

# ENGR 210/EEAP 240 Lab3

## DC Measurements

### Background

In this lab you will examine how to make DC measurements in LabVIEW and how to use digital meters. In the first part of the lab you will modify your VI from Lab1 to measure voltage through a data acquisition board. In the second part of the lab you will use a DC power supply and a Digital Multimeter (DMM) to make voltage, current and resistance measurements.

### Computer Measurement of Voltage

Figure 1 shows a LabVIEW program which continuously reads a voltage through a data acquisition board and adds the digital value of the voltage to a displayed chart. The gray box shown in Figure 1 is a While Loop. The program elements inside the While Loop will execute repeatedly as long as the While Loop control is true. That is, as long as the variable **stop** input to the loop is false. **Stop** is connected to the button on the front panel shown in Figure 2. When the user presses the button, **stop** becomes true, and the value which feeds into the While Loop control is inverted (changed to false). When the While Loop in this example stops, there are no other program elements to execute, and the program stops running.

In the center of the While Loop, you see the “work” being done in the loop. The block labeled **AI ONE PT** performs the operation of getting a voltage from the channel specified by **Channel** and the device specified by **Device**. **AI ONE PT** reads one voltage reading from each of the specified channels on the specified device. The output of **AI ONE PT** is a list of voltages in a structure called an array. The terminal labeled **Voltage Display** is the connection point for the chart in the front panel shown in Figure 2. The update of the chart is such that every time a new number is input to it, the new number is graphed along with all the previous numbers. The programmer can specify a limit on the number of points that can be graphed at one time.

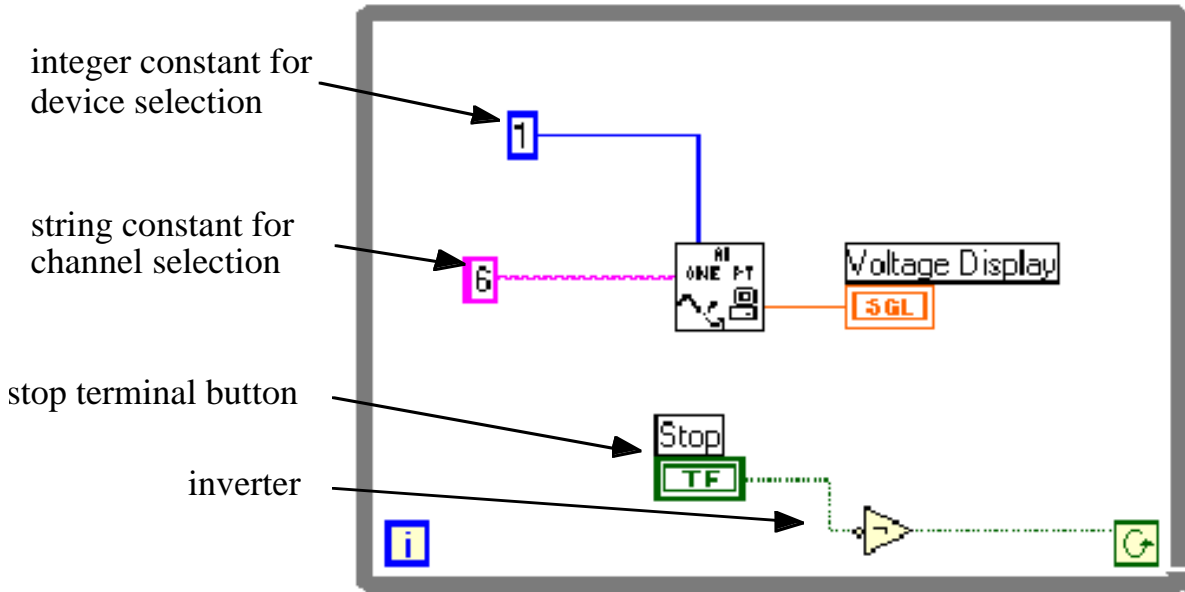
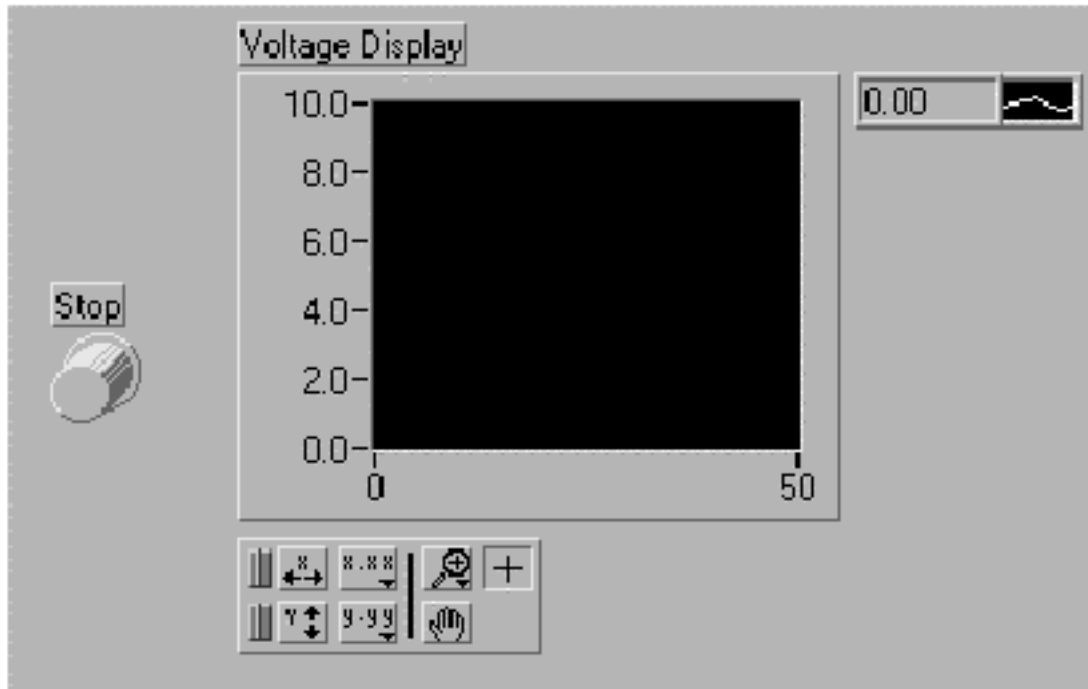


