Section	
Bench No.	

ECE110 Introduction to Electronics

Experiment 2: Resistor Network for Speed Control

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This part is reserved for your instructor

Score	
Instructor Signature	
Date	

Experiment 2: Resistor Network for Speed Control

Laboratory Outline

This week, you will use resistors to control the speed of each motor on your car. You are going to do this in a fairly direct, manner by placing resistance between the battery supply and the motors to limit the current supplied to each. Because the battery is capable of supply high power to the resistors (in excess of their watt rating), we will use “networks” of resistors such that the effective rating of the resistance created by the combination of resistance is higher than that of a single resistor.

Learning Objectives

- Learn to pulse wheels for control of motors speed and car direction.
- Investigate power rating and equivalent resistance to implement a simple method of motor speed control.
- Measure the equivalent resistance of resistors in parallel to determine a descriptive formula for equivalent resistance

Introduction

Drop off your Prelab hardware on your own work bench. Your instructor will check that you have completed your prelab assignment. Also, you can ask any questions you may have about last week’s lab or today’s prelab. You will also receive a quick rundown of what is planned for today.

At your Bench

After your instructor finish check your prelab, you will start today's lab. First your instructor will introduce today's lab, and tell you what need to be noticed in today's lab. Then students can start today's work. First students could discuss and perfect their prelab assignments which often involve a circuit built at home or other group discussion. Today, you will work with the snap-action switches. Start by placing the wheels on your car if you did not in the previous lab session.

Experimental Setup

Snap-Action Switch

On your car’s breadboard, build the switched circuit of Figure 1 and Figure 3. It is very much like your prelab circuit, but replaces the resistor/LED combinations with the car motors and the buttons with the snap-action switches.

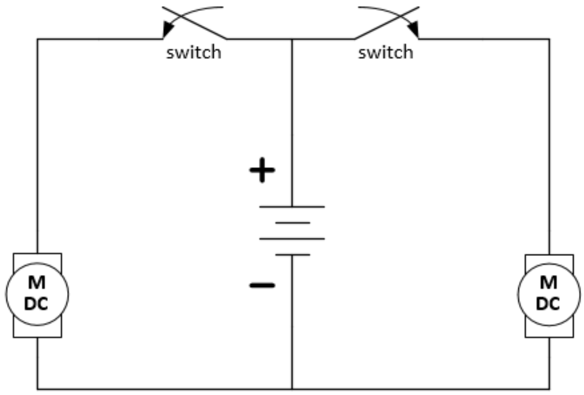
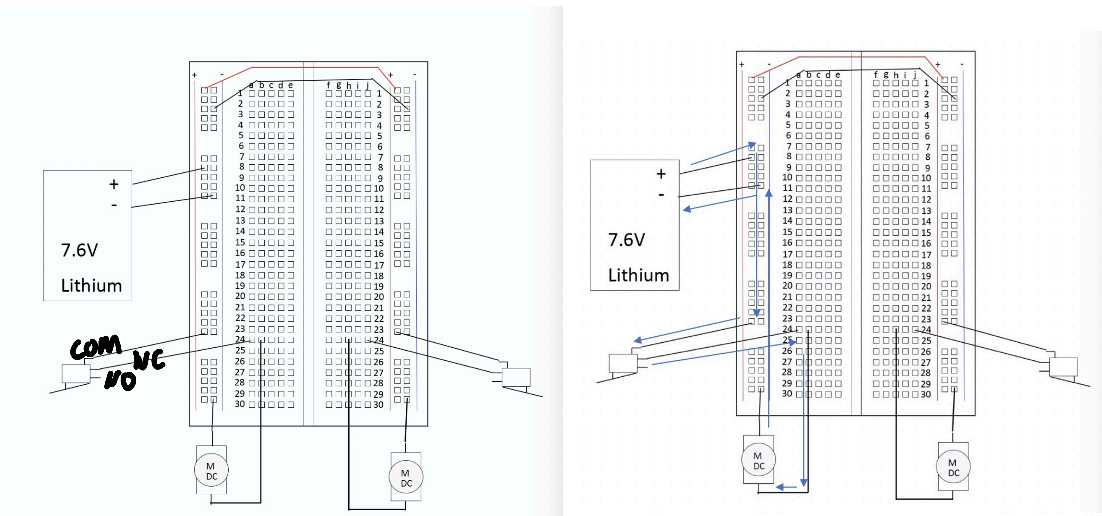


Figure 1: Circuit schematic for switching motors.

Figure 2: The snap-action(lever) switch. The second wire on the switch should be the "normally-open" (NO) connector which connects to the common (COM) when the switch is pressed. The other is "normally closed" (NC).



