Lab 8. Series and Parallel Resistors

Goals

- To understand the fundamental difference between resistors connected in series and in parallel.
- To calculate the voltages and currents in simple circuits involving only resistors using the rules for "adding" series and parallel resistors.
- To learn to connect components correctly according to a circuit diagram and then to make valid current and voltage measurements with ammeters and voltmeters.
- To compare the predicted and measured currents and voltages for three circuits.

Introduction

Circuits are often composed of multiple resistors connected in various ways. Two general configurations that recur again and again are the so-called "series" and "parallel" combinations. Many resistor networks can be broken down into these simple units. For the sake of the following discussion, assume that the terminals of each resistor are labeled Terminal 1 at one end and Terminal 2 at the other end.

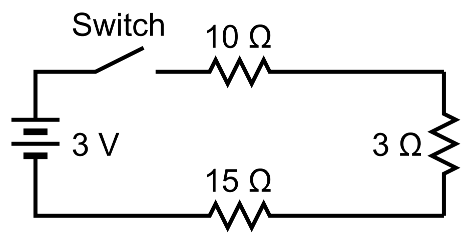
A "series" connection is when Terminal 2 of one resistor is connected to Terminal 1 of the next resistor and so on. This is like adding lengths of garden hose to reach the far corner of the yard. A battery or power supply is connected between Terminal 1 of the first resistor in the chain and Terminal 2 of the last resistor in the chain. Just like the water hose, where water flows into one end of the hose at the same rate as water flows out of the other end, the same electrical current (charge flow) flows through each of the resistors connected in series. It is important to note that in series connections, no other electrical connections can be made anywhere along the chain to add more current or take some away. If extra connections are present, even though the resistors may appear to be in a chain, our assumptions are invalid and the circuit is no longer a simple series combination. It is straightforward to show that resistances connected in series can be summed together to get the total resistance of the whole chain. In other words

$$R_{total} = R_1 + R_2 + R_3 + R_4 + \ldots \tag{8.1}$$

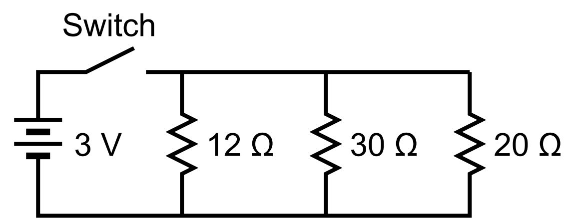
A “parallel” connection is when all of the Terminal 1’s of several resistors are connected together. Likewise, all of the Terminal 2’s are connected together. A battery or power supply is then connected between the combined Terminal 1 and the combined Terminal 2. In this case the applied voltage (“pressure” if you will) across each resistor is the same. Using this observation it again is straightforward to show that the total resistance of such a parallel combination is

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + ... \tag{8.2}$$

Simple series and simple parallel resistor configurations



(a) Circuit 1.



(b) Circuit 2.

Figure 8.1. Diagrams of (a) series and (b) parallel circuits for study.

Analyze Circuits 1 and 2

Answer the following questions for both Circuits 1 and 2. Be sure to explain your reasoning and show your calculations in your notes! You can summarize your numerical results in the provided table.

1. Which circuit contains the series combination and which the parallel combination?
2. What is the value of current through each resistor?
3. What is the voltage across each resistor?
4. What is the total current flowing through the power supply into the entire circuit?
5. What is the power dissipated (as heat) in each resistor? If any value exceeds 2 W, talk with your TA before proceeding to the next step.

Construct and study Circuits 1 and 2

Caution: Set the power supply to 3 V *before* connecting it to your circuit!

1. Measure the current through each resistor, showing on a circuit diagram exactly how and where the ammeter is connected in the circuit for each of the measurements.
2. Measure the voltage across each resistor, showing on a circuit diagram exactly how and where the voltmeter is connected in the circuit for each of the measurements.

3. Measure the total current flowing through the circuit, showing on a circuit diagram exactly how and where the ammeter is connected in the circuit.

4. Measure the total voltage across the whole circuit, showing on a circuit diagram exactly how and where the voltmeter is connected in the circuit.

Compare measured and predicted potential differences and currents

Compare your calculated and measured values using table at the end of the lab. (Remove this table from the manual and turn it in with your lab notes.) Percent differences are a good way to compare. Note whether the measured values are larger or smaller than the calculated ones. This is a good way to determine whether the differences are due to a systematic error or to some random process. If all the calculated values are larger than the measured ones, this suggests a systematic error, perhaps due to an non-ideal measuring device. If some values are a little high and others are a little low, the cause of variation is more likely to be random, such as variations in reading the meters.

Use these results to address the following questions. Explain your reasoning and justify your conclusions based on your data.

