

## Revisions

was: 9/5/05b

9/3/08

Removed Wire Kit from check out list

2/2/09 Minor change to the parts list (1/4 watt resistor explanation)

8/28/12

Removed reference to ECE 2210 kit.

Changed order of buy and checkout.

Changed Servo wiring picture

**University of Utah**  
**Electrical & Computer Engineering Department**  
 ECE 2210/2200  
 Experiment No. 2  
**DC Circuits**

A. Stolp, 9/27/99  
 rev, A.S., 8/28/12

**Objectives**

- 1.) Verify Ohm's and Kirchoff's laws.
- 2.) Verify series and parallel equivalence, and the divider rules.
- 3.) Feel the power dissipation of a resistor as heat.
- 4.) See that the position sensors in the servo are simply voltage dividers.

**Parts to be supplied by the student:** (These items may be bought from stockroom but they should all be in the ECE 2210 kit)

- Two 390  $\Omega$ , 560  $\Omega$ , and 1 k $\Omega$  resistors, (The little resistors in the ECE 2210 kit are rated for 1/4 watt power dissipation)
- Breadboard and wires

**Check out from stockroom:**

- Portable digital multimeter
- Servo

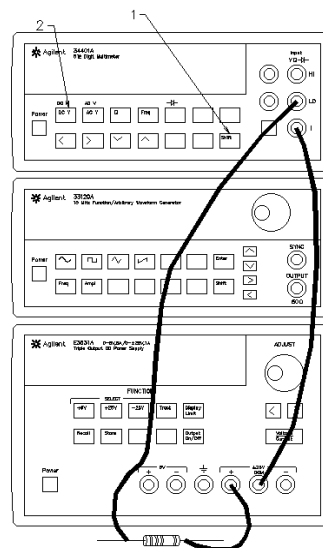
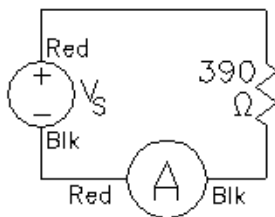
**Experiment**

**Resistor measurements**

Use the Agilent digital multimeter as an ohmmeter to measure the resistance of each of the four resistors listed above. Record these values for use in later calculations.

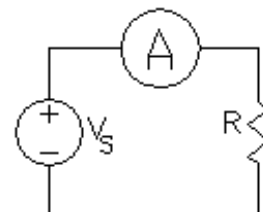
**Basic Laws**

Build the circuit shown at right. For  $V_s$ , use the +25V and COM outputs of an Agilent or HP E3631A DC power supply. Notice that the ammeter is in the bottom wire (negative return wire). Set the power supply output to about 10 volts (10 V). You may rely on the voltmeter built into the power supply. Record the actual voltage in your notebook.



Record the current measured by the ammeter. Why does it show a negative current? Swap the leads to the ammeter, what changes and why?

Move the ammeter to the top wire of the circuit, as shown in the schematic at right. Is the current the same in the top wire? Comment on Kirchoff's current law (KCL).



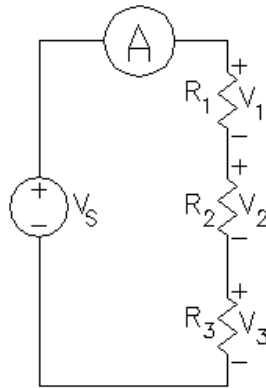
Use Ohm's law to calculate the resistance of your resistor. (Voltage

shown on the power supply divided by the current shown on the ammeter.) How does this calculated value compare to what you measured earlier with the ohmmeter?

Calculate the power dissipated by the resistor. Is it within the resistor's rating ( $\leq 1/4$  watt)? Energy is power times time ( $E = Pt$ ). If the resistor is dissipating power, what is happening to the energy? Carefully feel the resistor. Is it warm? If you can't feel the heat, turn up the voltage to 15 or 20 V and try again. Now be careful, the resistor can get hot.