Figure 1. LabVIEW Program to Read a Voltage from a Single Channel and Display that Voltage Value

The **AI ONE PT** block in Figure 1 performs the DAQ procedure. It is the only piece of programming needed to read a voltage level. National Instruments has all the programming needed to drive the DAQ system in the **AI ONE PT** block in your program.



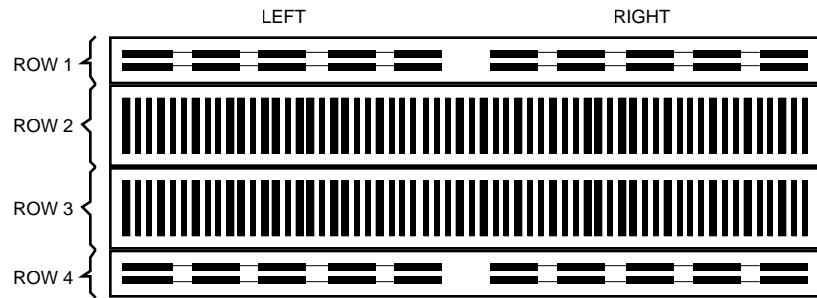
**Figure 2. Front Panel of a Program that Reads and Displays a Voltage Input**

Outside the computer, the voltage to measure is at some unknown level. A real number represents that level. Remember that a real number can be any number between positive and negative infinity and can have an infinite number of digits. The PCI-1200 NI-DAQ data acquisition boards in the Circuits Lab are set to digitize voltages which lie in the range of 0 to +10 volts. The input analog value can be any value in between these limits. Once the value is inside the computer, you represent that value with a digital number with some limited number of digits.

In this part of the laboratory you will learn to use two of the instruments in the laboratory, namely the Digital Multimeter (DMM) and the Triple Output Power Supply. You will learn to use the DMM by measuring resistances as well as currents and voltages in circuits.

### Building Circuits Using a Solderless Breadboard (Prototyping Board)

You have already seen a protoboard in the Lab 2 simulation; however, the ones we will actually use in the lab are slightly different. The solderless breadboard, or prototyping board, is a white plastic device with holes in it. The holes are connected together on the bottom of the breadboard in a specific pattern which serve as substitutes for wires in connecting components into a circuit. You place your circuit components in the breadboard by inserting their wires into the holes. Since the holes are connected together in a specific pattern, components can be connected together without any other wiring. The typical hole-to-hole connection pattern for the solderless breadboard used in the lab is shown in Figure 3. Note that yours may be slightly different.



