EXPERIMENT NO 1

Objectives

The objectives of Experiment 1 are

- to learn to read resistors by color bands
- to learn to use a multimeter
- to learn to build circuits using a breadboard
- to measure and calculate equivalent circuit resistance
- to verify Ohm's Law and Kirchhoff's Voltage Law.

A. BACKGROUND

Resistors

A component that is specifically designed to have a certain amount of resistance is called a resistor. The principal applications of resistors are to limit current in a circuit, to divide voltage, and, in certain cases, to generate heat. Although resistors come in many shapes and sizes, they can all be placed in one of two main categories: fixed or variable.

Fixed Resistors

Fixed resistors are available with a large selection of resistance values that are set during manufacturing and cannot be changed easily. They are constructed using various methods and materials. Figure 1 shows several common types.

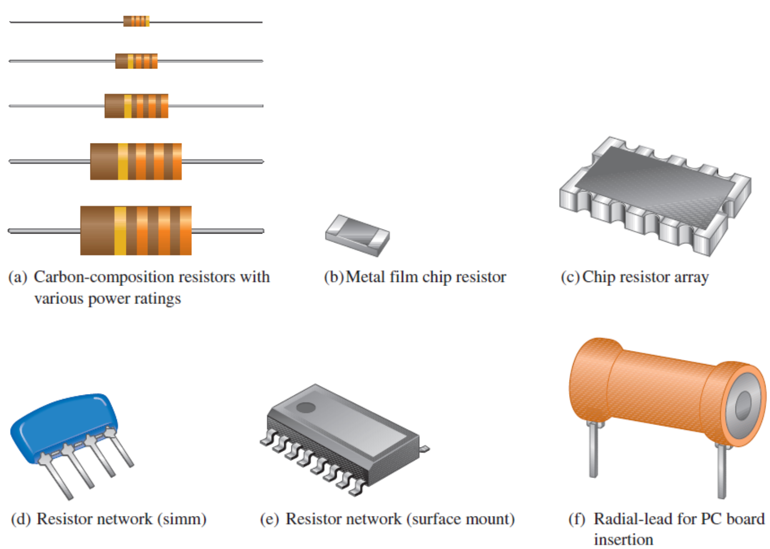


Figure 1. Typical Fixed Resistors

Resistor Color Codes

Fixed resistors with value tolerances of 5% or 10% are color coded with four bands to indicate the resistance value and the tolerance. This color-code band system is shown in Figure 2, and the color code is listed in Table 1. The bands are always closer to one end.

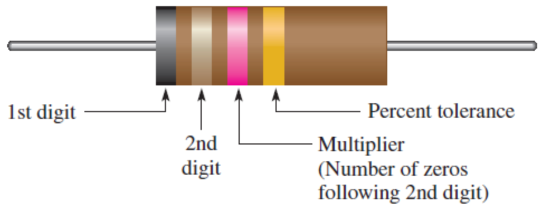


Figure 2. Color-code bands on a 4-band resistor.

The color code is read as follows:

1. Start with the band closest to one end of the resistor. The first band is the first digit of the resistance value. If it is not clear which is the banded end, start from the end that does not begin with a gold or silver band.
2. The second band is the second digit of the resistance value.
3. The third band is the number of zeros following the second digit, or the multiplier.
4. The fourth band indicates the percent tolerance and is usually gold or silver. If there is no band, it means 20% tolerance.
For example, a 5% tolerance means that the *actual* resistance value is within ±5% of the color-coded value. Thus, a resistor with a tolerance of ±5% can have an acceptable range of values from a minimum of 95 Ω to a maximum of 105 Ω.

