Background
In the labs we have done to date, we have used DC power supplies for our independent current and voltage sources. In this lab, we will study some time-varying signals, and learn how to calculate the effective (RMS) value of periodic signals.
A function generator can generate sinusoidal, square-wave, and triangle-wave periodic voltages. If we try and measure these voltages with a digital voltmeter, using the AC voltage setting, the meter will display a number that represents the RMS or the effective value of the voltage. However, the shape of the voltage waveform is unknown. In order to view the voltage waveform, we will use a test instrument called an oscilloscope. The goal of this lab is to introduce these two pieces of equipment to the student, and demonstrate the basic controls used in setting them up.

Preliminary –
RMS can be done in Mathcad or by calculator.
1) Calculate how the source voltage \( v_s(t) \) should divide between resistors \( R_1 \) and \( R_2 \) in Fig. 1 given \( R_1 = 3.3 \, \text{k}\Omega \) and \( R_2 = 2.2 \, \text{k}\Omega \). Ohm’s Law, Kirchoff’s Current (KCL), and Voltage (KVL) Laws apply to time-varying signals. Therefore, we can still apply the voltage division rule. Record your results in the table below.

\[
\begin{align*}
v_1 &= \phantom{00}\phantom{00} \\
v_2 &= \phantom{00}\phantom{00}
\end{align*}
\]

2) Determine the cyclical frequency \((f = \omega/2\pi)\) of \( v_s(t) = 3 \sin(2000\pi t) \) volts. \( f = \phantom{0000000}\phantom{0000000} \)

3) Calculate the RMS value for \( v_s(t) = 3 \sin(2000\pi t) \). Note that you will be integrating over 1 period, so it will be necessary to determine \( T = 1/f \). Sketch the waveform that you would expect to see on the oscilloscope and label the time of one period and amplitude.

\[
\begin{align*}
\text{RMS of } v_s &= \phantom{0000000} \\
\text{RMS of } v_1 &= \phantom{0000000} \\
\text{RMS of } v_2 &= \phantom{0000000} \\
\text{Frequency of } v_1 &= \phantom{0000000} \\
\text{Frequency of } v_2 &= \phantom{0000000}
\end{align*}
\]
4) Calculate the RMS value for \( v_s(t) = 1 + 3\sin(2000\pi t) \). Sketch the waveform for \( v_s \) that you would expect to see on the oscilloscope and label the time of one period and amplitude.

\[
\begin{align*}
\text{RMS of } v_s &= \underline{\phantom{0000}} \\
\text{RMS of } v_1 &= \underline{\phantom{0000}} \\
\text{RMS of } v_2 &= \underline{\phantom{0000}} \\
\text{Frequency of } v_1 &= \underline{\phantom{0000}} \\
\text{Frequency of } v_2 &= \underline{\phantom{0000}}
\end{align*}
\]

5) Calculate the RMS value for a 1000 Hz square waveform centered on zero (no DC offset) with a peak-to-peak value of 4 volts. (so the signal ranges from \(-2\) volts to 2 volts). Sketch the waveform that you would expect to see on the oscilloscope and label the time of one period and amplitude.

\[
\begin{align*}
\text{RMS of } v_s &= \underline{\phantom{0000}} \\
\text{RMS of } v_1 &= \underline{\phantom{0000}} \\
\text{RMS of } v_2 &= \underline{\phantom{0000}} \\
\text{Frequency of } v_1 &= \underline{\phantom{0000}} \\
\text{Frequency of } v_2 &= \underline{\phantom{0000}}
\end{align*}
\]

**Experimental**

1) Sinusoidal voltage waveform (no DC offset):
   a) Set the function generator to generate \( v_s(t) = 3\sin(2000\pi t) \) volts, and set-up the oscilloscope to view it so that 2 periods of the waveform are shown on the display. Obtain a printout.

   b) Measure the RMS voltage with a DMM and with the oscilloscope and record the readings.