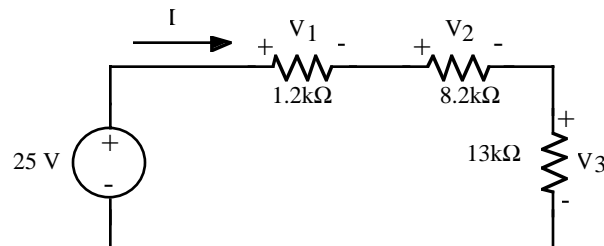
**Figure 3. Solderless breadboard**

Within each heavy line in the figure all the holes are connected together. In rows 2 and 3, the heavy lines run top to bottom and the holes are connected together vertically. For rows 1 and 4, the lines are horizontal and the holes within each line are connected together horizontally. In addition, for rows 1 and 4 the lines on the left half are connected together and the lines on the right half are connected together. Note that for these rows, the left half is not connected to the right half (the connection has a gap). The horizontally connected holes are usually used for power and for ground. The vertically connected holes are used for general purpose connections. The spacing between the holes is standard and some standard components that we will use later in the semester fit nicely on the breadboard. Resistors and other components with flexible wire leads also fit nicely on the breadboard. Because the breadboard is just made up of wire connections we can treat these as ideal wires for modeling purposes.

## LABORATORY PREPARATIONS

To prepare for this Lab you must complete the following calculations **before** you come to the laboratory.

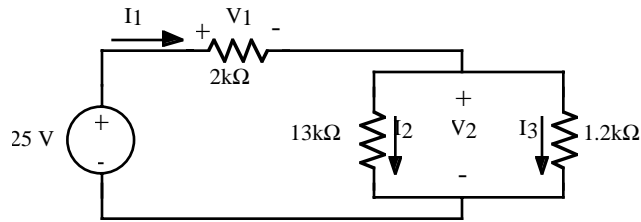
### 1. Voltage Divider Circuit



**Figure 4. Voltage divider circuit.**

The circuit shown in Figure 4 is a voltage divider. Calculate the current,  $I$ , in the circuit and the voltage across each resistor using the voltage divider relationships you learned in class. Record your results in Data Table 4 of the Data Sheets.

## 2. Current Divider Circuit



**Figure 5. Current divider circuit.**

The circuit shown in Figure 5 includes a current divider. Calculate the current that you would expect to measure through each resistor and the voltages  $V_1$  and  $V_2$ . Use the current divider relationship you learned in class. Record your results in Data Table 5 of the Data Sheets.

### **Part 1: LabVIEW Measurements**

In this part of the lab will write a LabVIEW virtual instrument (VI) which can read voltages and display them. The idea is to build an instrument that works like a graphing digital multimeter. This lab requires a PC with LabVIEW software and a National Instruments data acquisition card. You will have to do this lab in the Circuits Lab because only the lab computers have the necessary data acquisition cards in them.

**BRING IN YOUR VI FROM LAB 1 ON A FLOPPY DISK.** This is your responsibility.

Since you will be doing LabVIEW programming a short summary of some LabVIEW commands is given in Table 1.

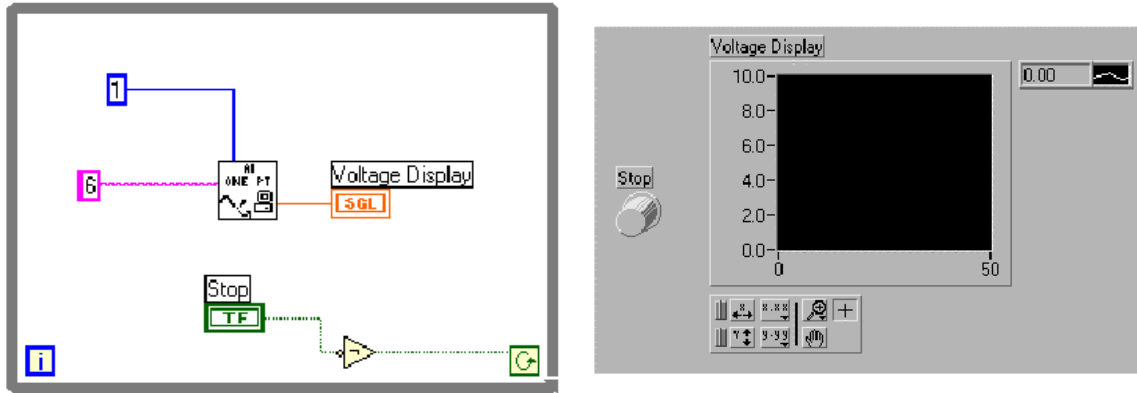
Command/Tool	Purpose	Used When	Picture
Delete key	Deletes selected objects	There are unwanted objects in the program	<Delete>
Ctrl-S	Saves files	You want to save your Changes	<Ctrl-S>
Positioning tool	Moves and selects objects	You need to move or delete program elements or insert new ones	
Wiring tool	Connects objects together	Program elements must be connected to allow data to flow between them	
Ctrl-B	Removes all broken wires	There are several unwanted wires in the program; use with caution	<Ctrl-B>
Operating tool	Changes values	You need to change a value in a front panel object	
Text tool	Edits text	You need to change a label or a comment	

