| SIERRA COLLEGE | MECH 10 - Lab 08<br>Series / Parallel Circuits | Mechatronics<br>Real Skills Real Jobs |
|---|---|---|
| Name: Cayce Beames<br>Date: October 1, 2019<br>Professor Steven Gillette | | |


**Abstract**
In this lab, I used several resistors, a Zener diode, a breadboard and a DC power supply to simulate combination series / parallel circuits as well as to understand the behavior of a Zener diode.

Because I missed this lab in class, I substituted resources from my home lab including an 830 connection-point breadboard, a UNI-T UTP3315TFL-II regulated DC power supply and a UNI-T UT89XD digital multimeter.


**Learning Objectives**

- Build series / parallel circuits as per a schematic diagram
- Measure electrical values using a digital voltmeter
- Use Ohm's Law to reduce a series /parallel circuit to the simplest form
- 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 | DC Power Supply |
| 1 | Digital multimeter (DMM) |
| 1 | Breadboard |
| | **Circuit 1 & 2** |
| 1 | R1, R2, R3, R4, R5, R6 – choose any resistors between 1KΩ and 5.6KΩ, each of different value |
| | **Circuit 3** |
| 1 | Zener diode, 1N4733A, 5.1V |
| 1 | R1 – 300Ω |
| 1 | R2 – 470Ω and 1kΩ |

**Procedure – Series / Parallel Circuits**
**Circuit 1**
1. Selected resistors for circuit 1, 2 and 3 according to the materials chart above.
2. Built Circuit 1 ***without the voltage source connected*** (i.e. left the circuit power supply leads disconnected)

3. **Total Resistance (expected) -** *Calculated and recorded $R_{Texp}$*, the total circuit resistance using circuit reduction, expected resistor values and one of the $R_{equiv}$ formulas.

| | Series Resistor Value (Ω) | | Branch Resistance (Ω) | Branch Conductance (g) | Expected Parallel Resistance (Ω) | Expected Total Resistance (Ω) |
|---|---|---|---|---|---|---|
| **R1** | 1.00E+03 | **Branch 1** | 2.00E+03 | 500.00E-06 | 1.15E+03 | 2.15E+03 |
| **$V_{source}$** | 10.00E+00 | **Branch 2** | 2.70E+03 | 370.37E-06 | | |

4. **Total Resistance (measured)** – *Measured and recorded $R_T$* and compared the measured value to the expected value using the % Error formula.

| Expected Total Resistance (Ω) | Measured Total Resistance (Ω) | % Error |
|---|---|---|
| 2.15E+03 | 2.16E+03 | -0.3% |

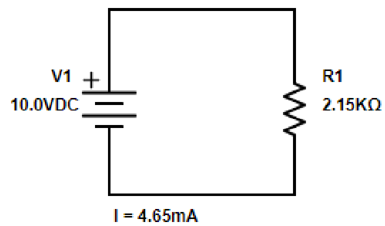
5. Set the power supply to 10V. *Measured and recorded* $V_S$, the power supply voltage to three significant figures.
6. **Circuit Currents (expected) -** *Calculated and recorded $I_T$* , $I_{R2,}$ $I_{R3}$ – expected circuit currents using Ohm's Law, $V_S$, and $R_{Texp}$ values. Used Kirchoff's Law to show that total current equals the sum of the branch currents.

| | Expected Current (Amp) |
|---|---|
| **$R_1$** | 4.65E-03 |
| **Branch 1** | 2.67E-03 |
| **Branch 2** | 1.98E-03 |

7. **Circuit Currents (measured)** *Measured and recorded $I_T$* , $I_{R2,}$ $I_{R3,}$circuit current using the DMM as an ammeter. Recorded the values and compare measured to expected values using the % Error formula.

| | Expected Current (Amp) | Measured Current (Amp) | % Error |
|---|---|---|---|
| **$R_1$** | 4.65E-03 | 4.61E-03 | 0.9% |
| **Branch 1** | 2.67E-03 | 2.61E-03 | 2.4% |
| **Branch 2** | 1.98E-03 | 1.99E-03 | -0.5% |

8. **Reduction schematic** – drew the circuit reduction steps for Circuit 1 on the Circuit Reduction Worksheet




