Circuit Lab

Practice #4—More Advanced Series and Parallel Circuits

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Agenda

- 15 minutes—Grading homework.
- 30 minutes—Learning Lesson of the Day
- 15 minutes—In Practice quick test on Lesson of the Day
- 25 minutes—Practical testing
- 5 minutes—Sending out homework

The Big Three—Volta, Ampere, and Ohm

Equivalent Resistance

- Multiple resistors can be combined into a single resistance to represent all of them called an Equivalent Resistance or R_{eq}
- The current flowing through both of the circuits on the right is exactly the same

Series Circuit

- Two or more resistors in series
- Current is the same through all resistors (electrons have no other path)
- Voltage is split between resistors
- $R_{eq} = R_1 + R_2 + R_3$
- R_{eq} is always greater than the largest single resistance
- Current = Voltage / R_{eq}

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Series Circuit (example)

- $R_{eq} = R_1 + R_2 + R_3$
- $R_1 = 300\ \Omega$
- $R_2 = 300\ \Omega$
- $R_3 = 400\ \Omega$
- $R_{eq} = 300\ \Omega + 300\ \Omega + 400\ \Omega$
- $R_{eq} = 1{,}000\ \Omega$ or $1\ k\Omega$
- If V =1,000 V or 1 kV
- $I = V/R = 1kV/\ 1\ k\Omega = 1\ A$

- ** R_{eq} = the sum of the resistors or if they are all the same value then multiply them by that number
  - Two 300Ω resistors in series = 2 x 300Ω = 600Ω
  - Three 300Ω resistors in series = 3 x 300Ω = 900Ω
  - Two 200Ω resistors in series = 2 x 200Ω = 400Ω

Parallel Circuit

- Two or more resistors in parallel
- Voltage is the same through all resistors
- Current is split between resistors (electrons are split between all branches)
- $1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3$
- R_{eq} is always less than the smallest single resistance
- Current (from battery) = Voltage / R_{eq} ,which is then split among the three branches

Parallel Circuit (Example

- $1/R_{eq} = 1/R_1 + 1/R_2$
- $R_1 = 2\ \Omega$
- $R_2 = 2\ \Omega$
- $1/R_{eq} = ½_{\Omega} + ½_{\Omega} = 1/_{\Omega}$
- $R_{eq} = 1\ \Omega$

- If V = 6 V
- I = V/R = 6 V/ 1 Ω = 6A, which is split among the two resistors

Parallel Circuit (Example

- $1/R_{eq} = 1/R_1 + 1/R_2$
- $R_1 = 4\ \Omega$
- $R_2 = 4\ \Omega$
- $1/R_{eq} = ¼\Omega + ¼\ \Omega = ½\ \Omega$
- $R_{eq} = 2\ \Omega$
- If V = 6 V
- I = V/R = 6 V/ 2 Ω = 3 A, which is then split among the two resistors
- **If the resistors have the same value, Req = the resistance is divided by the number in parallel
  - Two 4Ω resistors in parallel are 4Ω/2 = 2Ω
  - Two 6Ω resistors in parallel are 4Ω/2 = 3Ω
  - Three 6Ω resistors in parallel are 6Ω/3 = 2Ω

Combination Circuit

- Two or more resistors in parallel, plus series resistance
- Voltage and Current are both split.
- Have to solve by combining series and parallel elements

Combination Circuit Example 1

- $V = 10\ V$, $R_1=R_2=R_3=R_4=100\ \Omega$
- Combine Series Resistors where possible
  - None at start
- Combine Parallel Resistance where possible
  - $1/R_{eq1} = 1/100\Omega + 1/100\Omega = 0.02\ S$
  - $R_{eq1} = 1/0.02\ S = 50\Omega$
  - $1/R_{eq2} = 1/100\Omega + 1/100\Omega = 0.02\ S$
  - $R_{eq2} = 1/0.02\ S = 50\Omega$
- Repeat until you get a single $R_{equivalent}$
  - $R_{equivalent} = 50\Omega + 50\Omega = 100\Omega$
- Use final $R_{equivalent}$ to calculate total I out of battery
  - $I_{total} = V/ R_{eqtotal} = 10V/100\Omega = 0.1A$

Combination Circuit Example 2

- Combine Series Resistors where possible
  - $R_{eq1} = 25\Omega + R_{load} + 25\Omega = 150\Omega$
- Combine Parallel Resistance where possible
  - $1/R_{eq2} = 1/40\Omega + 1/R_{eq1} = 0.025\ S + 0.00667\ S = 0.03167\ S$
  - $R_{eq2} = 1/0.03167\ S = 31.58\Omega$
- Repeat until you get a single $R_{equivalent}$
  - $R_{eqtotal} = 20\Omega + R_{eq2} + 20\Omega = 71.58\Omega$
- Use final $R_{equivalent}$ to calculate total I out of battery
  - $I_{total} = V/R_{eqtotal} = 60V/71.58\Omega = 0.838A$

