BASIC ELECTRICAL QUANTITIES; SYSTEM OF UNITS; CIRCUIT COMPONENTS

CHAPTER - 3
CHAPTER – 2 CONTENT

- History of Electricity and Electronics
- Electronic Components
- Units
- Scientific Notations
- Molecules and Atomic Structure
- Electric Charges
- The Motion of Electric Charge
- Electric Current
- Direct Current and Alternating Current
CHAPTER – 2 CONTENT

- Electric Potential and Voltage
- Voltage and Current Sources
- Resistance
- Relationship between the Temperature and Resistance
- Wire Sizes
- Load Resistance
- Resistors
BRIEF HISTORY OF ELECTRICITY

- 600 B.C., Greeks discovered that certain substances, when rub with fur, caused other substances to be attracted to them.
- Thales of Miletus (640 B.C. – 546 B.C.) – among the first to observe the attraction of amber for small fibrous materials and bits of straw.
  AMBER – greek word is elektron, the root word for electricity.
- Sir William Gilbert (1544 – 1603) – many substances could be electrified by friction
  All fundamental properties of electricity and magnetism can be traced to the state or motion of something called electric charge.
- Charles F. DuFay (1698 – 1739) – Frenchman – Experimented the conduction of electricity
BRIEF HISTORY OF ELECTRICITY

- Benjamin Franklin (1706 – 1790) – introduced the terms positive (+) and negative (-) to describe the two types of electricity.
- Charles Augustin de Coulomb (1736 – 1806) – proved the laws of attraction and repulsion. Formulated the Coulomb’s Law.
  
  “The force acting between two charges is directly proportional to the product of the two charges and inversely proportional to the square of the distances between the charges.”
- Alessandro Volta (1796) – proved that electricity could be produced if unlike metals separated by moistened paper were brought into contact. First battery was made.
BRIEF HISTORY OF ELECTRICITY

- Hans Christian Oersted (1777 – 1851) – a current-carrying wire influenced the orientation of a nearby compass needle – origin of magnetic field called *electromagnetism*.
- George Simon Ohm (1787 – 1854) – observed that the electrical resistance of metallic conductors remains constant over wide ranges of potential difference. Formulated Ohm’s Law.
- Heinrich Geissler (1814 – 1879) – developed “geissler tube” – electrical discharges in rarefied gases produced different colors.
BRIEF HISTORY OF ELECTRICITY

- Sir William Crookes (1832 – 1919) – invented the first cathode ray tube.
- Thomas Edison (1847 – 1931) – discovered the incandescent light bulb.
- John Fleming (1904) – developed the vacuum tube rectifier or diode.
- Lee de Forest (1873 – 1961) – patented the first vacuum tube capable of boosting or amplifying small electrical signals. He used triode tube.
- Walter Schottky (1938) – invented the first semiconductor diode.
BRIEF HISTORY OF ELECTRICITY

- Ted Hoff (1971) – invented the microprocessor.
- Motorola Corporation (1979) – began marketing a powerful 16-bit microprocessor.
- Microsoft (1980) – introduced the MS-DOS disk-operating system for personal computers.
ELECTRONIC COMPONENTS

TYPES OF ELECTRONIC COMPONENTS

- Semiconductors – these includes diodes, transistors and integrated circuits
- Visual Display Device – these includes:
  - Cathode-Ray Tube (CRT) – for television sets
  - Liquid-Crystal Display (LCD) – for calculators
  - Light-Emitting Diode (LED) – usually used to indicate ON or OFF status
- Resistor – made of either carbon-composite materials or wound with special resistance wire and wrapped around a ceramic-core form. It is rated by their ability to resist the flow of current and dissipate heat.
ELECTRONIC COMPONENTS

TYPES OF ELECTRONIC COMPONENTS

- Capacitor – capable of storing an electric charge and is popular in electronic circuits where filtering is required.

