Electric Circuits I

Laboratory 4 – Network Analysis and Wheatstone Bridge

Objective:

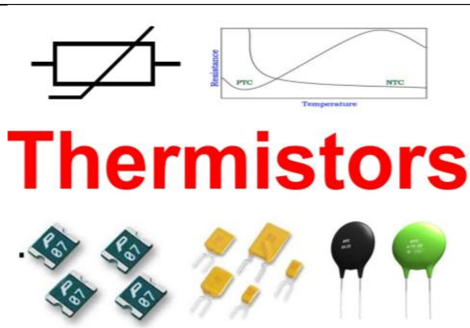
- To verify experimentally the function of a resistive network.
- To verify experimentally the operation of a typical bridge circuit to measure the resistance of unknown resistors.
- To apply the Wheatstone Bridge to various applications.

I. Equipment:

- DC Power Supply (Keysight EDU36311A)
- Digital Multimeter (Keysight EDU34450A)
- 5 unknown resistors from TA
- Breadboard for connecting resistors
- Resistance Decade R_{adj}

- Two resistors, R_1 and R_2, are between 1kΩ to 10kΩ.

Thermistor	Photoresistor 



II. Background & Theory

A. Resistive Networks

We can quickly analyze a resistive network by combining series and parallel resistors. With Ohm's law, we can determine other voltages across or currents going through elements using voltage or current division.

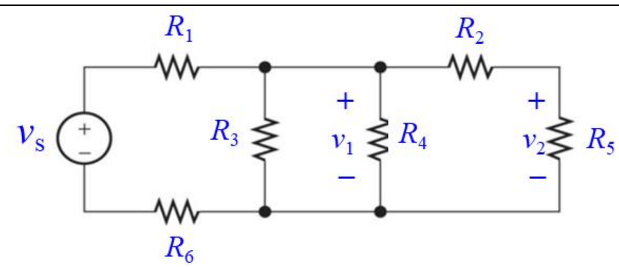


Figure 1 – Resistive Network

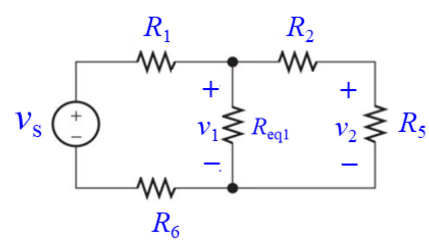


Figure 2 – Resistive Network

Figure 1 and **Figure 2** show an example of a resistive network where we need to determine the voltages v_1 and v_2 based on the known values of resistors and the supply voltage v_s. In **Figure 2**, we combine two parallel resistors R_3 and R_4, into an equivalent resistor R_{eq1}:

$$R_{eq1} = R_3 || R_4$$

We can temporarily combine series and parallel resistors in **Figure 2** as,

$$R_{eq2} = R_{eq1} || (R_4)$$

From there, we can apply voltage division to determine v_1 and v_2:

$$v_1 = \left(\frac{R_{eq2}}{R_1 + R_{eq2} + R_6}\right) v_s,$$

$$v_2 = \left(\frac{R_5}{R_2 + R_5}\right) v_1.$$

B. Wheatstone Bridge

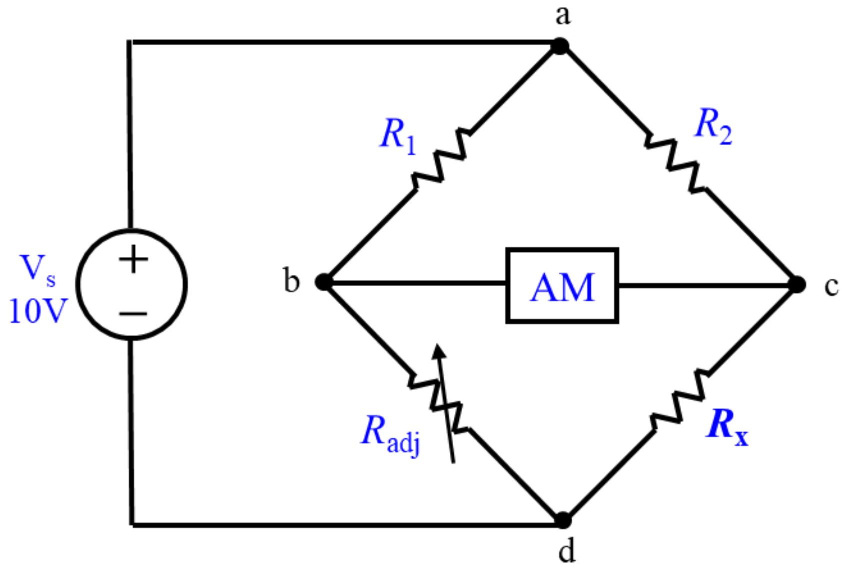


Figure 3 – Wheatstone Bridge

The circuit diagram of a Wheatstone bridge is shown in **Figure 3**. In the circuit, $\boldsymbol{R}_x$ is a known resistor, and R_{adj} is an adjustable resistor. An ammeter (AM) measures the current between nodes b and c (I_{bc}). R_{adj} is adjusted until the ammeter shows zero (I_{bc} = 0A) or the bridge is balanced. The unknown $\boldsymbol{R}_x$ is calculated as:

