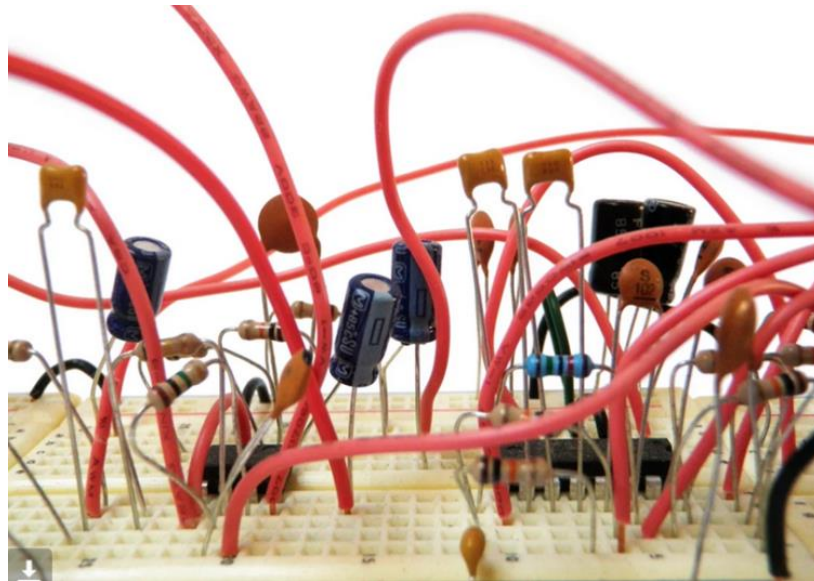


Biomedical Equipment Servicing

Level – II

Based on September 2021, Curriculum Version-II



Module Title: Constructing and Interpreting Basic Electronic/Electrical Circuits

Module Code: HLT BES2 M05 0921

Nominal Duration: 100 Hour

August 2022

Addis Ababa, Ethiopia

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Acronyms

AC	Alternative Current
DC	Direct Current
IC	Integrated Circuit
LAP	Learning Activity Performance
LED	Light Emitting Diode
MoH	Ministry of Health
MoLS	Ministry of Labor and Skill
PCB	Printed Circuit Board
TTLM	Teaching, Training and Learning Materials
TVET	Technical and Vocational Education, and Training

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Introduction to Basic Electronic /Electrical Circuits

An electrical circuit (also known as an electrical network or electric circuit) is an interconnection of various active and passive components in a prescribed manner to form a closed path. Electric current must be able to flow from the source through some conductive medium and then back to the other terminal of the source.

Thus, this module aims to provide the trainees with the knowledge, skills and attitudes needed to draw and construct diagram, calculate electrical quantities and test performance.

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Module units:-

- Tools and circuit components
- Calculating electrical quantities
- Circuit diagrams
- Constructing electronic circuit

Module Contents: Learning objectives of the Module

At the end of this session, the students will able to

- Plan and prepare tools and circuit components
- Calculate electrical quantities
- Draw circuit diagrams
- Construct electronic circuit

Module Learning Instructions:

- Read the specific objectives of this Learning Guide.
- Follow the instructions described below.
- Read the information written in the information Sheets
- Accomplish the Self-checks
- Perform Operation Sheets
- Do the “LAP test”

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Unit One: Tools and Circuit Components

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Tools and Components
- OHS guidelines
- Electrical wiring/electronic circuits

This unit will also assist you to attain the learning outcomes stated in the cover page.

Specifically, upon completion of this learning guide, you will be able to:

- Check tools and components
- Plan tasks to ensure OHS guidelines
- Prepare Electrical wiring/electronic circuits

1.1 Tools and Components

1.1.1 Tools

a) Soldering lead

Soldering lead is an alloy (mixture) of tin and lead, typically 60% tin and 40% lead. It melts at a temperature of about 200°C. Coating a surface with solder is called 'tinning' because of the tin content of solder. Lead is poisonous and you should always wash your hands after using solder.



Figure1.1: Soldering lead

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b) Wires and Cable

A wire is a single slender rod or filament of drawn metal. This definition restricts the term to what would ordinarily be understood as solid wire. The word “slender” is used because the length of a wire is usually large when compared to its diameter. If a wire is covered with insulation, It is an insulated wire. Although the term “wire” properly refers to the metal, it is also includes the insulation.

Either a cable is a stranded conductor (single-conductor cable) or a combination of conductors insulated from one another (multiple-conductor cable). The term “cable” is a general one and usually applies only to the large sizes of conductor. A small cable is more often called a stranded wire or cored (such as that used for an iron or a lamp cord). Cables may be bare or insulated. Insulated cables may be sheathed (covered) with lead, or protective armor.

- A conductor: is a wire suitable for carrying an electric current.
- A stranded conductor is a conductor composed of a group of wire or of any combination of group of wires. The wires in a stranded conductor are usually twisted together and not insulated from each other.



Figure1.2: Stranded conductor

c) Insulating materials

Insulators are materials whose atoms have tightly bound electrons. These electrons are not free to roam around and be shared by neighboring atoms. Insulators are used to protect us from the dangerous effects of electricity flowing through conductors.

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List of Common some common insulator materials are

- Clay (ceramic)(porcelain) - This is the standard material for high voltage and RF insulators.
- Plastics – PVC and other plastics replaced rubber as an insulator for wires and other parts. PVC and nylon are now standard in most types of wire.
- Glass (silica, soda ash and limestone) - This material worked fine for telegraph and other low voltage apparatus. It is still used today to some degree.
- Paper/Cardboard – paper and cardboard are used as insulators in certain circumstances as these materials are cheap and can work in situations without high heat or high voltages
- Mica - This is a good stable material even when exposed to the elements. It is a good thermal conductor while being an insulator. Sheet mica is easily stamped and shaped for electrical components. Mica is very important for the most common types of capacitors.

d) Soldering flux (paste)

Flux is a cleaning agent to remove oxidation during soldering. Heating a metal causes rapid oxidation. Oxidation prevents solder from reacting chemically with a metal. Flux cleans the metal by removing the oxide layer. Without flux most joints would fail because metals quickly oxidized and the solder itself will not flow properly onto a dirty, oxidized, metal surface.

Soldering flux performs three functions.

- It is an additional cleaning agent.
- It aids in tinning or coating the conductor when solder is applied.
- It ensures adhesion or connection of solder to the splice.

e) Pliers

Pliers are made in various shapes and sizes and for many uses. Some are used for gripping something round like a pipe or rod, some are used for twisting wires, and others are designed to be used for a combination of tasks including cutting wire

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Figure 1.3: Pliers

- f) **Long Nose:** It is used for holding, bending and stretching the lead of electronic component or connecting wire.



Figure 1.4: Long nose

- g) **Side Cutter:** It is a wire-cutting plier, though they are not used to grab or turn anything, but are used to cut wire



Figure 1.5: Side cutter

- h) **Wire Stripper:** It is a pair of opposing blades much like scissors or wire cutters. The addition of a center notch makes it easier to cut the insulation without cutting the wire. This type of wire stripper is used by rotating it around the insulation while applying pressure order to make a cut around the insulation. Since the insulation is not bonded with the wire, it will be pulled easily at the end.

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Figure 1.6: Wire stripper

- i) **A sharp knife:** may be used to strip the insulation from a conductor. The procedure is much the same as for sharpening a pencil. The knife should be held at approximately a 60° angle to the conductor. Use extreme care when cutting through the insulation to avoid nicking or cutting the conductor.



Figure 1.7: Sharp knife

- j) **Soldering Iron:** It is a device used for applying heat to melt solder in attaching two metal parts. A soldering iron is composed of a heated metal tip and an insulated handle. Heating is often achieved electrically, by passing a current, supplied through an electrical cord, through a heating element. For electrical work, wires are usually soldered to printed circuit boards, other wires, or small terminals. A low-power iron (15-30 Watts) is suitable for this work.

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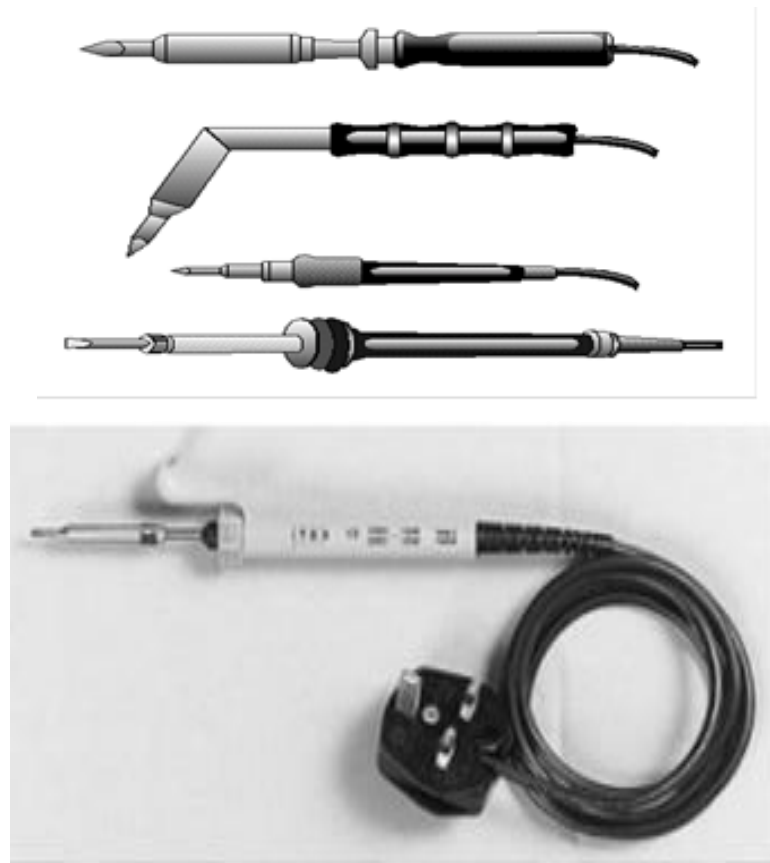


Figure 1.8: Types of hand solders irons.

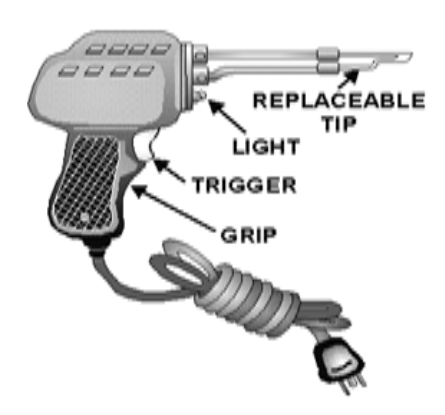


Figure 1.9: Soldering gun

- k) Soldering Tool Stand:** It is a place of the soldering iron to keep them away from flammable materials. The stand often also comes with a sponge and flux pot for cleaning the tip.

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Figure1.10: Soldering Tool Stand

- l) **De-soldering tool:** It is used for the removal of solder and components from a circuit when troubleshooting, repair purposes and to save components. Electronic components are often mounted on a circuit board and it is usually desirable to avoid damaging the circuit board, surrounding components, and the component being removed.



Figure 1.10: De-soldering tool

- m) **Screwdrivers:** Is a tool, manual or powered, for screwing (installing) and unscrewing (removing) screws. A typical simple screwdriver has a handle and a shaft, ending in a tip the user puts into the screw head before turning the handle. The shaft is usually made of tough steel to resist bending or twisting



Figure 1.11: Screwdriver

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- n) **Multi-meter:** Is a test tool used to measure two or more electrical values principally voltage , current and resistance. Multimeter combine the testing capabilities of single-task meters—the voltmeter (for measuring volts), ammeter (amps)& ohmmeter (ohms)



Figure1.12: Multi-meter

1.1.2 Basic Electronic Components

Basic Electronic Components are electronic devices or parts usually packaged in a discrete form with two or more connecting leads or metallic pads. These devices are intended to be connected together, usually by soldering to a Printed Circuit Board (PCB), to create an electronic circuit with a particular function (for example an amplifier, radio receiver, oscillator, wireless).

Some of the Basic Electronic Components are resistor, capacitor, transistor, diode, operational amplifier, resistor array, logic gate etc.

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Figure 1.13: Electronic Components

Types of Electronic Components

These are of two types: Passive and Active Components. Both these types of components can be either Through-Hole or SMD.

1. Passive Components

These components are those that do not have gain or directionality. They are also called Electrical elements or electrical components.

Example: Resistors, Capacitors, Diodes, Inductors

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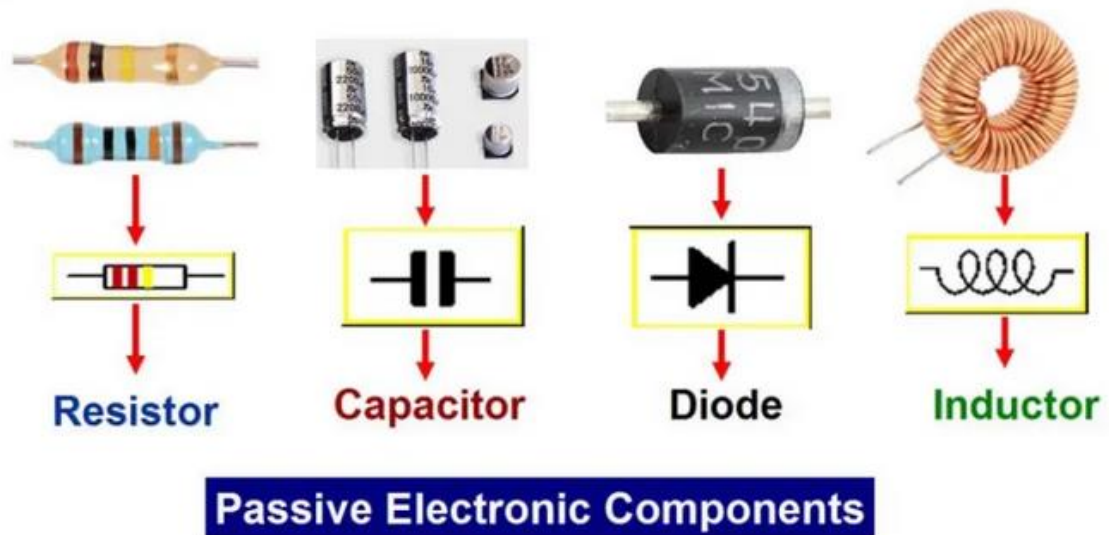


Figure 1.14: Passive Electronic components

2. Active Components

These components are those that have gain or directionality.

