Lab 1

DC Measurements

REFERENCE: Horowitz and Hill: Sections 1.01 - 1.05
Appendix C (Resistor color code)
Appendix E (How to draw schematic diagrams)

INTRODUCTION

" This experiment has the following objectives:

Become familiar with:

- multimeter
- prototyping board
- resistor color code
- reading a schematic diagram
- wiring a circuit

Study a current source.

A *voltage source* (Figure 1-1) such as a battery or power supply is inherently a device with a low internal resistance. It should provide a *constant voltage* for a wide range of currents.

A *current source* (Figure 1-2) on the other hand should provide a *constant current* to a wide range of load resistances.

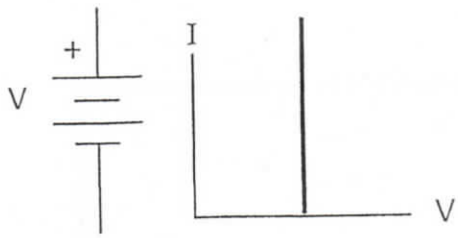


Figure 1-1
Voltage source

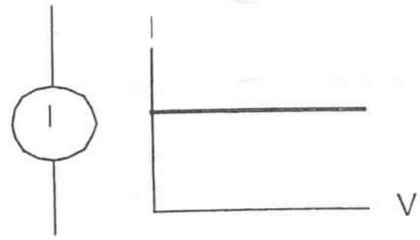
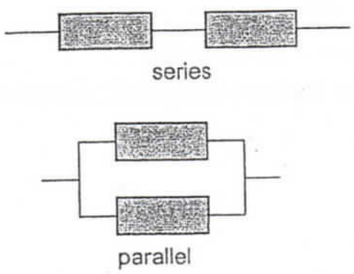
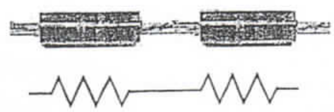


Figure 1-2
Current source



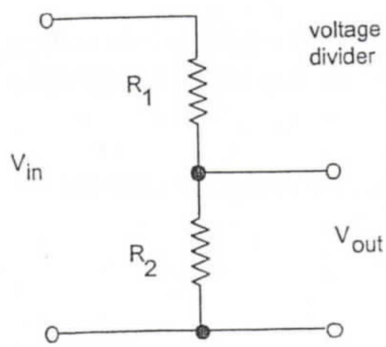


$$R_{series} = R_1 + R_2$$

Series and parallel circuits.

Study a voltage divider

A *voltage divider* is two resistors connected in series.

