# University of Jordan
# School of Engineering
# Electrical Engineering Department

# EE 219
# Electrical Circuits Lab

# EXPERIMENT 2
# RESISTORS AND DC CIRCUITS

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# EXPERIMENT 2
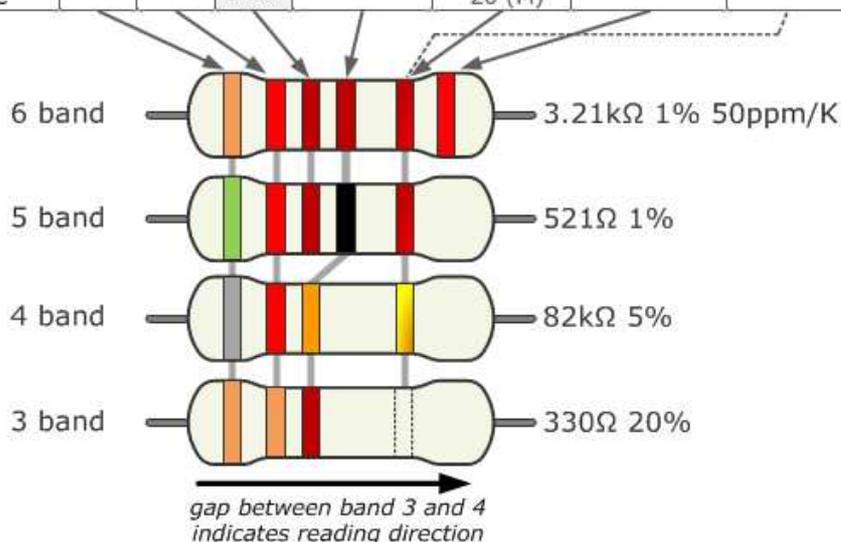# RESISTORS AND DC CIRCUITS

## OBJECTIVE

When you have completed this exercise, you 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, and nodal/mesh analysis.

## DISCUSSION

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) | | |



6 band — 3.21kΩ 1% 50ppm/K

5 band — 521Ω 1%

4 band — 82kΩ 5%

3 band — 330Ω 20%

*gap between band 3 and 4 indicates reading direction*

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).
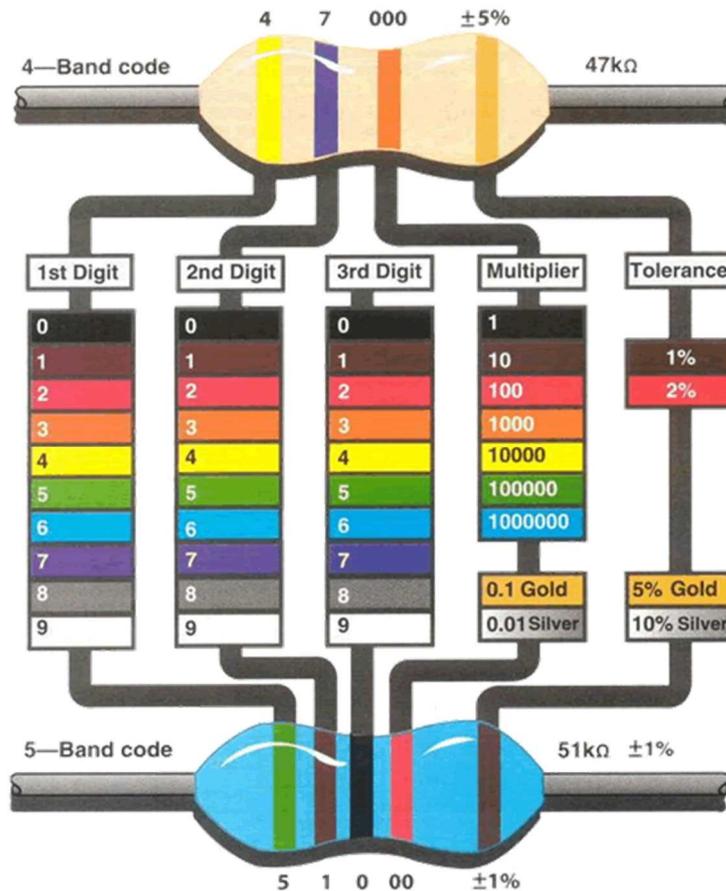


