BME 211 Circuit Analysis Laboratory

Week#1 Resistors in DC Circuits, Measurement of Voltage and Current, Ohm’s Law

Objective

The objective of this experiment is to become familiar with the concept of resistance, to learn resistor types and color coding, to measure DC voltage and current using digitial multimeters and to examine Ohm’s Law using different circuits.

Background

1. Resistors

The flow of charge through any material encounters an opposing force similar in many respects to mechanical friction. This opposition, due to the collisions between electrons and between electrons and other atoms in the material, which converts electrical energy into another form of energy such as heat, is called the **resistance** of the material. The circuit element used to model this behaviour is the **resistor** [1].

The unit of measurement of resistance is the ohm (Ω, the capital Greek letter omega). The circuit symbol and notation for resistance is given in Figure 1.1.

Figure 1.1 Resistance symbol and notation

Types of resistors

Resistors are made in many forms, but all belong in either of two groups: fixed or variable.

a) Fixed Resistors

Fixed resistors are classified into wire-wound resistors, composition resistors, and metal-film resistors:

Wire-Wound Resistors

Wire-wound resistors are made by winding wire of nickel-chromium alloy on a ceramic tube covering with a vitreous coating. The spiral winding has inductive and capacitive characteristics that make it suitable for operating above 50kHz. The frequency limit can be raised by noninductive winding so that the magnetic field produced by the two parts of the winding is cancelled [2].

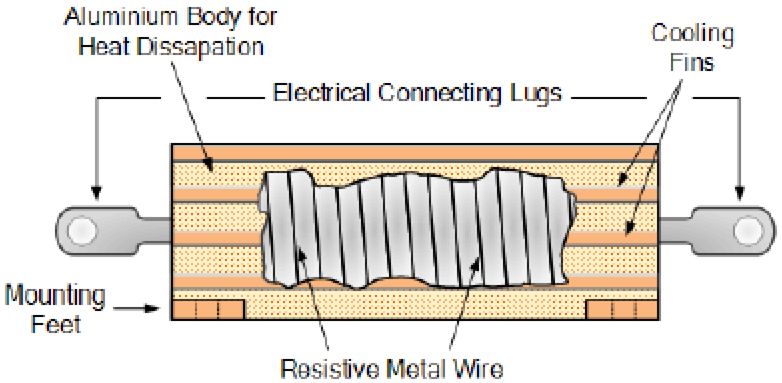


Figure 1.2 Wire-Wound Resistor [2]

Composition Resistors

Composition resistors are composed of carbon particles mixed with binder. This mixture is molded into a cylindirical shape and hardened by baking. Leads are attached axially to each end, and the assembly is encapsuled in a protective encapsulation coating. Color

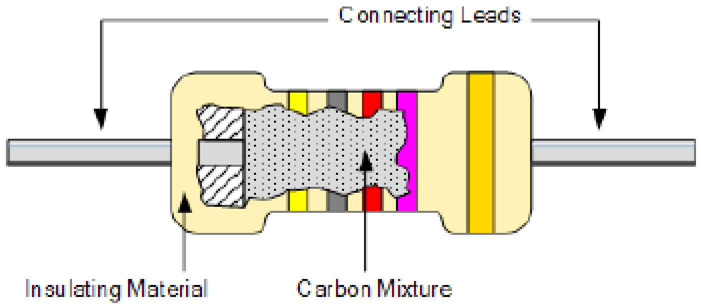


Figure 1.3 Composition Resistor [2]

bands on the outer surface indicate the resistance value and tolerance. Composition resistors are economical and exhibit low noise levels for resistance above 1MΩ. Composition resistors are usually rated for temperatures in the neighborhood of 70^0C for power ranging from 1/8 to 2W. Composition resistors have end-to-end shunted capacitance that may be noticed at frequencies in the neighborhood of 100 kHz, especially for resistance values above 0.3 MΩ [2].

Metal-Film Resistors

Metal film resistors are commonly made of nichrome, tin-oxide or tantalum nitride, either hermetically sealed or using molded-phenolic cases. Metal-film resistors are not as stable as the wire-wound resistors [2].

