Lab 1 - Electrical Test Instruments

Format
All laboratories during this semester will be conducted by groups of students acting as laboratory partners. However, each student is responsible for learning all of the material. This means that you are expected to rotate roles during the lab. You may ask the lab instructor for assistance if needed, but successful completion of the lab is both required and is your responsibility.

Report
A short, typed report, written independent of all other students in the course, is due at 8:00 AM on the Thursday of the week after you complete this lab. This report is not one of the three (3) FORMAL laboratory reports that you will do for the semester. A template of the expected format is found on the WEB site, www.me.ua.edu/me360/lab.format.pdf, and its form MUST be strictly followed to achieve maximum credit for the laboratory.

In the template you will see that, among other things, there is a section where you are expected to answer questions that are asked within the laboratory procedures documentation. These question are indicated for you by the symbol, \( \Rightarrow \).

Finally, as a reminder of the information covered in the lectures, the minimum requirement for passing this course is that you successfully complete all assigned laboratories and submit a corresponding report.

Introduction
Most modern instruments include electrical elements for measurement, filtering, amplification, and/or display. Mechanical engineers must be knowledgeable in the proper operation of many common electrical test instruments, which include the digital multimeter (DMM), analog and digital oscilloscopes, and the function generator.

Procedures

I. Electrical Measurement Devices – Measuring Voltages with a Digital Multi-Meter (DMM)
A set of four (4) resistors have been installed in a breadboard for this exercise. Voltages of nominally +12V and −12V are applied at each end of the set of resistors as shown in the figure below. You are to use the DMM to measure the voltages between the colored wires on the breadboard given in the table below. (If you need help in the operation of the DMM, read the Tutorial, “Voltage Measurement”, for additional details. Be sure to set the DMM to measure DC voltages. The symbol is \( V-- \).)
Use your measured data to verify the following theoretical equations.

1. \( V_1 = V_2 + V_3 \)
2. \( V_4 + V_5 + V_6 + V_9 = 0 \)
3. \( V_5 + V_6 + V_7 + V_8 = 0 \)
4. \( V_3 = V_4 + V_5 + V_6 + V_7 \)

Discuss possible reasons if any of these theoretical equations are not exactly correct.

II. Electrical Measurement Devices - Measuring Current with a Digital Multi-Meter (DMM)

Use the DMM to measure the current through the resistor network between the 2.2 kΩ and 5.6 kΩ resistors. This requires the DMM to be connected in series with the elements of the circuit. However, in doing so, you must use the proper switch setting on the instrument or you may cause serious, irreparable damage to it. **If you are in any way unclear on this procedure, first read the Tutorial “Current Measurement” and then please ask the lab instructor for assistance!**

- Assume that your measurement of \( V_3 \) is correct and use your knowledge of series resistors to compute the current through each resistor. Compare this computed current to your measured current and, if they are different, explain the cause(s).
III. Electrical Measurement Devices - Oscilloscopes

The goal of this exercise is familiarization with the operations of an analog oscilloscope, a digital oscilloscope (*VirtualScope™*) and a function generator. You will use the scope to observe both the input and output waveforms as sine and square waves are applied to an active, first-order, low-pass, RC filter.

1. Connect the ChA (or Ch1) input of the analog scope to the left side of the circuit and the ChB (or Ch2) input of the analog scope to the right side of the circuit as shown in Figure L1-2.

2. Connect the Ch0 input of the digital scope (*VirtualScope™*) to the left side of the circuit and the Ch1 input of the digital scope (*VirtualScope™*) to the right side of the circuit as shown in Figure L1-2.

3. Connect the output of the function generator to op-amp input as shown in the color schematic that will be provided at the experiment station.
   - Use the analog output, typically labeled as 50Ω. Do not use the TTL output on the function generator as its output is used to generate a square wave signal having 0 to 5 volts (0-5V) only.

4. Set the function generator to create a sine wave with a frequency of about 1000 Hz. The exact value is not critical – anything between 950 and 1050 Hz is satisfactory.

Steps #5 through #13 involve the analog scope:

5. Several key settings for the type of analog scopes found in the lab are given in Table L1-1. Adjust the scope to the settings listed for the correct analog scope in the table. You should see some type of sine wave trace on your scope at this point.

