Manonmaniam Sundaranar University,

Directorate of Distance & Continuing Education,

Tirunelveli - 627 012 Tamil Nadu, India

OPEN AND DISTANCE LEARNING (ODL) PROGRAMMES

(FOR THOSE WHO JOINED THE PROGRAMMES FROM THE ACADEMIC YEAR 2023–2024)

II YEAR

B.Sc. Physics

Course Material

Maintenance of Electronic Appliances

Prepared

By

Dr. S. Shailajha

Assistant Professor

Department of Physics

Manonmaniam Sundaranar University
Tirunelveli – 12

UNIT I	**SOLDERING TECHNIQUES**
Soldering tools – Soldering Iron – Soldering Station – Dry solder Joint, cold solder joints – Good and bad solder joints, Groove board, bread board and printed circuit Board.	
UNIT – II	**POWER SUPPLY AND MEASURING INSTRUMENTS**
Transformer Zener Voltage regulators – Dual Power Supply IC's 7805,7905 – Switch Mode Power Supply(SMP's), Principle of SMP's- Block diagram of SMP'S, Practical uses of Multimeter (analog and digital)- testing and Measurements of resistor, capacitor and transistor.	
UNIT-III	**MAINTENANCE OF ELECTRONIC HOME APPLIANCES**
LED/LCD TV- music player, CCTV Camera block diagram-its working- Cathode ray Oscilloscope- its principle and block diagram – Measurement of Frequency, AC and DC using CRO	
UNIT-IV	**MAINTENANCE OF COMPUTER SYSTEMS**
Various parts of computer-its assembling-installing windows operating system, software and antivirus computer hardware maintenance- formatting and maintenance- Basic Network Installation-IP address setting and its maintenance Modem -working, principle	
UNIT -V	**SOLAR POWER SYSTEMS AND INVERTERS**
Solar Inverter-their principle and operation, power rating, Protection circuits used in Inverters-Solar Battery-Battery level, Over load, Over charging, Various Faults and its rectification.	
REFERENCE BOOKS	1. Basic Electronics, 6th edition by B Grob,Mc Graw Hill NY1 2. Integrate electronics – Millman and Halkias 3.Electronic Principles-Malvino 6th Edition 4. Operational Amplifier- Gyaskwar 5.Basic Electronics B.Basavaraj, H.N.Shivasankar University Press

UNIT – I

SOLDERING TECHNIQUES

Soldering is a process that joins two or more types of metals through melting solder. The first soldering iron was developed in 1896 by Richard Schneider and August Tinnerhol and was called the **"First Electric Heating Apparatus".**

Soldering is commonly used in electronics, as it is simple and safe in joining sensitive materials. Likewise, the process is also known for metalworking, plumbing, roofing and joining wires.

Soldering

Soldering uses a filler metal with a low melting point, also known as solder, to join metal surfaces. The solder is usually made up of an alloy consisting of tin and lead whose melting point is around 235°C and 350°C, respectively.

But when tin and lead are mixed then the melting point of the mixture is reduced to 183°C. The alloy is melted by using a hot iron at above 316 °C (600 °F).

As the solder cools, it creates a strong electrical and mechanical bond between the metal surfaces. The bond allows the metal parts to achieve electrical contact while it is held in place.

Note that lead-free solders are increasingly used as an alternative to environmentally harmful lead-based solders due to regulations.

The first step in soldering is to wear protective gear in a well-ventilated area. Next, the soldering iron should be preheated. For cleaning the soldering tip, you can use a wet sponge. Likewise, any residue on the work piece surface should be wiped off.

After finishing the preparations, it's time to heat the base metal to a working temperature using the hot iron. Doing so will help prevent thermal shock, activate the solder, and overall improve the quality of the joint. A good indicator that the metals are well-heated is when the molten solder freely flows into the joint. The filler material solidifies as it cools down, making it the best time for inspection.

The key to successful soldering is ensuring that the metals being joined are clean and free of any oxides or other contaminants.

Desoldering

From time to time, components fail and need replacement. When these components are mechanically held in place with solder, a process called desoldering removes the material cleanly and safely.

A **soldering iron** or a **heat gun** can be utilised to melt the solder, allowing you to safely remove any soldered components. To remove the liquid solder, you can use a **desoldering pump** as a vacuum, or a **soldering wick** to absorb the molten solder.

Alternatively, you can resort to an aggressive method using **compressed air** that can blow off the liquid solder.

Soldering vs Welding

While soldering and welding are processes that join two pieces of metal alloy together, there are some key differences in how the metals are joined.

Soldering uses melted filler metals to bond heated base materials. It works at a lower temperature than welding but requires preheating the base materials to create an effective joint.

Welding runs at higher temperatures to melt both filler material and workpiece together. It results in a stronger bond, with some changes to the mechanical properties of the metal from heating and cooling.

Metals

Soldering works well with the following base metals:

- Gold
- Silver
- Iron
- Brass
- Copper
- Aluminium
- Steel
- Titanium

While some of these metals can easily be soft-soldered, harder metals may require filler materials with a higher melting point to be joined.

Soldering Tools

Soldering irons are hand tools that heat the solder above its melting temperatures. They offer a wide variety of sizes, which is great for different applications. The tip of the iron has different types and sizes that suit a variety of projects.

Soldering guns are employed when higher temperatures require more power. A soldering gun heats quicker and offers better flexibility as it can be operated in confined spaces, heavy electrical connections, and metalworks.

Soldering stations are multipurpose devices that have everything covered for minor projects. They are more durable than regular soldering irons due to them being equipped with sensors, fuses, alerts and temperature regulation.

Solders

Lead-based solder

Most soldering projects are typically performed using lead solder consisting of a 60-40 tin-to-lead ratio. This solder melts in a range of 180 to 190°C and is usually the best choice for soldering electrical connections.

Lead-free solder

As a way to mitigate the use of harmful elements, lead-free solders were developed. These usually come as solder wire and are composed of metals with higher melting points: tin, copper, bismuth, silver, brass, indium, and antimony.

Flux core solder

These filler metals come as paste or soldering wires that contain a flux solder core. The flux releases a protective layer around the workpiece as it is consumed, which achieves cleaner electronic connections and better wetting properties.

Flux

Rosin flux (alternatively called passive flux) is used for electronics as it leaves a residue that doesn't lead to corrosion.

Acid flux solders contain aggressive properties, which are effective in removing the oxides of the metal surface. This leads to stronger and cleaner metal joints compared to rosin.

The type of flux can be broken down into two groups depending on its application. **No-clean flux** is made with natural rosin or other synthetic materials, requiring no post-cleanup, while **water-soluble flux** contains water-soluble resin that is easily removed by rinsing.

Heating Methods

While the concept of soldering is fairly simple, there are different heating methods that depend on the application or project. Primitive methods involve a fire heating element through butane, but this has now evolved into more advanced techniques.

Laser

Commonly used in delicate electronics, lasers at 30-50 watts can accurately create a soldered joint while preventing heat in the surrounding area. It is commonly used on circuit boards where the components are compact.

Induction

Copper coils induce heat to the solder by using an oscillating high-frequency alternating current. Induction allows for an even application of thermal energy to heat solder, being a great application to cylinders and pipes, minimizing holes and maintaining uniformity.

Resistance

This soldering form generates heat by applying an electrical current to the solder and soldering iron. Heat is generated in a small space and it dissipates quickly, reducing the risk of damaging components.

Infrared

This method uses infrared (IR) light as a mode of heat transfer to the targeted area. It only takes a few seconds, reducing the heat exposure time of the surrounding area.

Types of Soldering

Here are three soldering types that are used at varying temperature levels that result in different joint strengths:

- **Soft soldering (90 °C – 450 °C)**

  The solder melts alloys containing lead that has a low melting point. With a lower melting point, this soldering type minimises the thermal stress wherein the base metals are subjected.
- **Hard soldering (above 450 °C)**

  Brass and silver are usually hard soldered, with the use of a flame via blowtorch to melt the filler metal. Hard soldering has better mechanical strength than soft soldering, which applies to crafting jewellery and some machining operations.
- **Brazing (above 450 °C)**

  Brazing uses metals with a much higher melting point compared to hard and soft soldering. It produces the strongest result, which is perfect for metal repairs and for pipe joining.

Advantages of Soldering

1. Soldering is operated at lower temperatures compared to common welding methods.
2. Most metals and non-metals can be soldered.
3. A simple process makes it easy to learn.
4. The base metal isn't melted in the process, unlike welding techniques such as stick welding, flux-cored welding, etc.
5. Soft soldering can be undone using a desoldering tool without damaging the base materials.

Disadvantages of Soldering

1. Weaker joints compared to other welding methods such as MIG and TIG.
2. Soldering isn't suitable at high temperatures, as the solder has a low melting point.
3. Heavy metals aren't suitable for soldering.
4. Melted solder might leave a toxic flux residue.
5. Improper heating may cause deformities or voids in the solder.

Applications

Electronics Industry

The most popular application of this fusion process is electronics soldering, where wires are joined and electronic components are fused to a circuit board. This technique allows soldering components together with the luxury of desoldering when needed.

Roofings

Soldering can be used in creating leak-proof roofings wherein the galvanised steel is infused with solder. The soldering iron tip is far broader when used in this application compared to other uses.

Sections

Soldering is applied in the piping and plumbing industry as a way to create joint sections. It is a straightforward process and a reliable solution in sealing the connections in copper pipes, for example.

Art

Soldering can be used to create stained glass art, wire modelling, sculptures, jewellery and other creative works.

Metalwork

The soldering material can be used to fill cavities and even out rough surfaces. This process is practiced to fuse metal sheets, pipes and other applications where metals don’t undergo high temperatures.

Automation

Technology allows us to automate the soldering process through the use of programmed robots. Not only does it create precise joints but it is also fast in production speed.

Soldering iron

Most people opt for using a soldering iron to solder. It's a great heat source that heats up and cools down quickly and can maintain a pretty constant temperature. Soldering irons can be purchased from a variety of places. I have picked up some at Radioshack - evil yes, but convenient, some from the hardware store, some from garage sales and a bunch more from retailers online. Low wattage (15-40 watt) soldering irons work best for soldering components on circuit boards while more powerful (60-140 watt) soldering irons work well joining thicker materials like braided speaker wire. If you use too powerful of a soldering iron on a circuit board you might damage the components you are trying to join. I like to keep a low-wattage iron around for detail work, and a high-wattage iron that I can use when I am not too concerned

about exposing the material I am working with to high temperatures. It's a real pain to solder thick wires without a powerful soldering iron.

The soldering iron in most of the pictures is made by Weller, and has a variable temperature control. This is the best of both worlds since you can set the heat exactly where you want it, but it's significantly more expensive than fixed-temperature irons.

Dry soldering refers to a poor solder joint that lacks proper electrical connectivity on a PCB assembly product. This issue occurs when the solder does not properly melt and bond to the components, leading to weak connections. These joints are often brittle and prone to failure, which can result in intermittent or complete loss of electrical connectivity.

Dry solder joints occur due to several reasons, each impacting the quality of the solder connection. First of all, the solder paste reflow process is only a small area, which is easier to harden than the solder paste in the solder paste can. At this time, the solder paste will not melt, and the flux cannot cover the solder joint, resulting in poor welding of the solder joint. Meanwhile, the solder paste is easier to heat transfer, and the high temperature actually makes the solder paste not easy to melt, so we can slightly adjust the reflow welding temperature curve to solve the problem, or welding in a nitrogen environment is basically a good way to solve this problem.

Secondly, the solder paste does not melt because its own composition contains a very volatile flux, which is also the reason why the solder paste is easy to harden. Among them, the flux with the largest content of solder paste is rosin, rosin contains a lot of rosin acid, rosin acid is easy to lose activity at too high temperature. Therefore, the temperature of the welding process should be controlled to ensure that the temperature is about 200 ° C, which is not suitable for too high or too low. At the same time, the quality of thixotropic agent will also lead to the solder paste is easy to dry, the quality of thixotropic agent is not good will affect the viscosity of the solder paste, the viscosity of the solder paste is easy to dry. Therefore, the choice of high-quality solder paste can fundamentally solve the problem that the solder paste is easy to harden.

DRY SOLDER FIX

Solder paste is one of the very important materials in the electronics industry, and it has an important impact on the production quality of the entire component. Here are some tips that can help to fix the dry solder paste.

1.**Add flux**

Usually, if the solder paste is too dry, you can try to add some water to the right amount of flux, stir well and add it to the solder paste. This can play a certain role in alleviating drying and improve the fluidity of the solder paste.

2. **Take some measurements during management**

a. Keep the ambient temperature moderate during storage;

b. Stir well before use;

c. Cover the solder paste in time after welding to avoid exposure to the air.

3. Replace it with new one

If the solder paste becomes too dry, adding flux is difficult to restore its original properties, it is recommended to replace the solder paste to avoid affecting the quality of the components.

Therefore, we need to regularly maintain and manage the solder paste to ensure that its quality meets the standard requirements.

PREVENTION OF DRY SOLDER

Preventing dry solder joints is key to maintaining the reliability of your electronic projects. You can try to use these tips to prevent your solder paste become dry.

- Proper heating
- Clean surfaces
- Use quality solder

- Steady hand
- Maintain equipment
- Fast usage and storage

A **Cold Solder Joint** occurs when solder fails to melt entirely to form a proper joint. A cold solder joint or an improperly formed joint can be the trigger for reliability problems of an electronic assembly. Cold solder joints increase the electrical resistance of the solder joints, and hence reduce the reliability of the solder joints.

There are a number of factors that can cause cold solder joints. These include:

- Improper melting or reflow or wetting of solder at the joints
- Disturbances such as vibrations while the solder is cooling
- Too high a process temperature causes the flux to break down prematurely
- Too low a process temperature at the solder joint - can lead to incomplete wetting
- Unmatched geometry of the components

Cold solder joints can be detected by visual checking or using a magnifying glass. Primarily, a cold solder joint could look dull, whitish, and convex, or deformed, which is very different from a proper solder joint.

Another way to detect a cold solder joint is by using a Multimeter. Since one of the effects of a cold solder joint is an increase in resistance. A Multimeter can be used to test for this – It can be used to test for an increase in electrical resistance or test the continuity of the circuit.

However, the detection of cold solder joints gets more challenging when a lead-free soldering process is used. So it is best to try and avoid these cold solder joints from arising.

Here are a few things that you can do to avoid cold solder joints:

- Use an appropriate reflow profile as per the solder manufacturers' specification
- The peak temperature must be set of at least 15°C above the melting point of the solder alloy for more than 45 seconds.

- Try to identify any vibration sources that can cause the solder to spread unevenly
- Use a good quality solder paste - alloy analysis should be done to check for contaminants

Figure 1

Figure 2

This how different a Cold Solder joint looks from a proper solder joint.

Figure 1 - shows a properly soldered joint that is shining, bright, and concave in shape.

Figure 2 - Shows a Cold Solder joint that is dull looking, whitish, convex, and deformed in shape.

A good soldering joint exhibits several signs that indicate its quality and reliability.

Here are some signs of a good soldering joint:

- **Shiny Appearance:** A good solder joint typically appears shiny or bright after **the soldering process**. This indicates that the solder has properly flowed and adhered to the metal surfaces, creating a strong bond.
- **Smooth and Continuous:** A well-made solder joint should have a smooth and continuous surface without any gaps, cracks, or irregularities. It should appear as a solid connection between the components being soldered.
- **Proper Fillet Formation:** The solder joint should form a distinct fillet or concave shape around the component lead or wire being soldered. The fillet ensures good mechanical strength and helps distribute the solder evenly.
- **Proper Wetting:** Wetting refers to the ability of the molten solder to spread and adhere to the metal surfaces being soldered. A good solder joint exhibits proper

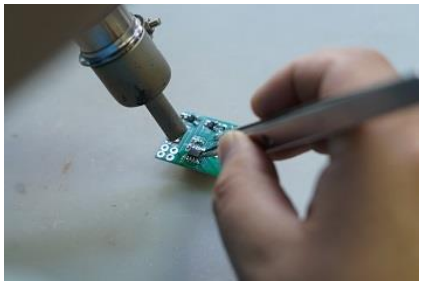
wetting, with the solder flowing and covering the entire surface of the joint, including the pad and component lead or wire.

- **Minimal Solder Excess:** An ideal solder joint has just enough solder to create a strong and reliable connection. Excessive solder, often referred to as a "solder blob," can lead to short circuits, poor electrical performance, or mechanical issues.
- **Minimal Solder Bridges:** Solder bridges occur when the solder unintentionally connects adjacent pins or pads, causing a short circuit. **A good solder joint** should not have any solder bridges or unintended connections between components.
- **Consistency:** A sign of skilled soldering is consistency across multiple joints. When examining a set of solder joints, they should exhibit similar characteristics, indicating that the soldering process was performed consistently and reliably.

Bad solder can lead to dry joints and other issues. So, how can we identify if my solder paste is bad? May you can follow these points. If everything matches up, there's no doubt that your solder paste is broken.

