SIERRA COLLEGE	MECH 10 - Lab 06 Series Circuits	Mechatronics Real Skills Real Jobs

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Date: September 16, 2019
Professor Steven Gillette

Abstract

In this lab, I built 5 circuits according to the schematic diagram below. Each circuit consisted of a number of resistors connected in-line with each other. The marked values of the components were noted and measured with error rates calculated. I calculated and measured the current and voltage drops across the components and further calculated the error rates between the calculated and expected values. I lastly built a circuit using a transistor and LED, which demonstrated that voltage drops occur across all components, not just resistors.

Introduction

Learning Objectives

- Build series circuits as per a schematic diagram
- Measure electrical values using a digital voltmeter
- Use Ohm's Law to validate field measurements
- Use a data table and schematic diagrams to capture field measurements

Notes:

1. Take all voltage measurements relative to ground (unless otherwise stated)
2. Record relevant measurements and calculation results in data tables
3. Record all measured values on the circuit schematics
4. Use all available precision in calculations, round off answers to 3 significant figures

Materials

Quantity	Description
1	Global Specialties Circuit Trainer
1	Digital multimeter (DMM)
	Circuit 1 & 2
3	Resistors between 200Ω and 5KΩ
	Circuit 3
1	10K Ω potentiometer
	Circuit 4
1 each	R1 – 1K
	R2 – 1.8K
	R3 – 2.7K
	R4 – 3.9K Ω
	Circuit 5
1	LED
1	R1 – 180 Ω
1	R2 – 4.7K Ω
1	Q1 – 2N4401

Procedure – Series Circuits

Circuit 1

1. Selected resistors for circuit 1 & 2 according to the materials chart above. Measured each resistance value using a DMM. Created a data table that shows;
    a. Expected resistance values (from resistor color codes)
    b. Measured resistance values (from DMM measurements)
    c. % Error – the difference between expected and measured values

Resistor Expected & Measured Values			
	R_{exp} (Ohm)	R_{meas} (Ohm)	% Error
R1	1.00E+03	980.00E+00	2.00%
R2	4.70E+03	4.73E+03	-0.64%
RT	5.70E+03	5.72E+03	-0.35%

2. Recorded ***all measured values*** directly on the circuit schematics as I encountered them in this lab.

See Attachment A – Signature and Lab Notes for schematic.

3. Built Circuit 1 ***without the voltage source connected*** (i.e. left the circuit power supply leads disconnected)
4. ***Calculated R_T***, the total series resistance of the circuit using expected resistor values.
5. ***Measured R_T*** and compare the measured value to the expected value using the %Error formula.
6. Set the trainer power supply to 10V. Record the V_S, the supply voltage to three significant figures.
7. ***Calculated I_T***, the expected circuit current using Ohm's Law, V_S, and R_{Texp}.
8. ***Measured I_T*** using the DMM as an ammeter. Recorded the value.
9. Calculated the % Error between expected and measured I_T values.

Circuit Supply Voltage	
V_S	10.0

Circuit Total Resistance & Current		
	Total Resistance	% Error
R_{Texp}	5.70E+03 Ω	0.35%
R_{tmeas}	5.72E+03 Ω	
I_{Texp}	1.75E-03 Amp	-0.25%
I_{Tmeas}	1.75E-03	

10. Used Ohm's Law, I_{Texp} and resistor expected values to ***calculate the voltage drop*** across each resistor. Recorded data in tables.

11. ***Measured the voltage drop*** across each resistor and compared with the expected value with the % Error formula. Showed in data tables and on the circuit schematic.

Resistor Voltage Drops

	V_{rexp}	V_{rmeas}	% Error
R1	1.75	1.720	-1.96%
R2	8.25	8.260	0.17%
V_T	10.00	9.990	-0.10%

Circuit 2

12. Repeated the procedures used for Circuit 1 on Circuit 2. Recorded values in data table(s) and compared expected to measured values.