### Series circuit

Wire any three of your resistors in series with your ammeter and connect them to the power supply (set at about 10 V). As you should whenever you make a new circuit, sketch the circuit in your notebook, showing all the pertinent values. Also label your resistors as  $R_1$ ,  $R_2$  and  $R_3$ . Use the portable digital voltmeter to measure (and of course record) the voltage across each element of your circuit, including your ammeter. Measure the voltage across  $R_1$  and  $R_2$  together (measure from the bottom of  $R_2$  to the top of  $R_1$  and call this voltage  $V_{12}$ ). Measure the voltage across  $R_2$  and  $R_3$  together ( $V_{23}$ ), and finally measure the voltage across all three resistors together ( $V_{123}$ ). Use the concepts of Kirchoff's voltage law (KVL), series equivalence, and the voltage divider rule to calculate several of the voltages that you've just measured. Comment on the agreement between theory and measurement.



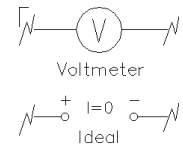
Use Ohm's law and your measurements to calculate the resistance of  $R_1$  and  $R_2$  together ( $V_{12} / I$ ), and all three resistors together ( $V_{123} / I$ ). Comment on the agreement between these values and those you get from series equivalence calculations ( $R_1 + R_2$ , and  $R_1 + R_2 + R_3$ ).

Use Ohm's law to calculate the resistance of the ammeter. An ideal ammeter would have zero resistance, but our ammeter is not ideal. Keep this in mind as you do the following sections of this lab.

### Meters

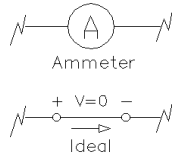
A voltmeter measures the voltage difference

**ACROSS** it. An ideal voltmeter acts like an open circuit (no connection) and can be connected between any two points in the circuit to show the voltage (potential) difference between those two points.



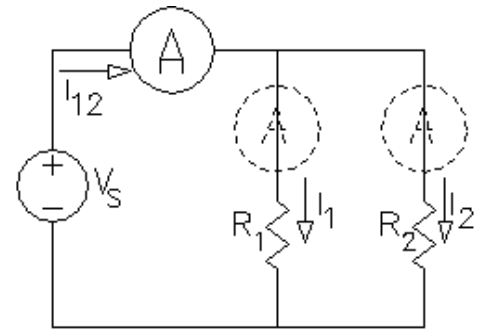
They are fairly hard to misuse unless you're dealing with high voltages—and we'll try to avoid that in here. The registrar doesn't like it when we kill tuition sources.

An ammeter, however, is very easy to misuse. An ammeter measures the current that passes **THROUGH** it. An ideal ammeter acts like wire. A wire in the wrong place is known as a short circuit (a direct, low resistance connection, usually unwanted). An ammeter makes a connection, and if you're not careful, you'll make a connection that you don't want. To use an ammeter; make your complete circuit first, then open part of the circuit and replace a wire or connection with the ammeter. The key phrase here is *open up*. If you aren't breaking open some connection in order to insert the ammeter, then you're doing something wrong.



## Parallel circuit

Build the circuit shown, using any two of your resistors in parallel. Ignore the “dotted” ammeters for now. Label your resistors as  $R_1$  and  $R_2$ . Record the voltage across the parallel resistors (shown on the power supply).



Record the ammeter reading ( $I_{12}$ ). Move the ammeter into the two other positions shown by the dotted outlines in the drawing above and record all the currents  $I_1$  and  $I_2$ .

Since current must flow through the ammeter for it to work, you will need to do some rewiring each time you move the ammeter (See box on previous page). Admittedly, this is a pain in the neck but it is good practice. Be very careful with your wiring.

Now calculate  $I_1$  and  $I_2$  from the power supply voltage and the resistance values. Add these to calculate the current  $I_{12}$ . Comment on the agreement between these calculations and your ammeter measurements.

What is the equivalent resistance of  $R_1$  and  $R_2$  together calculated from the formula for parallel resistors? Now use Ohm's law and your measurements to calculate the equivalent resistance ( $V / I_{12}$ ). Comment on the agreement between these values.