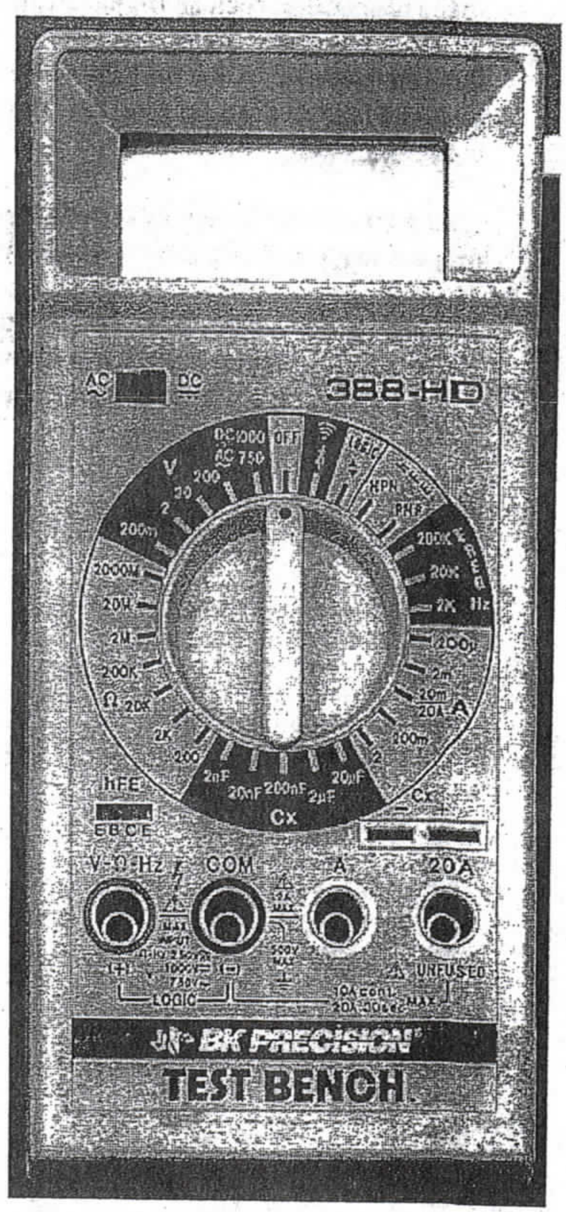


$$V_{out} / V_{in} = R_2 / (R_1 + R_2)$$

EQUIPMENT

Digital multimeter (BK Model 388-HD)	
Battery	1.5 V (2)
Battery	weak 1.5 V (marked X or "weak")
DC power supply	
Resistors	100, 560, 1 k, 1.8 k, 3.2 k, 50k
Box of assorted of resistors	
Decade box	
~8 V transformer (TA note: borrow these from lab coordinator if necessary)	
Prototyping board	
Two short solid-core wires (to stick into prototyping board)	
Alligator clips for multimeter test leads	
Boards with three terminals (2)	
Wire kit	
2 A fuses, may be needed by TA	

TA note: Check batteries and fuses on all multimeters before use.



Multimeter

PROCEDURE

Familiarization with equipment

- *The digital multimeter*

The hand-held digital multimeter is used widely to make electrical measurements of

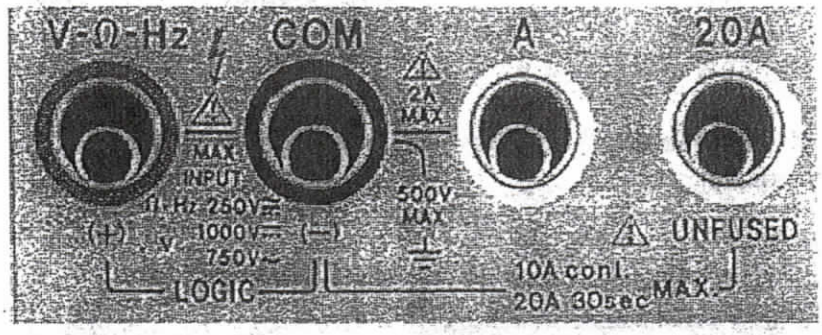
voltage dc & ac
current dc & ac
resistance
continuity
other quantities, such as frequency, depending on the features of your meter.

Input impedance: In the voltage mode, the input impedance of a digital multimeter is usually high enough (several MΩ) that it has negligible effect on the circuit being measured.

