University of Jordan
School of Engineering
Electrical Engineering Department

EE 204
Electrical Engineering Lab

EXPERIMENT 1

INTRODUCTION OF MEASUREMENT DEVICES

Prepared by: Prof. Mohammed Hawa

OBJECTIVE

When you have completed this exercise, you will be familiar with the main devices and equipment you will use in this Lab, including: multimeters, power supplies and breadboards. You also will know about the different resistor types, and learn the resistor color code. You will also test different DC circuit analysis techniques, including parallel/series combinations, voltage/current division.

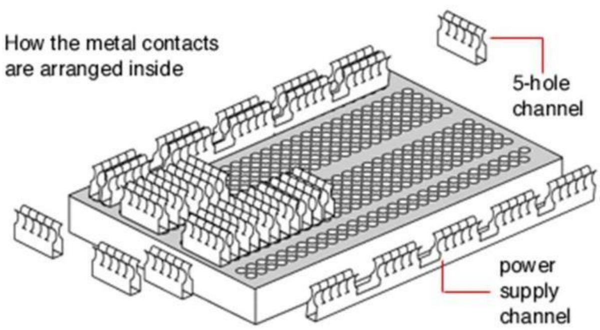
DISCUSSION

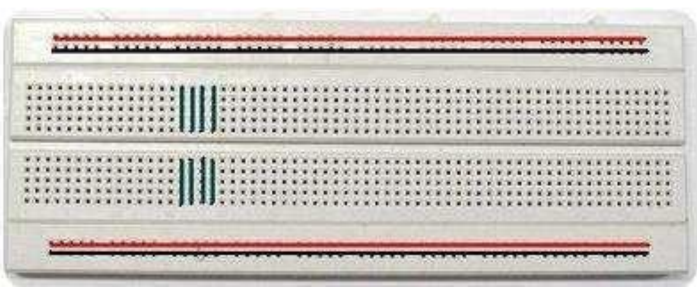
Breadboard

A breadboard (shown below) is usually used to build a prototype of an electrical circuit, without the need for soldering, usually for quick temporary testing.

A breadboard consists of a perforated block of plastic with numerous metal spring clips under the perforations. Such metal clips are laid out in groups of fives as shown below. Discrete electrical components (such as capacitors, resistors, inductors, etc) can be inserted into the free holes to complete the circuit topology. The holes are made so that they will hold the component in place. A typical breadboard will also have metallic strips, known as bus strips, down both sides to carry the power rails.

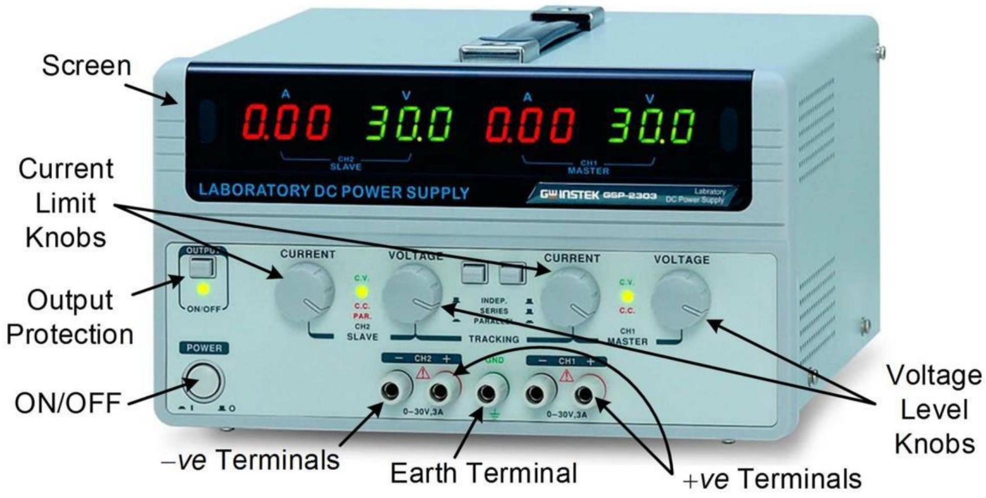
However, due to large stray capacitance between contact points, breadboards are usually limited to relatively low frequencies, usually less than 10 MHz, depending on the nature of the circuit.