- Inductors – are used in a wide variety of applications. It is also known as:
  - Coils
  - Chokes

It is used to store energy in an electromagnetic field.
<table>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol</th>
<th>Unit</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitance</td>
<td>C</td>
<td>farad</td>
<td>F</td>
</tr>
<tr>
<td>Conductance</td>
<td>G</td>
<td>siemens</td>
<td>S</td>
</tr>
<tr>
<td>Electric Charge</td>
<td>Q</td>
<td>coulomb</td>
<td>C</td>
</tr>
<tr>
<td>Electromotive Force</td>
<td>E</td>
<td>volt</td>
<td>V</td>
</tr>
<tr>
<td>Energy, Work</td>
<td>W</td>
<td>joule</td>
<td>J</td>
</tr>
<tr>
<td>Force</td>
<td>F</td>
<td>newton</td>
<td>N</td>
</tr>
<tr>
<td>Frequency</td>
<td>f</td>
<td>hertz</td>
<td>Hz</td>
</tr>
<tr>
<td>Inductance</td>
<td>L</td>
<td>henry</td>
<td>H</td>
</tr>
<tr>
<td>Magnetic Flux</td>
<td>Φ</td>
<td>weber</td>
<td>Wb</td>
</tr>
<tr>
<td>Magnetic Flux Density</td>
<td>β</td>
<td>tesla</td>
<td>T</td>
</tr>
</tbody>
</table>
## UNITS

### LIST OF INTERNATIONAL STANDARD (SI) UNITS

<table>
<thead>
<tr>
<th>QUANTITY</th>
<th>QUANTITY SYMBOL</th>
<th>UNIT</th>
<th>UNIT SYMBOL</th>
</tr>
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<tbody>
<tr>
<td>Power</td>
<td>P</td>
<td>watt</td>
<td>W</td>
</tr>
<tr>
<td>Resistance</td>
<td>R</td>
<td>ohm</td>
<td>Ω</td>
</tr>
<tr>
<td>Reactance</td>
<td>X</td>
<td>ohm</td>
<td>Ω</td>
</tr>
<tr>
<td>Impedance</td>
<td>Z</td>
<td>ohm</td>
<td>Ω</td>
</tr>
</tbody>
</table>
A number written in scientific notation is expressed as the product of a number greater than or equal to 1 and less than 10, and is a power of 10.

To express a number in scientific notation, the decimal point is moved until there is one significant digit to the left of the decimal point.

The result is then multiplied by the appropriate power of 10 to return the quality to its original value.
SCIENTIFIC NOTATION

Example 1.

72,300 = 7.23 \times 10^4

Example 2.

0.0057 = 5.7 \times 10^{-3}

Example 3.

7.84 \times 10^5 = 784,000
<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Scientific Notation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>tera</td>
<td>T</td>
<td>$10^{12}$</td>
<td>1,000,000,000,000</td>
</tr>
<tr>
<td>giga</td>
<td>G</td>
<td>$10^{9}$</td>
<td>1,000,000,000</td>
</tr>
<tr>
<td>mega</td>
<td>M</td>
<td>$10^{6}$</td>
<td>1,000,000</td>
</tr>
<tr>
<td>kilo</td>
<td>k</td>
<td>$10^{3}$</td>
<td>1,000</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>$10^{-3}$</td>
<td>0.001</td>
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<tr>
<td>micro</td>
<td>μ</td>
<td>$10^{-6}$</td>
<td>0.000001</td>
</tr>
<tr>
<td>nano</td>
<td>n</td>
<td>$10^{-9}$</td>
<td>0.00000001</td>
</tr>
<tr>
<td>pico</td>
<td>p</td>
<td>$10^{-12}$</td>
<td>0.0000000001</td>
</tr>
<tr>
<td>femto</td>
<td>f</td>
<td>$10^{-15}$</td>
<td>0.0000000000001</td>
</tr>
</tbody>
</table>
To add or subtract numbers expressed in scientific notation, it is necessary to convert numbers to a common power of 10.

Example 4. Calculate the sum of \((3.4 \times 10^5) + (5.9 \times 10^6)\)

\[
\begin{align*}
0.34 & \times 10^6 \\
+ & \quad 5.9 \times 10^6 \\
\hline
6.24 & \times 10^6
\end{align*}
\]

answer
SCIENTIFIC NOTATION

- To add or subtract numbers expressed in scientific notation, it is necessary to convert numbers to a common power of 10.

Example 5. Calculate the difference of $(8.4 \times 10^3) - (4.7 \times 10^2)$

\[
\begin{align*}
8.4 \times 10^3 & \quad - \quad 0.47 \times 10^3 \\
\hline
7.93 \times 10^3 & \quad \text{answer}
\end{align*}
\]
SCIENTIFIC NOTATION

To multiply numbers expressed in scientific notations, the exponents are added; to divide, the exponents are subtracted.

