Basic DC Meter Design
ECE 2100 Circuit Analysis Laboratory
updated 6 September 2016

Equipment and Supplies

<table>
<thead>
<tr>
<th>Equipment</th>
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<tbody>
<tr>
<td>Meter Movement (0-100µA)</td>
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<tr>
<td>DC Voltage Source, 0 to 12V</td>
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<tr>
<td>Digital Multimeter (DMM)</td>
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<tr>
<td>Breadboard w/ Hookup Wire</td>
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<tr>
<td>Assortment of 1/4 W resistors</td>
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<tr>
<td>1kΩ ¼W resistor</td>
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<tr>
<td>100kΩ ¼W resistor</td>
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<tr>
<td>Banana-to-Banana Plug Cables w/ Alligator Clip Adapters</td>
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Pre-Laboratory Assignment

1. Design an ammeter with full scale current $I_{FS}$ equal to 5 mA using a meter movement rated at 0.5 mA and 100 mV.

2. Design a voltmeter with a full scale voltage $V_{FS}$ equal to 10 V using the meter movement specified in pre-lab part 1.

Procedures

Part One

1. Determine the value of $r_m$ for a meter movement by measuring the voltage across the meter movement when the current is full scale. **Place a large resistor in series with the meter movement when determining $r_m$.**

2. Using the measured data for your meter movement, design and construct an ammeter with $I_{FS}$ equal to 5 mA.

3. Using the test circuit of Figure 1, compare your designed ammeter measurements to measurements obtained using a standard ammeter (your digital multimeter) for several values of current $I$. Vary the source voltage $V_S$ and note that both the standard and designed ammeters see the same current. Your choice of $V_S$ values must insure that the full current range is tested. Tabulate and compare your results. Compute the average error for your ammeter design by assuming that the standard ammeter provides perfect measurements.
Part Two

4. Using the measured data for your meter movement, design and construct a voltmeter with \( V_{FS} \) equal to 10 V.

5. Using the circuit of Figure 2, compare your designed voltmeter measurements to the measurements obtained with a standard voltmeter (your digital multimeter) for different values of \( V_S \). Your choice of \( V_S \) values must insure that the full voltage range is tested. Tabulate and compare your results. Compute the average error for your voltmeter design by assuming that the standard voltmeter provides perfect measurements.
<table>
<thead>
<tr>
<th>$V_S$</th>
<th>designed voltmeter voltage</th>
<th>standard voltmeter voltage</th>
<th>% error</th>
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average % error:

**Figure 2. Voltmeter Test Circuit**

**Part Three**

6. Consider the following circuit. Calculate the voltage $V$ in terms of $V_S$, $R_1$ and $R_2$.

**Figure 3. Voltage Divider Circuit**
7. Set the source voltage to 12V. Using relatively small standard resistors available to you (R1 = R2 = 1kΩ):
   a. Calculate the value of V.
   b. Construct the circuit and measure voltage V using the standard voltmeter.
   c. Measure the value of V using the designed voltmeter.
   d. Compare your results. Explain any discrepancies.

8. Set the source voltage to 12V. Using relatively large standard resistors available to you (R1 = R2 = 100kΩ):
   a. Calculate the value of V.
   b. Construct the circuit and measure voltage V using the standard voltmeter.
   c. Measure the value of V using the designed voltmeter.
   d. Compare your results. Explain any discrepancies.

Analysis

A calibration curve enables correction of measurements by plotting standard measurements (in this case from the assumed perfect digital multimeter) on the y-axis vs. actual measurements (from the designed meter) on the x-axis. To find the true value of an actual measurement, locate the actual measurement on the x-axis, and then locate the corresponding standard measurement on the y-axis. A perfectly calibrated meter would exhibit a straight line calibration curve passing through the origin at a 45° angle.

1. Draw the calibration curve for your ammeter using the data of laboratory procedure step 3. Be sure to include the full dynamic range (0 mA ≤ I ≤ 5 mA) for which the device was designed. Your results must be done using a spreadsheet. Be sure that all points, axes, and curves (use a legend) are suitably labeled.

2. Draw the calibration curve for your voltmeter using the data of laboratory procedure step 5. Be sure to include the full dynamic range (0V ≤ V ≤ 10 V) for which the device was designed. Your results must be done using a spreadsheet. Be sure that all points, axes, and curves (use a legend) are suitably labeled.

3. Using an appropriate circuit model, verify the voltage values measured by the designed meter in laboratory procedure steps 7 and 8 (hint: add a resistor to model the effect of the designed meter on the measured voltages).

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Adapted from material developed by current and former ECE faculty, including Professors Joseph Kelemen and Frank Severance, and input from ECE laboratory instructors.
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