- **Appearance of solder joints**

Bad solder joints often appear dull or matte instead of shiny and smooth. They may also show cracks or a brittle texture, indicating poor bonding or excessive heating. These visual signs suggest that the solder did not properly melt or flow.



- **Solder flow and coverage**

  If the solder does not adequately cover the component leads or PCB pads, or if it spreads unevenly, it is likely bad. Proper soldering should result in a well-formed, consistent fillet around the leads, ensuring reliable electrical connections.

- **Difficulty in melting**

  Solder that requires unusually high temperatures or takes a long time to melt may be old or contaminated. Proper solder should melt easily at the recommended temperature and flow smoothly to create a solid joint.

- **Contamination indicators**

  Oxidized or tarnished solder indicates contamination and can affect its performance. Excessive residue or debris also points to poor quality, affecting how well the solder adheres and flows.

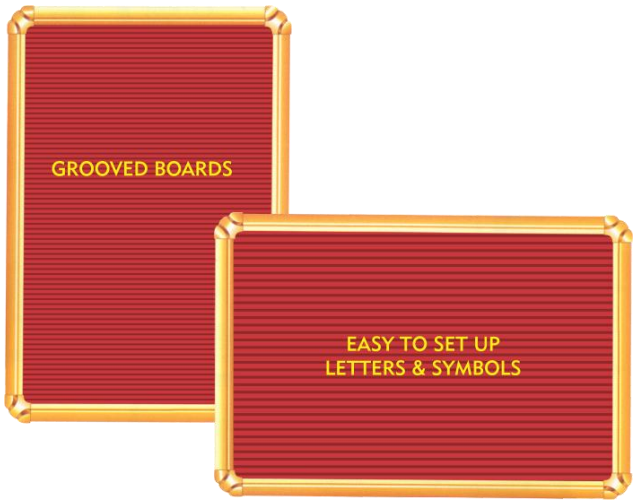
Best Technology is a one-stop PCB manufacture and PCBA service provider, our SMT factory is equipped with more than 6 assembly lines. Meanwhile, we have automatic SPI machine and solder paste printing machine, with good management system, we can ensure the good quality of solder paste. In addition, there are many advanced equipment in our workshop, including online dual AOI, X-ray, Nitrogen reflow oven, dry-ice cleaning machine, and so on.

Groove Boards

Golden Grooved Boards are used for display presentation purposes in welcome and luxury places like Hotels, receptions, conference rooms, entrance etc. Very attractive and glamorous look makes Grooved Boards to be used in welcome places. Golden frame and golden letters makes the boards more aesthetically attractive.

Features

- Suitable for Corporate and Welcome places like hotels, receptions, conference rooms, showrooms
- Available in vertical and horizontal grooves
- Golden framing and corners
- Presentation made by Golden colored letters & figures



BREADBOARD

A breadboard is a rectangular plastic board with a bunch of tiny holes in it. These holes let you easily insert electronic components to **prototype** (meaning to build and test an early version of) an electronic circuit, like this one with a battery, switch, resistor, and an LED (light-emitting diode). To learn more about individual electronic components, see our Electronics Primer.

The connections are not permanent, so it is easy to *remove* a component if you make a mistake, or just start over and do a new project. This makes breadboards great for beginners who are new to electronics. You can use breadboards to make all sorts of fun electronics projects, from different types of robots or an electronic drum set, to an electronic rain detector to help conserve water in a garden, just to name a few.

Modern breadboards are made from plastic, and come in all shapes, sizes, and even different colors. While larger and smaller sizes are available, the most common sizes you will probably see are "full-size," "half-size," and "mini" breadboards. Most breadboards also come with tabs

and notches on the sides that allow you to snap multiple boards together. However, a single half-sized breadboard is sufficient for many beginner-level projects.

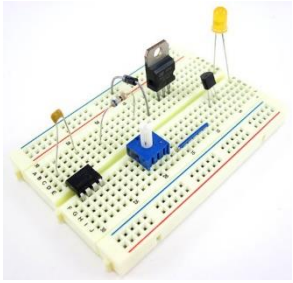
"SOLDERLESS" BREADBOARD

Technically, these breadboards are called **solderless** breadboards because they do not require soldering to make connections. **Soldering** (pronounced SAW-der-ing) is a method where electronic components are joined together by melting a special type of metal called **solder**. Electronic components can be soldered directly together, but more commonly they are soldered onto **printed circuit boards** (PCBs). PCBs are what you will see if you take the cover off many electronic devices, like a computer or cell phone. Frequently, engineers will use solderless breadboards to prototype and test a circuit before building the final, permanent design on a PCB. This image shows the same circuit (battery, switch, resistor, and LED) built three different ways: on a solderless breadboard (left), with the components soldered directly together (middle), and on a printed circuit board (right):

Soldering is a great technique to learn if you are interested in electronics, but the connections are much more permanent and it requires purchasing some tools to get started. The rest of this tutorial will focus on solderless breadboards, but you can read our soldering tutorial to learn more about soldering.

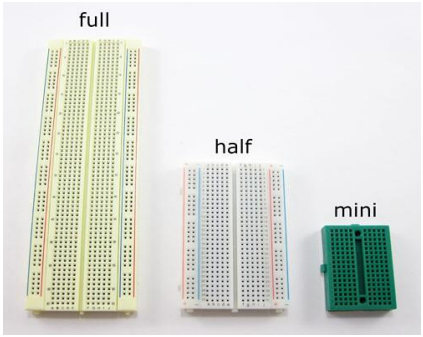
So, how do electronic components fit into a breadboard? Many electronic components have long metal legs called **leads** (pronounced "leeds"). Sometimes, shorter metal legs are referred to as **pins** instead.

Breadboards are designed so you can push these leads into the holes. They will be held in place snugly enough that they will not fall out (even if you turn the breadboard upside-down), but lightly enough that you can easily pull on them to remove them.



The leads can fit into the breadboard because the *inside* of a breadboard is made up of rows of tiny metal clips. This is what the clips look like when they are removed from a breadboard.

Modern breadboards are made from plastic, and come in all shapes, sizes, and even different colors. While larger and smaller sizes are available, the most common sizes you will probably see are "full-size," "half-size," and "mini" breadboards. Most breadboards also come with tabs and notches on the sides that allow you to snap multiple boards together. However, a single half-sized breadboard is sufficient for many beginner-level projects.

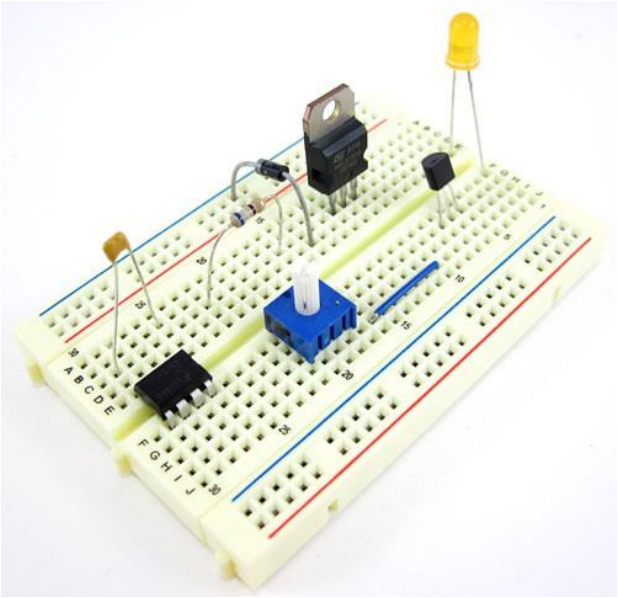


Soldering is a great technique to learn if you are interested in electronics, but the connections are much more permanent and it requires purchasing some tools to get started. The rest of this

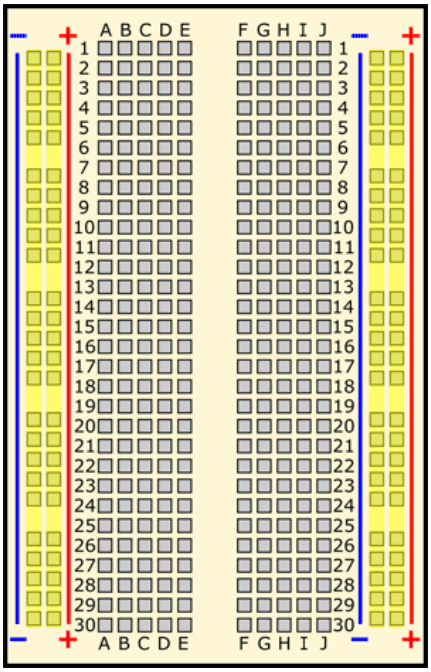
tutorial will focus on solderless breadboards, but you can read our soldering tutorial to learn more about soldering.

So, how do electronic components fit into a breadboard? Many electronic components have long metal legs called **leads** (pronounced "leeds"). Sometimes, shorter metal legs are referred to as **pins** instead. Almost all components with leads will work with a breadboard (to learn more about these components and which types work with a breadboard, see the Advanced section).

Breadboards are designed so you can push these leads into the holes. They will be held in place snugly enough that they will not fall out (even if you turn the breadboard upside-down), but lightly enough that you can easily pull on them to remove them.



Most breadboards have a backing layer that prevents the metal clips from falling out. The backing is typically a layer of sticky, double-sided tape covered by a protective layer of paper. If you want to permanently "stick" the breadboard to something (for example, a robot), you just need to peel off the paper layer to expose the sticky tape underneath. In this picture, the breadboard on the right has had its backing removed completely (so you can see all the metal clips). The breadboard on the left still has its sticky backing, with one corner of the paper layer peeled up.



These strips are typically marked by red and blue (or red and black) lines, with plus (+) and minus (-) signs, respectively. They are called the **buses**, also referred to as **rails**, and are typically used to supply electrical power to your circuit when you connect them to a battery pack or other external power supply. You may hear the buses referred to by different names; for example, *power bus*, *positive bus*, and *voltage bus* all refer to the one next to the red line with the plus (+) sign. Similarly, *negative bus* and *ground bus* both refer to one next to the blue (or black) line with the minus (-) sign. Sound confusing? Use this table to help you remember—there are different ways to refer to the buses, but they all mean the same thing. Do not worry if you see them referred to by different names in different places (for example, in different Science Buddies projects or other places on the internet). Sometimes you might hear "power buses" (or rails) used to refer to *both* of the buses (or rails) together, not just the positive one.

Positive	Negative
Power	Ground

Positive	Negative
Plus sign (+)	Minus sign (-)
Red	Blue or black

Note that there is no physical difference between the positive and negative buses, and using them is not a requirement. The labels just make it easier to organize your circuit, similar to color-coding your wires.

Remember that the inside of the breadboard is made up of sets of five metal clips. This means that each set of five holes forming a half-row (columns A–E or columns F–J) is electrically connected. For example, that means hole A1 is electrically connected to holes B1, C1, D1, and E1. It is *not* connected to hole A2, because that hole is in a different row, with a separate set of metal clips. It is also *not* connected to holes F1, G1, H1, I1, or J1, because they are on the other "half" of the breadboard—the clips are not connected across the gap in the middle (to learn about the gap in the middle of the breadboard, see the Advanced section). Unlike all the main breadboard rows, which are connected in sets of five holes, the buses typically run the entire length of the breadboard (but there are some exceptions). This image shows which holes are electrically connected in a typical half-sized breadboard, highlighted in yellow lines.

Buses on opposite sides of the breadboard are *not* connected to each other. Typically, to make power and ground available on both sides of the breadboard, you would connect the buses with jumper wires, like this. Make sure to connect positive to positive and negative to negative (see the section on buses if you need a reminder about which color is which).

Sometimes, breadboard diagrams might be accompanied by (or replaced with) written directions that tell you where to put each component on the breadboard. For example, the directions for this circuit might say:

1. Connect the battery pack's red lead to the power bus.
2. Connect the battery pack's black lead to the ground bus.
3. Connect the resistor from hole B12 to the ground bus.

4. Insert the pushbutton's four pins into holes E10, F10, E12, and F12.
5. Insert the LED's long lead into the power bus, and the short lead into hole J10.
6. Printed circuit board (PCB) design has grown into its own specialized field within the electronics industry. PCBs play an important role in that they provide electrical interconnections between electronic components, rigid support to hold components, and a compact package that can be integrated into an end product. They are the main component in an electronic device that is responsible for form and function, and they allow advanced semiconductors to communicate with each other at very high data rates.

Printed Circuit Board

A printed circuit board (PCB) is an electronic assembly that uses copper conductors to create electrical connections between components. PCBs also provide mechanical support for electronic components so that a device can be mounted in an enclosure.

All PCBs are built from alternating layers of conductive copper with layers of electrically insulating material. Conductive features on printed circuit boards include copper traces, pads, and conductive planes. The mechanical structure is made up of the insulating material laminated between the layers of conductors. The overall structure is plated and covered with a non-conductive solder mask, and silk screen is printed on top of the solder mask to provide a legend for electronic components. After these fabrication steps are completed, the bare board is sent into printed circuit board assembly, where components are soldered to the board and the PCBA can be tested.

During manufacturing, the inner copper layers are etched, leaving the intended traces of copper for connecting components in the circuit board. Multiple etched layers are laminated in succession until the printed circuit board stack-up is complete. This is the overall process used in PCB design fabrication, where the bare board is formed before passing through a printed circuit board's assembly process.

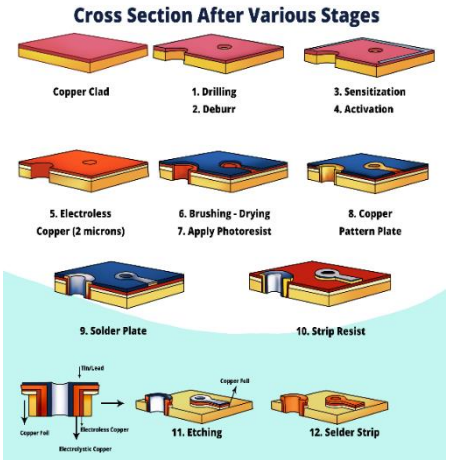
PCBs Past and Present

In the past, electronics were designed and assembled from small integrated circuits (ICs) and discrete components, which were connected together using wires, and the components were

mounted to a rigid substrate. This original substrate was initially a material called bakelite, which was used to replace the top ply on a sheet of plywood. The number of wires was so great that they could get tangled or inhabit a large space within a design. Debugging was difficult and reliability suffered. Manufacturing was also slow, where multiple components and their wired connections were manually soldered.

Old PCBs often looked like the system shown below, where copper traces are exposed and many through-holes are used to hold large, bulky components.

Today, standard designs can have many small components, such as tiny ICs, very small passive components, and advanced chips with very high pin counts. It's impossible to manually connect all of these components together with soldered wires, so the copper connections are deposited directly on insulating substrates as described in the above manufacturing process. Many of today's devices are advanced high-density interconnect (HDI) designs with thousands of connections and multiple electrical interfaces, powering everything from smartphones to heart rate monitors to rockets.



Types of PCBs

In the previous section, I focused on typical PCBs that are assembled on rigid substrates as these are the most common. However, there are other types of circuit boards that are constructed on a range of possible materials. The common types of these are:

- **Single-sided** - This board only has components mounted on one surface. The back surface is typically fully copper (ground) and coated with a solder mask.

- **Double-sided** - This type of circuit board has components mounted on both surfaces. Each surface is defined as a signal layer in the PCB stack-up, so the surfaces will contain traces that carry signals between components.
- **Multi-layer PCBs** - These boards have conductors on internal layers that carry electrical signals between components, or the internal layers could be conductive plane layers. Multi-layer PCBs may be single-sided or double-sided.
- **Rigid-flex PCBs** - Rigid-flex PCBs use a flexible polyimide ribbon that connects two or more rigid sections in a printed circuit board assembly. A rigid-flex board might be used when the design must have some movable element, such as a folding or bending enclosure.
- **Flex PCBs** - Fully flexible PCBs do not use any rigid materials and are made entirely of flexible polyimide ribbons. These boards can have components mounted and soldered on the, just like rigid and rigid-flex printed circuit boards.
- **Printed flex PCBs** - These PCBs use a flexible material as the base, and copper conductors are printed onto the flexible material in an inkjet process or in a similar additive process. The resulting boards are very similar to flex PCBs.
- **Metal-core PCBs (or insulated metal substrate (IMS) PCBs)** - These boards use a metal slab in the core layer (normally aluminum) in order to provide much greater rigidity and heat dissipation than in typical rigid printed circuit boards. The metal-core PCB design manufacturing process is quite different from the standard rigid PCB design manufacturing process, and there are a few design points to consider to ensure solvability. These boards are common in high-power lighting and some industrial applications.
- **Ceramic PCBs** - These boards are less common and are used in applications that require very high thermal conductivity such that the board can dissipate large amounts of heat away from components.
- **HDI PCBs** - These PCBs use very high pin count components that require a specialized manufacturing process and specialized materials to accommodate a very high density of copper connections.
- **UHDI and Substrate-like PCBs** - These PCBs are so small and dense that they have bypassed capabilities of subtractive etching, and instead they require a specialized additive manufacturing process used to build IC packages.