   DMM RMS = \underline{\phantom{0000}}

   Oscilloscope RMS = \underline{\phantom{0000}}

   c) Apply the voltage to the circuit of Fig. 1 and observe how the voltage divides using both the oscilloscope (obtain a printout) and DMM. Record the DMM and oscilloscope RMS readings.

   DMM RMS for \( v_1 \) = \underline{\phantom{0000}}

   Oscilloscope RMS for \( v_1 \) = \underline{\phantom{0000}}

   DMM RMS for \( v_2 \) = \underline{\phantom{0000}}

   Oscilloscope RMS for \( v_2 \) = \underline{\phantom{0000}}

   Note: \( V_1 \) cannot be measured with the oscilloscope by placing the black clip on the negative terminal of \( R_1 \). The black clip on the probe is connected to earth ground, as is the black clip on the signal generator. Hence, putting the black clip on the negative terminal shorts \( R_2 \) and changes the circuit.
2) Sinusoidal voltage waveform (DC offset):
   a) Set the function generator to generate \( v_s(t) = 1 + 3 \sin(2000\pi t) \) volts, and set-up the oscilloscope to view it so that 2 periods of the waveform are shown on the display. Obtain a printout.
   
   b) Measure the RMS voltage with a DMM and with the oscilloscope and record the readings.
      DMM RMS = _________________
      Oscilloscope RMS = _________________
   
   c) Apply the voltage to the circuit of Fig. 1 and observe how the voltage divides using both the oscilloscope (obtain a printout) and DMM. Record the DMM and oscilloscope RMS readings.
      DMM RMS for \( v_1 = \) _________________
      Oscilloscope RMS for \( v_1 = \) _________________
      DMM RMS for \( v_2 = \) _________________
      Oscilloscope RMS for \( v_2 = \) _________________

3) Square voltage waveform (no DC offset):
   a) Set the function generator to generate a 1000 Hz, 2 V\text{peak} (4 V\text{P-P}), square wave with no DC offset, and set-up the oscilloscope to view it so that 2 periods of the waveform are shown on the display. Obtain a printout.
   
   b) Measure the RMS voltage with a DMM and with the oscilloscope and record the readings.
      DMM RMS = _________________
      Oscilloscope RMS = _________________
   
   c) Apply the voltage to the circuit of Fig. 1 and observe how the voltage divides using both the oscilloscope (obtain a printout) and DMM. Record the DMM and oscilloscope RMS readings.
      DMM RMS for \( v_1 = \) _________________
      Oscilloscope RMS for \( v_1 = \) _________________
      DMM RMS for \( v_2 = \) _________________
      Oscilloscope RMS for \( v_2 = \) _________________
**Post-Lab Questions**

1) Where the measured RMS values close to the calculated values? What were the differences?

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Calculated RMS</th>
<th>DMM RMS</th>
<th>Oscilloscope RMS</th>
<th>% Difference of DMM RMS</th>
<th>% Difference of Oscilloscope RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$v_2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Summary of Sine Waveform with a DC Offset

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Calculated RMS</th>
<th>DMM RMS</th>
<th>Oscilloscope RMS</th>
<th>% Difference of DMM RMS</th>
<th>% Difference of Oscilloscope RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$v_2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Summary of Square Waveform with No DC Offset

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Calculated RMS</th>
<th>DMM RMS</th>
<th>Oscilloscope RMS</th>
<th>% Difference of DMM RMS</th>
<th>% Difference of Oscilloscope RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$v_2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2) Did the voltage divide in the same manner a DC?

3) Did any modifications need to be made to use Ohm’s Law, KCL and KVL in AC?

4) Was the RMS reading the same for the DMM and oscilloscope? If not, which would you trust more?

5) Did the frequency change between the input and output voltages?

6) What two methods could be used to see $V_1$ on the oscilloscope? What are the limitations and advantages of each one?