Name/NetID: Teammate/NetID:

Module:

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Laboratory Outline

In the core part of Lab 1 you learned how to use the power supply as a source of electrical energy. And you used the multimeters to quantify the behavior of a circuit by measuring the voltage and current associated with each device. You even characterized the resistors used in the circuit you built by measuring the resistance, again, using the multimeter. When using this equipment you did not have to consider how the power was supplied or how the measurements were taken. The assumption was made that these are *ideal devices*.

The plots below illustrate how we think about ideal sources and measuring devices. The ideal power sources maintains a set voltage V_s or current I_s no matter what circuit is connected across the terminals. Even if the terminals are shorted (connected together by a wire) the *ideal* supply maintains the voltage. Ideal measuring devices do not modify the circuit behavior in any way. The ideal voltmeter draws no current into itself but still registers the correct voltage between two points with a circuit. The ideal ammeter accepts any current, creating no voltage drop, and also registers the correct current flowing through the device/circuit tested. The graphs below illustrate the ideal behavior as presented in the core lab.

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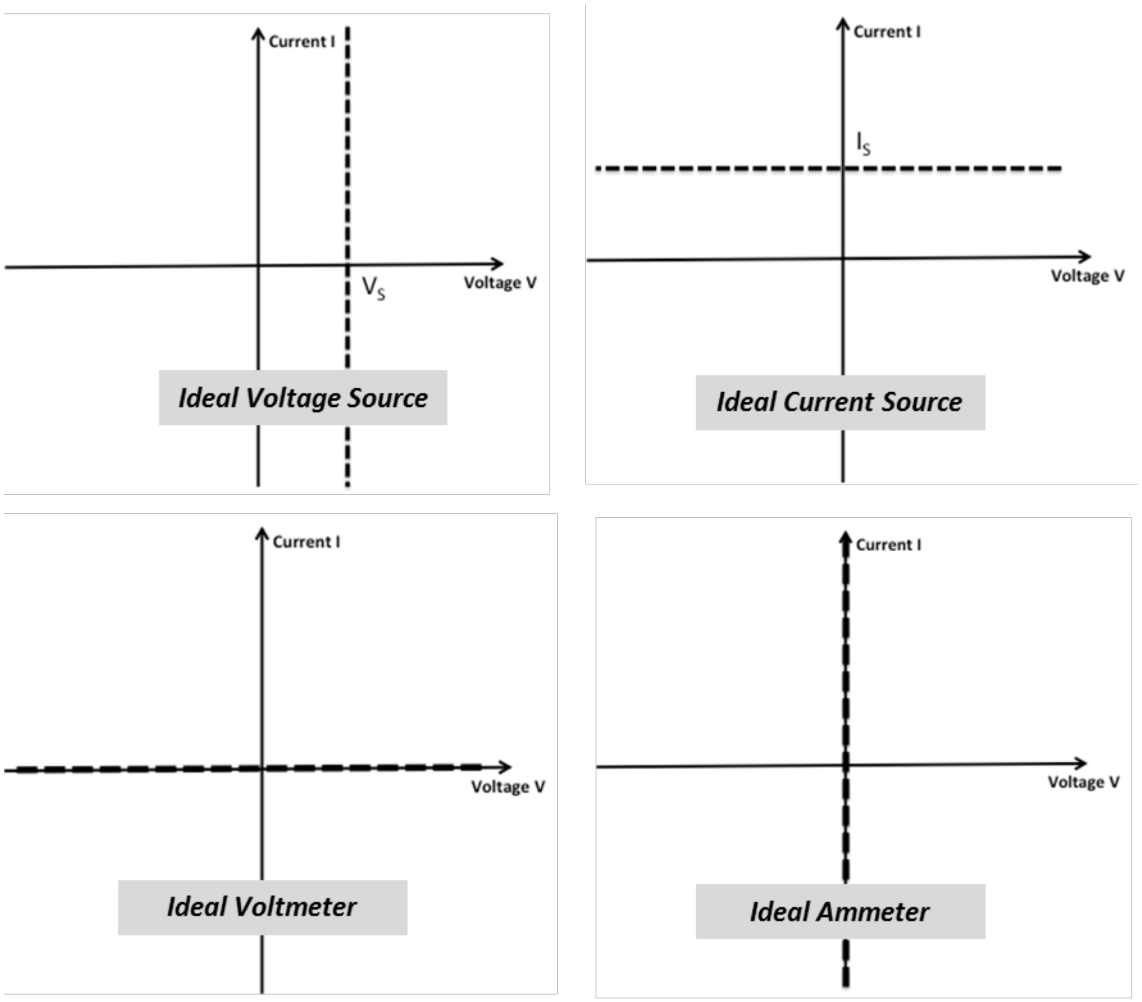