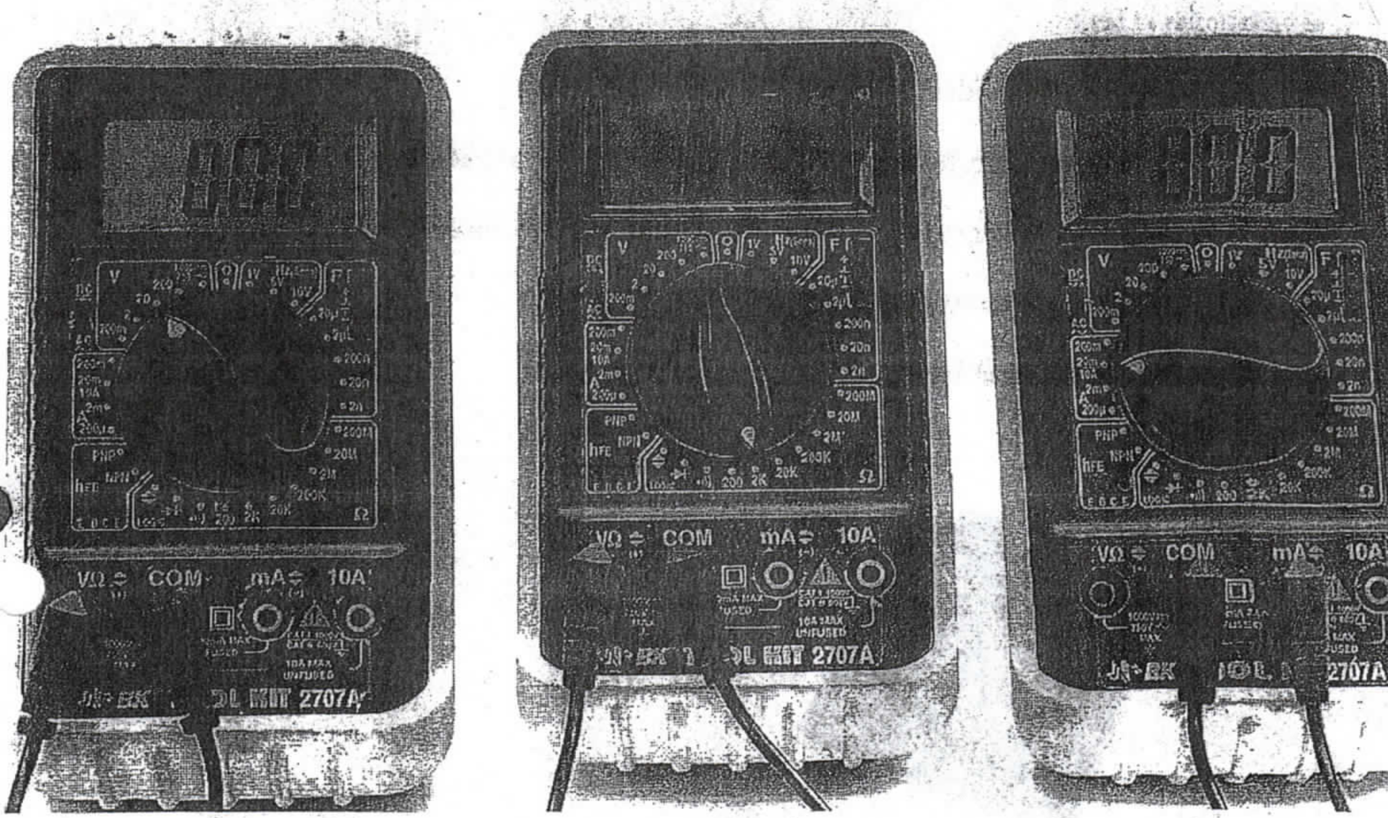
Continuity check: Many models allow you to check continuity, emitting an audible beep so that you don't need to look at the meter while making the test.

Hooking up the meter: Note that the meter is connected:

- in parallel to measure voltage or resistance
- in series to measure current.



Input jacks on a multimeter



(a) Voltage *V* (b) Resistance *Ω* (c) Current *A*

Multimeters. The meter can measure voltage, resistance and current. Note two things:

- which connectors at the bottom are used
- where the dial points (your dial might look different from the one shown here, but somewhere it will have *V*, *Ω*, and *A* for measuring voltage, resistance, and current).

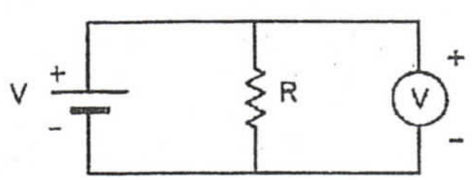


Figure 1-4. Using a multimeter (shown by the circle with a *V*) to measure *voltage.*

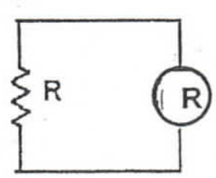


Figure 1-3. Using a multimeter (shown by the circle with a *R*) to measure *resistance.*

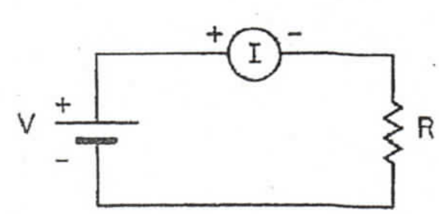


Figure 1-5. Using a multimeter (shown by the circle with an *I*) to measure *current.*

1. DC voltage

☛ Set the function switch of the multimeter to DC volts, with a scale commensurate with the voltages expected in the circuit.