Resistor Expected & Measured Values

	R_{exp} (Ohm)	R_{meas} (Ohm)	% Error
R1	1.00E+03	980.00E+00	2.00%
R2	4.70E+03	4.73E+03	-0.64%
R3	2.70E+03	2.68E+03	0.74%
RT	8.40E+03	8.40E+03	0.00%

Circuit Supply Voltage

V_S	10.0

Circuit Total Resistance & Current

	Total Resistance	% Error
R_{Texp}	8.40E+03 Ω	0.00%
R_{tmeas}	8.40E+03 Ω	
I_{Texp}	1.19E-03 Amp	-0.88%
I_{Tmeas}	1.18E-03	

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Resistor Voltage Drops

	V_{rexp}	V_{rmeas}	% Error
R1	1.18	1.170	-0.85%
R2	5.55	5.620	1.33%
R3	3.19	3.180	-0.19%
V_T	9.91	9.950	0.38%

Circuit 3

13. Wired Circuit 3 as per the schematic diagram. The potentiometer in this circuit served as a variable voltage divider, allowing me to split the DC voltage into any ratio.

14. Set the potentiometer to approximately mid position and measured the voltage to ground at the wiper (middle terminal). Rotated the pot and noted the change in voltage. Recorded the minimum and maximum voltage values.

V_{min} $\boxed{0.3v}$ V_{max} $\boxed{9.70v}$

Circuit 4

15. Built Circuit 4 ***without the voltage source connected*** (i.e. left the circuit power supply leads disconnected)
16. ***Calculated R_T***, the total series resistance of the circuit using expected resistor values.
17. ***Measured R_T*** and compared the measured value to the expected value using the %Error formula.
18. ***Calculated I_T***, the expected circuit current using Ohm's Law, V_S, and R_{Texp}.
19. ***Measured I_T*** using the DMM as an ammeter and compared the measured value to the expected value using the %Error formula.
20. ***Calculated V_{R1}, V_{R2}, V_{R3}, V_{R4}*** using Ohm's Law and I_{Texp} and resistor expected values. Recorded in a data table.
21. ***Measured V_{R1}, V_{R2}, V_{R3}, V_{R4}*** and compared the measured value to the expected value using the %Error formula.

Circuit 4
Resistor Expected & Measured Values

	R_{exp} (Ohm)	R_{meas} (Ohm)	% Error
R1	1.00E+03	980.00E+00	2.00%
R2	1.80E+03	1.78E+03	1.11%
R3	2.70E+03	2.68E+03	0.74%
R4	3.90E+03	3.97E+03	-1.79%
RT	9.40E+03	9.44E+03	-0.43%

Circuit Supply Voltage

V_S	10.0

Circuit Total Resistance & Current

	Total Resistance	% Error
R_{Texp}	9.40E+03 Ω	0.43%
R_{tmeas}	9.44E+03 Ω	
I_{Texp}	1.06E-03 Amp	-0.36%
I_{Tmeas}	1.06E-03	

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Resistor Voltage Drops	V_{rexp}	V_{rmeas}	% Error
R1	1.06E+00	1.040	-2.24%
R2	1.91E+00	1.880	-1.82%
R3	2.87E+00	2.830	-1.47%
R4	4.15E+00	4.190	0.99%
V_T	10.00E+00	9.950	-0.50%

Circuit 5

22. Built circuit 5. Set power supply voltage to 5V ±.2. Recorded the source voltage V_S.
23. Activated the transistor base using a digital switch in the lower left side of the trainer.
24. Demonstrated working circuit to the instructor for signature. (See Attachment A – Lab Notes and Signature for signature)
25. Measured V_{LED}, V_{R1}, and V_{CE}
26. Added V_{LED}, V_{R1}, and V_{CE} and recorded the value as V_T
27. Compared V_T with V_S using the % Error formula

V_S 5.05V
R_1 179Ω
V_{LED} 41.5mV
V_{R1} 2.91V
V_{CE} 63.0mV
V_T 4.88V

1%

Circuit 5 Source & Component Voltage Drops	
V_{LED}	1.91E+00
V_{R1}	2.91E+00
V_{CE}	63.00E-03
V_{total}	4.88E+00
V_{source}	4.93E+00
% Error	1.0%

Formulas

$$E = IR, I = \frac{E}{R}, R = \frac{E}{I}$$

Where;
E = voltage (Volts)
I = current (Amperes)
R = circuit resistance (Ohms)

$$\%Error = \frac{measured - \exp ected}{\exp ected} x100\%$$

Where;
%Error = % change between measured and expected values
measured = a value taken from direct measurement
expected = a value taken from component or process specifications

Critical Thinking

1. Circuits 1, 2, 3 & 4 are all considered "voltage divider" circuits. Explain the advantages and disadvantages of using voltage dividers to reduce DC voltages.