**Table 1. Some Useful Commands and Tools**

#### **A. Building a DC Voltmeter with LabVIEW**

1. The easiest way to do this lab is to modify your program from Lab 1 if you used LabVIEW 4.1; otherwise, if you used LabVIEW 5 you should start with a new LabVIEW 4.1 file. Insert your floppy disk with your program into a lab computer. Save the program under a different name such as **Graphing Digital Voltmeter.vi**. Use the extension \*.vi for all virtual instruments.

- These instructions assume you are modifying your VI from Lab 1. Remove the random number generator as well as the addition, subtraction and multiplication blocks that you placed inside the while loop in Lab 1. Do not remove the output terminal; just rename it. Insert the **AI Sample Channel** sub-VI needed for data acquisition in your program in the middle of the screen. Note: A sub-VI is LabVIEW's version of a subroutine. The **AI Sample Channel sub-VI** is located in **Data Acquisition » Analog Input » AI Sample Channel**. Remember that you find this menu by pointing the cursor where you want the icon to appear and clicking the right mouse button.
- Open the Help window if it is not already open. This can be done by typing <Ctrl-H> and positioning the cursor on the AI Sample Channel Sub-VI.



(a) Diagram View

(b) Front Panel View

**Figure 6. Sample VI that Reads Channel 6 from Device 1**

- Insert a digital constant to set the device number for **AI Sample Channel**. Set this digital constant to 1 for the PCs we have in the lab. NOTE: The digital constant can be found by following the path Function palette>>Numeric (the blue box with 123 in it)>>Numeric Constant.
- Insert a string constant to set the channel number for **AI Sample Channel**. String constants work the same as digital controls, except they use a different data type. Set this string constant to 0 [Not 6 as shown in Figure 6] for the PCs we have in the laboratory. The clip leads in the input board are connected to the appropriate screw terminals for channel 0 and 1 inputs. NOTE: The numeric constant symbol can be found by following the path Function palette>>Numeric>>Numeric Constant (i.e., follow the blue boxes with 123 in them). The string constant is similarly found by following the path Function palette>>String>>String Constant (i.e., follow the pink boxes with abc in them).
- Remember to save your VI after every few changes, so you can return to a known state if necessary.

## **B. Testing your LabVIEW DC voltmeter**

- Connect alligator clips to the appropriate inputs of the LabVIEW connection module. This is the printed circuit board which has a number of screw terminals and is connected by a cable to the LabVIEW board inside the computer. You have already specified the channel and device number in steps 4 and 5 above. The alligator clips should be already connected to the terminals 1, 2 and 11 of the LabVIEW connection module. If they are not, refer to the connections posted on the course web page.
- Start your VI.
- Measure the voltages of five (5) DC batteries supplied in the lab. Record the battery label and the corresponding measured voltage in Data Table 1.

## Part 2: DMM Measurements

### A. Instrument Familiarization

In this laboratory you will use two instruments, a power supply and a digital multimeter (DMM) similar to the simulated instruments you used in Lab 2. Both are rather sophisticated so you will test some of their capabilities before you actually use them for any circuit measurements. It is very important that you learn to use them correctly. Both of these instruments, as well as all of the other instruments that you will use during the semester, have the capability of being controlled by a computer. However, for this laboratory you will not make use of this capability.

#### 1. Triple Output DC Power Supply (HP E3631A)

The front panel of the Triple Output DC Power Supply is shown in Figure 7. The supply can produce outputs in the range 0V to +6V, 0V to +25V, and 0V to -25V. The +25V and -25V supplies have a common terminal and all three supplies are isolated from earth (power line) ground, although any terminal can be grounded.