☛ To protect the meter from damage:
ALWAYS SELECT THE MAXIMUM VOLTAGE SCALE TO START WITH.
Then adjust the scale downward until a meaningful reading is obtained.

(a) Batteries in series

☛ ✍ Measure the individual voltages of two 1.5 V batteries.

☛ ✍ Then connect the batteries in series and measure the total voltage.

☛ ✍ Reverse the polarity of one of the batteries and repeat the measurement.

☛ ✍ Calculate the error values, using propagation of errors.[§]

✍ Compare with expected results.

(b)

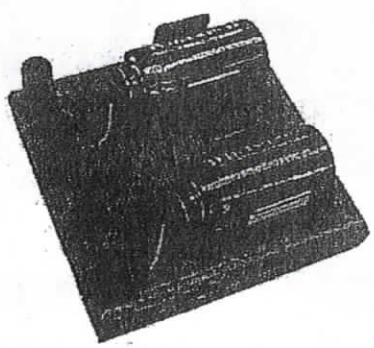


Figure 1-6.
Board with two batteries.

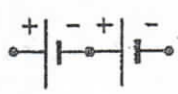


Figure 1-7.
Two batteries
connected in series.

[§] You are asked to use propagation of errors twice in this lab.

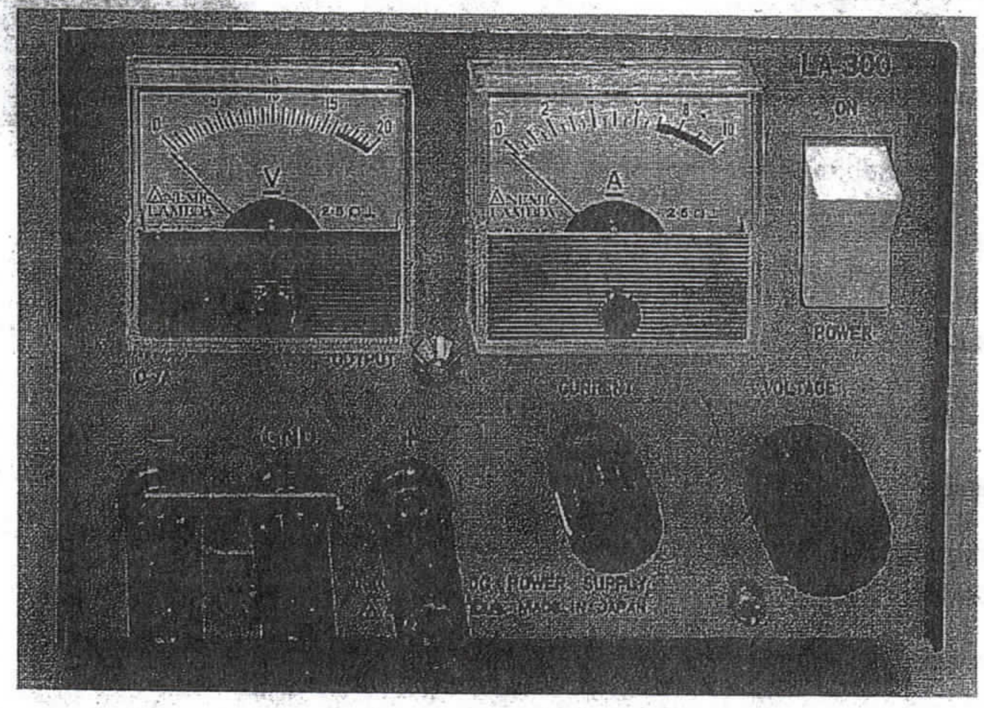
Power supply

“ A power supply is a voltage source powered by 110VAC. You will use a “bench” power supply, which has supplies an adjustable voltage.

