THRUST MIT TASK PHASE 2

Abstract—This report explains gauge wire systems (AWG and SWG), resistors, inductors, and capacitors including their types, working principles, advantages, and limitations.

I. INTRODUCTION

This document provides an overview of wire gauges, resistors, inductors, and capacitors, which are fundamental components in electronics.

II. GAUGE WIRE

It is a device which calculates the amount of resistance, the current it can carry, and weight of the wire. The wire gauges are used for standardising the measurement of the wire its thickness etc, to ensure consistency and safety.

A. Type of Gauge Wire

- Wire Gauge Sheet (Plug Gauge)
- Calliper or Micrometre

1) Wire Gauge Sheet (Plug Gauge)

These were used in olden days to measure the diameter of the wire. It is a thick metal plate with a large amount of holes of varying size to pass the wire through it. To measure the diameter the wire is lipped tightly through the hole of certain specification. The specification in these wire gauge is according to either American Wire gauge (AWG) or Standard wire gauge (SWG). Nowadays these are used to check inner diameter of the wire to check for its tolerance.

2) Calliper or Micrometre

Currently we use this technology to find the size and diameter of wire accurately. This has very high accuracy and it can measure up to 0.01 mm precisely.

III. AMERICAN WIRE GAUGE (AWG)

It is a measurement system used predominantly in North America. It has been in use since 1857. Used to find diameter of round, non-ferrous, solid wires. Dimensions are according to American Society of Testing and Materials. It actually uses logarithmic steps which are standardised by ASTM.

Rule:

- Smaller gauge number → Thicker wire → Lower resistance → Higher current capacity.
- Larger gauge number → Thinner wire → Higher resistance → Lower current capacity.
- 36 AWG is the smallest standard.
- 0000 AWG (written 4/0 AWG) is the largest standard (0.460 in ≈ 11.68 mm diameter).
- Each step in AWG represents a size change factor of about 1.12293 in diameter.

Advantages:

- Simple fixed table – easy to look up values.
- Historically common in UK, India and still used in some industries (motors, sheet metal).
- Values directly tied to wire drawing dies – practical for manufacturing.
- Sometimes also used for sheet thickness (not only wires).

Cons:

- No formula → must always refer to tables.
- Not globally accepted → mostly replaced by mm^2 (metric) or AWG.
- Less precise step sizes compared to AWG (uneven increments).
- Conversion required if working with international standards.

IV. STANDARD WIRE GAUGE (SWG)

It is a British wire gauge system and is also called imperial wire gauge system. Over the years its use has reduced significantly but is still used to measure the guitar strings. These are widely used in UK and in older industries. Unlike AWG these are table based and don't work on formula.

Advantages:

- Mathematical/logarithmic system → formula allows direct calculation.
- Widely used in USA, Canada, aerospace, telecom, electronics.
- Consistent step size (~26% reduction in area per step).
- Tables give not just diameter, but also resistance and ampacity.
- Easier to design and calculate voltage drop, resistance, skin effect etc.

Cons:

- Not commonly used in the UK, EU, or India (where mm^2 is preferred).
- Uses gauge numbers instead of direct mm^2 → less intuitive for beginners.
- Can cause confusion with SWG (e.g., AWG 10 ≠ SWG 10).
- For very fine wires (<40 AWG), special charts are still needed.

RESISTORS

It is a passive two terminal device that is used to increase resistance in the circuit intendedly. This is made to control the amount of current/power flowing through the circuit. The resistance applied is in ohm (Ω).

A. Working

The resistor works on Ohm's law which states voltage is proportional to current until temperature is changed. A resistor actually dissipates energy in form of heat to the surrounding. Inside a resistor, electrons collide with atoms of the resistive material (carbon, metal film, wire, etc.). These collisions slow down electron movement and convert some electrical energy into heat (Joule heating).