Short Cuts for Some Parallel Circuits

- If Parallel Circuits <u>have the same value</u> you can easily calculate the $R_{equivalent}$
  - For two resistors of the same value, $R_{equivalent} = R/2$
  - For three resistors of the same value, $R_{equivalent} = R/3$
  - For four resistors of the same value, $R_{equivalent} = R/4$
  - In example below, $R_1 = R_2 = R_3 = 3k\Omega$
    - $R_{equivalent} = R/3 = 3k\Omega/3 = 1k\Omega$

Short Cuts for Some Parallel Circuits (Short Circuit)

- If Parallel Circuits <u>have a short</u>, $R_{equivalent} = 0$
  - Doesn't matter the number or size of other resistors.
  - In example below, $R_1 = 0$, $R_2 = R_3 = 3k\Omega$
    - $R_{equivalent} = 0$, it is a short circuit and very dangerous because current is high (theoretically infinity)
    - <u>All the current will flow through the Short</u>

What is a Load

- An element (resistor, light, speaker, motor, etc.) connected across the <u>output</u> terminals of a circuit that draws current from the circuit
- Normally the element in a circuit upon which work is done.

Impedance Matching

- Impedance Matching is a technique used to match a load resistance to a source resistance in order to achieve maximum transfer of power.
  - For instance most speakers are 8 ohm speakers (Load) and the source resistance is then usually set to 8 ohms to get maximum power.
  - In this example, the Impedance/Resistance is matched when $R_1 = R_{load}$

Power

- Power –The rate of energy usage equal to the voltage times the current.
- $P = VI = V^2/R = I^2R$
- The unit are Watts (W)
- Maximum Power Transfer—A transfer of maximum power from a source to a load when the load resistance equals the internal source resistance.
- For resistors, the Power is normally dissipated
- If you exceed the Power Rating, the resistor can be damaged, smoke, catch on fire, or explode.

In Practice Quiz #1

- $V = 15V$, $R_1 = 100\Omega$, $R_2 = 100\Omega$, $R_3 = 100\Omega$
  - What is $R_{equivalent}$
  - What is the current from the battery?
  - What is the current through R_1, also called I_{12} ?
  - What is the current back to the battery, also called I_{56} ?
  - What is the power through R_1, R_2, and R_3?

In Practice Quiz #2

- $V = 10V$, $R_1 = 100\Omega$, $R_2 = 0\Omega$, $R_3 = 100\Omega$
  - What is $R_{equivalent}$
  - What is the current from the battery?
  - What is the current through R_1, also called I_{12} ?
  - What is the current back to the battery, also called I_{56} ?
  - What is the power through R_1, R_2, and R_3?

In Practice Quiz #3

- $V = 5V$, $R_1 = 0\Omega$, $R_2 = 100\Omega$, $R_3 = 100\Omega$
  - What is $R_{equivalent}$
  - What is the current from the battery?
  - What is the current through R_1, also called I_{12} ?
  - What is the current back to the battery, also called I_{56} ?
  - What is the power through R_1, R_2, and R_3?

In Practice Quiz #4

- $V = 12V$ and $R_{load} = 16\Omega$
- What resistance should our R_1 be for maximum power?
- For maximum power, what is $R_{equivalent}$
  - What is the current I from the battery?
  - What is the power on R_{Load}?
  - What is the total power on the system?

Practical

- Create the circuit with the materials provided
  - Measure $V_{bat} = V_{16}$
  - Measure $V_{R1} = V_{12}$
  - Measure $V_{R2} = V_{25}$
  - Measure $V_{R3} = V_{34}$
  - Notice anything about the relationships between the voltages?
  - Calculate the power through R_1, R_2, and R_3?

Homework

- Homework Generator Level 3 Combination
- If you still have issues, also do Level 1 VIR and Level 2 Parallel
- Remember
  - V = I R (Ohm's Law)
  - P = VI (Watt's Law)
  - Series Resistance
    - $R_{eq} = R_1 + R_2 + R_3$
    - R_{eq} is always greater than the largest single resistance
  - Parallel Resistance
    - $1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3$
    - R_{eq} is always less than the smallest single resistance
  - Remember to combine Parallels and Series resistances until you get back to one R_{eq}
- We will grade them at next practice