## Circuit 2

9. Built circuit 2.
10. ***Calculated and recorded*** total resistance

| | Series Resistor Values (Ω) |
|---|---|
| **R1** | 1.00E+03 |
| **R6** | 5.00E+03 |
| **$V_{source}$** | 10.00E+00 |

| | Branch Resistance (Ω) | Branch Conductance (g) | Expected Parallel Resistance (Ω) | Expected Total Resistance (Ω) |
|---|---|---|---|---|
| **Branch 1** | 4.70E+03 | 212.77E-06 | 2.92E+03 | 8.92E+03 |
| **Branch 2** | 7.70E+03 | 129.87E-06 | | |

11. ***Measured and recorded*** total resistance

| Measured Total Resistance (Ω) |
|---|
| 8.98E+03 |

12. ***Compared measured with expected***

| Expected Total Resistance (Ω) | Measured Total Resistance (Ω) | % Error |
|---|---|---|
| 8.92E+03 | 8.98E+03 | -0.7% |

13. ***Calculated and recorded*** total circuit current

| | Expected Current (Amp) |
|---|---|
| **R1** | 1.12E-03 |
| **R6** | 1.12E-03 |
| **Branch 1** | 696.27E-06 |

| | |
|---|---|
| Branch 2 | 424.99E-06 |

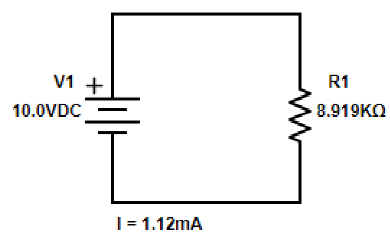
14. ***Measured and recorded*** total circuit current

| | Measured Current (Amp) |
|---|---|
| R1 | 1.10E-03 |
| R6 | 1.10E-03 |
| Branch 1 | 679.00E-06 |
| Branch 2 | 418.00E-06 |

15. ***Compared measured total with expected total***

| | Expected Current (Amp) | Measured Current (Amp) | % Error |
|---|---|---|---|
| R1 | 1.12E-03 | 1.10E-03 | 1.9% |
| R6 | 1.12E-03 | 1.10E-03 | 1.9% |
| Branch 1 | 696.27E-06 | 679.00E-06 | 2.5% |
| Branch 2 | 424.99E-06 | 418.00E-06 | 1.6% |

16. ***Drew a circuit reduction schematic***




## Circuit 3

17. Built Circuit 3 with $R_2$ equal to 1000Ω. ***Note;*** zener diodes are operated in reverse bias, with the cathode facing the positive supply.
18. ***Measured and recorded*** $\mathbf{V_{R1}, V_{R2}, V_{ZD}}$**.** Recorded findings in the table below.
19. ***Calculated and record*** $I_T$, $I_{ZD}$, and $I_{R2}$. ***Note***: Zener diodes are active components and do not comply with Ohm's Law. To determine $I_{ZD}$, use Ohm's Law to calculate $I_{R1}$ and $I_{R2}$ then subtract $I_{R2}$ from $I_{R1}$.
20. Changed $R_2$ to 470 Ohm
21. ***Measured and recorded*** $\mathbf{V_{R1}, V_{R2}, V_{ZD}}$**.** Recorded findings in the table below.

22. ***Calculate and record*** $I_T$, $I_{ZD}$, and $I_{R2}$. ***Note***; The voltage drop across the Zener diode is largely unaffected changes in current through the diode. Zener diodes find application as constant voltage sources.

| Ω | Voltage Performance 1000 | 470 | % Voltage Change | % Current Change | Current Performance 1000 | 470 | Ω |
|---|---|---|---|---|---|---|---|
| $V_{R1}$ | 7.03E+00 | 7.10E+00 | 1.00% | 1.00% | 23.43E-03 | 23.67E-03 | $I_{R1}$ |
| $V_{R2}$ | 4.97E+00 | 4.89E+00 | 1.61% | 109.34% | 4.97E-03 | 10.40E-03 | $I_{R2}$ |
| $V_{ZD}$ | 4.97E+00 | 4.89E+00 | 1.61% | 28.17% | 18.46E-03 | 13.26E-03 | $I_{ZD}$ |
| $V_T$ | 12.00E+00 | 11.99E+00 | | | 23.43E-03 | 23.67E-03 | $I_{R2} + I_{R1}$ |