Example: Transistors, Integrated Circuits or ICs, Logic Gates

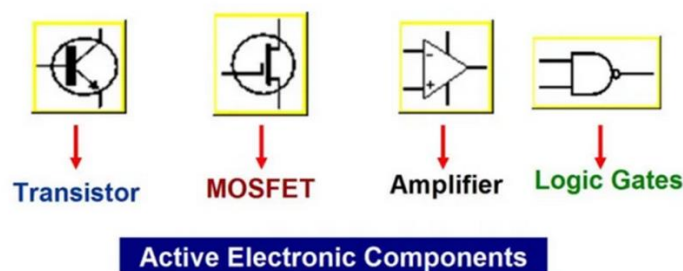


Figure 1.15: active electronic components

Function of Basic Electronic Components

1. **Terminals and Connectors:** Components to make electrical connection
2. **Resistors:** Components used to resist current.
3. **Switches:** Components that may be made to either conduct (closed) or not (open).
4. **Capacitors:** Components that store electrical charge in an electrical field
5. **Magnetic or Inductive Components:** These Electrical components use magnetism.
6. **Network Components:** Components that use more than one type of Passive Component

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7. **Semiconductors:** Electronic control parts with no moving parts
8. **Diodes:** Components that conduct electricity in only one direction
9. **Transistors:** A semiconductor device capable of amplification
10. **Integrated Circuits or ICs:** A microelectronic computer circuit incorporate

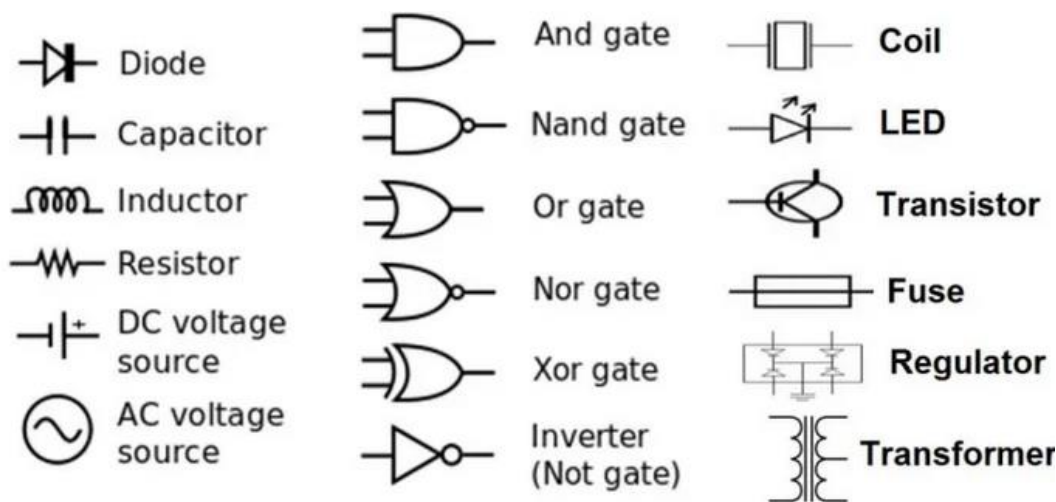


Figure 1.16: Circuit Symbols of Electronic Components

1.2 OHS guidelines

Planning to perform a certain task in a safe manner. When planning work practices with colleagues it is important to keep the health and safety of workers at the forefront of issues to be considered. In workplaces where potentially dangerous machinery is operated, or dangerous situations are encountered, this is not difficult. However, when the potential threat is not so obvious, the health and safety factors may be overlooked. Poorly designed furniture, inadequate lighting, unstable filing cabinets or screens, poor ventilation, inappropriate workloads and much more can become OHS issues. When planning work practices; use the “what if” principle. Try to think of all the things that could go wrong and then what could reasonably be done to prevent them. You are not expected to eliminate risk; this is not possible.

1.2.1 Safety Rules

The following general safety rules are provided as a guide.

- Support your local safety program and take an active part in safety meetings.
- Inspect tools and equipment for safe conditions before starting work.

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- Advise your supervisor promptly of any unsafe conditions or practices.
- Learn the safe way to do your job before you start.
- Think safety, and act safety at all times.
- Obey safety rules and regulations-they are for your protection.
- Wear proper clothing and protective equipment.
- Conduct yourself properly at all times-horseplay is prohibited.
- Operate only the equipment you are authorized to use.
- Report any injury immediately to your supervisor.

1.2.2 Purpose of OHS

A health and safety policy ensures that the employer complies with the Occupational Safety and Health. It provides guidelines for establishing and implementing programs that will reduce workplace hazards, protect lives and promote employee health.

1.2.3 An OHS Policy

An OHS Policy is simply a method of stating how you, your employees, contractors and visitors are expected to behave when they are on Company property or performing Company related activities.

1.3 Electrical wiring/electronic circuits

Preparing the circuits so that connection and termination can be taken easily and safely. Conductor splices and connections are an essential part of any electrical circuit. When conductors join each other or connect to a load, splices or terminals must be used. Therefore, it is important that they be properly made. Any electrical circuit is only as good as its weakest link. The basic requirement of any splice or connection is that it is both mechanically and electrically as sound as the conductor or device with which it is used. Quality workmanship and materials must be used to ensure lasting electrical contact, physical strength, and insulation.

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1.3.1 Conductor Splices and Terminal Connections

Conductor splices and connections are an essential part of any electrical circuit. When conductors join each other or connect to a load, splices or terminals must be used. Therefore, it is important that they be properly made. Any electrical circuit is only as good as its weakest link.

The basic requirement of any splice or connection is that it be both mechanically and electrically as sound as the conductor or device with which it is used. Quality workmanship and materials must be used to ensure lasting electrical contact, physical strength, and insulation. The most common methods of making splices and connections in electrical cables is explained below.

i) Insulation Removal

The preferred method of removing insulation is with a wire-stripping tool, if available. A sharp knife may also be used.

- ***Stripping wire with a hand stripper***

- ✓ Insert the wire into the center of the correct cutting slot for the wire size to be stripped
- ✓ The wire sizes are listed on the cutting jaws of the hand wire strippers beneath each slot.
- ✓ After inserting the wire into the proper slot, close the handles together as far as they will go.
- ✓ Slowly release the pressure on the handles so as not to allow the cutting blades to make contact with the stripped conductor. On some of the newer style hand wire strippers, the cutting jaws have a safety lock that helps prevent this from happening. Continue to release pressure until the gripper jaws release the stripped wire, and then remove.

- ***Knife Stripping***

- ✓ A sharp knife may be used to strip the insulation from a conductor.
- ✓ The procedure is much the same as for sharpening a pencil.
- ✓ The knife should be held at approximately a 60° angle to the conductor.
- ✓ Use extreme care when cutting through the insulation to avoid nicking or cutting the conductor.

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Figure 1.17: Knife Stripping

- **Wire Nut and Split Bolt Splices**

- ✓ The wire nut is a device commonly used to replace the rattail joint splice.
- ✓ The wire nut is housed in plastic insulating material.
- ✓ To use the wire nut, place the two stripe conductors into the wire nut and twist the nut. In so doing, this will form a splice like the rattail joint and insulate itself by drawing the wire insulation into the wire nut insulation.

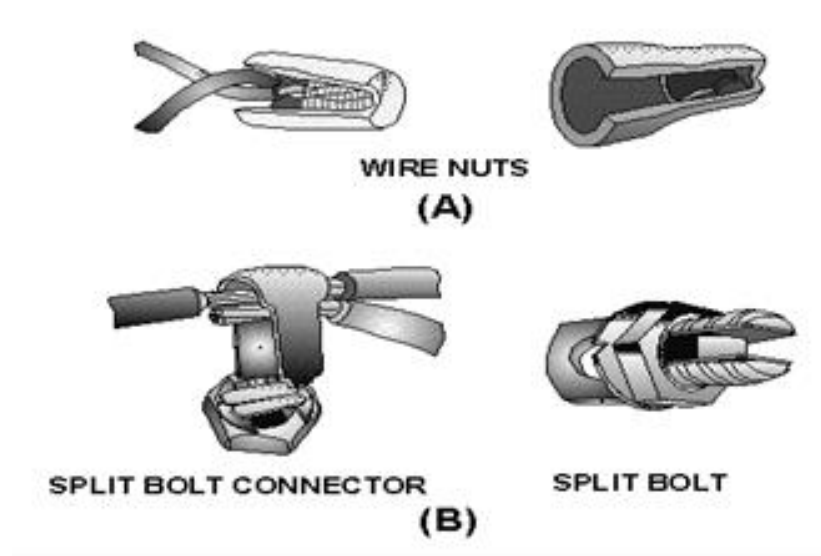


Figure 1.18: Wire Nut and Split Bolt Splices

The split bolt splice (view B) is used extensively to join large conductors. In the illustration, it is shown replacing the knotted tap joint. The split bolt splice can also be used to replace the "buted" splices mentioned previously when using large conductors.

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ii) Splice Insulation

The splices we have discussed so far are usually insulated with tape. The following discussion will cover some characteristics of rubber, friction, and plastic insulation tapes

- ***Rubber Tape***

Latex (rubber) tape is a splicing compound. It is used where the original insulation was rubber. The tape is applied to the splice with a light tension so that each layer presses tightly against the one beneath it. This pressure causes the rubber tape to blend into a solid mass. Upon completion, insulation similar to the original is restored.

In roll form, there is a layer of paper or treated cloth between each layer of rubber tape. This layer prevents the latex from fusing while still on the roll. The paper or cloth is peeled off and discarded before the tape is applied to the splice.

The rubber splicing tape should be applied smoothly and under tension so no air space exists between the layers. Start the first layer near the middle of the joint instead of the end. The diameter of the completed insulated joint should be somewhat greater than the overall diameter of the original wire, including the insulation.

- ***Plastic Electrical Tape***

Plastic electrical tape has come into wide use in recent years. It has certain advantages over rubber and friction tape. For example, it can withstand higher voltages for a given thickness. Single thin layers of certain plastic tape will withstand several thousand volts without breaking down. However, to provide an extra margin of safety, several layers are usually wound over the splice. The extra layers of thin tape add very little bulk. The additional layers of plastic tape provide the added protection normally furnished by friction tape.

- ***Terminal Lugs***

Since most cable wires are stranded, it is necessary to use terminal lugs to hold the strands together to aid in fastening the wires to terminal studs. The terminals used in electrical wiring are either of the soldered or

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crimped type. Terminals used in repair work must be of the size and type specified on the electrical wiring diagram for the particular equipment

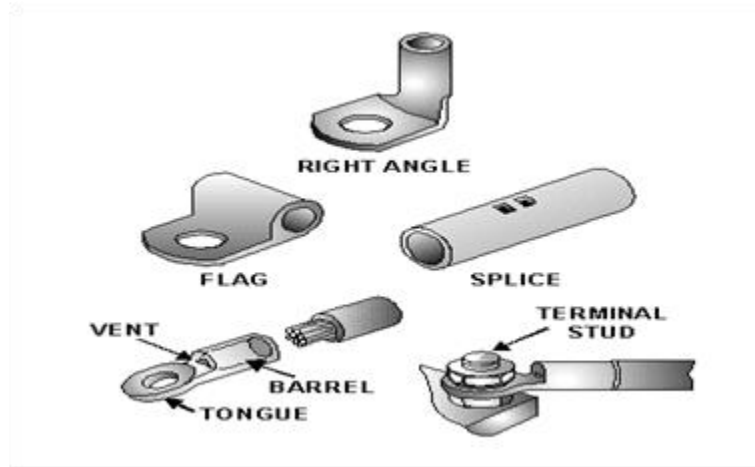


Figure 1.19: Terminal lugs

iii) Soldering

A solder type connection allows for a strong, solid mechanical and electrical connection. Clean the connection well. For electrical circuits you must use a rosin type flux to clean all connections. Do not use acid flux that is commonly used for plumbing installation. The acid based flux will cause corrosion and inherently cause intermittent problems with the electrical signal. The choice of solder is also important. Using a solder standard 60/40 formula will meet the majority of your soldering needs. However, lead-free and high-grade silver solder is available for special applications. Also, use a soldering iron of the proper wattage. If the soldering iron is not hot enough, you may not be able heat the connection enough to get a good solder joint. This may cause what is known as a "cold" solder joint and can cause intermittent problems like opens to occur. However, if the soldering iron is too hot, you can cause damage to the components of the system near the connection. This can also cause the insulation to possibly melt causing the bare primaries to make contact with each other resulting in a short.

- ***Tinning Copper Wire and Cable***

Wires to be soldered to connectors should be stripped so that when the wire is placed in the barrel; there will be a gap of approximately 1/32 inch between the end of the barrel and the end of the insulation. This is done

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to prevent burning the insulation during the soldering process and to allow the wire to flex easier at a stress point. Before copper wires are soldered to connectors, the ends exposed by stripping are tinned to hold the strands solidly together. The tinning operation is satisfactory when the ends and sides of the wire strands are fused together with a coat of solder. Do not tin wires that are to be crimped to solder less terminals or splices

Self-check-1

Direction I: Match the different hand tools with their actual pictures.

_____1.Desoldering Sucker

_____4.For soldering metal

_____2.Soldering Stand

_____5.Long Nose Pliers

_____3.For cutting wires

_____6. Wire Splicer



a



b



c



d



e



f

Direction II: Match the following question column A to column B

A

1. splicing
2. Stripping
3. Terminal Lugs
- 4 wire nut

B

- A. hold the strands together
- B. used for extension purpose
- C. used to replace the rattail joint splice
- D. Removing insulation
- E. connecting wires together

Operation sheet -1

Operation Title: Soldering technique

Instruction: In, solder the given circuit.

Purpose: to solder workshop the given components properly

Required tools and equipment: resistor, solder, soldering iron, desoldering, and strip board

Precautions:

- Never touch the pin of soldering iron

Procedures:

Step 1- Follow the safety procedure

Step 2- Hold the soldering iron like a pen near the base of the handle.

Step 3- Touch the soldering iron onto the joint to be made.

Step 4- Feed a little solder onto the joint.

Step 5- Remove the solder, then the soldering iron while keeping the joint still.

Step 6- Inspect the joint closely. It should look shiny with a volcano shape

Quality criteria:

- Safety
- Soldering technique

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LAP Test 1

Name: _____

Date: _____

Time started: _____

Time finished: _____

Instruction I: Given necessary templates, tools and materials you are required to perform the following tasks within 2 hours

Task 1: Solder the Project

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Unit Two: Calculating Electrical Quantities

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Electrical quantities
- Types of electrical circuit
- Calculating electrical quantities
- Measuring electrical quantities and comparing with calculated values

This unit will also assist you to attain the learning outcomes stated in the cover page.

Specifically, upon completion of this learning guide, you will be able to:

- Identify electrical quantities
- Describe types of electrical circuit
- Calculate electrical quantities
- Measure electrical quantities and comparing with calculated values

1.1.Electrical Quantities

The basic electrical quantities are electrical current and voltage, electrical charge, resistance, capacitance, inductance and electric power

a) Conductors

- An electric current is produced when free electrons move from one atom to the next.
- Materials that permit many electrons to move freely are called conductors.
- Copper, silver, aluminum, zinc, brass, and iron are considered good conductors.

b) Insulators

- Materials that allow few free electrons are called insulators.
- Materials such as plastic, rubber, glass, mica, and ceramic are good insulators.

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An electric cable is one example of how conductors and insulators are used. Electrons flow along a copper conductor to provide energy to an electric device such as a radio, lamp, or a motor. An insulator around the outside of the copper conductor is provided to keep electrons in the conductor.



Figure 2.1: An electric cable

c) Semiconductors

- Semiconductor materials, such as silicon, can be used to manufacture devices that have characteristics of both conductors and insulators.
- Many semiconductor devices will act like a conductor when an external force is applied in one direction. When the external force is applied in the opposite direction, the semiconductor device will act like an insulator. This principle is the basis for transistors, diodes, and other solid-state electronic devices.

d) Current

Electricity is the flow of free electrons in a conductor from one atom to the next atom in the same general direction. This flow of electrons is referred to as current and is designated by the symbol “I”. Electrons move through a conductor at different rates and electric current has different values. The numbers of electrons that pass through a cross section of a conductor in one second determines current. We must remember that atoms are very small. It takes about 1,000,000,000,000,000,000,000 atoms to fill one cubic centimeter of a copper conductor. This number can be simplified using mathematical exponents. Instead of writing 24 zeros after the number 1, write 10^{24} . Trying to measure even small values of current would result in unimaginably large numbers. For this reason, current is measured in an ampere that is abbreviated “amps”. The letter “A” is the symbol for amps. A current of one amp means that in one second about 6.24×10^{18} electrons move through a cross-section of conductor. These numbers are given for information only and you do not need to be concerned with them. It is important, however, that the concept of current flow be understood.

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e) Direction of Current Flow

Some authorities distinguish between electron flow and current flow. Conventional current flow theory ignores the flow of electrons and states that current flows from positive to negative. To avoid confusion, this book will use the electron flow concept, which states that electrons flow from negative to positive.

