Lab-1, Electronic Basics

Physics U371/372, Electronics for Scientists
Don Heiman, Northeastern University (9/8/2007)

This lab is a review, at a somewhat deeper level, of things that you have probably seen or heard in the freshman courses and labs. You will use Digital Multimeters (DMM) to study some simple circuit elements, their characteristics, and the behavior of some combinations of these. You will also get a sense of possible complications when you introduce measuring instruments into a circuit, since the measuring instrument can alter a circuit.

In any scientific work, record keeping is a basic requirement. It is important that you carefully record in your lab notebook: (1) the instruments used; (2) the measurement configuration; (3) all raw data (in tables); and (4) preliminary analysis. You should arrange your data in well-designed tables. Don't just write down numbers – include dimensions. If you are planning to do calculations on your data, include columns/rows in you tables in the appropriate places for recording these results.

For this Lab, and most other Labs you will need the following:

- Variable DC power supply (PS) (12 V, 0.5A)
- 2 DMMs
- Resistors (kΩ and 10Ω range), Capacitors (10-100μF), Diodes (standard, 5V Zener)
- Flashlight bulb in holder
- Jumper wires

In the first (abbreviated) lab session, do parts I-III. The rest can be done in the second week.

I. The DMM – Familiarize yourself with the buttons and controls of your DMM. Set the DMM to DC and to VOLTAGE measurement.

1. Set the range to a high value, such as 100V. Look at the other buttons to see what they do. Make sure that the input leads for the DMM are plugged into GND (ground) and V (voltage). Meters often have other input terminals. Look at the other terminals to see what they are for.
2. Connect the meter to the power supply (PS) and measure the voltage for various settings of the supply (turn the supply control knob). Be careful - if the meter is set for measuring current or resistance you can blow a fuse, or worse.
3. What are the minimum and maximum voltages from the PS? Try to make a voltage measurement with the meter set to AC. What do you find?
4. Next, make some resistance measurements. Disconnect the meter from the PS. Have the instructor give you a few resistors. From the color code, find their nominal resistances and tolerances. Measure their resistances with the meter. Explore the different meter ranges and find the optimum setting for these measurements. Are your measurements within the resistor tolerances?
5. Finally, explore the current settings of the meter by measuring the current through an R=1kΩ resistor. Describe what you find.

II. Resistance – Here, you will investigate Ohm's Law for a resistor.

1. Measure the I-V (current-voltage) characteristics of a carbon composite resistor in the ~kΩ range. Use two DMMs, one to measure voltage and one to measure current. Plot your results while you are taking the data. Use at least 5 measurements for both positive and negative voltage. Explore the full range of the PS, while not exceeding the resistor power rating.
2. Did the resistor show ohmic behavior?
3. Discuss the slope of the data.
4. What is the power dissipated by the resistor at each voltage and how does it compare to the resistor rating?

III. I-V Characteristics – Use the same setup to measure the I-V (current-voltage) characteristics of:

(a) light bulb;
(b) standard 1 amp diode (1N4005);
(c) 5.1V, 0.2 amp Zener diode (1N5231).

Do not exceed the power ratings of the components – compute the maximum allowable voltages and currents. If you exceed the ratings of a diode or transistor for even a short time it will be destroyed.

1. Make I-V plots (V on x-axis) for all three elements. Remember to take data for both polarities.
2. Replot the data by plotting resistance versus voltage, R(V), for the 3 devices.
3. Replot the standard diode I-V using a log scale for the positive I-axis, and discuss.

IV. Voltage Divider – Here, you will investigate *series resistors*.

1. Choose two different resistors in the kΩ range and arrange them in series with the power supply and current meter. Next, apply a voltage and measure the voltage across each resistor using the first DMM, and the current using the second DMM.
2. Compare the ratio V_{R1}/V_{R2} with the ratio of resistances.
3. Compare the calculated resistance (R=V/I) of each resistor, with that obtained with the DMM used as an ohmmeter, and with the resistances obtained from the color code on the resistors.
4. Comment on any discrepancies or agreements.
5. Discuss how these two resistors in series make a *Voltage Divider*.

V. Capacitors – Connect two different capacitors in the 10-100μF range in series and to the power supply. **Make sure you use the correct polarity on the electrolytic capacitors (longer lead is positive).** Setup the two DVMs to measure the voltages across each capacitor. Turn on the power supply and measure the voltages quickly after the voltage is applied.

1. Compare your measurements to the calculated voltages.
2. Can you think of why the voltages slowly change after the PS is turned on?

VI. Meter Input Impedance – All voltmeters have an effective resistance, referred to as the *input impedance*. When placed in a circuit, the added resistance of the meter will draw a small amount of current, in effect, changing the circuit. Determine the input impedance of the DVM by using a voltage divider network with the DVM in place of one resistor and use R_o~1MΩ for the other resistor. Use the second DVM to alternately measure the voltage across the resistor (R_o) and the supply voltage (V_o).

1. What is the computed value of R_{DVM}?
2. Does the value of R_o~1MΩ affect your value for R_{DVM}?
3. Does the input impedance depend on the range settings?

VII. Power Supply Internal Impedance – All power supplies have a maximum voltage and current which they are capable of producing. For example, leaving the output terminals open produces the maximum voltage, while shorting the output terminals produces the maximum current. In effect, they have an internal resistance that limits the current. Determine the *internal impedance* R_{PS} of the power supply using a using a voltage divider network as before, where the PS impedance is one resistor and the other is an R=10Ω (P=1W) resistor. Hint: obtain the supply voltage (V_o) by removing the 10 Ω resistor.

1. Compute the maximum allowable voltage for the P=1 W resistor. **Do not exceed the power ratings of the resistor**.
2. What is the computed value for R_{PS}?
3. Explain why removing the R=10Ω resistor allows you to measure V_o.
4. Does the internal impedance depend on the voltage setting?