Figure 1: I-V Characteristics of Ideal Sources and Measuring devices

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In the previous labs you also measure resistance – Is there such a thing as an ideal ohmmeter and how would you graph its behavior? Since the multimeter is capable of measuring the resistance of a single resistor without access to an external power source the equipment must act as power supply and measuring device.

This module explores the limitations of your bench equipment. Experimenting with the limits you will come to a better understanding of how the multimeter and power supply works. Even though you will rarely be aware of the limitations when using the bench equipment these procedures are meant to give you additional understanding so that when you are using non-ideal components like a battery you will be able to work within the limitations of the device.

Let's start by pushing the limits.   You will build very simple circuits with the resistances chosen to make powering the circuit with a quantifiable voltage and current imprecise. You will build other circuits that tax the ability of the multimeter to make precise measurements. Even the bench equipment is really just a circuit – a very well-designed circuit – but a circuit, just like the one you are testing and it must considered as part of the circuit if you want precise measurements.

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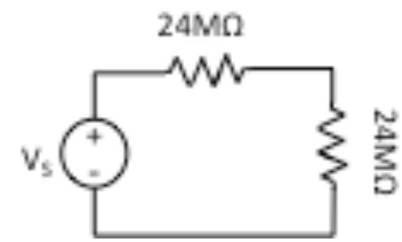

Getting the Multimeter to give an Improper Value of the Voltage

Using the simple circuit you built for the DC Measurements lab you will first baffle the multimeter into giving you the incorrect voltage reading. This is a non-invasive procedure and will not hurt the multimeter or the circuit.

- ✓ Build the circuit below consisting of two resistors in series connected to the power supply. The resistors should have a high resistance > 1MΩ. The diagram shows two 24 MΩ resistors. See schematic in sidebar.
- ✓ Use the power supply set to 5V as V_S.
- ✓ Set the multimeter into the proper mode to measure DC voltage.

Question 1: Probe the voltage across each of the resistors. Record the values that you read from the multimeter. They should be both about the same but are either value even close to 2.5V the value that you expect.

Question 2: One source of error might be the precise resistor value since they are only rated to 5%. Estimate the range of error if one of the resistors is 5% higher than 24MΩ and the other is 5% lower than 24MΩ. This error is not enough to compensate for the difference that you see in the measurement taken in Question 1.

The measurement does not give the value you have come to expect because the circuitry inside the DMM changes how the circuit being tested behaves. The figure below shows that a simple model for the multimeter ***when measuring DC voltage*** is a parallel connection of a perfect measuring device that reads the voltage across a resistor with large resistance. The value of R_{DMM} = 10MΩ for our multimeters – a value that is huge compared to the resistances you normally use in the lab and your