DC Power Supply
A DC power supply is used to generate a constant DC voltage (just like a battery). Recall that DC is short for *direct current*. In the Lab, the voltage produced by the DC power supply is controlled by the knobs labeled "**Voltage**" as shown below.

Both "voltage level" and "current limit" settings can be adjusted by two adjacent knobs. Sometimes there is a "Coarse" knob used for quick changes in values (i.e., high number of steps), and a "Fine" knob that is used for more accurate values with smaller steps.



When connecting the DC power supply to the breadboard use suitable wires to connect both the "+ terminal" (high voltage terminal) and the "– terminal" (low voltage terminal) to your circuit. "Real GND" is for earth grounding and it is connected to the device chassis. In this Lab we will not use the earth grounding terminal.

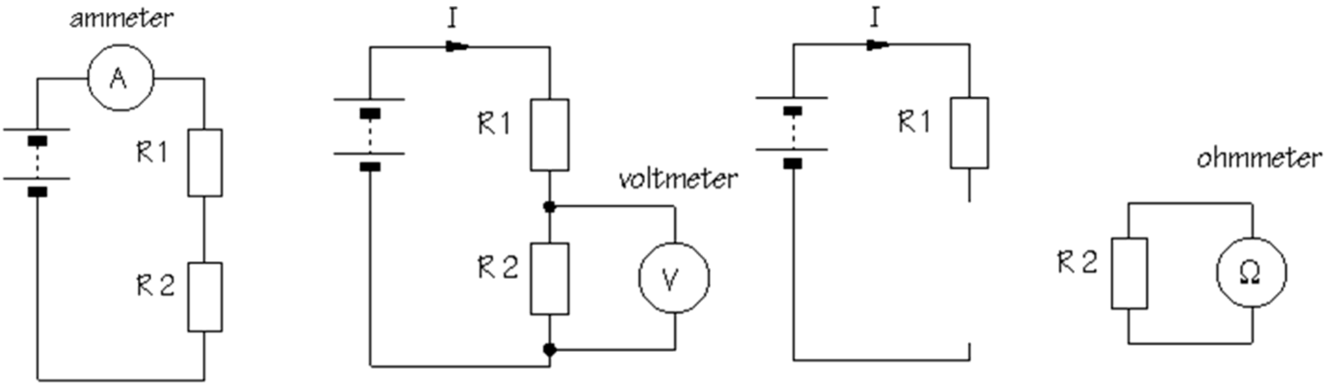
Multimeter
A multimeter is a measuring device that can perform multiple functions. For example, it can act as a Voltmeter, Ammeter, Ohmmeter, etc. The following is a description of some of these functions:

1) **Ammeter**: Measures DC or AC current (in units of µA, mA and A). You must connect the Ammeter in series with the element in the circuit through which you want to measure the current. The ammeter has a **very small internal resistance** so it does not disturb the current it is trying to measure. Due to this fact, however, if it is connected by accident in parallel with the circuit element, a large amount of current will flow through it, thus damaging it. That is why ammeters are usually protected by a current limiting fuse.