Example 6. Calculate the product of \((4 \times 10^5) \times (2.2 \times 10^2)\)

\[
(4 \times 10^5) \times (2.2 \times 10^2) = (4 \times 2.2) \times 10^{(5 + 2)}
\]

\[
= 8.8 \times 10^7 \text{ answer}
\]
SCIENTIFIC NOTATION

- To multiply numbers expressed in scientific notations, the exponents are added; to divide, the exponents are subtracted.

Example 7. Calculate the result of \((6 \times 10^6) / (3 \times 10^2)\)

\[
\frac{6 \times 10^6}{3 \times 10^2} = \frac{6}{3} \times 10^{(6-2)} = 2 \times 10^4 \quad \text{answer}
\]
MOLECULES AND ATOMIC STRUCTURE

- Galileo (1564 – 1642) – discovered that when no force is exerted on a body, it stays at rest or it moves with constant velocity. This became known as Galileo’s Law of Inertia.
- Mass – is a measure of inertia. It is a universal constant equal to the ratio of a body’s weight to the gravitational acceleration due to its weight.
- Matter – anything that occupies space and has mass.
- Atom – is the smallest particle of matter.
MOLECULES AND ATOMIC STRUCTURE

- Elements – are known types of atoms, presently equal to over 100 types.
- Molecules – are the combination of atoms, example is water (H₂O).
- John Dalton (1808) – presented his version of atomic theory entitled *A New System of Chemical Philosophy*. He noted that matter consists of individual atoms, atoms are unchangeable, and each element consists of a characteristic kind of identical atoms.
- Humphry Davy and Michael Faraday proved that electricity and matter are closely related using the Dalton’s Atomic Theory.
MOLECULES AND ATOMIC STRUCTURE

- Their research in electrochemistry, now called *Electrolysis*, help to establish the fact that “electricity is atomic in character and that the atoms of electricity are part of the atoms of matter”

- Ernest Rutherford (1911, English Scientist) – established an atomic structure based on the principle of the atomic being primarily an open space with all the mass concentrated in a central core, called the *Nucleus*.

MOLECULES AND ATOMIC STRUCTURE

- The charge of a proton is equal in magnitude to that of an electron.

- Bohr’s Model of a hydrogen atom:
MOLECULES AND ATOMIC STRUCTURE

- The orbits that the electrons revolve are called *shells*.
- The number of electrons in each shell follows a predictable pattern according to the formula, $2N^2$, where $N$ is the number of the shell.
- The atomic structure of a copper atom:
## MOLECULES AND ATOMIC STRUCTURE

### Properties of three particles

<table>
<thead>
<tr>
<th>Particle</th>
<th>Symbol</th>
<th>Charge</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td>p</td>
<td>+e</td>
<td>1.6725485x10^{-27}\text{kg}</td>
</tr>
<tr>
<td>Neutron</td>
<td>n</td>
<td>0</td>
<td>1.6749543x10^{-27}\text{kg}</td>
</tr>
<tr>
<td>Electron</td>
<td>e^-</td>
<td>-e</td>
<td>9.109534x10^{-31}\text{kg}</td>
</tr>
</tbody>
</table>
ELECTRIC CHARGES

- Law of Conservation of Electric Charge:
  "The Algebraic sum of all electric charges in any isolated system is a constant"

- There are two types of charges:
  - Positive – when there is a deficiency of electrons
  - Negative – when there is an excess of electrons

- The charge of electron and proton are equal

- Static Electricity is the presence of a net positive or negative charge in a material
  "Like charges repel each other, and unlike charges attract each other"
ELECTRIC CHARGES

- Electrical Charge is measured in Coulombs, C
  "One coulomb of charge is the total charge possessed by 6.25x10^{18} electrons"
  "A single electrons has a charge of 1.6x10^{-19} C"
- The equation for defining a charge in coulombs is
  \[ Q = \frac{n}{6.25 \times 10^{18}} \]
  Where:  Q = charge, in coulombs
  n = number of electrons
Example 8. How many coulombs do $93.75 \times 10^{16}$ electrons represents?

Solution:

\[
Q = \frac{n}{6.25 \times 10^{18}} \\
= \frac{93.75 \times 10^{16}}{6.25 \times 10^{18}} \\
= 0.15 \text{ C}
\]

Answer
THE MOTION OF ELECTRIC CHARGE

- When no external electric field is present, the valence electrons move in a random motion.
  
  "The random motion of the free electrons from atom to atom is normally equal in all directions so that no lost or gained by any particular part of the material."