The fabrication and assembly processes for these types of PCBs vary, but today's ECAD software can help designers create any of these boards as long as the right PCB design rules are enforced in the software.

Structure and Applications of PCBs

Many of the important performance characteristics of a PCB are defined in the stack-up or the arrangement of layers in the PCB. The layer stack-up is built with alternating layers of conductive and insulating material, and with alternating layers of core and prepreg (two types of dielectrics used in the layer stack-up). The dielectric and mechanical properties of the core and prepreg will determine reliability and signal/power integrity in the design, and they should be selected carefully when designing for high-reliability applications. For example, military and medical applications need highly reliable designs that might be deployed in harsh environments, and a PCB for a telecom system might require a low-loss PTFE laminate in a small package.

An example of a PCB stack-up is shown below. In this example, the stack-up implements a 4-layer structure with two internal plane layers (L02_GND for ground, and L03_PWR for power). This type of stack-up is appropriate for IoT devices, lightweight embedded systems, and many other designs that use high-speed protocols. The internal plane arrangement helps ensure power integrity while also providing some shielding against external EMI. The internal plane layers also provide a consistent reference for controlled impedance signals. This type of stack-up is typical for many designs and is often a starting point for many modern printed circuit boards.

High-Density Interconnect (HDI) PCB Designs

Today's advanced devices in PCB design utilize high density interconnect (HDI) design practices, where the sizes of features in a PCB can be extremely small. These circuit boards largely follow the same engineering process as any other circuit board, but they are deployed in more advanced systems requiring large numbers of components and connections. Some of the well-known products where these circuits boards are used include:

- Smartphones and other mobile devices
- Data center architecture, such as server motherboards
- Add-in cards for servers and embedded computers
- Very small medical wearables or implants

The main component packaging type that can drive the use of HDI design and manufacturing in a PCB build is ball grid array (BGA) packaging, as well as related packaging types like land grid array (LGA). Many popular microcontrollers, MPUs, and FPGAs are offered in BGA packaging as this is the easiest way to fit a large number of I/O pins into a small component package size. BGA packages are the biggest drivers of miniaturization in many devices, and many consumer products use custom processors in BGA packages. For example, the image below shows the bottom side of an older CPU, but the supporting components on the IC substrate are visible from the bottom side.

UNIT -II

POWER SUPPLY AND MEASURING INSTRUMENTS

Zener Diode

A Zener diode, also known as a breakdown diode, is a heavily doped semiconductor device that is designed to act in the opposite direction. Zener diode is commonly used as a voltage regulator to maintain a constant DC output voltage.

A voltage regulator is a part of the power source that maintains a consistent voltage under all operating conditions. It maintains voltage throughout power fluctuations and load changes. It can control both AC and DC voltages. Their secondary function is to shield the electric circuit from voltage spikes that could damage or fry it.

A Zener diode is a special type of electronic component that can control the flow of electric current in a circuit. It's like a valve for electricity. It is a handy device for controlling and stabilizing voltages in electronic circuits, keeping everything running smoothly and protecting other components from excessive voltage.

Zener Diode as a Voltage Regulator

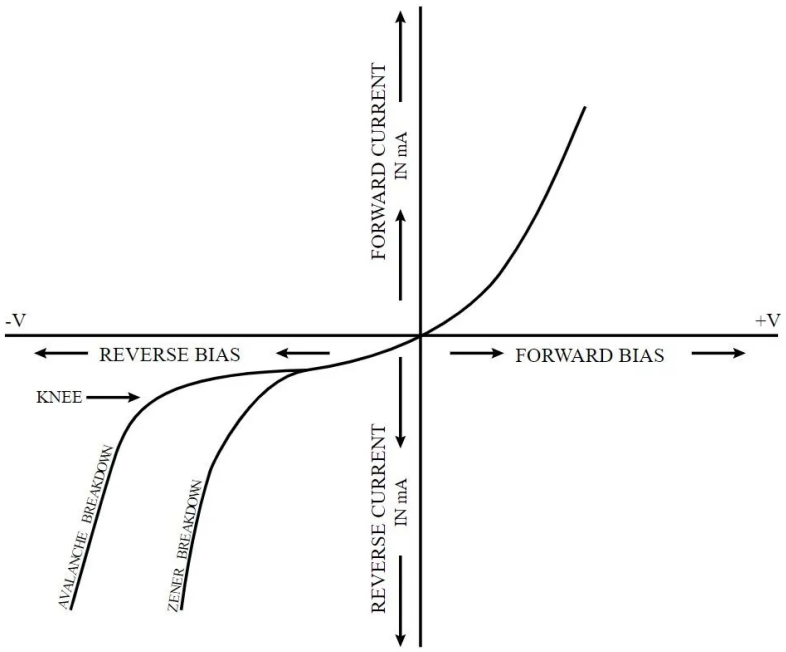
When provided reverse bias feedback, the Zener diode operates as a voltage regulator, generating a little leakage current till a constant voltage is achieved. A Zener diode has a typical current flow from anode to cathode. The Zener diode behaves like a general-purpose diode with a silicon PN junction whenever loaded in a forward direction. This forward flow can be reversed if the voltage surpasses a particular limit. The constant voltage aids the Zener diode’s voltage regulation.

V-I Characteristics of Zener Diode

We can see that the Zener diode has an area in its reverse bias characteristics where a continuous negative voltage emerges independent of the current that flows through the diode from the V-I characteristic curve. Even when the current changes dramatically, the voltage

remains constant. A Zener diode's capacity to manage itself can be utilised to regulate or stabilise the voltage source in the face of supply or load fluctuations. Because of this feature, a voltage regulator can be made out of a Zener diode operating in the breakdown zone.

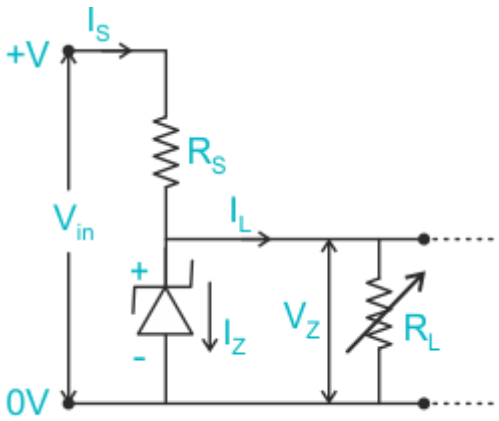
The Zener diode's capacity to manage itself can be utilised to moderate or maintain a voltage source in the face of supply or load changes. Because it can be utilised in the simplest forms of voltage regulator applications, the fact that now the voltage across the diode inside the breakdown zone seems to be almost constant turns out to be a significant feature of the Zener diode. A voltage regulator's job is to deliver a constant voltage to a load parallel connection with it, regardless of supply voltage waves or load current fluctuations.



Working of Zener Diode as a Voltage Regulator

The capacity of a Zener diode to keep a constant voltage regardless of changes in source or load current is critical in this application. A voltage regulation device's general role is to give a constant output voltage to a load connected in parallel to it, regardless of variations in the load's energy drawn (Load current) or fluctuations and instability in the supply voltage. If the current remains within the limit of the min and max reverse currents, the Zener diode will produce a constant voltage.

To restrict the current that flows through the Zener diode, a resistor R_s is connected in series with the diode, and also the input voltage V_{in} is connected across as shown in the image, and the output voltage V_{out} is chosen to take across the Zener diode with $V_{out}=V_z$. Because the reverse bias features of the Zener diode are required to control the voltage, it is wired in reverse bias mode, and with a cathode linked to the circuit's positive rail.



Whenever the load is connected, a small valued resistor would result in a big diode current and electricity, which would raise the power dissipation need of the diode, which could exceed the Zener's maximum power rating and harm it.

The value of the resistor can be determined by the formula

$$R_S=(V_{in}-V_Z)I_zR_S=(V_{in}-V_Z)I_z$$

Where, R_S is the value of series resistance and V_{in} is the input voltage and V_z is Zener voltage.

Using this method, it is simple to assure that the resistor value chosen does not result in a current flow greater than the Zener can tolerate.

One minor issue with Zener diode-based regulatory circuits is that although attempting to moderate the input voltage, the Zener might generate electrical noise just on the supply rail. Although it may not be a problem in most cases, a big value decoupling capacitor placed across the diode may address the problem. This helps to keep the Zener's output stable.

Dual Power Supply

A dual power supply or dual voltage supply refers to a configuration that generates two independent and symmetrical output voltages, typically a positive and a negative voltage, often known as the +Vcc and -Vcc, respectively. It provides a balanced power source, enabling devices to operate with positive and negative voltages simultaneously.

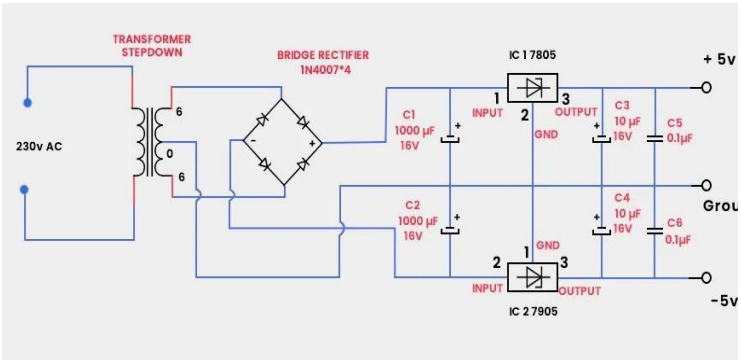
Importance of a Dual Power Supply

A dual power supply is an important component in numerous electronic systems, particularly those involving amplifiers, audio equipment, operational amplifiers, and analog circuits. By providing both positive and negative voltages, a dual power supply allows for proper biasing, amplification, and operation of these devices, enabling them to function optimally.

Types of Dual Power Supply

There are three types of dual power supply as maximum electronic equipment requires a DC power source in the range of 5-15V. They are as follows:

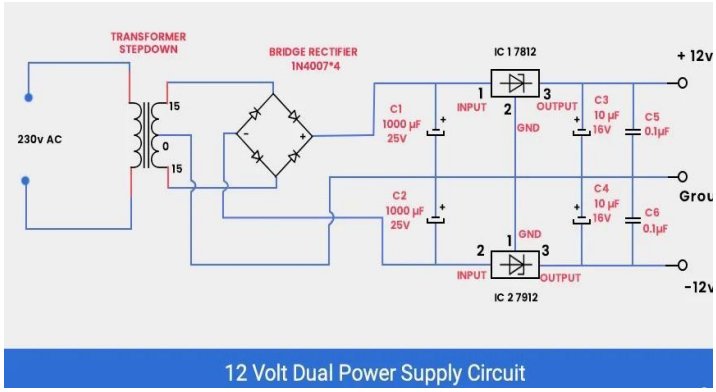
5 Volt Dual Power Supply Circuit Diagram



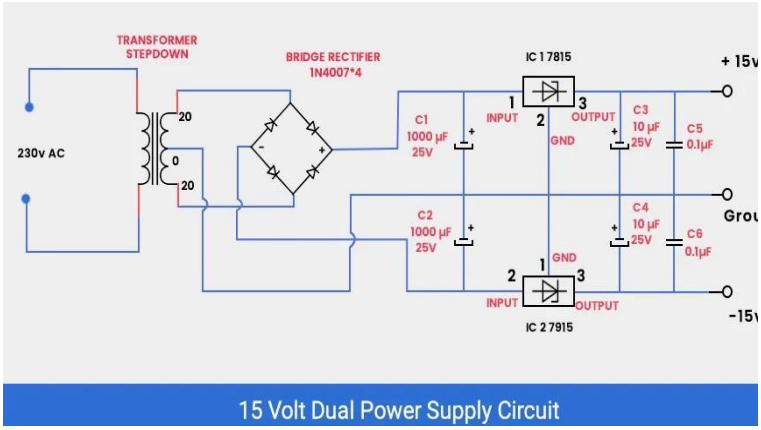
5 Volt Dual Power Supply Circuit

12 Volt Dual Power Supply Circuit Diagram

15 Volt Dual



Power Supply Circuit Diagram



Components Requirement for Dual Power Supply Circuit

1. AC to DC Converter: Converts alternating current (AC) to direct current (DC).(such as LM50, LS10, LS05, LD10, LD15, LO30)
2. DC to DC Converter: Converts DC voltage levels to the desired output voltage levels. For e.g. Mornsun k7803, PV200, Mornsun k7805.
3. AC to DC Power Supply: Provides a stable and regulated DC power source. E.g. LM150, LI120.
4. Transformer: AC-to-AC or AC-to-DC and DC-DC transformer with dual secondary windings.
5. Diodes: Rectifier diodes (bridge or individual diodes).
6. Capacitors: Electrolytic capacitors for filtering.
7. Voltage Regulators: Positive and negative voltage regulators for regulating the output voltages.
8. Resistors: For voltage regulation and current limiting.
9. LEDs: Optional indicators for power status.

Step By Step Construction Guide for Dual Power Supply Circuit

- ✓ Identify the transformer's primary and secondary windings and connect them appropriately to the AC power source.
- ✓ Connect rectifier diodes to the transformer's secondary winding outputs to convert AC to DC.
- ✓ Add electrolytic capacitors to filter the rectified DC voltage and minimize ripple.
- ✓ Integrate AC to DC converter, DC to DC converter, and voltage regulators to obtain regulated positive and negative voltages.
- ✓ Incorporate resistors for voltage regulation and current limiting.
- ✓ Optional: Include LEDs and resistors as power indicators.

Working Principle of a Dual Power Supply

A dual power supply operates on the principle of converting alternating current (AC) to direct current (DC) using a transformer and rectifier diodes. The filtered DC voltage is regulated by voltage regulators, such as the LM50, LS10, LS05, LD10, LD15, LO30, Mornsun k7803, PV200, Mornsun k7805, ensuring a stable and controlled output voltage. The positive and negative voltage regulators generate regulated $+V_{cc}$ and $-V_{cc}$ outputs, respectively, which are used to power different sections of the circuit or electronic device.

Advantages of Dual Power Supply

1. Provides symmetric positive and negative voltages for balanced circuit operation.
2. Enables amplifiers, audio equipment, and analog circuits to function optimally.
3. Ensures proper biasing, amplification, and operation of electronic devices.

Applications of Dual Power Supply

Audio Equipment

Audio amplifiers, mixers, and other sound processing equipment rely on dual power supplies to handle audio signals that fluctuate above and below ground. This enables high-fidelity sound reproduction and minimizes distortion in audio applications.

Testing & Measurement Equipment

Instruments like oscilloscopes, multimeters, and signal generators require dual power supplies to provide the necessary voltage levels for accurate calibration and testing of electronic components and devices. This ensures reliable and precise measurements in various testing environments.

Medical Devices

Medical equipment such as electrocardiograms (ECGs), medical imaging systems, and diagnostic tools depend on dual power supplies for precise voltage control. This is crucial for accurate measurements and reliable operation in medical diagnostics and patient monitoring.

Communication Systems

Communication devices and circuits, including radio transmitters, receivers, and signal processing units, use dual power supplies to process complex signals with both positive and negative voltage swings. This supports clear and stable communication signals in various applications.

Charging Circuits

Dual power supplies ensure stable and efficient charging in devices like cell phone chargers and power banks by providing the required dual voltages. This helps manage the charging and discharging processes, ensuring battery longevity and reliability in portable electronic devices.

DC Motors

Dual power supplies are used in DC motor control circuits to supply the necessary bipolar voltages for efficient operation and control. This enables precise speed and direction control in applications such as robotics, automation, and industrial machinery.

Dual Power Supply ICs 7805

For every electronic device, the regulated power supply is essential because these devices use semiconductor material with a fixed rate of voltage and current. If there is any difference in the fixed rate of voltage and current, then the device will get damage. Batteries are one of the main DC supply sources but we cannot use battery over time in sensitive electronic circuits as they lose their potential & drain out ultimately. The batteries provide different voltage ranges like 1.2 Volts, 3.7 Volts, 9 Volts, and 12 Volts. Most of the integrated circuits work with 5V supply therefore we require a device to supply a reliable 5V Supply called voltage regulator. Here, a 7805 voltage regulator comes from 78XX series of the linear voltage regulators. This regulator generates 5V regulated output.

The voltage regulator is one kind of electrical component used to maintain a stable voltage across any electronic device. The fluctuations in the voltage can cause an undesirable cause in an electronic system. For that, maintaining a stable voltage is compulsory based on the system voltage requirement.

For instance, a simple LED uses a maximum of 3V. Once the voltage increases than this voltage, then the diode will get damage. Similarly, in all the electrical and electronic components, it is common. Once the voltage increases, all the components in the system will get damaged. To overcome this situation, a voltage regulator is used to provide a regulated power supply.