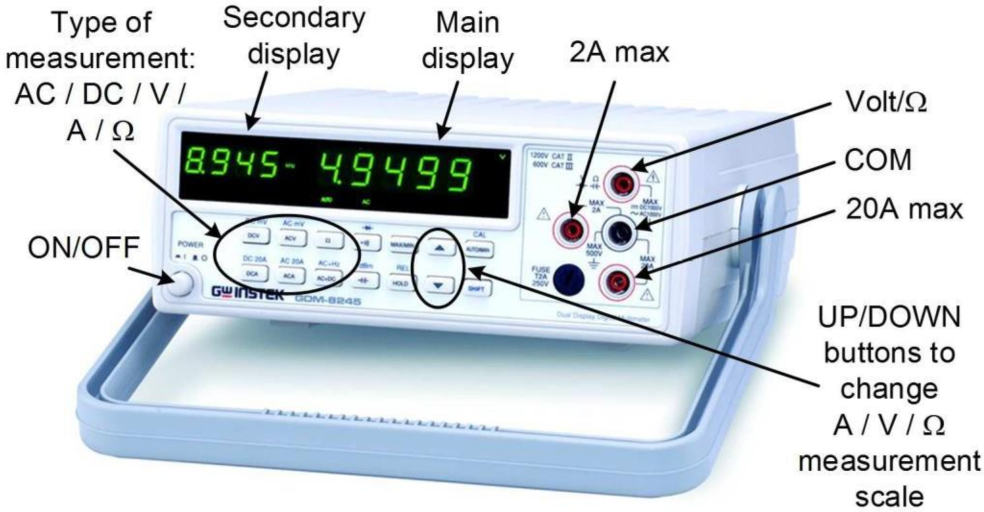
2) **Voltmeter**: Measures DC or AC voltage (in units of mV and V). You must connect the Voltmeter in parallel with the element in the circuit across which you want to measure the voltage. To avoid drawing extra current, thus disturbing the voltage it is trying to measure, **the internal impedance of the voltmeter is very large**.

3) **Ohmmeter**: Measures resistance (in units of Ω and KΩ). You must connect the Ohmmeter in parallel with the element in the circuit for which you want to measure the resistance. An

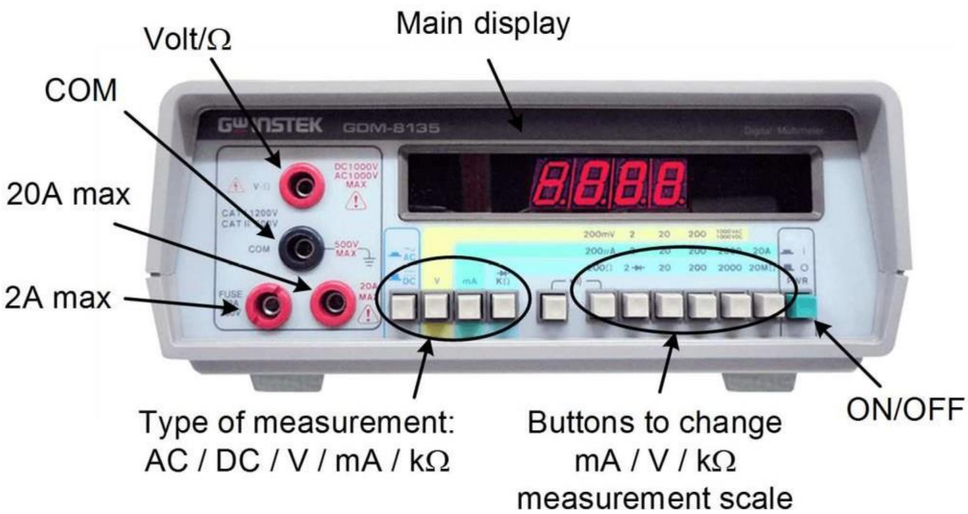
Ohmmeter usually employs an internal battery (voltage source) across the resistance you are trying to measure. The battery drives a current into the resistor, which is measured by a current sensor. The value of the resistance is the calculated from Ohm's law by dividing the battery voltage by the current. Hence, be careful *not* to connect any external power supply to the resistor you are trying to measure because an extra current can damage the ohmmeter and can also affect the overall Thevenin resistance the ohmmeter measures.



The Figure below shows two types of digital multimeters (DMM) available the Lab: a *portable* multimeter and a *bench-type* multimeter. A brief description of the main buttons is also provided.



