



MARINE INSTITUTE

Electrotechnology 1100

Experiment 8
Voltmeter Design and Voltmeter Loading

SAMPLE CALCULATIONS:

Using your own data, provide one worked sample of each formula used in this Lab.

BASIC INFORMATION

About 90% of all analog meters are based upon the moving coil or D'Arsonval meter movement. The same meter movement could be used to construct meters to measure resistance, current, voltage, frequency, temperature, pressure, etc. Each meter would use a specific circuit to convert the quantity being measured into a current for the moving coil meter movement and have a scale to reflect the quantity being measured.

Analog meters are used at sea because they steal the current they need to work from the circuit being examined without the need for external power. If the circuit works, typically the analog meters work. If an analog meter in an essential circuit fails, typically it can be replaced by an equivalent meter movement from a non-essential circuit or a non-equivalent meter movement can be jury-rigged until permanent repairs can be completed.

Digital meters require external power supplies and fuses to protect the meter. If there is no external power or a fuse blows, the digital meter will not work. This means that operators may not have or lose feedback on essential equipment at a critical time, which may endanger the safety of a ship at sea.

In ELTK1100, we examine the design of three analog meters: ammeter; voltmeter; and ohmmeter. In this experiment, you will design and test one of these meters (voltmeter).

All meters have some negative effect on the quantity they are measuring. They introduce error. In electric circuits, ammeters and voltmeters act as loads. Ammeters steal voltage and voltmeters steal current. Whether this theft is significant depends upon the relative difference between the theft and the quantity being measured.

In designing an analog voltmeter, a resistor called a multiplier is connected in series with the meter movement moving coil resistance. So an analog voltmeter is just a fancy resistor that measures voltage. When you connect the voltmeter in parallel with a resistor to measure voltage, the voltmeter will steal current from the circuit. The closer this meter current (I_{meter}) is to the circuit current (I_T), the more error the voltmeter will introduce.

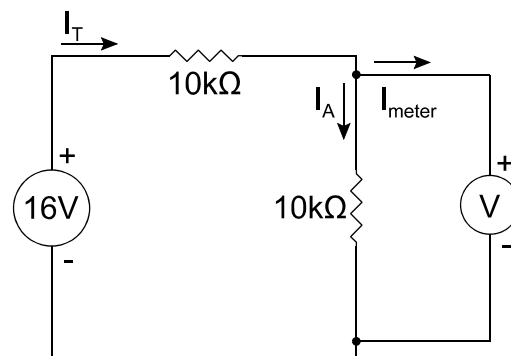


Figure 8-1

In general, as long as the $R_{\text{Meter}} \gg R_{\text{Measured}}$ (voltmeter resistance is much larger than circuit resistance), then the meter will not have a significant effect on the measurement. In this experiment, we will examine this effect, which is called voltmeter loading.

OBJECTIVES:

When you have completed this experiment, you should be able to:

- Design a single range voltmeter.
- Determine the effect voltmeter loading has on voltage measurements.

EQUIPMENT & MATERIALS REQUIRED:

Power Supply:	0-60/70V dc.
Instruments:	Analog Voltmeter. FLUKE 8010A Digital Multi-Meter (DMM)
Resistors:	Two 1k Ω . Two 10k Ω . Two 100k Ω .
Miscellaneous:	1mA, 100 Ω Meter Movement. Resistance Decade Box. Orange board. 3 Black Alligator Clip to Banana Plug test leads. 3 Red Alligator Clip to Banana Plug test leads. Quick clips.

PROCEDURE:

PART A: Voltmeter Design - Design an experimental analog voltmeter.

- A1. Obtain a meter movement from a demonstrator.
- A2. Record the Sensitivity (I_{FSD} - the full-scale deflection current) as shown on the meter movement scale in Table 8-1.
- A3. Convert the Fluke 8010A DMM into an ohmmeter by pressing the buttons shown in Figure 8-2.