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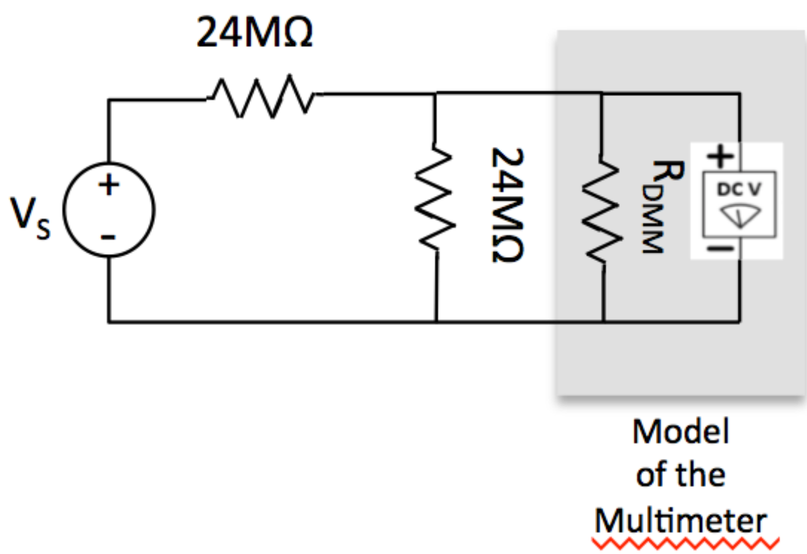
designs. But the resistances in the circuit below are even larger. The power supply now sees a single 24MΩ resistor in series with a resistance that is the parallel combination of 24MΩ and 10MΩ.



Question 3: Using the voltage divider rule estimate the voltage you expect to read on the multimeter now that you are considering the internal resistance of the multimeter when it is set in DC V mode. Is this value closer to values you measured?

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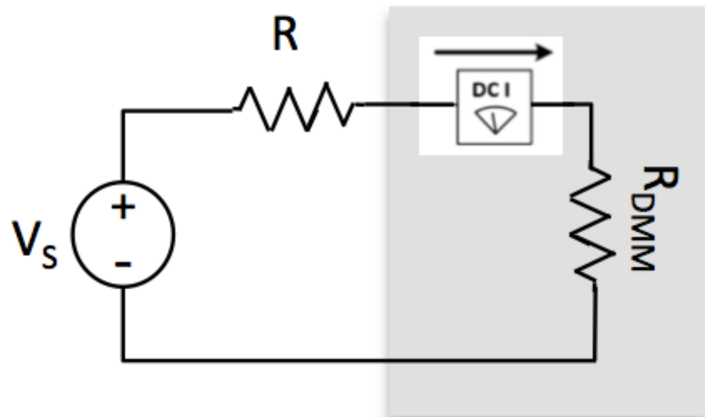
You can get the multimeter to misread the current as well, though it is more risky to do so let's do a thought experiment. When measuring current you break the circuit and insert the multimeter in series with the circuitry under test. Below is a schematic of a circuit with a single resistor and the multimeter in DC I mode measuring current.



Model
of the
Multimeter

Question 4: In this mode R_{DMM} is between .1 -2Ω. You would expect the value to be small to minimize the voltage drop across the device when measuring current. What range of values of R would cause the multimeter to significantly affect the current flowing through the circuit. Let's put a number on it – assuming that R_{DMM} is .5Ω what value of R will cause the multimeter to measure the current so that it is 10% lower than the value you expect using Ohm's Law $= \frac{V_S}{R}$.

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Getting the Multimeter to give an Improper Value of the Resistance

- ✓ Disconnect the Power Supply.
- ✓ Continuing with the same circuitry – set the multimeter in the proper mode to measure resistance.

Question 5: Measure the resistance of one of 24MΩ resistors and record the value.

When the multimeter is put into resistance measuring mode, the resistor, or resistive circuit under test must be disconnected from the power supply. We know that the multimeter is in the mode to measure DC voltage or DC current an external source drives the circuit being probed. A resistor inside the multimeter either bleeds off a little current into a resistor with a huge resistance when measuring voltage, or changes the amount of current flowing through a resistor with a small resistance when measuring current. In both cases the sources of power are part of the external circuitry. How does the multimeter measure resistance?