## Formulas

### Ohm's Law

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

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

**% Error**

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

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

### Parallel Resistance – Conductance Method

$$R_{equiv} = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \frac{1}{R_n}}$$

**Where;**
**$R_{equiv}$ =** circuit total resistance
**R =** resistance
**1/R** = conductance in mho's

### Parallel Resistance – Product over Sum Method

$$R_{equiv} = \frac{R1 \times R2}{R1 + R2}$$

**Note; Product Over Sum may only be used when there are only 2 parallel loads.**

### Parallel Resistance – Equal Value Resistance

$$R_{equiv} = \frac{R_{all}}{n}$$

**Note; Equal Value Resistance may only be used when there are identical resistance paths through *n* parallel loads.**

### Circuit 3 Calculations

$$I_{R1} = \frac{(V_{R1})}{R_1}$$

$$I_{R2} = \frac{V_{R2}}{R_2}$$

$$I_{ZD} = I_{R1} - I_{R2}$$

$$I_T = I_{R1}$$

**Where;**
**$I_{R1}$ = resistor 1 current**
**$V_{R1}$ = resistor 1 voltage drop**
**$R_1$ = resistor 1 value**

**$I_{R2}$ = resistor 2 current**
**$V_{R2}$ = resistor 2 value**
**$R_2$ = resistor 2 value (1000 & 470Ω)**

**$I_{ZD}$ = zener current**

**$I_T$ = total circuit current**

## Questions / Conclusions

1. What are the primary characteristics of a combination series / parallel circuit?

Any circuit having both series and parallel connected components is considered a combination series / parallel circuit. The series components of the circuit will have common current paths and the parallel components will have a common voltage supply.

2. Describe the procedure used for circuit reduction analysis for series / parallel circuits?

Procedures for circuit reduction include first combining parallel branch resistance portions into series equivalants and then adding all series components into a total representative resistance component.

3. Using your measured values from Circuit 1, show calculations that demonstrate that Ohm's Law and Kirchhoff's Current Law provide equivalent results. (total current is equal to the sum of the branches)

R1 shows the current through the circuit relative to the source and through R1 and returning from the parallel portion. The voltage source is 10v, the total resistance measured is 2.16kΩ. As I = V/R, I = 10V / 2.16 kΩ = 4.64mA

The sum of the currents through branch 1, and branch 2 are:
2.61mA + 1.99mA = 4.60mA

4.64mA ≈ 4.60mA

4. In circuit 3, why did the voltage drop remain relatively constant across R2 with different value resistors? Was Ohm's Law violated?

The stable voltage drop phenomenon seen in circuit 3 is due to the behavior of the 1N4733A Zener diode that was used. When a certain voltage is present at the diode, it will start conducting. This particular diode according to the datasheet has a voltage range up to 5.1V. When the resistor was changed to the 470Ω resistor, in parallel with the diode, the same voltage was required to be dissipated at the bottom of the circuit. The diode and the 470Ω resistor, in parallel had the same voltage drop, but the current doubled through the 470Ω resistor and decreased by approximately 5mA through the diode. Ohm's law wasn't violated, the diode resistance automatically changed from approximately 269Ω to approximately 369Ω

## Appendix A –Lab Notes

| SIERRA COLLEGE | MECH 10 - Lab 08<br>Series / Parallel Circuits | Mechatronics<br>Real Skills Real Jobs |
|---|---|---|
| **Name** Cayce Beames | | 9/29/19 |

**Learning Objectives**

- Build series / parallel circuits as per a schematic diagram
- Measure electrical values using a digital voltmeter
- Use Ohm's Law to reduce a series /parallel circuit to the simplest form
- 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** |
| 1 | R1, R2, R3, R4, R5, R6 – choose any resistors between 1KΩ and 5.6KΩ, each of different value |
| | **Circuit 3** |
| 1 | Zener diode, 1N4733A, 5.1V |
| 1 | R1 – 300Ω |
| 1 | R2 – 470Ω and 1kΩ |

**Procedure – Series / Parallel Circuits**
**Circuit 1**

1. Select resistors for circuit 1, 2 and 3 according to the materials chart above. Create a data table that shows;
   a. Expected resistance values (from resistor color codes); use these values for ***all expected value calculations***
2. Build Circuit 1 ***without the voltage source connected*** (i.e. leave the circuit power supply leads disconnected)
3. **Total Resistance (expected)** - *Calculate and record $R_T$*, the total circuit resistance using circuit reduction, expected resistor values and one of the $R_{equiv}$ formulas.
4. **Total Resistance (measured)** – *Measure and record $R_T$* and compare the measured value to the expected value using the % Error formula.