Voltage dividers are useful because they are able to deliver specific required voltage to a portion of a circuit easily. A potential disadvantage of a voltage divider circuit is that it requires additional current that is absorbed by resistors resulting in heat. This requires more total power for the circuit to deliver the appropriate current to the divided circuit components.

2. Calculate Circuit 4 resistor voltage drops if all the resistors were changed to 10K Ω? Calculate the expected total current.

Circuit 4

Resistor Expected & Measured Values

	R_{exp} (Ohm)	R_{meas} (Ohm)	% Error
R1	10.00E+03	10.00E+03	0.00%
R2	10.00E+03	10.00E+03	0.00%
R3	10.00E+03	10.00E+03	0.00%
R4	10.00E+03	10.00E+03	0.00%
RT	40.00E+03	40.00E+03	0.00%

Circuit Supply Voltage

V_S	10.0

Circuit Total Resistance & Current

	Total Resistance	% Error
R_{Texp}	40.00E+03 Ω	0.00%
R_{tmeas}	40.00E+03 Ω	
I_{Texp}	250.00E-06 Amp	0.00%
I_{Tmeas}	250.00E-06	

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Resistor Voltage Drops

	V_{rexp}	V_{rmeas}	% Error
R1	2.50E+00	2.500	0.00%
R2	2.50E+00	2.500	0.00%
R3	2.50E+00	2.500	0.00%
R4	2.50E+00	2.500	0.00%
V_T	10.00E+00	10.000	0.00%

250μA which is approximately 810 μA less than the original components in the 1KΩ range.

Conclusions

This lab was a great introduction to series circuit evaluations and understanding the relationship between resistance and current relative to voltage in a series circuit. This lab also served as a proof of Kirchhoff's Voltage law that states "The algebraic sum of all voltages in a loop must equal zero." I expect that this principle will be explored again in upcoming parallel and series parallel circuit labs.

Appendix A – Signature and Lab Notes

SIERRA COLLEGE	MECH 10 - Lab 06 Series Circuits	Mechatronics Real Skills Real Jobs
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Learning Objectives

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- Measure electrical values using a digital voltmeter
- Use Ohm's Law to validate field measurements
- Use a data table and schematic diagrams to capture field measurements

Notes:

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	R3 – 2.7K
	R4 – 3.9K Ω
	Circuit 5
1	LED
1	R1 – 180 Ω
1	R2 – 4.7K Ω
1	Q1 – 2N4401

Procedure – Series Circuits
Circuit 1

1. Select resistors for circuit 1 & 2 according to the materials chart above. Measure each resistance value using a DMM. Create a data table that shows;
   a. Expected resistance values (from resistor color codes)
   b. Measured resistance values (from DMM measurements)
   c. % Error – the difference between expected and measured values
2. Record ***all measured values*** directly on the circuit schematics as you encounter them in this lab.
3. Build Circuit 1 ***without the voltage source connected*** (i.e. leave the circuit

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power supply leads disconnected)

4. ***Calculate R_T***, the total series resistance of the circuit using expected resistor values.
5. ***Measure R_T*** and compare the measured value to the expected value using the %Error formula.
6. Set the trainer power supply to 10V. Record the V_S, the supply voltage to three significant figures.
7. ***Calculate I_T***, the expected circuit current using Ohm's Law, V_S, and R_{Texp}.
8. ***Measure I_T*** using the DMM as an ammeter. Record the value.
9. Calculate the % Error between expected and measured I_T values.

10. Use Ohm's Law, I_{Texp} and resistor expected values to ***calculate the voltage drop*** across each resistor. Record your data in tables.
11. ***Measure the voltage drop*** across each resistor and compare with the expected value with the % Error formula. Show in data tables and on the circuit schematic.

Circuit 2

12. Repeat the procedures used for Circuit 1 on Circuit 2. Record your values in data table(s) and compare expected to measured values.

Circuit 3

13. Wire Circuit 3 as per the schematic diagram. The potentiometer in this circuit will serve as a variable voltage divider, allowing us to split the DC voltage into any ratio.
14. Set the potentiometer to approximately mid position and measure the voltage to ground at the wiper (middle terminal). Rotate the pot and note the change in voltage. Record the minimum and maximum voltage values.

