

LABORATORY 1

BREADBOARDS & DC MEASUREMENTS

OBJECTIVES

1. To learn the internal connections of a typical breadboard.
2. To construct a breadboard layout from a schematic diagram.
3. To connect and use an ohmmeter without causing damage to the instrument.
4. To correctly connect a voltmeter to a circuit.
5. To correctly connect an ammeter in a circuit.
6. To interpret ohmmeter, voltmeter and ammeter ranges.

Starting in Lab 3, you will be expected to know how to use the multimeters and oscilloscope (Lab 2) as well as how to construct circuits on the breadboard. Your performance in the lab will be marked. **Please make sure that at the end of Labs 1 and 2 you understand how to use the instruments and the breadboard. Simply following instructions without understanding how to make measurements independently is not sufficient.**

INFORMATION

Note: Actual lab procedure follows this information section.

1. Circuit construction breadboard

A circuit construction breadboard allows the user to conveniently build an experimental circuit (as opposed to a permanent one, meant for repeated use) without having to solder components. Figure 1.1 shows a photograph of the PROTO-BOARD breadboard used in this laboratory.

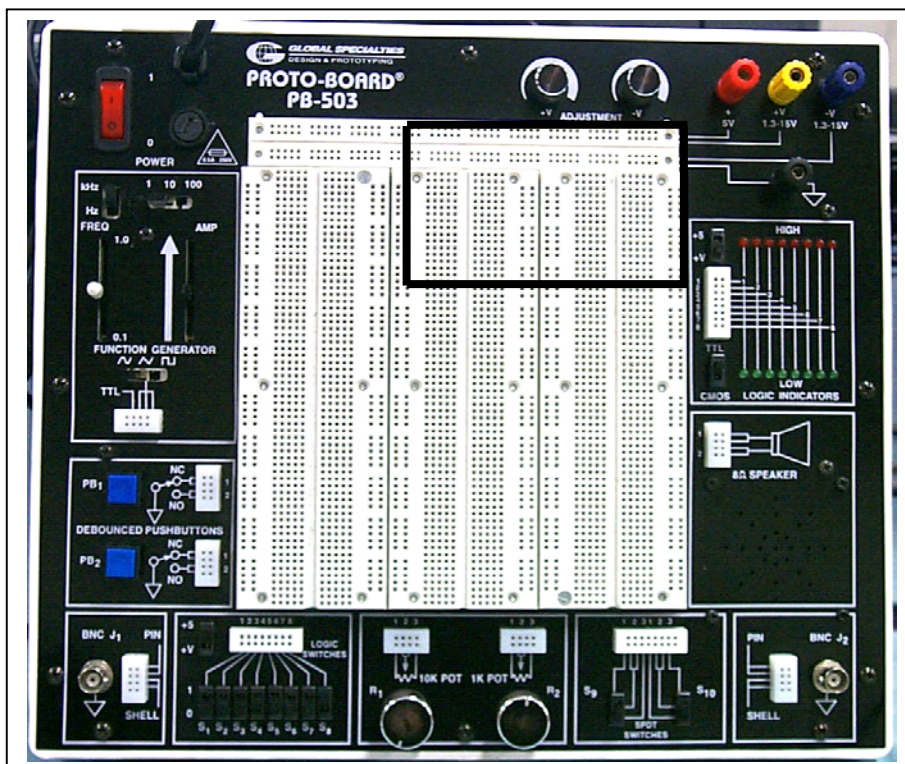
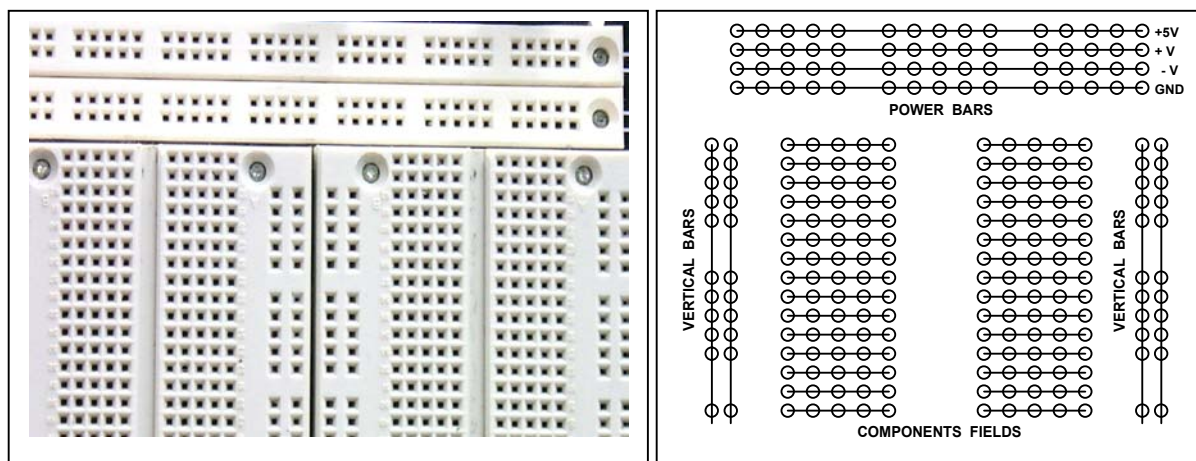