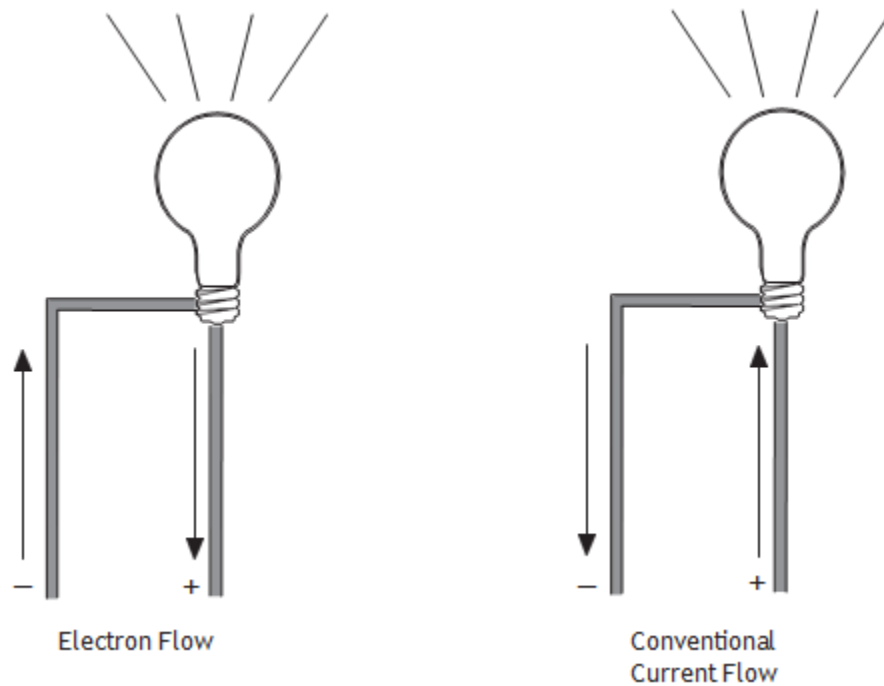


Figure 2.2: Direction of current flow

f) Voltage

Electricity can be compared with water flowing through a pipe. A force is required to get water to flow through a pipe. This force comes from either a water pump or gravity. Voltage is the force that is applied to a conductor that causes electric current to flow.

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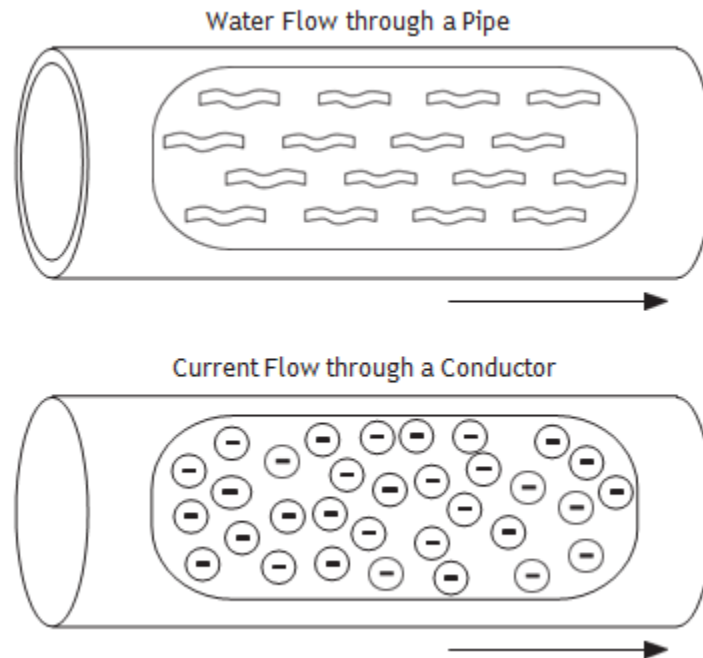


Figure 2.3: Comparison of electricity with water flowing through a pipe

Electrons are negative and are attracted by positive charges. They will always be attracted from a source having an excess of electrons, thus having a negative charge, to a source having a deficiency of electrons that has a positive charge. The force required to make electricity flow through a conductor is called a difference in potential, electromotive force (emf), or more simply referred to as voltage. The letter “E”, or the letter “V” designates voltage. The unit of measurement for voltage is volts, which is also designated by the letter “V”.

g) Capacitors

Capacitors are components that can store electrical pressure (Voltage) for long periods. When a capacitor has a difference in voltage (Electrical Pressure) between its two leads it is said to be charged. A capacitor is charged by forcing a one way (DC) current to flow through it for a short period. It can be discharged by letting an opposite direction current flow out of the capacitor. The amount of charge a capacitor can hold (capacitance) is measured in Farads. In practice, one farad is a very large amount of capacitance, making the most common term used microfarad or one millionth of a farad.

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h) Inductors

Inductors are made by coiling a wire, they are often called Coils. In practice, the names Inductor and Coil are used interchangeably. From the above analogy, it is obvious that a coiled hose will pass Direct Current (DC), since the water flow increases to equal the resistance in the coiled hose after an elapsed period. If the pressure on the plunger is alternated, (pushed, then pulled) fast enough, the water in the coil will never start moving and the Alternating Current (AC) will be blocked.

The nature of a Coil in electronics follows the same principles as the coiled hose analogy. A coil of wire will pass DC and block AC. Recall that the nature of a Capacitor blocked DC and passed AC, the exact opposite of a coil. Because of this, the Capacitor and Inductor are often called Dual Components.

1.2.Types of electrical circuit

A complete path, or circuit, is needed before voltage can cause a current flow through resistances to perform work.

A simple electric circuit consists of a voltage source, some type of load, and a conductor to allow electrons to flow between the voltage source and the load. In the following circuit, a battery provides the voltage source, electrical wire is used for the conductor, and a light provides the resistance. An additional component has been added to this circuit, a switch. There must be a complete path for current to flow. If the switch is open, the path is incomplete and the light will not illuminate. Closing the switch completes the path, allowing electrons to leave the negative terminal and flow through the light to the positive terminal.

An electrical circuit (also known as an electrical network or electric circuit) is an interconnection of various active and passive components in a prescribed manner to form a closed path. Electric current must be able to flow from the source through some conductive medium and then back to the other terminal of the source.

The main parts of an ideal electric circuit are:

1. Electrical sources for delivering electricity to the circuit and are mainly electric generators and batteries

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2. Controlling devices for controlling electricity and are mainly switches, circuit breakers, MCBs, and potentiometer-like devices, etc.
3. Protection devices for protecting the circuit from abnormal conditions and are mainly electric fuses, MCBs, switchgear systems.
4. Conducting path to carry electric current from one point to other in the circuit and these are mainly wires or conductors.
5. Load

Thus, voltage and current are the two basic features of an electric element. Various techniques by which voltage and current across any element in any electric circuit are determined is called electric circuit analysis.

Basic Properties of Electric Circuits

The basic properties of electric circuits include:

- A circuit is always a closed path.
- A circuit always contains at least an energy source that acts as a source of electrons.
- The electric elements include an uncontrolled and controlled source of energy, resistors, capacitors, inductors, etc.
- In an electric circuit, flow of electrons takes place from the negative terminal to the positive terminal.
- The direction of flow of conventional current is from positive to negative terminal.
- The flow of current leads to a potential drop across the various elements.

Types of Electric Circuits

The main types of electric circuits are:

- a) Open circuit
- b) Closed circuit
- c) Short circuit
- d) Series Circuit

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- e) Parallel Circuit
- f) Series Parallel Circuit

a) Open Circuit

- If due to disconnection of any part of an electric circuit if there is no flow of current through the circuit, is said to be an open circuited.



Figure 2.4: Open circuit

b) Closed Circuit

If there is no discontinuity in the circuit and current can flow from one part to another part of the circuit, the circuit is said to be closed circuit.

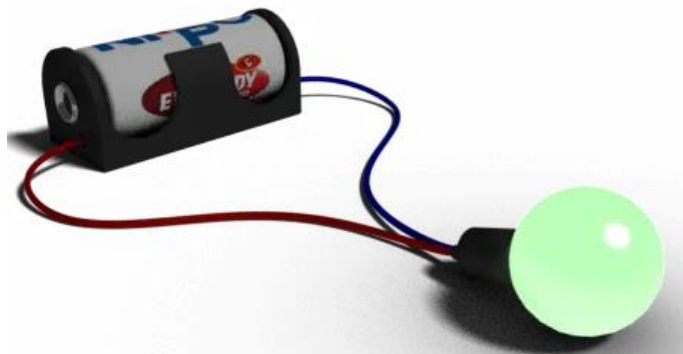


Figure 2.5: Closed circuit

c) Short Circuit

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If two or more phases, one or more phases and earth or neutral of AC system or positive and negative wires or positive or negative wires and earth of DC system touch together directly or connected together by a zero impedance path then the circuit is said to be short-circuited.

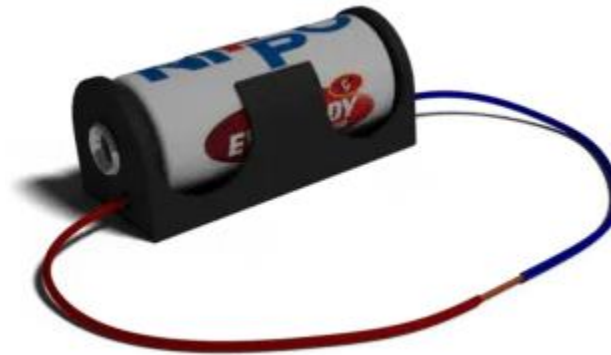


Figure 2.6: Short circuit

d) Series Circuit

A series circuit is the simplest circuit. The conductors, control and protection devices, loads, and power source are connected with only one path for current. The resistance of each device can be different. The same amount of current will flow through each. The voltage across each will be different. If the path is broken, no current flows.

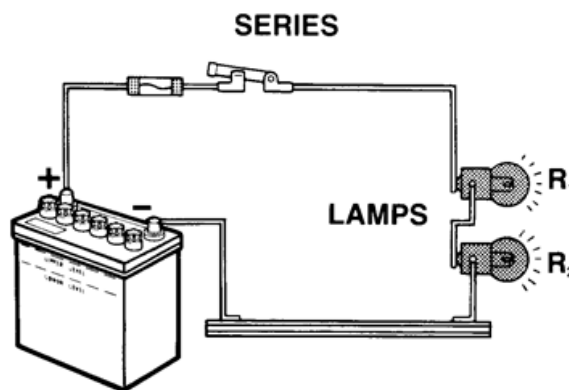


Figure 2.7: Series circuit

e) Parallel Circuit

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A parallel circuit has more than one path for current flow. The same voltage is applied across each branch. If the load resistance in each branch is the same, the current in each branch will be the same. If the load resistance in each branch is different, the current in each branch will be different. If one branch is broken, current will continue flowing to the other branches.

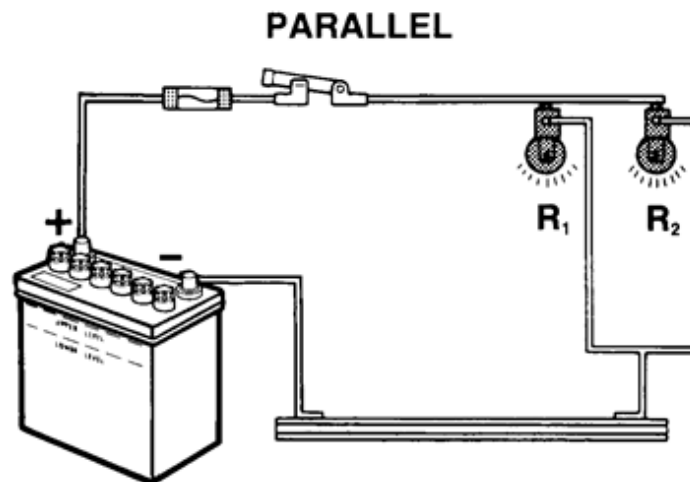


Figure 2.8: Parallel circuit

f) Series-Parallel Circuit

A series-parallel circuit has some components in series and others in parallel. The power source and control or protection devices are usually in series; the loads are usually in parallel. The same current flows in the series portion, different currents in the parallel portion. The same voltage is applied to parallel devices, different voltages to series devices. If the series portion is broken, current stops flowing in the entire circuit. If a parallel branch is broken, current continues flowing in the series portion and the remaining branches.

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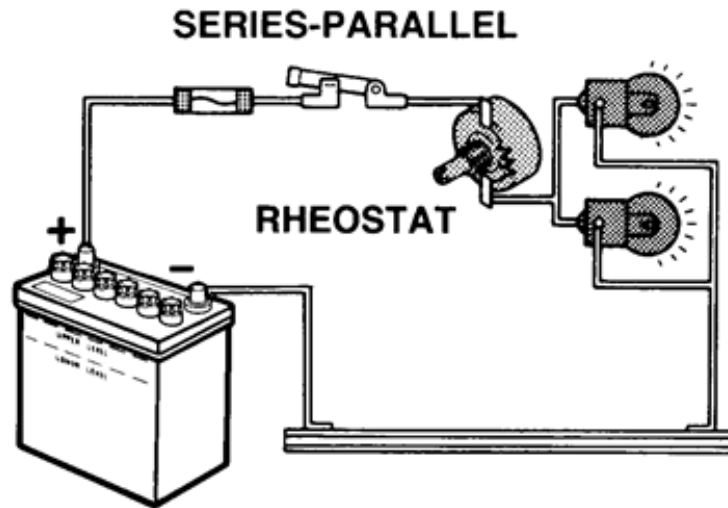


Figure 2.9: Series-parallel circuit

1.3. Calculating electrical quantities

Fundamental relationship between current, voltage, and resistance expressed by ohms law

What is Ohm's Law?

Ohm's law states that the electrical current flowing through any conductor is directly proportional to the potential difference (voltage) between its ends, assuming the physical conditions of the conductor do not change.

In other words, the ratio of potential difference between any two points of a conductor to the current flowing between them is constant, provided the physical conditions (e.g., temperature etc.) do not change.

Ohm formulated a law, which states that current varies directly with voltage and inversely with resistance. From this law the following formula is derived:

$$I = \frac{E}{R}, \quad E = I * R \quad R = \frac{E}{I}$$

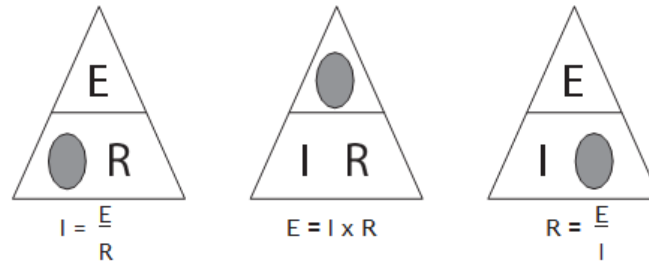
There is an easy way to remember which formula to use. By arranging current, voltage and resistance in a triangle, one can quickly determine the correct formula.

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Ohms law triangles

To use the triangle, cover the value you want to calculate. The remaining letters make up the formula.

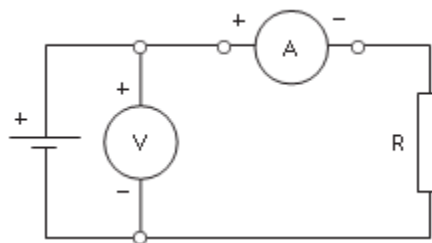


Ohm's Law can only give the correct answer when the correct values are used. Remember the following three rules:

- Current is always expressed in amperes or amps
- Voltage is always expressed in volts
- Resistance is always expressed in ohms

Examples of Solving Ohm's Law

Using the simple circuit below, assume that the voltage supplied by the battery is 10 volts, and the resistance is 5Ω .