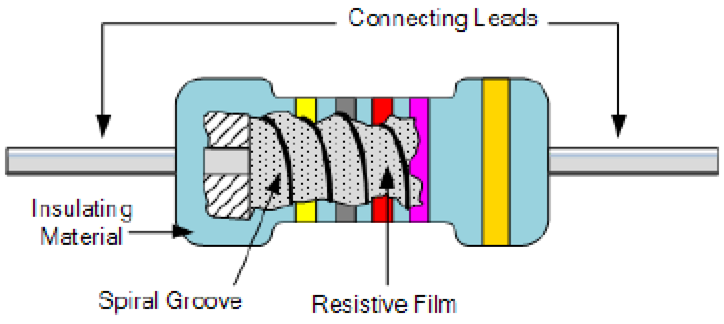
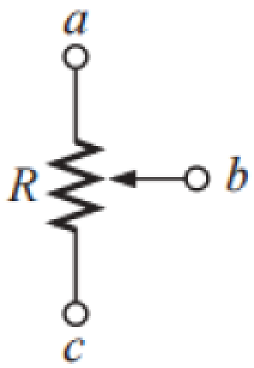


Figure 1.4 Metal Film Resistor [2]

b) Variable Resistors

Variable resistors, as the name implies, have a terminal resistance that can be varied by turning a dial, knob, screw, or whatever seems appropriate for the application. They can have two or three terminals, but most have three terminals. Device which is used for controlling potential levels is called as potentiometer. The symbol and the basic construction of potantiometer is shown in Figure 1.5 [1].



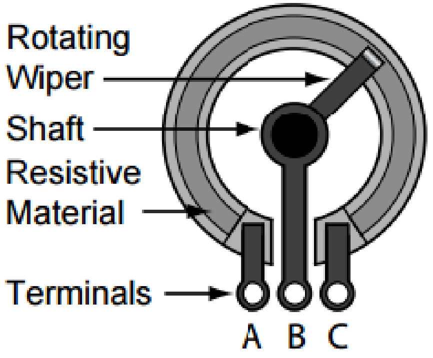


Figure 1.5 a) Symbol of potantiometer b) Construction of potantiometer [1]

- The resistance between the outside terminals a and c is always fixed at the full rated value of the potentiometer, regardless of the position of the wiper arm b.
- The resistance between the wiper arm and either outside terminal can be varied from a minimum of 0 Ω to a maximum value equal to the full rated value of the potentiometer.

- The sum of the resistances between the wiper arm and each outside terminal will equal the full rated resistance of the potentiometer. Terminal resistance of a potentiometer is demonstrated by Figure 4 [1].

$$R_{ac} = R_{ab} + R_{bc} \qquad \text{(Eq. 1.1)}$$

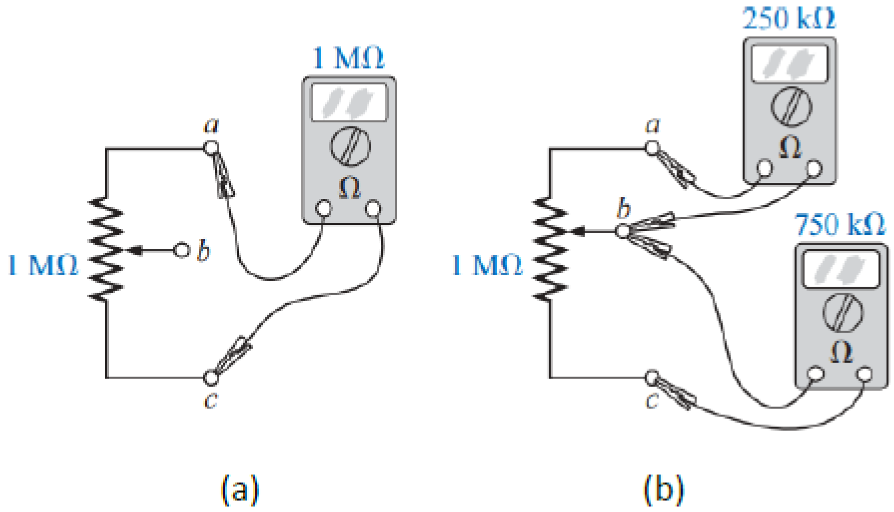


Figure 1.6 Terminal resistance of a potentiometer (a) between outside terminals; (b) among all three terminals [1].