Figure 1.1 PB-503 PROTO-BOARD

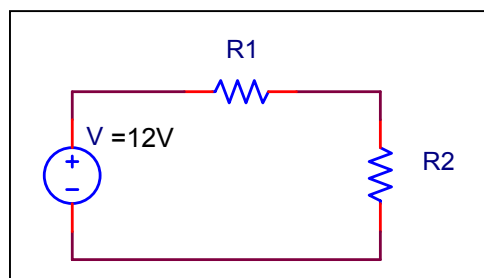
Figure 1.2(a) shows a portion of the breadboard outlined in Figure 1.1. The main part of the board consists of sets of holes. The holes are actually sockets that have spring clips inside in order to make electrical contact with any component lead that may be inserted into the hole. Each set of holes is connected internally. Figure 1.2(b) schematically illustrates by means of lines which sets of holes are connected together internally. The two sets of horizontal sockets at the top of the board (designated by +5V, +V, -V and GND signs) are commonly called “Power Bars,” and **are internally connected** to the built-in power supplies. Notice that the socket interconnections for the “Components Fields” run only horizontally. Vertical connections exist only in “Vertical Bars” below the power bars. The vertical bars are used to supply power to your circuits however they **are not internally connected** to the built-in power supplies. Therefore you could use the vertical bars to supply power to your circuit both from the internal and the external power sources.



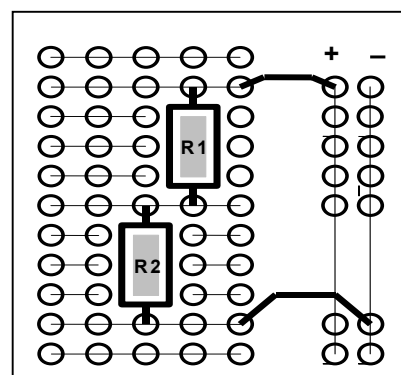
(a) Section of breadboard outlined in Figure 1.1. (b) Internal breadboard connections.

Figure 1.2 Schematic illustration of a generic circuit construction breadboard.

Figure 1.3(a) is a schematic diagram of a DC circuit consisting of two resistors, R_1 and R_2 , in series with each other. Figure 1.3(b) shows how the circuit would be laid out on a breadboard. Note that the two resistors share a common node in the schematic diagram, and this is realized by connecting one lead of R_1 and one lead of R_2 to the same set of holes on the breadboard, i.e., a set of connected holes on the breadboard represents a single node in the circuit.



(a) Schematic diagram



(b) Breadboard layout

Figure 1.3 Example of connecting a circuit with two resistors in series.

Figure 1.4(a) shows two resistors in parallel with each other, and Figure 1.4(b) shows the breadboard layout. Components such as resistors and capacitors can be connected to a breadboard by inserting their leads directly into holes. Wires can be used to form connections

between components on the breadboard. Simply strip approximately 1 cm of insulation off of each end of the wire and insert the bare end directly into a hole.

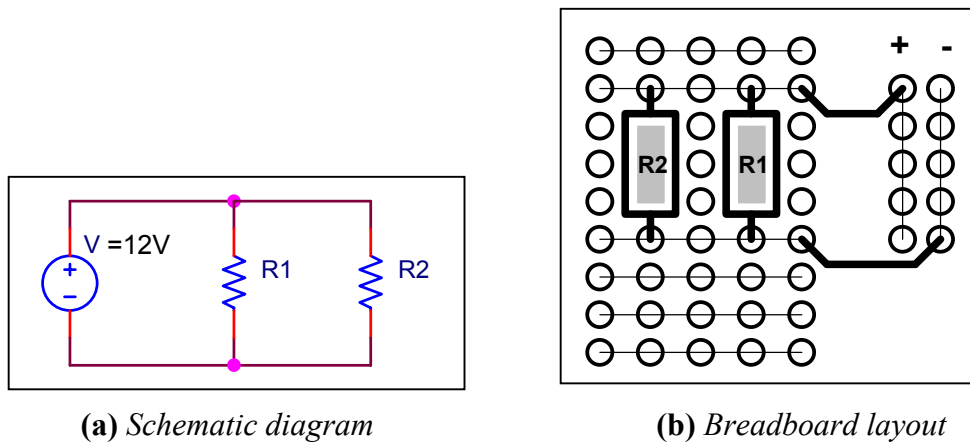


Figure 1.4 Example of connecting a circuit with two resistors in parallel.

Figure 1.5 (a) shows an example of a circuit, consisting of serial and parallel-connected resistors, which will be used during this lab for resistance, voltage and current measurements. The breadboard layout of this circuit is shown in Figure 1.5 (b).