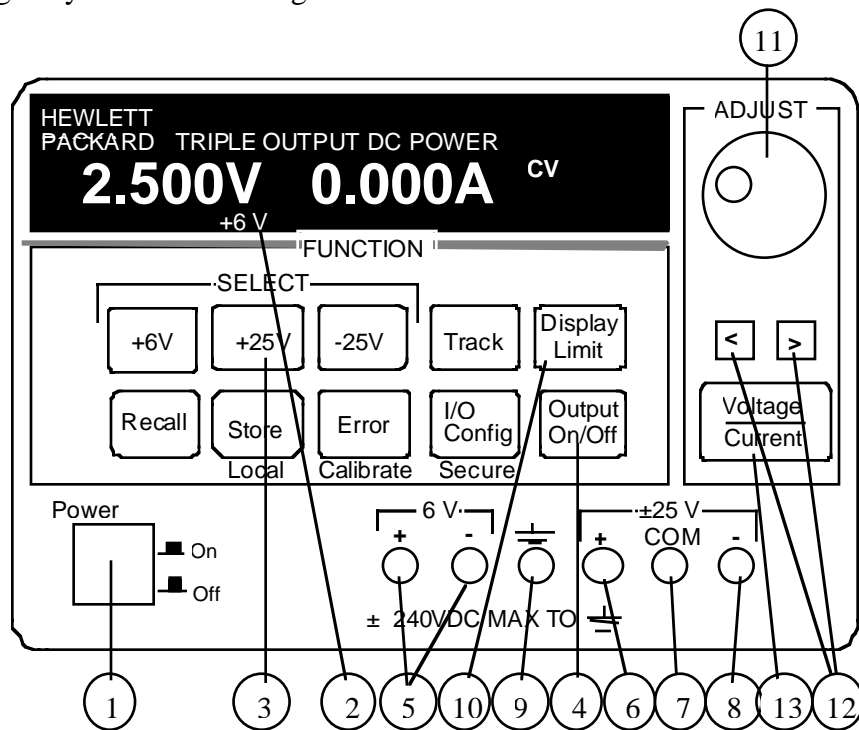


Figure 7. HP Triple Output DC Power Supply

- 1) With nothing connected to the outputs, turn on the power supply by pressing the Power switch (1). After a self check, the display will indicate OUTPUT OFF and show that the +6V supply is connected for metering (2). Select the +25V supply for metering by pressing the +25V switch (3). The display will indicate that the +25V supply has been selected.
- 2) Turn the outputs on by pressing the Output On/Off switch (4). This connects the outputs of all three supplies to the output terminals, with the indicated supply being metered. The +6V output is available between + and - terminals (5) under the 6V label, the +25V output is available between the + terminal (6) and COM (7) terminal, and the -25V between the - terminal (8) and COM (7) terminal. YOU SHOULD ALWAYS USE THE COM (7) TERMINAL TO GET +25 or -25 OUTPUTS. Do NOT use the - terminal (5) of the 6V output or the ground terminal (9) to complete a + 25 or - 25 volt output connection..

All three supplies are isolated from ground. The +25V and -25V supplies can be referenced to ground by connecting the COM (7) to ground (9). Either side of the +6V supply can be referenced to ground by connecting the + or - terminal to ground.

At power on, the power supplies are set to the following **maximum** outputs:

Supply	Max $V_{out}$	Max $I_{out}$
6V	0V	5.0 A
+25V	0V	1.0 A
-25V	-0V	1.0 A

To view the limits, press the Display Limit switch (10). On doing this, the term “Lmt” appears just below the output numbers on the display and the second digit of the voltage display is blinking. When Lmt is illuminated, the display shows the limiting (maximum) current available from the selected supply. After 6 seconds of inactivity an internal timer automatically switches the display back to the meter mode.

- Use the display Limit function and the Select switches to check the above default settings. If the Lmt illumination turns off, press the Display Limit switch again.
- Select the +25V output for display. Turn the Adjust knob (11) and observe that the output voltage changes. The digit being adjusted can be changed by using the Left/Right arrow keys (12). Experiment with the adjustment and digit selection until you understand how the system operates, then set the output voltage back to 0V and switch off the output using the Output On/Off switch.

Although we have not used them, the +6 V and -25 V supplies are controlled in the same manner as the +25 V supply. The remaining switches are for functions that we will not use, so do not press them.