IC 7805 is a linear voltage regulator and it includes three terminals including 5V of the fixed output voltage. This voltage is used in a variety of applications. At present, the manufacturing of this voltage regulator can be done by different manufacturing companies like STMicroelectronics, ON Semiconductor, Texas Instruments, Infineon Technologies, Diodes incorporated, etc. These ICs are available in different packages namely TO-3, TO-220, TO-263, and SOT-223. But the most frequently used package is TO-220.
The equivalent ICs of this voltage regulator are IC LM7809, IC LM7806, IC LM317, IC LM7905, IC XC6206P332MR & IC LM117V33.

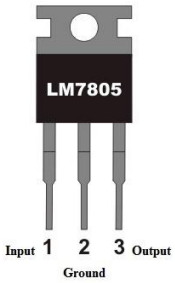
Features

The main features of the IC 7805 voltage regulator include t following.

- It uses fewer components to work properly.
- It delivers the current up to 1.5 A.
- Thermal shut down & internal current limiting.
- Minimum & maximum input voltages are 7V & 25V.
- The operating current is 5mA.
- Protection of short circuit and thermal overload.
- The highest junction temperature is 125 degrees Celsius.
- It is available in KTE and TO-220 package.

Pin Diagram

The **pin diagram of the 7805-voltage regulator** is discussed below. This voltage regulator includes three pins namely input pin, ground pin, and output pin. Each pin and its function can be discussed below.

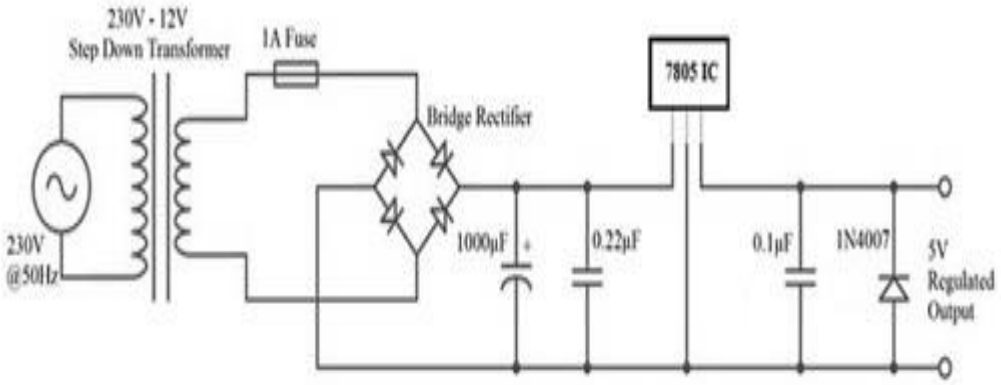


7805 Voltage Regulator Pin Diagram

- Pin1 (Input): This is an input pin, where a positive unregulated voltage can be given like an input toward this pin.
- Pin2 (Ground): This is the GND pin where this pin is common to both input & output.
- Pin3 (Output): This is the output pin where the 5V of regulated voltage can be taken at this pin.

7805 Voltage Regulator Circuit

The circuit diagram of the 7805 voltage regulator is shown below. This circuit generates a 5V regulated supply from AC mains. This circuit can built with a step-down transformer (230V-12V), bridge rectifier, Fuse 1A, Capacitor-1000µF, IC 7805-voltage regulator, capacitors- 0.22µF & 0.1µF, diode 1N4007.



7805 Voltage Regulator Circuit

IC 7805 Voltage Regulator Working

In the above circuit, the AC power supply is converted into DC. This circuit is designed with a transformer, a bridge rectifier, IC 7805linear voltage regulator otherwise capacitors.

This circuit is divided into two portions wherein the first portion of the circuit, the AC mains can be changed into DC. In the second portion, this DC can be changed into regulated 5V DC. At first, a step-down transformer is used to step down the voltage from 230V to 12V by connecting its primary winding to the mains supply. The secondary winding of the transformer can be connected to bridge rectifier

A 1A fuse is arranged in between the bridge rectifier and the transformer to stop the flow of current that is drawn through the 1A circuit. The bridge rectifier generates a rectified DC that is smoothened using 1000µF Capacitor. So, the output of the 1000µF capacitor is 12V unregulated DC. This DC can be given used like an input to the IC 7805 voltage regulator. After that, this regulator changes regulated 5V DC & the o/p is attained at its o/p terminals.
In the above circuit, the input voltage must be higher compare with the o/p voltage. The I/O currents are nearly the same. Once the 7.5V 1A supply can be given at i/p, then the o/p will be 5V 1A. The residual power can be dissipated like heat using the 7805 IC.

Heat Dissipation in IC 7805

In this kind of regulator, huge energy can be exhausted in heat form. The disparity in the input & output voltage will generate heat. So, if the difference in the voltage is high, then there will

be a high generation of heat. So a heat sink is used with IC 7805 otherwise surplus heat will be the reason for malfunction.

Advantages

The **advantages of the IC 7805 voltage regulator** include the following.

- This does not need any component to handle its output voltage.
- In includes built-in protection to protect from the overvoltage.
- A heat sink can be used through the GND terminal to protect the IC from high current or short circuits.

7805 Voltage Regulator Applications

The applications of 7805IC include in a wide range of electrical and electronic circuits like the following.

- Changeable Output Regulator
- Permanent O/P Regulator
- Current Regulator
- DC Voltage Regulator
- Reverse Bias based Projection Circuit
- Inductance Meter
- Phone Charger
- Portable CD Player
- Extension of IR remote control
- UPS power supply circuits.
- Used as +5V voltage regulator

7905 Voltage Regulator

The 7905 is a negative voltage regulator from the 79XX series, designed to provide a fixed output of 5V. This regulator is part of the three terminal regulator family, which includes

positive (78XX series) and negative (79XX series) regulators. The "05" in its name represents the output voltage (5V), and it can handle currents up to 1.5A when properly cooled.

Working Principle of the 7905 Voltage Regulator

The 7905 works similarly to its positive counterpart (7805), but it is used in circuits that require negative voltage regulation. It receives an input voltage (typically between 7V and 35V) and regulates it down to a constant 5V. This stable negative output voltage is crucial for various analog, audio, and dual supply systems.

1. Input Voltage: The 7905 requires a negative voltage input higher (in magnitude) than 5V, usually around 7V to 35V.
2. Output Regulation: The regulator reduces this input voltage to a precise 5V output.
3. Filtering: Input and output capacitors (usually 0.33 µF and 0.1 µF, respectively) are used to reduce noise and stabilize the output.

Applications of the 7905 Voltage Regulator

The 7905 finds applications in various circuits that require stable negative voltage. Here are some common examples:

- Dual Power Supply Circuits: In circuits requiring both positive and negative voltage (e.g., op-amp based designs), the 7905 works in conjunction with a 7805 to provide a dual-voltage power supply.

- Analog and Audio Circuits: Many audio circuits require negative voltage for proper biasing of amplifiers and signal processing ICs.

- Operational Amplifier Circuits: The 7905 helps provide the necessary negative supply rail in opamp circuits, ensuring proper operation and signal fidelity.

- Reverse Polarity Circuits: In cases where reverse polarity is needed for certain components or operations, the 7905 regulates the negative supply voltage.

Pin Configuration

The 7905 has a simple 3pin configuration, similar to the 7805:

1. Pin 1 (Input): The unregulated negative voltage is supplied to this pin.
2. Pin 2 (Ground): This pin is connected to the system's ground.
3. Pin 3 (Output): Provides the regulated 5V output.

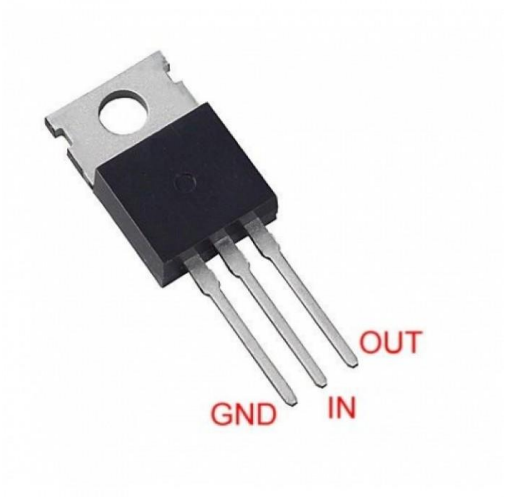
Important Considerations for Using the 7905

1. Heat Dissipation: The 7905 can handle up to 1.5A, but at higher currents, it will generate heat. Using an appropriate heatsink is essential to prevent thermal shutdown.

2. Input Capacitor: Always use a 0.33 µF capacitor on the input to help stabilize the voltage and prevent oscillations.

3. Output Capacitor: A 0.1 µF capacitor on the output is recommended for noise reduction and improved stability.

4. Voltage Drop: The input voltage should be at least 7V to ensure proper regulation. The 7905 has a voltage dropout of around 2V, meaning the input must be more negative than 5V by at least 2V.



Switched-mode power supplies (SMPS), sometimes referred to as switch mode power supplies, have become the workhorse of efficient power conversion, taking a mains voltage AC input and converting it down to a low voltage DC output. AC-DC switched-mode converters are omnipresent; the external desktop power supply for your laptop, inside your set-top box, and the wall plug-in charger for your smartphone.

In the past, a linear method of power conversion performed the conversion task. Linear power supplies typically require heavy and bulky transformers with analog “linear’ regulation circuitry. Due to average conversion efficiencies of less than 65%, transformers generate relatively large amounts of waste heat, which requires dissipation.

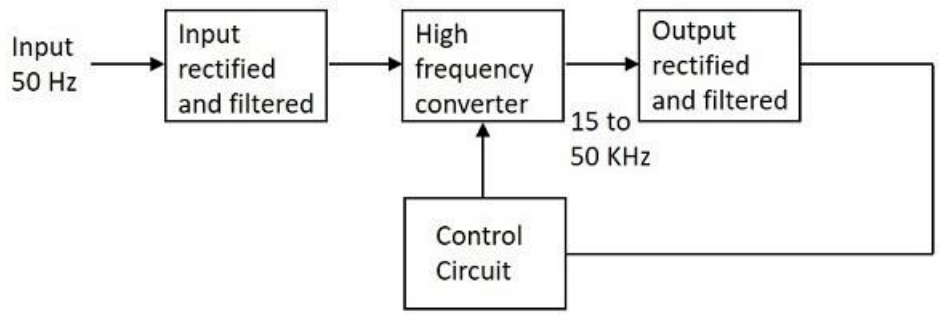
By comparison, switched-mode power supplies are compact, power-efficient, typically better than 85%, and lightweight. Switched-mode power supplies are also extremely flexible from a design perspective, enabling designers to find an optimal solution for whatever power requirements their end-product might have.

Switched-mode principles

The principles of switched-mode conversion apply for both AC-DC and DC-DC power supplies. In the case of an AC-DC power supply, there are a couple of stages, including

rectification of a single-phase 230Vac or 3-phase 400Vac 50Hz mains voltage, before the DC-DC conversion stages.

In both cases, in a DC-DC conversion stage, a primary circuit of power semiconductors (a power switch circuit) generates a high frequency alternating voltage to a transformer. This causes a current in the primary windings that will induce an alternating current in the secondary windings, so a secondary voltage is built up. The winding ratio of the transformer specifies stepping up or down. A secondary circuit rectifies the high frequency voltage and could create a feedback signal to the primary electronics for regulation.



Input Stage

The AC input supply signal 50 Hz is given directly to the rectifier and filter circuit combination without using any transformer. This output will have many variations and the capacitance value of the capacitor should be higher to handle the input fluctuations. This unregulated dc is given to the central switching section of SMPS.

Switching Section

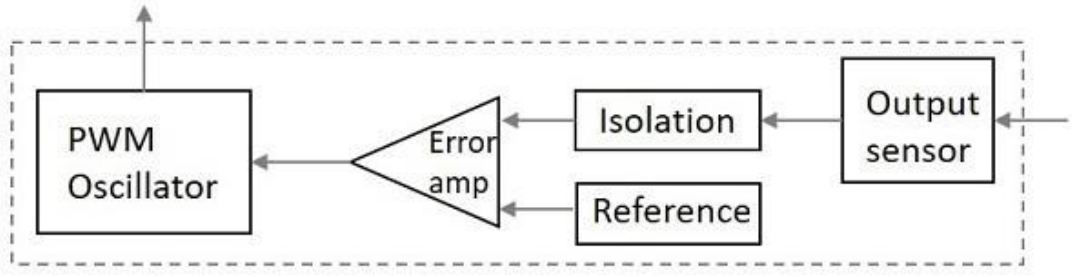
A fast switching device such as a Power transistor or a MOSFET is employed in this section, which switches ON and OFF according to the variations and this output is given to the primary of the transformer present in this section. The transformer used here are much smaller and lighter ones unlike the ones used for 60 Hz supply. These are much efficient and hence the power conversion ratio is higher.

Output Stage

The output signal from the switching section is again rectified and filtered, to get the required DC voltage. This is a regulated output voltage which is then given to the control circuit, which is a feedback circuit. The final output is obtained after considering the feedback signal.

Control Unit

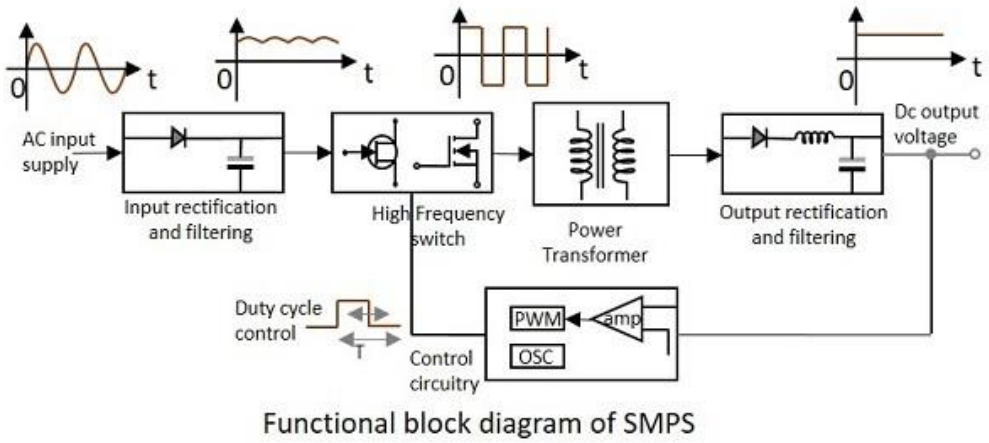
This unit is the feedback circuit which has many sections. Let us have a clear understanding about this from The following figure.



The above figure explains the inner parts of a control unit. The output sensor senses the signal and joins it to the control unit. The signal is isolated from the other section so that any sudden spikes should not affect the circuitry. A reference voltage is given as one input along with the signal to the error amplifier which is a comparator that compares the signal with the required signal level.

By controlling the chopping frequency the final voltage level is maintained. This is controlled by comparing the inputs given to the error amplifier, whose output helps to decide whether to increase or decrease the chopping frequency. The PWM oscillator produces a standard PWM wave fixed frequency.

We can get a better idea on the complete functioning of SMPS by having a look at the following figure.



Functional block diagram of SMPS

The SMPS is mostly used where switching of voltages is not at all a problem and where efficiency of the system really matters. There are few points which are to be noted regarding SMPS. They are

- SMPS circuit is operated by switching and hence the voltages vary continuously.
- The switching device is operated in saturation or cut off mode.
- The output voltage is controlled by the switching time of the feedback circuitry.
- Switching time is adjusted by adjusting the duty cycle.
- The efficiency of SMPS is high because, instead of dissipating excess power as heat, it continuously switches its input to control the output.

Disadvantages

There are few disadvantages in SMPS, such as

- The noise is present due to high frequency switching.
- The circuit is complex.
- It produces electromagnetic interference.

Advantages

The advantages of SMPS include,

- The efficiency is as high as 80 to 90%
- Less heat generation; less power wastage.

- Reduced harmonic feedback into the supply mains.
- The device is compact and small in size.
- The manufacturing cost is reduced.
- Provision for providing the required number of voltages.

Applications

There are many applications of SMPS. They are used in the motherboard of computers, mobile phone chargers, HVDC measurements, battery chargers, central power distribution, motor vehicles, consumer electronics, laptops, security systems, space stations, etc.

Types of SMPS

SMPS is the Switched Mode Power Supply circuit which is designed for obtaining the regulated DC output voltage from an unregulated DC or AC voltage. There are four main types of SMPS such as

- DC to DC Converter
- AC to DC Converter
- Fly back Converter
- Forward Converter

The AC to DC conversion part in the input section makes the difference between AC to DC converter and DC to DC converter. The Fly back converter is used for Low power applications. Also there are Buck Converter and Boost converter in the SMPS types which decrease or increase the output voltage depending upon the requirements. The other type of SMPS include Self-oscillating fly-back converter, Buck-boost converter, Cuk, Sepic, etc.