It is important to note that the physical size of the resistor indicates its *power dissipation* rating, not its ohmic value. Power rating is the amount of power the resistor can dissipate as heat without itself overheating and burning up. Typical power ratings for modern resistors in most applications 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.
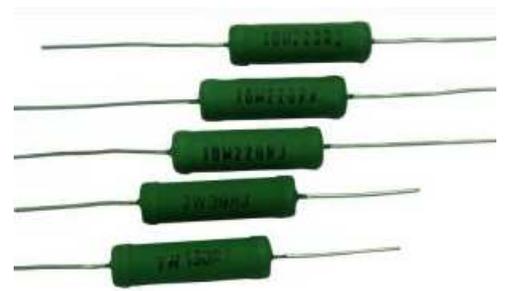
Resistors can be built in different shapes and from different materials. Some of the most common are shown below:
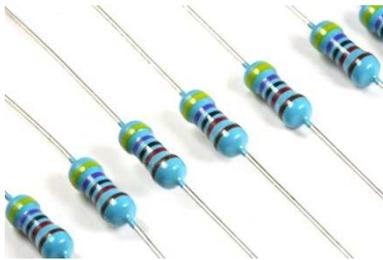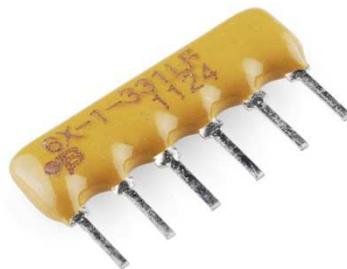


Carbon film resistors
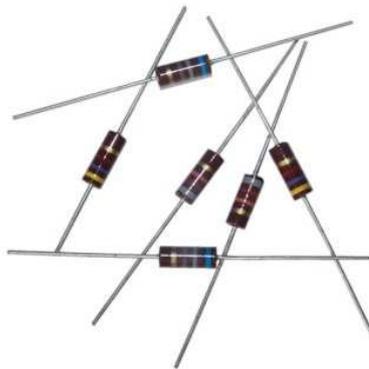


Carbon composition resistors



Wire-wound resistors



Metal film resistors



Resistor network (SIL)



SMT (surface mount technology)

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.

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.

**Nodal and Mesh Analysis**

Electric circuits may be analyzed using a node voltage technique or a mesh current technique. In nodal analysis, all circuit nodes are first identified, a node being a point where various branches combine. A reference node, usually ground, is included. Kirchhoff's Current Law (KCL) is then applied to each node. KCL states that the sum of currents entering a node must equal the sum of the currents exiting that node. Consequently a set of simultaneous equations are created with an unknown voltage for each node with the exception of the reference. Once the node voltages are determined, various branch currents and component voltages may be derived.

In mesh analysis, a minimum number of small loops are identified in the circuit. The loop currents are referred to as mesh currents as each current interlocks or meshes with the surrounding loop currents. Kirchhoff's Voltage Law (KVL) is then applied to each loop. KVL states that the sum of voltages around a loop must equal zero. Hence, a set of simultaneous equations is created, which can be solved for unknown mesh currents. Once the mesh currents are determined, various branch currents and component voltages may be derived.

## PROCEDURE A – RESISTORS

1. You will be provided with three resistors $R_1$, $R_2$, and $R_3$ in the Lab. Using their color coding, read their nominal values and tolerances and record that information in Table 1.

**Table 1**

|  | $R_1$ | $R_2$ | $R_3$ | $R_{series}$ | $R_{parallel}$ |
|---|---|---|---|---|---|
| **Nominal Value** | 1600Ω | 1200Ω | 1000Ω |  |  |
| **Color Code** |  |  |  | ///// | ///// |
| **Tolerance (%)** |  |  |  | ///// | ///// |
| **Measured Value** |  |  |  |  |  |
| **Deviation (%)** |  |  |  |  |  |

2. Use an ohmmeter to measure the actual value for each of the three resistances. Record that in Table 1. Also record the deviation between the nominal value and the measured value as a percentage, calculated as follows:

$$Deviation = \frac{Measured - Nominal}{Nominal} \times 100\%$$

3. Does the deviation you calculated reside within the tolerance declared by the color code?

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

4. Connect the three resistors $R_1$, $R_2$ and $R_3$ in series on the breadboard, and measure the equivalent resistance $R_{series}$. Record the nominal, measured and deviation values in Table 1.

