Chapter 2

Lab 2 - Resistive Circuits

2.1 Objective

The objective of the laboratory is to introduce basic resistive circuits, the effect of resistors in series and parallel, and the ways in which voltages and currents are measured. Potentiometers are also introduce briefly as a sort of variable resistor (not to be confused with a varistor).

2.2 Materials

- Laptop with Waveforms
- Digilent Analog Discovery
- Breadbaord
- Wiring kit
- Lab parts kit

2.3 Introduction

Resistors are a fundamental part of all electronic circuits and understanding how they work and how to apply them is a basic requirement for any electorates course.

2.3.1 Resistor Combinations

Resistors in series will always add together

$$R_{Total} = R_1 + R_2 \ldots R_N \tag{2.1}$$

while resistors in parallel combine as the addition of reciprocals.

$$\frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2} \cdots \frac{1}{R_N} \tag{2.2}$$

Series resistances are fairly straight forward, add one resistor to the other, but the parallel combination leads to different results based on the values of the resistors in parallel. For instance, a large resistor in parallel with a small resistor gives an equivalent resistance approximately equal to the small resistor. Similarly, two resistors of the same value in parallel gives an equivalent resistance equal to half of either resistor.

2.3.2 Voltage and Current Dividers

Resistors can be used to make both voltage and current dividers. The use of either depends on the application but often times it is required to generate a small voltage from a large voltage or a smaller current from a larger current.

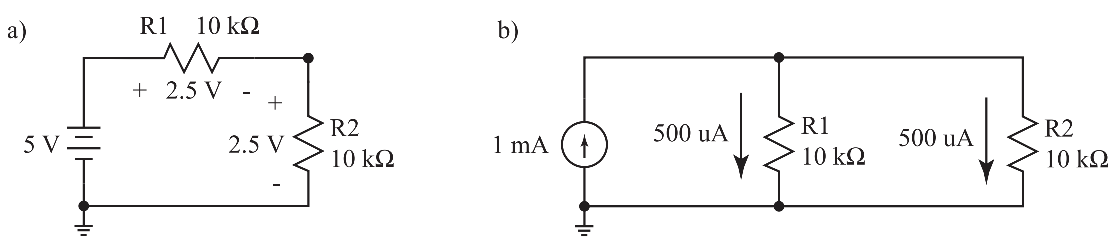


Figure 2.1: Examples of a voltage divider (a) and a current divider (b).

Figure 2.1 shows examples of a simple voltage divider (a) and a simple current divider (b). The output of a voltage divider can be simply calculated as

$$V_{out} = \frac{R2}{R1 + R2} V_{in} \tag{2.3}$$

In the example shown, the output voltage is 2.5 V, or the voltage across R2, which follows simply from plugging in to the equation. Because of the values for R1 and R2 are the same, the voltage drop across R1 is also 2.5 V.

$$\left(\frac{10\ \text{k}\Omega}{10\ \text{k}\Omega + 10\ \text{k}\Omega} \right) 5\ \text{V} = 2.5\ \text{V} \tag{2.4}$$

Similarly, a current divider is calculated in the same way where

$$I_{out} = \frac{R2}{R1 + R2} I_{in} \tag{2.5}$$

and the resulting current in each resistor is 500 μA which is again found by plugging in to the equation. Because the values for R1 and R2 are the same, the current through R1 is also 500 μA.

$$\left(\frac{10\ \text{k}\Omega}{10\ \text{k}\Omega + 10\ \text{k}\Omega}\right) 1\ \text{mA} = 500\ \mu\text{A} \tag{2.6}$$

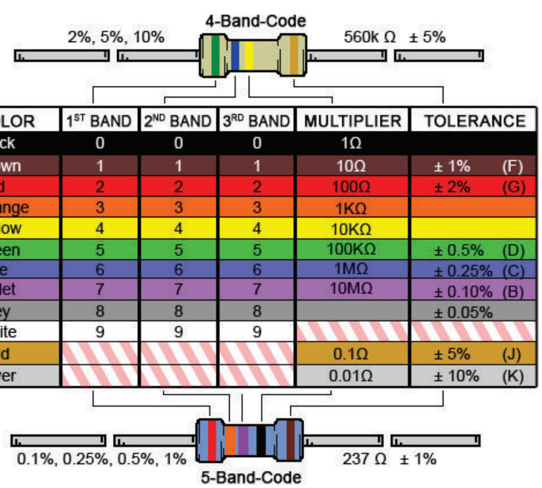
Note that a voltage divider applies to resistors in series while a current divider applies to resistors in parallel.