- When most of the electron movement takes place in the same direction, so that one part of the material loses electrons while the other gains, the net electron movement or flow is called current.

- The effective velocity of electrons is nearly 186,000 miles per second, the speed of light.
ELECTRIC CURRENT

Conductor – is a material that has the ability to transfer charge from one object to another
- Materials through which charges move easily
- Good metal conductors have large numbers of free electrons
- In particular, excellent conductors are silver, copper, gold, and aluminum
ELECTRIC CURRENT

Insulators – are materials that are poor conductors have electrons that are tightly bound to individual atoms

- It is used to prevent the wires from touching and to protect us from electric shock.
- Insulators do not conduct because they have full or nearly full valence shells and thus their electrons are tightly bound.
ELECTRIC CURRENT

Semiconductors – is intermediate between conductors and insulators in its ability to transfer charge.

- Silicon and germanium (plus a few other materials) have half-filled valence shells and are thus neither good conductors nor good insulators.
ELECTRIC CURRENT

- Current – is the rate of flow of charged particles through a conductor in a specified direction.
- Ampere (A) – is the SI unit of electric current
  
  "One ampere is equal to one coulomb of electric charge passing a certain point in an electric circuit in one second"

- The symbol of electric current is I.
When the amount of charge that passes a point in one second is one coulomb, the current is one ampere.
ELECTRIC CURRENT

The equation form is

\[ I = \frac{Q}{t} \]

Where:

I = current, in amperes
Q = charge transferred, in coulombs
t = time, in seconds
Example 1. If 1.80 C of charge pass a certain point in a conductor every minute, what is the electric current?

\[ I = \frac{Q}{t} = \frac{1.80 \text{ C}}{60.0 \text{ s}} = 30 \text{ mA} \]
DIRECT AND ALTERNATING CURRENT

- When a unidirectional current is unchanging or changes negligibly, it is referred to as Direct Current (DC).
- If the magnitude of the unidirectional current varies with time, it is called Pulsating Current.
- If the magnitude and direction of the current varies with time, it is referred to as Alternating Current (AC).
DIRECT AND ALTERNATING CURRENT

Direct Current, DC

Pulsating Direct Current
DIRECT AND ALTERNATING CURRENT

Alternating Current, AC
ELECTRIC POTENTIAL AND VOLTAGE

Potential Energy...
- It is defined as energy possessed by a system by virtue of position
- It is energy that can be stored for long periods of time in its present form
- It is capable of doing work when it is converted from its stored form into another form, such as kinetic energy
- Its charge at a given point is directly proportional to the charge itself
ELECTRIC POTENTIAL AND VOLTAGE

Work is the amount of energy converted from one form to another, as a result of motion or conversion of energy from potential to kinetic.

Three things must occur for work to be done:
- A force must be applied
- The force must act through a certain distance
- The force must have component along the displacement

The SI unit of work is Joule, J
ELECTRIC POTENTIAL AND VOLTAGE

“One joule is equal to the work done by a force of one newton acting through a distance of one meter”

Electric Potential or Potential Difference

- It is the amount of work required to move a unit charge from one point to another.
- It is the measure of work per unit of charge
- The unit is joules per coulomb (j/C) or Volts (V)

“One volt is the potential difference between two points in an electric circuit, when one joule of energy is required to move one coulomb of electric charge from one point to another”
ELECTRIC POTENTIAL AND VOLTAGE

The equation form is

\[ E = \frac{W}{Q} \]

Where:

\( E \) = the potential difference, in volts
\( W \) = energy, in joules
\( Q \) = electric charge, in coulombs
Example 2. What value of charge is moved between two points if 0.44 J of energy is used and a potential of 2.6 V is developed?

\[ E = \frac{W}{Q} \]

\[ Q = \frac{0.44 \text{ J}}{2.6 \text{ V}} \]

\[ Q = 0.169 \text{ C} \]
ELECTRIC POTENTIAL AND VOLTAGE

- Voltage rise – represents when a source of emf or device produces voltage

- Voltage drop – represents the energy used by the free electrons while engaged in current flow
VOLTAGE AND CURRENT SOURCES

Voltage Source is a device capable of converting one form of energy into electrical potential energy.