5. Now connect the three resistors in parallel on the breadboard, and measure the equivalent resistance $R_{parallel}$. Record the nominal, measured and deviation values in Table 1. What is the equation you used to calculate $R_{parallel}$?

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6. Are the series and parallel equivalent resistances close to the measured values or not?

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7. Try to identify the power ratings of each of the three resistors. State them here:

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

## PROCEDURE B - 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 $R_1 = 1600\Omega$, $R_2 = 1200\Omega$, and $R_3 = 1000\Omega$.
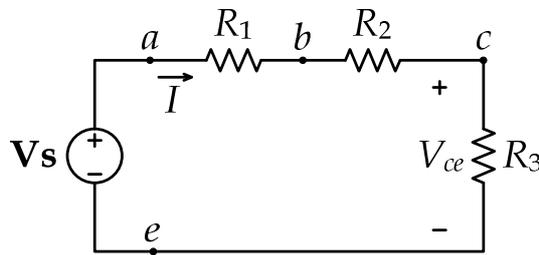


2. Set the DC supply output voltage controls to minimum then connect it to the circuit. Switch the DC supply ON, and set its voltage Vs to 10 Volts. Verify this voltage using a voltmeter.

3. Use theoretical analysis to determine the expected current $I$ and record it in Table 2. What equation did you use?

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

4. Using the theoretical current found above, apply Ohm's law to determine the expected voltage drops across $R_1$, $R_2$, and $R_3$. Record these values in the Theory row of Table 3. An alternative to using Ohm's law is to use a voltage divider rule. 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 (which means you have to insert the ammeter at a certain point in the circuit, such as point $a$). 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 2.

6. Use the DMM to measure the voltages $V_{ab}$, $V_{bc}$, $V_{ce}$ and $V_s$ and record them in Table 3. 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.
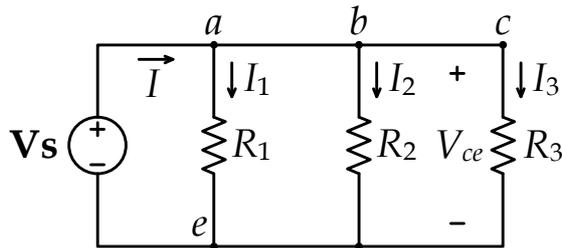
**Table 2**

| I Theory (mA) | I point a (mA) | I point b (mA) | I point c (mA) |
|---|---|---|---|
|  |  |  |  |

**Table 3**

|  | $V_{ab}$ (V) | $V_{bc}$ (V) | $V_{ce}$ (V) | $V_{ab}+V_{bc}+V_{ce}$ | $V_S$ (V) |
|---|---|---|---|---|---|
| **Theory** |  |  |  |  | **10 V** |
| **Measured** |  |  |  |  |  |

7. Construct the circuit shown below. Assume that $R_1 = 1600\Omega$, $R_2 = 1200\Omega$, and $R_3 = 1000\Omega$.



8. Set the DC supply output voltage controls to minimum then connect it to the circuit. Switch the DC supply ON, and set its voltage Vs to 10 Volts.

9. Use theoretical analysis to determine the expected currents $I_1$, $I_2$, $I_3$ and $I$ along with the voltage $V_{ae}$. Record these values in Table 4. What is the current divider equation for the current in resistor $R_1$?

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

10. Use the DMM to measure the currents $I_1$, $I_2$, $I_3$ and $I$ along with the voltage $V_{ae}$. Record these values in Table 4.

**Table 4**

|  | $I_1$ (mA) | $I_2$ (mA) | $I_3$ (mA) | $I_1+ I_2+ I_3$ | I (mA) | $V_{ae}$ (V) |
|---|---|---|---|---|---|---|
| **Theory** |  |  |  |  |  |  |
| **Measured** |  |  |  |  |  |  |

## PROCEDURE C – CAPACITORS AND INDUCTORS IN DC CIRCUITS

In this PROCEDURE section, you will investigate the behavior of capacitors and inductors within DC circuits.

1. Construct the circuit shown below. Assume that $R_1 = 1600\Omega$, $R_2 = 1200\Omega$, $R_3 = 1000\Omega$, $L = 100\text{mH}$, and $C = 0.1\mu\text{F}$.



2. Set the DC supply output voltage controls to minimum then connect it to the circuit. Switch the DC supply ON, and set its voltage Vs to 10 Volts. Verify this voltage using a voltmeter.

