

I. Objective

To discover how DC values are measured using various tools in the laboratory. This includes the basic design of multimeters and oscilloscopes, and how to model these circuits using Spice.

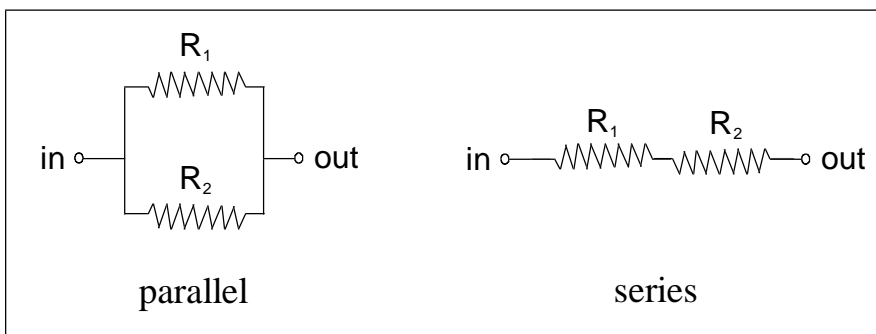
II. Background

DC (Direct Current) values are steady with time, compared to AC (Alternating current) values which vary with time. In this first experiment, we'll cover only DC values for simplicity. In future labs, we'll be examining AC values as well.

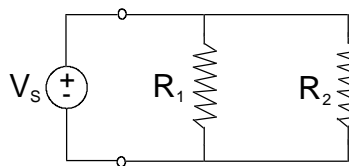
Important to this lab is your understanding of Ohm's Law,

$$V = I \cdot R$$

and how resistances function in series and parallel configurations.



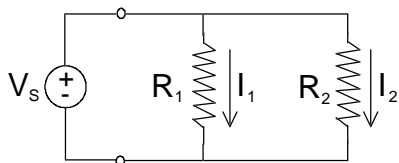
Connecting a voltage source across two resistors in parallel forces the voltage to be the same across both resistors.



$$V_1 = V_s = \text{Voltage across } R_1$$

$$V_2 = V_s = \text{Voltage across } R_2$$

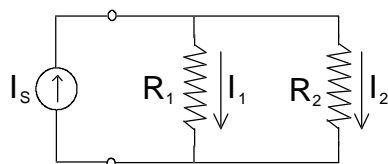
Using Ohm's Law, we can show that a different amount of current flows through R_1 than flows through R_2 if $R_1 \neq R_2$.



$$V_s = V_1 = I_1 \cdot R_1 = I_2 \cdot R_2$$

$$\frac{I_1}{I_2} = \frac{R_2}{R_1}$$

If we had connected a current source across the two resistors in parallel, the current would be divided between the two resistors.

