Chapter 3

ECE Tools and Concepts

3.1 Section Overview

This section has four exercises. Each exercise uses a prototyping board for building the circuits. Understanding how to use a prototyping board is therefore crucial to finishing these exercises.

Following is a brief description of the four exercises:

- ***Exercise One*** explores the internal resistance of an ammeter and then proceeds to use a voltmeter to measure current.
- ***Exercise Two*** uses the passive sign convention to find if the tekbot battery is generating or dissipating power.
- ***Exercise Three*** explores current power and voltage are related in different combinations of resistors in series and parallel.

Ensure that the batteries are fully charged. They need about 14 hours to completely charge.

3.2 Basics of the Prototyping Board

A prototyping board (also called a protoboard) is used to build prototype circuits. They are a quick and convenient way to build simple circuits without soldering. See Figure 3.1.

This section describes the method to seat the contacts in the new protoboard, and about the protoboard layout itself.

Figure 3.1: A Protoboard

Figure 3.2: Seating a protoboards contacts

Using double-sided tape on the back of the prototyping board is **not** recommended. If the protoboard is attached to a surface with the tape, removal may be impossible without destroying the board.

3.2.1 Seat the Contacts

With the new protoboard, we will need to seat the contacts for the first time that we use it. Push on the back of the board using the thumbs to ensure that the internal contacts are firmly seated.

See Figure 3.2 for a view of how to seat the contacts in the new protoboard.

3.2.2 Protoboard Layout

Component leads/wires are inserted into the holes on the board. Inside each hole are metallic contacts that connect an inserted wire to four other adjacent holes. The sets of five holes can be used to form circuit nodes. Most of the nodes that can be formed will consist of up to five wires. However, at the top and bottom of the board, nodes of up to twenty wires may be created. These are most convenient for forming ground and power contacts. See Figure 3.3.

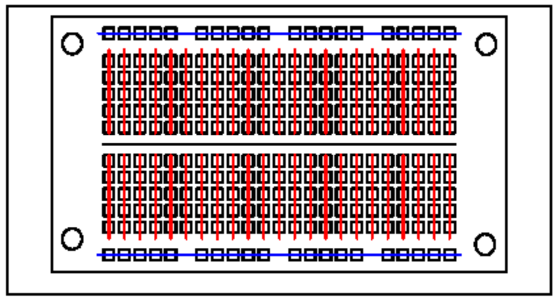

Figure 3.3: Arrangement of nodes and buses on a protoboard

When inserting a component into the protoboard, apply firm pressure. However, forcing component leads into the protoboard that are too large in diameter may permanently deform the contacts, and future connections to those holes will be intermittent and unreliable.

3.3 Procedure

As mentioned earlier, the procedure for Lab Two is divided into three exercises, and will deal with the following concepts respectively:

1. Ammeter Characteristics
2. Passive Sign Convention and Power Equation
3. Power Dissipation and Equivalent Resistance

3.4 Exercise One: Ammeter Characteristics

When measuring current with an ammeter, the current being measured flows through the meter. The ammeter is designed to have zero internal resistance ideally, because any resistance in the ammeter will alter the current flowing through the circuit under test, resulting in inaccurate measurements. However, a real ammeter must have some small resistance to be able to measure current. We will first examine the internal resistance of a Digital Multimeter (DMM) ammeter. Later, a voltmeter is used as an improvised ammeter.

To implement the above, follow these steps:

1. Work with a neighbor and measure the internal resistance of each other's ammeters. With one DMM set to the 200 milliAmperes (mA) setting, measure and record the internal resistance using the other DMM. (Remember the resistance should be very small, so use an appropriate resistance setting).
2. To avoid having to hold the DMM probes, use the micrograbber wires instead of the probes. See Figure 13.4.

ENTER VALUE FOR:

Internal DMM Ammeter
Resistance ► ________

Figure 3.4: Micrograbber Wires

3. Use the protoboard to build the circuit shown in Figure 3.5. (Use the battery pack to power the circuit.) Set the DMM to the 200mA scale. Measure and record the current drawn by the motor.

4. Now build an improvised ammeter by placing a 1Ω resistor in series with the motor, and measuring the voltage across it. The circuit is shown in Figure 3.6. The current through the motor is computed using Ohms Law $I = \frac{V}{R}$. Use the DMM in the 2V setting (not mA). Measure and record the voltage across the 1Ω resistor.