Color Coding and Standart Resistor Values

A wide variety of resistors, fixed or variable, are large enough to have their resistance in ohms printed on the casing. Some, however, are too small to have numbers printed on them, so a system of color coding is used. For the fixed molded composition resistor, four or five color bands are printed on one end of the outer casing, as shown in Figure 1.5 [1]. Each color has the numerical value indicated in Table 1.

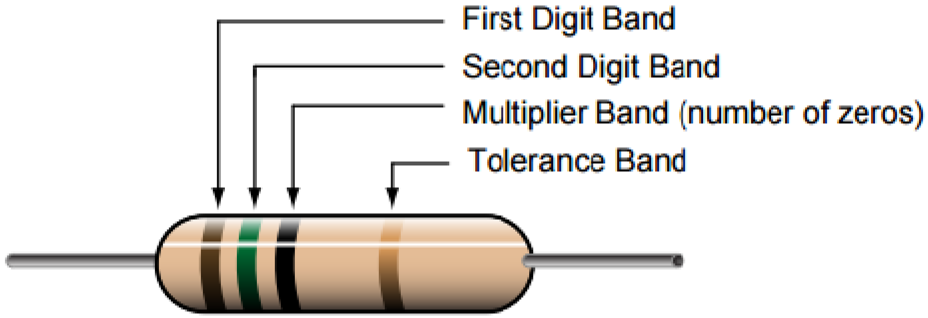


Figure 1.7 Color bands of fixed resistor

Table 1.1 Color coding for resistors

Color	First digit band	Second digit band	Multiplier band	Tolerance
Black	0	0	$10^0 = 1$	
Brown	1	1	$10^1 = 10$	1 %
Red	2	2	$10^2 = 100$	2 %
Orange	3	3	$10^3 = 1000$	3 %
Yellow	4	4	$10^4 = 10000$	4 %
Green	5	5	$10^5 = 100000$	
Blue	6	6	$10^6 = 1000000$	
Violet	7	7	$10^7 = 10000000$	
Gray	8	8	$10^8 = 100000000$	
White	9	9	$10^9 = 1000000000$	
Gold				5 %
Silver				10 %
None				20 %

For example, the nominal value for a resistor with Brown – Black – Red – Silver bands is calculated as

Brown	Black	Red	Value
1	0	x $10^2 = 100$	10 x 100 = 1000Ω = 1kΩ

and the tolerance for the silver band is 10%. Therefore, the value of this resistor is 1kΩ ± 10%. Ten percent of 1kΩ is 100Ω which indicates that the value of the resistor is in the range 900Ω to 1100Ω (or 1.1kΩ).

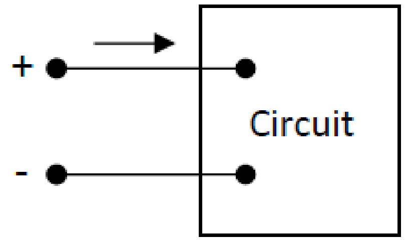
2. Measurement of Voltage and Current

Voltage is the potential difference between two points, moving the electrons in a conductor to create electrical current. It is measured in volts (V).

Current is described as the time rate of change of charge, measured in amperes (A). A **direct current** (DC) is a current that remains constant with time. An **alternating current** (AC) is a current that varies with time.

The assignment of the reference polarity for voltage and current are entirely arbitrary. However, once you have assigned the references, you must write all subsequent equations to agree with the chosen references. The most widely used sign convention is **passive sign convention,** which we use throughout our experiments. The passive sign convention can be stated as follows:

> *Whenever the reference direction for the current in an element is in the direction of the reference voltage drop across the element (as in Figure), use a positive sign in any expression that relates the voltage to the current. Otherwise, use negative sign [2].*



Multimeters are connected to the circuit in parallel to measure the voltage, Figure 1.8 (a), and in series to measure the current, Figure 1.8 (b). It is very important to control the connections of probes and and the settings of the multimeter before starting the measurement to make correct measurements and to avoid fuse burning.