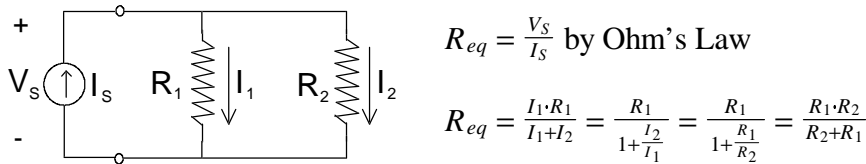


$$I_1 = \text{Current through } R_1$$

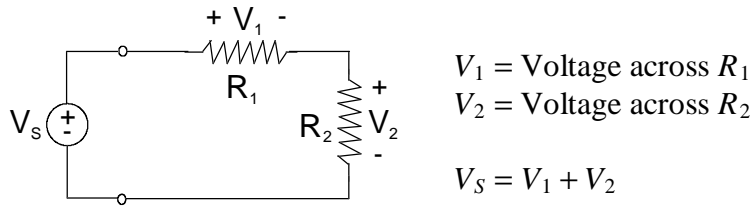
$$I_2 = \text{Current through } R_2$$

$$I_s = I_1 + I_2$$

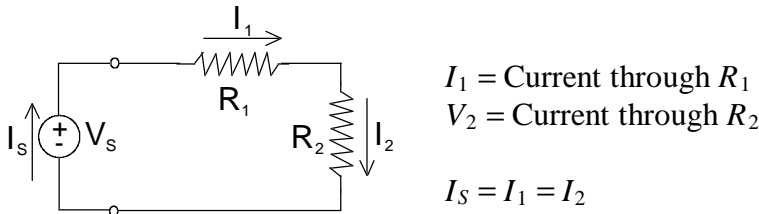
The resistor with the least resistance would have the greatest current flowing through it as shown by the ratio derived above, $\frac{I_1}{I_2} = \frac{R_2}{R_1}$. Because there are two paths for current to flow, the overall resistance seen by the source is lower than the lowest resistance.



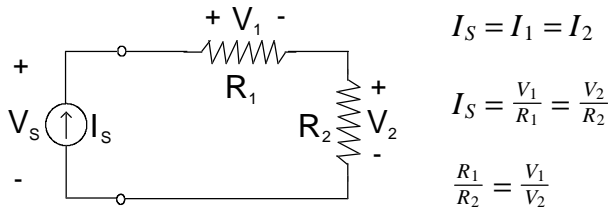
Connecting a voltage source across two resistors in series divides the potential across each resistor.



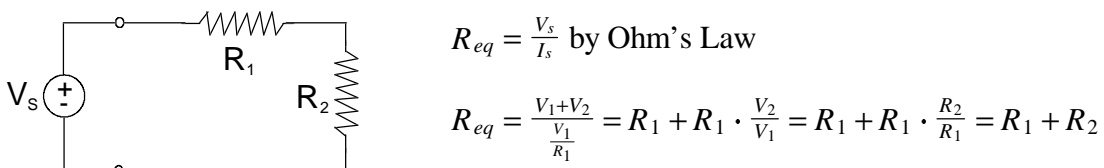
The current through each resistor must be the same. This is necessary to keep the amount of current flowing out of the voltage source the same as the amount that flows into the voltage source..



If we connected a current source across the two resistors in series, the current would also be forced to be the same through both resistors.

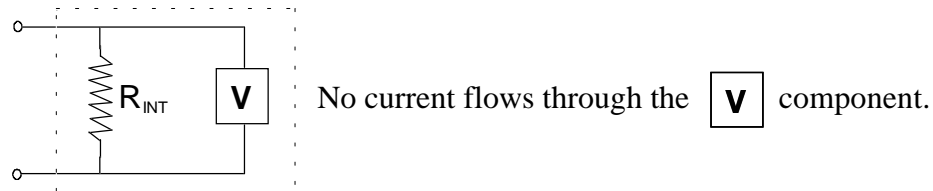


The resistor with the greatest resistance also has the greatest voltage across it. Because the current must go through both resistors (only one path), the overall resistance seen by the source is larger than the largest resistance.

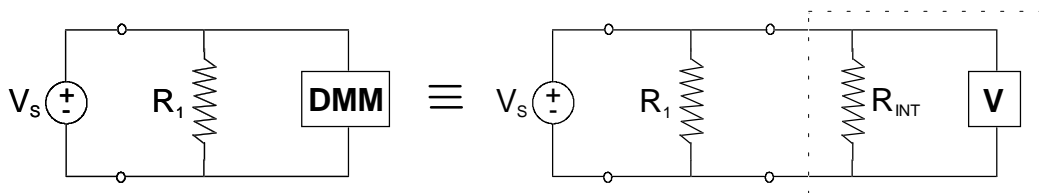


III. Operation

The DMM (Digital MultiMeter) and oscilloscope are both used to measure voltage across two points in a circuit. Even when the DMM is used to measure current, it's really measuring the voltage across an extremely small internal resistor. A DMM and Oscilloscope can be modeled using the following equivalent circuit:



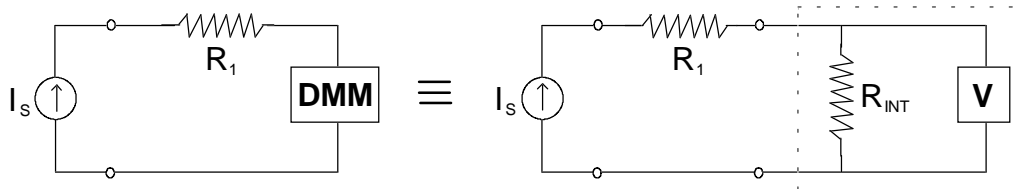
Because of the way a DMM and oscilloscope operate, it must be properly attached to a circuit in order to correctly measure voltage, current, or resistance (only the DMM can measure current and resistance). To find the voltage *across* a resistor, the device must be connected in *parallel* to the resistor. As shown above, this forces the voltage across both elements to be the same.



In order to keep the equivalent resistance the same as that being tested, the internal resistance of the device must be large.

$$R_1 \ll R_{INT}$$

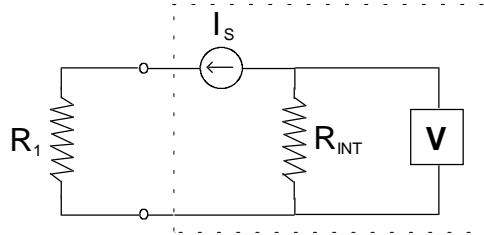
To correctly measure current *through* a resistor, the device must be connected in series with the resistor. As shown above, this forces the current through both elements to be the same.



In order to keep the equivalent resistance the same as without the device being connected, the internal resistance must be small.

$$R_1 \gg R_{INT}$$

The DMM measures resistance by using an internal current source to produce a voltage across the resistor.



IV. Controls

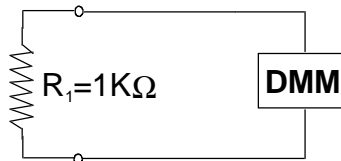
Read Appendices II, III, and IV for complete specifications of the DMM's, oscilloscope's, and power supply's respective controls.

V. Hands On

A. MEASURING USING THE DMM

1. Resistors

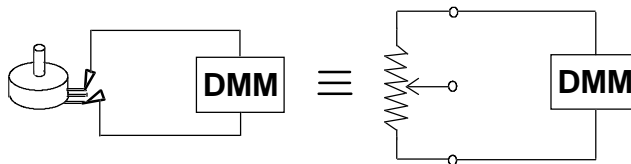
- a) Read Appendix I for the correct color coding scheme for resistors.
- b) Turn on the meter by pressing the on/off button.
- c) Make sure one probe is in the **COM** port and the other is in the **V/K Ω** port
- d) Press the **K Ω** button on the DMM to measure resistances.
- e) Attach the DMM's probes to make a closed-loop circuit consisting of both the DMM and a 1K Ω resistor.



- f) If the displayed value isn't within 10% of 1K Ω , then try a new resistor and/or ask the TA for help.

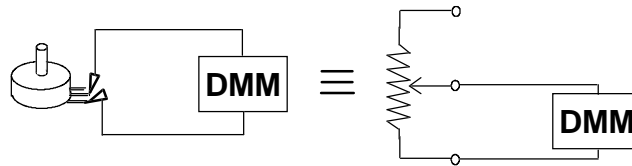
2. Potentiometers

- a) Attach the DMM's probes on the two outer legs of the potentiometer



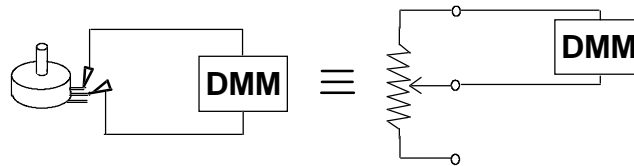
- b) Record the measured value. _____

c) Attach the DMM's probes on one of the outside legs and middle legs.



d) Turn the knob clockwise. Does the resistance increase or decrease?
(Circle one)

e) Attach the DMM's probes on the other outside leg and middle leg.



f) Turn the knob clockwise. Does the resistance increase or decrease?
(Circle one)

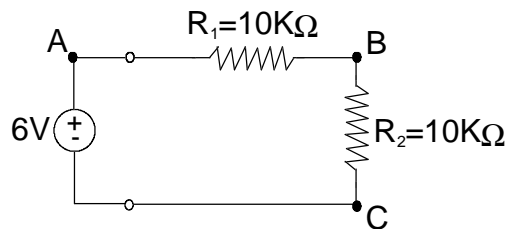
g) Find the maximum and minimum possible resistances:

maximum _____ minimum _____

h) Notice that the potentiometer has the largest possible resistance indicated on the package.