ENTER VALUES FOR:

Motor Current ► ________

Voltage across
1Ω Resistor ► ________

Calculated Motor
Current using
1Ω Resistor ► ________

Using the DMM in the 200mA setting or with the leads plugged into the wrong holes for Step 4 will blow its internal fuse.

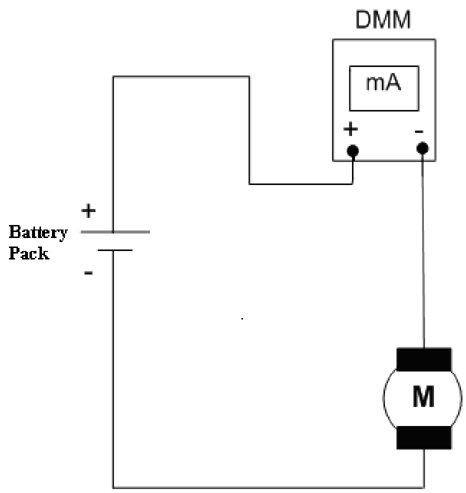

Figure 3.5: Measurement Circuit *200 mA setting*

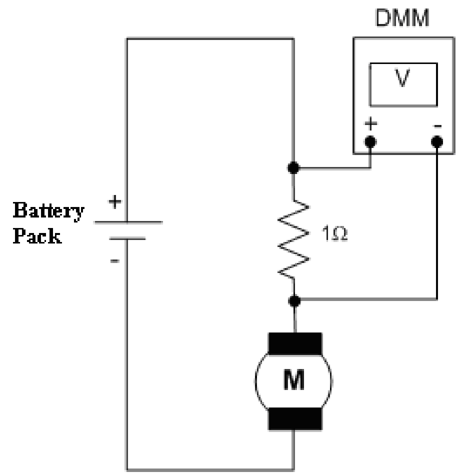

Figure 3.6: Measurement Circuit *2V setting*

3.5 Study Questions for Exercise One

1. Was there a difference in the motor current directly measured by the DMM and the ammeter improvised by using a voltmeter and a 1Ω resistor, as shown in Figure 3.6. ______________________________

2. What was the percent difference between the two measured current values? Show your calculations in the space provided below, and write the answer here ______________________________.

3. Which current measurement is more accurate? Why?

4. Show how you could build an ohmmeter with an ammeter and a voltage source. Illustrate it with a drawing and write the calculation needed to compute its resistance.

3.6 Exercise Two: Passive Sign Convention and Power Equation

A battery can generate or dissipate power. It dissipates power while being charged, (since the energy is being used to create chemical potential energy). However, it generates power when powering a circuit, (since the chemical potential energy is being converted back to electrical energy). Utilizing the passive sign convention, we can determine when power is being either generated or dissipated by the battery pack.

In Figure 3.7, the ammeter measures the current that enters or exits the battery. This circuit is a conceptual representation of the charger board.

When the wall wart is plugged in, current flows into the battery, because the wall wart output is at a higher voltage potential than the battery pack. In this situation, the battery pack is being charged and it therefore is ***dissipating power.*** Since the current is entering the positive $(+)$ ammeter terminal, it will read positive current.

When the wall wart is unplugged, the battery pack discharges through the 1K resistor then through the multimeter. The current will not pass through the wall wart because it is not connected and acting like an open circuit. In this situation, the battery is delivering or generating power. Since the current is flowing out of the positive $(+)$ ammeter terminal, it will read negative current.

> Normally, the batteries should never be charged from an unregulated source like a wall wart. However, in this case, the $1K\Omega$ current limiting resistor protects the wall wart and the batteries.