SDG 03/14 Page 1 of 4

5. Set the trainer power supply to 10V. Measure and record $V_S$, the power supply voltage to three significant figures.

6. **Circuit Currents (expected)** - *Calculate and record* $I_T = I_{R1}, I_{R2}, I_{R3}$ – expected circuit currents using Ohm's Law, $V_S$, and $R_{Texp}$ values. Show that total current equals the sum of the branch currents.

7. **Circuit Currents (measured)** *Measure and record* $I_T = I_{R1}, I_{R2}, I_{R3}$, circuit current using the DMM as an ammeter. Record the values and compare to expected values using the % Error formula.

8. **Reduction schematic** – draw the circuit reduction steps for Circuit 1 on the Circuit Reduction Worksheet

**Circuit 2**

9. Build circuit 2.
10. ***Calculate and record*** total resistance
11. ***Measure and record*** total resistance
12. ***Compare measured with expected***

13. ***Calculate and record*** total circuit current
14. ***Measure and record*** total circuit current
15. ***Compare measured total with expected total***

16. ***Draw a circuit reduction schematic***

**Circuit 3**

17. Build Circuit 3. ***Note;*** zener diodes are operated in reverse bias, with the cathode facing the positive supply. $R_2 = 1k$

18. ***Measure and record*** $\mathbf{V_{R1}, V_{R2}, V_{ZD}}$. Record your findings

19. ***Calculate and record*** $I_T$, $I_{ZD}$, and $I_{R2}$. ***Note***: Zener diodes are active components and do not comply with Ohm's Law. To determine $I_{ZD}$, Calculate $I_{R1}$ and $I_{R2}$ then subtract $I_{R2}$ from $I_{R1}$.

20. Change R2 to 470 Ohm

21. ***Measure and record*** $\mathbf{V_{R1}, V_{R2}, V_{ZD}}$. Record your findings

22. ***Calculate and record*** $I_T$, $I_{ZD}$, and $I_{R2}$. ***Note***; The voltage drop across the Zener diode is largely unaffected by the change in the load resistor $I_{R2}$. Zener diodes find application as constant voltage sources.

## Formulas

### Ohm's Law

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

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

**% Error**

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

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

### Parallel Resistance – Conductance Method

$$R_{equiv} = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \frac{1}{R_n}}$$

Where;
**$R_{equiv}$** = circuit total resistance
**R** = resistance
**1/R** = conductance in mho's

### Parallel Resistance – Product over Sum Method

$$R_{equiv} = \frac{R1 \times R2}{R1 + R2}$$

**Note; Product Over Sum may only be used when there are only 2 parallel loads.**

### Parallel Resistance – Equal Value Resistance

$$R_{equiv} = \frac{R_{all}}{n}$$

**Note; Equal Value Resistance may only be used when there are identical resistance paths through *n* parallel loads.**

### Circuit 3 Calculations

$$I_{R1} = \frac{(V_S - V_{ZD})}{R_1}$$

$$I_{R2} = \frac{V_{ZD}}{R_2}$$

$$I_{ZD} = I_{R1} - I_{R2}$$

$$I_T = I_{R1}$$

**Where;**
**$I_{R1}$ = resistor 1 current**
**$V_S$ = source voltage**
**$V_{ZD}$ = zener voltage**

**$I_{R2}$ = resistor 2 current**
**$I_{ZD}$ = Zener diode current**
**$I_T$ = total circuit current**

### Questions / Conclusions

1. What are the primary characteristics of a combination series / parallel circuit?
2. Describe the procedure used for circuit reduction analysis for series / parallel circuits?
3. Using your measured values from Circuit 1, show calculations that demonstrate that Ohm's Law and Kirchhoff's Current Law provide equivalent results. (total current is equal to the sum of the branches)

**Series / Parallel Circuits**

A series parallel circuit has both single and multiple current paths. Some loads are wired in series with the power supply and other loads are wired in parallel, making circuit analysis more complex than simple series or parallel circuits. The current that travels through the circuit is controlled by the applied voltage, series resistance, and branch resistances with the total current flow found using circuit reduction to an equivalent resistance. Total circuit current is found by dividing source voltage by the circuit equivalent resistance.