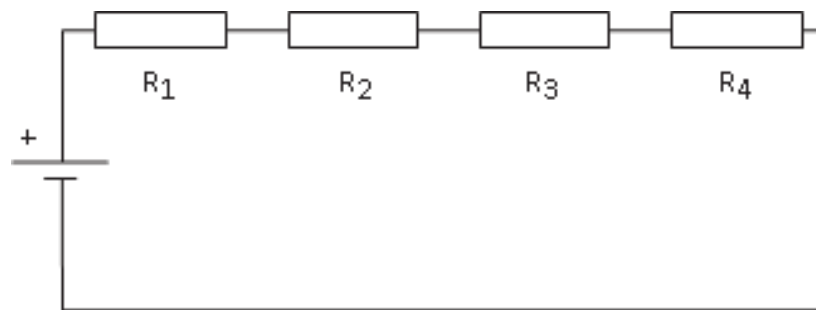
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To find how much current is flowing through the circuit, cover the “I” in the triangle and use the resulting equation.

$$I = \frac{E}{R} \rightarrow I = \frac{10 \text{ Volts}}{5\Omega} \rightarrow I = 2 \text{ Amps}$$

Resistance in Series Circuit

A series circuit is formed when any number of resistors is connected end-to-end so that there is only one path for current to flow. The resistors can be actual resistors or other devices that have resistance. The following illustration shows four resistors connected end-to-end. There is one path of current flow from the negative terminal of the battery through R4, R3, R2, R1 returning to the positive terminal.

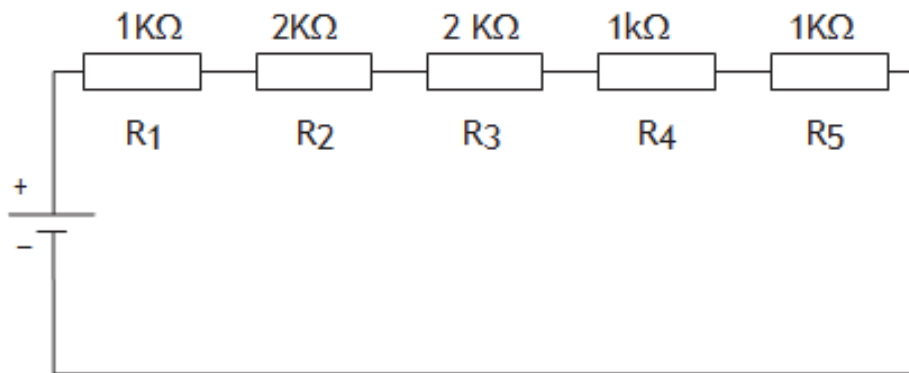


The mathematical formula for resistance in series is:

$$R_{TOTAL} = R_1 + R_2 + R_3 + R_4 + \dots + R_N$$

Example: find the total resistance of the below circuit.

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$$R_T = R_1 + R_2 + R_3 + R_4 + R_5$$

$$R_T = 1 \text{ k} \Omega + 2\text{k}\Omega + 2\text{k}\Omega + 1\text{k}\Omega + 1\text{k}\Omega$$

$$R_T = 7\text{k}\Omega$$

Current in a Series Circuit

The equation for total resistance in a series circuit allows us to simplify a circuit. Using Ohm's Law, the value of current can be calculated. **Current is the same** anywhere it is measured in a series circuit.

$$I_T = I_1 = I_2 = I_3 = I_4 = \dots = I_N$$

Example: find the total Current of the below circuit

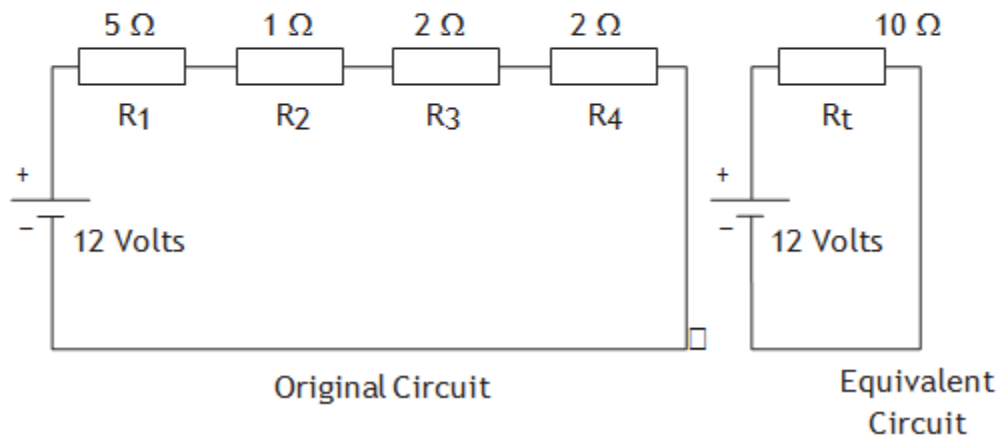
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$$I = \frac{E}{R}$$

$$I = \frac{12}{10}$$

$$I = 1.2 \text{ Amps}$$

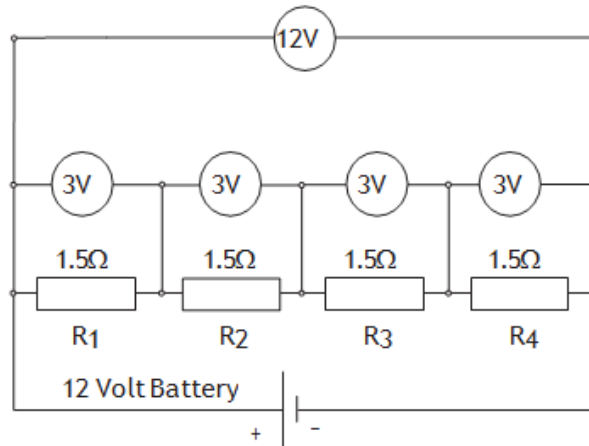


Voltage in a Series Circuit

Voltage can be measured across each of the resistors in a circuit. The voltage across a resistor is referred to as a voltage drop. A German physicist, Kirchhoff, formulated a law, which states the sum of the voltage drops across the resistances of a closed circuit equals the total voltage applied to the circuit. In the following illustration, four equal value resistors of 1.5Ω each have been placed in series with a 12-volt battery. Ohm's Law can be applied to show that each resistor will “drop” an equal amount of voltage.

$$V_T = V_1 + V_2 + V_3 + V_4 + \dots + V_N$$

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First, solve for total resistance:

$$R_T = R_1 + R_2 + R_3 + R_4$$

$$R_T = 1.5\Omega + 1.5\Omega + 1.5\Omega + 1.5\Omega$$

$$R_T = 6\Omega$$

Second, solve for current:

$$I = E / R$$

$$I = 12V / 6\Omega$$

$$I = 2 \text{ Amps}$$

Third, solve for voltage across any resistor:

$$E = I * R$$

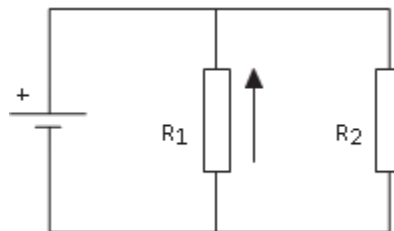
$$E = 2A * 1.5\Omega$$

$$E = 3 \text{ Volts}$$

If voltage were measured across any single resistor, the meter would read three volts. If voltage were read across a combination of R3 and R4, the meter would read six volts. If voltage were read across a combination of R2, R3, and R4, the meter would read nine volts. If the voltage drops of all four resistors were added together, the sum would be 12 volts, the original supply voltage of the battery.

Resistance in a Parallel Circuit

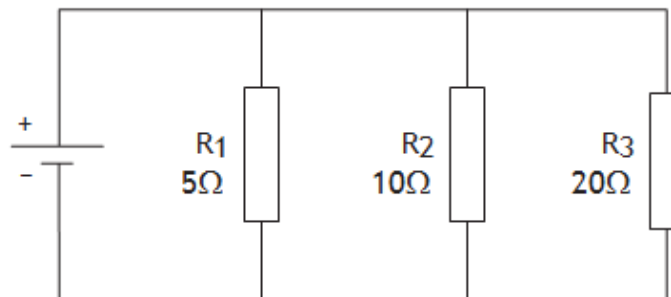
A parallel circuit is formed when two or more resistances are placed in a circuit side-by-side so that current can flow through more than one path. The illustration shows two resistors placed side-by-side. There are two paths of current flow. One path is from the negative terminal of the battery through R1 returning to the positive terminal. The second path is from the negative terminal of the battery through R2 returning to the positive terminal of the battery.



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_N}$$

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_N}}$$

Example: Find the total Resistance of the below circuit



Solution

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$$R_T = \frac{1}{\frac{1}{5\Omega} + \frac{1}{10\Omega} + \frac{1}{20\Omega}}$$

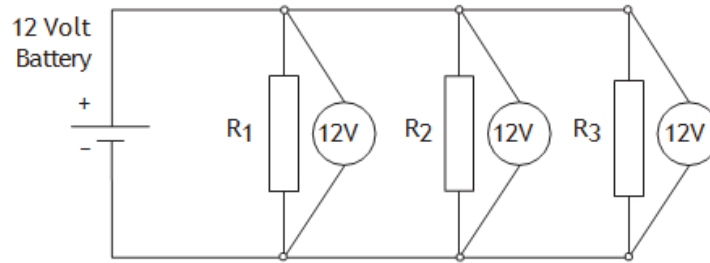
$$R_T = 2.86\Omega$$

Voltage in a Parallel Circuit

When resistors are placed in parallel across a voltage source, the voltage is the same across each resistor. Parallel resistors have a common Voltage across them.

$$V = V_1 = V_2 = V_3 = \dots = V_N$$

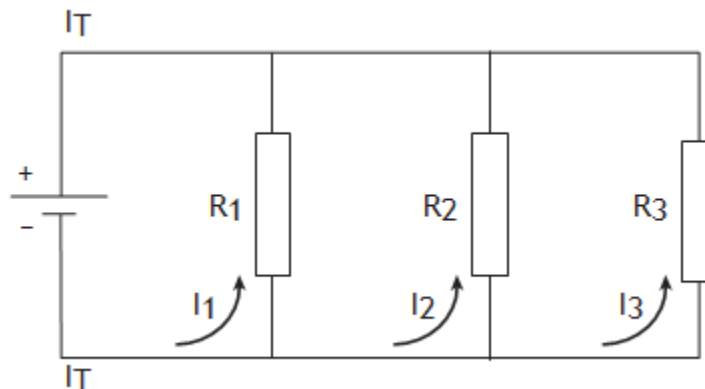
In the following illustration three resistors are placed in parallel across a 12 volt battery. Each resistor has 12 volts available to it.



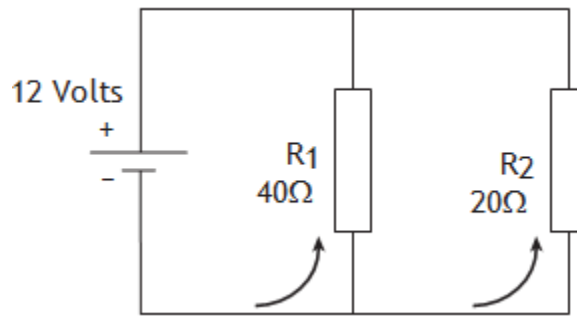
Current in a Parallel Circuit

Current flowing through a parallel circuit divides and flows through each branch of the circuit. Total circuit current flow is equal to the sum of all the individual branch currents added together.

$$I = I_1 + I_2 + I_3 + \dots + I_N$$



Example: Find the total current, and the current pass through each resistor.



Solution:

Using Ohm's Law, the total current for each circuit can be calculated

$$I_1 = \frac{E}{R_1}$$

$$I_1 = \frac{12\text{Volts}}{40\Omega}$$

$$I_1 = 0.3 \text{ Amps}$$

$$I_2 = \frac{E}{R_2}$$

$$I_2 = \frac{12 \text{ Volts}}{20\Omega}$$

$$I_2 = 0.6 \text{ Amps}$$

$$I_T = I_1 + I_2$$

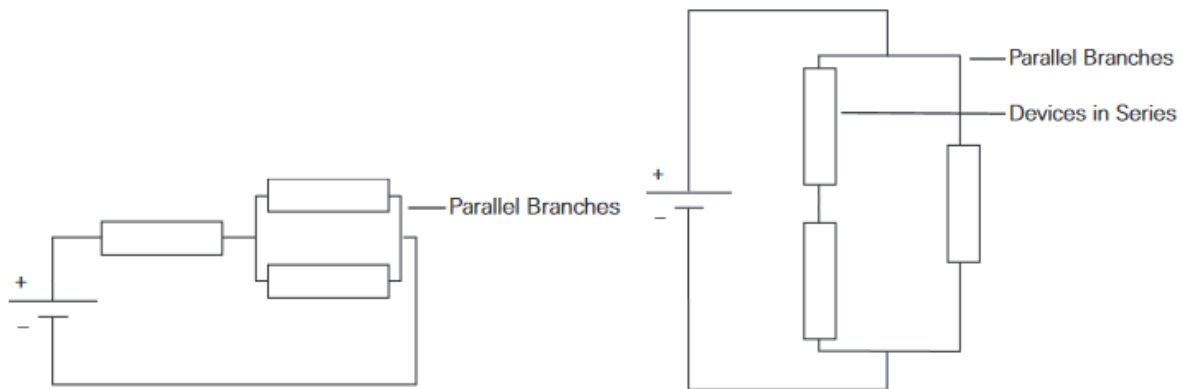
$$I_T = 0.3 \text{ Amps} + 0.6 \text{ Amps}$$

$$I_T = 0.9 \text{ Amps}$$

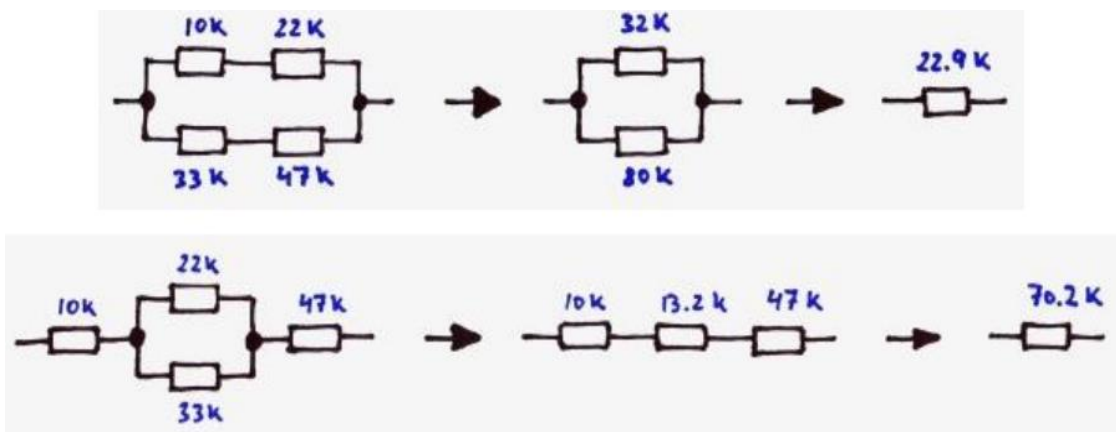
Series-Parallel Circuits

Series-parallel circuits are also known as compound circuits. At least three resistors are required to form a series-parallel circuit. The following illustrations show two ways a series-parallel combination could be found. A series-parallel connection is nothing else than a combination of a serial and a parallel connection. The calculation has to be done step by step with using the above mentioned formulas.