6. Set the input switch to "Gnd" (which "grounds" the input). A horizontal line should appear on the scope. The vertical position of this line can be adjusted using the appropriate "Adjust trace vertically" option for your scope. Center the horizontal line vertically on the scope. Switch the input back to DC and the sine wave should re-appear.
7. Several other key adjustments for the scope are shown in Table L1-2. Set your scope to a time scale of 1 millisecond (ms) per division. There should be approximately 10 full cycles of the sine wave on the screen.

8. The vertical sensitivity has two adjustments - coarse and fine. Set the inner knob (fine adjustment) to the "calibrated" position indicated in Table L1-2. You should feel a slight "click" when the knob is in the calibrated position.

•⇒ Note in your report - Check and set the position of the inner knob whenever you use an analog scope, otherwise your voltage readings will be incorrect! This is very important!

9. Set the coarse vertical sensitivity to 1 volt/division.

10. Adjust the amplitude setting on the function generator so that the input sine wave (on ChA or Ch1) has \( V_{p-p} \) (peak-to-peak voltage) of about 5.0 volts (between 4.8 volts and 5.2 volts will be close enough).

11. Adjust vertical sensitivity to the following settings. Return sensitivity to 1 V/div when done.

\[
\begin{align*}
&200 \text{ mV/div} \\
&500 \text{ mV/div} \\
&2 \text{ V/div}
\end{align*}
\]

•⇒ Note in your report what happens to the traces on the screen in each of these three cases.

12. Adjust the sweep rate to the following settings. Return sweep rate to 1 ms/div when done

\[
\begin{align*}
&0.2 \text{ ms/div} \\
&0.5 \text{ ms/div} \\
&2 \text{ ms/div}
\end{align*}
\]

•⇒ Note in your report what happens to the traces on the screen in each of these three cases.
Table L1-1. Key settings on analog oscilloscopes.

<table>
<thead>
<tr>
<th>Model of Oscilloscope</th>
<th>Leader</th>
<th>Omega</th>
<th>Tektronix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input switch</td>
<td>AC - Gnd - DC (lever)</td>
<td>DC - AC - Gnd (slide)</td>
<td>AC – Gnd – DC (slide)</td>
</tr>
<tr>
<td>Single input setting</td>
<td>Vmode - Ch1</td>
<td>CH 1 Norm (out)</td>
<td>Vertical Mode – CH 1</td>
</tr>
<tr>
<td>Triggering</td>
<td>Mode - Auto</td>
<td>Trigger Selector – AC</td>
<td>Norm (in)</td>
</tr>
<tr>
<td></td>
<td>Coupling - AC</td>
<td>Ext. Trig. (out)</td>
<td>INT – CH 1</td>
</tr>
<tr>
<td></td>
<td>Source - Ch 1</td>
<td></td>
<td>Source - INT</td>
</tr>
<tr>
<td>Adjust trace vertically</td>
<td>‡ Position</td>
<td>Y-POS 1</td>
<td>‡ Position</td>
</tr>
</tbody>
</table>

Table L1-2. Key adjustments on analog oscilloscopes.

<table>
<thead>
<tr>
<th>Model of Oscilloscope</th>
<th>Leader</th>
<th>Omega</th>
<th>Tektronix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjust sweep rate</td>
<td>Time / Div</td>
<td>TIMEBASE</td>
<td>SEC/DIV</td>
</tr>
<tr>
<td>(Horizontal sensitivity)</td>
<td>0.1 - 50 ms, 0.2 - 50 µs</td>
<td>0.1-200 ms/DIV, 0.5-50 µs/DIV</td>
<td>0.1-0.5 s, 0.1-50 ms, 0.5-50 µs</td>
</tr>
<tr>
<td>Vertical calibration</td>
<td>Rotate inner knob full CW (UnCal light is OFF)</td>
<td>Rotate inner knob full CCW</td>
<td>Rotate inner knob full CW</td>
</tr>
<tr>
<td>Vertical sensitivity</td>
<td>Volts / Div</td>
<td>Y-AMPL. 1</td>
<td>CH 1 VOLTS/DIV</td>
</tr>
<tr>
<td></td>
<td>0.1 - 5 V, 5 - 50 mV</td>
<td>0.1-20 V/DIV, 5-50 mV/DIV</td>
<td>0.1-50 V, 2-50 mV</td>
</tr>
</tbody>
</table>
Steps #14 through #20 involve the digital scope (often referred to as *VirtualScope™*):