Kirchoff's Current Law applies, with total circuit current equal to the sum of the branch currents.

$$I_T = \frac{V_S}{R_{equiv}} = I_{B1} + I_{B2} + \ldots I_N$$

Where;

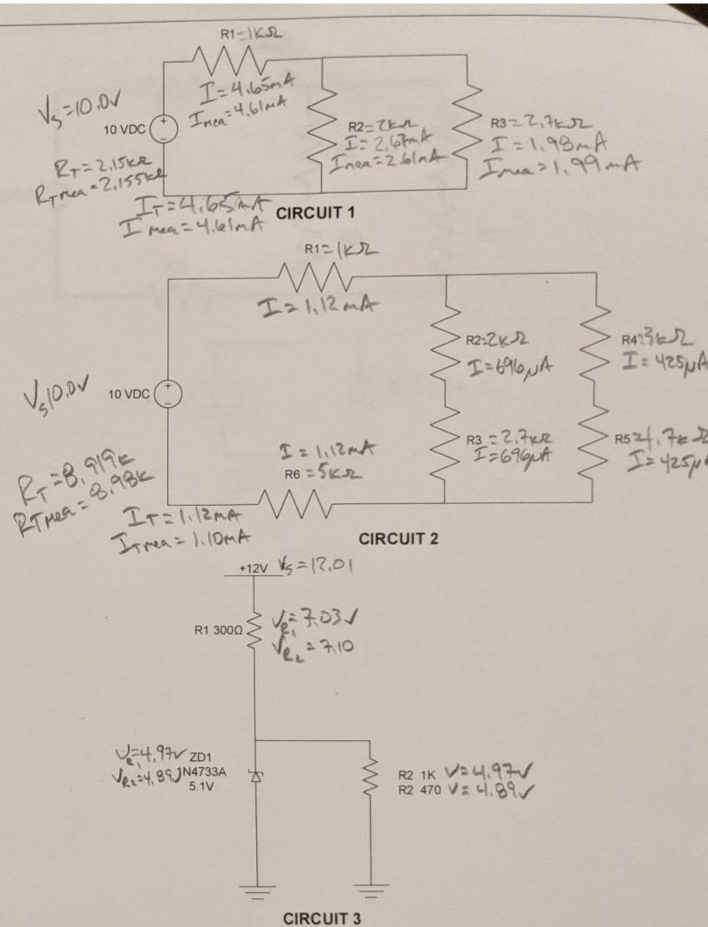
$I_T$ = total circuit current
$V_S$ = source voltage
Requiv = circuit equivalent resistance
$I_{B1}$ = branch 1 current
$I_{B2}$ = branch 2 current
$I_{Bn}$ = branch n current

**Parallel Equivalent Resistance**

$$R_{equiv} = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R_n}}$$ General Form