(a) (b)

Figure 3: Example physical diagram for switching motors using the snap-action switch. The path of current flow is shown in the figure on the right for a single motor.

By adjusting two snap-action switches, the car can be made to go in a straight line, those of you who are interested can try it.

Question 1: Please label NO, NC and COM in Figure 3 (a).

Power Rating

In this session we will learn to consider the role of power in motor operation through measure-ment and calculation, and how to make the current limiting resistor work at the rated power through the resistance network.

While it was fun to control your car and make it move in a straight line, it should also be possible to build a type of "cruise control" to make your car go in a straight line as well. To do so, we might consider placing a resistor in series with each motor in order to limit the current flow and slow the motors. To match wheel speeds (compensating for differences in the motors due to loose specifications), a different resistance would be necessary for each wheel. See Figure 4.

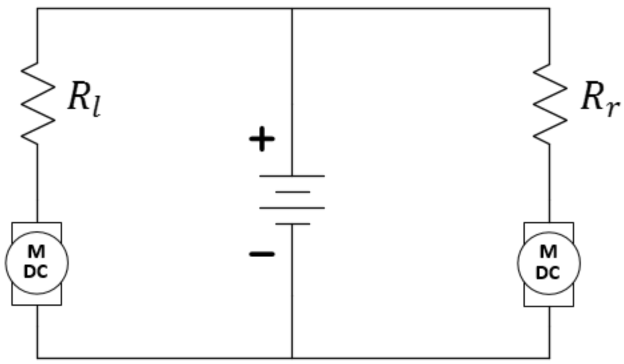


Figure 4: A grand idea! Use two different resistances to make the speeds of the left and right motors match

Procedure:

1. Set the **Voltage supply** to 7.6V.

    1) Turn on the power supply with nothing attached to it (this way, we will have an opportunity to check our circuit for errors before adding power).

    2) **Push the button labeled "1" under Channel area** to allow the device to deliver at most 30 volts (and currents up to 3A). You will use the pair of terminals labeled **+** and **– of Channel 1.** See Figure 5.

    3) Now you can use the knob to **raise the voltage to 7.6 V**. Make certain that you

are varying the voltage and not the current.

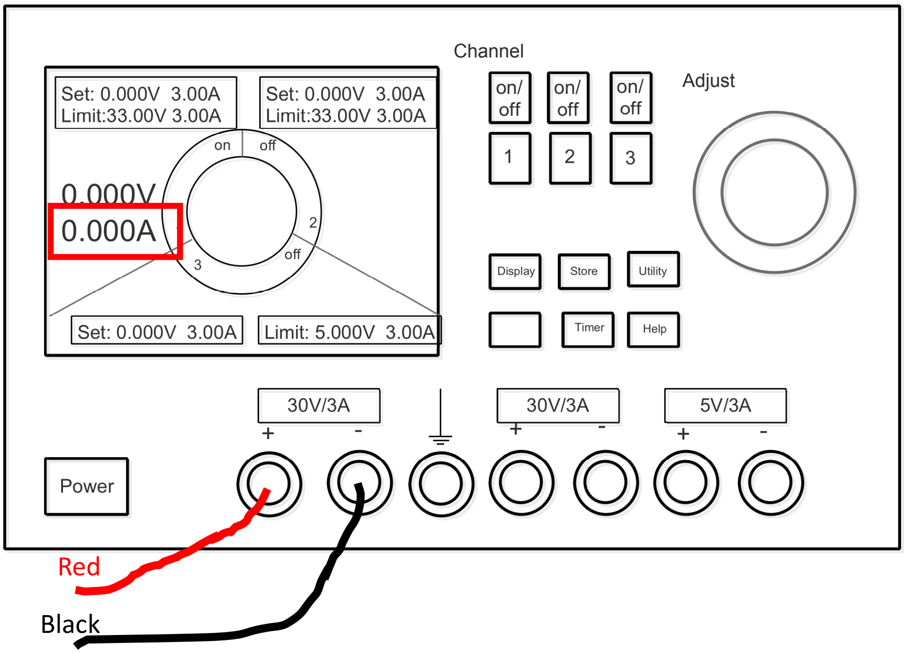


Figure 5: Configuration of the power supply when providing a voltage to a circuit

2. Connect a single motor with the DC power by the breadboard.

3. Make sure you make the right connection, then turn on the DC power. Run the motor for 1 minute to "warm it up". Now we will record how much current flows through the motor. The current can be read directly from the voltage supply (As show in Figure 5).

Question 2: Write the voltage and the resulting current below.