V_{min} 0.3V

V_{max} 9.70V

Circuit 4

15. Build Circuit 4 ***without the voltage source connected*** (i.e. leave the circuit power supply leads disconnected)
16. ***Calculate R_T***, the total series resistance of the circuit using expected resistor values.
17. ***Measure R_T*** and compare the measured value to the expected value using the %Error formula.
18. ***Calculate I_T***, the expected circuit current using Ohm's Law, V_S, and R_{Texp}.
19. ***Measure I_T*** using the DMM as an ammeter and compare the measured value to the expected value using the %Error formula.
20. ***Calculate V_{R1}, V_{R2}, V_{R3}, V_{R4}*** using Ohm's Law and I_{Texp} and resistor expected values. Record in a data table.
21. ***Measure V_{R1}, V_{R2}, V_{R3}, V_{R4}*** and compare the measured value to the expected value using the %Error formula.

Circuit 5

22. Build circuit 5. Set your power supply voltage to 5V ±.2. Record the source voltage V_S.
23. Activate the transistor base using a digital switch in the lower left side of the trainer.
24. Demonstrate your working circuit to the instructor or lab assistant for signature.

SDS

V_S 5.05

R_1 179Ω

V_{LED} 41.5mV

V_{R1} 2.91

25. Measure V_{LED}, V_{R1}, and V_{CE}

V_{CE} 63mV

26. Add V_{LED}, V_{R1}, and V_{CE} and record the value as V_T

V_T 4.88V

27. Compare V_T with V_S using the % Error formula

1 %

Formulas

$$E = IR, I = \frac{E}{R}, R = \frac{E}{I}$$

Where;
E = voltage (Volts)
I = current (Amperes)
R = circuit resistance (Ohms)

$$\%Error = \frac{measured - \text{expected}}{\text{expected}} x100\%$$

Where;
%Error = % change between measured and expected values
measured = a value taken from direct measurement
expected = a value taken from component or process specifications

Series Circuits

A series circuit has a single current path with the current being equal in all connected series loads. The total circuit current I_T is controlled by the sum of the load resistances. Total circuit current is found by applying Ohm's Law.

$$I_T = \frac{V_S}{R_T}$$

Where:
I_T = total circuit current
V_S = supply voltage
RT = total resistance = R1 + R2 +R3 + R_n

Kirchoff's Voltage Law

The sum of the voltage drops in the circuit is equal to the applied circuit voltage.

In a series circuit, Kirchoff's Voltage Law dictates that the total circuit potential must equal the sum of the load voltage drops. A simple Ohm's Law analysis of a series circuit provides insight into series resistance.

Series Voltage Drops

Using Circuit 1 as a reference, assume that R1 is a 100 Ω resistor, and R2 is a 500 Ohm resistor. Total circuit current is;

$I_T = V_S / (R_1 + R_2) = 10V / (100 + 500\ \Omega) = 16.6mA$

The voltage dropped across each component then is equal to;

$V_{R1} = I_T \times R_1 = 16.6mA \times 100\ \Omega = 1.66V$
$V_{R2} = I_T \times R_2 = 16.6mA \times 500\ \Omega = 8.33V$

The sum of the individual resistance voltage drops (V_R) equals the applied circuit voltage.