13. Set the function generator to create a sine wave with a frequency of about 1000 Hz.

14. Click the button labeled “Auto Setup” – you should get two sine wave traces approximately centered on the screen.

15. The vertical sensitivity (upper right-hand corner) can be set independently for each channel. Set the coarse vertical sensitivity to 1 volt/division for both channels.

16. Adjust the vertical sensitivity for each channel to the following settings. Return the sensitivity to 1 V/div when done.

   \[
   \begin{align*}
   200 \text{ mV/div} & \quad 500 \text{ mV/div} & \quad 2 \text{ V/div}
   \end{align*}
   \]

   •⇒ Note in your report what happens to the traces on the screen in each of these three cases.

17. Adjust the sweep rate to the following settings. Return the sweep rate to 1 ms/div when done.

   \[
   \begin{align*}
   0.2 \text{ ms/div} & \quad 0.5 \text{ ms/div} & \quad 2 \text{ ms/div}
   \end{align*}
   \]

   •⇒ Note in your report what happens to the traces on the screen in each of these three cases.

18. Save the data shown on the *VirtualScope* screen for each of the 3 cases given in #17 to an ASCII text file by clicking the *File/Save Waveforms* option along the top of the screen.

   *While still in the lab, test each of your 3 data files by importing them into Excel for subsequent calculations and plotting. If you cannot open the file in Excel (see sample below), then you have not stored it correctly in VirtualScope.*

•⇒ Out of Lab:

   Use Excel to prepare three plots of the three sets of data collected in Step #18 above. Follow all of the rules for plotting and graphing of technical data as given in the ME 360 course manual.

Sample Text File from VirtualScope:

<table>
<thead>
<tr>
<th>National Instruments VirtualBench-Scope V1.00 Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date Created: 9/7/00 2:18:12 PM</td>
</tr>
<tr>
<td>START DATA</td>
</tr>
<tr>
<td>Time Ch 1 Ch 2</td>
</tr>
<tr>
<td>0.000000   -1.762695</td>
</tr>
<tr>
<td>2.000000E-5 -1.765137</td>
</tr>
<tr>
<td>&quot;         &quot;</td>
</tr>
<tr>
<td>0.002000   1.313477</td>
</tr>
<tr>
<td>0.002020   2.236328</td>
</tr>
<tr>
<td>&quot;         &quot;</td>
</tr>
<tr>
<td>0.009980   2.231445</td>
</tr>
<tr>
<td>0.010000   2.231445</td>
</tr>
</tbody>
</table>
Description of VirtualBench controls:

1. Input channels (Ch1, Ch2, or both) - button is "push ON / push OFF"
2. Timebase selector (click on dial with mouse, hold left button, then rotate)
3. Timebase setting (adjusted with #2)
4. Vertical position for the trace (the triangle indicates the current setting)
5. Vertical sensitivity adjustment (Note in your report the channel setting above dial)
6. Vertical sensitivity setting (adjusted with #5)
7. Measurements of selected trace (frequency & period require 2-3 cycles)
8. Single sweep or continuous Run push-buttons

Figure L1-3. VirtualScope panel.
**Things to remember about your laboratory write-ups:**

- Be clear and thorough.
- Do not make your reader work to understand.
- Use a table, if necessary, to present all relevant measurements.
- Emphasis is on your presenting the material in a clear and informative manner. If you do not present a sufficient description, then you are not being informative. At the same time, if you fill the page with garbage, then you are being obstructive, not informative. Strike a balance that indicates that you *understand*
  - What you did and
  - What you found.

I cannot stress this enough: you must demonstrate

A. That you understand the material and
B. That you can convey the relevant information to an educated reader.

Remember: incomplete explanations indicate a lack of understanding, but at the same time, wordy, long-winded explanations can be demonstrations of a lack of understanding, too, *EVEN IF* some part of the explanation actually hits the mark.