$$V_{ab} = V_{ac}$$

$$V_{bd} = V_{cd}$$

$$\frac{V_{ab}}{V_{bd}} = \frac{V_{cd}}{V_{cd}} \Leftrightarrow \frac{R_1 I_{R1}}{R_{adj} I_{R1}} = \frac{R_2 I_{R2}}{R_x I_{R2}} \Leftrightarrow \frac{R_1}{R_{adj}} = \frac{R_2}{R_x}$$

$$\Rightarrow R_x = \left(\frac{R_2}{R_1}\right) R_{adj} \quad (1)$$

III. Prelab Assignment:

The prelab assignments should be completed and submitted to Camino before the lab.

1. Select 6 resistors (R_1 to R_6) from the standard resistor values in **Table 1** between 1kΩ to 20kΩ.
1. With v_s = 12V, create a MATLAB script to
    a. calculate the voltages v_1 and v_2 in **Figure 1**.
    b. calculate the currents going through R_4 and R_5 (i_{R_4} and i_{R_5}) in **Figure 1**.
    c. calculate the dissipated power in R_4 and R_5 (P_{R_4} and P_{R_5}) in **Figure 1**.

Table 1 – Standard Resistor Values (K = * 1e3, M = *1e6)

1.0	5.6	33	160	820	3.9K	20K	100K	510K	2.7M
1.1	6.2	36	180	910	4.3K	22K	110K	560K	3M
1.2	6.8	39	200	1K	4.7K	24K	120K	620K	3.3M
1.3	7.5	43	220	1.1K	5.1K	27K	130K	680K	3.6M
1.5	8.2	47	240	1.2K	5.6K	30K	150K	750K	3.9M
1.6	9.1	51	270	1.3K	6.2K	33K	160K	820K	4.3M
1.8	10	56	300	1.5K	6.6K	36K	180K	910K	4.7M
2.0	11	62	330	1.6K	7.5K	39K	200K	1M	5.1M
2.2	12	68	360	1.8K	8.2K	43K	220K	1.1M	5.6M
2.4	13	75	390	2K	9.1K	47K	240K	1.2M	6.2M
2.7	15	82	430	2.2K	10K	51K	270K	1.3M	6.8M
3.0	16	91	470	2.4K	11K	56K	300K	1.5M	7.5M
3.3	18	100	510	2.7K	12K	62K	330K	1.6M	8.2M
3.6	20	110	560	3K	13K	68K	360K	1.8M	9.1M
3.9	22	120	620	3.2K	15K	75K	390K	2M	10M
4.3	24	130	680	3.3K	16K	82K	430K	2.2M	15M
4.7	27	150	750	3.6K	18K	91K	470K	2.4M	22M
5.1	30								

IV. Laboratory Part 1 – Resistive Network

1. Use the digital multimeter to measure 6 resistors chosen in the prelab assignments. Record their measured values in **Table 2** below.

Table 2 – Resistance Values

	R_1	R_2	R_3	R_4	R_5	R_6	
Nominal Values							kΩ
Measured Values							kΩ

2. Use the MATLAB script to recalculate voltages and currents with measured values of resistors and record them (theoretical values) in **Table 3**.
3. Build the circuit in **Figure 1** with v_s = 12V. Measure the voltages and currents, record them in **Table 3**, and compare them with the results from the theoretical calculations.

Table 3 – Voltages and Currents

	Theoretical (V)	Measured (V)	Percent Error
v_1			
v_2			
i_{R4}			
i_{R5}			

4. If there are any discrepancies, explain them.

V. Laboratory Part 2 – Measuring Unknown Resistance with Wheatstone Bridge

1. Select two new resistors or reuse the two resistors in **Part 1**. Measure R_1 and R_2 with an ohmmeter. Build the Wheatstone bridge in **Figure 3**. Record all values in **Table 4** – Resistance Values.

Table 4 – Resistance Values

Resistor	Nominal Value (kΩ)	Measured with Ohmmeter (kΩ)
R_1		
R_2		

2. Obtain 5 known resistors from TA. Measure the resistance of each resistor using an ohmmeter and record all values in **Table 5** – Unknown Resistance Values.