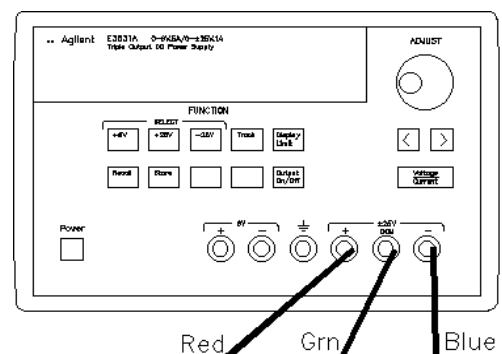
## Series-parallel circuit

The resistors in the circuits you have made so far have been either all in series or all in parallel. In a series-parallel circuit some resistors are in series and some are in parallel at the same time. Design a series-parallel circuit using all four of your resistors. Make your circuit and connect it to the power supply through the ammeter. Record the power supply voltage (which is the voltage across the entire resistor network) and the ammeter reading (which should be the total current through the entire network). Use Ohm's law and measurements to calculate the resistance of all the resistor network. Use series and parallel formulas to calculate the resistance of the network from the individual resistor values. Comment on the agreement between these values.

Make at least one more voltage measurement across and one more current measurement elsewhere in the circuit. Assume that the power supply voltage is correct and use theory to find the same voltage and current you just measured. Comment on the agreement between theory and measurement.

## Voltage Dividers in the Simple Servo

Turn off the power switch on the servo and hook it up to the power supply. Adjust the power supply to provide  $\pm 6V$  as you did in the first lab. If you've forgotten how to do this, refer back to the lab handout for lab 1. Remember that you may be able to recall the  $\pm 6V$  configuration by simply hitting the **Recall** button twice (If no one else changed it in the meantime). Turn on the power switch on the servo and make sure that it is functioning properly.



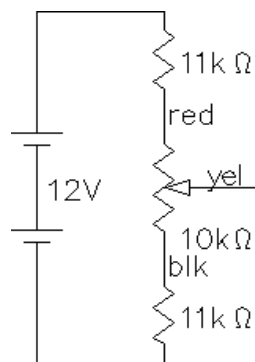
## Potentiometers used as position sensors

If you look at the servo, you'll see three potentiometers. One is used to adjust the gain of the circuit, you will learn about that near the end of the semester. The other two are used as position sensors. They translate shaft position into voltage. When the shaft is turned, the voltage on the center lead changes.

One of the pots is labeled "Input Position" and is the one you turn. Another is coupled to the output shaft of the motor and geartrain. The circuit compares the positions of these two pots and amplifies the difference to run the motor in the correct direction to eliminate that difference. Each of these pots is simply a voltage divider.

Measure the voltage between the two outside leads of the "Input Position" pot. Turn the pot through its range. Does this voltage change significantly? Now measure from the black to the yellow lead and try it again. What range of voltages do you measure?

Look at the schematic that shows how this part of the servo circuit is wired. Calculate the voltage that you expect to see across the 10 kΩ pot. Compare to the measured voltage. Explain why black-to-yellow lead measurements make sense.



Measure the voltage from the black to the brown leads of the other position sensor as you make the motor turn through its range of motion. Compare to the similar measurement at the first pot.

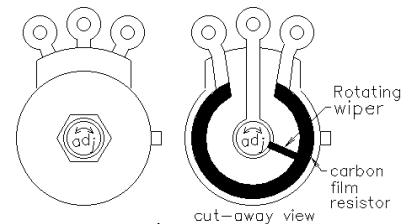
## Conclude

Before you put everything away, call your lab instructor over to check you off. Write a conclusion in your notebook. Discuss the agreement of measurements and calculations. If you are concerned about disagreements, make some % error calculations. Usually your errors are smaller than they at first appear. Also remember that no measuring instrument is perfect and neither are parts. Mention any problems that you encountered in this lab and how you overcame them.

## Potentiometers

A *potentiometer* is resistor with a special third connection. (The name comes from its old-time use in voltage measurements.) The third (center) connection can be made anywhere along the length of the resistor, it's position is adjustable. All potentiometers (pots) and volume controls work in a similar manner, with a moveable slider or "wiper" that makes

contact with a resistor somewhere between its two ends. A



rotary potentiometer is shown here,



first in its package, then as bare workings, and finally as a schematic symbol.

The resistance of a pot is the full resistance between the two outside terminals and is usually written on the part somewhere.

Usually, when you turn a knob on a stereo, TV, or instrument in the lab, you are turning a potentiometer.

The resistor in a potentiometer can have a linear or an audio "taper". Audio taper potentiometers are used as volume controls in audio circuits. Your hearing does not respond linearly to changes in loudness, so the resistor in a volume control is nonlinear to compensate. The potentiometers used in the servo are all linear taper.