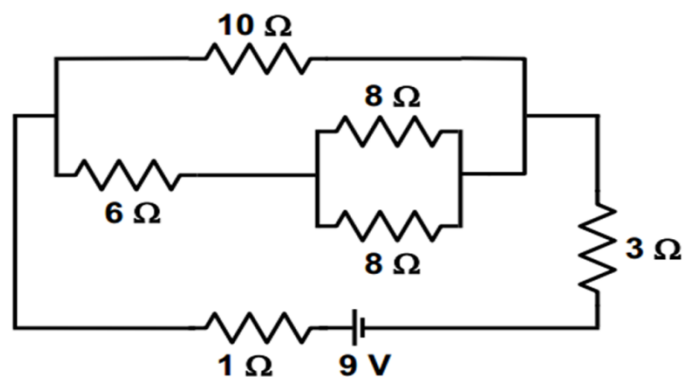
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Example of Series-Parallel Circuits

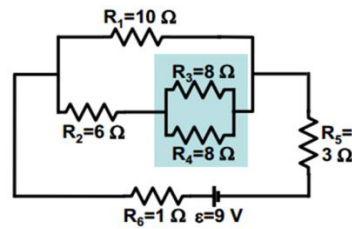


Example: Calculate Req



Solution:

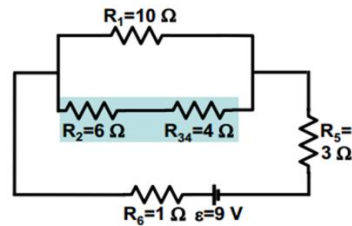
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R_3 and R_4 are in parallel.

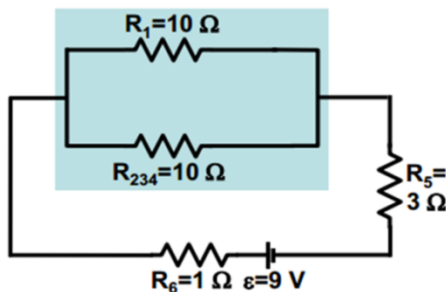
$$\frac{1}{R_{34}} = \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{8} + \frac{1}{8} = \frac{2}{8} = \frac{1}{4}$$

$$R_{34} = 4 \Omega$$



R_2 and R_{34} are in series.

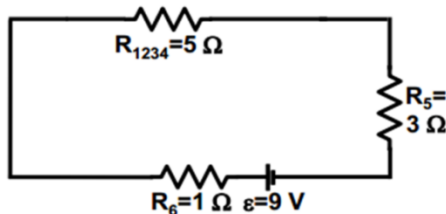
$$R_{234} = R_2 + R_{34} = 6 + 4 = 10 \Omega$$



R_1 and R_{234} are in parallel.

$$\frac{1}{R_{1234}} = \frac{1}{R_1} + \frac{1}{R_{234}} = \frac{1}{10} + \frac{1}{10} = \frac{2}{10} = \frac{1}{5}$$

$$R_{1234} = 5 \Omega$$



R_{1234} , R_5 and R_6 are in series.

$$R_{eq} = R_{1234} + R_5 + R_6 = 5 + 3 + 1$$

$$R_{eq} = 9 \Omega$$

1.4.Measuring electrical quantities and comparing with calculated values

Electrical Units of Measure

Electrical Units of Measurement are used to express standard electrical units along with their prefixes when the units are too small or too large to express as a base unit

The standard electrical units of measure used for the expression of voltage, current and resistance are the Volt [V], Ampere [A] and Ohm [Ω] respectively. These electrical units of measurement are based on the

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International (metric) System, also known as the SI System with other commonly used electrical units being derived from SI base units. Sometimes-in electrical or electronic circuits and systems it is necessary to use multiples or sub-multiples (fractions) of these standard electrical measuring units when the quantities being measured are very large or very small. The following table gives a list of some of the standard electrical units of measure used in electrical formulas and component values.

Table 1: Standard Electrical Units of Measure

Electrical Parameter	Measuring Unit	Symbol	Description
Voltage	Volt	V or E	Unit of Electrical Potential $V = I \times R$
Current	Ampere	I or i	Unit of Electrical Current $I = V \div R$
Resistance	Ohm	R or Ω	Unit of DC Resistance $R = V \div I$
Conductance	Siemen	G or \mathcal{U}	Reciprocal of Resistance $G = 1 \div R$
Capacitance	Farad	C	Unit of Capacitance $C = Q \div V$
Charge	Coulomb	Q	Unit of Electrical Charge $Q = C \times V$
Inductance	Henry	L or H	Unit of Inductance $V_L = -L(di/dt)$
Power	Watts	W	Unit of Power $P = V \times I$ or $I^2 \times R$
Impedance	Ohm	Z	Unit of AC Resistance $Z^2 = R^2 + X^2$
Frequency	Hertz	Hz	Unit of Frequency $f = 1 \div T$

Table 2: Prefixes

Prefix	Symbol	Multiplier	Power of Ten
Terra	T	1,000,000,000,000	10^{12}
Giga	G	1,000,000,000	10^9
Mega	M	1,000,000	10^6
Kilo	K	1,000	10^3
None	None	1	10^0
Centi	C	1/100	10^{-2}
Milli	M	1/1,000	10^{-3}
Micro	μ	1/1,000,000	10^{-6}
Nano	N	1/1,000,000,000	10^{-9}

So to display the units or multiples of units for Resistance, Current or Voltage we would use as an example:

- $1\text{kV} = 1$ kilo-volt – which is equal to 1,000 Volts.
- $1\text{mA} = 1$ milli-amp – which is equal to one thousandths (1/1000) of an Ampere.
- $47\text{k}\Omega = 47$ kilo-ohms – which is equal to 47 thousand Ohms.
- $100\mu\text{F} = 100$ micro-farads – which is equal to 100 millionths (100/1,000,000) of a Farad.
- $1\text{kW} = 1$ kilo-watt – which is equal to 1,000 Watts.
- $1\text{MHz} = 1$ mega-hertz – which is equal to one million Hertz.

To convert from one prefix to another it is necessary to either multiply or divide by the difference between the two values. For example, convert 1MHz into kHz.

Well we know from above that 1MHz is equal to one million (1,000,000) hertz and that 1kHz is equal to one thousand (1,000) hertz, so one 1MHz is one thousand times bigger than 1kHz. Then to convert Mega-hertz into Kilo-hertz we need to multiply mega-hertz by one thousand, as 1MHz is equal to 1000 kHz.

Likewise, if we needed to convert kilo-hertz into mega-hertz we would need to divide by one thousand. A much simpler and quicker method would be to move the decimal point either left or right depending upon whether you need to multiply or divide.

Electrical quantity measuring instruments

Electrical measuring instruments are a type of device that measures the electrical quantity

- a) Ohm Meter
- b) Volt Meter
- c) Ammeter
- d) Clamp Meter
- e) Watt Meter
- f) Multi Meter

a) Ohmmeter

An ohmmeter is an electrical measuring instrument that measure electrical resistance. measures across the resistor (but be sure the circuit is not turned on “hot”).

- Micro-ohmmeter makes low resistance measurement.
- Mega-ohmmeter measure large values of resistance
- The SI unit of resistance is ohm (Ω).

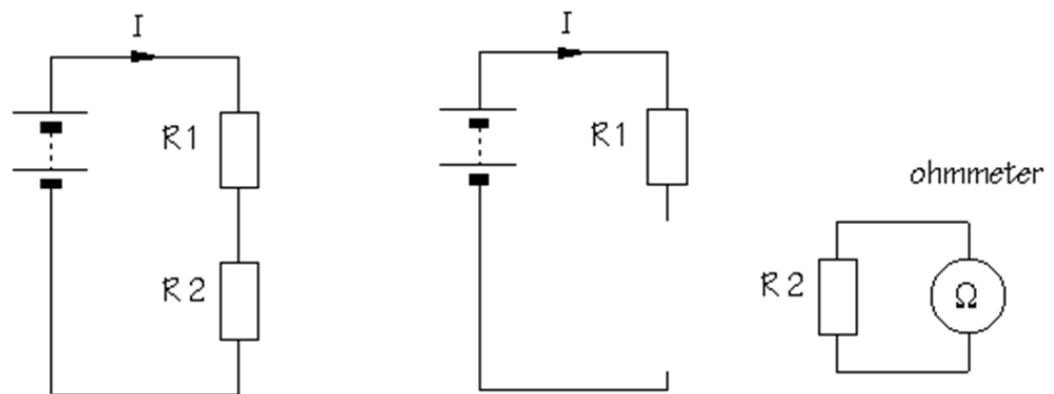


Figure 2.10: Ohmmeter connection

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b) Voltmeter

A voltmeter is an instrument used for measuring voltage between two points in an electric circuit. It is used in parallel with a circuit to be measured. It measures across the circuit (in parallel to the voltage to be measured) .

There are two types of voltmeter

1. Analog: - voltmeter moves a pointer across a scale in proportion to the voltage of the circuit.
2. Digital:- voltmeter gives a numerical display of voltage

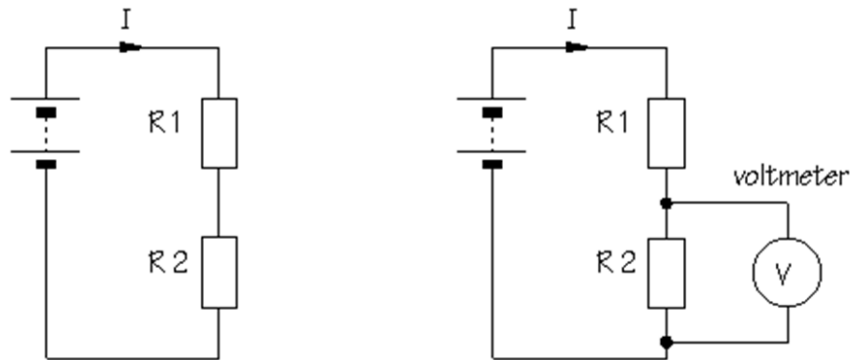


Figure 2.11: Voltmeter connection

c) Ammeter

An ammeter is an instrument used to measure the electrical current in a circuit, the flow of electrons in the circuit. Ammeter must be part of the circuit to measure the current. Electrical current are measured in amperes (A), therefore the SI unit of current is ampere. Hence the name instruments used to measure smaller current, in the milli-ampere, or microampere range, are designated as milli-ammeters or micro-ammeters.

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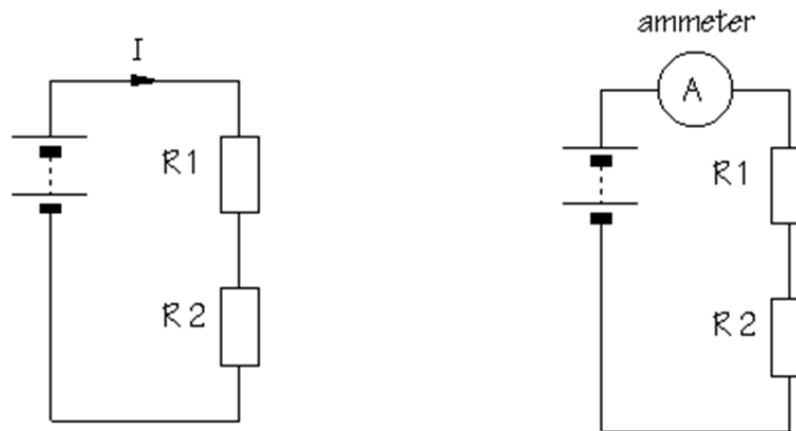


Figure 2.12: Ammeter connection

d) Clamp Meter

Clamp Meter is an electrical device having two jaws, which open to allow clamping around an electrical conductor. This allows properties of the electric current in the conductor to be measured, without having to make physical contact with the wire.

e) Wattmeter

The wattmeter is an instrument used for measuring the electric power (the rate of electrical energy) in watts of any given circuit.

$$P = VI,$$

Where P-Power, V-Voltage, and I-Current

f) Multimeter

Multimeter or volt-ohmmeter is an electronic measuring instrument that combines several measurement functions in one unit. A typical Multimeter would include basic features such as the ability to measure voltage, current and resistance. A Multimeter is a combination of a multi-range AC, DC meters.

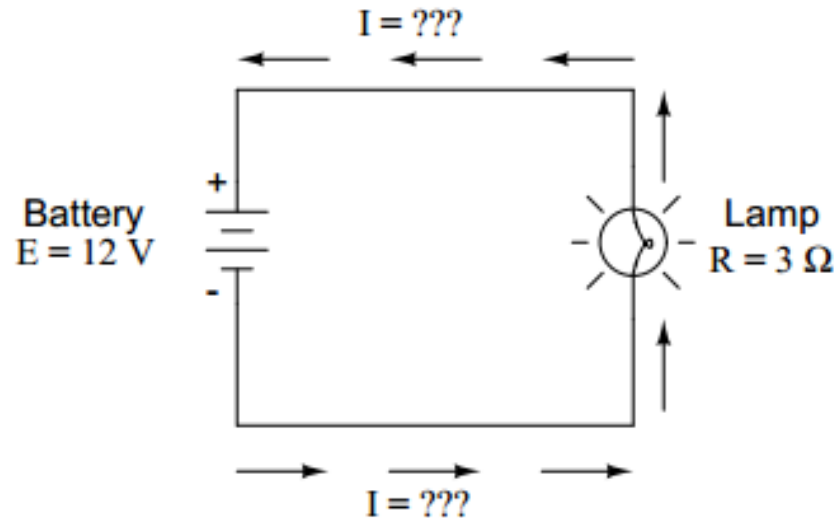
Self- check2

Direction I: Define the following

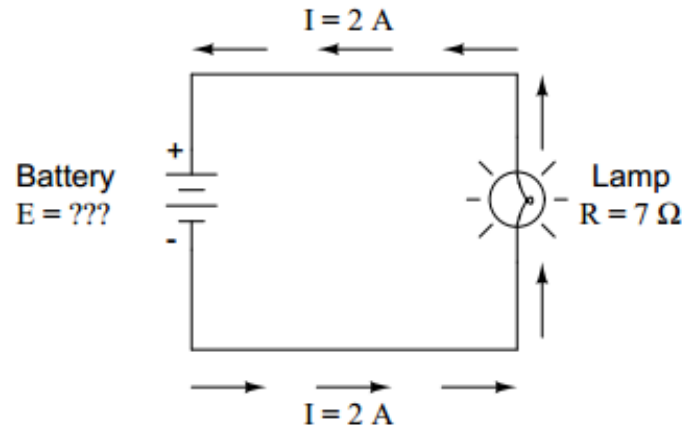
- Conductor
- Insulator
- Current
- Voltage
- Resistance
- Open circuit
- Short circuit
- Closed circuit
- Series circuit
- Parallel circuit
- Ohms law

Direction II: Answer the following question clearly

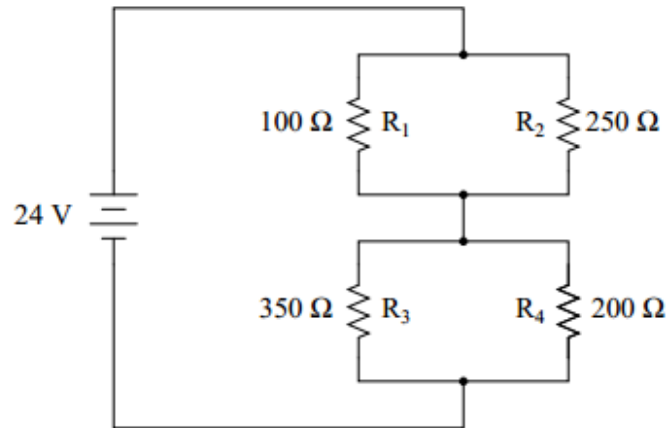
- Calculate the amount of current (I) in a circuit, given values of voltage (E) and resistance (R).