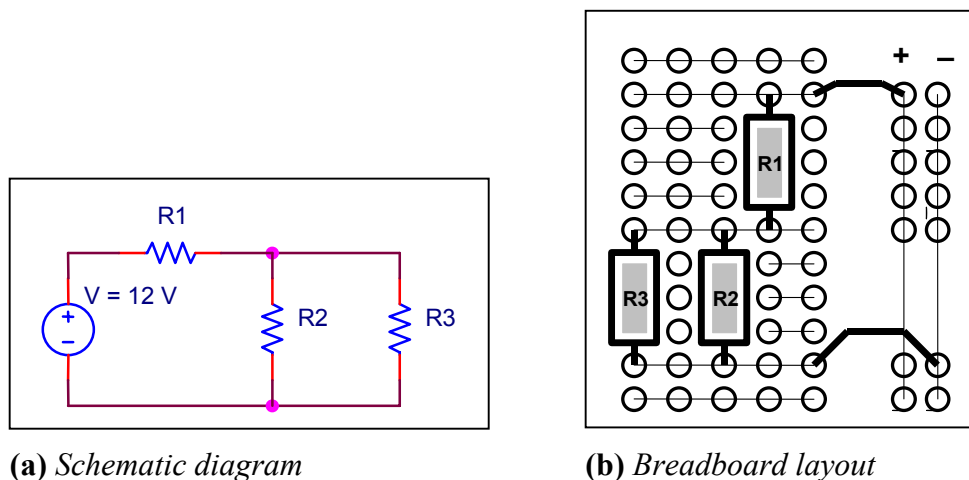


Figure 1.5 Circuit that you will connect in this lab.

Key features of the board used in our laboratory:

The PB-503 PROTO-BOARD is a complete design workstation, including instrumentation, breadboarding, and a rugged DC regulated triple power supply.

The instrumentation features:

- eight individual selectable logic switches (offering settings of +5volts / +V and ground);
- eight individual red (high) and green (low) buffered logic LED indicators;
- 100KHz function generator with continuously variable sine, square, and triangle waveforms plus TTL pulse;
- triple output power supply (one fixed at +5VDC and two variable from ± 1.3 to ± 15 VDC). All three supplies are short-circuit protected, automatically current limiting the output to a safe level.
- two digital pulse generators;
- audio experimentation 8 Ω speaker;
- SPDT switches;

- Potentiometers;
- debounced pushbutton switches.

The breadboarding area has a total of 2520 uncommitted tie points, enough space for circuits containing 24 IC's of 14 pins or equivalent.

Some rules for wiring a circuit on a breadboard

Although you may not understand all of the features of the Proto-Board and some of the rules for circuit wiring at present, please read them now and refer to them for future labs.

An example for correct component connection is shown in Figure 1.6 (a).

The following typical connection mistakes are shown in Figure 1.6 (b):

- Integrated Circuit (IC) A is inappropriately connected to the power supply bus;
- IC B is improperly placed over the component field and its pins are short-connected by the breadboard;
- Component C is short-connected by the power bus;
- Component D is short-connected by the internal breadboard connection;
- Component D and wire E are connected together to the same breadboard socket.

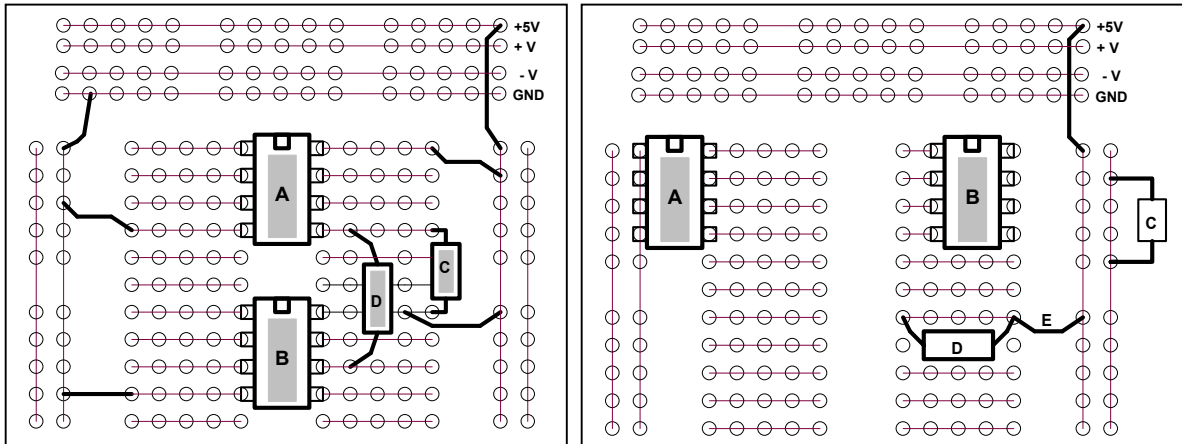


Figure 1.6 (a) *Correctly connected components* (b) *Typical connection mistakes*

2. Power Supply Unit

The front panel of the adjustable dual voltage Power Supply Unit is shown in Figure 1.7



Figure 1.7 *Front panel of power supply unit.*

This Power Supply Unit provides dual adjustable voltages from 0V to 15V. It has built-in short current and overload protection circuits, that automatically drop the output voltage when the current supplied to the load exceeds 250 mA.