2.3.3 Measuring Voltage and Current

There was a time when voltages and currents had to be measured with separate meters. But today, analog voltage and current meters have been supplanted by Digital Multimeters (DMM). A typical DMM has the ability to make several measurements such as AC and DC voltage, AC and DC current, resistance, and continuity. For the purpose of this experiment the measurements will focus on DC voltage and current.

2.3.4 Resistor Color Code

There are a variety of resistor in the course kit and while it's possible to measure all of the values individually, learning how to read the color codes will make identifying individual resistors much easier. See the look up table below.



COLOR	1ST BAND	2ND BAND	3RD BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	± 0.5% (D)
Blue	6	6	6	1MΩ	± 0.25% (C)
Violet	7	7	7	10MΩ	± 0.10% (B)
Grey	8	8	8		± 0.05%
White	9	9	9		
Gold				0.1Ω	± 5% (J)
Silver				0.01Ω	± 10% (K)

Figure 2.2: Resistor color code look up table.

2.3.5 Potentiometers

A potentiometer (or "pot") is a three terminal resistor as shown in Figure 2.3. The resistance between terminals 1 and 3 is fixed and is equal to the rated value for the potentiometer. Terminal 2 is connected to a movable contact called the arm or wiper and the resistance between terminals 2 and 1 or between 2 and 3 can be varied by moving the arm. If terminals 1 and 3 are connected across a voltage source, then the voltage between terminals 2 and 1 or between 2 and 3 can be varied by moving the arm. In some cases, terminal 2 is connected to either terminal 1 or 3 so that the resistance from terminals 1 to 3 can be varied.

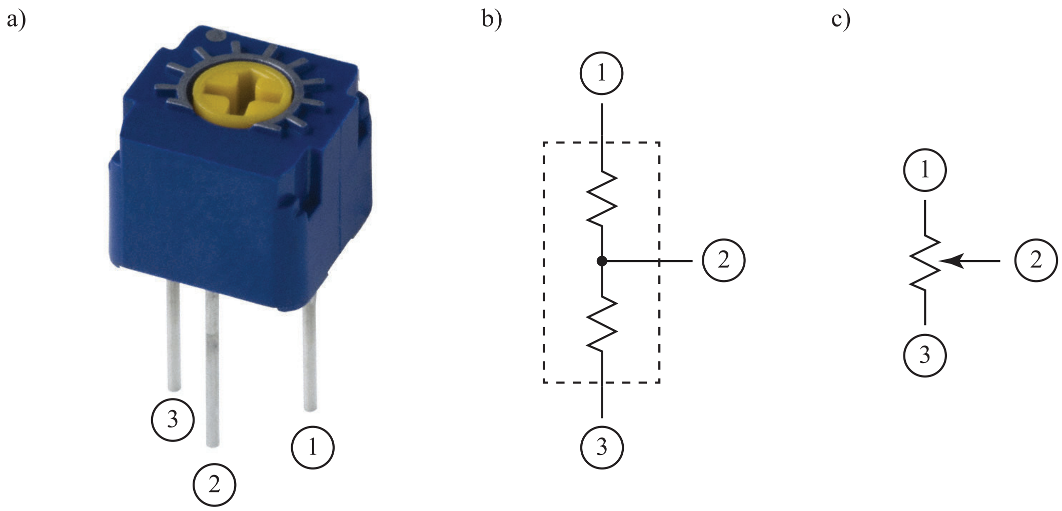


Figure 2.3: A picture of a practical potentiometer with the appropriate pins labeled (a), an equivalent circuit diagram of a potentiometer with the wiper in a fixed position (b), and the common circuit schematic representation for a potentiometer (c).

2.4 Pre-lab Requirements

2.4.1 Theoretical Calculations

Using the circuit below, complete the following.

1. Calculate the parallel combination of R2, R3, and R4 and the parallel combination of R5 and R6.

2. Calculate the voltage at nodes A and B.

3. Calculate the current through R2, R3, and R4 and the current through R5 and R6.

4. Using the parallel and series combination of resistors, simplify the circuit to a single resistor.

2.4.2 Simple Resistor Circuits

Recall the circuit in Figure 2.4.