Five main types of Voltage Sources:
- Chemical Sources – convert chemical energy into electrical energy
  - Primary Cell – are nonrenewable voltage sources
  - Secondary Cell – is capable of being recharged
- Solar and Photovoltaic Cells – is a semiconductor device consisting of a thin layer of heavily doped P-typed silicon on a heavily doped N-typed silicon wafer.
VOLTAGE AND CURRENT SOURCES

- Thermoelectric Generation – is based on the principle that if a metal rod is heated at one end, negatively charged electrons flow from the hot end to the cooler end to reduce their energy.
- Electromagnetic Generation – is capable of converting mechanical energy to electrical energy. Example: generator or dynamo
- Electrical Conversion (power supply) – is a device that converts one type of electric potential or current to another.
VOLTAGE AND CURRENT SOURCES

Current Source ...
- It is similar to a voltage source
- Provides a specified value of current through its terminals regardless of the voltage across the terminals.

Fixed DC Voltage Supply
Variable DC Voltage Supply
AC Voltage Supply
Alternating Current Supply
RESISTANCE

- When there is electron flow, the atom collision increases the temperature of the conductor, and some of the potential energy is converted to heat energy;
- The property of the material that restricts the flow of electrons is called Resistance, $R$;
- The unit of measurement of resistance is Ohm, $\Omega$.

“Ohm is the resistance at zero degrees Celsius of a column of mercury of uniform cross section having a mass of 14.4521 grams and a length of 106.3 cm”
RESISTANCE

Four factors affecting resistance of any materials:

- The kind of material
- The length
- The cross-sectional area
- The temperature

“The resistance of a conductor is directly proportional to its length, and inversely proportional to its cross-sectional area”
RESISTANCE

The equation form is

\[ R = \frac{\rho L}{A} \]

Where:

- \( R \) = resistance of material, ohm
- \( L \) = length of the conductor, meters
- \( A \) = cross-sectional area, \( m^2 \)
- \( \rho \) = proportionality constant, \( \text{ohm} \cdot \text{meter} \)

Resistivity = is the resistance of a conductor having unit length and unit cross-sectional area.
# RESISTANCE

## Resistivities of Common Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Resistivity, $\Omega \cdot m@20^\circ C$</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>$2.83 \times 10^{-8}$</td>
<td>Conductor</td>
</tr>
<tr>
<td>Copper</td>
<td>$1.72 \times 10^{-8}$</td>
<td>Conductor</td>
</tr>
<tr>
<td>Germanium</td>
<td>$47 \times 10^{-2}$</td>
<td>Semiconductor</td>
</tr>
<tr>
<td>Gold</td>
<td>$2.45 \times 10^{-8}$</td>
<td>Conductor</td>
</tr>
<tr>
<td>Mica</td>
<td>$2.02 \times 10^{10}$</td>
<td>Insulator</td>
</tr>
<tr>
<td>Silicon</td>
<td>$6.4 \times 10^2$</td>
<td>Semiconductor</td>
</tr>
<tr>
<td>Silver</td>
<td>$1.64 \times 10^{-8}$</td>
<td>Conductor</td>
</tr>
<tr>
<td>Teflon</td>
<td>$3 \times 10^{15}$</td>
<td>Insulator</td>
</tr>
</tbody>
</table>
Example 3. What is the resistance of a piece of silicon 0.4 cm long with a cross-sectional area of 1 cm$^2$?

\[ R = \rho \frac{L}{A} \]
\[ = (6.4 \times 10^2 \ \Omega \cdot \text{m}) \frac{0.004 \ \text{m}}{0.0001 \ \text{m}^2} \]
\[ R = 25.6 \ \text{k}\Omega \]

- For small diameter of wire diameter is in mil; 1 mil = 0.001 in.
- Cross-sectional Area is in Circular Mill (CM) 1CM = 7.854x10$^{-7}$ in$^2$
- Area in CM = $d^2$
RELATIONSHIP BETWEEN TEMPERATURE AND RESISTANCE

"The higher the temperature, the greater the resistance"

- The increase in resistance for most metals is approximately linear when compared with temperature changes.
- The equation is:

\[ R = \frac{\Delta R}{\alpha \Delta T} \]

Where:

- \( \Delta R \) = change in resistance
- \( \Delta T \) = change in temperature
- \( \alpha \) = temperature coefficient of resistance
  - \( = 1/(T + 20°C) \)
## RELATIONSHIP BETWEEN TEMPERATURE AND RESISTANCE