☛ ✍ Set the power supply to four different voltages and measure each of these.

✍ How does the value on the power supply's meter compare with the value measured on the multimeter?

“ As a practice, remember that meters on a power supply are less reliable than multimeters. Always make measurements of voltage and current with an external meter.



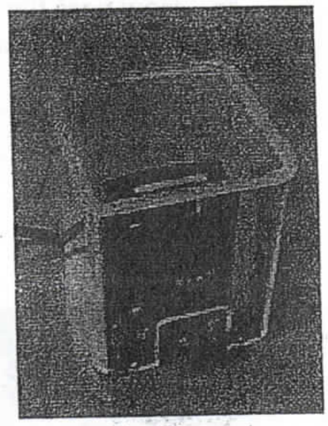
Power supply

2. AC voltage and frequency

☞ Set the AC/DC switch to AC and reset the scale to maximum voltage.

☞✍ Plug the primary of the transformer (it's labeled 8 V rms, but you will measure this yourself) into the AC outlet and measure the AC voltage of the transformer secondary.

" The house wiring is nominally rated at 110 V rms, but will vary from this value. Since this is connected to the primary of the transformer, and the voltage on the secondary is a fixed fraction of the primary voltage, you may find that your output voltage is not exactly the level printed on the transformer.



Transformer

" The electrical generators used by utility companies produce a 60 Hz voltage

☞ ✍ If your multimeter has a frequency (Hz) feature, use it to measure the frequency of the transformer output.

☞ Return the multimeter's ac/dc switch, if there is one, to dc.

3. Resistance**

☞ Set the function switch to Ohms.

☞ Check the meter by shorting the test leads. The meter should read zero ohms.

(a) Tolerances

☞ For this step only, use the box of assorted resistors. Measure the resistance of ten of your resistors.

☞ Determine the fractional error from the nominal value (obtained from the color code).

✍ Make a table of values, fractional errors, and tolerances. How many of the values fall within the specified tolerance?

(b) Series & parallel

** If you are color blind, you will be unable to identify the colors on the resistors. Inform the TA so that you can be excused from this step. Otherwise in this course, you will need to rely on your multimeter to determine your resistor values, if you are unable to read the color code.

☞ Choose two resistors that are within a factor of ten of the same value. Wire them up in series and then in parallel, using the board with three terminals. Measure the series and parallel resistances.

☞✍ Calculate the expected resistances (use measured values from part a) and compare with your measurements, including error values calculated using propagation of errors.[††]

4. <u>Continuity</u> [no response needed for lab report]

☞ With the function switch set to Ohms, touch the two test leads together while watching the display.

☞ Now set the function switch to continuity. (This may be indicated with the diode symbol —▶|— on your meter.) Touch the two test leads together and listen for the beep.

> 66 **Caution:**
>
> It is easy to damage a multimeter when used improperly in the *current* function.
>
> Never connect a *current* meter directly to a voltage source like 110 VAC or a battery. Without a resistor to limit the current, this would destroy the meter, or at least blow a fuse inside the meter.

5. <u>Current</u>

(a) <u>Measured values</u>

☞ ✍ Measure the actual value of the resistor shown in Fig. 1-5. (Throughout this course, always measure your resistor values before assembling the circuit.)

(b) <u>Comparison to predicted values</u>

☞ Wire up the circuit in Figure 1-5. Set the function switch to the maximum current scale (2 A) and connect the meter into the circuit.

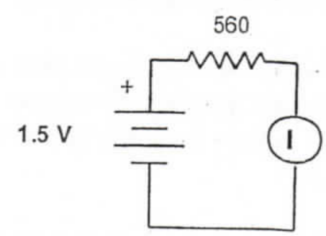


Figure 1-5

66 Note that for <u>current</u> measurements the meter is in <u>series</u> with the other elements of the circuit. This is

†† This is one of two instances in this lab where you are asked to use propagation of errors.

different from voltage measurements, where it is in parallel.

☛ ✍ Compare the measured value with the value of current you would calculate using the measured values of voltage and resistance. Explain any discrepancy.