## 2. Digital Multimeter (HP 34401A)

The front panel of the HP 34401A Multimeter (DMM) is shown in Figure 8. This is a very sophisticated instrument that can measure resistance by two methods, as well as DC and AC voltage and current, power level, frequency, and continuity. For each of these functions, the DMM automatically selects the most appropriate range for the specific measurement being done. We will only use a few of its capabilities in this lab.

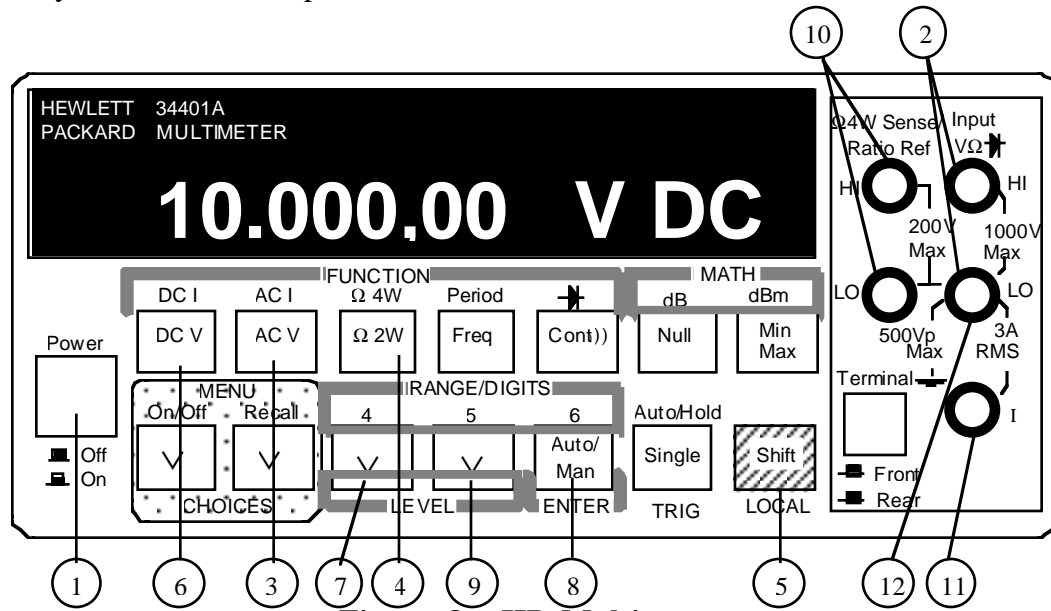


Figure 8. HP Multimeter

The front panel of the Multimeter has a seemingly confusing array of labels and switches. Don't worry - we will work through their use as you need them, beginning with voltage measurement. Start by pressing the Power switch (1). Like the power supply, the DMM goes through an internal self check at each turn-on. Following this, the display will indicate mV DC and some of the numbers will most likely be oscillating. The meter automatically adjusts its range to suit the measurement. Since there is no voltage source connected, the voltmeter goes to its most sensitive range.

- 1) Before proceeding with measurements, let's try out some of the controls with nothing connected to the DMM. Since the meter is currently in the DC V mode, press the AC V switch (3) and observe that the display now indicates mVAC. Press the  $\Omega$  2W switch (4) and the display reads MOHM and indicates OVLD (overload). (This means that the resistance of the open input is much larger than the meter can read.) Observe that many of the function labels are light blue. To activate these functions, the Shift switch, which is also blue, must be pressed first. For example, press the Shift switch (5), then the switch below the DC I label (6). The display now should read mADC. Return to the DC voltage measurement mode by pressing the DC V switch (6). Turn off the power supply using the output on/off switch.
- 2) Make sure that the output of the power supply is turned off using the Output On/Off switch. You will measure the output of the +25V supply of the Power Supply by connecting "banana" test leads from the +25V output to the DMM. In general, voltage measurements can be made by connecting the voltage source to the Input V $\Omega$   $\blacktriangleright$  HI and LO inputs (2). Connect the + output to the HI input and the COM output to the LO input. After you have done this, turn on the power supply using the Output On/Off switch and adjust the output to +25V, as given by the display on the supply. The DMM should read approximately +25V. Record the voltage given by the DMM and that given on the Power Supply display in Data Table 2, then switch off the power supply output.
- 3) Reverse the connections at the DMM (connect the + output to the LO input and the COM output to the HI input). Again turn on the power supply output and record the DMM and Power Supply display voltages in Data Table 2. Turn off the power supply output and return the leads to the configuration that you used in Step 2 above.