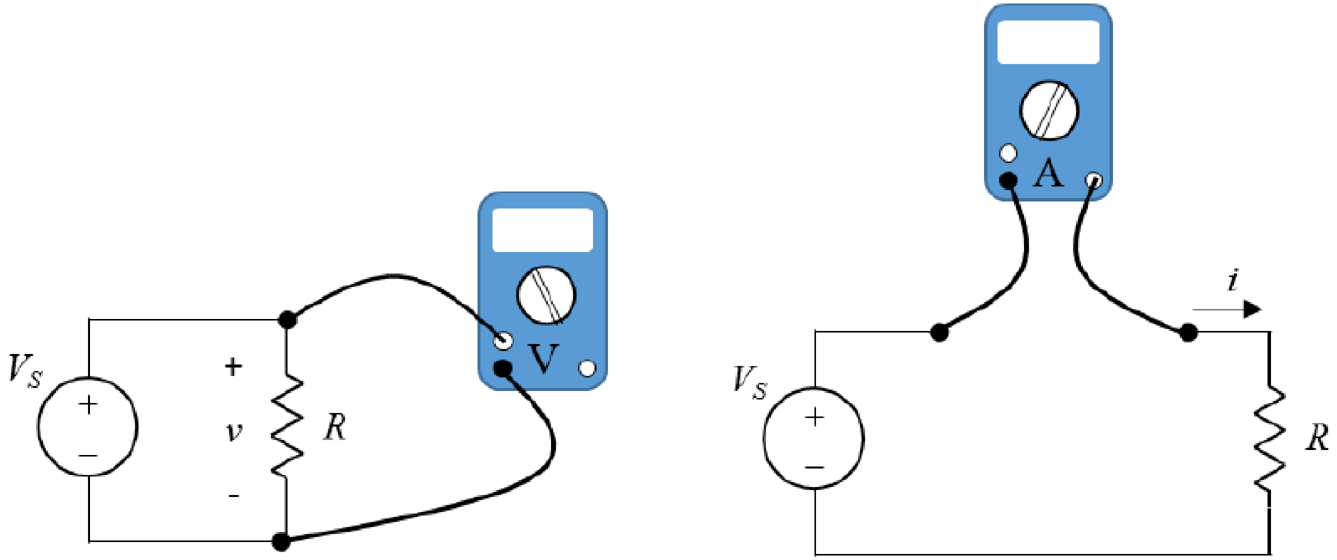
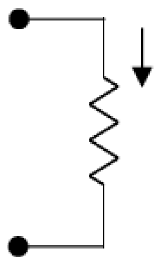


Figure 1.8 Multimeter connections

WARNING: MAKE SURE THAT YOU MAKE NECESSARY CONNECTION CHANGES AND ADJUSTMENTS ON THE MULTIMETER BEFORE CARRYING OUT CURRENT MEASUREMENTS!

3. Ohm's Law

Ohm's law states that the voltage (v) across a resistor is directly proportional to the current (i) flowing through the resistor and the constant of proportionality for a resistor is the resistance, R.



$$v = i R \qquad \text{(Eq. 1.2)}$$

From Eq 1.1, the resistance value in terms of voltage and current is given as

$$R = v / i \qquad \text{(Eq. 1.3)}$$

Preliminary Work

1. Find magnitude ranges for resistors with the following color bands:
    a. Green – Blue – Yellow – Gold
    b. Red – Red – Red – Silver
    c. Brown – Black - Brown
2. Calculate the desired voltage or current values for the following cases using Ohm’s Law:
    a. Calculate the current through the 1.5 kΩ resistor, if the voltage drop on the resistor is 15 V.
    b. Calculate the current through the 270 Ω, 750 Ω, 6.8k Ω, 100 kΩ and 750 kΩ resistors respectively, if the voltage drop on each of them is 15 V. How does the current change with increasing resistance if the voltage remains constant?
    c. Calculate the current through the 6.8 kΩ resistor, if the voltage drops on the resistor are 5 V, 10 V, 15 V, 20 V and 25 V, respectively. How does the current change with increasing voltage if the resistance remains contant?
    d. If a soldering iron draws 0.65 A at 120 V, what is its resistance?
    e. The internal resistance of a dc generator is 0.5 Ω. Determine the loss in terminal voltage across this internal resistance if the current is 12 A.

Procedure

The laboratory will start with a tutorial on the use of DC voltage supply and desktop multimeter.