- **DCV**: Set to Voltmeter for DC (*average*) value measurements.
- **ACV**: Set to Voltmeter for AC (*rms*) value measurements.
- **DCA**: Set to Ammeter for DC (*average*) value measurements.
- **ACA**: Set to Ammeter for AC (*rms*) value measurements.
- **Ω**: Set to Ohmmeter.
- **V/Ω**: Positive terminal for voltage or resistance measurements.
- **2A max**: Positive terminal for low current measurements with maximum value of 2A.
- **20A max**: Positive terminal for high current measurements with maximum value of 20A.
- **COM**: Negative terminal that is common for all types of measurements.
- **Main display**: Shows the current measurement value (units are also shown on the screen).



- **DC**: Choose to perform DC (*average*) value measurements.
- **AC**: Choose to perform AC (*rms*) value measurements.
- **V**: Set to Voltmeter (in **Volts** if the range button did not indicate another unit).
- **mA**: Set to Ammeter (in **milli Amperes** if range button did not indicate another unit).
- **kΩ**: Set to Ohmmeter (in **kilo Ohms** if the range button did not indicate another unit).
- **V/Ω**: Positive terminal for voltage or resistance measurements.

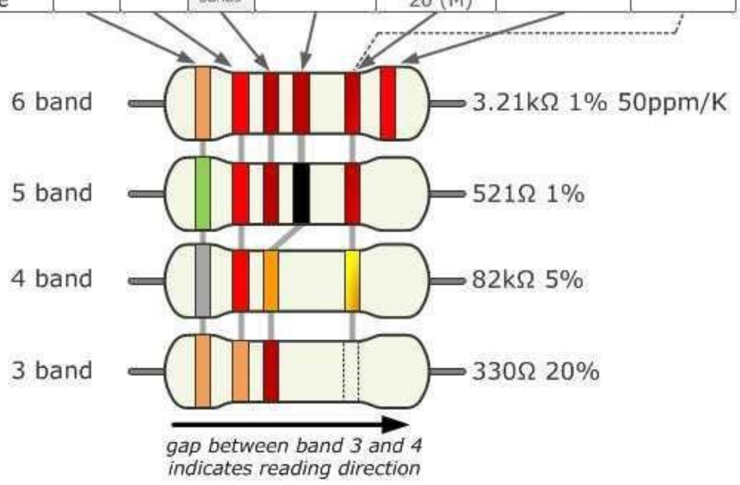
- **2A max**: Positive terminal for low current measurements with maximum value of 2A.
- **20A max**: Positive terminal for high current measurements with maximum value of 20A.
- **COM**: Negative terminal that is common for all types of measurements.
- **Scale**: Several range buttons available. For example, if **20V** range was selected, the voltmeter reading will be as accurate as possible if the measured value is between 2V and 20V. If the value is less than 2V a less accurate reading will appear on the multimeter screen, and if the value is higher than 20V an overload reading will appear on the screen.

Resistor

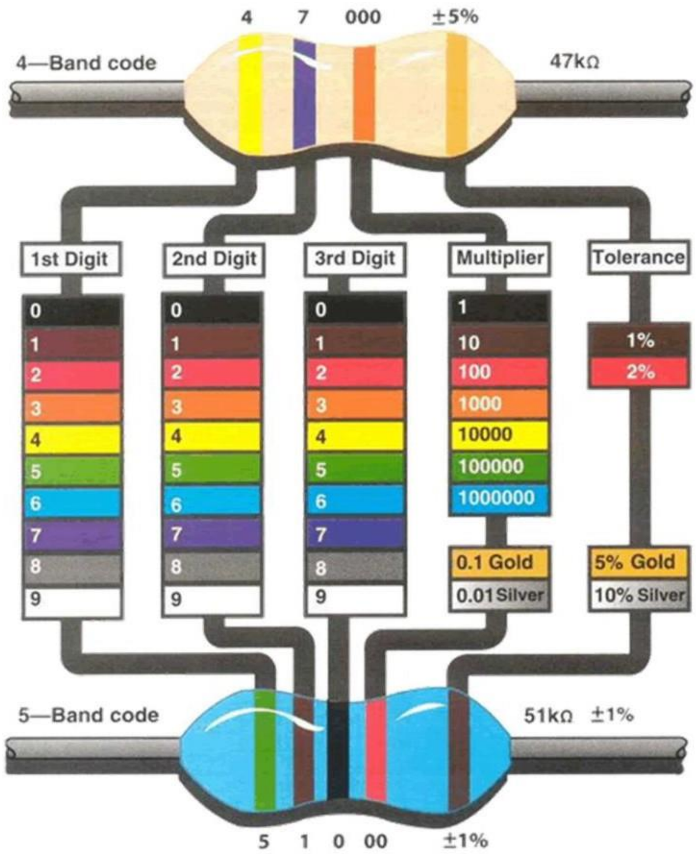
The resistor is a fundamental electrical component. It resists the flow of electric current: The greater the resistance, the greater the resistance to current. Resistance is measured in Ohms. Like all components, resistors cannot be manufactured to perfection. That is, there will always be some variance of the true value of the component when compared to its nameplate or *nominal* value.