Example: 470 kΩ → Yellow, Violet, Yellow

Table 1 Resistor 4-band color code

	Digit	Color
Resistance value, first three bands: First band—1st digit Second band—2nd digit Third band—multiplier (number of zeros following the 2nd digit)	0	Black
	1	Brown
	2	Red
	3	Orange
	4	Yellow
	5	Green
	6	Blue
	7	Violet
	8	Gray
	9	White
Fourth band—tolerance	±5%	Gold
	±10%	Silver

Breadboard

A breadboard holds circuit components in place and connects them electrically. A breadboard is shown in Figure 3. The breadboard has many strips of metal that run underneath the plastic top. The metal strips are arranged as shown in the Figure 3. These strips connect to the holes on top of the board. This makes it easy to connect components together when building a circuit.

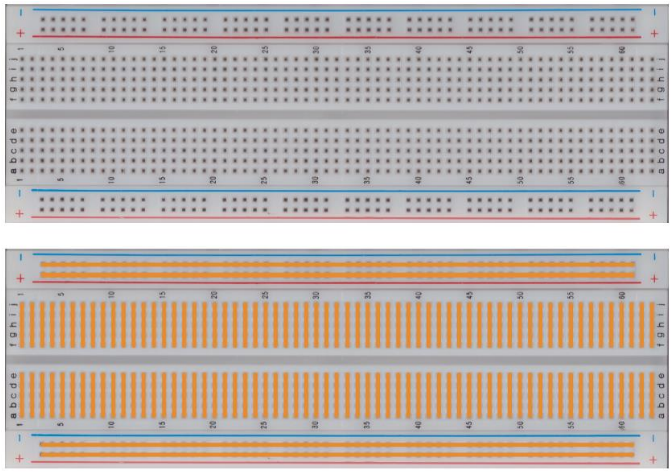


Figure 3. Breadboard and breadboard connection pattern

In Figure 4, schematic of a circuit is given, and it is shown how to build it on the breadboard.

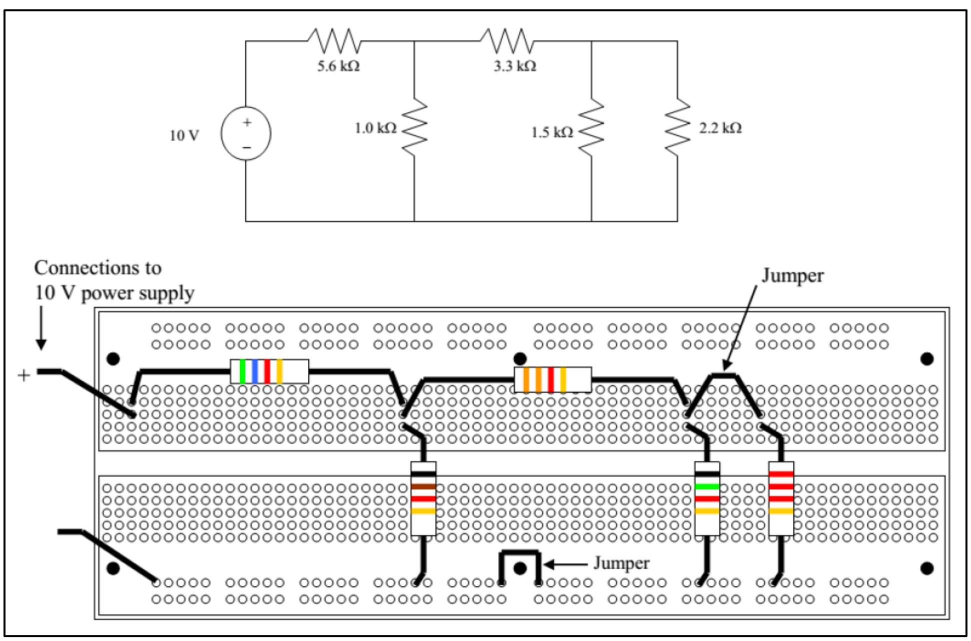


Figure 4.

Multimeter:

The multimeter, also called a volt-ohm meter (or VOM), is the basic tool for anyone working in electronics. You can see a fairly typical modern multimeter in Figure 5. You use a multimeter to take a variety of electrical measurements — hence the term "multi."

Figure 5. A simple multimeter

With this one tool, you can:

- Measure AC voltages
- Measure DC voltages
- Measure resistance
- Measure current going through a circuit
- Measure continuity (whether a circuit is broken or not)

Voltmeter:

A voltmeter measures electrical potential between its terminals. Voltmeters are always placed in parallel with the circuit or circuit element where the voltage measurement is desired. Since the voltage across two or more parallel elements is the same, the voltage measured by the meter will be the same as the element to which the meter is connected. When using a non-auto-ranging meter, select the highest possible range and reduce the range as necessary until the desired level of accuracy is reached. Always start with a range higher than the expected value to prevent damage to the meter.

Ammeter:

An ammeter measures the current that flows between its terminals. An ammeter is always placed in series with the circuit or circuit element where the current flow is of interest. Since the current in each element of a series circuit is the same, the current flow through the meter will be the same as the current flow to the element of interest. Never connect an ammeter in parallel unless you intend to measure the short circuit current of a circuit or circuit element and you have made sure that destructive current levels won't be reached. When using a non-auto-ranging meter, select the highest possible range and reduce the range as necessary until the desired level of accuracy is reached. Always start with a range higher than the expected value to prevent damage to the meter.

Ohmmeter:

An ohmmeter measures the electrical resistance between its terminals. An ohmmeter is connected to the circuit or circuit element of interest after the element of interest has been isolated from the rest of the circuit. The element of interest has to be isolated from the rest of the circuit so that its resistance value isn't obscured by the resistance values of the other circuit components connected to the element of interest. Never connect an ohmmeter to an energized circuit or the meter could be destroyed.

Measurement Errors:

- ***Absolute Error***

In general, the result of any measurement of physical quantity must include both the value itself and its error. The result is usually quoted in the form

$\pm\Delta X = X_0 - X_{measured}$

where X_0 is the best estimate of what we believe is a true value of the physical quantity and ΔX is the estimate of absolute error (uncertainty). ΔX indicates the reliability of the measurement, but the quality of the measurement also depends on the value of X_0.

- ***Fractional Error***

Fractional error is defined as $\frac{\Delta X}{X_0}$

Fractional error can be also represented in percentile form: $\frac{\Delta X}{X_0} \times 100$

Ohm's law states that current is directly proportional to voltage and inversely proportional to resistance. Ohm's law is given in the following formula:

$$I = \frac{V}{R}$$

where I is current in amperes (A), V is voltage in volts (V), and R is resistance in ohms

Kirchhoff's Voltage Law:

Kirchhoff's voltage law is a fundamental circuit law that states that the algebraic sum of all the voltages around a single closed path is zero or, in other words, the sum of the voltage drops equals the total source voltage.

Kirchhoff's voltage law applied to a series circuit is illustrated in Figure 6. For this case, Kirchhoff's voltage law can be expressed by following equation:

$V_S = V_1 + V_2 + V_3 + ... + V_n$

where the subscript n represents the number of voltage drops.

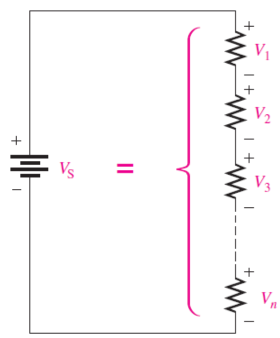


Figure 6. Sum of n voltage drops equals the source voltage.

If all the voltage drops around a closed path are added and then this total is subtracted from the source voltage, the result is zero. This result occurs because the sum of the voltage drops always equals the source voltage.

Therefore, another way of expressing Kirchhoff's voltage law in equation form is

$V_S - V_1 - V_2 - V_3 - ... - V_n = 0$

B. PRELIMINARY WORK:

1. Find out how to read the value of a resistor using color bands.
2. Find out working principles of voltmeter, ammeter and ohmmeter.
3. Find out how to use multimeter which you purchased. Read its user manual.
4. Find out how to connect circuit components in series or parallel on a breadboard.
5. The values of resistors are given in Table 2. Write the corresponding color bands into related fields in Table 2.

Table 2

The resistance	1st color	2nd color	3rd color	4th color
820 Ω ± 10%				
2.7 kΩ ± 5%				
56 kΩ ± 20%				
47 kΩ ± 5%				
1.8 kΩ ± 20%				

6. The color bands are given in Table 3. Write the corresponding resistors into related fields in Table 3.

Table 3

1st color	2nd color	3rd color	4th color	The resistance
Brown	Green	Orange	No band	
Green	Blue	Black	Silver	
Yellow	Violet	Red	Gold	
Blue	Gray	Black	Gold	
Orange	White	Orange	No band	

7. Calculate equivalent resistance of $R_{a\text{-}b}$ for Fig. 7, Fig. 8 and Fig. 9. Write your results into related fields in Table 4.
8. Calculate all node voltages and mesh currents in Fig. 10 using nodal and mesh analysis and write your results into related field in Table 5.
9. Determine voltages across each component in Fig. 10 using calculated node voltages in previous question and write them into related fields in Table 5.
10. Show that Kirchhoff's Voltage confirms your calculations for Fig. 10.

Instructions for preliminary work report:

1. All calculations must be given in your report.
2. All the tables must be given in your report. You will write your calculations into related fields and other fields will be completed in the experiment.
3. Using SPICE, build each circuit schematic at Fig.10-11 and add them to your report with simulation results for the circuits in the order of experimental part. Give all the requested results in experimental part as graphics and/or tables. Simulation results must be clear. You can select Analysis Type as 'Bias Point' for Fig.10. You can select Analysis Type as 'Time Domain (Transient) and select 'Run To Time' as 0.5 millisecond and 'Maximum Step Size' as 0.0001millisecond for Fig.11.

This preliminary work report is of prime importance to check your results in experiment.

C. EXPERIMENTAL PART:

1. Build the circuit given in Fig. 7 on breadboard. Measure equivalent resistance seen between a and b terminals using multimeter and write the result into Table 4. Repeat this process for Fig. 8 and Fig. 9 and compare measured and calculated equivalent resistance values. Calculate absolute and % errors for each one and write them into Table 4.

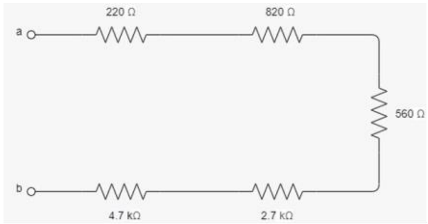


Figure 7. Voltage Divider Circuit

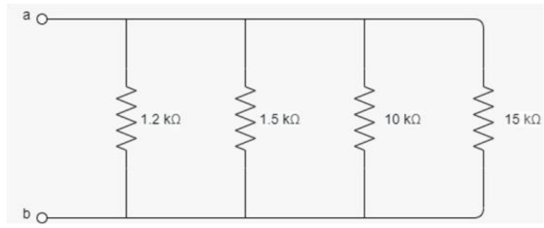


Figure 8. Current Divider Circuit

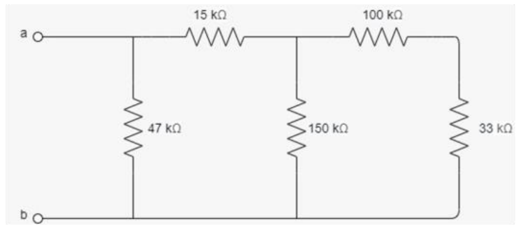


Figure 9. Ladder Circuit

Table 4

Circuit	R_{ab} [Ω]		Absolute Error [Ω]	% Error
	Calculated [V]	**Measured [V]**		
Figure 7				
Figure 8				
Figure 9				

2. Build the circuit given in Fig. 10, measure voltages and currents given in Table 5 using multimeter and write them in related places in Table 5. Write expressions for the generated and dissipated powers and calculate them.

