Basic DC Meter Design
ECE 2100 Circuit Analysis Laboratory
version 11 November 2021

Equipment and Supplies

Item
Meter Movement (0-100µA)
DC Voltage Source, 0 to 10V
Digital Multimeter (DMM)
Breadboard
Hookup wires
Resistor Substitution Box
1kΩ 1/4W resistor (2)
100kΩ 1/4W resistor (2)
Banana-to-Banana Plug Cables
SAFETY GLASSES

Learning Outcomes

Students will:
1. Design and validate a meter-movement based ammeter and voltmeter, including characterization of the error between the designed meters and a DMM.
2. Prepare a calibration curve.
3. Explore limitations of the designed voltmeter.
4. Determine if the designed ammeter and voltmeter meet a desired accuracy specification using experimental data.

Pre-Laboratory Assignment (STEPS 1-2)

1. Design an ammeter with full-scale current I_{FS}=5mA using a 100µA meter movement with resistance r_{mm}=2.4kΩ. Be sure to show the design schematic.

2. Design a voltmeter with full-scale voltage V_{FS}=10V using the meter movement of pre-lab step 1. Be sure to show the design schematic.

Procedures

Ammeter Design and Validation

1. Construct the circuit of Figure 1 using your designed ammeter.

   Before connecting the power supply, DISABLE its output using the OUTPUT button (not illuminated). Set the power supply voltage to 0V and current limit to as near 6mA as possible.

   Your DMM, configured as an ammeter, is the ‘standard,” and your designed ammeter is the “design.”

   Ask your lab instructor to check your circuit before applying power.

2. Enable power supply output via the OUTPUT button.
   Starting at 0V, **SLOWLY** vary the power supply voltage so that current I_S varies from 0 to 5mA.

3. Measure and record at least ten cases of Vs (from your internal power supply voltmeter), the current I_S as measured by your DMM and designed ammeter, so I_S is spaced about equally over the 0-5mA range. Use the format of Table 1.

4. Set power supply to 0V and turn it off.

5. Compute the average error for your ammeter design assuming that the "standard" ammeter (your DMM) provides perfect measurements.

   DO NOT PROCEED unless your "standard" and "design" current values closely match.

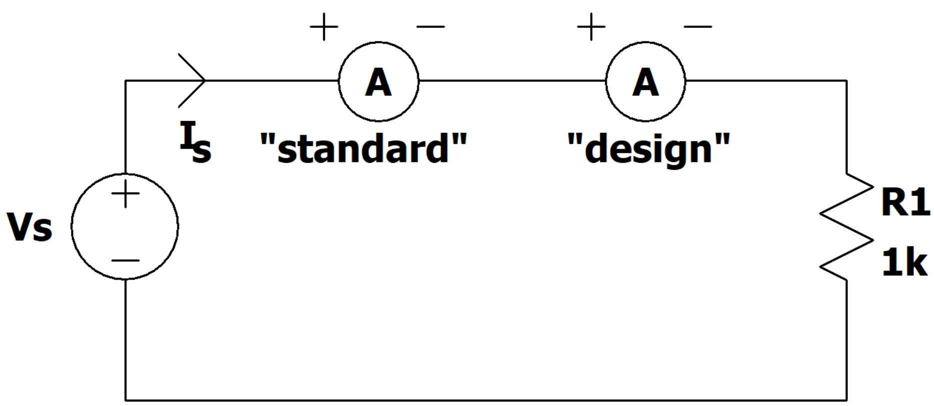

Figure 1. Ammeter test circuit

Vs (V)	**standard ammeter current** (mA)	**designed ammeter current** (mA)	**% error**
0V			
. . .			
		average % error:	

Table 1. Table for ammeter test circuit data

Voltmeter Design and Validation

6. Construct the circuit of Figure 2 using your designed voltmeter.

   Before connecting the power supply, DISABLE its output using the OUTPUT button (not illuminated). Set the power supply voltage to 0V and current limit to as near 120µA as possible.

Your DMM, configured as a voltmeter, is the ‘standard” and your designed voltmeter is the “design.”

Ask your lab instructor to check your circuit before applying power.

7. Enable power supply output via the OUTPUT button.
   Starting from 0V, **SLOWLY** vary the supply voltage so Vs varies from 0 to 10V.

8. Measure and record at least ten cases of Vs as measured by your DMM and designed voltmeter, spaced about equally over the 0-10V range. Use the format of Table 2.

9. Set power supply to 0V and turn it off.

10. Compute the average error for your voltmeter design by assuming that the “standard” voltmeter (your DMM) provides perfect measurements.

    DO NOT PROCEED unless your “standard” and “design” voltage values closely match.