Table 5 – Unknown Resistance Values

Resistor	Measured with Ohmmeter (kΩ)	Measured with Wheatstone Bridge (kΩ)	Percent Error
R_a			
R_b			
R_c			
R_d			
R_e			

3. Measure each unknown resistor using the Wheatstone bridge. Set the ammeter in µA range. Adjust the decade resistor R_{adj} until the reading on the ammeter is close to zero. Using the measured values of R_1 and R_2, calculate the value of the unknown resistor using **Eq**. 1
4. Compare the measured values of resistors by the Ohmmeter and the Wheatstone bridge. Explain if they are different.

VI. Laboratory Part 3 – Wheatstone Bridge Applications

A. Temperature Measurement with Wheatstone Bridge

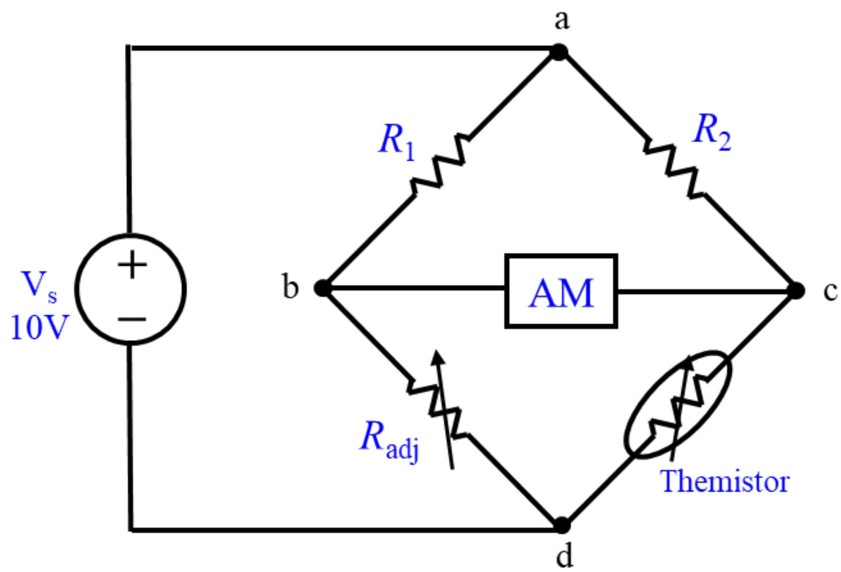


Figure 4 – Temperature Measurement with Wheatstone Bridge

1. Replace R_x with a thermistor, as in **Figure 4**. Adjust R_{adj} until the reading of the ammeter is close to zero. It is the setting at room temperature of the thermistor.
2. Increase or decrease the temperature of the thermistor and see how the reading of the ammeter changes.
3. Make comments or conclusions about your observations.

B. Measure Light Intensity with Wheatstone Bridge

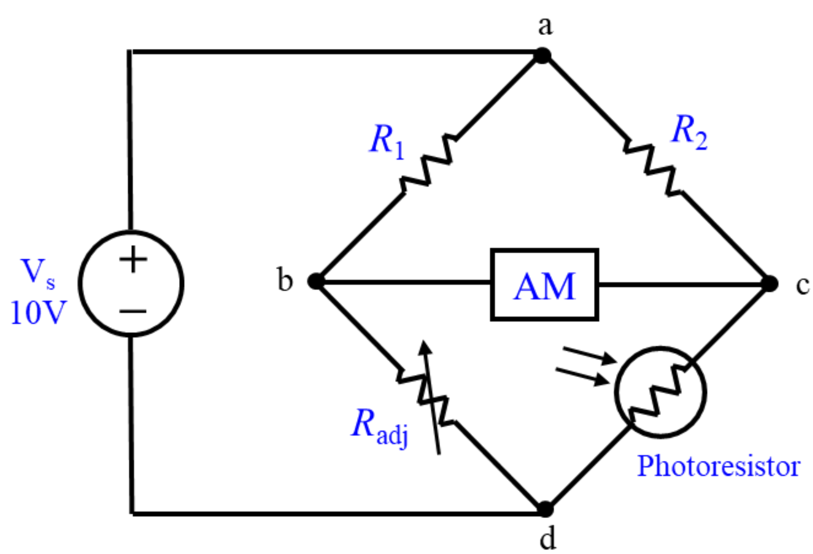


Figure 5 – Light Measurement with Wheatstone Bridge

1. Replace R_x with a photoresistor, as in **Figure 5**. Cover the photoresistor and adjust R_{adj} until the reading of the ammeter is close to zero. It is the setting of low light.
2. Expose the photoresistor to different light settings and see how the reading of the ammeter changes.
3. Make comments or conclusions about your observations.

Make sure to check off with the TA before leaving the lab section.

VII. Laboratory Report:

Include the measurements, computations, and answers to questions from the laboratory procedure. Clearly label all steps.