When V=_7.59 V_, I=_0.15A_

4. Ohm's law states that the current that flows through and the voltage across an Ohmic device are related by the resistance of that Ohmic device, that is, $R = \frac{V}{I}$. A motor is not really an Ohmic device, but we could attempt to model it as an Ohmic device.

Question 3: Model the motor as an Ohmic device based on the voltage supplied across the motor and the current that flows through it. Write down the value of the motor resistance.

$R_m =$ _36.4 Ω_

5. Assuming you connect the circuit as shown in Figure 5 , and you use the battery as the power source. If you want most of the battery voltage appear across the motor (so it doesn't stall), R_l and R_r should be no larger than the resistance of the motor. Now measure the open circuit voltage of your rechargeable battery, answer the following question.

Question 4： Assuming we choose $R_m = R_l = R_r$, estimate how much current might flow through each resistor, and therefore, each motor ?

$V_{battery,oc} =$ 7.6V $\qquad\qquad I_m =$ 0.10A

Question 5： Again, continuing with this model for the motors, how much power will be dissipated by each of the resistors and each of the motors? $P_R \approx$ 0.364 W

But the resistors are only rated at $\frac{1}{4}$ Watt! Therefore, we have established that simple resistors used in this manner are attempting to dissipate power well beyond their rated values and bound to 1) get hot, 2) burn your fingers when you touch them, and 3) eventually fail. What can we do? Let's use your understanding of cylindrical conductors to think about this… replace it with more resistors in panell that can give the same vesistence.

Question 6: If a 20Ω resistor is dissipating 1 W, how much power would be dissipated by each of five 100Ω resistors used in parallel to replace the single 20Ω resistor?

0.2W.

Resistor network to solve power-limiting problem

Let's not use a single -watt resistor for R_l and R_r, but rather use a network of parallel resistors to build an equivalent resistance with an effective higher power rating. Please follow the following procedures carefully…

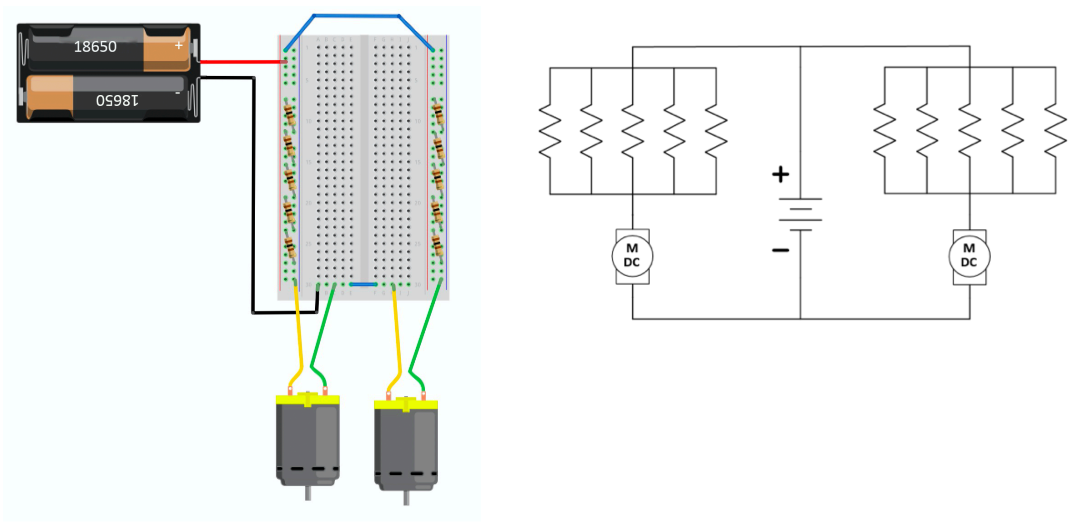
Procedure：

1. With your battery turned OFF, construct the circuit of Figure 6. Note how we are using the “power rail” of the breadboard to facilitate the placement of multiple resistors. Use 100 Ω for each resistor. Five such resistors in parallel will provide the equivalent of around 20 Ω, but with a higher power rating. Carefully trim the wires of each 100 Ω resistor so that there is less chance of creating a “short circuit” across the desired resistive network. Leave space for more resistors to be added. Don’t miss adding the two “jumper” wires that connect one side of the board to the other.

2. Now, with your car sitting on a wooden block (so it doesn’t run away from you), turn on the battery. Both wheels should spin, but you might note that one wheel is faster than the other. Attempt to speed a slow wheel by adding another resistor in parallel with the network on that side of the car. Alternately, attempt to slow a wheel by removing a resistor. **BUT DO NOT USE LESS THAN FIVE RESISTORS PER NETWORK** or you may go beyond the power rating and burn your fingers!