Turn the Power Supply ON. Adjust the voltage of the Power Supply to 12V. This will set both positive and negative power sources respectively to +12V and –12V. Turn the Power Supply OFF before connecting to the circuits. Connect the **POS** terminal of the Power Supply to the **V+** of your circuit. Connect the **COM** terminal of the Power Supply to the ground of your circuit, marked with the symbol \perp . **Do not connect** the **NEG** terminal of the Power Supply to your circuit.

3. Resistance measurements

Ohmmeters are used to measure the resistance of a component or a group of components. However, some precautions must be observed before connecting the component or group across the meter's probes. Ohmmeters differ significantly from voltmeters or ammeters in that they use their own power supply to accomplish a resistance measurement. Both voltmeters and ammeters use power from the circuit under test, thus the circuit must remain energized. A circuit must be de-energized before a resistance measurement can be made. Simply opening the circuit where it is desired to measure resistance can do this. Care must be taken that the circuit is not closed by the ohmmeter itself. Detailed procedures for using all meters described in this and the following two sections are given in the “Procedures” section; however, some precautions are noted below.

Both analog and digital multimeters are available in the lab. Multimeters permit voltage, current, resistance, and possibly other measurements to be made using the same instrument. Analog meters display measured values by means of a needle, whereas digital meters provide a numeric display. The **Fluke** digital meter is shown in Figure 1.8(a), and the **Simpson** analog multimeter is shown in Figure 1.8(b). Digital ohmmeters are the easiest to read since the user typically must only determine if the digital reading is in units of Ohms or kOhms; however, analog displays are often used in industry since they allow easier visualization of the variation of a value with time. Analog displays can also be colour coded to indicate when extreme values are reached.

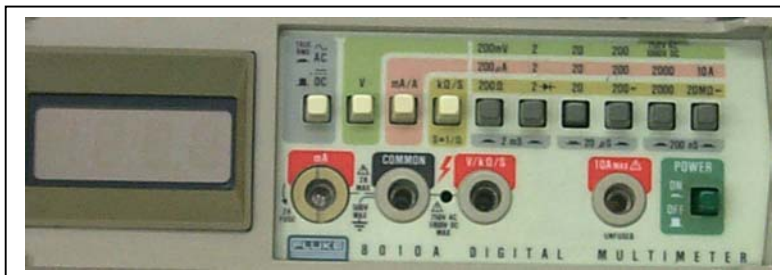
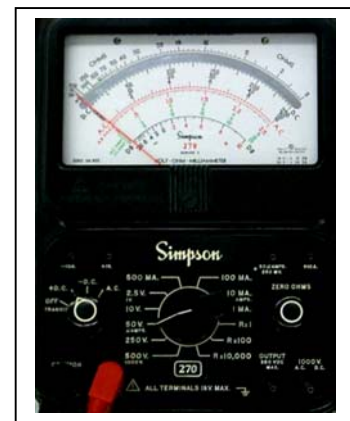


Figure 1.8 (a) *Fluke digital multimeter*



(b) *Simpson analog multimeter*

Suppose we wish to measure the value of R_1 in Figure 1.5, we need to observe the following:

1. Before starting measurements, be sure that DC power supply is disconnected from the measured circuit as shown in Figure 1.9(a).
2. At least one end of the measured component or Group should be disconnected from the rest of the circuit as shown in Figure 1.9(b).
3. For a more accurate measurement, carefully select a range which provides the greatest number of digits in the display.

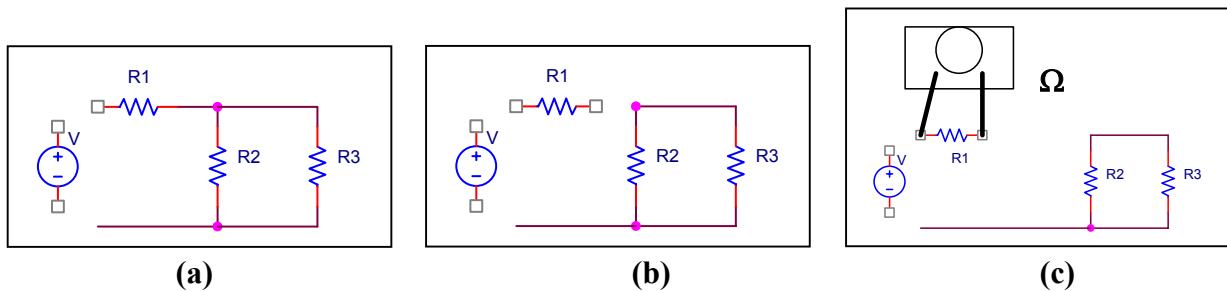


Figure 1.9 Steps in connecting an ohmmeter. (a) Disconnect power supply. (b) Disconnect one end of component to be measured. (c) Connect meter across terminals of component.