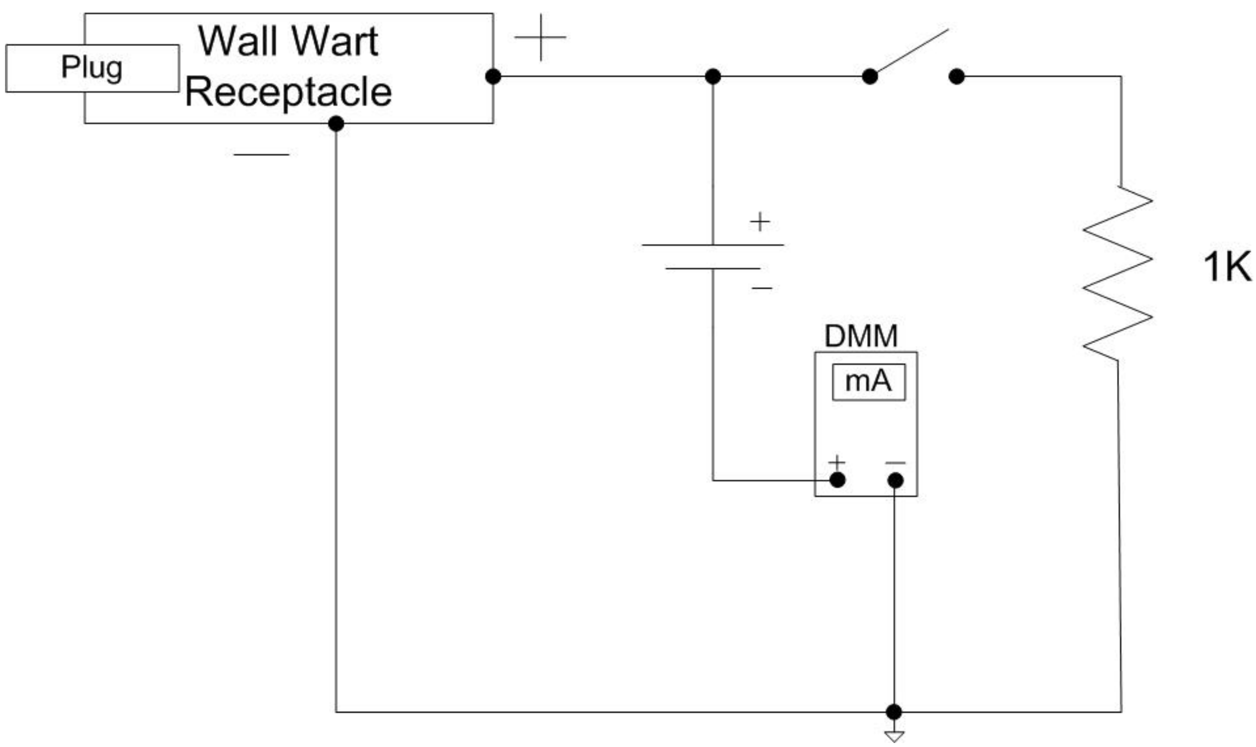

Figure 3.7: Power Dissipation/Generation

To implement the above, follow these steps:

1. Measure and record the voltage of the battery pack. (It should be approximately 7.5V).

   Battery Pack Voltage________________________

2. Begin with the wall wart unplugged, the switch in the off position and witht he multimeter set to the 200mA setting.

   > If the multimeter is not set high enough when measuring current, the internal fuse will blow and the multimeter will not longer function properly.

3. Borrow a 1000 ohm resistor from your T.A. and plug it into the power block. One resistor lead will plug into ”GND” and the other resistor lead will plug into the ”+” terminal of the header. A resistor does not have polarity so it does not matter which direction you plug it in.

4. Use the multimeter micrograbbers to complete the circuit. Take the red micrograbber and hook it onto the black lead of the tekbot battery back. See figure 3.8. Take the red lead of the batter pack and plug it into the ”+” terminal of J7. Attach a wire to the black micrograbber and put in into the ground terminal of J7. See figure 3.9.

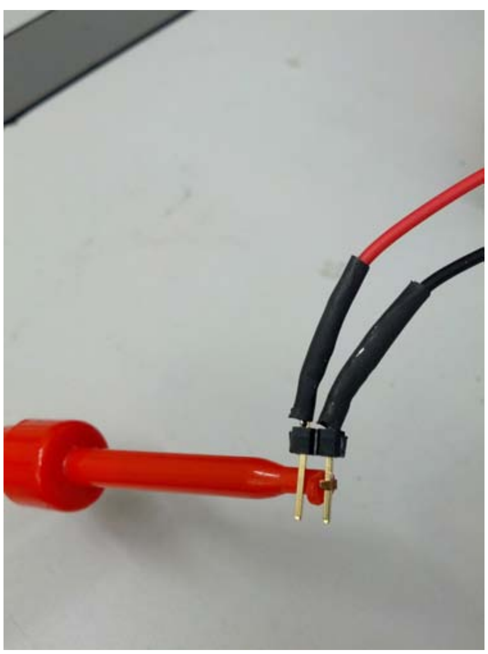

Figure 3.8: Micrograbber

Figure 3.9: Circuit setup

5. Flip the switch from the off position to the on positiion. Measure and record the current and direction(in or out of the battery) in the table below.

6. Leave the switch in the on positiion and plug in the wall wart. Measure and record the current and direction.

ENTER VALUES FOR:

1. With Wall Wart Plugged:

Battery Current ► __________

Direction ► __________

2. With Wall Wart Unplugged:

Battery Current ► __________

Direction ► __________

3.7 Study Questions for Exercise Two

1. With reference to Figure 3.7, draw a schematic diagram of the circuit when the wall wart is plugged in. Show the current magnitude, directions and the orientation of the battery. Also write down the battery voltage taken earlier, next to the battery symbol.

2. Using the power equation, the passive sign convention and your readings, determine the power dissipated by the battery when wall wart is plugged in.

3. Repeat questions 1 and 2 assuming that wall wart is unplugged.

3.8 Exercise Three: Power Dissipation and Equivalent Resistance

Resistors have different physical sizes to accommodate different levels of power dissipation. Bigger resistors can dissipate more power in the form of heat energy because of their larger surface area. However, a sufficient quantity of small resistors can safely dissipate as much power as a single but bigger resistor.

3.8.1 Resistors in Series

Follow these steps:

1. Use the protoboard to build the circuit shown in Figure 3.10, *Plug the batteries in last.* Once the circuit is built, plug in the batteries and quickly measure and record the voltage across the resistor. Then carefully touch the resistor and see how hot it is. It will be fairly warm. Unplug the batteries.
2. Using the voltage just measured, compute and record the power dissipated by the resistor, as shown in Equation 3.1. This resistor is rated at 1/8 watt maximum. Is it operating within its capabilities? ________________________

$$Power_{(Watts)} = \frac{Voltage_{(Volts)^2}}{Resistance_{(Ohms)}} \tag{3.1}$$

ENTER VALUES FOR:

Voltage across the 160Ω resistor ► __________

Power dissipated by the 160Ω resistor ► __________

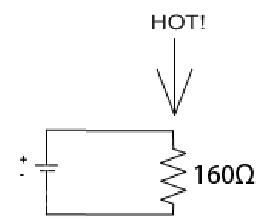

Figure 3.10: Voltage Across the Resistor

3. Consider the string of series-connected resistors in Figure 3.12. Determine the Equivalent Resistance of this string of resistors. Record the value R_{eq}.

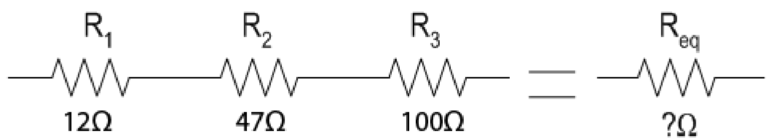

Figure 3.11: Resistors in Series

$R_{eq} =$ ______________________

4. Using the protoboard, connect the string of resistors into the circuit, as shown in Figure 3.12. Plug in the wall wart.

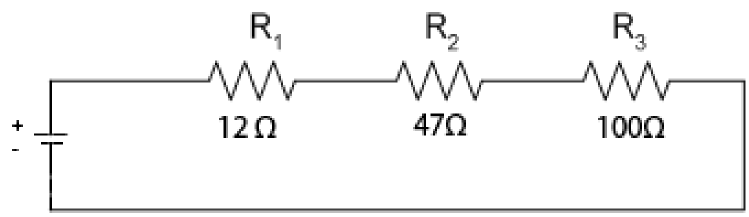

Figure 3.12: Series-Connected Resistors in a Circuit

5. Measure and record the values for the voltage drop and current flowing in each resistor. Also, calculate the power dissipated by each resistor. Record these values in the table. Touch each resistor to see how hot it is. Compare the power dissipation of each resistor with how warm it is. Is there a correlation?

____

<u>ENTER VALUES FOR:</u>

Resistor (Ω)	R_1	R_2	R_3
Voltage across it			
Current through it			
Calculated power dissipated			
Is it warm?			