2. Calculate the amount of voltage supplied by a battery, given values of current (I) and resistance (R).



3. Find total resistance of the following circuits



Note: Satisfactory rating - 3 points

Unsatisfactory - below 3 points

Unit Three: Circuit Diagrams

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Electronic circuit diagrams
- Representing electronic components using symbol

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Draw electronic circuit diagrams
- Depict electronic components using symbol

3.1 Electronic circuit diagrams

3.1.1 Series and Parallel Circuits

There are two basic ways in which to connect more than two circuit components: series and parallel.

a) Series Configuration Circuit

First, an example of a series circuit:

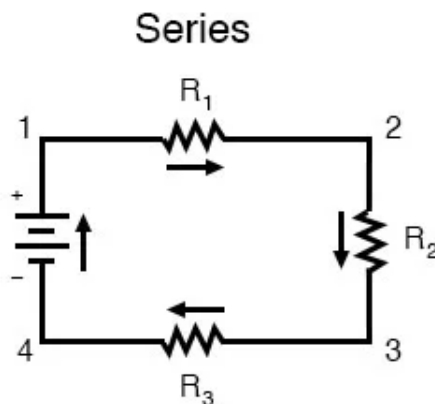


Figure 3.1: Series Circuit diagram

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Here, we have three resistors (labeled R_1 , R_2 , and R_3) connected in a long chain from one terminal of the battery to the other. (It should be noted that the subscript labeling—those little numbers to the lower-right of the letter “R”—are unrelated to the resistor values in ohms. They serve only to identify one resistor from another.)

The defining characteristic of a series circuit is that there is only one path for current to flow. In this circuit, the current flows in a clockwise direction, from point 1 to point 2 to point 3 to point 4 and back around to 1.

b) Parallel Circuit Configuration

Now, let’s look at the other type of circuit, a parallel configuration:

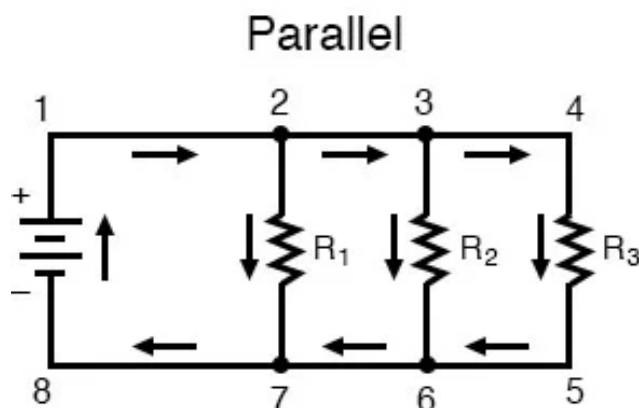


Figure 3.2: Parallel circuit diagram

Again, we have three resistors, but this time they form more than one continuous path for current to flow. There is one path from 1 to 2 to 7 to 8 and back to 1 again. There is another from 1 to 2 to 3 to 6 to 7 to 8 and back to 1 again. Then there is a third path from 1 to 2 to 3 to 4 to 5 to 6 to 7 to 8 and back to 1 again. Each individual path (through R_1 , R_2 , and R_3) is called a branch.

The defining characteristic of a parallel circuit is that all components are connected between the same set of electrically common points. Looking at the schematic diagram, we see that points 1, 2, 3, and 4 are all electrically common. So are points 8, 7, 6, and 5. Note that all resistors, as well as the battery, are connected

between these two sets of points. In addition, of course, the complexity does not stop at simple series and parallel either! We can have circuits that are a combination of series and parallel, too.

c) Series-Parallel Configuration Circuit

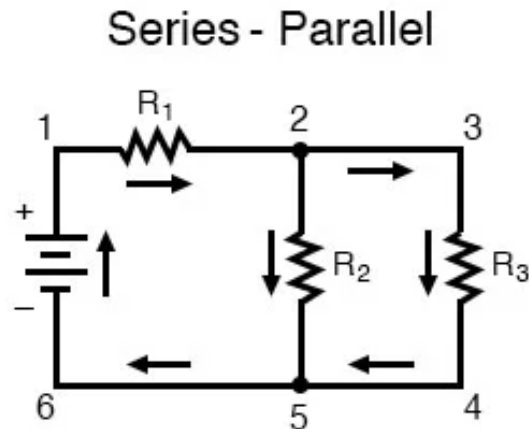


Figure 3.3: Series-parallel circuit diagram

In this circuit, we have two loops for the current to flow through one from 1 to 2 to 5 to 6 and back to 1 again, and another from 1 to 2 to 3 to 4 to 5 to 6 and back to 1 again. Notice how both current paths pass through R_1 (from point 1 to point 2). In this configuration, we'd say that R_2 and R_3 are in parallel with each other, while R_1 is in series with the parallel combination of R_2 and R_3 .

3.1.2 The Basics of Series and Parallel Connections

i) What is a series connection?

The basic idea of a “series” connection is that components are connected end-to-end in a line to form a single path through which current can flow:

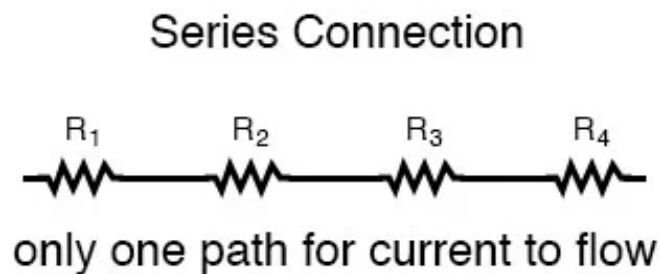


Figure 3.4: Series connection

ii) What Is a Parallel Connection?

The basic idea of a “parallel” connection, on the other hand, is that all components are connected across each other’s leads. In a purely parallel circuit, there are never more than two sets of electrically common points, no matter how many components are connected. There are many paths for current flow, but only one voltage across all components:

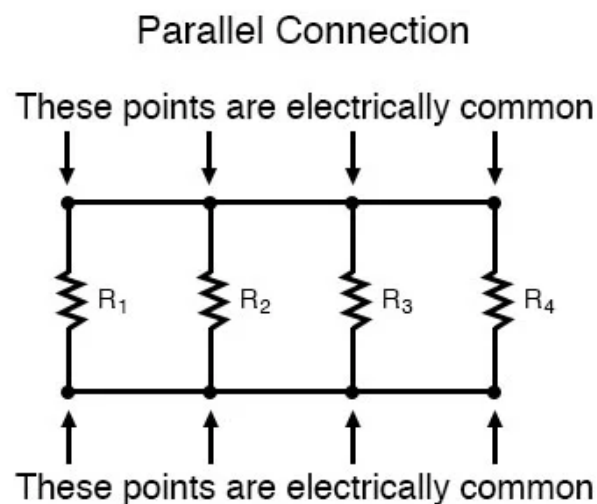


Figure 3.5: Parallel connection

Series and parallel resistor configurations have very different electrical properties. We will explore the properties of each configuration in the sections to come.

Review:

- In a series circuit, all components are connected end-to-end, forming a single path for current flow.
- In a parallel circuit, all components are connected across each other, forming exactly two sets of electrically common points.
- A “branch” in a parallel circuit is a path for electric current formed by one of the load components (such as a resistor).

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3.2 Representing Electronic components using symbol

Circuit diagrams show how electronic components are connected together. Each component is represented by a symbol.

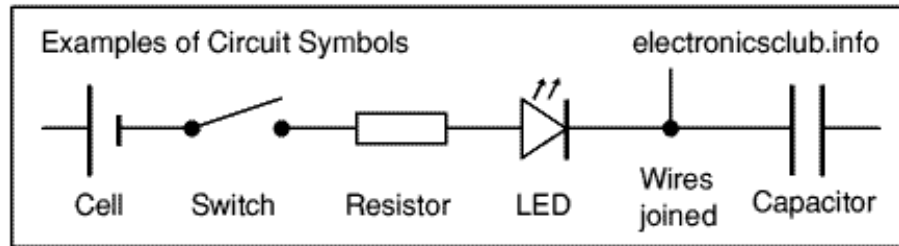


Figure 3.6: Circuit symbols

Circuit diagrams and component layouts

Circuit diagrams show the connections as clearly as possible with all wires drawn neatly as straight lines. The actual layout of the components is usually quite different from the circuit diagram and this can be confusing for the beginner. The secret is to concentrate on the connections, not the actual positions of components.

A circuit diagram is useful when testing a circuit and for understanding how it works. That is why instructions for projects usually include a circuit diagram as well as the strip board or printed circuit board layout, which you need to build the circuit.

Example

The circuit diagram and strip board layout for the timer project are shown below - the circuit diagram is clearly different from the layout on strip board.

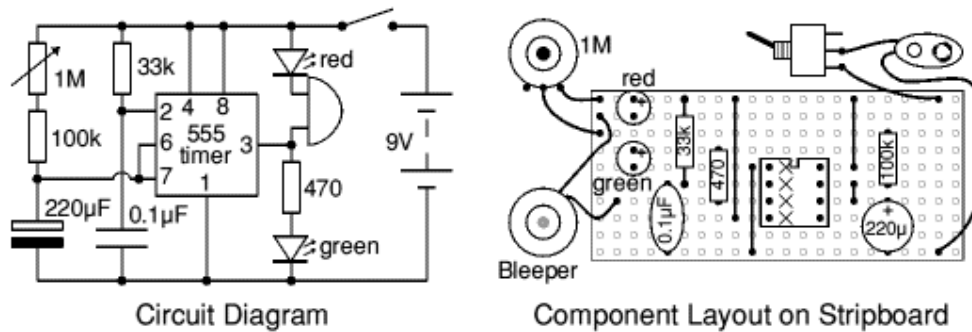


Figure 3.7: Circuit diagram and strip board layout

Good and Bad Circuit Diagrams

Drawing circuit diagrams is not difficult but it takes a little practice to draw neat, clear diagrams. This is a useful skill for science as well as electronics. You will certainly need to draw circuit diagrams if you design your own circuits.

Follow these tips for best results:

- Use the correct symbol for each component.
- Draw wires as straight lines (use a ruler).
- Label components such as resistors and capacitors with their values.
- The positive (+) supply should be at the top and the negative (-) supply at the bottom. The negative supply is usually labeled 0V, zero volts (this is explained on the voltage page).

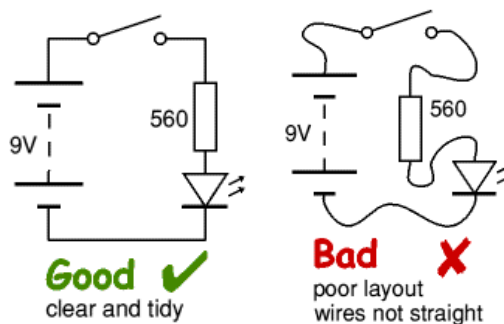


Figure 3.8: Good and bad circuit diagrams

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Self-check 3

Direction I: say True or False

1. There are two basic ways in which to connect more than two circuit components those are series and parallel
2. The amount of current in series circuit is different, and in parallel circuit is the same.
3. In a series circuit, all components are connected end-to-end, forming a single path for current flow.
4. In a parallel circuit, all components are connected across each other, forming exactly two sets of electrically common points.
5. One characteristic of a series circuit is that there is only one path for current to flow

Direction II: Answer the following question properly

Draw one example of series, parallel, and series-parallel circuit

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Unit Four: Construct Electronic Circuits

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Components and material requirements
- Tools, equipment and electronic components
- Construction of circuit using components and wiring techniques
- Testing constructed circuit

This unit will also assist you to attain the learning outcomes stated in the cover page.

Specifically, upon completion of this learning guide, you will be able to:

- Identify components and material requirements
- Select tools, equipment and electronic components
- Construct circuit using components and wiring techniques
- Test constructed circuit

4.1 Components and Material Requirement

Numerous basic electronic components are used for building electronic circuits. Without these components, circuit designs are never complete or did not function well. These components include resistors, diodes, capacitors, integrated circuits, and so on. Some of these components consist of two or more terminals that are soldered to circuit boards. Some may be packaged types like integrated circuits in which different semiconductor devices are integrated.

Electronic components are basic discrete devices in any electronic system to use in electronics otherwise different associated fields. These components are basic elements that are used to design electrical and electronic circuits. These components have a minimum of two terminals which are used to connect to the circuit. The classification of electronic components can be done based on applications like active, passive, and electromechanical.

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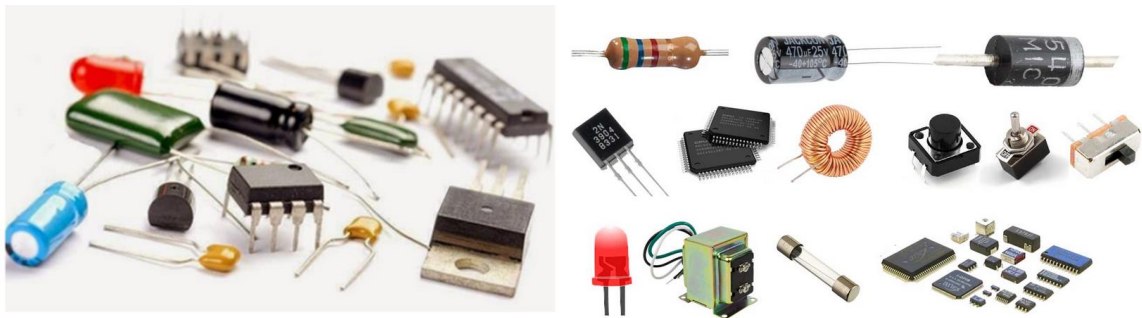


Figure 4.1: Electronic components

Electronic components function depends on type and need of the circuit. These Electronic components are basic electronic parts packaged in a discrete form with two or more connecting leads or metallic pads.

Electronic Components are intended to be connected together, usually by soldering to a Printed Circuit Board (PCB), to create an electronic circuit with a particular function (for example an amplifier, radio receiver, oscillator, wireless). Some of the Main Electronic Components are Resistor, Capacitor, Transistor, Diode, Operational Amplifier, Resistor Array, Logic Gate etc.

4.2 Components and wiring techniques

A pin connection: works essentially like a lapped joint. It transfers vertical and horizontal shear loads and cannot resist any bending or moment (rotational) forces. Many pin connections might look like they are designed to rotate but do not actually function as points of rotation for the structure.

A clamp: is a fastening device used to hold or secure objects tightly together to prevent movement or separation through the application of inward pressure.

Plugs: a device for making an electrical connection between an appliance and the mains, consisting of an insulated casing with metal pins that fit into holes in a socket. "the cable is fitted with a two-pin plug"

Soldering: is a process in which two or more items are joined together by melting and putting a filler metal (solder) into the joint, the filler metal having a lower melting point than the adjoining metal.

Termination: is the process of connecting lugs or connectors to the wires as well as the preparation of the wire ends to enable them to be connected to the terminals of electrical equipment

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a) Soldering

After splicing, conductors must be soldered. Soldering adds security to the splice and discourages conductor oxidation. To do an effective soldering job, the parts to be soldered must be clean. Use sand paper or lightly scrap the conductor with a knife.

To ensure a good solder job, use noncorrosive soldering flux. Soldering flux performs three functions.

- 1) It is an additional cleaning agent.
- 2) It aids in tinning or coating the conductor when solder is applied.
- 3) It ensures adhesion of solder to the splice.

Acid type flux must never be used in electrical soldering job.

After the splice is completed and is, mechanically secure, apply heat with soldering iron or solder gun. Remove the heat momentarily and apply small amount of flux once again, apply the heat until the flux sizzles. Touch solder to the splice solder to the splice and if its surface hot is enough, the solder will flow freely and neatly throughout the splice. A well-soldered splice will be smooth, clean and have a shiny surface. Only enough solder to cover the connection is necessary, avoid a buildup of solder. Finally proceed to insulate the splice.

a) Soldering Gun

Depending on the size of our work piece, we use soldering gun with different power rating. The soldering iron must produce sufficient heat for heating the entire work piece, i.e. we need to use high power soldering iron for thick wires and copper bars. Low powdered nonce for thin wires and small parts. For soldering two pieces, choose the right size of soldering iron. Keep your soldering gun in good condition. Tighten the screws to fix the soldering copper.