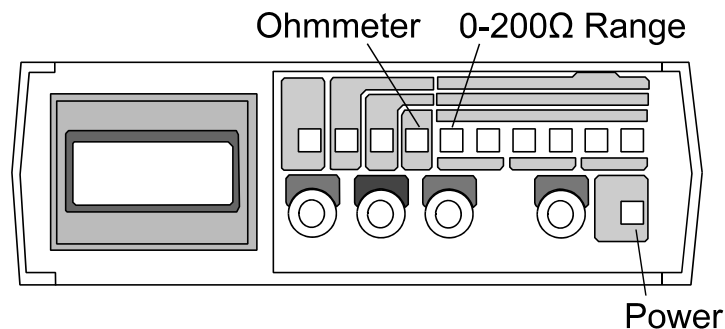


Figure 8-2

- A4. Measure and record in Table 8-1, the actual resistance of the meter movement using the DMM.

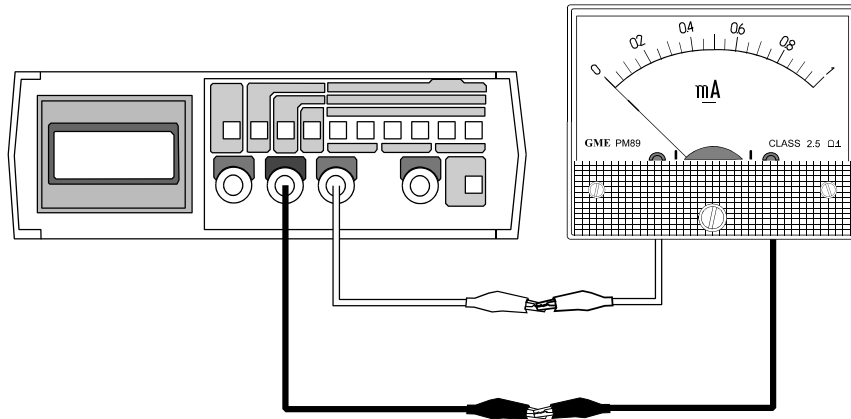


Figure 8-3

- A5. Using the values recorded in Table 8-1, design a 10V voltmeter and record your design values in Table 8-2.

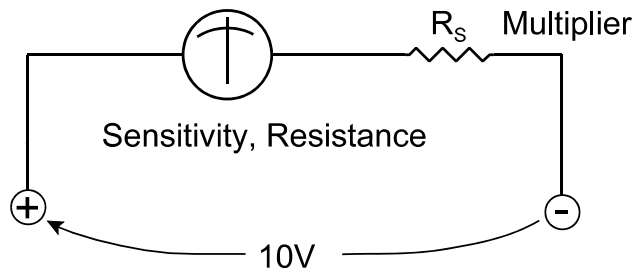


Figure 8-4

- A6. Using a decade box as your multiplier resistance, construct your experimental 0-10V voltmeter as shown in Figure 8-5.

Leave the decade box connected to the meter movement for the rest of the experiment. The series resistor (decade box) converts the meter movement from a device that measures current into a device that measures voltage. $1\text{mA} = 10\text{V}$, $0.8\text{mA} = 8\text{V}$, $0.6\text{mA} = 6\text{V}$, etc.

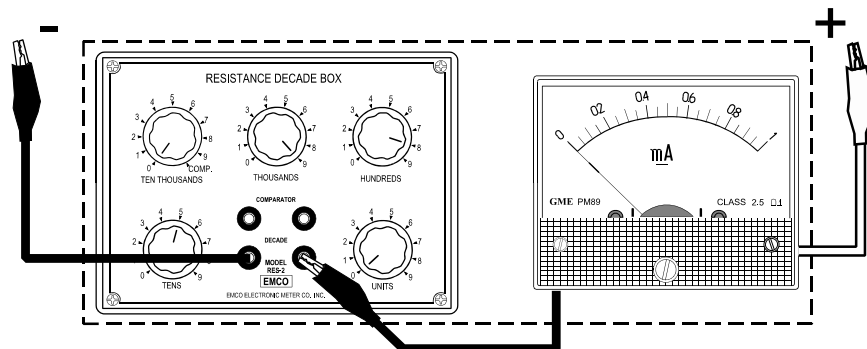


Figure 8-5

- A7. Convert the DMM into a 0-20V DC voltmeter by pressing the buttons shown in Figure 8-6.