3. Voltages

a) Build the following circuit



i) Create the voltage source by turning on the power supply (See Appendix IV for a more in-depth description of the power supply.)

ii) Set the voltage to 6 volts.

iii) Set the current limit to 0.1 amps.

b) Press the **DVC** button on the DMM to start reading voltages

c) Measure V_{AC} by putting one probe on node A and the other on node C.

_____ Volts

d) Measure V_{AB} by putting one probe on node A and the other on node B.

_____ Volts

e) Measure V_{BC} by putting one probe on node B and the other on node C.

_____ Volts

f) Note that if you reverse the probes' connections to the nodes, you get opposite sign answers.

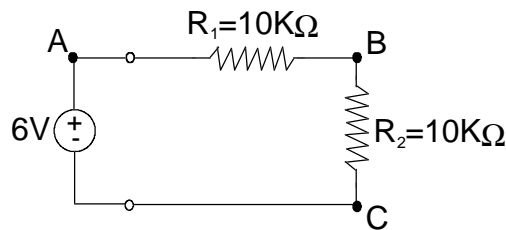
g) What if you put the DMM in series with R_1 and R_2 ? What's the Voltage?

_____ Volts

Why? _____

4. Currents

a) Build the following circuit



b) Press the **DC** button on the DMM to read DC values...

c) Put the positive lead in the **mA** port on the DMM (this has low internal resistance).

d) Measure the current through R_1 and R_2 by placing the DMM in series with R_1 and R_2 .

_____ Amps

e) Measure the current if you place the DMM in parallel to R_1 .

_____ Amps

f) Measure the current if you place the DMM in parallel to R_2 .

_____ Amps

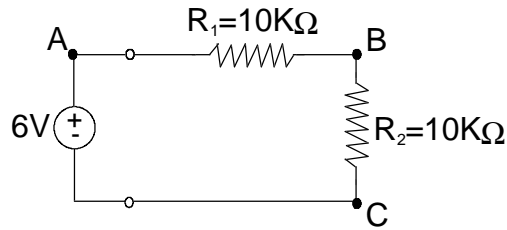
g) Why does the current measured change? _____

h) What's the voltage across R_1 when the DMM is in parallel to it? (Just think about it without actually doing it.)

B. MEASURING USING THE OSCILLOSCOPE

1. DC Voltage

a) Build the following circuit



- b) Turn on the oscilloscope.
- c) Plug probes into the first and second channels on the oscilloscope if they aren't already present.
- d) Attach both probes' ground leads to node C.
- e) Attach the first channel's positive lead to node A.
- f) Attach the second channel's positive lead to node B.
- g) Activate the first channel, and set it to ground by pressing the correct buttons.
- h) Align the displayed line to the center horizontal line.
- i) Set the scale of the first channel to be 5V per division.
- j) Make the first channel read the signal at node A by pressing the correct button.
- k) What's the voltage? _____ Volts
- l) Activate the second channel, and set it to ground by pressing the correct buttons.
- m) Align the displayed line to the center horizontal line.
- n) Set the scale of the second channel to be 5V per division.
- o) Make the second channel read the signal at node B by pressing the correct button.
- p) What's the voltage? _____ Volts
- q) Press the button to display both nodes A and B simultaneously. What's the difference in their voltages? _____ Volts
- r) Press the button to invert the second channel's signal and then the button to add the two signals together. What's the voltage? _____ Volts
- s) Press the button to display both A and B simultaneously and reinvert the second channel.
- k) Connect the first channel's ground lead to node B. What happens?