How to Solder?

First a few safety precautions:

- **Never touch the element or tip of the soldering iron.**
They are very hot (about 400°C) and will give you a nasty burn.
- **Take great care to avoid touching the mains flex with the tip of the iron.** The

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iron should have a heatproof flex for extra protection. An ordinary plastic flex will melt immediately if touched by a hot iron and there is a serious risk of burns and electric shock.

- **Always return the soldering iron to its stand when not in use.**

Never put it down on your workbench, even for a moment!

- **Work in a well-ventilated area.**

The smoke formed as you melt solder is mostly from the flux and quite irritating. Avoid breathing it by keeping your head to the side of, not above, your work.

- **Wash your hands after using solder.**

Solder contains lead, which is a poisonous metal.

Preparing the soldering iron:

- **Place the soldering iron in its stand and plug in.**

The iron will take a few minutes to reach its operating temperature of about 400°C.

- **Wait a few minutes for the soldering iron to warm up.**

You can check if it is ready by trying to melt a little solder on the tip.

- **Melt a little solder on the tip of the iron.**

This is called '*tinning*' and it will help the heat to flow from the iron's tip to the joint. It only needs to be done when you plug in the iron, and occasionally while soldering if you need to wipe the tip clean on the sponge.

What is a solder?

Solder is an alloy (mixture) of tin and lead, typically 60% tin and 40% lead. It melts at a temperature of about 200°C. Coating a surface with

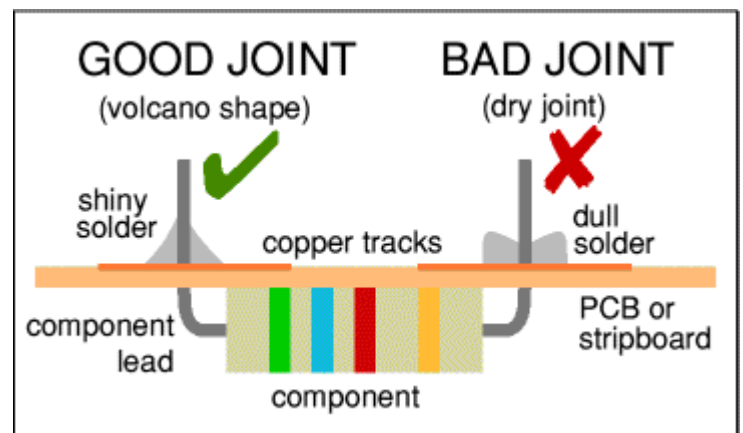


Figure 4.11: Soldering components



Figure 4.12: Solder

solder is called 'tinning' because of the tin content of solder. Lead is poisonous and you should always wash your hands after using solder.

Solder for electronics use contains tiny cores of flux, like the wires inside a mains flex. The flux is corrosive, like an acid, and it cleans the metal surfaces as the solder melts. This is why you must melt the solder actually on the joint, not on the iron tip.

Without flux, most joints would fail because metals quickly oxidize and the solder itself will not flow properly onto a dirty, oxidized, metal surface.

b) Desoldering

At some stage, you will probably need to desolder a joint to remove or re-position a wire or component. There are two ways to remove the solder:

With a desoldering pump (solder sucker)

- Set the pump by pushing the spring-loaded plunger down until it locks.
- Apply both the pump nozzle and the tip of your soldering iron to the joint.
- Wait a second or two for the solder to melt.
- Then press the button on the pump to release the plunger and suck the molten solder into the tool.
- Repeat if necessary to remove as much solder as possible.
- The pump will need emptying occasionally by unscrewing the nozzle.

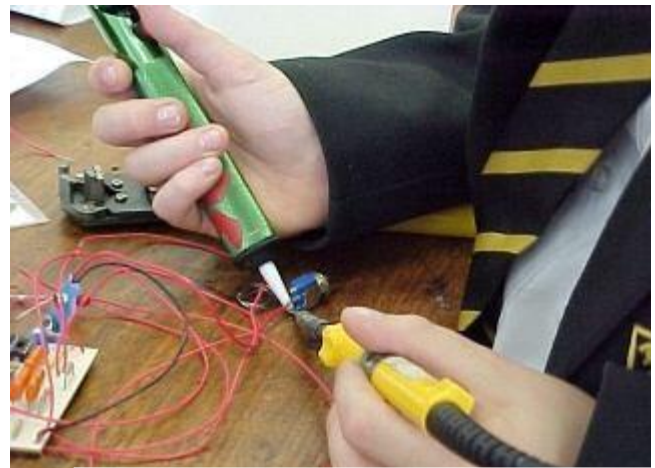


Figure 4.13: Soldering pump

With solder remover wick (copper braid)

- Apply both the end of the wick and the tip of your soldering iron to the joint.
- As the solder melts, most of it will flow onto the wick, away from the joint.
- Remove the wick first, then the soldering iron.
- Cut off and discard the end of the

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After removing most of the solder from the joint(s) you may be able to remove the wire or component lead straight away (allow a few seconds for it to cool). If the joint will not come apart easily apply your soldering iron to melt the remaining traces of solder at the same time as pulling the joint apart, taking care to avoid burning yourself.



Figure 4.14: copper braid

Soldering iron stand

You must have a safe place to put the iron when you are not holding it. The stand should include a sponge, which can be dampened for cleaning the tip of the iron.



Figure 4.15: Soldering iron stand

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Desoldering pump (solder sucker)

A tool for removing solder when desoldering a joint to correct a mistake or replace a component.



Figure 4.16: solder sucker

Conductor Splices and Terminal Connections

Conductor splices and connections are an essential part of any electrical circuit.

When conductors join each other or connect to a load, splices or terminals must be used. Any electrical circuit is only as good as its weakest link. The basic requirement of any splice or connection is that it is both mechanically and electrically as sound as the conductor or device with which it is used. Quality workmanship and materials must be used to ensure lasting electrical contact, physical strength, and insulation. The most common methods of making splices and connections in electrical cables are explained in the discussion that follows.

Insulation Removal

The preferred method of removing insulation is with a wire -stripping tool, if available. A sharp knife may also be used. Other typical wire strippers in use are illustrated in figure below. The hot-blade, rotary, and bench wire strippers (views A, B, and C, respectively) are usually found in shops where large wire bundles are made. When using any of these automatic wire strippers, follow the manufacturer's instructions for adjusting the machine; this avoids nicking, cutting, or otherwise damaging the conductors. The hand wire strippers are common hand tools found. The hand wire strippers (view D) are the ones you will most likely be using. Wire strippers vary in size according to wire size and can be ordered for any size needed.

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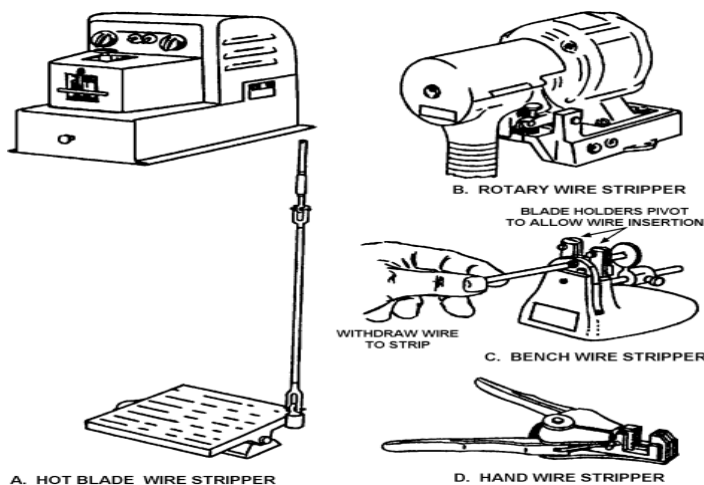
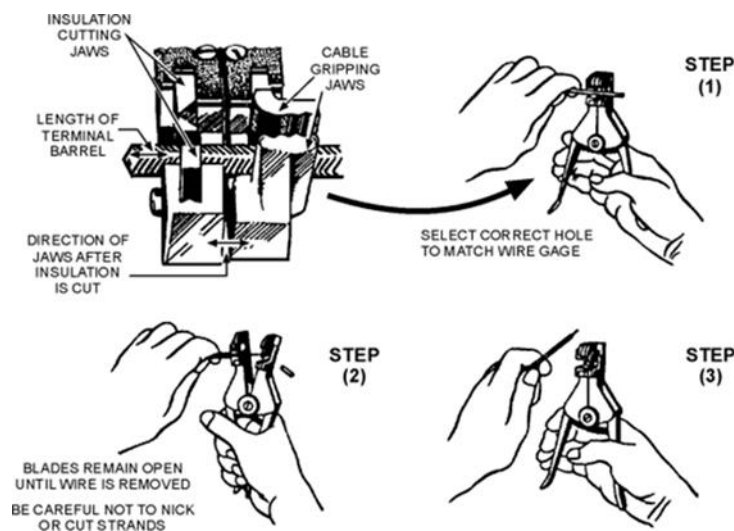


Figure 4.2: Insulation removal

Hand Wire Stripper

The procedure for stripping wire with the hand wire stripper is as follows.

1. Insert the wire into the center of the correct cutting slot for the wire size to be stripped. The wire sizes are listed on the cutting jaws of the hand wire strippers.
2. After inserting the wire into the proper slot, close the handles together as far as they will go.
3. Slowly release the pressure on the handles so as not to allow the cutting blades to make contact with the stripped conductor.



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Figure 4.3: Hand Wire Stripper

Knife Stripping

A sharp knife may be used to strip the insulation from a conductor. The procedure is much the same as for sharpening a pencil. The knife should be held at approximately a 60° angle to the conductor. Use extreme care when cutting through the insulation to avoid nicking or cutting the conductor.

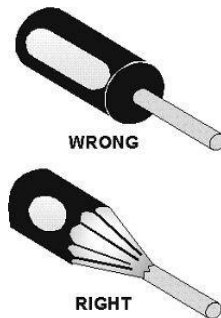


Figure 4.4: Knife Stripping

Types of Splices

There are six commonly used types of splices. Each has advantages and disadvantages for use. Each splice will be discussed in the following section.

Pigtail Splice

A splice that is used in a junction box and for connecting branch circuits is the rattail joint.

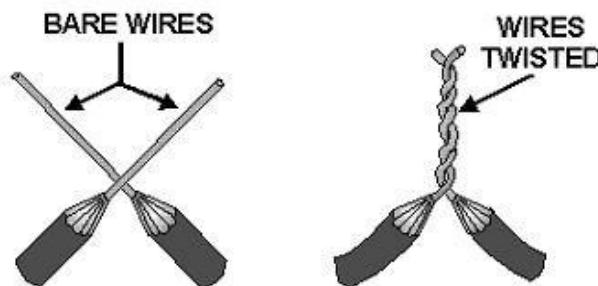


Figure 4.5: Pigtail Splice

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Western Union Splice

The Western Union splice joins small, solid conductors. Figure below shows the steps in making a Western Union splice.

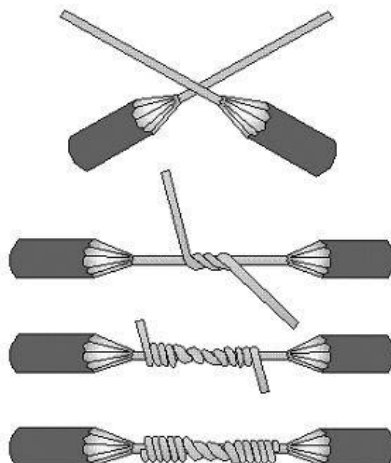


Figure 4.6: Western Union Splice

1. Prepare the wires for splicing. Enough insulation is removed to make the splice. The conductor is cleaned.
2. Bring the wires to a crossed position and make a long twist or bend in each wire.
3. Wrap one end of the wire and then the other end four or five times around the straight portion of each wire.
4. Press the ends of the wires down as close as possible to the straight portion of the wire. This prevents the sharp ends from puncturing the tape covering that is wrapped over the splice.

Staggering Splices

Joining small multi-conductor cables often presents a problem. Each conductor must be spliced and taped. If the splices are directly opposite each other, the overall size of the joint becomes large and bulky. A smoother and less bulky joint can be made by staggering the splices.

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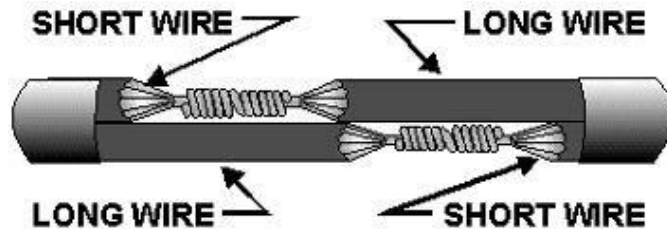


Figure 4.7: Staggering Splice

Center or T-Tap Splice

All the splices discussed up to this point are known as butted splices. Each was made by joining the free ends of the conductors together. Sometimes, however, it is necessary to join a branch conductor to a continuous wire called the *main wire*. Such a junction is called a *tap joint*. The main wire, to which the branch wire is to be tapped, has about 1 inch of insulation removed. The branch wire is stripped of about 3 inches of insulation.

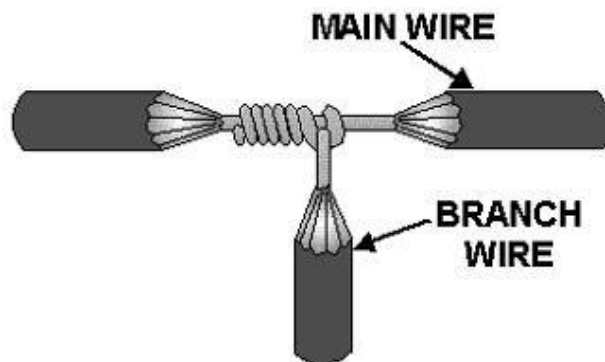


Figure 4.8: Center or T-Tap Splice

Wire Nut and Split Bolt Splices

The wire nut (view A of figure below) is a device commonly used to replace the pigtail joint splice. The wire nut is housed in plastic insulating material. To use the wire nut, place the two stripped conductors into the wire nut and twist the nut. In so doing, this will form a splice like the pigtail joint and insulate itself by drawing the wire insulation into the wire nut insulation.

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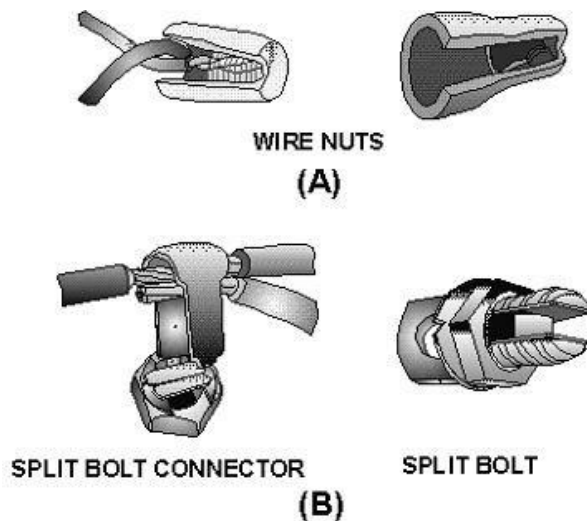


Figure 4.9: Wire Nut and Split Bolt Splices

4.3 Testing constructed circuit

Definition of Terms

- **Amperage (Amps):** a unit of measurement of electrical current flow
- **Ampere:** a unit of measurement which describes the amount of electric current passing a certain point at a particular time
- **Multi-tester:** an electrical measuring instrument used to measure the voltage, the resistance or the current of a circuit. It is connected either through parallel or series with the circuit depending on what to measure
- **Ohm:** the unit of measurement used to express resistance
- **Ohmmeter:** an instrument used to measure resistance in ohms
- **Volt:** a unit of measurement of electrical pressure or voltage
- **Voltmeter:** an instrument specially designed for measuring voltage
- **Wire Gauge:** used to measure the diameter of magnetic wire

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4.3.1 Conducting testing of all completed termination/ connections of electric wiring/ electronic circuits

Quality control starts with good planning and management. An inspection and test plan, which lists down the project's inspection and testing requirements, should be prepared to detail the checks required to achieve good workmanship. The plan should cover the responsibilities of each party, inspection methods, requirement references and frequency of inspections.