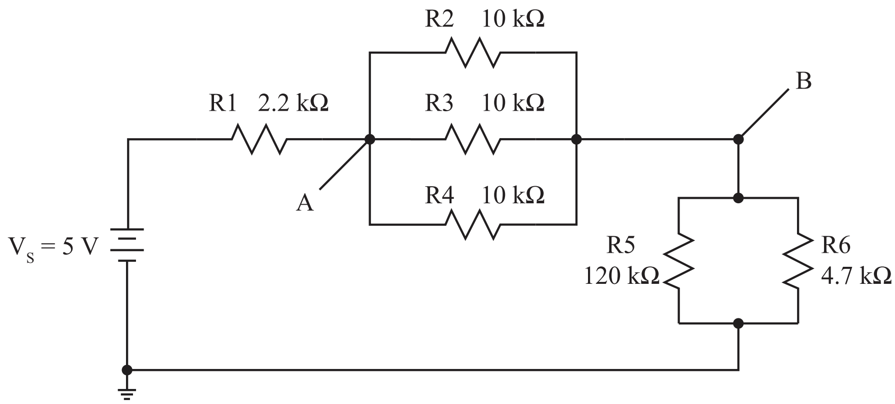


Figure 2.4: Pre-lab circuit.

1. Build the circuit and then measure the node voltages using the oscilloscope, record the values measured.

2. Calculate the experimental currents using the node voltages measured in the previous step. Table the results and calculate the percent error for each voltage and curernt. Have the table (typed) in hand to show your lab instructor

2.4.3 Potentiometers

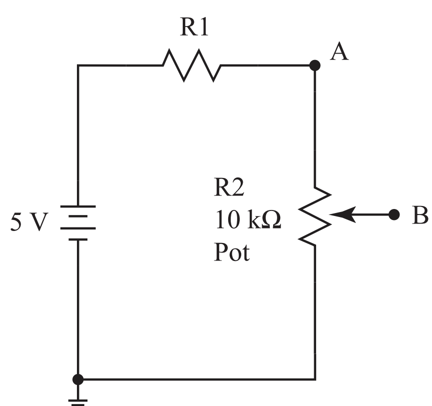


Figure 2.5: A simple voltage divided where R2 is a potentiometer. The potentiometer has a total resistance of 10 kΩ but the location between the internal resistors, B, can be physically moved.

1. Choose R1 in Figure 2.5 such that the voltage at node A is 2 V.

2. Build the circuit using the value for R1 you chose in the previous step.

3. Vary the position of the wiper and record the range of possible voltages at node A.

4. Save the completed circuit to demo to your lab instructor.

2.5 In-Lab Requirements

The following items must be ready at the start of lab and students who do not have both items completed and ready to show at the beginning of lab will receiver a zero and denied access to the lab.

- Show the table of voltages, currents, and their percent error when comparing theoretical to experimental.

- Demo the potentiometer circuit to your lab instructor.

2.5.1 Measuring Voltage and Current

A voltmeter should always be placed in parallel with whatever it's measuring and an ammeter should be placed in series. While the explanation for why each meter has a specific placement is straight forward, it's worth investigating what happens when either meter is used incorrectly.

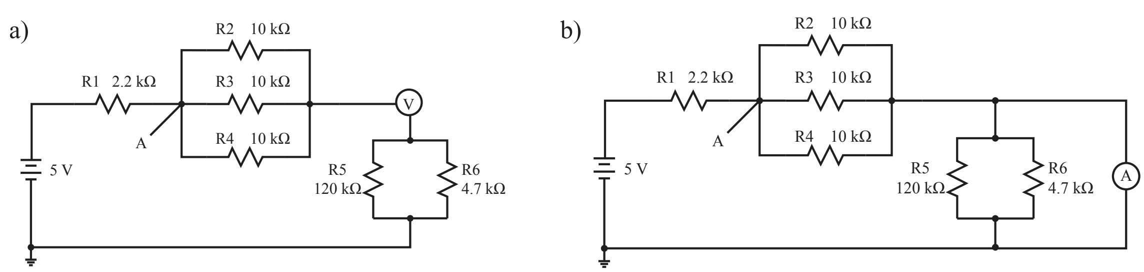


Figure 2.6: The circuit from the pre-lab with a voltmeter in series at Node B (a), and an ammeter in parallel (b).

1. Build the circuit from the pre-lab as shown in Figure 2.4.

2. Place the voltmeter in series as shown in Figure 2.6 (a) and record the voltage measured.

3. Place the ammeter in parallel as shown in Figure 2.6 (b) and record the current measured.

2.6 Write Up

Detail the results from Section 2.5.1 and explain how the loading effects of a voltmeter or ammeter used improperly can result in inaccurate values.