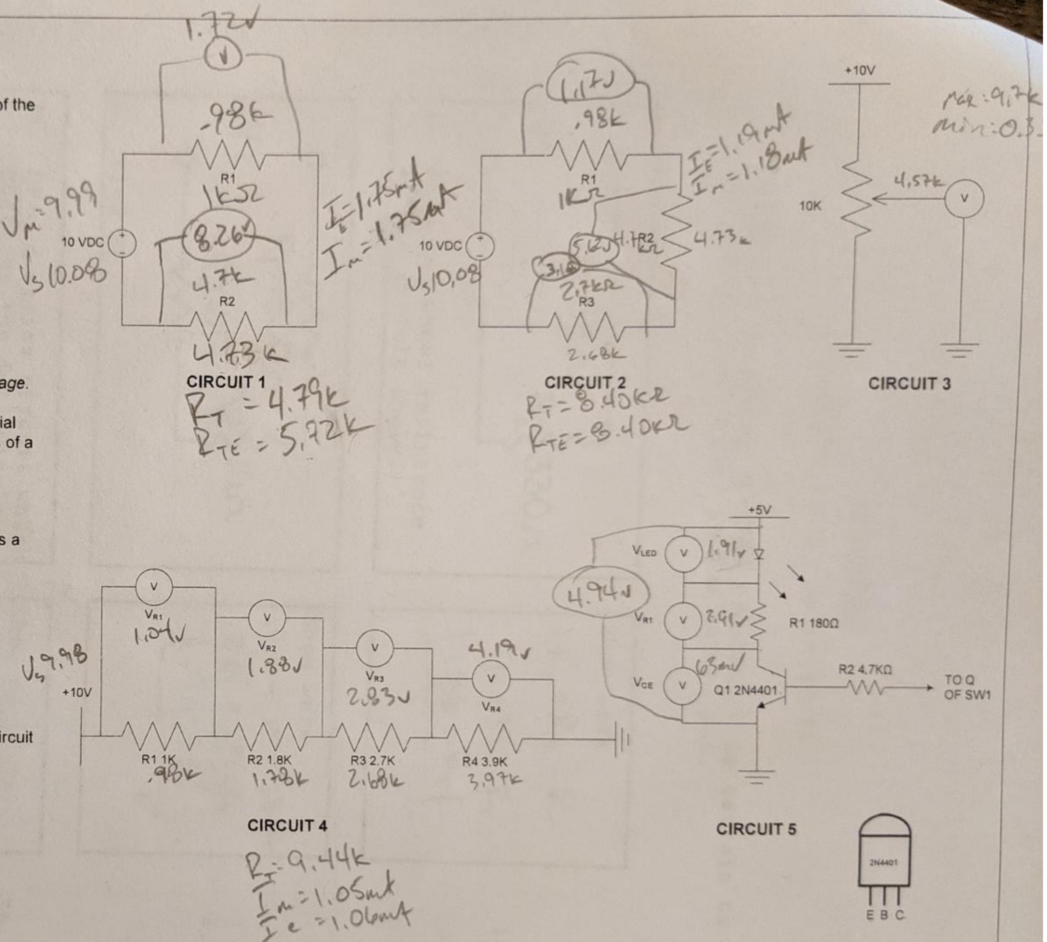
Equivalent Resistance

Total series resistance is simply the sum of circuit resistances.

$$R_T = R_1 + R_2 + R_3 + R_n$$

Voltage Dividers

Source DC voltages may be divided into various levels using a series resistor network called a voltage divider. Circuit 4 illustrates an unloaded voltage divider. The voltage outputs at each point in the circuit depend on the proportion of individual resistance to total circuit resistance. Voltage dividers are a quick and easy way to reduce DC voltages to meet component and auxiliary circuit requirements. Voltage dividers are effective in low power control applications, but become inefficient in higher power applications due to the continuous bleeder current passing through the divider network.



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	LAB 06 – SERIES CIRCUITS				
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Grading Criteria

		Points Possible	Points Earned
Documentation	Abstract, introduction, experiment, data results, conclusions, attachments, clarity, spelling, grammar	**10**	
Circuit 1	Resistor values recorded, total resistance recorded, voltage drops recorded, expected and measured values compared	**10**	
Circuit 2	Total resistance recorded, voltage drops recorded, expected and measured values compared	**10**	
Circuit 3	Min / max voltage levels recorded	**5**	
Circuit 4	Total resistance, voltage drops and circuit current recorded, all expected and measured values compared	**10**	
Circuit 5	V_S, V_{LED}, V_{R1}, V_{CE} recorded. Total voltage drop calculated and compared with V_S using the % Error formula	**5**	
Critical Thinking	Questions answered completely & accurately. State conclusions drawn and lessons learned from the lab	**10**	
On-time submittal	Lab report is submitted in accordance with the assignment due date as posted on Canvas	**5**	
	Total	**65**	

Lab Report Format

Abstract - a summary and high-level overview of the lab and its results
Introduction - State the objectives of the laboratory and list the equipment required
Experiment - Describe the procedure used to carry out the lab
Results Data - list data taken in table or graphical format where appropriate
Conclusion - State the conclusions drawn and lessons learned from the laboratory activities. Answer any questions found within the lab procedure.
Attachments – grading criteria, verification signatures, circuit diagrams, lab procedures & notes