General purpose resistors usually use a color code to indicate their nominal value. The resistor color code typically uses 4 color bands (and sometimes 5 or 6 color bands). The first two bands indicate the significant figures while the third band indicates the power of ten applied (i.e. the number of zeroes to add) as shown below. The fourth band indicates the tolerance.

Color	Signficant figures			Multiply	Tolerance (%)	Temp. Coeff. (ppm/K)	Fail Rate (%)
black	0	0	0	x 1		250 (U)	
brown	1	1	1	x 10	1 (F)	100 (S)	1
red	2	2	2	x 100	2 (G)	50 (R)	0.1
orange	3	3	3	x 1K		15 (P)	0.01
yellow	4	4	4	x 10K		25 (Q)	0.001
green	5	5	5	x 100K	0.5 (D)	20 (Z)	
blue	6	6	6	x 1M	0.25 (C)	10 (Z)	
violet	7	7	7	x 10M	0.1 (B)	5 (M)	
grey	8	8	8	x 100M	0.05 (A)	1(K)	
white	9	9	9	x 1G			
gold			3th digit only for 5 and 6 bands	x 0.1	5 (J)		
silver				x 0.01	10 (K)		
none					20 (M)		



The following figure shows two examples: The first is a 4-band resistor that has a nominal value of 470 kΩ and ±5% tolerance (yellow-violet-yellow-gold). The second example is a 5-band resistor with a nominal value of 51 kΩ and ±1% tolerance (green-brown-black-red- brown).



It is important to note that the physical size of the resistor indicates its *power dissipation* rating, not its ohmic value. Power rating is the amount of power the resistor can dissipate as heat without itself overheating and burning up. Typical power ratings for modern resistors in most applications are 1/8 watt, 1/4 watt and 1/2 watt. High-power applications can require high-power resistors of 1, 2, 5, or 10 watts, or even higher. A general rule of thumb is to select a resistor whose power rating is at least double the amount of power it will be expected to handle.

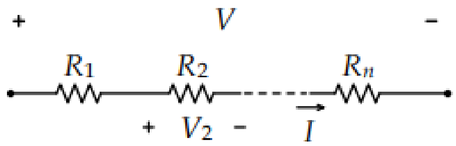
Measurement of resistance with a digital multimeter (DMM) is a very straight forward process. Simply set the DMM to the Ohmmeter function and connect the DMM in parallel with the resistance (after disconnecting it from any other circuit).

Series and Parallel Resistors

A series connection happens when all resistors are arranged in daisy-chain fashion. In this case, the current that flows in all components is exactly the same and may be found by dividing the total voltage source by the total resistance. The voltage drop across any resistor may then be found by multiplying that current by the resistor value (Ohm's law). Consequently, the voltage drops in a series circuit are directly proportional to the resistance. An alternate technique to find the voltage is the voltage divider rule. This states that the voltage across any resistor (or combination of resistors) is equal to the total voltage source times the ratio of the resistance of interest to the total resistance.