Multimeter

A multimeter is an electrical measuring instrument used for measuring voltage, current, resistance, and other electrical parameters. It can measure “multiple” electrical quantities that depend on the type of multimeter.

They are handheld devices that vary in size, precision, and accuracy. They are mostly used by electricians, engineering students, and hobbyists for troubleshooting electrical devices and circuits.

It has an LCD or scale, a dial, testing probes and ports. The LCD or scale is used for displaying the measurement. The dial has multiple functions that can be selected by turning the knob. The testing probes are used for connected the meter to the circuit. The ports are used for inserting the testing probes into the meter.

Working of Multimeter

A multimeter can be either analog or digital. However, both types of multimeters have the same working procedures.

It has a dial that is used for selecting the required measurement. it has multiple measurement symbols written on it. The dial is rotated to select measurement. it can also select the proper range for the measurement. Some meter has auto range features.

It has two probes i.e. black and white. The black probe is always inserted in the black “COM” or common port while the red probe is inserted into one of the other red ports according to the measurement.
The probes are used to connect the meter to the circuit. The internal circuit of the multimeter measures the selected parameter and displays its reading on the LCD or scale.

However, the precaution and the configuration used for connecting the multimeter to the circuit or a component varies with the type of measurement.

Functions

Function	Description	Symbol
AC Voltage	Measure AC Voltage	V~

A

DC Voltage	Measure DC Voltage	V⎓
AC Current	Measure AC Current	A~
DC Current	Measure DC Current	A⎓
Resistance	Measure resistance of a circuit or component	Ω
Frequency	Measure frequency of a signal	Hz
Duty Cycle	Measure the duty cycle of the signal	%
Diode Test	Checks a diode in a circuit	
Capacitance	Microfarad, measure capacitance in microfarads	μF
Continuity	Gives an audible indication for continuity between two points.	
Transistor Test	The forward current gain of a transistor	hFE
Relative Mode	Measure the offset value. Used for accurate measurement of small values	REL
Temperature	Measures temperature in Fahrenheit or Celsius	F°, C°

multimeter has multiple functions that depend on the type of the multimeter. These functions can be activated by using the selection dial as well as some buttons. Its main function is to measure current, voltage and resistance. Here are some of the functions available in a multimeter:

Types of Multimeter

There are two main types of multimeter i.e. analog multimeter and digital multimeter.

Analog Multimeter

Analog multimeter is the oldest form of a multimeter. it has a needle that rotates along a scale. They are cheap but are difficult to read. However, they are more sensitive than a digital multimeter. It can sense even small changes in the readings.

It is made of a coil placed between two permanent magnets. A needle is placed on top of the coil. When a current passes through the coil, it generates a magnetic field that interacts with the magnetic field of the permanent magnet. As a result, the coil rotates moving the needle along the scale. The angle of rotation depends on the amount of current flowing through the coil. This configuration is also known as a galvanometer. It has a very small resistance therefore, it is more sensitive.

Due to the same reason, Full Scale Deflection (FSD) should be avoided. Because the current exceeds the range of the coil deflection and it starts to burn the coil which will destroy the meter itself. Therefore, the multimeter has multiple ranges where shunt resistors are used in parallel to divide the current and measure larger values.

Analog multimeter is difficult to read for beginners because it has multiple scales on a single dial. You have to spot the selected scale and sometimes it requires you to multiply the reading by 10 or 100 to get the final measurement for larger ranges. The needle can also cause parallax error where you have to look at exact 90 degrees at the scale to get a precise reading.

Advantages

- It does not require a battery to measure voltage and current.

- It is very sensitive.
- It can detect small changes in the reading in real-time.
- It has a quicker response time for checking continuity or leakage.
- It is cheaper than a digital multimeter.
- It can show fluctuations in current and voltages.

Disadvantages

- Full scale deflection or “overloading” can damage the analog multimeter
- It is difficult to read from the analog scale.
- There are different uncertainties in the reading.
- It can cause parallax error.
- They are physically not very strong.
- They do not have extra features such as in digital multimeter.
- Unable to show negative values.
- It has Low input impedance that affects the circuit due to the loading effect.
- It requires “zero adjustment” to adjust the needle.

Digital Multimeter

A digital multimeter or DMM measures electrical quantities and shows them on an LCD screen. It computes the readings digitally and displays them on an easily readable digital screen. On the other hand, the analog multimeter displays the readings without any computation thus having a quick response time.

It has an LCD, a dial and multiple ports. The dial includes internal circuitry that is connected through a trace of concentric rings. The knob is used to activate a circuit for specific measurements.

Digital multimeter includes a microprocessor to compute readings. However, the input voltage or current is in analog form. Therefore, an ADC (analog to digital converter) is included to convert the readings and display them on the LCD screen. The LCD makes the measurement easily readable as opposed to the scale on an analog multimeter.

The dial is also used to select from multiple ranges having different shunt resistors. When the measurement exceeds the range, the multimeter overloads. Therefore, it has overload protection. Some DMMs have auto range features that automatically select the proper shunt resistor for the measurement to avoid overloading.

Advantages

- The readings are easy to read from the LCD display
- The readings are more accurate.
- There are fewer uncertainties and no parallax error.
- It has a high input impedance that does not affect the circuit.
- They are physically robust.

- It can show both positive and negative readings.
- It has extra added features such as capacitance, frequency, temperature measurement.
- There is no requirement for zero adjustment.
- It can record and display minimum and maximum values of reading.
- Auto range feature allows selecting a suitable circuit for the measurement and avoid any potential damage to the meter.

Disadvantages

- It requires a battery for any kind of measurement.
- They are expensive than an analog multimeter.
- It cannot detect fluctuations in readings.
- It has a slower response time due to computation.
- It has a voltage limit due to sensitive electronic circuitry.

Terms of Multimeter

There are several terms used for multimeters that define how good and reliable the multimeter is.,

Sensitivity

The sensitivity of the multimeter is defined as the resistance offered per volt of full-scale deflection by the multimeter. Its unit is ohm/volt (Ω/V).

Sensitivity shows the internal resistance of a meter. If a meter has high sensitivity, it has high internal resistance. Such meters do not affect the circuit for voltage measurement. it draws no current from the circuit.

Resolution

The resolution of a multimeter is defined as the smallest change in the electrical parameter (current, voltage, resistance, etc.) it can detect and display.

For example, a resolution of 1mA at the range of 400mA means the multimeter can detect 1mA of change in the reading. A multimeter that has a smaller resolution and has more accurate reading.

Range

The range of the multimeter is the maximum value the circuitry of the meter can measure. It is related to the resolution of the multimeter. If the range is lower, it has a smaller resolution. The resolution increases with the range.

If the measurement exceeds the range, it overloads the multimeter. Therefore, the best and accurate reading is obtained at the lowest range without overloading the meter.

Accuracy

The accuracy of a multimeter is defined as the largest allowable error in a measurement. It shows how close the reading in to the actual measurement. it is expressed in %.

For example, a multimeter having ±1% accuracy has reading of 100 ohms. Then the actual reading can be 99 ohms or 101 ohms.

If a multimeter has low % accuracy, it has a more accurate reading.

Precision

The precision of a multimeter refers to how close the measurements are when they are repeated under the same conditions. It tells if the multimeter is reliable and its measurement does not change.

Precision also identifies the error pattern in the multimeter that can be compensated.

Probes

The probes of a multimeter are used to connect the meter to a circuit or a component. Their one end is inserted into the port of the meter called banana jack. While the other end is connected to the circuit called probe tips and they can be of various types.

Type of Multimeter Probe Tips

There are several types of multimeter probes that are classified based on its shape and function. However, their main function is to connect the meter to the circuit.

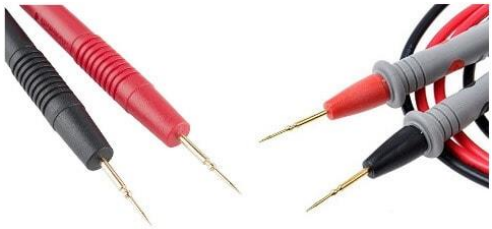
Black and Red Probe

The probes can be mainly classified into black and red probes. The black probe inserts into the "COM" or common port of the meter. It is connected at a lower voltage point.

The red probe inserts into one of the other ports depending on the selected measurement such as voltage, current and resistance. It is connected to the higher voltage point of the circuit.

Pointed Probes

These are the most common type of probes and are the cheapest of them all. They are commonly used for any kind of reading. They are suitable for quick and frequent use.



Alligator Clip

The alligator clip or crocodile clip is a spring-loaded metal clip that has serrated teeth that resemble the jaw like an alligator, thus its name. It makes a firm connection and holds on to the wire. They are suitable for a long-term test.

The con of the alligator clip is that it has a wider tip and it gets wider when it opens. It can touch or create a short circuit with adjacent wires. Therefore, it is not suitable for use in tight spaces such as circuit boards and IC.

Retractable Hook Clips

Retractable hook also known as J-hook or IC test leads has hooks for tips. It has a narrow tip that is retractable. It is used for makes a secure connection in tight spots. The hooks make it easier to hold-on to closely packed small wires and pins.

Tweezer Probes

As the name suggests, such probes are designed in the shape of tweezers. They are used for testing between closely spaced points such as in SMDs (surface mount devices)

Tweezer Probes

Clamp Probes

Clamp probes clamp around a conductor and measure the current flowing through it without physically touching the conductor. Clamp probes are peripheral used for safely measuring current in a circuit. it converts the current into voltage where the conversion ratio is used to calculate the measurement.

The **clamp meter** has built-in clamp probes used for directly measuring current and displaying the current value on its LCD.

Applications of Multimeter

There are different kinds of multimeters ranging from a few dollars to thousands of dollars. The more expensive the multimeter, the more features and functions it has. Some of the basic applications of the multimeter are:

- To measure voltage.
- To measure current.
- To measure resistance.
- To test the continuity in a circuit.
- To measure temperature.
- To measure the frequency of a signal.
- To measure the capacitance of a capacitor.
- Test a diode, check a transistor, troubleshot a relay and test other electronics components.

These basic functions of multimeters are used for troubleshooting any kind of electrical circuit such as

- Voltage measurement is used to know the health of a battery.
- It also tells if an outlet or a switch is working properly.
- The current measurement tells the condition of the load, either it's drawing normal current or too much.
- The continuity test or resistance test detects any broken connection or cable.

How to Measure Resistance using Digital & Analog Multimeter?

Measuring resistance just like voltage and current is an important part of troubleshooting any component. It tells the condition of the components. The resistance measurement is also used to check for open or closed circuits.

Measuring Resistance **using Digital Multimeter:**

- Switch off the power supply to the circuit.

- If there is a capacitor on board, discharge it first.
- Isolate the component whose resistance needs to be measured. If possible remove it from the circuit to avoid any parallel paths that may interfere with the total resistance.
- Switch ON the multimeter.
- Turn the selector knob to the resistance Ω
- Select a suitable range slightly higher than the expected resistance reading for high accuracy. If it is unknown, select the higher settings. It can be brought back down later.

Insert the black probe in the COM (common) socket.

- Insert the red probe in the Ω Most DMMs have a shared socket used for Ω, V and continuity. Use the socket that has Ω symbol on it.
- Connect the leads across the component.
- Note the reading. Change the range to the lowest possible setting to get an accurate reading.

The given 1K Ohm resistor's measurement shows 1004 Ohm resistance which is more accurate as the 4th color band (gold) shows tolerance of 5%

- When finished, remove the probes and turn the selector knob into the voltage mode to prevent damage by accidentally connecting to high voltage.

Measuring Resistance using Analog Multimeter:

Analog multimeter has the same procedure. However, it has a little calibration to perform while measuring resistance.

- As usual, switch off the power supply to the circuit first and discharge if there is any capacitor.
- The component being tested must not have any component in parallel. If possible, remove the component from the circuit.
- Switch ON the Analog multimeter.
- Turn the selector knob to the resistance Ω
- Select a suitable range slightly higher than the expected resistance reading for high accuracy. It can be changed back later.
- Insert the black probe in the COM (common) socket.
- Insert the red probe in the Ω Some meters share the Ω socket with voltage. Use the socket having the Ω symbol on it.
- Calibrate or adjust the zero of the meter by connecting both probes together and rotating the zero adjustment knob to show full-scale deflection i.e. 0 ohms.
- Connect the leads across the component.
- Note the reading. Adjust the range of the meter to show maximum possible deflection to get maximum accuracy.
- If the range is x1, then this reading is 100 ohms. If the range x10, the reading is 1000 ohms. If the range is x100, the reading is 10,000 ohms.
- After finishing, remove the probes and select the voltage measurement mode to avoid accidently connecting it to voltage.

Factor Affecting Resistance Readings

The resistance can be affected by many factors. Therefore, while measuring resistance the following factors must be considered:

Component in a circuit: If the component is inside a circuit, its resistance can be affected by any other components in parallel.

Power through the circuit: if there is power supplied to the circuit or any charged capacitor, it will affect the readings since the ohmmeter works on the basis of current flowing through the meter.

Diode in a circuit: If there is a diode in a circuit, the resistance of the circuit will vary if the probes are swapped with each other. it is due to the fact that the diode does not allow current in one direction.

Fingers touching the leads: if your fingers are touching the leads, it will affect the reading due to the leakage of some current through your body. Do not touch the tip of the leads while measuring resistance.

How to Test a Capacitor using Digital and Analog Multimeter

In most electrical and electronics troubleshooting and repair tasks, a common challenge is testing capacitors. This tutorial outlines eight methods with circuit diagrams to test a capacitor using multimeter and **determine whether it is functioning properly, defective, shorted, or open.**

Capacitors can be tested using either an analog multimeter (AVO meter: Ampere, Voltage, Ohm meter) or a digital multimeter to assess their condition and decide if they are in good working order or need replacement with a new one.

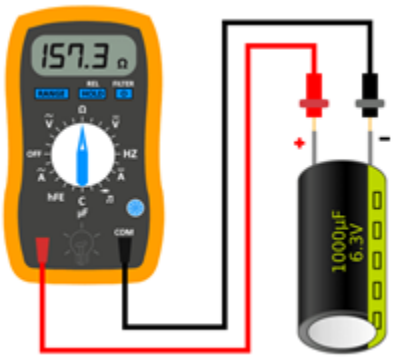
Test a Capacitor using Digital Multimeter – Resistance Mode

To test a capacitor by DMM (Digital Multimeter) in the **Resistance "Ω" or Ohm mode**, follow the steps given below.

1. Make sure the capacitor is fully discharged.
2. Set the meter on the Ohmic range (Set it at least on 1000 Ohm = 1kΩ).
3. Connect the multimeter probes to the capacitor terminals (Negative to Negative and Positive to Positive).
4. Digital multimeter will show some numbers for a second. Note the reading.
5. And then immediately it will return to the OL (Open Line) or infinity "∞". Every attempt of Step 2 will show the same result as shown in steps 4 and 5. It means that **Capacitor is in Good Condition**.
6. If there is no Change, then **Capacitor is dead**.

Warning & Safety Precautions for Testing a Capacitor

For proper safety, use a 12 to 24V DC source in case of both polar and non polar capacitors with a 1kΩ~10kΩ, 5~50W resistor. The resistor should be connected in series with battery and capacitor positive terminals. This way, it will reduce the excessive current while charging the capacitor.



In case of absence of DC source (like batteries), the high rated capacitors (i.e. fan capacitors rated for. 3.5µF, 120, 230 or 400V) you may use 120-230V AC, but you have to connect a series of resistors (say 1kΩ~10kΩ, 5~50Watts) to connect between capacitor and 230V AC supply. This way, it will reduce the charging and discharging current. Here is the step by step tutorial on how you may check a capacitor by this method.

1. Disconnect the suspected capacitor from the power supply or make sure at least one lead of the capacitor is disconnected from the PCB board.
2. Make sure that the capacitor is fully discharged.
3. Connect two separate leads to the capacitor terminals. (Optional)
4. Now safely connect these leads to 24VDC or 230 V AC Supply for a very short period (about 1-4 Sec) [or for a short time where the Voltage rises to 63.2% of the Source Voltage]
5. Remove safety leads from the 24VDC/230V AC Supply.
6. Now short the capacitor terminals (Please be careful to do that and make sure that you have worn safety goggles)
7. If it makes a strong spark, then the **capacitor is good**.
8. If it makes a weak or no spark at all, then it is a **defective capacitor**. You would have to change it immediately with a new one.

How to Test a Transistor using Multimeter (DMM+AVO) – NPN & PNP

Basically a transistor is nothing but two pn-junctions connected back to back. By examining both the junctions (Emitter-Base junction and Collector-Base junction) with the help of a digital multimeter, we can comment on the functionality of the transistor.

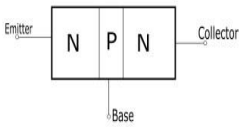
The test of the transistor is based on the principle of pn-junction biasing, i.e., when a forward bias is applied to the pn-junction (by connecting positive terminal to the p-region and negative terminal to the n-region), the junction allows current to through it. When the reverse bias applied to the junction, it behaves as an open circuit.