We will learn about other functions of the DMM in the course of the experiments to follow.

### Notes on instrument accuracy

In conducting the voltage measurements on the power supply you most likely observed that the readings obtained from the DMM did not agree with those given by the Power Supply display. Does this mean that one of the meters is malfunctioning or giving erroneous readings? Probably not. Rather, the difference is most likely the result of the accuracy specifications of the two instruments.

The accuracy specifications for the Power Supply readout are given in Table 2 and those for the DMM are in Table 3.

	+6V Output	+25V Output	-25V Output
<b>Voltage</b>	$\pm(0.1\% + 5 \text{ mV})$	$\pm(0.05\% + 10 \text{ mV})$	$\pm(0.05\% + 10 \text{ mV})$
<b>Current</b>	$\pm(0.2\% + 10 \text{ mA})$	$\pm(0.15\% + 4 \text{ mA})$	$\pm(0.15\% + 4 \text{ mA})$

**Table 2. Power Supply Readout Specifications [ $\pm$ (% of output + offset)]**

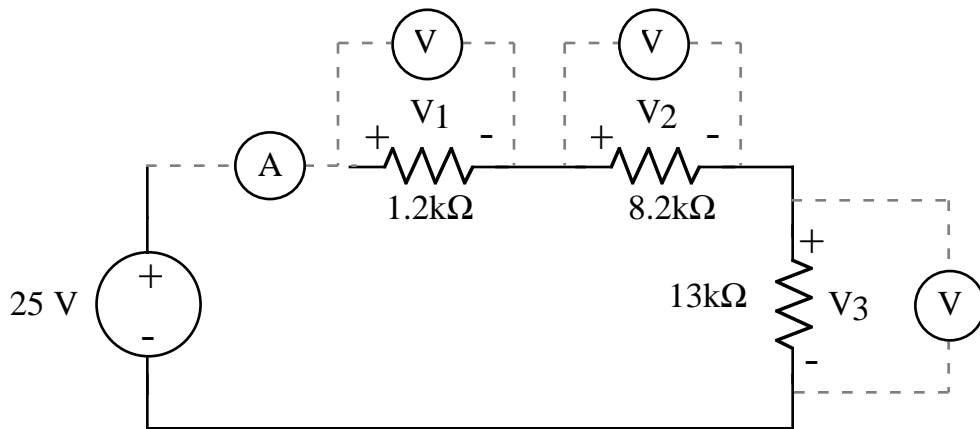


Function	Range	Accuracy
DC Voltage	100.0000 mV	0.0030 + 0.0030 mV
	10.00000 V	0.0015 + 0.0004 V
	1000.000 V	0.0020 + 0.0006 V
Resistance	100.0000 $\Omega$	0.0030 + 0.0030 $\Omega$
	10.00000 k $\Omega$	0.0020 + 0.0005 k $\Omega$
	1.000000 M $\Omega$	0.002 + 0.001 M $\Omega$
DC Current	10.00000 mA	0.005 + 0.010 mA
	100.0000 mA	0.01 + 0.004 mA
	1.000000 A	0.05 + 0.006 mA

**Table 3. Selected Multimeter Accuracy Specifications (6 1/2 digit resolution)**  
 $[\pm(\% \text{ of reading} + \% \text{ of range})]$