4. DC voltage measurements

A voltage exists as a potential difference across two points of an energized circuit. To correctly measure a voltage, a voltmeter must be connected across the two points of interest. The positive or red test lead is connected to whichever point is closest in potential to the positive side of the energy source. The negative or black test lead connects to the other point.

A single subscripted voltage, such as V_a , refers to the potential from point “a” to a ground or circuit common reference point. To measure this voltage, the positive test lead is connected to point “a” while the negative is connected to ground or circuit common (Figure 1.10). When using an analog meter, an upscale deflection is recorded as a positive voltage, although a plus sign is not required. If deflection is downwards, the meter leads must be reversed, and the resulting measurement must be recorded as a negative voltage. Some voltmeters will automatically correct for reversed polarity and provide a separate indicator of correct polarity.

Double subscripted voltages, such as V_{bc} , refer to the potential from point “b” to point “c”. The positive lead must be connected to point “b”, the negative to point “c”. Again, an upscale reading is a positive voltage, while a reversed deflection must be recorded as a negative voltage. Correct polarity must always be expressed in a single or double subscripted voltage, whereas the notation “ V_{R3} ” does not imply any polarity and simply means “the voltage across the resistor $R3$.”

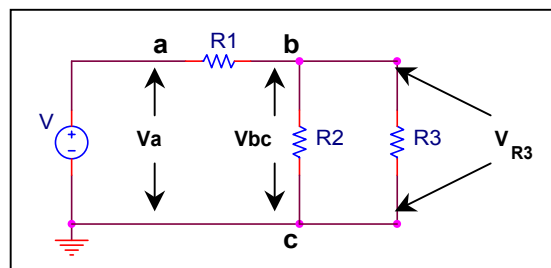


Figure 1.10 Reference voltages

Precautions:

1. When measuring voltages, start on a high voltage range and successively reduce the range to obtain the maximum number of digits in the display (digital) or as large a deflection (analog) as possible without causing the needle to exceed maximum deflection.

5. DC current measurements

The flow of current in a circuit is much like the flow of water through a pipe. For this reason, the current must be made to pass through the meter to make a measurement. Referring to

Figure 1.11, the easiest way to remember how to do this is as follows. The measured circuit in Figure 1.11(a) must be physically broken before a current measurement can be accomplished, as shown in Figure 1.11(b). When a circuit is broken at a location, it leaves a hole with two wire ends available. The ammeter must be connected to each of these wire ends, thus completing the circuit again. The positive lead of the ammeter, marked as “A”, should be connected to the wire end nearest to the positive side of the energy source. The negative lead of the ammeter, marked as “COM” should be connected to the wire end nearest to the negative side of the power source, shown in Figure 1.11(c). The current I that originally flowed through the point of interest must now flow through the ammeter, which is now located at the point of interest.

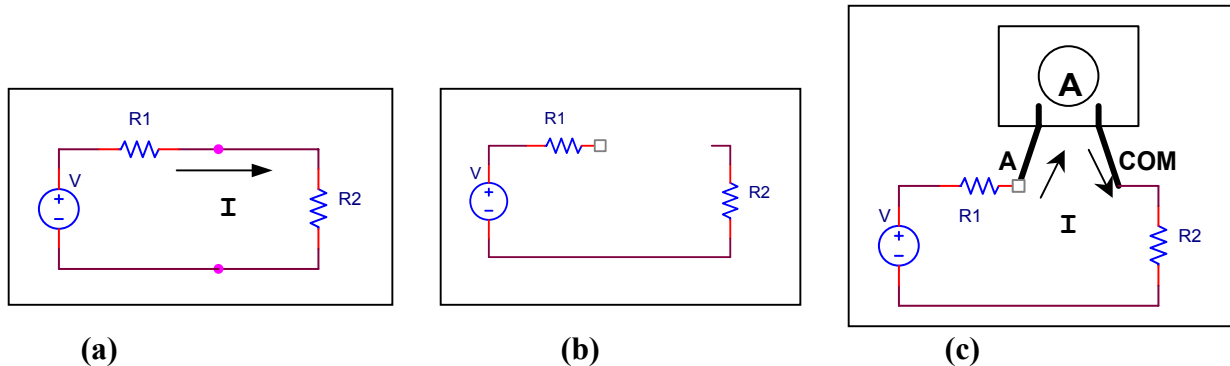


Figure 1.11 Steps in using an ammeter. (a) Current I to be measured. (b) “Break” circuit. (c) Insert ammeter.

Precautions:

1. Be sure to break the circuit and insert the ammeter in the resulting hole. Start on a high range and successively reduce ranges until the maximum number of digits are displayed (digital) or a reasonably high deflection (analog) is obtained.
2. Be extremely careful to connect the ammeter in series with the line in which a measurement is required; never connect an ammeter in parallel with a component.
3. Some meters require that one or more test leads be plugged into different sockets from those used for voltage measurement; consequently, care must be taken when switching back and forth between current and voltage measurements.

