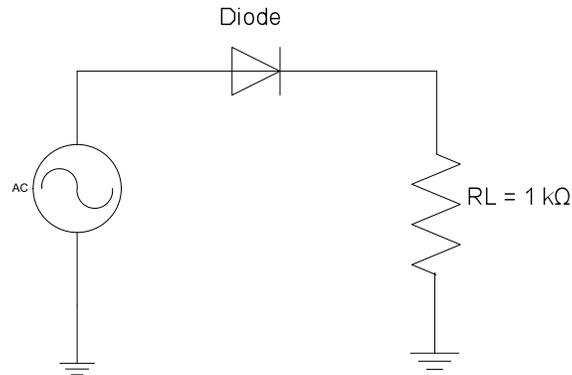21.   Based on the data comment on the output from a rectifier circuit.

Figure 2 Half-wave rectifier circuit

D. LED
22.   Connect the circuit as shown in Figure 3.
23.   Increase the voltage from the dc power supply until the LED lights up. Record the voltage need to light the LED also record the current it draws.
24.   What happens if you were to increase the voltage? Do not increase the voltage by a lot otherwise the LED with blow off.
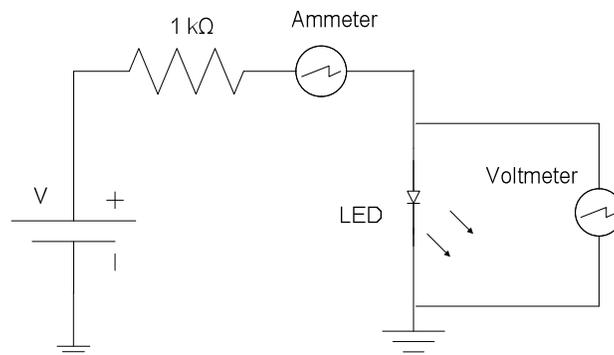
Figure 3 LED circuit

E. DC motor
25.   Connect the circuit as shown in Figure 4.
26.   Increase the voltage from the dc power supply until the motor starts to spin. Record the voltage need start to motor also record the current it draws.

27.   What happens if you were to increase the voltage? Do not increase the voltage by
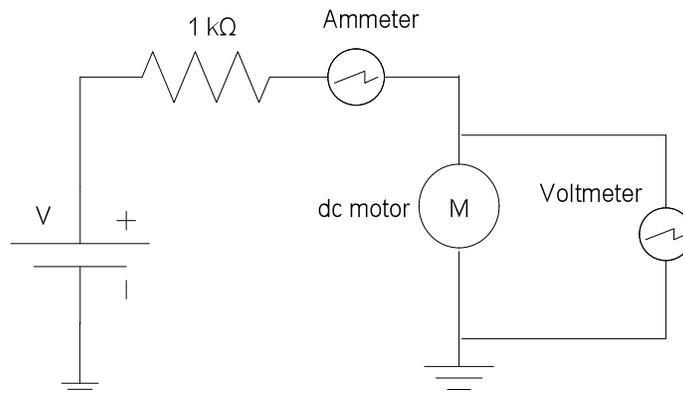   a lot otherwise you might damage the motor.

Figure 4 DC motor circuit

F. Perception of current
28.   Select frequency of 10 kHz on the signal generator and set the voltage to 20 Vpp.
29.   Connect 1 kΩ resistor in series with two electrodes attached on your arm and
       form a resistor–arm voltage divider as shown in Figure 5
30.   Decrease the frequency in steps of 10 Hz until you feel a tingling sensation.
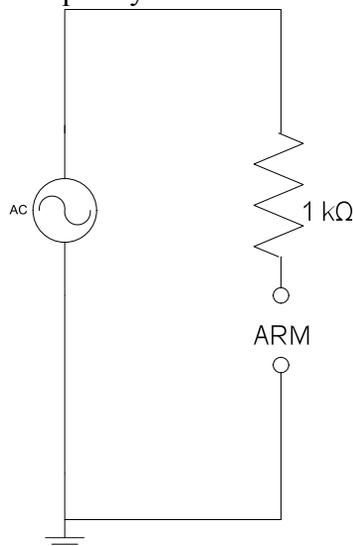   Record the value of the frequency.

Figure 5. Resistor and arm voltage divider.

References
1. Webster, J. G., BME 310 Lab 2 Circuits, 2008.
2. Floyd, T. L., Electronics Fundamentals: Circuits, Devices and Application, 4th edition
Prentice Hall.