Before starting, read the laboratory safety instructions on Page 4.

While using these devices;

- *Always turn off the supply when you are constructing the circuit and turn it on after checking your connections;*
- *Always check the probe connections on the multimeter to make sure that it is suitable for current/voltage measurement and correct mode is selected on the device.*

1. Find R1 = 27 Ω , R2 = 270 Ω , R3 = 390 Ω , R4 = 6.8 kΩ, R5 = 1.2 MΩ in your component box using color coding. Measure the resistance of these resistors using a multimeter and tabulate the results. Compare the measured values with the color coding calculations and comment on the results if there are any discrepancies.
2. In circuit analysis experiments, finding the correct results depends on a lot of different factors. One of those factors is adjusting the power supply correctly. Adjust the output of the voltage supply to 12V and check the output using a multimeter. Are the values on the supply and multimeter the same?
3. Another important component that must be checked before the experiments is the cables that are used. Jumper cables are used to connect the components of circuit to each other and if they are broken, the circuit is not completed. Jumper cables must be checked using multimeter in short circuit test mode. Test all the cables in your component box.
4. For the circuit in Figure 1.9,

   a. Measure the current for R = 1.5 kΩ and V_{in} = 15 V and compare the result with Preliminary Work 2(a).

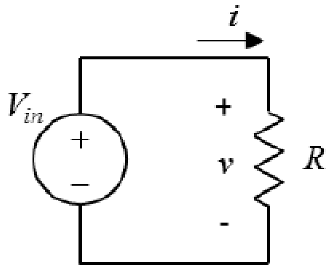


Figure 1.9

MAKE SURE THAT YOU CHANGE THE MULTIMETER PROBES FOR CURRENT MEASUREMENT AND SELECT THE APPROPRIATE MODE ON THE DEVICE!!!

b. Measure the current values for R = 270 Ω, 750 Ω, 6.8k Ω, 100 kΩ, 750 kΩ and V_{in} = 15 V and compare your results with the Preliminary Work 2(b).

c. Measure the current values for R = 6.8 kΩ and V_{in} = 5 V, 10 V, 15 V, 20 V and 25 V and compare your results with Preliminary Work 2(c).

5. Using the 10 kΩ potantiometer in your component box:

   a. Measure and record the resistance between the two outer terminals of the potantiometer. Does the reading change when you adjust the rotating wiper?

   b. Adjust the rotating wiper of the potantiometer about midway between the two extremes. Measure and record the resistance between the central and one of the outer terminals of the potantiometer. Does the reading change when you adjust the rotating wiper?

   c. Set the rotating wiper somewhere in between extreme values and record the resistance values between each outer terminal and central terminal. Calculate the sum of two values and compare it with your measurement in part (a). Comment on your results.

List of Components

Equipments: DC Voltage Supply, Digital Multimeter

Resistors: 27 Ω, 270 Ω, 390 Ω, 750 Ω, 1.5 kΩ, 6.8kΩ, 100 kΩ, 750 kΩ, 1.2 MΩ, 10 KΩ potantiometer

References

[1] Boylestad, Introductory Circuit Analysis (Tenth Edition)

[2] James W. Nilsson, Susan A. Riedel (Sixth Edition)

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Objective

Results

1. Comparison of nominal and measured resistor values:

Nominal Resistor Value	Percent(%) Tolerance	Minimum Value	Maximum Value	Measured Value

Comments:

2. $V_{supplied}$ (adjusted) = ... $V_{supplied}$ (measured) = ...

4. Comparison of calculated and measured current values:

   a. R = 1.5kΩ , V_{in} = 15V, $I_{measured}$ = ... , $I_{calculated}$ = ...

b. V_{in} = 15V

R	750Ω	6.8kΩ	100kΩ	750kΩ
$I_{calculated}$				
$I_{measured}$				

c. R = 6.8 kΩ

V	5V	10V	15V	20V	25V
$I_{calculated}$					
$I_{measured}$					

Comments:

5. a. R_{Pot} (outer terminals) = ...

b. R_{Pot} (center - outer) = ...

Comment:

c. $R_{Pot,1}$ (center – outer 1) = ... $R_{Pot,2}$ (center – outer 2) = ...

$R_{Pot,Total}$ = ...

Comment: