Class #7: Battery Analysis

Purpose: The objectives of this experiment are to gain some experience with the tools we use (i.e. the electronic test and measuring equipment and the analysis software) and to gain some fundamental understanding of voltage dividers.

Background: Before doing this experiment, students should be able to
- Determine the values of series and parallel combinations of resistors
- Identify the value of standard, low wattage resistors from the color and pattern of their stripes

Learning Outcomes: Students will be able to
- Develop the circuit model of a physical battery using an ideal voltage source and an ideal resistor.
- Design an analysis process to determine the internal voltage and resistance of a battery

Equipment Required

- Digital Multimeter with 9V battery
- A separate 9V battery will be provided (1 per team) for this experiment
- Variety of Resistors and wires from Parts Kit
- Protoboard

Pre-Lab

Required Reading: Before beginning the lab, at least one team member must read over and be generally acquainted with this document and the other **required reading** materials listed on the course website.

Background

Voltage Dividers (repeated from experiment 6): Basically, when a voltage in a circuit is applied across two or more resistances, it divides up in a manner proportional to the resistances. That is, a larger resistance will have a larger voltage drop and that voltage drop will be proportional to the size of the resistance divided by the total resistance of a circuit.

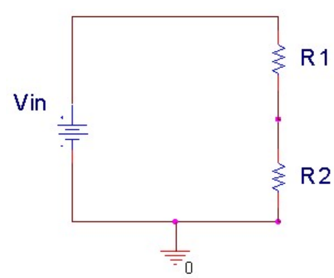

Figure A-1.

In **Figure A-1** above, Vin is divided between R1 and R2. Mathematically, this can be expressed:

$$Vin = V_{R1} + V_{R2} \qquad V_{R1} = \frac{R1}{R1+R2}Vin \qquad V_{R2} = \frac{R2}{R1+R2}Vin$$

In the voltage divider circuit, R1 and R2 are in series. Using the series expressions on the previous page, we can determine the total resistance 'seen' be the source, $R_{Tot} = R1 + R2$.

Battery Characteristics: In the simple electrical model of the battery shown in **Figure A-2**, the internal resistance of the battery depends on the battery size and chemistry. This is a simple model that ignores much of the internal chemistry including changes as the battery is discharged. The default assumption normally is that the voltage output of a battery doesn't change with the load. We will investigate how this works in an actual circuit.

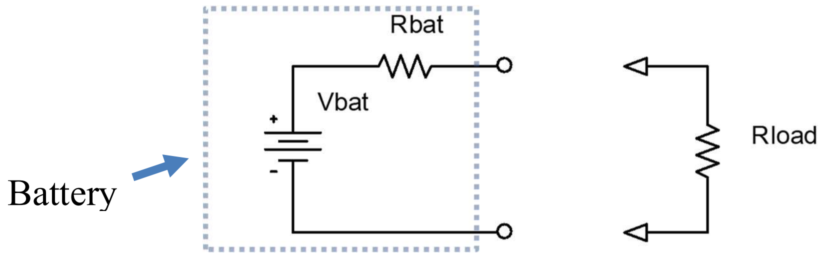

Figure A-2.

Vbat represents the internal voltage of the battery and Rbat represents the internal resistance of the battery. ***Rbat is not a resister added to the circuit***. Rload represents the load, which we can change as desired and then measure the voltage across it.

Using the voltage divider rule, we know that the voltage drop across the load is given by:

$$V_{measured} = \frac{Rload}{Rbat + Rload} Vbat\ .$$

After picking a value for Rload, the voltage across the resistor can be measured. When considering the voltage divider expression, we then have two unknowns (Vbat and Rbat).

Part A – Battery Analysis

Based on your previous laboratory experiences and the above discussion, design an experiment that will determine the internal voltage and the internal resistance of a battery. Use a 9 V that is provided in class or an unused 9V battery of your own to get reasonable values of Vbat and Rbat. Record those values and check them with a TA/UGSA or Instructor.

Important note: When making connections with the battery, please don't leave the battery in your circuit for more than a few seconds. It can drain the battery and significantly change your Vbat and Rbat values. Disconnect things from the battery as soon as you note down results using digital multimeter. No need for Alice tools or M1K for this experiment.

Part B – Measurement Considerations

In many settings, if values are too large or too small, they may not be useful when analyzing data. Using your Part A results, apply a 1Meg (1000000) Ω resistor and measure the load voltage. Use that measurement to recalculate Rbat. Are the results close to Part A? Try the same thing with the 1.1Ω resistor.

When considering the voltage divider expression, we then have two unknowns (Vbat and Rbat).