Engr325 **Lab #2** **Winter, 2020**

Calibrating a Measuring Device

Name ___________________________________

Partner (s)_______________________________ **Grade** _______/10

Introduction
The goal of this lab is to understand the need and approach for calibrating an instrument, sensor, or transducer.

Objectives
By the end of the laboratory exercise, you should have accomplished the following:
- Refreshed knowledge of circuits;
- Reviewed operation and use of basic electronic test equipment;
  - Power supply, voltmeter, and bread board.
- Determined calibration constants for an "ohmmeter".

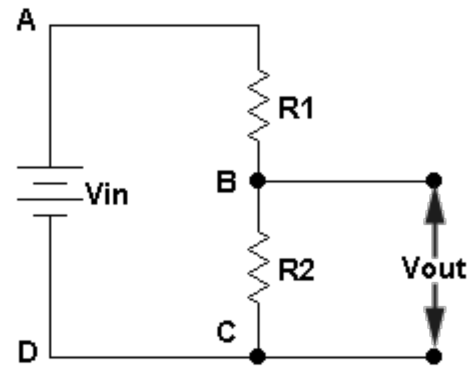
Equipment Provided
- DC Power supply;
- Fluke Benchtop Digital Multi-Meter (DMM);
- Resistance decade box;
- Breadboard;
- Assorted resistors.

References
- Instrumentation text book;
- Course web page.

Procedure - Calibration of an "Ohmmeter"
You are going to be constructing and calibrating a circuit whose purpose is to measure resistance. To do so, you will use a voltage-divider circuit that acts like an ohmeter, and develop a calibration routine to improve the performance of your resistance measuring circuit.

1) Select 3 resistors from the resistor bin: 1kΩ, 10kΩ, and 100kΩ. Do not measure their values until the end of this lab.

2) For the circuit shown at the right, solve analytically for V_{out} in terms of V_{in}, R_1, and R_2.



3) Now, solve your equation from step 2 for R_2.

4) The next step is to determine accurate values for R_1 and V_{in} in your equation in step 3. You will do this by using optimization techniques applied to data gathered when you measure V_{out} as a function of R_2. Wire up the circuit shown above. Use the 3 resistors you selected in step 1 for R_1 (one at a time), and use the decade resistance box where R_2 is indicated in the schematic. Set V_{in} to 5.00V ± 1% and record the actual value below:

V_{in} ____________ VDC

5) Using $R_1 = 1\text{k}\Omega$, fill in the two columns below with your measured values for R_2 and V_{out}. Use four significant figures for all measurements.

R_2 Ideal	R_2 Measured (resistance box)	V_{OUT}
$0.1R_1$		
$0.3R_1$		
$0.5R_1$		
$0.7R_1$		
$0.85R_1$		
R_1		
$1.5R_1$		
$2.5R_1$		
$4R_1$		
$7R_1$		
$10R_1$		

6) Repeat for $R_1 = 10k\Omega$.

R_2 Ideal	R_2 Measured (resistance box)	V_{OUT}
$0.1R_1$		
$0.3R_1$		
$0.5R_1$		
$0.7R_1$		
$0.85R_1$		
R_1		
$1.5R_1$		
$2.5R_1$		
$4R_1$		
$7R_1$		
$10R_1$		

7) Repeat again for $R_1 = 100k\Omega$.

R_2 Ideal	R_2 Measured (resistance box)	V_{OUT}
$0.1R_1$		
$0.3R_1$		
$0.5R_1$		
$0.7R_1$		
$0.85R_1$		
R_1		
$1.5R_1$		
$2.5R_1$		
$4R_1$		
$7R_1$		
$10R_1$		

8) Open Excel and load the **Solver** Add-in by executing the following steps:
    a. Go to File → Options → Addins
    b. Select "Solver Add-in" and hit "Go…"
    c. Check the Solver Add-In box and hit OK
    d. You can now find the Solver entry under the **Data** tab.

9) Download the Lab2 **Excel Solver Spreadsheet** file from the course web page. This spread sheet has columns whose purpose is as follows:
    a. **R2 Meas** – Enter your values of R_2 measured from the decade resistance box.

b. **Vout Meas** – Enter your measured values of Vout.
c. **Vout Calc** – These are voltage values calculated using the equation you derived in step 2. ***Do not modify this column in any way.***
d. **Sq. Error** – The square of the difference between $V_{OUTmeas}$ and $V_{OUTcalc}$. These errors are summed in cell D14. ***Do not modify this column.***
e. **Vin** (Cell E2) – Enter the value of Vin that you measured.
f. **R1** (Cell F2) – Enter the nominal value for R_1(1000, 10000, 100000) .

10) Put your data measurements into the first two Excel columns. Enter 5.000 in cell E2 (for V_{in} measured) and (1000, 10000, 100000) in cell F2 for the three separate cases of R_1 measured. Use the Solver function to find the values of V_{in} and R_1 that minimize the sum-squared error in ($V_{OUTmeas}$ - $V_{OUTcalc}$) while it fits the data to the following equation:

$$V_{OUT} = V_{IN} \frac{R_2}{R_1 + R_2}$$

Record your results from the Solver output:

$R_1 = 1K\Omega$: $R_{1solver}$ = ___________ Ω $V_{IN,solver}$ = ___________ V

$R_1 = 10K\Omega$: $R_{1solver}$ = ___________ Ω $V_{IN,solver}$ = ___________ V

$R_1 = 100K\Omega$: $R_{1solver}$ = ___________ Ω $V_{IN,solver}$ = ___________ V

11) Now measure and record the values of your 3 resistors you selected in step 1.

1k _____________ kΩ 10k _____________kΩ 100k _____________ kΩ

12) Use the following formula to calculate percentage errors for measured values vs. solver values for R_1.

$$Percentage\ Error = |(Measured\ value - Solver\ value)|/(Measured\ value) * 100\%$$

1k ____________ % 10k ____________% 100k ____________ %

13) Next, you are going to compare your calculations using nominal values vs. calibrated values to calculate the value of R_2. Use your $R_1 = 10K\Omega$ resistor for this part. Use the following guide for the table on the following page:

- Second and third column data can be copied from your table in step 6.
- Use your formula derived in step 3 to calculate R_2 using Vin = 5.00V and $R_1 = 10k\Omega$ (nominal values).
- Use your formula derived in step 3 to calculate R_2 using solver values for Vin and R_1 (calibrated values).
- Calculate the Per cent Improvement in the last column:

$$Percent\ Improvement = |(Calculated\ R2 - Calibrated\ R2)|/(Calculated\ R2) * 100\%$$

R_2 Ideal	R_2 Measured (resistance box)	V_{OUT}	Calculated R_2	Calibrated R_2	Percent Improvement
1kΩ					
3kΩ					
5kΩ					
7kΩ					
8.5kΩ					
10kΩ					
15kΩ					
25kΩ					
40kΩ					
70kΩ					
100kΩ					

Draw conclusions regarding any improvement in calculating the value of R_2 using nominal vs. calibrated values.

Summary

What you have done in this lab is find accurate values for the internal characteristics of the meter you created to measure resistance. This is precisely what calibration does – attempts to get an accurate handle on how an instrument or sensor can be mathematically modelled to provide the most accurate results in spite of internal variations between instruments.