6. Current Source

☛ Connect a 1.5 V battery and a large-valued resistor (1 MΩ) to make a current source. Use the decade box for a load resistor up to 200 kΩ, connected in series as shown in Figure 1-7.

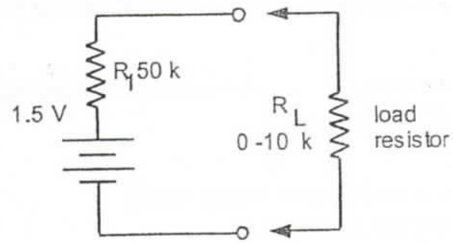


Figure 1-7
Testing a current source

66 This combination of a battery in series with a large resistor will act as a current source, provided the load resistance connected to the terminals is small. The current is:

$$
\begin{aligned}
I &= V/(R_1 + R_L) \\
&= (V/R_1)/(1 + R_L/R_1) \\
&\approx V/R_1 \quad \text{for } R_L \ll R_1.
\end{aligned}
$$

This is a crude current source, because the current depends on the load resistance, especially when R_L is not much less than R_1. You will build a better current source using a transistor in Lab 4.

☛ ✍ Connect several different load resistances across the terminals and measure the current through the load resistor and the voltage across it in each case.

✍ (a) What is the most accurate way for you to use a multimeter to measure current: passing the current directly through the meter, or using the meter to measure the voltage drop across a known resistance and computing the current from Ohm's Law?

(b) Make a table and/or plot of current vs. load resistance.

(c) Compliance: Determine the range of load resistance over which the current remains constant to 10%.
[Note: In Lab 4 (Junction Transistors) you will need this result again.]

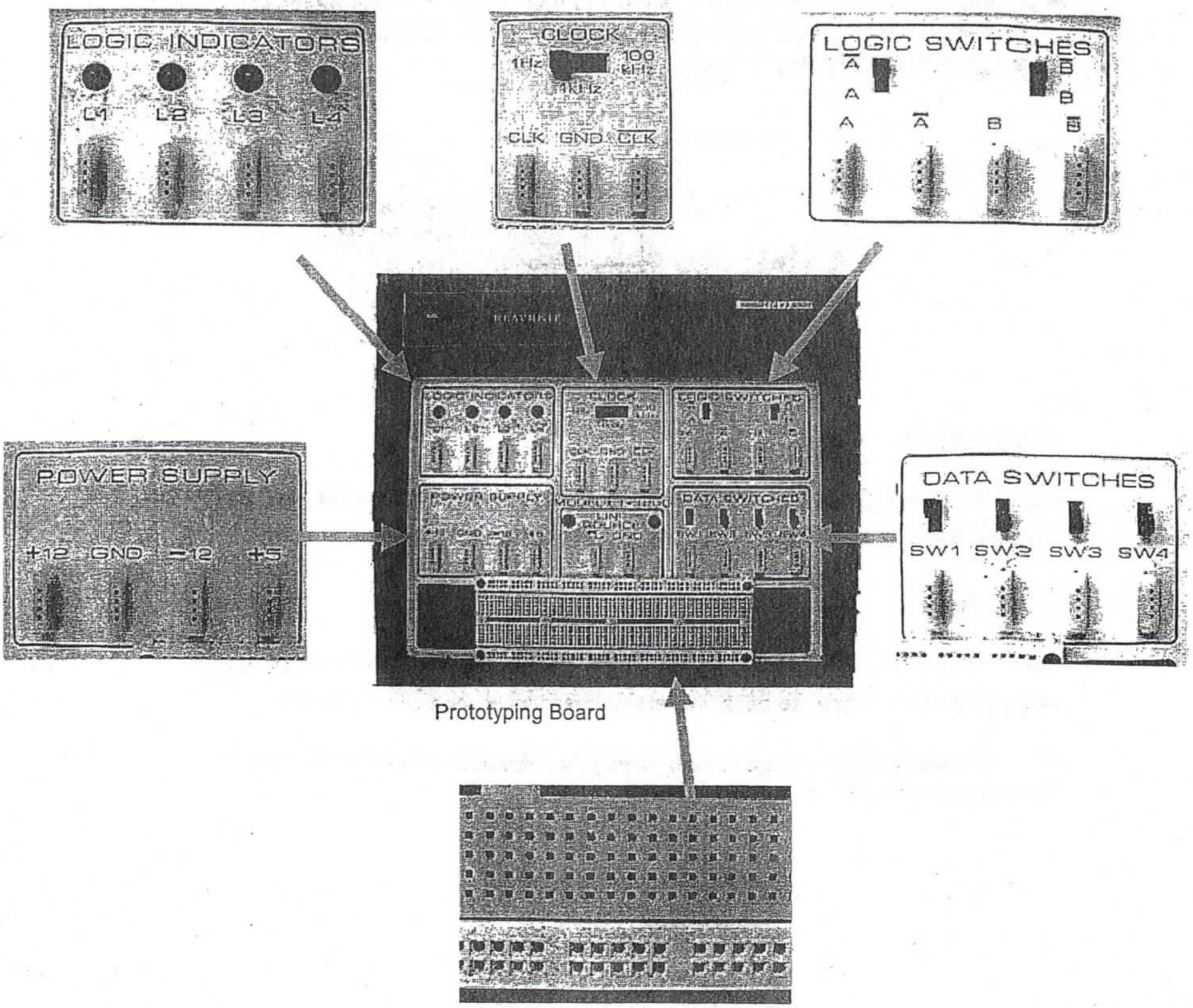
7. <u>Learn how to use the prototyping board</u> [no response needed for lab report]