$$R_{equiv} = \frac{R_1 \times R_2}{R_1 + R_2}$$ Two-branch circuits

$$R_T = \frac{R_{all}}{N}$$ Equivalent branch resistances

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| SIERRA COLLEGE<br>Mechatronics<br>Real Skills Real Jobs | MECH 10 – FUNDAMENTALS OF ELECTRONICS<br>LAB 08 – COMBINATION CIRCUITS |
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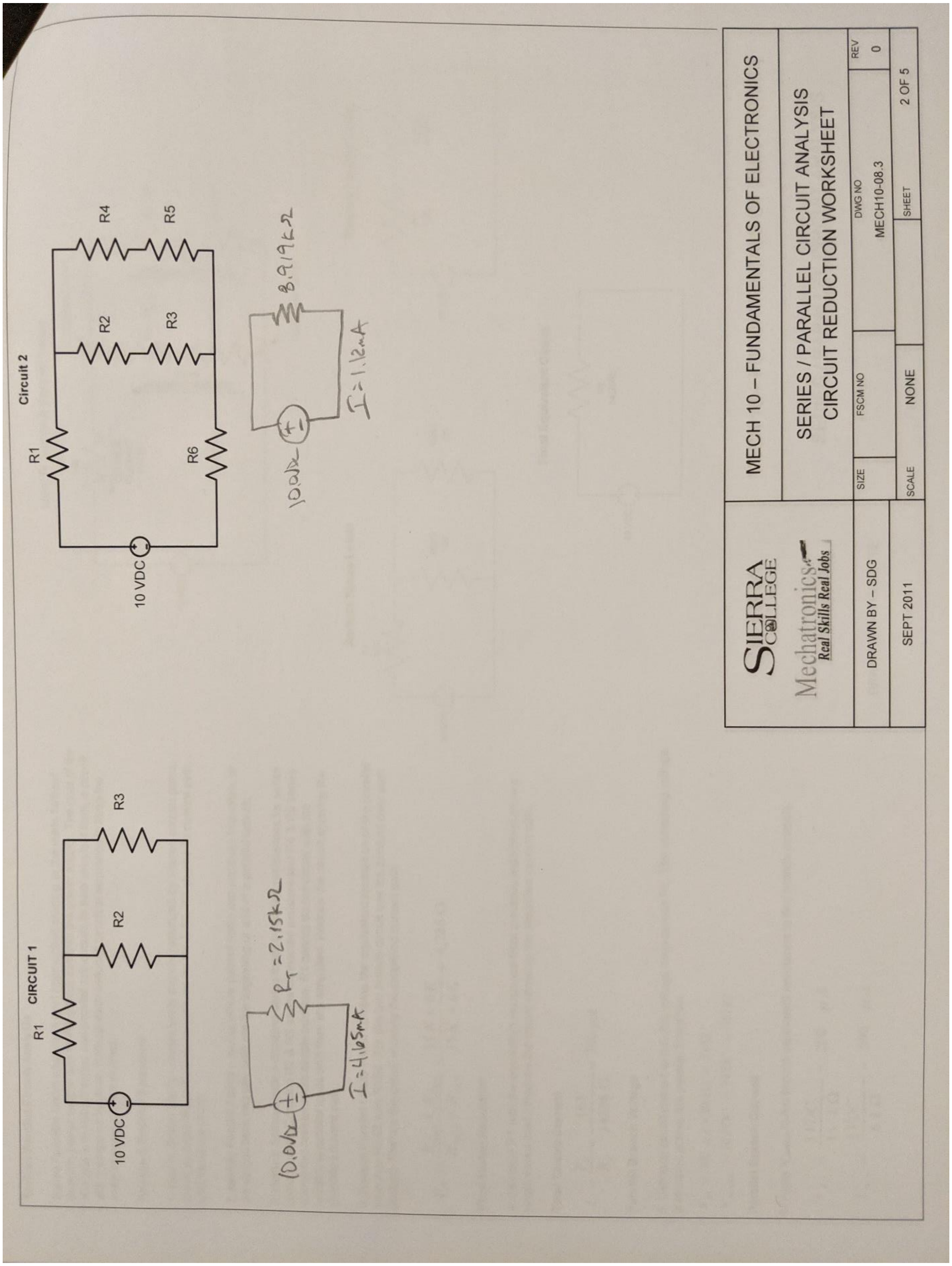
CIRCUIT 1
R1
R2
R3
10 VDC
10.0Vdc
$R_T$ = 2.15kΩ
I = 4.65mA
Circuit 2
R1
R2
R3
R4
R5
R6
10 VDC
10.0Vdc
8.919kΩ
I = 1.12mA
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MECH 10 – FUNDAMENTALS OF ELECTRONICS
SERIES / PARALLEL CIRCUIT ANALYSIS
CIRCUIT REDUCTION WORKSHEET
DRAWN BY – SDG
SEPT 2011
SIZE
FSCM NO
DWG NO
MECH10-08.3
REV
0
SCALE
NONE
SHEET
2 OF 5

**Grading Criteria**

| | | Points Possible | Points Earned |
|---|---|---|---|
| **Documentation** | Abstract, introduction, experiment, data results, conclusions, attachments, clarity, spelling, grammar | **10** | |
| **Circuit 1** | Expected and measured resistance, and current recorded in data table with percent error, circuit reduction diagram complete & accurate | **10** | |
| **Circuit 2** | Expected and measured resistance and, current recorded in data table with percent error, circuit reduction diagram complete & accurate | **10** | |
| **Circuit 3** | Voltages measured, currents calculated for both $R_2$ values. | **10** | |
| **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** | **55** | |

## 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
**Critical Thinking -** 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