B. Types of Resistors

1. **Fixed Resistors**
    - **Carbon Composition Resistors**-carbon composition resistor is a type of fixed resistor that limits or reduces the current in a circuit. It is made of a solid cylindrical body of carbon or graphite powder mixed with a binder, such as clay or resin. The carbon powder acts as a conductor, while the binder acts as an insulator. Used mainly in general-purpose circuits; durable but less precise.
    - **Carbon Film Resistors**- carbon film resistors are different than carbon composition resistors; they are two distinct types of carbon resistors with different constructions and performance characteristics. Carbon composition resistors are made from a mixture of carbon powder, a ceramic filler, and a binder, while carbon film resistors use a thin film of pure carbon deposited onto an insulating ceramic rod.
    - **Metal Film Resistors- metal** film resistor are usually made of Nichrome, but also other materials such as tantalum nitride is used. The resistive film is printed on a cylindrical or flat insulating substrate. The resistive material is a combination of a Ceramic material and a Metal, and therefore these resistors are also referred to as Cermet. Just as with carbon film, the resistance value is

adjusted by cutting a spiral pattern in the film. This can be done with an abrasive or a laser.

- **Wire-wound Resistors**-. A wire wound resistor is an electrical passive component that limits current. The resistive element is an insulated metallic wire that is wound around a core of non-conductive material. The wire material has a high resistivity and is usually made of an alloy such as nickel-chromium (Nichrome) or a copper-nickel-manganese alloy called Manganin.
- **Metal Oxide Resistors-** hey are like metal film with the difference that the resistive material is a metal oxide, such as tin oxide. These durable resistors feature a better reliability and stability than metal film resistors. Furthermore, the operating temperature is higher. Therefore, they are more used in applications requiring a high endurance.

2. Variable Resistors

- **Potentiometer (POT)-** A potentiometer is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider.[1] If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat. Potentiometers are commonly used to control electrical devices such as volume controls on audio equipment. It is also used in speed control of fans. Potentiometers operated by a mechanism can be used as position transducers, for example, in a joystick. Potentiometers are rarely used to directly control significant power (more than a watt), since the power dissipated in the potentiometer would be comparable to the power in the controlled load.
- **Rheostat-** A rheostat is a variable resistor which is used to control current. They are able to vary the resistance in a circuit without interruption. The construction is very similar to the construction of potentiometers. It uses only two connections, even when 3 terminals (as in a potentiometer) are present. Rheostats were often used as power control devices, for example to control light intensity (dimmer), speed of motors, heaters, and ovens. They are not typically used for this function anymore. This is because of their relatively low efficiency. In power control applications, they have been replaced by switching electronics. As a variable resistance, they are often used for tuning and calibration in circuits.
- **Trimpot-** A trimmer, or preset, is a miniature adjustable electrical component. It is meant to be set correctly when installed in some device, and never seen or adjusted by the device's user. Trimmers can be variable resistors (potentiometers), variable capacitors, or trimmable inductors. They are common in precision circuitry like A/V components, and may need to be adjusted when the equipment is serviced. Trimpots (trimmer potentiometers) are often used to initially calibrate equipment after manufacturing. They are

common in precision circuitry like A/V components, and may need to be adjusted when the equipment is serviced. Trimpots are often used to initially calibrate equipment after manufacturing. Unlike many other variable controls, trimmers are mounted directly on circuit boards, turned with a small screwdriver and rated for many fewer adjustments over their lifetime.

3. Special Resistors

- **Thermistors (PTC, NTC)-** A thermistor is a semiconductor type of resistor in which the resistance is strongly dependent on temperature The varying resistance with temperature allows these devices to be used as temperature sensors, or to control current as a function of temperature. This allows them to be used for limiting current to cold circuits, e.g. for inrush current protection, or for limiting current to hot circuits, e.g. to prevent thermal runaway.
    - **PTC (Positive Temperature Coefficient)-** resistance increases as temperature rises; usually because of increased thermal lattice agitations, particularly those of impurities and imperfections. PTC thermistors are commonly installed in series with a circuit, and used to protect against overcurrent conditions, as resettable fuses.
    - **NTC(Negative Temperature Coefficient)-** resistance decreases as temperature rises; usually because electrons are bumped up by thermal agitation from the valence band to the conduction band. An NTC is commonly used as a temperature sensor, or in series with a circuit as an inrush current limiter.
- **Photoresistor (LDR)-** A photocell or photoresistor is a sensor that changes its resistance when light shines on it. The resistance generated varies depending on the light striking at his surface. A high intensity of light incident on the surface will cause a lower resistance, whereas a lower intensity of light will cause higher resistance. Cadmium sulfasalazine (CdS) is a photoconductive material commonly used in photoresistors (*226–229*).