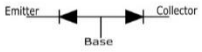
NPN Transistors are widely used. We can test an NPN transistor by testing the junction's continuity in the forward bias and reverse bias mode. In the same manner, we can test a PNP transistor too.

Step by Step Testing of NPN Transistor

- Set the digital multimeter to Diode or Continuity range.
- Connect the Positive probe (Red coloured) of multimeter to the base terminal of the transistor.
- Connect the negative or common probe (Black coloured) of multimeter to the emitter terminal. The multimeter should give some reading.
- Connect the negative or common probe (Black coloured) of multimeter to the collector terminal. Again, the multimeter should give some reading.
- Now, connect the negative or common probe of multimeter to the base terminal of the transistor.
- Connect the positive probe of multimeter to the emitter terminal. This time, the multimeter should read open circuit.
- Connect the positive probe of multimeter to the collector terminal. Again, the multimeter should read open circuit.
- Now, connect the negative probe of the meter to the emitter and the positive probe to the collector. The meter should read open circuit in this case.
- Also, connect the positive probe of the meter to emitter and the negative probe to the collector. Again, the meter should read open circuit.

- If the transistor passes all the tests then, it is functional and all the junctions are in healthy condition.





UNIT – III

MAINTENANCE OF ELECTRONIC HOME APPLIANCES

LIQUID CRYSTAL DISPLAY TV

LCD (Liquid Crystal Display) is a flat panel display technology that uses Liquid crystals to regulate light. The fundamental concept is the control of light waves via liquid crystal materials positioned between two polarized screens.

- Consists of an array of tiny segments known as pixels that may be adjusted to display different types of content.
- Using light polarization to show objects.
- To illuminate the display, solely use ambient light.

Types of Liquid Crystal Displays (LCDs)

Three types of LCD screens can be distinguished: TN (twisted nematic), IPS (in-plane switching), and VA (vertical alignment).

TN (Twisted Nematic)

TN (Twisted Nematic): Nematic liquid crystal is positioned between two glass plates in this technique. The liquid crystals twist at 90° when electricity is applied to the electrodes. The most common kind of LCD screens are TN (Twisted Nematic) screens. They provide modest viewing angles and full-color visuals.

VA (Vertical Alignment)

VA (Vertical Alignment): Displays with VA, or Multi-Domain Vertical Alignment, (MVA), offer characteristics present in both TN and IPS screens. Light can pass through VA displays because when voltage is applied, the pixels align vertically with the glass substrate.

Construction of Liquid Crystal Display

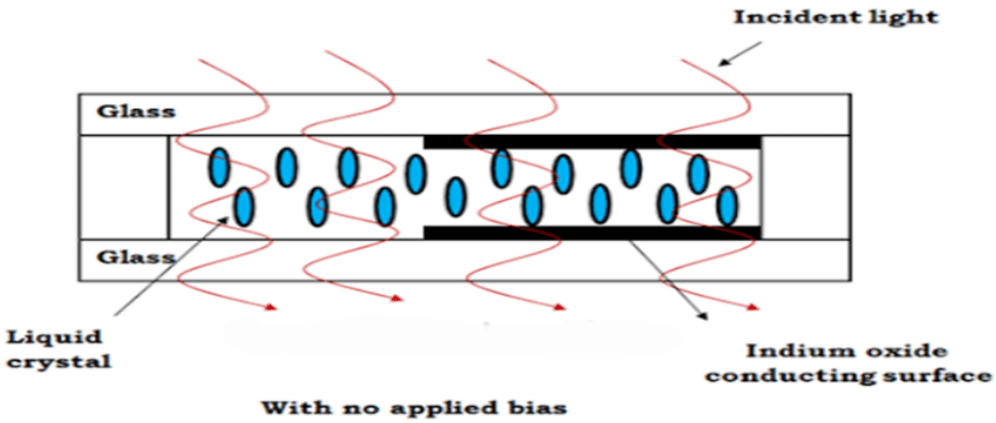
The LCD is constructed from two pieces of polarized glass. There are two electrodes used: a positive electrode and a negative electrode.

External voltage is applied to the LCD to LCD using these electrodes and it is made up of indium-tin-oxide. A 10–20 μm liquid crystal layer is sandwiched between two sheets of glass.

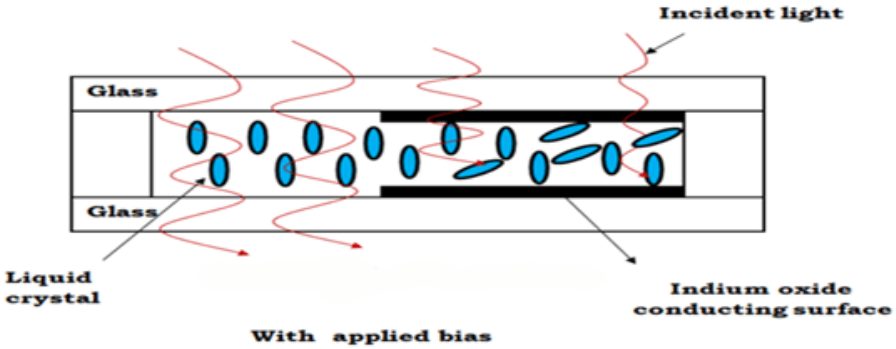
By altering the polarization, light can be transmitted through or prevented.

Working Principle

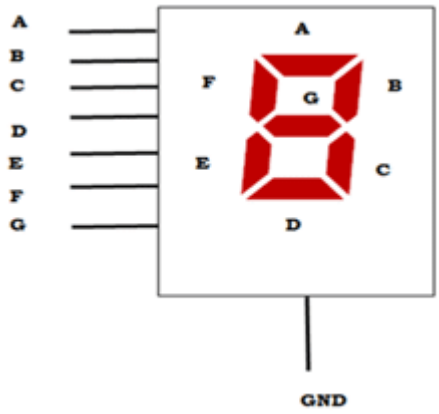
The basic working principle of LCD is obstruction of light. It cannot generate light by itself. Thus, an external light source is required. When external light moves from one polarizer to the next, a liquid crystal receives an external supply, and the polarized light aligns itself to form an image on the screen.



The transparent layer on each side of the sealed thick layer of liquid crystal is the indium oxide conducting surface. The molecular arrangement is unaffected in the absence of any external bias.



The molecular arrangement changes when an external bias occurs, making one area appear dark and the other area appear clear.



In a positive LCD panel, the polarizers are positioned perpendicular to one another, and the segments have dark backgrounds. Whereas the polarizers are lined up with each other, the segments in the negative LCD display appear white against a dark backdrop.

Advantages of LCD

- Low power consumption
- Thin and lightweight
- No geometric distortion
- Sharp images with good color reproduction

Disadvantages of LCD

- Limited viewing angles
- Slower response times
- Lower contrast ratios compared to OLED
- Prone to dead pixels

Applications of LCD

- Mobile phones and tablets
- Televisions and monitors
- Digital watches and calculators
- Instrument panels and displays in vehicles

LIGHT EMITTING DIODE

A light emitting diode is a diode that gives off visible light (usually red, orange, yellow, or green) when a forward bias is applied. LED is made of semiconductor materials like GaAs, GaASP, and GaP. The operation of a light emitting diode (LED) is based on electroluminescence, which is the emission of light from a semiconductor because of the influence of an electric field.

Light emitting diode, abbreviated as LED, is a semiconductor device that emits infrared or visible light when charged with an electric current. The figure below shows a circuit diagram for the LED indicator circuit.

LEDs made from GaAs emit invisible infrared light, LEDs constructed of GaAsP tend to emit either red or yellow light. The GaP LEDs give either red or green light. In silicon and germanium diodes, most electrons give up their energy in the form of heat. However, with GaAsP and GaAs semiconductors, the electrons give up their energy by emitting Photons.

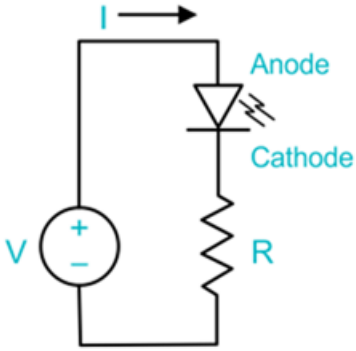
LED Symbol

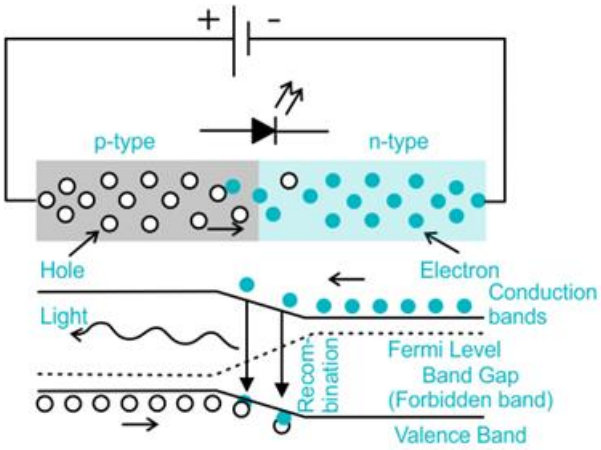
This figure represents the standard symbol of a diode, where the anode represents the positive side of the diode and the cathode represents the negative side of the diode. These arrows are essential in the symbol as it means the emission of light that makes a difference between the diode and LED.

The arrows pointing away from the diode represent that light is being emitted by the material when forward biased. This schematic symbol is the same for all types of LEDs. There is nothing in the symbol to indicate the color of a particular LED.

Working of Light Emitting Diode

LED is nothing but a diode made of semiconductors having a P-N junction. LED is based on the phenomenon of recombination of electrons with holes. When LED is forward biased, the electrons from the N-region cross the P-N junction and recombine with the holes existing in P-region. For the electrons to recombine with holes existing in P-region, they must give some of their energy. When recombination occurs, the recombining electrons release energy in the form of heat and light.





The operation of a light emitting diode(LED) is the phenomenon of electroluminescence. The emission of light from a semiconductor because of the influence of an electric field is called electroluminescence.

I-V Characteristics of Light Emitting Diode

The I-V characteristics of an LED describe the relationship between the current flowing through the LED and the voltage applied across it. The I-V characteristics of an LED are typically plotted as a graph, with the current on the x-axis and the voltage on the y-axis.

The I-V characteristics of an LED can be divided into two regions: the forward bias region and the reverse bias region.

- Forward bias region: When an LED is forward biased, current flows through it and the LED emits light. The forward bias region of the I-V curve is typically exponential, with the current increasing rapidly as the voltage increases. The voltage at which the LED begins to emit light is called the turn-on voltage.
- Reverse bias region: When an LED is reverse biased, current does not flow through it and the LED does not emit light. The reverse bias region of the I-V curve is typically a straight line, with a very small current flowing through the LED.

Types of LEDs

Several types of LEDs are discussed below:

1. **Colour LEDs:** These LEDs emit different colours like red, green, blue, etc. The most common use of these types of LEDs is a light show, video display, and status indicator.
2. **Miniature LEDs:** These LEDs are usually small in size and available in a single color. These LEDs are the most common. These are used in cell phones and calculators.
3. **Lighting LED:** These LED are used in our homes commonly. These LEDs are obtainable in different shapes and sizes. These are also named LED lamps. E.g., the Edison bulb.
4. **High Power LED:** These LEDs are also called High output LEDs because it generates high lumen(unit to measure emitted light) output than normal light. These LEDs are used in Automobile headlights and high-powered lamps.
5. **Flash LEDs:** The Flash LEDs looked similar to the regular LEDs. It flashes the light of a particular frequency. These LEDs are used in vehicles, sign boards, etc.

Determines an LED's Colour

The colour of an LED is determined by the energy band gap of the semiconductor material used to make the LED. The energy band gap is the difference in energy between the valence band and the conduction band of a semiconductor material. LEDs made of different semiconductor materials with different energy band gaps will emit light of different colors.

For example, red LEDs are made of gallium arsenide (GaAs), which has a relatively small energy band gap. Blue LEDs are made of gallium nitride (GaN), which has a relatively large energy band gap. White LEDs are typically made of gallium indium nitride (GaInN), which has an energy band gap that can be tuned to emit different colours of light. White LEDs are also made using a combination of different coloured LEDs.

Characteristics of LEDs

Following are the characteristic of LEDs.

1. They are made up of semiconductor devices.
2. LED requires 2-3Volts to conduct.
3. LEDs always work in forwarding bias means the positive terminal anode should be connected to the higher potential, and the negative terminal should be connected to the lower potential.

4. LEDs can work in a wide range of temperatures.

Advantages and Disadvantages of LEDs

Advantages of LEDs

1. LEDs are small-sized and can be assembled to form numeric and alphabet displays.
2. LEDs are environmentally and economically friendly.
3. LEDs are rugged and can-, therefore, withstand shocks and vibrations.
4. LEDs can be operated in a wide range of temperatures.
5. The switching time of LED (both on and off) is less than one. So, they are very suitable for the dynamic operation of many arrays.
6. LEDs are available in different colours like red, yellow, green, and blue.
7. They need moderate power. They are used where low dc power is available.
8. They occupy a small area.
9. LED devices can be driven by transistor-transistor logic (TTL), whereas gas discharge devices need intermediate transistor stages to be driven by 5V TTL.

Disadvantages of LEDs

1. The drawbacks of LEDs are that they get damaged by overvoltage or overcurrent.
2. They have wide optical bandwidth compared to LASER (≅ 10nm).
3. Their temperature depends on the radiant output power and wavelength.
4. LEDs are not suited for large-area displays, primarily because of their high cost. For larger displays, devices using gas-filled are used.
5. Protecting against reverse bias. The LEDs have low reverse voltage ratings. For example, a typical LED may have a maximum reverse voltage rating of 3V. Therefore, the LED may get destroyed if a reverse voltage greater than 3V is applied to the LED. Therefore, we must be careful not to use LEDs with a high level of reverse bias.

Applications of LEDs

LED have broad uses due to their small size, less consumption of energy, extended lifetime, and adjustability in terms of use in various applications. Some uses of LEDs are:

- **Seven Segment Display:** Seven segment displays are the best alternative to a dot matrix display and are easier to display decimal numerals. We have seen this display in our digital watches, meters, boards, etc. The small size of the LED makes it the best fit for this display.

- **LED used in TV Remote:** TV remote controls work on the principle of sending and receiving signals but use a type of light called infrared (or IR for short). The remote control has an LED light that flashes quickly to emit a message picked up by the TV. The remote is the transmitter, and the TV is the receiver.
- **Picturephone:** LEDs are used in image sensing circuits for 'picturephones.'
- **Computers:** LEDs supply power to LASERs for entering information into optical computer memories.

Types of MP3 Players

Flash Memory Players

The flash memory MP3 player is the smallest and lightest and typically stores fewer songs than hard drive players. Because it's small and contains no moving parts, it's ideal for exercisers. And with some models boasting up to 8 GB of storage (2,000 songs) and other models offering video and photo capability, it also appeals to the multimedia aficionado. Its batteries can last up to 28 hours.

Hard Drive and Mini-hard Drive Players

Hard drive players are larger and heavier than flash memory players and offer considerably more storage.

For those looking for a player that can contain their entire music collection (up to 20,000 songs), photographs, data, and video and allow podcast recording, the hard drive is best. However, these features and the hard drive consume more power, with some batteries lasting

eight to 20 hours for music playback and up to six hours for video playback. The players include moving parts, which may skip. However, some players have anti-shock buffers and or anti-skip protection.

Smaller in size and internal storage capacity, miniature-hard drive players are lighter than traditional hard drive players, but contain less memory -- usually up to 8 GB. They, too, contain moving parts.

MP3 CD Players and MiniDisc MP3 Players

There is a breed of CD players available that plays MP3 and other digital files. These MP3 files are burned to CD-R/RW discs from your old CD collection and used in the MP3 CD player. A CD can hold about 10 hours of music. A CD burner is necessary for those buying an MP3 CD player. The MP3 CD player is cheaper than the flash memory and hard drive memory players, but may skip when jostled. They are also much larger in size than their digital counterparts.

For those who appreciate MiniDisc technology, there's Sony's MiniDisc Walkman digital music player. This player supports the trademark Sony file format codec ATRAC3 -- but it also supports MP3, WMA and WAV formats, too. And the multitasking doesn't stop there. Sony reports that the 1GB Hi-MD discs can also store and transfer loads of PC data files (think PowerPoint presentations, spreadsheets, et cetera). The discs retail for less than $10, store up to 600 songs and are re-recordable. Depending on the model, users can expect anywhere from 30-plus hours of playtime from just one AA battery.

The Hybrid Players

MP3 is no longer just a stand-alone technology. Technology companies are now offering MP3 capability in other consumer products, including satellite radios, personal digital assistants, DVD players, sunglasses, swim goggles and even a combination Swiss Army Knife-MP3 player. Most notably, the iPhone from Apple crosses a cell phone with an iPod and Web browser, along with a variety of other features.