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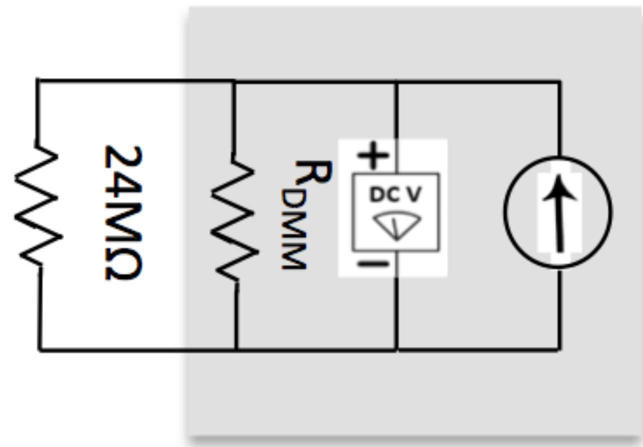
As the figure blow shows the multimeter uses the same circuitry used to measure the voltage across the resistor including the internal resistance or R_{DMM}=10MΩ. Additional circuitry inside the multimeter injects a known current through the circuit under test.



Model of the Multimeter

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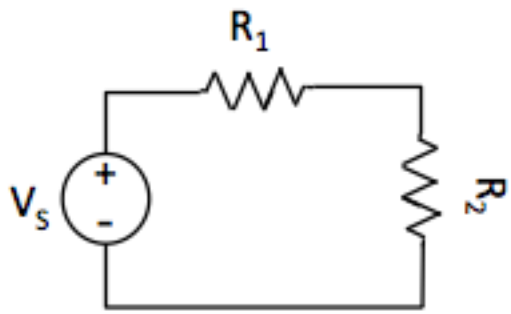
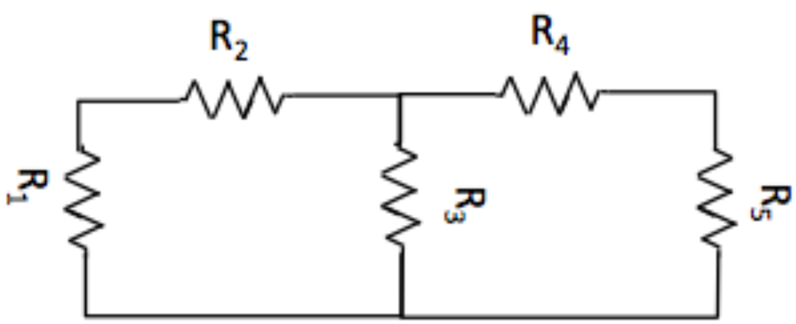
Question 6: Assuming that you want to measure the resistance of resistor R_2 draw the model of the multimeter across the terminals of R_2. Use the diagram to explain why you must disconnect the resistor being tested from the power source.



Question 7: Assuming that you want to measure the resistance of resistor R_2 draw the model of the multimeter across the terminals of R_2. Use the diagram to explain why you must isolate the resistor being tested from the rest of the circuit.

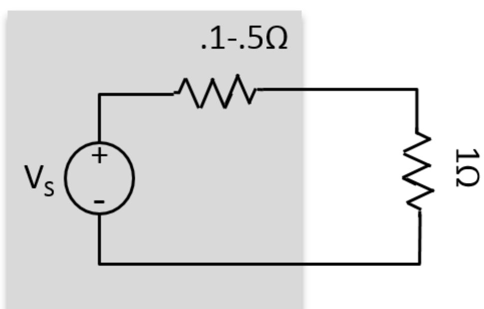


Pushing the Power Supply

It is more difficult to drive the power supply into exhibiting non-ideal behavior. The power supplies are very well-designed so that the simplest model is an ideal source with a very small series resistance. For the power supply to fail to deliver the correct voltage the circuit being powered must have a very low resistance. Be certain when doing this portion that the small resistor is up to the task.

- ✓ Build the circuit in the sidebar. USE THE 1Ω RESISTOR THAT IS MADE TO CARRYING A LARGE CURRENT. **NOT THE ONES IN YOUR KIT**. Be certain that the power supply is not connected until you have set it to 1V.
- ✓ Set the power supply to 1V.

Question 8: Using one of the multimeters, measure the voltage across the 1Ω resistor. Is it 1V? It is probably pretty close. It is hard to stress the power supply unless you resort to almost shorting the terminals, but not so the batteries you will be using when building the autonomous wall-following car. In one of the labs you will experiment with the batteries connected to different loads to determine the linear model for them.



Model
of the
Power Supply

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