3. Using theoretical analysis determine the expected currents $I_1$, $I_2$, $I_3$ and $I$ along with the voltage $V_{ae}$. Record these values in Table 5. What is the current divider equation for the current in resistor $R_1$?

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

4. Use the DMM to measure the currents $I_1$, $I_2$, $I_3$ and $I$ along with the voltage $V_{ae}$. Record these values in Table 5.

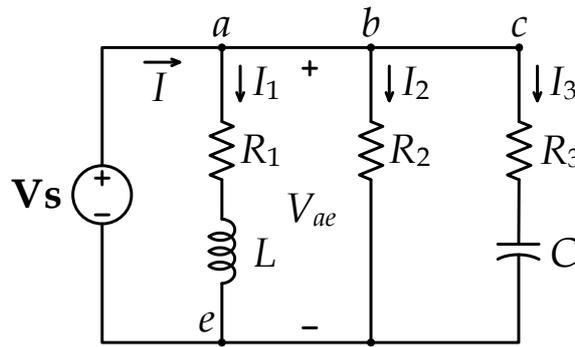**Table 5**

|  | $I_1$ (mA) | $I_2$ (mA) | $I_3$ (mA) | $I_1 + I_2 + I_3$ | $I$ (mA) | $V_{ae}$ (V) |
|---|---|---|---|---|---|---|
| **Theory** |  |  |  |  |  |  |
| **Measured** |  |  |  |  |  |  |

5. Why is the measured current $I_1$ slightly smaller than the theoretically expected value?

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

6. What happens to inductors in DC circuits?

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

7. What happens to capacitors in DC circuits?

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## PROCEDURE D – NODAL AND MESH ANALYSIS

In this PROCEDURE section, you will apply nodal and mesh analysis to multi-source DC circuits.

1. Construct the dual-supply circuit shown below. Assume that $R_1$ = 1200Ω, $R_2$ = 2200Ω, $R_3$ = 1000Ω, and $R_4$ = 1600Ω.
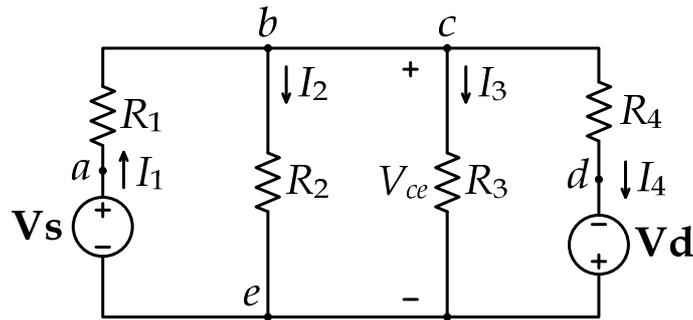


2. Set the DC supplies output voltage controls to minimum then connect them to the circuit. Switch both DC supplies ON, and set their voltages to Vs = 10 Volts and Vd = 15 Volts. Verify these voltages using a voltmeter.

3. Use **nodal** analysis to calculate the theoretical values of the voltages $V_{ae}$, $V_{be}$, $V_{ce}$ and $V_{de}$. Record these values in Table 6. What was the nodal equation you wrote at node $b$?

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

4. Use the DMM to measure the voltages $V_{ae}$, $V_{be}$, $V_{ce}$ and $V_{de}$. Record these values in Table 6.

**Table 6**

|  | $V_{ae}$ (V) | $V_{be}$ (V) | $V_{ce}$ (V) | $V_{de}$ (V) |
|---|---|---|---|---|
| **Theory** |  |  |  |  |
| **Measured** |  |  |  |  |
| **Deviation (%)** |  |  |  |  |

5. Now use **mesh** analysis to calculate the theoretical values of the currents $I_1$, $I_2$, $I_3$ and $I_4$. Record these values in Table 7. What was the mesh equation you wrote for the *left* mesh?

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

6. Use the DMM to measure the currents $I_1$, $I_2$, $I_3$ and $I_4$. Record these values in Table 7.

**Table 7**

|  | $I_1$ (mA) | $I_2$ (mA) | $I_3$ (mA) | $I_4$ (mA) |
|---|---|---|---|---|
| **Theory** |  |  |  |  |
| **Measured** |  |  |  |  |
| **Deviation (%)** |  |  |  |  |

** End **