1. How are the currents through each resistor related to the total current flowing through the power supply in a series circuit? Look for a general rule that will apply to all series circuits.

2. How are the voltages across each resistor related to the total voltage across the power supply in a series circuit? Look for a general rule that will apply to all series circuits.

3. How are the currents through each resistor related to the total current flowing through the power supply in a parallel circuit? Again, look for a general rule that will apply to all parallel circuits.

Combined series and parallel configuration of resistors

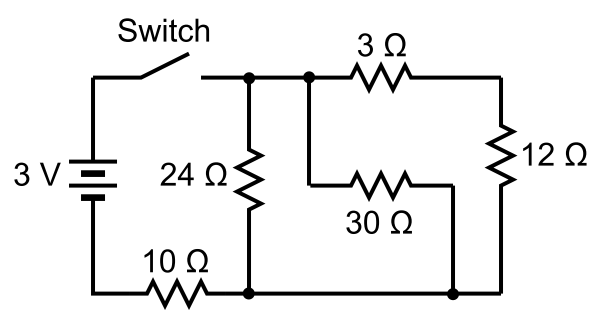


Figure 8.2. Diagram of Circuit 3.

Calculate, then measure the potential differences across and currents through each component in Circuit 3.

Before you leave the lab please:

Turn off the power to all the equipment.

Please put all leads and small components in the plastic tray provided.

Report any problems or suggest improvements to your TA.

Resistor Color Code

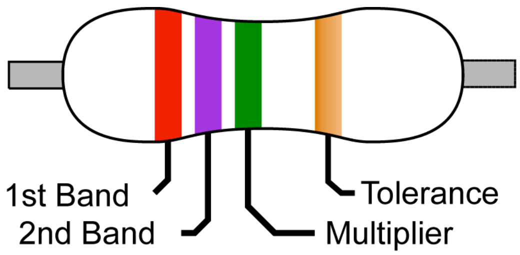


Figure 8.3. Resistor with labeled bands. To read the bands in order, orient the resistor so that the tolerance band (which is all by itself) is on the right. If the first band is red (2), the second violet (7), and the third green (10^5), the resistance is 27×10^5 ohms or 2.7 MΩ. If the tolerance band is gold, the actual resistance of a new resistor may differ from the indicated value by ±5%. Exceeding the current rating of a resistor can destroy it or change its resistance permanently. Image courtesy of Wikipedia (public domain).

Color Blank	Band 1 First Digit	Band 2 Second Digit	Band 3 Third Digit	Band 4 Tolerance
Black	0	0	$10^0 = 1$	
Brown	1	1	10^1	
Red	2	2	10^2	
Orange	3	3	10^3	
Yellow	4	4	10^4	
Green	5	5	10^5	
Blue	6	6	10^6	
Violet	7	7	10^7	
Gray	8	8	10^8	
White	9	9	10^9	
Gold			10^{-1}	±5%
Silver			10^{-2}	±10%
No Color				±20%

Series and Parallel Resistors Data Sheet

Circuit 1 — Series Resistors

		Calculated	Measured	%Difference	Power (W)
$R_{total} = \_\_\_ \,\Omega$	ΔV_{total} (V)				
	I_{total} (A)				
$R_1 = 10\,\Omega$	ΔV_1 (V)				
	I_1 (A)				
$R_2 = 3\,\Omega$	ΔV_2 (V)				
	I_2 (A)				
$R_3 = 15\,\Omega$	ΔV_3 (V)				
	I_3 (A)				

Circuit 2 — Parallel Resistors

		Calculated	Measured	%Difference	Power (W)
$R_{total} = \_\_\_ \,\Omega$	ΔV_{total} (V)				
	I_{total} (A)				
$R_1 = 12\,\Omega$	ΔV_1 (V)				
	I_1 (A)				
$R_2 = 30\,\Omega$	ΔV_2 (V)				
	I_2 (A)				
$R_3 = 20\,\Omega$	ΔV_3 (V)				
	I_3 (A)				

Circuit 3 — Combined Series and Parallel Resistors

		Calculated	Measured	%Difference	Power (W)
$R_{total} = \_\_\_ \,\Omega$	ΔV_{total} (V)				
	I_{total} (A)				
$R_1 = 10\,\Omega$	ΔV_1 (V)				
	I_1 (A)				
$R_2 = 24\,\Omega$	ΔV_2 (V)				
	I_2 (A)				
$R_3 = 30\,\Omega$	ΔV_3 (V)				
	I_3 (A)				
$R_4 = 3\,\Omega$	ΔV_4 (V)				
	I_4 (A)				
$R_5 = 12\,\Omega$	ΔV_5 (V)				
	I_5 (A)				