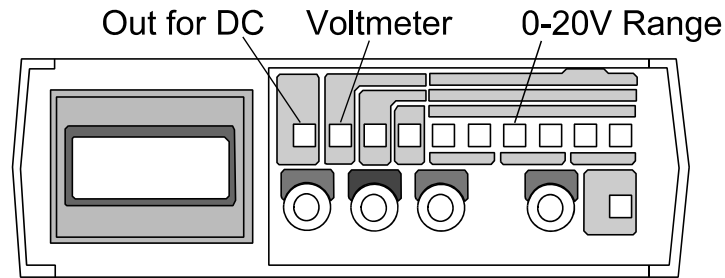


Figure 8-6

- A8. Construct the circuit shown in Figure 8-7 or the pictorial shown in Figure 8-8 to evaluate your experimental voltmeter.

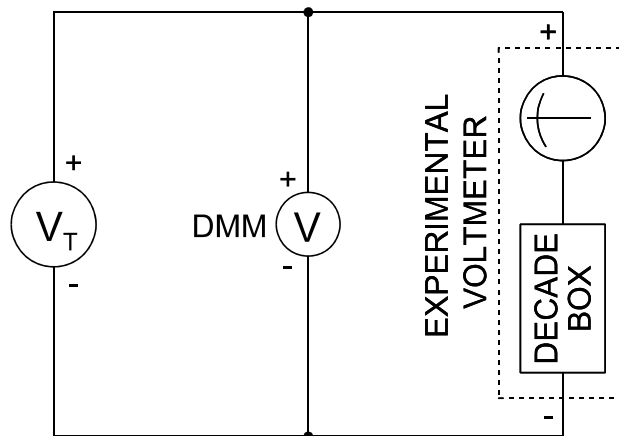


Figure 8-7

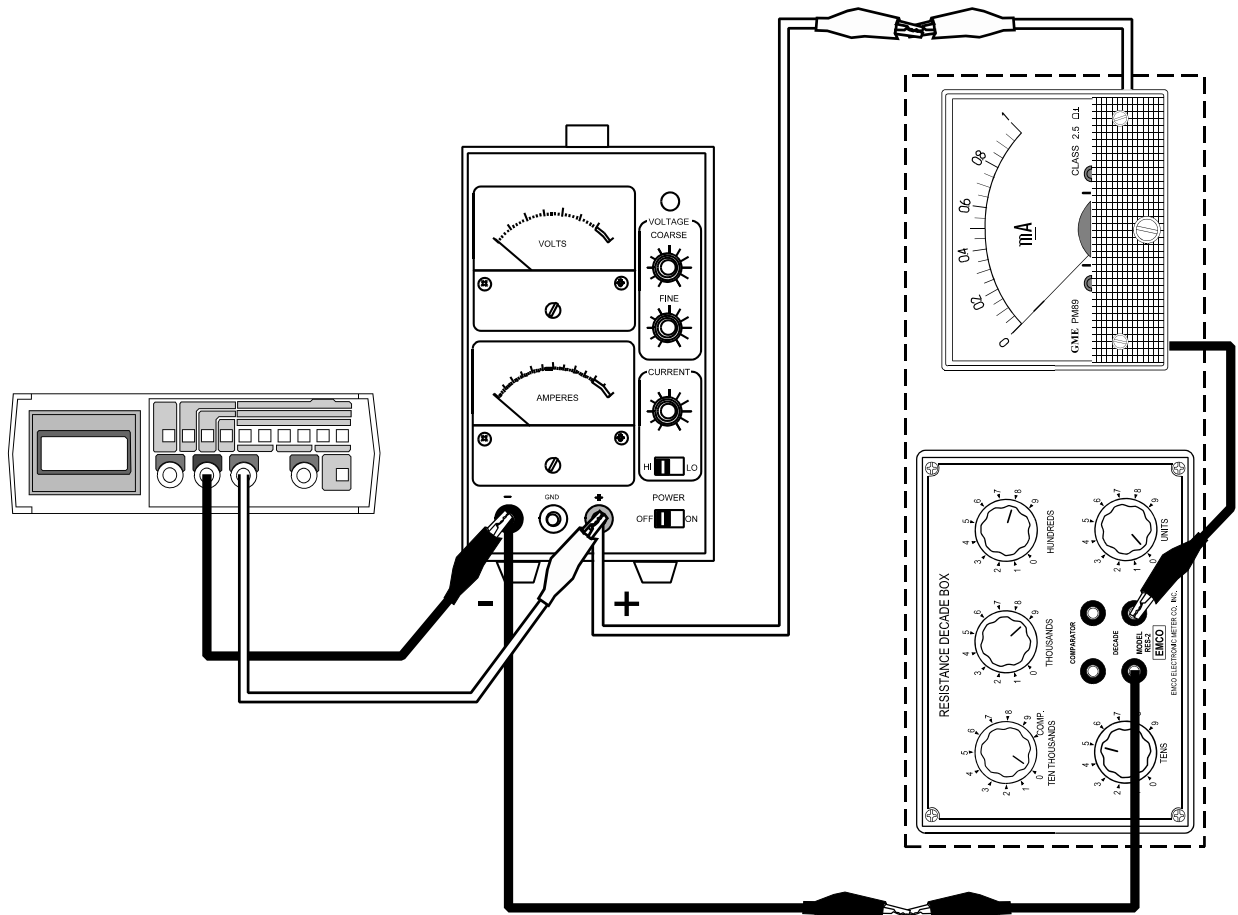


Figure 8-8

- A9. Adjust the power supply until the analog meter reads 2V (0.2mA).
- A10. Read the actual voltage off of the DMM and record in Table 8-3.
- A11. Repeat Steps A9 and A10 for the other voltages in Table 8-3.
- A12. Disassemble the circuit, but do **NOT** disconnect the meter movement from the decade box.

PART B: Voltmeter Loading - Determine the % Error caused by analog meters.