“ *<u>The prototyping board</u>*

Prototyping boards are rows of connectors wired together behind a plastic face.

Things you can stick into the little holes of prototyping boards include:

wire (22 gauge solid-core is typical)
resistor leads (1/4 or 1/8 Watt is typical)
leads for transistors, capacitors, diodes, etc.
ICs (the hole spacing is made for DIP [dual-inline package]chips)

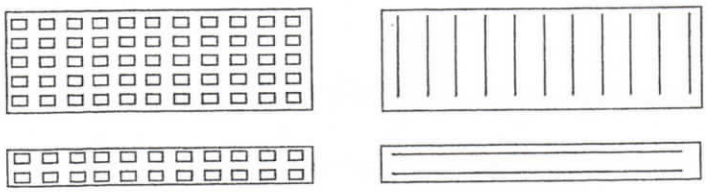


Prototyping Board

☞ Put an alligator clip connector on each test lead of the multimeter.

☞ Insert two wires into various holes in the prototyping board. Checking for continuity, convince yourself that the board is connected as shown below.

what it looks like from outside   connections under the surface



8. Voltage Divider

“ A voltage divider reduces a voltage to a desired level.

☞ Measure the values of the resistors shown in Figure 1-8, then wire up the circuit. Use the prototyping board. Use the 5-Volt power supply built into the prototyping board to supply V_{in}.

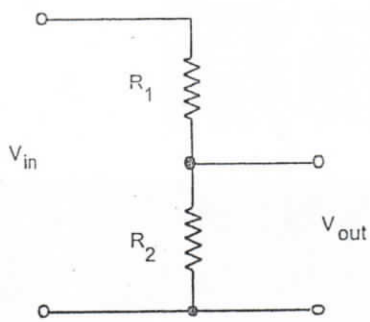


Figure 1-8
Voltage Divider

(a) without load

☞ ✍ Measure V_{in} and V_{out} for $R1$ =3.2 k and $R2$ = 1.6 k. Then repeat, with $R1$ = 1.6 k and $R2$ = 3.2 k. Compare V_{out} / V_{in} to the predicted values.

(b) with load

☞ ✍ Connect a 1 kΩ load resistor across the output. Determine how much V_{out} is reduced (loaded). Using the rules for parallel resistances, compare to theory.

“ Note that while a voltage divider is easy to build, it is a poor voltage source. Its output is not “stiff”. It is easily “loaded”.