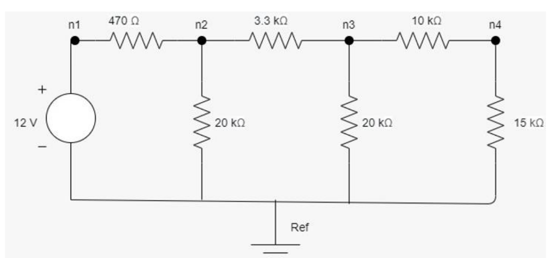


Figure 10.

Table 5

	V(n_1) (V)	V(n_2) (V)	V(n_3) (V)	V(n_4) (V)	V(R_1) (V)	V(R_2) (V)	V(R_3) (V)	V(R_4) (V)	V(R_5) (V)	V(R_6) (V)	I(R_1) (A)	I(R_3) (A)	I(R_5) (A)
Calculated													
Measured													

Table 6

Generated power:	
Dissipated power:	

3. Set-up the circuit shown in Fig. 11, connect the probes to the indicated points. Draw your waveforms on Fig. 12 and measure the phase angles between these two signals.

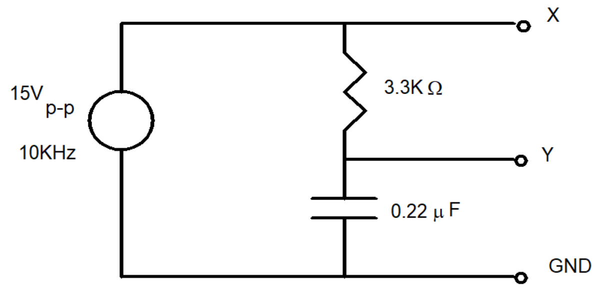
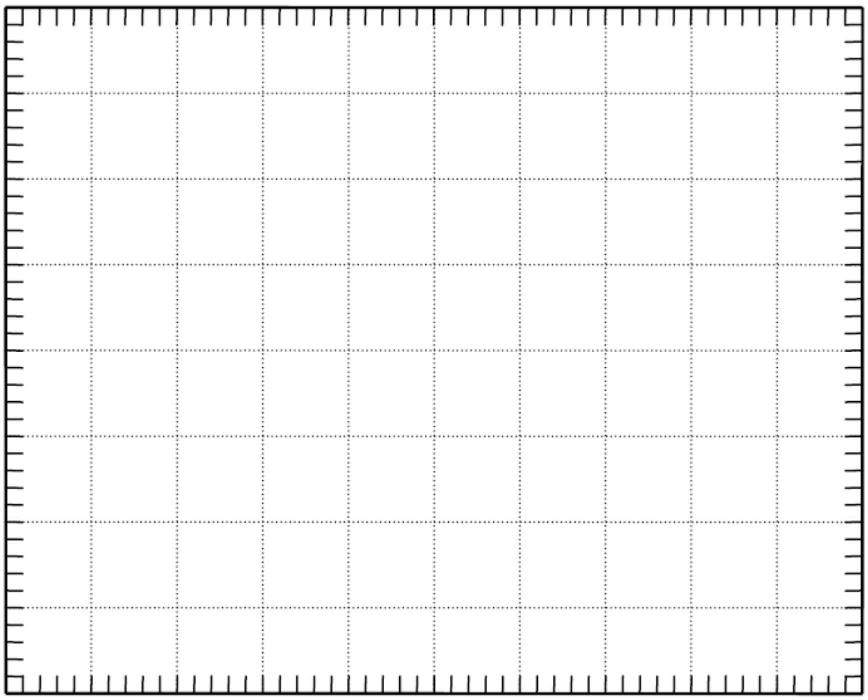


Figure 11



Time division:

………… ……./div

T = ……………….

f = ………………..

Channel 1 scale:

………… ……./div

V_{p-p} = ……………

Channel 2 scale:

………… ……./div

V_{p-p} = ……………

Figure 12