Other Audio Sources

Many MP3 players have the ability to record songs directly from your CD player. For those who don't want to bother with a computer, this streamlines the conversion process. No longer do users put a CD into the computer, rip the track from it, convert it to MP3 format, save it and then download it to an MP3 player. The song goes directly from the CD to MP3 format in the user's preferred playlist.

Some MP3 players also have a built-in FM radio tuner, providing users with an additional source of entertainment. Radio listeners can record the tunes from their favorite stations in the MP3 format and instantly add it to their playlist. Several MP3 players allow you to playback your MP3 music on your FM radio using unused frequencies.

Some combination cell phone-MP3 players allow the user to browse and purchase songs, which are then delivered to the phone for immediate playback.

An additional audio source is the user's own voice, which can be recorded on an MP3 player and then transferred to a computer for storage or transmission via e-mail.

CCTV -CLOSED-CIRCUIT TELEVISION

CCTV (closed-circuit television) is a TV system in which signals are not publicly distributed but are monitored, primarily for surveillance and security purposes.

How does CCTV work?

CCTV relies on strategic placement of cameras, and observation of the camera's input on monitors somewhere. Because the cameras communicate with monitors and/or video recorders across private coaxial cable runs or wireless communication links, they gain the designation "closed-circuit" to indicate that access to their content is limited by design only to those able to see it.

CCTV use cases

Older CCTV systems used small, low-resolution black and white monitors with no interactive capabilities. Modern CCTV displays can be color, high-resolution displays and can include the ability to zoom in on an image or track something (or someone) among their features. Talk CCTV allows an overseer to speak to people within range of the camera's associated speakers.

A CCTV camera system makes use of video cameras, also called surveillance cameras to keep track of the interior and exterior of a property, transmit the signal to a monitor or set of monitors, and give real-time 24/7 viewing access.

With all these benefits, a surveillance system has become a must in a society where there is an increase in the crime rate. So when you decide which security system is best for your unique necessities, these are the 5 essential components you should give importance to:

1. Camera

If you're building a CCTV Camera System, you have two camera options: Internet Protocol (IP) or analog. IP is usually the preferred choice due to its compatibility with most devices. Many different types of cameras can be installed, for example -dome cameras, bullet cameras, covert cameras.

Depending on how many angles you want to cover, how many cameras you will need in that specific area, how much resolution or detailing you require when you choose your preferred cameras.

2. Monitoring Station

A monitor arguably facilitates the most important function of a security camera: viewing recorded images and footage. Deciding how many monitors you'll need is dependent upon what, and which area you are monitoring. You wouldn't need more than three to five screens if you aren't operating in a large-scale facility. Although if your requirements change, you can easily add or remove monitors anytime to match the compatibility of your camera.

3. Cables & Routers

Depending on the type of surveillance system, and cameras you choose, you will need supporting technologies like cables, and routers to be integrated into your system for a seamless connection. For example, wireless systems require a router, while wired versions do not.

Therefore, choose the cables, and wires after selecting your cameras, and monitors according to your unique needs.

4. Video Recorders

The video recorder is the device where video recorded on the camera gets processed for storage & viewing. There are two types of video recorders: DVR (Digital Video Recorders) and NVR (Network Video Recorders). You can learn more about them here.

5. Data Storage

Your CCTV security system is only as good as the hard disk backing it. The storage device for a security camera system should be able to record, store and re-play videos non-stop from multiple feeds. Regular hard drives that are used in PCs and Laptops are ill equipped to handle CCTV storage needs. Hence, it is critical to choose a robust storage system for safe data storage.

CCTV is commonly used for a variety of purposes, including:

- Maintaining perimeter security in medium- to high-secure areas and installations.
- Observing behavior of incarcerated inmates and potentially dangerous patients in medical facilities.
- Traffic monitoring.
- Overseeing locations that would be hazardous to a human, for example, highly radioactive or toxic industrial environments.
- Building and grounds security.
- Obtaining a visual record of activities in situations where it is necessary to maintain proper security or access controls (for example, in a diamond cutting or sorting operation; in banks, casinos, or airports).

CCTV is finding increasing use in law-enforcement, for everything from traffic observation (and automated ticketing) to observation of high-crime areas or neighborhoods. Such use of CCTV technology has fueled privacy concerns in many parts of the world, particularly in those areas in the UK and Europe where it has become a routine part of police procedure.

Types of CCTV Camera's Selection

Indoor Camera

Outdoor Camera

Infrared Days/ Night Camera

Dome Camera

Bullet Camera

Hidden Camera

Pan tilt zoom Camera

Motion Detection

Wireless

Advantages of CCTV

• Can improve work quality

• Reduce costs

• Improves communication

• Groups can meet more frequently

• Critical meetings can be conducted in less time

• More faculty and staff can be involved

Disadvantages of CCTV

• Difficult to see and hear people who are not close to the microphone/camera, Thus difficult to have multiple people at one site, sharing a computer to.

• Lack of personal interaction during the videoconference.

• Body language can be lost if movement is jerky and/or picture quality is reduced.

• Some people are naturally camera shy‟ and do not like being filmed; a person who is confident with phone conferencing may be nervous in front of a camera.

Uses of Television and CCTV in Instruction

1. To show practical application of principle already written in the textbooks and to show the laboratory work and demonstrations.
2. To humanize distance education and to improve language skills and teaching skills by showing model teaching techniques.

3. To show real life situation and microscope things on magnified scale
4. Animations, dramatic presentations, slow motions and case studies.

Television in the field of Education

1. Instructing
2. Explaining, Clarifying
3. Summarizing
4. Reinforcement
5. Imposing study speed
6. Supporting and enhancing teaching
7. Motivation and encouragement
8. Using as supplementary for the other materials
9. Presenting a reference to large masses
10. Presenting unreachable facts and events

CATHODE RAY OSCILLOSCOPE (CRO)

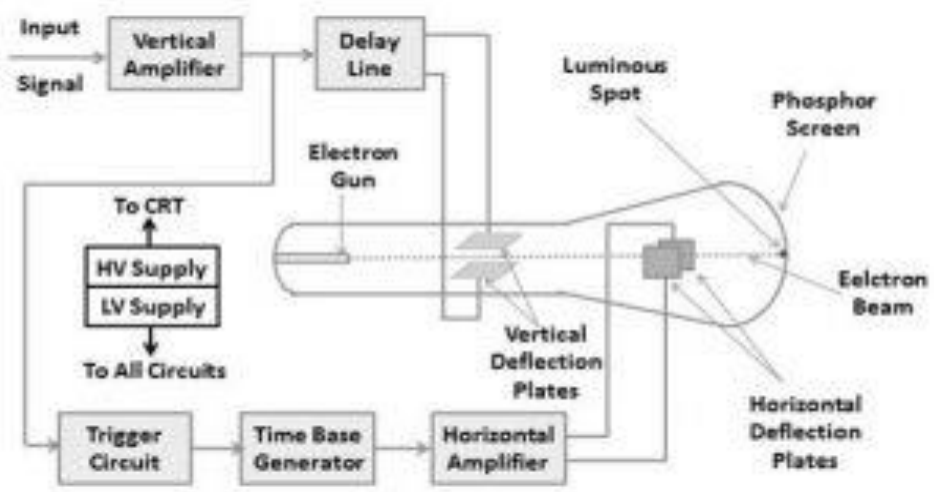
The CRO stands for a cathode ray oscilloscope. It is typically divided into four sections which are display, vertical controllers, horizontal controllers, and Triggers. Most of the oscilloscopes are used the probes and they are used for the input of any instrument. We can analyze the waveform by plotting amplitude along with the x-axis and y-axis. The applications of CRO are mainly involved in the radio, TV receivers, also in laboratory work involving research and design. In modern electronics, the CRO plays an important role in the electronic circuits.

The **cathode ray oscilloscope is an electronic test instrument**, it is used to obtain waveforms when the different input signals are given. In the early days, it is called as an Oscillograph. The oscilloscope observes the changes in the electrical signals over time, thus the voltage and time describe a shape and it is continuously graphed beside a scale. By seeing the waveform, we can analyze some properties like amplitude, frequency, rise time, distortion, time interval, and etc.

Block Diagram of CRO

The following **block diagram shows the general-purpose CRO contraction**. The CRO recruits the cathode ray tube and acts as a heat of the oscilloscope. In an oscilloscope, the CRT produces the electron beam which is accelerated to a high velocity and brings to the focal point on a fluorescent screen.

Thus, the screen produces a visible spot where the electron beam strikes with it. By detecting the beam above the screen in reply to the electrical signal, the electrons can act as an electrical pencil of light which produces a light where it strikes.



CRO Block Diagram

To complete this task we need various electrical signals and voltages. This provides the power supply circuit of the oscilloscope. Here we will use high voltage and low voltage. The low voltage is used for the heater of the electron gun to generate the electron beam. A high voltage is required for the cathode ray tube to speed up the beam. The normal voltage supply is necessary for other control units of the oscilloscope.

The horizontal and vertical plates are placed between the electron gun and the screen, thus it can detect the beam according to the input signal. Just before detecting the electron beam on the screen in the horizontal direction which is in X-axis a constant time-dependent rate, a time base generator is given by the oscillator. The signals are passed from the vertical deflection plate through the vertical amplifier. Thus, it can amplify the signal to a level that will be provided the deflection of the electron beam.

If the electron beam is detected in the X-axis and the Y-axis a trigger circuit is given for synchronizing these two types of detections. Hence the horizontal deflection starts at the same point as the input signal.

Working Principle

The CRO working principle depends on the electron ray movement because of the electrostatic force. Once an electron ray hits a phosphor face, then it makes a bright spot on it. A Cathode Ray Oscilloscope applies the electrostatic energy on the electron ray from two vertical ways. The spot on the phosphor monitor turns due to the effect of these two electrostatic forces which are mutually perpendicular. It moves to make the necessary waveform of the input signal.

Construction of Cathode Ray Oscilloscope

The construction of CRO includes the following.

- Cathode Ray Tube
- Electronic Gun Assembly
- Deflecting Plate
- Fluorescent Screen For CRT
- Glass Envelop

Cathode Ray Tube

The CRO is the vacuum tube and the main function of this device is to change the signal from electrical to visual. This tube includes the electron gun as well as the electrostatic deflection plates. The main function of this electron gun is used to generate a focused electronic ray that speeds up to high frequency.

The vertical deflection plate will turn the ray up & down whereas the horizontal ray moved the electrons beams from the left side to the right side. These actions are autonomous from each other and thus the ray may be located anyplace on the monitor.

Electronic Gun Assembly

The main function of the electron gun is to emit the electrons to form them into a ray. This gun mainly includes a heater, a grid, cathode, and anodes like accelerating, pre-accelerating & focusing. At the cathode end, the strontium & barium layers are deposited to obtain the high electrons emission of electrons at the moderate temperature, the layers of barium, and are deposited at the end of the cathode.

Once the electrons are generated from the cathode grid, then it flows throughout the control grid that is generally a nickel cylinder through a centrally situated co-axial by the axis of CRT. So, it controls the strength of the generated electrons from the cathode.

When electrons flow throughout the control grid then it accelerates with the help of a high positive potential which is applied to the pre-accelerating or accelerating nodes. The electron ray is concentrated on electrodes to flow throughout the deflection plates like horizontal and vertical & supplies on to the fluorescent lamp.

The anodes like accelerating & pre-accelerating are connected to 1500v & the focusing electrode can be connected to 500v. The electron ray can be focused on using two techniques like Electrostatic & Electromagnetic focusing. Here, a cathode ray oscilloscope utilizes an electrostatic focusing tube.

Deflecting Plate

Once the electron ray leaves the electron gun then this ray will pass throughout the two sets of the deflecting plate. This set will generate the vertical deflection that is known as Y plate's otherwise vertical deflecting plate. The set of the plate is used for a horizontal deflection which is known as X plate's otherwise horizontal deflection.

Fluorescent Screen of CRT

In the CRT, the front face is known as the faceplate, For the CRT screen, it is flat and its size is about 100mm×100mm. The CRT screen is somewhat bent for bigger displays and the formation of faceplate can be done by pressing the molten glass into a form & after that heating it.

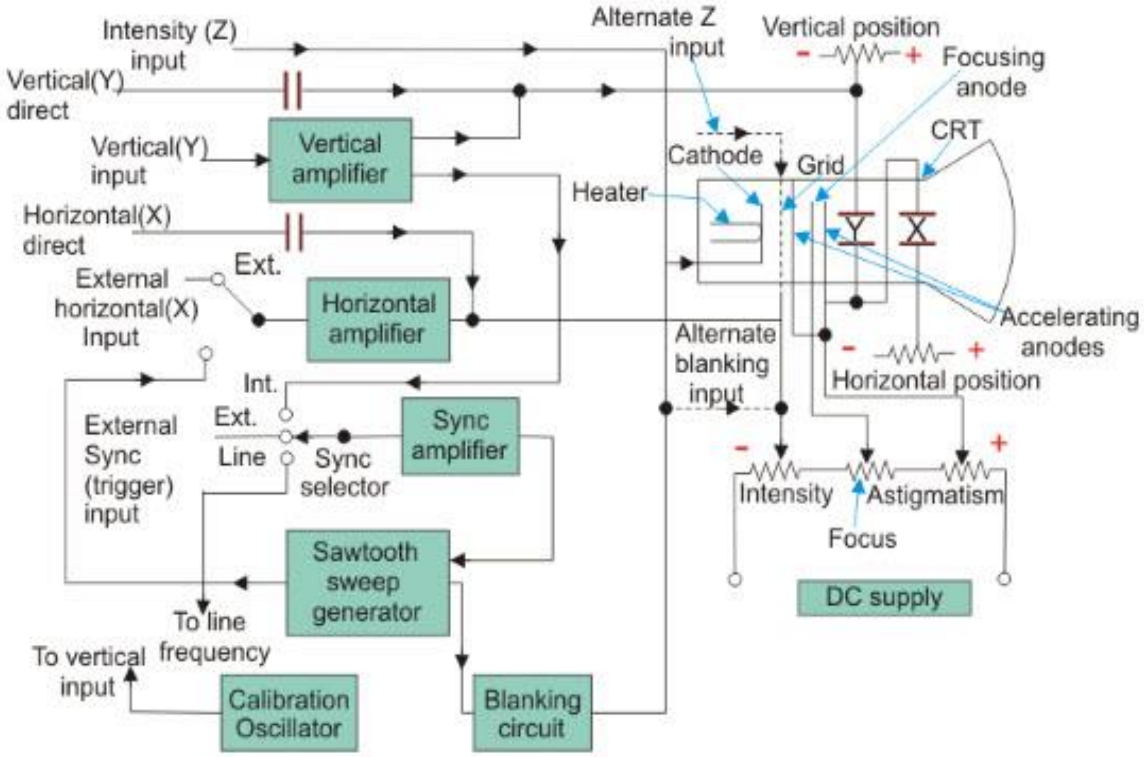
The inner face of the faceplate is covered by using phosphor crystal to change the energy from electrical to light. Once an electronics ray hits phosphor crystal, the energy level can be enhanced & thus light is generated throughout phosphorous crystallization, so this occurrence is known as fluorescence.

Glass Envelope

It is an extremely evacuated conical form of construction. The inside faces of the CRT among the neck as well as the display are covered through the aquadag. This is a conducting material that acts like a high-voltage electrode. The surface of the coating is connected electrically toward the accelerating anode to help the electron to be the center.

Working of CRO

The following circuit diagram shows the ***basic circuit of a cathode ray oscilloscope***. In this, we will discuss important parts of the oscilloscope.



Working of CRO

Vertical Deflection System

The main function of this amplifier is to amplify the weak signal so that the amplified signal can produce the desired signal. To examine the input signals are penetrated to the vertical deflection plates through the input attenuator and the number of amplifier stages.

Horizontal Deflection System

The vertical and horizontal system consists of horizontal amplifiers to amplify the weak input signals, but it is different from the vertical deflection system. The horizontal deflection plates are penetrated by a sweep voltage that gives a time base. By seeing the circuit diagram the sawtooth sweep generator is triggered by the synchronizing amplifier while the sweep selector switches in the internal position. So the trigger saw tooth generator gives the input to the horizontal amplifier by following the mechanism. Here we will discuss the four types of sweeps.

Recurrent Sweep

As the name, itself says that the sawtooth is respective that is a new sweep is started immodestly at the end of the previous sweep.

Triggered Sweep

Sometimes the waveform should be observed that it may not be predicted thus, the desired that the sweep circuit remains inoperative and the sweep should be initiated by the waveform under the examination. In these cases, we will use the triggered sweep.

Driven Sweep

In general, the drive sweep is used when the sweep is free-running but it is triggered by the signal under the test.

Non-Saw Tooth Sweep

This sweep is used to find the difference between the two voltages. By using the non-sawtooth sweep we can compare the frequency of the input voltages.