EQUIPMENT

1. Circuit construction breadboard PROTOBOARD PB503
2. Digital Multimeter FLUKE 8010A, BK PRECISION 2831B or BK PRECISION 2831C
3. DC Power Supply Unit
4. Resistors: $220\ \Omega$; $1\ \text{k}\Omega$; $4.7\ \text{k}\Omega$;

Precaution:

1. Resistors are supposed to be placed in bins labeled with their values; however, it is advisable that you check the value of the resistor yourself before using it. The colour codes on the resistor indicate value of the resistance. Appendix A explains how to read the value.

PRE-LAB PREPARATION

The lab preparation must be completed before coming to the lab. Show it to your TA at the beginning of the lab and get his/her signature in the Signature section of the Lab

Measurements Sheet. There is a penalty for incomplete preparation (see General Information).

1. Read Appendix A and the introduction to the manual.
2. Study the circuit shown in Figure 1.5(a) and the equivalent breadboard layout for this circuit shown in Figure 1.5(b). Make sure you understand the wiring diagram in Figure 1.5(b).
3. **[2 MARKS]** Calculate by hand the equivalent resistance of Group-2 (R2||R3) shown in Figure 1.12 in section 1 of the Lab Measurements Sheet. Record the calculated value in the column labeled “Theoretical R Values” in Table 1.1 of the Lab Measurements Sheet. Show your calculations.
4. **[12 MARKS]** Calculate by hand in section 2 the voltages listed in Table 1.2 of the Lab Measurements Sheet (i.e., the voltages V_a , V_b , V_c , V_{ab} , V_{bc} and V_{R1} in Figure 1.14), and record the final answers in the column labeled “Theoretical Values” in Table 1.2 of the Lab Measurements Sheet. Show your calculations.
5. **[6 MARKS]** Calculate by hand in section 3 the currents shown in Figure 1.15 and listed in Table 1.3 (i.e., the currents $I_1 - I_3$) of the Lab Measurements Sheet and record the final answers in the column labeled “Theoretical Values” in Table 1.3. Show your calculations.

PROCEDURE

1. Construct the circuit of Figure 1.12 on your breadboard. Try to layout the actual circuit as close as possible to the same placement as appears on the schematic diagram.
2. ***When the layout has been completed, have your TA check your breadboard for errors and get his/her signature in the Signature section of the Lab Measurements Sheet. You will be penalized marks if your sheet is not initialed.***

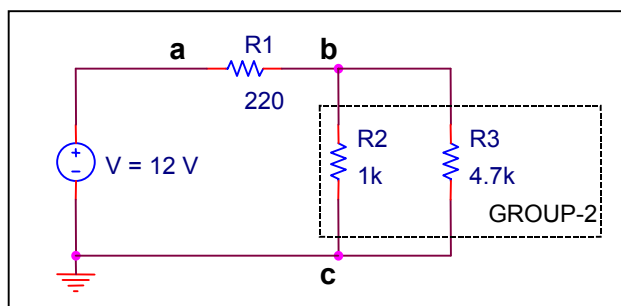


Figure 1.12 Resistor circuit diagram

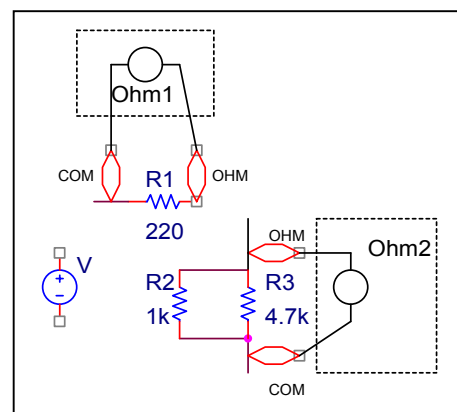


Figure 1.13 Resistance measurements

3. Resistance measurements

- 3.1 Measure the resistance of resistor R1 and Group-2 (R2||R3) as shown in Figure 1.12 using the digital meter and the following procedure:

- Remove power from the circuit.
- Press the Ω function switch of the Digital Meter
- Connect the red test lead to the **V- Ω** jack and black test lead to the **COM** jack. The red lead is (+) polarity.
- Connect the test leads to the points of measurement indicated in Figure 1.13, and record the measured values and ohmmeter ranges used in Table 1.1 of the Lab Measurements Sheet.
- If the expected resistance is unknown, start with the lowest range. If an over-range is indicated, continue selecting higher ranges until the over-range indication ceases. At this range greatest resolution is achieved.

4. DC voltage measurements

4.1 Measure V_a , V_b , V_c , V_{ab} , V_{bc} and V_{RI} listed in Table 1.2, using the digital meter as shown in Figure 1.14.