$$R_{\text{series}} = R_1 + R_2 + \cdots + R_n$$

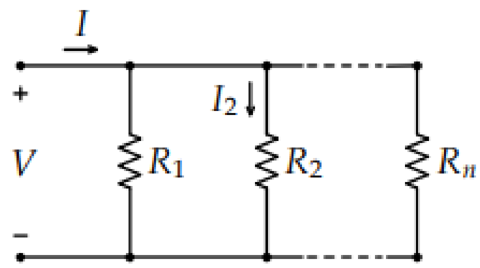
$$V_2 = \frac{R_2}{R_{\text{series}}} \times V = \frac{R_2}{R_1 + R_2 + \cdots + R_n} \times V$$



A parallel circuit occurs when all components share two common nodes. The voltage is the same across all components. The total supplied current may be found by dividing the voltage source by the equivalent parallel resistance. It may also be found by summing the currents in all of the branches. The current through any resistor branch may be found by dividing the source voltage by the resistor value. Consequently, the currents in a parallel circuit are inversely proportional to the associated resistances. An alternate technique to find a particular current is the current divider rule. For a two resistor circuit this states that the current through one resistor is equal to the total current times the ratio of the other resistor to the total resistance.

$$R_{\text{parallel}} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}}$$

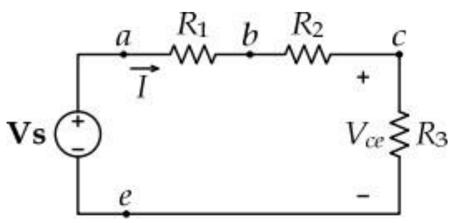
$$I_2 = \frac{1/R_2}{1/R_{\text{parallel}}} \times I = \frac{\frac{1}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}} \times I$$



PROCEDURE A - VOLTAGE AND CURRENT DIVISION

In this PROCEDURE section, you will investigate the voltage and current division rules in series and parallel circuits.

1. Construct the circuit shown below. Assume that R_1 = 2200Ω, R_2 = 1200Ω, and R_3 =820Ω.



2. Set the DC supply output voltage controls to **12 Volts**.

3. Use theoretical analysis to determine the expected current I. What equation did you use?

4. Using the theoretical current, apply Ohm's law to determine the expected voltage drops across R_1, R_2, and R_3. What is the voltage divider equation for the voltage across R_1?

---

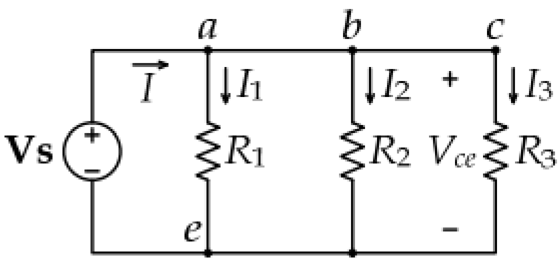
5. Use the DMM to measure the current I. Remember that an ammeter must be connected in series with an element to measure the current in that element. Set the ammeter to read DC current, and measure the current I at points a, b and c (pay attention to polarity). Record these values in Table 1.

6. Use the DMM to measure the voltages V_{ab}, V_{bc}, V_{ce} and V_s and record them in Table 2 in the report. Remember that a voltmeter must be connected in parallel with an element to measure the voltage across that element. Of course, you should set the voltmeter to read DC voltage, and pay attention to polarity.

7. Remove R2 from the circuit, connect it in any place on the breadboard and use the DMM to measure its resistance value. Remember that an ohmmeter must be connected in parallel with an element to measure its resistance.

---

8. Construct the circuit shown below. Assume that $R_1 = 2200\Omega$, $R_2 = 1200\Omega$, and $R_3 = 820\Omega$.



9. Set the DC supply output voltage **to 12 Volts**.

10. Use theoretical analysis to determine the expected currents I_1, I_2, I_3 and I. What is the current divider equation for the current in resistor R_1?

---

11. Use the DMM to measure the currents I_1, I_2, I_3 and I. Record these values in Table 3 in the report.

**** End ****