## B. VOLTAGE and CURRENT MEASUREMENT

### 1. Voltage divider circuit



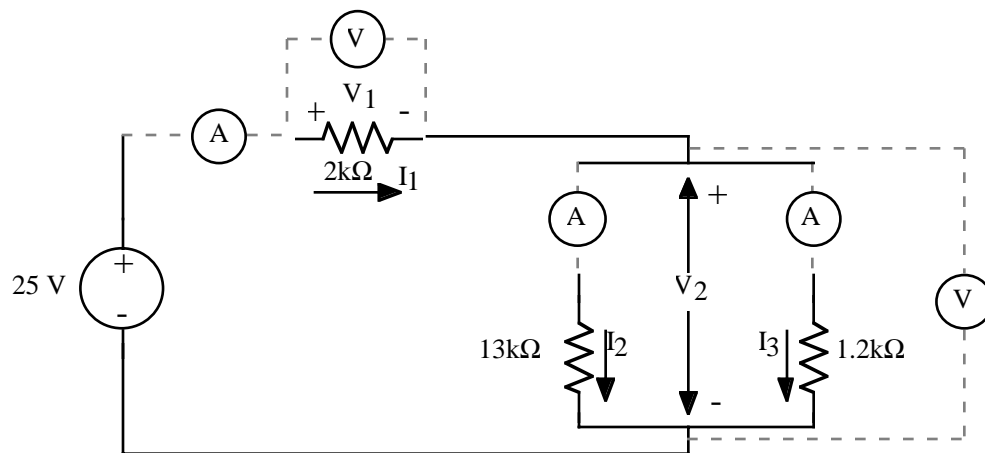
**Figure 9. Voltage divider circuit.**

- 1) Get 1.2k $\Omega$ , 8.2k $\Omega$  and 13k $\Omega$  resistors from the Circuits Lab instrument room. Connect banana leads with alligator connectors on one end to the inputs (2) on the DMM. Put the DMM into resistance measurement mode by pressing the  $\Omega$  2W switch (4) on the DMM front panel. Record these values in Data Table 3.
- 2) Build the circuit shown in Figure 9. Start by inserting the three resistors into the breadboard so that they are connected in series as shown. Before connecting the power supply to your circuit, connect the DMM directly to the +25V output and, using it, set the output to 25V. A good practice is to always turn the power supply off using the output on/off switch (4) [in Figure 7] in before connecting it to your circuit. Do so now.
- 2) You will want to connect the DMM as a current meter. To do this, connect the + output of the power supply to the I input of the DMM (11). Connect the LO input immediately above the I input (12) to the input of your resistor circuit — this is the unconnected end of the 1.2k $\Omega$  resistor as shown in Figure 9. Connect the unconnected end of your 13k $\Omega$  resistor resistor to the COM terminal of the power supply. To select the DC current mode of the DMM, first press the Shift switch, then the switch just below the DC I label. The DMM display should indicate mA.

- 3) Switch the power supply output on and record the current measured by the DMM in Data Table 4. Do NOT adjust the power supply output voltage or current. Turn off the power supply output and return the DMM to the DC voltage measurement mode.
- 4) Remove the current meter from the circuit and connect the power supply directly to the input of your resistor circuit, i.e., to the  $1.2\text{k}\Omega$  resistor.
- 5) Turn on the power supply output and measure the voltage drop across each resistor and the output voltage of the power supply with the DMM. Do NOT adjust the power supply output voltage or current. Record your data in Data Table 4. Turn off the power supply output.

## 2. Current divider circuit

- 1) Build the circuit shown in Figure 10. Start by inserting the resistors into the breadboard so that they are connected in the series/parallel combination shown. Before connecting the power supply, check to be certain that the output is 25V. (Use the DMM.) Turn the output off and connect the DMM in series with the resistor circuit to measure the total current,  $I_1$ .



**Figure 10. Current divider circuit.**

- 2) Switch the power supply output on and record the current,  $I_1$ , measured by the DMM in Data Table 5. Do NOT adjust the power supply output voltage or current. then turn off the power supply output.
- 3) In sequence, connect the DMM in series with each of the two resistors that are in parallel and measure the currents  $I_2$  and  $I_3$ . Note that you have to pull one end of each of these resistors out of the breadboard to connect the DMM as a current meter — this is just like the simulation in Lab 2. Record your measurements in Data Table 5. Turn off the power supply output while you are modifying the circuit. Make certain that the entire circuit is correctly connected before each measurement! Turn off the power supply output.
- 4) Connect the resistor circuit directly to the power supply. Use the DMM to measure the input voltage to the circuit. Then use the DMM to measure the two voltages  $V$  shown in Figure 10, i.e., across the  $2\text{k}\Omega$  resistor and the parallel combination of the  $13\text{k}\Omega$  and  $1.2\text{k}\Omega$ . Record your results in Data Table 5, then turn off the power supply output.



Parameter	Calculated Value	Measured Value	% Difference
Supply voltage	25 V		
I			
V <sub>1</sub>			
V <sub>2</sub>			
V <sub>3</sub>			

**Data Table 4. Voltage divider circuit**

Parameter	Calculated Value	Measured Value	% Difference
Supply voltage	25 V		
I <sub>1</sub>			
I <sub>2</sub>			
I <sub>3</sub>			
V <sub>1</sub>			
V <sub>2</sub>			

**Data Table 5. Current divider circuit**

## Questions

1. In Data Tables 2 to 5 complete the calculations, i.e., the % error and difference calculations.