C. Uses

- Limiting electric current
- Voltage division
- Heat generation
- Matching and loading circuits
- Gain control
- Setting time constants

- Electric brakes to dissipate kinetic energy

INDUCTOR

An inductor is a passive electronic component, also known as a coil, choke, or reactor, that stores energy in a magnetic field when an electric current flows through it. It consists of a coil of insulated wire wound around a core, and it resists changes in the current flowing through it.

A. Based on Core Material

1. **Air Core Inductor--** This is a nonmagnetic core inductor which is also called an air core coil. These inductors are used in applications where low inductance & high frequency are required. The lack of core losses permits air core inductors to function at maximum frequencies.

2. **Iron Core Inductor-**The fixed value inductor in which an iron core is used within the coil to increase the inductance value of an inductor is known as an iron core inductor. These inductors have a very low inductance value and the iron core of this inductor has very unique magnetic characteristics which strengthen the magnetic field

3. **Ferrite Core Inductor-** A ferrite core inductor definition is, a two-terminal passive electrical component used to resist changes in the electric current flowing through it. This inductor uses a ferrite material like the main core which has high electrical resistivity & high magnetic permeability. While using ferrite cores within inductors, different factors need to consider like high saturation, high impedance, fewer losses, stability within temperature & material properties.

B. Based on Construction

1. **Fixed Inductor-** a device which has fixed unchangeable inductance value, The primary function of a fixed inductor is to introduce a specific amount of inductance into a circuit, which is its property of opposing any change in current
2. **Variable Inductor -** A variable inductor definition is an inductor or coil whose effective inductance is adjustable continuously. The frequency range of this inductor typically ranges from 10 µH – 100 µH & currently available inductors range from 10nH – 100 mH.
3. **Toroidal Inductor-** Toroidal inductors and transformers are inductors and transformers which use magnetic cores with a toroidal (ring or donut) shape. They are passive electronic components, consisting of a circular ring or donut shaped magnetic core of ferromagnetic material such as laminated iron, iron powder, or ferrite, around which wire is wound.

C. Special Inductors

1. **Choke Inductor-** In electronics, a choke is an inductor used to block higher-frequency alternating currents (AC) while passing direct current (DC) and lower-frequency ACs in a circuit. A choke usually consists of a coil of insulated wire often wound on a magnetic core, although some consist of a doughnut-shaped ferrite bead strung on a wire.

2. **Coupled Inductor-** Coupled inductor definition is when the connection of two coils or inductors can be done through electromagnetic induction. Whenever an AC flows throughout the primary coil, the coil will set up a magnetic field that is connected to the secondary coil & induces a voltage within the coil. The phenomenon of inducing voltage from one inductor to another is known as mutual inductance.

CAPACITOR

A capacitor is an electronic component that stores electrical energy by accumulating electric charges on two insulated conducting surfaces, acting as a charge storage device in circuits. It consists of two conductors (plates) separated by an insulator called a dielectric, and its ability to store charge is known as capacitance. They are used in a wide range of electronic devices for tasks like filtering, energy storage, and smoothing out voltage fluctuations in both AC and DC circuits.

A. Based on Dielectric Material

1. **Ceramic Capacitor**- A ceramic capacitor uses a ceramic material as the dielectric. Ceramics were one of the first materials to be used in the producion of capacitors, as it was a known insulator. The types of ceramic capacitors most often used in modern electronics are the multi-layer ceramic capacitor, otherwise named ceramic multi-layer chip capacitor (MLCC) and the ceramic disc capacitor.