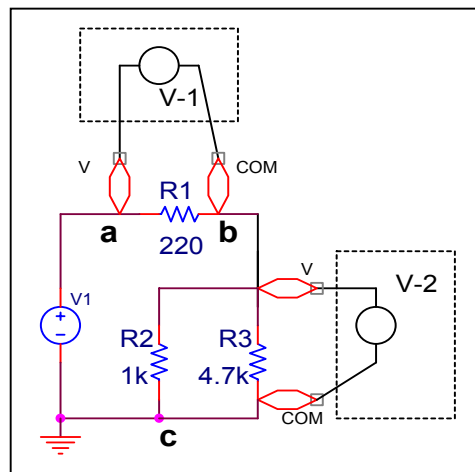


Figure 1.14 *Voltage measurements*

Use the following procedure:

- Connect the circuit of Figure 1.12 and turn the power supply ON.
- Adjust the power supply voltage to 12V.
- Press the **V** function switch of the digital multimeter.
- Select **DC** measurement by putting the **AC/DC** button in the “out” position.
- Press the voltage range switch for the range closest to an over-range for the measured signal.
- Connect the red test lead to the **V- Ω** jack and the black test lead to the **COM** jack.
 - Connect the leads across the circuit points to be measured, and record the measured values of V_a , V_b , V_c , V_{ab} , V_{bc} and V_{RI} in Table 1.2 of the Lab Measurements Sheet.

5. DC current measurements

5.1 Figure 1.15 illustrates how ammeters should be connected to measure the currents $I_1 - I_3$ required to complete Table 1.3 of the Lab Measurements Sheet.

CAUTION: For current measurements, the meter must be connected in series with the load. If incorrectly connected (in parallel with the load), the meter presents a very low resistance (almost a short circuit), that may blow the fuse or damage the meter or equipment under test. The 20A range has no fuse protection and may severely damage the meter or equipment under test or cause personal injury.

For current measurements greater than 2A, high current test leads should be used. High current measurements with standard test leads could cause the leads to heat up. This could result in injury to operator.

For current measurements with the digital meter, use the following procedure:

- Press the **A** function switch.
- Select **DC** measurement by putting the **AC/DC** switch in the “out” position.
- If an approximate current range is known, press the switch for the range desired.
- For current measurements of **2A** or less (as it is in our case), connect the red test lead to the **2A** jack and the black test lead to the **COM** jack.
- Remove power from the circuit (turn the Power Supply off) and open the normal circuit path where the measurements to be taken.
- Connect the meter **in series** with the circuit element through which current is to be measured.
- Apply power to the circuit, and record the measured values in Table 1.3 of the Lab Measurements Sheet.

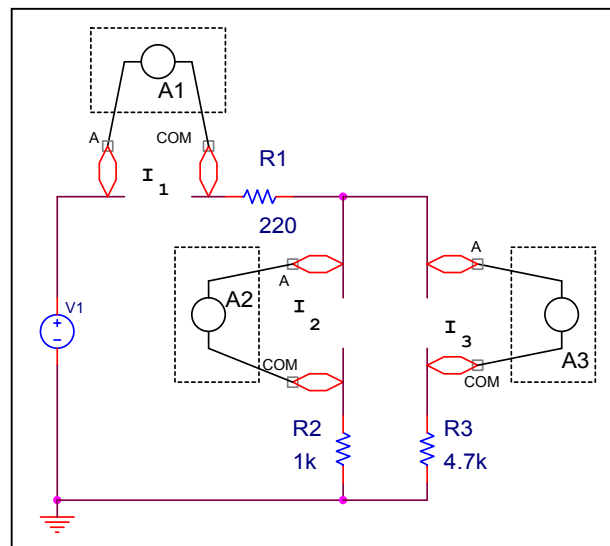


Figure 1.15 Current measurements

6. Setting up a circuit on your own

In the previous sections, you received detailed instructions on setting up your circuit on the breadboard. The objective in this section is to allow you to independently set up a circuit and make measurements. Set up the circuit shown in Figure 1.16, and show it to your TA before turning on the power supply. All resistors have a value of 1 k Ω .

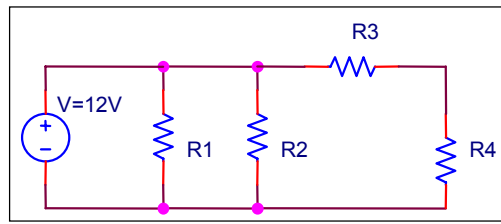


Figure 1.16. *Circuit to demonstrate skills with using breadboard*

Measure the voltage drop across resistor R4 and the current through it. Record your measurements in Table 1.4.

7. OPTIONAL

7.1. The behaviour of circuit elements can be represented by a plot of current versus voltage. This plot is usually called an I-V characteristic. In the section of the measurement sheets labeled “optional”, draw a circuit diagram to demonstrate how you would measure the I-V characteristic of a resistor using a variable DC power supply and a multimeter. Show instrument connections on your diagram. Ask your TA to check your diagram.