B1. Connect the circuit shown in Figure 8-9.

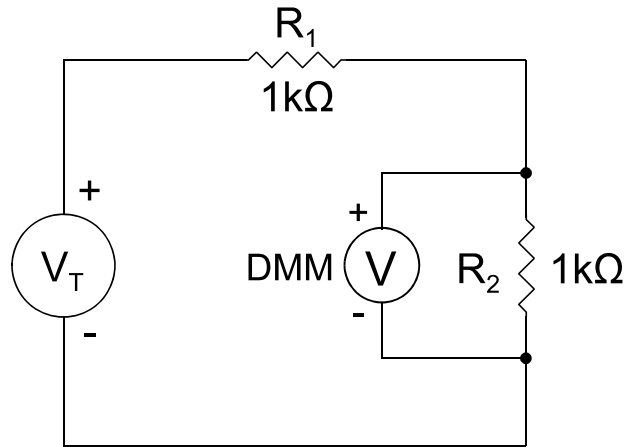


Figure 8-9

- B2. Use the DMM to measure the voltage drop across R_2 . Leave the DMM measuring V_2 for the rest of the Procedure.
- B3. Adjust the power supply until the DMM reads 8V. Do not change this setting for the rest of the measurements. Record this value in the first column (two positions) of Table 8-4.
- B4. Use your experimental voltmeter to measure the voltage drop across R_2 as shown in Figure 8-10. Record the DMM reading in Table 8-4.

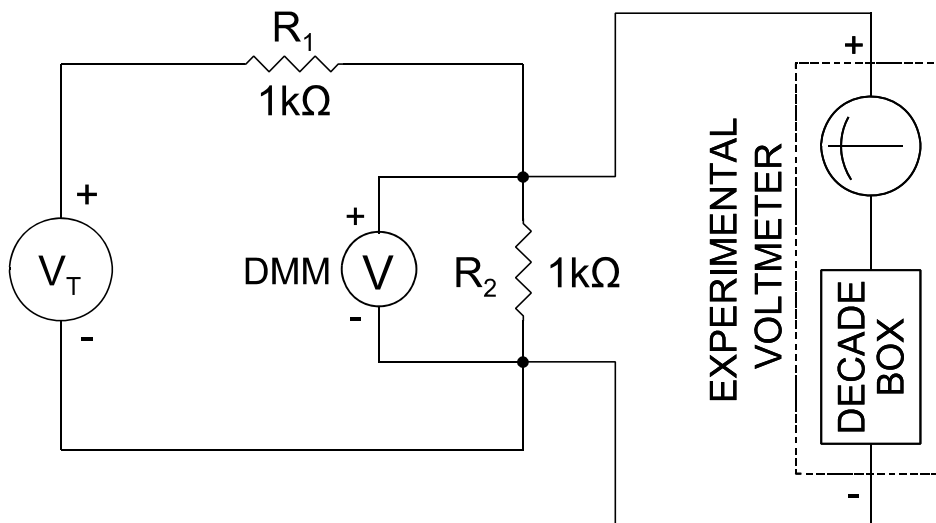


Figure 8-10

B5. Remove the experimental voltmeter.