   Hint: if the motor not turn on with 5 resistors’ network in series, you can add more resistor to the resistor network, for the internal resistor of motor is too small, so the voltage through it is not big enough to turn it on.

3. Make final adjustments by setting your car on the floor until it runs straight. If you have time, set up again the two rows of blocks and see if your car can clear them now without any physical control.



(a) (b)

Figure 6 : The breadboard circuit you are to build. (a) the physical diagram and (b) the schematic of the same circuit.

4. Let’s spend a little time decomposing the circuit we just build. Carefully follow these instructions. Remove the battery, the motors, and the two” jumper wires” from your circuit, leave **ONLY the two resistor networks on either side**.

Question 7: Beginning with the left resistor network circuit, attach the Ohmmeter to the two rails and record the resistance. Continue to remove resistors and record the measurement until all resistors have been removed from the left-side resistor network.

Hint: Figure 7 shows how to connect DMM when use as Ohmmeter, and DMM should connect with the resistor network **in parallel**.

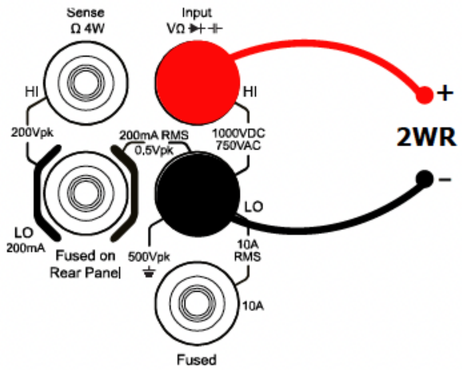


Figure 7: The resistance test connection diagram of DMM

Number of resistors	Resistance(measured, in Ω)	Theoretical Value(in Ω)	Comment
7	14.29	14.28	
6	16.61	16.67	
5	19.90	20.00	
4	24.84	25.00	
3	33.03	33.33	
2	49.39	50.00	
1	98.57	100.00	

Table 1: Left-side resistor network decomposition

Question 8: Repeat this procedure with the right-side network. We had a 330 Ω resistor for resistor No. 7

Number of resistors	Resistance(measured, in Ω)	Theoretical Value(in Ω)	Comment
7	15.93	15.86	
6	16.80	16.67	
5	20.20	20.00	
4	25.80	25.00	
3	33.29	33.33	
2	49.84	50.00	
1	99.80	100.00	

Table 2: Right-side resistor network decomposition

Question 9: Provide a formula for the resistance of n 100Ω resistors in parallel.

$$R = \frac{100}{n}$$

Question 10： Resistor Tolerance –Use one of the resistor in left resistor network as an example. How close do the resistances match their marked value? Let's use the value you measure in Table 1 and compare it to the values indicated by the colored bars. record the results of your measurements below. Compute the percent error as:

$$\%\text{error} = 100 \times \frac{labeled\ resistance - measured\ resistance}{labeld\ resistance}$$

labeled resistance = ________, measured resistance = ________, %error = _

Is the resistor within ~~5% or 10%~~ 1% error limit that is marked with a ~~gold or silver band~~ platium on the resistor as part of its code? Explain.

yes. take the left-side resistor as example.
except for the last resistor, all %error are within 1%

Question 11: Using your resistive model, R_m, for both motor and the resistor networks you designed above, predict how long a Lithium rechargeable battery rate at 1900mAh would operate both wheels of the car continuously before going dead (depleting its charge). Show your work. 1900mAh at 7.6V is 51984J

$$\frac{1}{R} = \frac{1}{36.4+15.93} + \frac{1}{36.4+14.24} \quad R = 25.74\Omega \quad P = \frac{U^2}{R} = 2.24W \quad t = 23157.5\ s.$$

Question 12: Explain in your own words why we needed a resistive network instead of a single resistor to slow the wheels.

to prevent the resistors from being to hot and improve power rating

Question 13: Using a resistor to slow the wheels results in some useful energy going to the wheels and "waste" energy dissipated as heat in the resistor. If we assume the wheel is modeled by a resistor (Question 3) and the resistance slowing the wheels is given by the value in the first row of Table 1, what is the efficiency of this system?

$$\eta = \frac{P_{useful}}{P_{useful} + P_{waste}} = \frac{I^2 R_m}{I^2 R_r + I^2 R_m} = 71.87\%$$

Explore More! Modules

The instructor will provide you with their preferences for this week's ***Explore More! Modules***. Continue with below with your choice. Remember, at the end of the semester, you will earn points towards your total semester lab score by having completed a minimum of 6 modules. If you wish to be eligible for a Course Aide position in the future, please consider doing more and impressing us with your command of the material and your ability to aid your classmates.