Resistors in Series

Resistors in Parallel

Follow these steps:

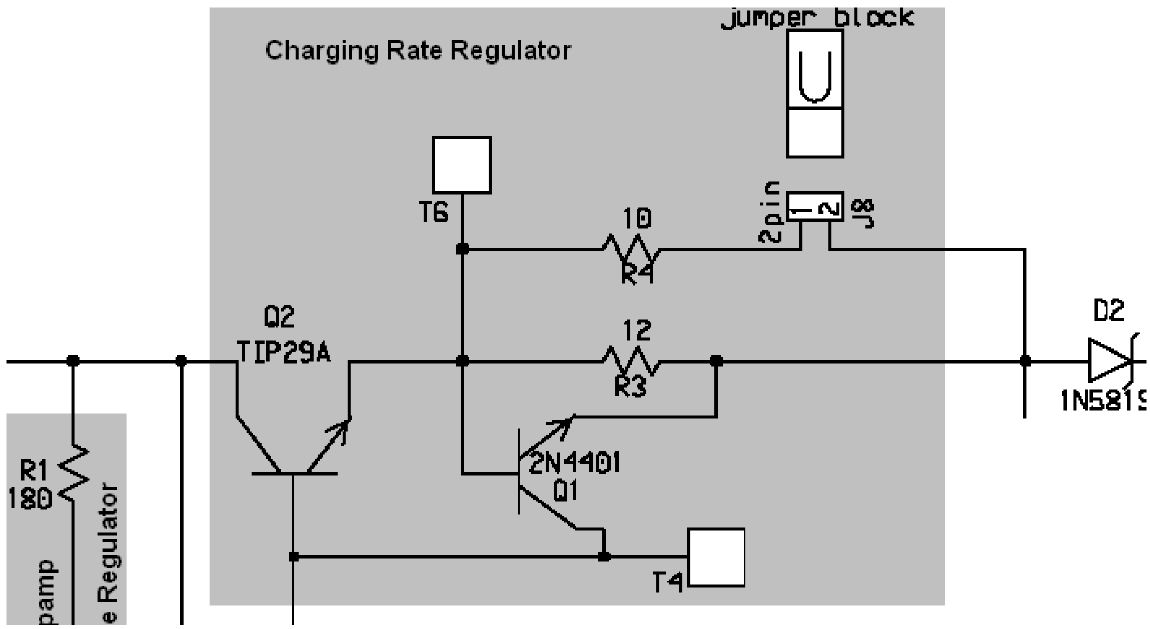

Figure 3.13: Charger Board Schematicl

1. Consider the parallel-connected resistors, R3 and R4, on the charger board schematic, figure3.13. Determine the equivalent resistance, R_{eq} when the J8 jumper is in.

$$R_{eq} = \underline{\hspace{6cm}}$$

2. Connect the wall wart. Measure and record the voltages across the resistors R3 and R4.

3. Calculate the current and power of R3 and R4.

ENTER VALUES FOR:

Resistor (Ω)	R_3	R_4
Voltage across it		
Current through it		
Calculated power dissipated		
Is it warm?		

Resistors in parallel

3.9 Study Questions for Exercise Three

1. Write the KVL equation for the circuit in Figure 3.12 and see if the equality holds. Write down all the steps and identify as to which resistor each term in the equation corresponds to. Circle or mark the final solutions.

2. Write the KCL equation for the circuit in Figure **??** and see if the equality holds. Write down all the steps. Identify each term and draw a schematic diagram indicating the direction of currents used. Circle or mark the final solutions.

Challenge

Our battery packs are rated at about 600mAH. At a discharge rate of 46mA (that is: $7.2V/154\Omega$), in theory, they should last for $\frac{600mAH}{47mA} = 12.7hours$. However, this is not the case for practical circuits. This calculation assumes that the circuit will operate until the last coulomb is consumed from the battery. However, as the battery pack discharges, its output voltage decays. A NiCad cell is considered discharged when it reaches 1V. At full charge is may be from 1.25 to 1.4V.

The challenge is to record the terminal voltage of the battery pack while it is driving a fixed 154Ω load and from the data, estimate how long it will take to reach a terminal voltage of 1 Volt per cell or a battery pack voltage of 6V.

Start with a fully-charged battery pack. Use the 154Ω string of resistors for the load and plot the battery voltage over time. Let the batteries power the load for several hours to get a trend for the data. Initially, take more frequent measurements. Once the trend is observed, take measurements less frequently. After sufficient data is taken to find the trend, make a graph of the data showing the estimated point at which the battery pack will be discharged.

If there is access to a power resistor, the load could be increased too. A load of about 200mA will closely approximate the nominal total current consumption of the TekBot. Using this load, estimate the nearest value for the run time of a robot. However, if there is no access to a power resistor, and the load needs to be increased, an option would be to immerse the resistor string in a glass of water, (which in turn drastically increases the ability of the resistors to dissipate power).