- B6. Use the analog voltmeter on the 10V range to measure the voltage drop across R_2 as shown in Figure 8-11. Record the DMM reading in Table 8-4.

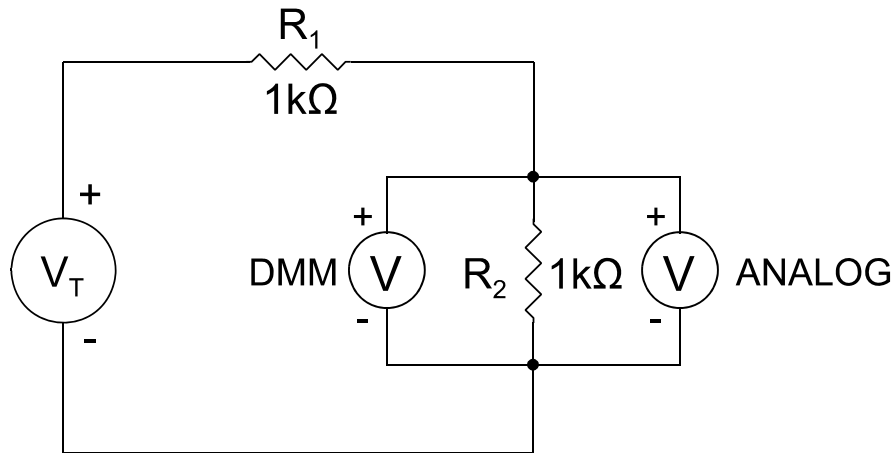


Figure 8-11

- B7. Remove the analog voltmeter.
- B8. Calculate the % Error for both voltmeters using Formula 1.

$$\% \text{ Error} = \left| \frac{\text{Actual} - \text{Measured}}{\text{Actual}} \right| * 100\% \quad \text{Formula 1.}$$

- B9. Repeat Steps B1 to B8 for 10kΩ and 100kΩ resistances and complete Tables 8-5 and 8-6, respectively.
- B10. Record the analog voltmeter's manufacturer and model number.
- B11. Disconnect your circuit and return all equipment to it's proper place.

RESULTS:

Table 8-1 Meter Movement Characteristics

Sensitivity I_{FSD} (mA)	Resistance (Ω)
A2	A4
Step	

Table 8-2 Voltmeter Design

Resistor	Power (mW)	Voltage (V)	Current (mA)	Resistance (Ω)
Total		10		
R_{MM}				
R_S				
Step	A5			

Table 8-3 Experimental Voltmeter Evaluation

Applied	2V	4V	6V	8V	10V
Measured					
Step	A10				

Table 8-4 Voltmeter Loading

1k Ω	V_2 (V) - Actual	V_2 (V) - Measured	% Error
Experimental			
Step	B3	B4	B8
Analog			
Step	B3	B6	B8

Table 8-5 Voltmeter Loading

10k Ω	V_2 (V) - Actual	V_2 (V) - Measured	% Error
Experimental			
Analog			

3. Compare the % Errors between your experimental voltmeter and the analog voltmeter in Tables 8-4, 8-5 and 8-6? What could you conclude about the characteristics (sensitivity, resistance) of the analog voltmeter?

Hint: In which Table are the % errors the closest?

4. Why did the size of the % Error increase as you completed Tables 8-4, 8-5 and 8-6 for both your experimental voltmeter and the analog voltmeter?

5. Analog meters typically have accuracies of 1-2%, but as demonstrated in this Lab, voltmeter loading can cause a significant error on voltmeter readings. Why was voltmeter loading **NOT** a significant source of error in previous experiments?

Hint: Check the Equipment & Materials Required list for previous experiments. Did we use resistors with orange ($\geq 10k\Omega$) or yellow ($\geq 100k\Omega$) multipliers?