Temperature Coefficients of Resistance and Conductor Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature Coeff., $\alpha$ (@ 20°C)</th>
<th>Inferred Zero-Resistance Temp (°C), T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>0.0039</td>
<td>-236</td>
</tr>
<tr>
<td>Copper</td>
<td>0.00393</td>
<td>-234.5</td>
</tr>
<tr>
<td>Nichrome</td>
<td>0.0004</td>
<td>-2480</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.006</td>
<td>-147</td>
</tr>
<tr>
<td>Platinum</td>
<td>0.003</td>
<td>-310</td>
</tr>
<tr>
<td>Silver (99.98% pure)</td>
<td>0.0038</td>
<td>-243</td>
</tr>
<tr>
<td>Steel, soft</td>
<td>0.0042</td>
<td>-218</td>
</tr>
</tbody>
</table>
RELATIONSHIP BETWEEN TEMPERATURE AND RESISTANCE

Variation in Resistance for Copper

\[ R_2 = R_1 \left(1 + \alpha \Delta T\right) \]

Where:

\[ \Delta T = t_2 - t_1 \]
Example 4. What is the resistance of a copper wire at 30°C if the resistance at 20°C is 4.31 Ω and if $\alpha @ 20°C = 0.00393$?

\[
R_2 = R_1(1 + \alpha \Delta T) \\
= 4.31[1 + 0.00393(30 - 20)] \\
R_2 = 4.48 \, \Omega
\]
RESISTORS

RESISTORS – are devices that conduct electricity but also dissipate electric energy as heat.

✓ The power or wattage rating of the resistor determines its size and shape.

✓ Two basic types of resistors:
  o Fixed – have permanent ohmic values that can not be changed
  o Variable – could be change manually or by applying energy such as heat or light.
RESISTORS

Specific purposes of resistors:

✓ When they are used to limit the flow of current to a safe value, they are called *current limiting resistors*;

✓ When it divides the voltage into different values from a single source, it is called *bleeder resistor*;

✓ If it performs the function of applying a load to a circuit, it is called *load resistor*;

✓ When it is designed to open when the power rating of the resistor is exceeded, it is called *fusible resistors*
RESISTORS

Four major categories of FIXED RESISTORS:

- Carbon-composition resistors
  - The resistive element composed of:
    - Graphite Powder – conductor
    - Silica – insulator
  - It is used in low-power application (under 1 watt)
  - Has typical tolerance of 5% to 10%

- Film resistors
  - Types
    - Carbon Film – thin coating of resistive material on a ceramic insulator. Less noise because of random electron motion
    - Metal Film – provide very precise ohmic values, tolerance < 1%
    - Metal-oxide Film – low noise and excellent temperature characteristics, made up of oxidizing tin chloride.
RESISTORS

Four major categories of FIXED RESISTORS:

- Wire-wound resistor – made up of alloy of relatively high resistivity and drawn into a wire with precisely controlled characteristic.
  - This wire is then wrapped around a ceramic-core form
  - High stability and power ratings up to 250 watts.
  - The ohmic value is usually stamped on the resistor case.

- Chip resistors – are designed for printed circuit board
  - Also available in packages that resemble integrated circuit (IC).
RESISTORS

Three basic types of VARIABLE RESISTORS:

✓ Manual

✓ Rheostat – used to control the circuit current by varying the amount of resistance in the resistance element

✓ Potentiometer – is used to control the voltage applied across the circuit load

✓ Trimmer resistors – used where small and frequent adjustments are necessary to maximize circuit performance, usually made with a screwdriver
RESISTORS
Three basic types of VARIABLE RESISTORS:

- Heat
  - Thermistor – resistor whose resistance varies with temperature
  - Ballast resistor – used to maintain a constant value of current through a wide range of temperatures

- Optical
  - Photoresistors – made up of semiconductor materials that change resistivity as the level of light around the semiconductor changes. As the light level increases, the resistance decreases.
RESISTORS

RESISTOR COLOR CODE (Four Band)

First Significant Digit
Second Significant Digit
Multiplier
Tolerance
<table>
<thead>
<tr>
<th>Color</th>
<th>First Band</th>
<th>Second Band</th>
<th>Third Band</th>
<th>Tolerance</th>
<th>Fourth Band</th>
<th>Digit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st Significant Digit</td>
<td>2nd Significant</td>
<td>Multiplier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>-</td>
<td>0</td>
<td>$10^0$</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>1</td>
<td>$10^1$</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
<td>2</td>
<td>$10^2$</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
<td>3</td>
<td>$10^3$</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
<td>4</td>
<td>$10^4$</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
<td>5</td>
<td>$10^5$</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
<td>6</td>
<td>$10^6$</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
<td>7</td>
<td>$10^7$</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gray</td>
<td>8</td>
<td>8</td>
<td>$10^8$</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td>9</td>
<td>$10^9$</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gold</td>
<td>-</td>
<td>-</td>
<td>$10^{-1}$</td>
<td>±5%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Silver</td>
<td>-</td>
<td>-</td>
<td>$10^{-2}$</td>
<td>±10%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>None</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>±20%</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
RESISTORS