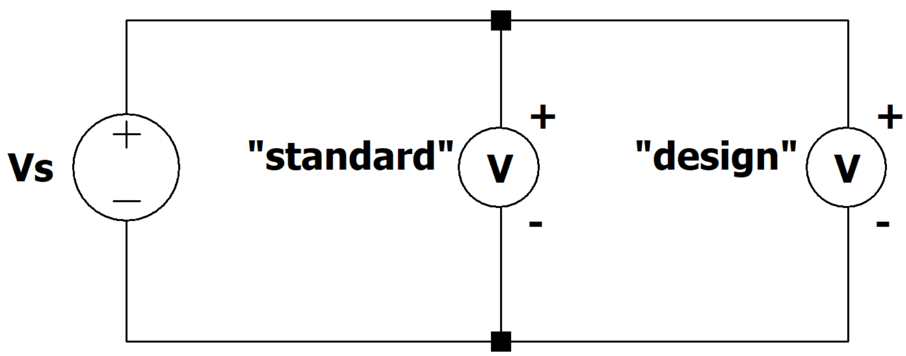

Figure 2. Voltmeter test circuit

V_S	**standard voltmeter voltage** (V)	**designed voltmeter voltage** (V)	**% error**
. . .			
		average % error:	

Table 2. Table for voltmeter test circuit data

Effect of Voltmeter Input Resistance

11. For the circuit of Figure 3 find an equation for voltage V_1 in terms of V_S, R_1 and R_2.
    Find the voltage V_1 for R1=R2=1k and V_S=10V.

12. Construct the circuit of Figure 3 for R1=R2=1k.

    Before connecting the power supply DISABLE its output using the OUTPUT button (not illuminated). Set its voltage to 10V and current limit to as near 6mA as possible.

    Ask your lab instructor to check your circuit before enabling power via the OUTPUT button.

13.
    a. Enable power supply output via OUTPUT button.
       Measure and record V_1.
       DISABLE power supply output.

    b. Connect your designed voltmeter to measure V_1.
       Ask your lab instructor to check your circuit before enabling power via the OUTPUT button.
       Measure and record V_1.
       Turn off power supply.

    c. Compare measurements of (a) and (b). Explain any discrepancies.

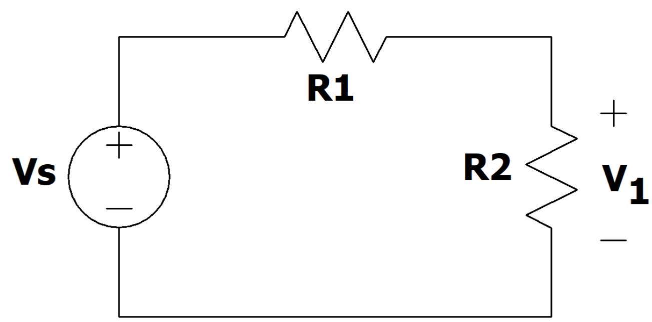

Figure 3. Voltage divider circuit

14. Find voltage V_1 for R1=R2=100k.

15. Construct the circuit of Figure 3 for R1=R2=100k.

    Before connecting the power supply DISABLE its output using the OUTPUT button (not illuminated). Set its voltage to 10V and current limit to as near 120µA as possible.

    Ask your lab instructor to check your circuit before enabling power via the OUTPUT button.

16.
    a. Enable power supply output via OUTPUT button.
       Measure and record V_1.
       DISABLE power supply output.

    b. Connect your designed voltmeter to measure V_1.
       Ask your lab instructor to check your circuit before enabling power via the OUTPUT button.
       Measure and record V_1.
       Turn off power supply.

c. Compare measurements of (a) and (b). 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 45º angle.

1. Draw the calibration curve for your ammeter using the data of Table 1. Be sure to include the full dynamic range ($0 \text{ mA} \leq I \leq 5 \text{ mA}$) for which the device was designed. Use a spreadsheet. Be sure that all points, axes, and curves (use a legend) are labeled.

2. Draw the calibration curve for your voltmeter using the data of Table 2. Be sure to include the full dynamic range ($0\text{V} \leq V_S \leq 10 \text{ V}$) for which the device was designed. Use a spreadsheet. Be sure that all points, axes, and curves (use a legend) are labeled.

3. CRITICAL: Complete the worksheet on the next page. You must attach this as the LAST PAGE of your lab report. **REPORTS WITHOUT A COMPLETED AMMETER/VOLTMETER PERFORMANCE EVALUATION** will not be accepted.

Credits and Copyright

Adapted from material developed by current and former ECE faculty, including Professors Joseph Kelemen and Frank Severance, and input from ECE laboratory instructors. Simin Masihi and Masoud Panahi provided helpful feedback that was incorporated into this lab. Figures drawn using LTspice®

ECE 2100 Laboratory
Ammeter/Voltmeter Performance Evaluation Worksheet
(TWO pages)

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Recall that *specifications* describe WHAT a device is supposed to do and *parameters* describe HOW the device will be constructed to meet the specifications [1].

Suppose that your meter-movement based meters should meet the following specifications.

1. The meter-movement based ammeter must measure a DC current between 0 and 5mA with at least 5% accuracy.
2. The meter-movement based voltmeter must measure a DC voltage between 0 and 10V with an accuracy of at least 5%.

Determine which of these specifications were met, if any, based on your experimental data. Use the following space to report your evaluation.

1. Is it appropriate to use the *average* error to evaluate the specifications? Explain.

2. Complete the table.

Specification	Specification met? (yes or no)	Use this space to **justify** your evaluation using your experimental data
1		
2		

3. If either specification was met, under what conditions can you *guarantee* that the specification will be met?

4. Complete the table.

TEAM MEMBER	**ENGINEERING MAJOR** (Enter N/A if not applicable)
1	
2	

[1] W. H. Middendorf and R. H. Engelmann, *Design of Devices and Systems*, Marcel Dekker, 3rd ed., 1998.