2. **Electrolytic Capacitor-** An electrolytic capacitor is a type of capacitor that uses an electrolyte to achieve a larger capacitance than other capacitor types. An electrolyte is a liquid or gel containing a high concentration of ions. Almost all electrolytic capacitors are polarized, which means that the voltage on the positive terminal must always be greater than the voltage on the negative terminal. The benefit of large capacitance in electrolytic capacitors comes with several drawbacks as well.

3. **Tantalum Capacitor-** A tantalum electrolytic capacitor is an electrolytic capacitor, a passive component of electronic circuits. It consists of a pellet of porous tantalum metal as an anode, covered by an insulating oxide layer that forms

the dielectric, surrounded by liquid or solid electrolyte as a cathode. The tantalum capacitor, because of its very thin and relatively high permittivity dielectric layer, distinguishes itself from other conventional and electrolytic capacitors in having high capacitance per volume (high volumetric efficiency) and lower weight.

B. Based on Polarity

1. Polarized Capacitors (Electrolytic, Tantalum)
2. Non-Polarized Capacitors (Ceramic, Mica, Film)

TYPE OF FORCES

TENSION-

It is a type of pulling force which acts along the length of the body like rope, cable, string. This force tries to stretch the objector elongate it. example, when you pull on a rope in a tug-of-war, the force you apply creates tension in the rope.

Eg-The rope pulls on you with an equal and opposite force, and on the opposing team with a force in the other direction. This force is a type of stress that causes a material to elongate, and the magnitude of the tension is determined by the pulling force.

COMPRESSION-

It is a force that squeezes or shortens an object by pushing on opposite ends. The forces act along the same line but opposite directions, trying to crush or reduce the object's length. It can cause its atoms and molecules to get closer together.

Eg-The legs of a chair under someone's weight

SHEAR-

occurs when two parallel forces act in opposite directions on different parts of the same material, causing it to deform by sliding, hear forces tend to split, cut, or rip materials – as seen in scissors slicing paper or wind acting on the side of buildings. A type of stress that causes parts of a body to **slide relative to each other.**

Eg- Scissors cutting paper (the blades apply shear force).

TORSION-

It is twisting the object using torque it is a type of stress applied in circular motion. It occurs when a force causes an object to rotate around its longitudinal axis.

Eg- A common example is wringing out a wet towel. You apply equal and opposite twisting forces to each end, causing it to deform by twisting

ELASTICITY-

It is the property that allows a material to deform under an applied force and return to its original shape and size when the force is removed. The elastic limit is the maximum stress a material can withstand before it starts to deform permanently

Eg- A rubber band stretches but comes back to shape.

PLASTICITY-

It is the property that enables a material to undergo permanent deformation without returning to its original shape when the external load is removed. Materials like clay and lead are highly plastic.

Eg- when a blacksmith hammers a piece of hot steel

DUCTILITY-

It is the ability of a material to be stretched into a wire under tensile stress without breaking. Gold and copper are excellent examples of highly ductile metals, as they can be easily pulled into long, thin wires

Eg- Gold can be drawn into very fine wires.

MALLEABILITY-

Malleability is the capacity of a material to be deformed or extended in two directions (usually into thin sheets) under compressive force It's similar to ductility but relates to compression rather than tension

Eg- Aluminium foil is a classic example of a malleable material that can be compressed into a very thin sheet.

BRITTLENESS-

Brittleness is the tendency of a material to break or fracture without significant plastic deformation when subjected to stress. brittle materials absorb very little energy before they fail, Glass, ceramics, and cast iron are all examples of brittle materials

Eg- Cast iron is strong but brittle

LEARNING OUTCOME-

- **Apply basic programming concepts**, such as variables, constants, arithmetic operators, and input/output formatting.
- **Use decision-making constructs** like if, else, and switch statements, along with logical operators, to handle different program conditions.
- **Employ loops and control statements** (for, while, do-while, break, continue) to solve repetitive tasks efficiently.

- **Develop modular programs** by writing and calling functions, managing scope of variables, and applying function prototypes and performing recursions.
- **Work with arrays and strings**, including multidimensional arrays, string operations, and sorting methods.
- The way the computer operates on mathematical calculations by using operator precedence.

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