1. The experimental results in Lab #5 are graphical images on the display of the oscilloscope. BRING GRAPH PAPER or a digital camera (which can be your cellphone) to the lab!
   1.1. Graph paper with cm×cm grid is best since that is the actual scale of the scope display. You will be sketching the current/voltage characteristics of several devices.
   1.2. In an alternate way, a digital camera can be used to take the picture of the display of the oscilloscope. Then the picture needs to be printed out and submit together with your lab report.
2. Current-voltage (i-v) characteristics of a device.
   2.1. The i-v characteristics of a resistor is linear. The i-v plot shows as a line with the slope of (1/R), i.e. \( i = \frac{1}{R} v \), where \( R \) is the resistance of the resistor according to Ohm’s Law, when the current (\( i \)) and voltage (\( v \)) are set as the y-axis and x-axis in the graph, respectively.
   2.2. The i-v characteristics of a resistor in series with a voltage source is also linear, with \( i = \frac{1}{R} (v \pm V_s) \), where \( V_s \) is voltage source voltage and the sign is determined by the voltage source polarity.
   2.3. The i-v characteristics of a diode is nonlinear.
   2.4. The i-v characteristics of a diode in parallel with a resistor is still nonlinear
**ECE 210 Experiment #5**

**Measure Current-Voltage \((i-v)\) Characteristics with Oscilloscope**

**Purpose:** Learn how to use oscilloscope to measure \(i-v\) characteristics of basic circuit devices such as resistors and diodes, and simple analysis of \(i-v\) plots.

**Equipments:** RIGOL DS2302A Oscilloscope, RIGOL DG831 35MHz Function/Arbitrary Waveform generator, Universal Breadbox

**I. Introduction**

One way to measure the \(i-v\) characteristic of a device is to attach a DC voltage source to it, measure the voltage and current, thus obtaining one \(i-v\) data point in a graph, and then repeat for many times to measure \(i\) at various \(v\). It is much more efficient to use the oscilloscope and the function generator to measure the \(i-v\) characteristics directly and show the \(i-v\) graph on the display screen of the oscilloscope. To do so the technique is as follows:

a. Press the Menu key and then change the time base option to \(XY\) option using the second softkey. This puts the scope into XY mode.

b. Apply the voltage "\(v\)" to the CH1 or "\(X\)" input terminals of the scope, so that the horizontal axis of the scope can be interpreted as "\(v\)";

c. Apply a voltage proportional to "\(i\)" to the CH2 or "\(Y\)" input terminals of the scope, so that the vertical beam deflection is proportional to "\(i\)". This sets up an "\(i\)" vertical axis on the scope;

d. Use an external time-varying source to cause "\(v\)" and "\(i\)" to change through a whole range of values, thus tracing out the \(i-v\) curve, and record the trace on the scope.

This is exactly what will be done in this experiment. The circuit is shown below. Note that the voltage across the 1K resistor is proportional to the current "\(i\)" through the device in question, and its resistance is chosen to be 1K so that this voltage will be 1 V when the device current is 1 mA, making the conversion to current units easy.

It is also important that both CH1 and CH2 be set to DC.
The Circuit Setup
Recall that the black terminal of the scope is the "ground" connection on the scope.
In this technique the voltage applied to the vertical input (to CH2) is \(-R_i\), so that the display will be the shape of the \(i-v\) characteristic. The vertical deflection = \(i\) in mA, and horizontal deflection = \(v\) in volts.
To cause the device to experience a variety of \(i-v\) combinations, so as to trace out the characteristic curve, it is convenient to use the signal generator set to a triangle function. Different sections of the \(i-v\) curve can be viewed by changing the DC offset and the amplitude of the triangle.

II. \(i-v\) Curve Of A Resistor

Set up the circuit with \(NL = 2.7K\) resistor, which is of course a linear device and should result in a linear \(i-v\) characteristic curve, through the origin and with a slope equal to \(1/R\). Position the appropriate axis of both CH1 and CH2 to the center of the scope, which becomes the origin of the \(i-v\) graph. Set the frequency of the signal generator to 60Hz. Display and record the \(i-v\) curve (as much of it as you can get with maximum signal amplitude and maximal variations of the DC offset). Be sure to record this graph in units of Volts (horizontally) and mA (vertically). All graphs in this course should be labeled in electrical units such as these. Compare the measured \(i-v\) graph with the theoretical expectation. If the 1 K resistor in the circuit is significantly different from 1000 ohms you may have to
insert a correction factor for that, or you might try "building" a resistor which measures exactly 1000 ohms.

Turn down the generator frequency to 1 Hz so you can see just what is happening here - a tracing out of a lot of individual \textit{i-v} combinations, so fast at 60Hz that they blend into an apparently solid curve. Incidentally you can do a little experiment here about human perception. Experiment to determine the lowest frequency (in the neighborhood of 20-30 Hz) where the scope trace appears to you to stop flickering and look "solid." Movies and TV must refresh their images at this frequency or faster in order to convey the impression of smooth movement.

III. \textit{i-v} Curves Of Other Elements

Once you understand part II, go on to record the characteristics of other devices, as given in the figures below. The first one is of course a linear circuit and should give a linear \textit{i-v} curve. It is constructed from the DC voltage source in series with a plain resistor. The other devices are not covered in this course but they have interesting \textit{i-v} curves. You don't need to know anything about the diodes in order to graph their \textit{i-v} characteristics! Some devices to try:

\begin{itemize}
  \item Thevenin Equivalent Circuit
  \begin{center}
    \includegraphics[width=0.3\textwidth]{thevenin_circuit}
  \end{center}
  \item Silicon Diode #1N4004
  \begin{center}
    \includegraphics[width=0.3\textwidth]{diode_circuit}
  \end{center}
\end{itemize}
Zener Diode #1N4773
You may need to position the graph to the right so that you can see the details on the left. Try using some negative DC offset if the curve does not break in a downward direction on the left side.

Leaky Diode Simulation

Leaky Zener Simulation

Note: diode polarity (direction) is indicated by a ring, as follows. The ring is the cathode.