RESISTOR COLOR CODE (Five Band)

- Fifth band indicates *reliability Factor*
- Gives the percentage of failure per 1000 hours of use
RESISTORS

RESISTOR COLOR CODE (Five Band)

- First Significant Digit
- Second Significant Digit
- Third Significant Digit
- Multiplier
- Tolerance
# RESISTORS

## Color Code for five-band precision resistors

<table>
<thead>
<tr>
<th>Color</th>
<th>First Band</th>
<th>Second Band</th>
<th>Third Band</th>
<th>Fourth Band</th>
<th>Fifth Band</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st Significant Digit</td>
<td>2nd Significant Digit</td>
<td>3rd Significant Digit</td>
<td>Multiplier</td>
<td>Tolerance</td>
</tr>
<tr>
<td>Black</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>10^0</td>
<td>-</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10^1</td>
<td>±1%</td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>10^2</td>
<td>±0.1%</td>
</tr>
<tr>
<td>Orange</td>
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<td>3</td>
<td>3</td>
<td>10^3</td>
<td>±0.01%</td>
</tr>
<tr>
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<td>4</td>
<td>4</td>
<td>10^4</td>
<td>±0.001%</td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>10^5</td>
<td>±0.5%</td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>10^6</td>
<td>±0.25%</td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>10^7</td>
<td>-</td>
</tr>
<tr>
<td>Gray</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>10^8</td>
<td>-</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>10^9</td>
<td>-</td>
</tr>
<tr>
<td>Gold</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10^{-1}</td>
<td>-</td>
</tr>
<tr>
<td>Silver</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10^{-2}</td>
<td>-</td>
</tr>
</tbody>
</table>
RESISTORS

- Numerical labels are used on certain type of resistors
  - Resistance value is stamped on the body of the resistor
    - using R to designate the decimal point
    - letters to designate tolerance as follows:
      - F = ±1%
      - G = ±2%
      - J = ±5%
      - K = ±10%
      - M = ±20%
  - First Three digits are used to resistance value
  - Fourth digit specify the number of zeros.
RESISTORS

Example:

(a) $6R8M = 6.8\ \Omega \pm 20\%$

(b) $3301F = 3,300\ \Omega \pm 1\%$

(c) $2202J = 22,000\ \Omega \pm 5\%$
LOAD RESISTANCE

- The name given to any device connected across an energy source is \textit{LOAD}.
- The amount of opposition to current flow offered by the load is \textit{LOAD RESISTANCE}.

"Load always represents voltage drops in a circuit because they absorb electrical energy and dissipate it as heat, sound, light, or mechanical energy."
LOAD RESISTANCE

Load resistance connected to a source
TROUBLESHOOTING RESISTORS

✓ A common problem is fixed-resistor failure.
  ✓ Due to excess heat caused by too large current
  ✓ The interior device will either burn out or melt
  ✓ It will produce open circuit
✓ Another problem is cold solder joints
  ✓ Caused an open circuit also
  ✓ Due to improper soldering in printed circuit board
✓ Short circuited resistor
  ✓ Resistor value has effectively fallen to zero ohms
  ✓ Very dangerous because there is no resistance between the two terminals of the power supply
TROUBLESHOOTING RESISTORS

✓ The most popular instrument used in troubleshooting resistors is the ohmmeter.

✓ Important notes to remember:
  - Never used ohmmeter on an energized circuit;
  - Power supply should be turned “OFF”;
  - At least one lead of the resistor should be disconnected;
WIRE SIZES

- Wires are manufactured in sizes numbered according to a standard called the *American Wire Gauge (AWG)*.
- The lower the AWG number indicates a greater cross-sectional area in circular mils.
- It is desirable to use wire of the smallest diameter consistent with the minimum resistance that can be tolerated.
- For such consideration as:
  - Cost
  - Weight
  - Bulk
Thank You!