7.2. Build the circuit and measure the I-V characteristic of a 1 k Ω resistor. Vary the voltage from 0V to +2.0V in steps of 0.5 V. Fill in Table 1.5 with I and V values. Sketch your results. What is the slope of the line, and how is it related to the value of the resistor?

LAB MEASUREMENTS SHEET – LAB 1

Name _____

Student No _____

Workbench No _____

NOTE: Questions are related to observations, and must be answered as a part of the procedure of this experiment.

*Sections marked * are pre-lab preparation and must be completed BEFORE coming to the lab.*

1. * Calculations for the equivalent resistance of Group-2 ($R_2 || R_3$):

Table 1.1 *Resistance Measurements*

Component/ Group	*Theoretical R values (Ω)	Ohmmeter range	Measured R values (Ω)
R1			
Group-2 (R_2, R_3)			

2. * Voltage calculations (use separate pages if needed):

Table 1.2 *DC Voltage measurements.*

Voltage Designations	V_a	V_b	V_c	V_{ab}	V_{bc}	V_{R1}
Voltage measured (V)						
*Theoretical values (V)						

3. * Current calculations (use separate pages if needed):

Table 1.3 *DC Current measurements.*

Current Designations	I_1	I_2	I_3
Current measured (mA)			
*Theoretical values (mA)			

4. Setting up a circuit on your own

Table 1.4 *DC voltage and current measurements.*

Voltage measured across R4 (V)	
Current through R4 (mA)	

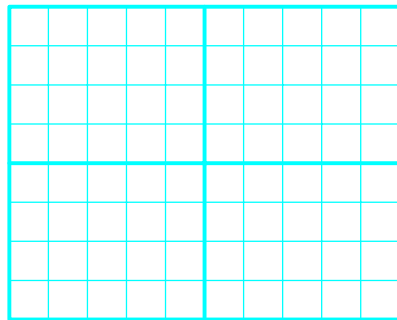
5. OPTIONAL

The space below is for the optional part of the lab.

Table 1.5 *OPTIONAL DC voltage and current measurements.*

V [V]	0	0.5	1.0	1.5	2.0
I [mA]					

I [mA]



V[V]

When you have finished collecting the data and answering the questions below, have a TA check and sign your Lab Measurements Sheet and your answers. You will lose marks if any signatures are missing.

QUESTIONS

- [3 MARKS]** What is the value of a resistor that has color bands green, black, and orange followed by a tolerance band?
- [7 MARKS]** In Figure 1.18 draw a breadboard layout (i.e., a diagram similar to what is shown in Figures 1.3(b), 1.4(b) and 1.5(b)) that shows how to connect the circuit, shown in Figure 1.17.

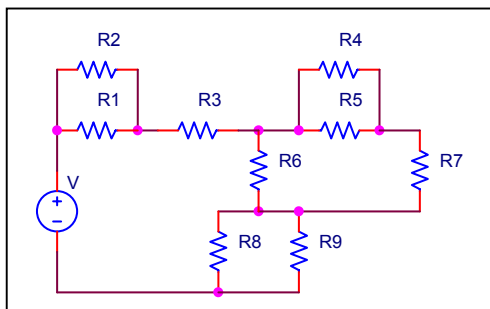


Figure 1.17. *Circuit to demonstrate skills with using breadboard*

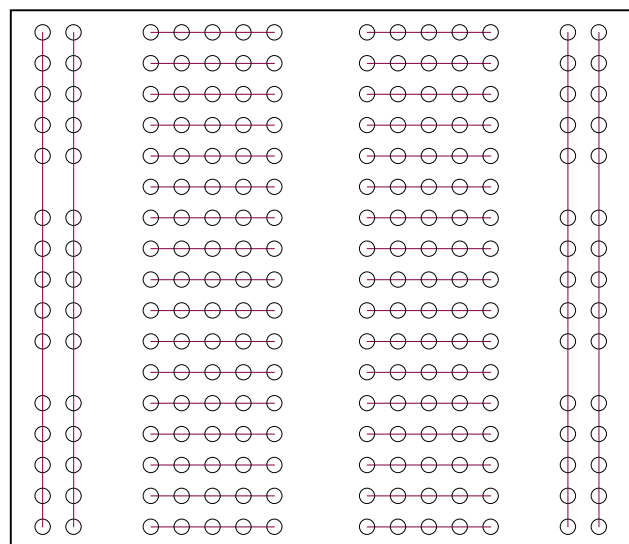


Figure 1.18 *Breadboard layout*

SIGNATURES**TA name:** _____

To be completed by TA during the lab session.

Check boxes				TA Signature	Student's Task
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		Pre-lab completed.
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		Circuit of Figure 1.12 connected correctly
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		Circuit of Figure 1.16 connected correctly
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		Data collected and observations made
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		Final questions completed

MARKS

To be completed by TA after the lab session.

Granted Marks	Max. Marks	Student's Task
	20	Pre-lab preparation
	0	Circuit of Figure 1.12 connected correctly.
	0	Circuit of Figure 1.16 connected correctly.
	70	Data collected and observations made
	10	Final questions completed
	100	Total