# ELE 215 – Lab 1 – Circuit Testing

## Objectives

- To build two simple circuits and test them using the signal generator and oscilloscope; to observe some differences between linear and non-linear circuits.

## Notes

- Circuits are commonly described as having *inputs* and *outputs,* specifically currents or voltages, in which the input is an independent source that is applied to the circuit (e.g. the voltage induced by radio waves on a cellphone's antenna) and the output is the circuit's response to that input (e.g. the voltage that produces the sound coming out of the cellphone's speaker). In our lab the input will typically be a voltage signal created by the benchtop signal generator and the output will typically be a voltage within the circuit as measured by the benchtop oscilloscope.

- Let $a(t)$ represent an input to the circuit and let $b(t)$ represent the circuit's output in response to that input. A circuit is called <u>linear</u> if it follows two rules:
  - If the input is multiplied by a constant, say $c$, so that the input is $c\ a(t)$, then the resulting output is $c\ b(t)$; in other words, the output is scaled by the same constant. And this must hold for all possible inputs $a(t)$ and all possible values for $c$.
  - Let two distinct inputs, say $a_1(t)$ and $a_2(t)$, result in outputs $b_1(t)$ and $b_2(t)$, respectively; then for an input equal to the sum of the inputs, $a_1(t) + a_2(t)$, then the output is equal to the sum of the outputs, $b_1(t) + b_2(t)$. And this must hold for all possible input pairs.

  You will be <u>partially</u> testing the first of these conditions on two circuits today.

- Information on our lab equipment for today, the Keithley 2110 Digital Multimeter, the TEK AFG 1022 Function Generator, and the TEK TBS2000 Oscilloscope, can all be found via links on the ELE 215 website.

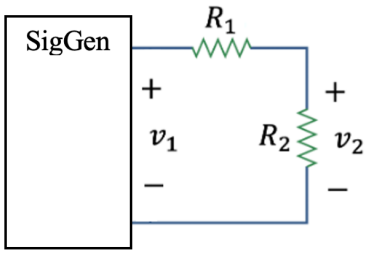
- Each pair of assigned students completes and submits <u>one</u> laboratory summary report via Brightspace. Follow the instructions at the end of this document and as presented at the first ELE 215 recitation meeting.

## Procedure

1. <u>Build the first circuit</u>:

   a) Pick two resistors with the <u>same</u> nominal value from the bins; choose this value to be between 10 k and 50 k ohms:
      - Measure their actual resistance values using the digital multimeter (DMM); if they are not close, reselect the resistors.
      - Record the values on the summary sheet. <u>Be sure to include units</u>.

b) Using a breadboard (or even just alligator clips), build the simple circuit shown below with your two resistors $R_1$ and $R_2$:
   - Connect the signal generator (SigGen) as the source on the left, $v_1$.
   - Set the signal generator to produce a sinusoid at a frequency of 1 kHz with amplitude equal to one volt (equivalently, 2 volts peak-to-peak).




c) Connect two channels of the oscilloscope (scope) to measure the signal generator's output, $v_1$, and the resistor voltage, $v_2$. You should see two aligned sinusoids with different amplitudes, $v_2$ equal to just about one-half of $v_1$.
   - Set both channels for DC coupling.
   - Adjust the vertical alignments of the two channels so that the zero volt lines of each are on top of each other (this is as simple as aligning the small triangles at the left end of each trace).
   - Set the vertical scaling of both channels to be equal.
   - Adjust the time scale so that you see between one and two full cycles of the sine functions.
   - Call your TA over to verity this result. If you've done this correctly you should see two overlapping sinusoids aligned in time with identical zero crossing but different amplitudes.

   The summary sheet provides multiple sets of axes for you to sketch what you observe on the scope. Accurately sketch one cycle of $v_2$ as a function of time on the first set of axes; one cycle of the signal $v_1$ is already shown for you as a dotted line. Make this sketch as accurate as you can; points will be deducted for sloppy work. And use a dark enough pencil or pen so that I can clearly see your result. Since this circuit is linear, the output should be a scaled version of the input. This result of identical shapes for the input and output is a characteristic of resistive circuits and we will discuss this more in ELE 212.

2. Test the first circuit for linearity:

Let's check the first requirement stated above for linearity of this resistive circuit:

a) Change the amplitude on the signal generator to 5 volts (equivalently 10 volts peak-to-peak). Sketch how your circuit responds on the second set of axes on the summary sheet. Again, the input is already drawn for you and you should make your sketch as accurate as possible.

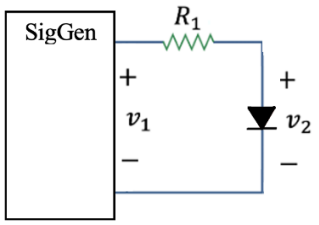
b) Reduce the amplitude back to 1 volt and change the waveform shape on the signal generator to a square wave. Sketch how your circuit responds on the third set of axes. Then change the amplitude to 5 volts and sketch again. In both cases the axes on the summary sheet show the input square wave as a dashed line.

Ideally, if you've done these parts correctly, you've seen that this circuit behaves like a linear circuit. Increasing the amplitude of the sine wave demonstrated the first condition of

linearity; repeating the test with the square wave shows that this holds for another input signal. Of course, this is not exhaustive in that we did not try all multipliers and all waveform shapes, but it was a good first attempt. Nor did we assess the second condition. We will discuss linearity in more detail in ELE 212 lecture; it is a tremendous asset when trying to analyze circuit performance.

3. Build and test a "nonlinear" circuit:

   a) Modify your circuit, replacing resistor $R_2$ with an LED as shown to the right. Be sure to get the direction of the LED correct. If you don't remember this from ELE 202, consult the TA.




   b) Repeat the experiments above with the 1 and 5 volt sinusoids, sketching the output voltages that you see.

   If you've done this part correctly you will see very different results than above. For the smaller amplitude you should see identical input and output (in other words, a scaling factor of one) while in the second case the output should not match the shape of the input; hence, this circuit is NOT linear and there is no need to test further. The addition of the LED to the circuit has changed the circuit's characteristics; the "non-linearity" of that single component (and you'll learn more about it next Fall in electronics) makes the circuit much more variable in its response.

4. Reporting: your submission should just be the two pages of the summary sheet:

   a) Scan both sides of the summary form to a single 2-page pdf document. As discussed in recitation last week, this should be a high-quality document. Upload this single document to the ELE 215 Brighspace site – I only need/want to receive one copy of this submission, so choose the student whose last name comes first alphabetically.

   b) To help me in grading, please use the following convention for the filename:

      If the students have HW IDs (not URI IDs) of 987656789 and 123454321, respectively, the filename would be

      `Lab_1_321_789.pdf`

      Specifically,
      - Start with an indicator of the assignment number (capital L please)
      - Accurately include the last 3 digits of each HW ID; the order of students does not matter.
      - Use single underscores to separate things
      - Include the pdf extension