Objectives of testing electrical wiring/electronic circuits

- To verify proper functioning of the equipment/system after installation; and
- To verify that the performance of the installed equipment/systems meet with the specified design intent through a series of tests and adjustments.
- To capture and record performance data of the whole installation as the baseline for future operation and maintenance

The purpose of these tests is to ensure that all components and systems are in a satisfactory and safe condition before start up. Preliminary adjustment and setting of equipment at this stage shall also be carried out at the same time to pave way for the coming functional performance tests. Before carrying out any test, the trainer shall ensure that the installation complies with all relevant statutory requirements and regulations. The test works shall comply with all site safety regulatory requirements currently in force, including but not limited to.

4.3.2 Functional Performance Tests

The purpose of functional performance tests is to demonstrate that the equipment/installation can meet the functional and performance requirements as specified in the General/Particular Specifications. Functional performance test should proceed from the testing of individual components to the testing of different systems in the installation.

The specific tests required and the order of tests will vary depending on the type and size of systems, number of systems, sequence of construction, interface with other installations, other specific requirements as indicated in the General/Particular Specifications. The testing of systems may have to be carried out in stages depending on the progress of work.

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Part of the tests may be required to be carried out in suppliers' premises in accordance with the provisions in the General/Particular Specification. Any performance deficiencies revealed during the functional performance tests must be evaluated to determine the cause and whether they are part of the contractual obligations. After completion of the necessary corrective measures, the trainer shall repeat the tests.

4.3.3 Inspection before Test

A visual inspection shall be made to verify that the electrical installation /equipment as installed are correctly selected. The visual inspection shall include a check on the following items, where appropriate:

- a) Adequacy of working space, access, and maintenance facilities;
- b) Connections of conductors;
- c) Identification of conductors;
- d) Adequacy of the sizes of conductor in relation to current carrying capacity
- e) Correct connections of all equipment with special attention to socket outlets,
- f) Presence of fire barriers and protection against thermal effects;
- g) Methods of protection against direct contact with live parts
- h) Presence of appropriate devices for isolation and switching;
- i) Choice and setting of protective and indicative devices;
- j) Labeling of circuits, fuses, protective devices, switches, isolators and terminals;
- k) (l) Presence of danger and warning notices;
- l) Presence of diagrams, instructions and other similar information;
- m) Connection of single pole devices for protection
- n) Method of protection against indirect contact;
- o) Prevention of mutual detrimental influence;
- p) Presence of under voltage protective devices;
- q) Erection method; and
- r) Any other appropriate inspection

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Electrical tests

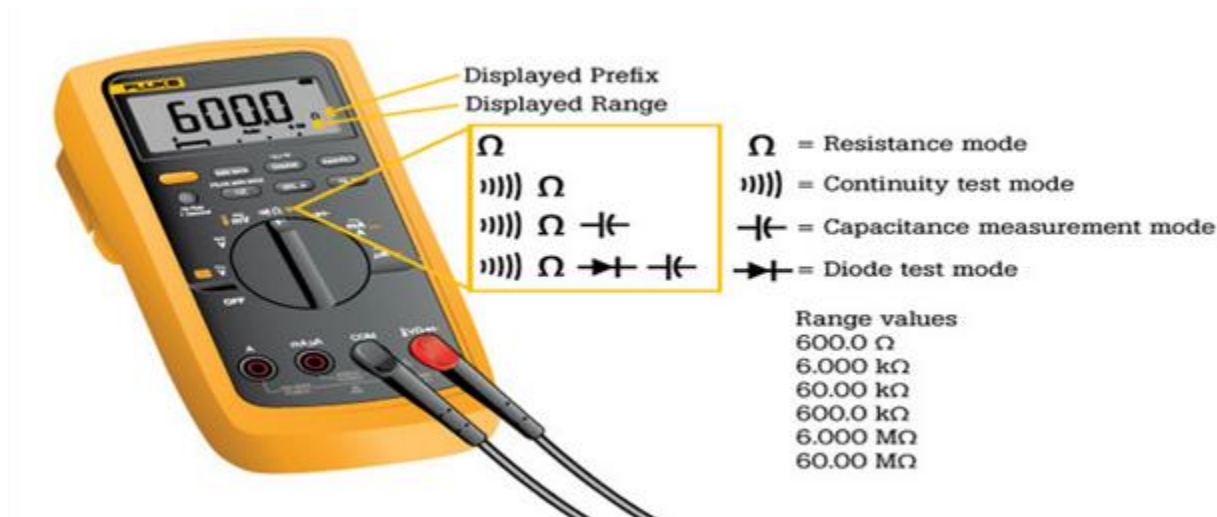


Figure 4.10: Multimeter

a) Testing Voltage

Steps of testing voltage:

1. Power off the circuit/wiring under test if there is a danger of shorting out closely spaced adjacent wires, terminals or other points which have differing voltages
2. Plug the black ground probe lead into the COM socket on the meter
3. Plug the red positive probe lead into the socket marked V (usually also marked with the Greek letter "omega" Ω and possibly a diode symbol)
4. Next, you need to decide whether the voltage being measured is AC or DC. If you are measuring the voltage from a mains socket outlet or the output voltage of a transformer, you need to select AC. Voltages of batteries, or the output of a power supply circuit or adapter is likely to be DC
5. Multi--meters may have several ranges for each function. For example, the DC measuring mode may have ranges of 200mv, 2v, 20v, 200v and 1000 V in order to facilitate the measurement of a large range of voltages. Turn the dial of the meter to a range, which is

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just above the voltage being measured, and ensure that you pick the AC voltage or DC voltage range. So for instance if you are measuring the voltage of a car battery which is approximately 12 volts, you can set the range to 20v. This gives the most number of decimal places in the reading. Setting the range to 200 volts gives less decimal places. If the meter is auto ranging, set it to the "V" setting. (See the photo near the bottom of the article for an explanation of symbols used).

6. Therefore, this means the two test probes should be connected in parallel with the voltage source, load or any other two points across which voltage needs to be measured. Touch the black probe against the first point of the circuitry/wiring
7. Power up the equipment
8. Touch the other red probe against the second point of test. Ensure you don't bridge the gap between the point being tested and adjacent wiring, terminals or tracks on a PCB
9. Take the reading on the LCD display

Note: A lead with a 4mm banana plug on one end and a crocodile clip on the other end is very handy. The croc clip can be connected to ground in the circuit, freeing up one of your hands

b) Testing Current

Steps of testing current

1. Turn off the power in the circuit being measured
2. A multi-meter must be inserted in series with the load in a circuit in order to measure current. Plug the ground probe into the COM socket and plug the red positive probe lead either into the mA socket or the high current socket which is usually marked 10A (some meters have a 20 A socket instead of 10A). The mA socket is often marked with the maximum current and if you estimate that the current will be greater than this value, you must use the 10 A socket, otherwise you will end up blowing a fuse in the meter
3. Connect the meter in series as in the diagram below
4. Turn the dial on the meter to the highest current range (or the 10A range if the probe is in the 10A socket). If the meter is auto ranging, set it to the "A" or mA setting. (See the photo at the bottom of the article for an explanation of symbols used).

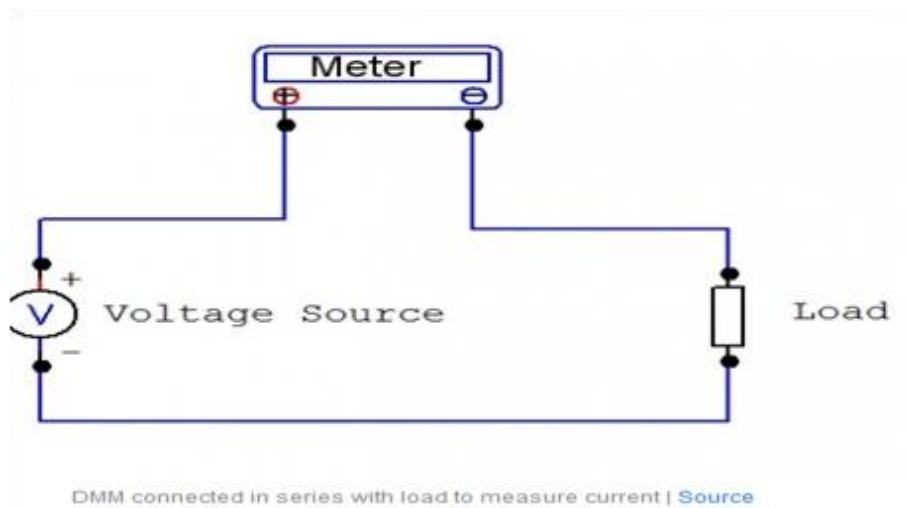
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5. Turn on the power
6. If the range is too high, you can switch to a lower range to get a more accurate reading
7. Remember to return the positive probe to the V socket when finished measuring current.

The meter is practically a short circuit when the lead is in the mA or 10 A socket. If you forget and connect the meter to a voltage source when the lead is in this position, you may end up blowing a fuse at best or blowing up the meter at worst! (On some meters the 10A range is un-fused)



Test leads and sockets on a DMM, setup to measure current | Source



DMM connected in series with load to measure current | Source

Figure 4.11: Testing of current

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c) Testing Resistance

Steps of testing resistance:

1. Turn power to circuit OFF. If a circuit includes a capacitor, discharge the capacitor before taking any resistance reading.
2. Turn dial to Ω (resistance, or ohms), which often shares a spot on the dial with one or more other test/measurement modes (continuity, capacitance or diode; see illustration below). Notes: The display should show OL Ω . Why? In Resistance mode, even before test leads are connected to a component, a digital Multimeter (DMM) automatically begins taking a resistance measurement. The M Ω symbol may appear in the display because resistance of open (unattached) test leads is very high. When the leads are connected to a component, a DMM automatically uses the Auto range mode to adjust to the best range. Pressing the Range button allows a technician to manually set the range. Best results will be achieved if the component to be tested is removed from the circuit. If the component is left in the circuit, the readings could be affected by other components in parallel with the component to be tested.
3. First, insert the black test lead into the COM jack.
4. Then insert the red lead into the V Ω jack. When finished, remove the leads in reverse order: red first, then black.
5. Connect test leads across the component being tested. Make sure that contact between the test leads and circuit is good. Tip: For very low-resistance measurements, use the relative mode. It may also be referred to as zero or Delta (Δ) mode. It automatically subtracts test lead resistance—typically 0.2 Ω to 0.5 Ω ideally, if test leads touch (are shorted together), the display should show 0 Ω . other factors that can affect resistance readings: Foreign substances (dirt, solder flux, oil), body contact with the metal ends of the test leads, or parallel circuit paths. The human body becomes a parallel resistance path, lowering total circuit resistance. Thus, avoid touching metal parts of test leads to avoid errors.
6. Read the measurement on the display.
7. When finished, turn the Multimeter OFF to prevent battery drain.

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d) Testing Continuity

A continuity test tells us whether two things are electrically connected: if something is continuous, an electric current can flow freely from one end to the other. If there's no continuity, it means there is a break somewhere in the circuit. This could indicate anything from a blown fuse or bad solder joint to an incorrectly wired circuit.

Steps of testing continuity:

Step 1: to begin, make sure no current is running through the circuit or component you want to test. Switch it off, unplug it from the wall, and remove any batteries.

- Plug the black probe into the COM port on your Multimeter.
- Plug the red probe into the VΩmA port.
- Switch on your Multimeter, and set the dial to continuity mode (indicated by an icon that looks like a sound wave). Not all multi meters have a dedicated continuity mode. If yours does not, that is okay! Skip to Step 6 for an alternate way to perform a continuity test.

Step 2: The Multimeter tests continuity by sending a little current through one probe, and checking whether the other probe receives it.

- If the probes are connected—either by a continuous circuit, or by touching each other directly—the test current flows through. The screen displays a value of zero (or near zero), and the Multimeter beeps. Continuity!
- If the test current is not detected, it means there's no continuity. The screen will display 1 or OL (open loop).

Step 3: To complete your continuity test, place one probe at each end of the circuit or component you want to test.

- It does not matter which probe goes where; continuity is non-directional.
- As before, if your circuit is continuous, the screen displays a value of zero (or near zero), and the Multimeter beeps.

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- If the screen displays 1 or OL (open loop), there's no continuity—that is, there's no path for electric current to flow from one probe to the other.

Step 4: If your multi-meter does not have a dedicated continuity test mode, you can still perform a continuity test.

- Turn the dial to the lowest setting in the resistance mode.
- Resistance is measured in ohms, indicated by the symbol Ω .

Step 5: In this mode, the multi-meter sends a little current through one probe, and measures what the other probe (if anything) receives.

- If the probes are connected—either by a continuous circuit, or by touching each other directly—the test current flows through. The screen displays a value of zero (or near zero—in this case, 0.8). Very low resistance is another way of saying that we have continuity.
- If no current is detected, it means there's no continuity. The screen will display 1 or OL (open loop).

Step 6: To complete your continuity test, place one probe at each end of the circuit or component you want to test.

- Does not matter which probe goes where; continuity is non-directional.
- As before, if your circuit is continuous, the screen displays a value of zero (or near zero).

If the screen displays 1 or OL (open loop), there's no continuity—that is, there's no path for electric current to flow from one probe to the other.

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Self-check 4

Directions I: Fill the blanks pace

- _____ is a fastening device used to hold or secure objects tightly together to prevent movement or separation through the application of inward pressure.
- _____ a device for making an electrical connection between an appliance and the mains, consisting of an insulated casing with metal pins that fit into holes in a socket
- _____ is a process in which two or more items are joined together by melting and putting a filler metal (solder) into the joint.

Directions II: Say True or False for the following question (10 point)

- A continuity test tells us whether two things are electrically connected
- A multi-meter must be connected in series in a circuit in order to measure voltage
- The $M\Omega$ symbol may appear in the display b/c resistance of open test leads is very high.
- To begin, a continuity test make sure current is running through the circuit
- A multi-meter must be inserted in series with the load in a circuit in order to measure current

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Operation sheet -2

Operation Title: Testing connections of electrical wiring/ electronics circuits:

Instruction: In workshop, test the given circuit.

Purpose: to test the constructed circuit properly

Required tools and equipment: Multimeter, and electronic circuit

Precautions:

- Never touch the power part

Procedures:

Step 1- Select the ac or dc function with the selection switch on the side of the unit.

Step 2- Place the black probe of the unit under test into the (-) terminal and press down firmly.

Step 3- Place the red test probe of the unit under test in the (+) and press down firmly.

Step 4- Verify the meter reading of the tester is valid for the function tested.

Step 5- For low impedance testers the output voltage sourced should be >50 VAC/ dc.

Step 6- It is recommended to test both ac and dc functions of your test tool

Quality criteria:

- Safety
- Testing technique

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LAP Test 2

Name: _____

Date: _____

Time started: _____

Time finished: _____

Instruction I: Given necessary templates, tools and materials you are required to perform the following tasks within 2 hours

Task 1: identify the required material and equipment for electrical tests.

Task2: construct DC parallel and series circuit

Task3: measure voltage and current in DC circuit

Task 4: tests voltage, current, resistance, continuity in DC and AC circuit

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