Synchronization

The synchronization is done to produce a stationary pattern. The synchronization is between the sweep and the signal should measure. There are some sources of synchronization that can be selected by the synchronization selector. Which are discussed below.

Internal

In this, the signal is measured by the vertical amplifier and the trigger is abstained by the signal.

External

In the external trigger, the external trigger should be present.

Line

The line trigger is produced by the power supply.

Intensity Modulation

This modulation is produced by inserting the signal between the ground and cathode. This modulation causes by brightening the display.

Positioning Control

By applying the small independent internal direct voltage source to the detecting plates through the potentiometer the position can be controlled and also we can control the position of the signal.

Intensity Control

The intensity has a difference by changing the grid potential with respect to the cathode.

Electrical Quantities Measurements

Electrical quantities measurements by using CRO can be done like amplitude, time period and frequency.

- Measurement of Amplitude
- Measurement of Time Period
- Measurement of Frequency

Measurement of Amplitude

The displays like CRO is used to exhibit the voltage signal like a time function on its display. The amplitude of this signal is stable; however, we can change the number of partitions that cover up the voltage signal within vertical way by changing volt/division button on top of the CRO board. So, we will acquire the signal's amplitude, which is there on the CRO screen with the help of the below formula.

$$\mathbf{A = j * nv}$$

Where,

'A' is the amplitude

‘j’ is the volt/division value

‘nv’ is the no. of partitions that cover up the signal within a vertical way.

Measurement of Time Period

CRO displays the voltage signal as a function of time on its screen. The Time period of that periodic voltage signal is constant, but we can vary the number of divisions that cover one complete cycle of the voltage signal in the horizontal direction by varying the time/division knob on the CRO panel.

Therefore, we will get the Time period of the signal, which is present on the screen of CRO by using the following formula.

$$T = k * nh$$

Where,

‘T’ is the Time period

‘j’ is the time/division value

‘nv’ is the number of partitions that cover up one whole cycle of the periodic signal within the horizontal way.

Measurement of Frequency

On the CRO screen, the measurement of tile & frequency can be done very simply through the horizontal scale. If you want to make sure accuracy while measuring a frequency, then it assists to enhance the area of the signal on your CRO display so that we can more simply convert the waveform.

Initially, the time can be measured with the help of the horizontal scale on the CRO & counting the number of flat partitions from one finish of the signal to the other wherever it crosses the flat line. After that, we can develop the number of flat partitions through the time or division to discover the time period of the signal. Mathematically the measurement of the frequency can be signified as frequency = 1/period.

$$f = 1/T$$

Basic Controls of CRO

The basic controls of CRO mainly include position, brightness, focus, astigmatism, blanking & calibration.

Position

In the oscilloscope, the position control knob is mainly used for position control of the intense spot from the left side to the right side. By regulating the knob, one can simply control the spot from left side to the right side.

Brightness

The ray's brightness mainly depends on the intensity of the electron. The control grids are accountable for the electron intensity within the electron ray. So, the grid voltage can be controlled by adjusting the electron ray brightness.

Focus

The focus control can be achieved by regulating the applied voltage toward the center anode of the CRO. The middle & other anodes in the region of it can form the electrostatic lens. Therefore, the main length of the lens can be changed by controlling the voltage across the center anode.

Astigmatism

In CRO, this is an extra focusing control & it is analogous toward astigmatism within optical lenses. A ray is focused in the middle of the monitor would be defocused on the screen edges as the electron paths lengths are dissimilar for the center & the edges.

Blanking Circuit

The time base generator present in the oscilloscope generated the blanking voltage.

Calibration Circuit

An oscillator is necessary for the purpose of calibration within an oscilloscope. However, the oscillator which is used should generate a square waveform for preset voltage.

Applications

- The CRO's are used in huge applications like radio stations for observing the transmitting & receiving the properties of the signal.

- The CRO is used to measure the voltage, current, frequency, inductance, admittance, resistance, and power factor.
- This device is also used to check the AM and FM circuits characteristics
- This device is used to monitor the signal properties as well as characteristics and also controls the analog signals.
- The CRO is used through the resonance circuit to view the shape of the signal, bandwidth, etc.
- The shape of voltage and current waveform can be observed by CRO which helps to take the necessary decision in a radio station or communication station.
- It is used in laboratories for the purpose of research. Once researchers design a new circuit, then they use CRO to verify the waveforms of voltage and current of every element of the circuit.

- Used for comparing phase & frequency
- It is used in TV, Radar, and analysis of engine pressure
- To check the reactions of nervous and heartbeat.
- In the hysteresis loop, it is used to find BH curves
- Transistor curves can be traced.

Advantages

The **advantages of CRO** include the following.

- Cost and Timeline
- Training requirements
- Consistency & quality
- Time efficiency
- Expertise & experience
- Capacity for problem-solving

- Hassle-free
- Assurance for regulatory compliance
- Voltage measurement
- Current measurement
- Examination of waveform
- Measurement of phase and frequency

Disadvantages

The **disadvantages of CRO** include the following.

- These oscilloscopes are expensive as compared with other measuring devices like multimeters.
- They are complicated to repair once it gets damaged.
- These devices need complete isolation
- These are huge, heavy and uses more power
- A lot of control terminals which is not so easy to understand at one instance but for easy of use, multiple channel capture and screen and waveform clarity one could go for Digital Storage Oscilloscope.

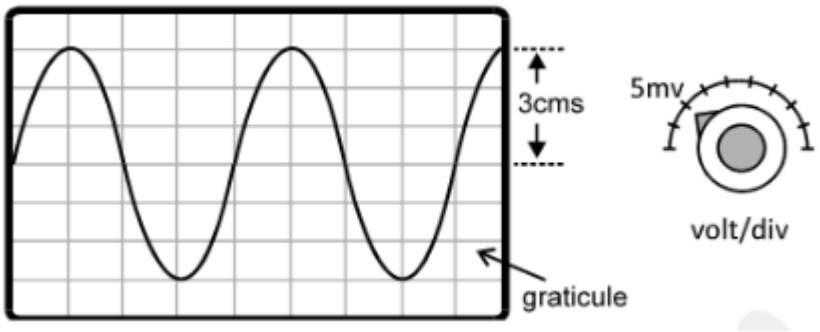
Uses of CRO

In the laboratory, the CRO can be used as

- It can display different types of waveforms
- It can measure the short time interval
- In voltmeter, it can measure the potential difference.
- The CRO is a versatile laboratory instrument. It is used for all types of measurements like AC/DC voltage, AC/DC current, frequency and phase measurements. These methods are given below.

Measurement of AC/DC voltage

Measurement of AC voltage: With this method, we can measure the peak value of AC voltage. Connect unknown AC voltage across y-input of CRO. A following type of waveform will be displayed on the screen.



Measure its peak displacement in centimeters on graticule scale. Note down the position of Volt/div scale in Volts. Then using the formula calculate the peak value V_p.

V_p = vertical displacement × volt/div and the RMS value of AC voltage is given by:

$$V_{rms} = V_p / \sqrt{2} = V_p / 1.414$$

In the above example, vertical displacement = 3cm and volt/div knob = 5mV. So peak value = 15mV

Measurement of DC voltage: Connect unknown DC voltage to y-input of CRO. A straight horizontal line will be displayed on screen. If it is above x-axis, then the applied voltage is positive, but if it is below x-axis, the voltage is negative.

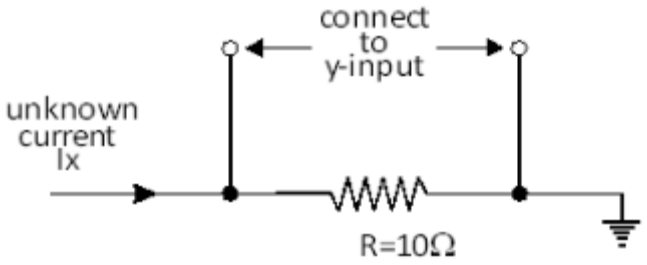
Measure its vertical displacement in centimeters from x–axis using graticule scale. Note down volt/div reading and calculate the unknown voltage V_{dc} as follows

V_{dc} = vert. displacement × volt/div

In above example, vert. displacement = 2cm and volt/div = 2V. So peak value will be +4V, because the horizontal line is above x-axis.

Measurement of AC/DC Current

We cannot measure current directly using CRO so we use indirect method, as shown below.



First pass the unknown AC/DC current through a known value of resistor, *say* 10Ω. Then connect the voltage drop across it to y-input of CRO. If the unknown current is AC we will get a waveform, but if it is DC, we will get a straight line. There are two possible conditions:

Measurement of AC current: When voltage drop across 10Ω resistor is connected to y-input, we will get a waveform on the screen. Measure its peak displacement in centimeters on graticule scale. Note down the position of Volt/div scale in Volts.

Then using the formula calculate the peak value V_p

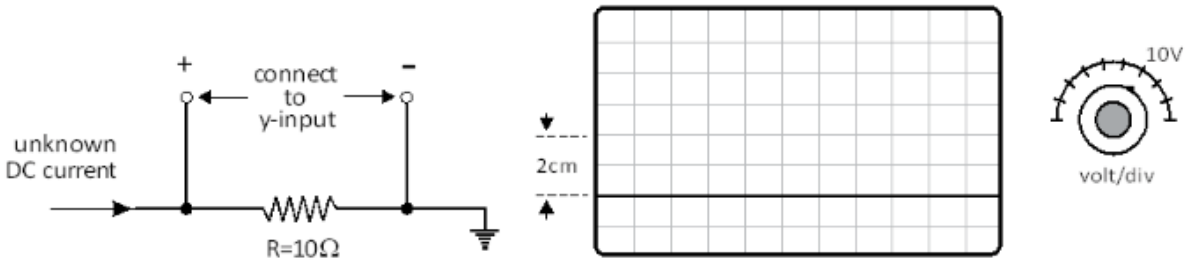
V_p = vertical displacement × volt/div

Now we can calculate the value of unknown current as

Unknown current = (vertical displacement × volt/div) / 10Ω

= (2.3 × 5) / 10Ω = 1.15A

Measurement of DC current: Connect the voltage drop across 10Ω resistor to y-input. Note down the position of Volt/div scale. Measure the displacement of the line from x-axis.



Then using the formula calculate the peak value V_{dc} = vert. displacement × volt/div

Now we can calculate the value of unknown current as –

Unknown current = (vertical displacement × volt/div) / 10Ω

= (2 × 10) / 10Ω = 2A

Since the line is below x-axis, the current is negative i.e. unknown current = – 2A

UNIT – IV

MAINTENANCE OF COMPUTER SYSTEMS

Basic computer skills are essential for professionals in all roles and industries. A computer comprises two primary components, namely hardware and software. Knowing the role and utility of different computer components can help you improve your computer skills.

Various Parts of Computer and their Functions

1. Central Processing Unit (CPU) and Memory

This is also known as 'The Brainy Parts' where the computer does its thinking and temporary storage.

- **CPU (Central Processing Unit)**: Known as the brain of the computer, the CPU processes instructions and manages tasks, deciding how things run and operate. It's the main unit for performing calculations and executing programs.
- **RAM (Random Access Memory)**: RAM is the short-term memory of the computer. It temporarily stores data that the CPU is currently using. The more RAM your computer has, the more tasks it can handle simultaneously without slowing down.

2. Storage Devices:

These parts store everything that doesn't disappear when the computer turns off.

- **HDD (Hard Disk Drive)**: An HDD is a long-term storage device where you can save everything, from pictures to programs. It's like a filing cabinet where all your files are stored for future access.
- **SSD (Solid State Drive)**: An SSD performs the same role as an HDD but much faster! It's a newer, faster storage type that uses flash memory to store data, making it quicker to load files and run applications.

3. Input Devices:

These parts let you communicate with the computer.

- **Keyboard**: The **keyboard** is an input device that allows you to type commands, letters, numbers, and symbols into the computer. It's essential for writing, chatting, and programming.
- **Mouse**: The **mouse** is used to point, click, and interact with items on the computer screen. It helps navigate through files, open programs, and select items easily.
- **Microphone**: Sometimes used for voice commands or recording sounds, the **microphone** is an input device that captures audio and sends it to the computer.

4. Output Devices:

These parts let you see or hear what the computer is doing.

- **Monitor (Display Screen)**: The **monitor** displays everything the computer is doing. It shows the user interface, programs, games, and everything you interact with visually.
- **Speakers**: **Speakers** produce sound, whether it's music, notifications, or sound effects from games and programs. They allow you to hear what's going on in the computer.
- **Printer**: **Printers** take the information from the computer and turn it into physical copies, like documents, photos, and reports.

5. Power Supply:

This is the part that provides electricity to the computer.

- **PSU (Power Supply Unit)**: The **PSU** converts electrical power from an outlet into usable power for the computer's components, including the CPU, motherboard, and storage devices. Without it, your computer would have no energy to run.

6. Communication and Connectivity Devices:

These allow your computer to connect to the internet, networks, and other devices.

- **Motherboard**: The **motherboard** is like the central hub of the computer, connecting all parts together and allowing them to communicate. It connects the CPU, RAM, storage, and all other components.
- **Network Card**: The **network card** (also known as a NIC or Network Interface Card) connects the computer to a local network (like Wi-Fi or Ethernet), allowing it to access the internet or communicate with other devices.
- **USB Ports**: **USB ports** are used to connect external devices like flash drives, printers, cameras, and other peripherals to the computer.

10 Parts of Computer

Now that you have understood what a computer is and how it functions, let's dive deeper into the components. To help you get a clearer picture, here’s a more detailed explanation of each part of the computer.

1. Central Processing Unit (CPU) – The "Brain" of the computer

The CPU is often referred to as the brain of the computer because it is responsible for executing instructions, performing calculations, and managing tasks. It processes input data and executes the instructions provided by the software. The CPU contains cores that handle tasks simultaneously, enhancing the computer's performance. Modern CPUs have multiple cores to process more tasks at the same time, making them faster and more efficient.

2. Motherboard – The Backbone of the Computer

The motherboard is the main circuit board that connects all the parts of the computer. It acts as the central hub, allowing communication between the CPU, memory, storage devices, and other peripherals. It also houses essential components such as the chipset, power connectors, and expansion slots, allowing additional hardware like graphics cards or sound cards to be added.

3. Random Access Memory (RAM) – Temporary Storage

RAM is the computer's short-term memory. It temporarily stores data that the CPU needs to access quickly. When you open a program or file, it gets loaded into RAM, allowing the CPU to access it more efficiently. However, RAM is volatile, meaning it loses all data when the computer is turned off. The more RAM a computer has, the more data it can handle at once, improving performance and multitasking capabilities.

4. Storage Device (Hard Drive/SSD) – Permanent Data Storage

Storage devices like hard drives (HDD) or solid-state drives (SSD) are where all your data is saved permanently. The operating system, programs, and personal files such as documents, pictures, and videos are stored here. HDDs use spinning disks to read and write data, while SSDs use flash memory, which is faster, quieter, and more durable but generally more expensive. SSDs are becoming more popular due to their speed advantages.

5. Power Supply Unit (PSU) – Providing Power

The PSU is responsible for converting electrical power from an outlet into usable power for the computer's components. It supplies the correct voltage and current to the motherboard,

CPU, storage devices, and peripherals. Without the PSU, a computer would not function, as it ensures that each part gets the required energy to operate.

6. Graphics Processing Unit (GPU) – Rendering Visuals

The GPU, or graphics card, is responsible for rendering images, videos, and animations. It takes the data from the CPU and translates it into visuals that are displayed on the monitor. While the CPU can handle graphics to an extent, a dedicated GPU is necessary for high-end gaming, video editing, 3D rendering, and graphic design. Modern GPUs also assist in general computing tasks, improving overall performance.

7. Input Devices (Keyboard, Mouse) – Interacting with the Computer

Input devices are hardware components that allow users to interact with the computer. The keyboard is used to type text and give commands, while the mouse is used to point, click, and scroll. There are also other input devices, such as a microphone (for voice commands), touchpads, and even voice recognition systems.

8. Output Devices (Monitor, Printer, Speakers) – Displaying Results

Output devices are the peripherals that display or provide the results of the computer's operations. A **monitor** is the primary output device that shows the graphical user interface, text, and images. A **printer** produces hard copies of documents and images, while **speakers** play sound, whether it’s music, video audio, or system alerts. Without these devices, it would be hard for users to visualize and hear what the computer is doing.

9. Cooling System – Keeping Everything Cool

Computers generate heat when they're running, especially the CPU and GPU, which perform complex tasks. The **cooling system** (often fans, heat sinks, or liquid cooling) is responsible for dissipating this heat to prevent components from overheating, which could lead to system instability or damage. A well-functioning cooling system is critical for maintaining the computer’s performance and longevity.

10. Network Interface Card (NIC) – Connecting to the Internet

The NIC allows your computer to connect to the internet and other networks. Whether it's via **Wi-Fi** or **Ethernet** cables, the NIC enables data to flow between the computer and the outside world. It's responsible for transmitting and receiving data packets that allow your computer to browse websites, send emails, or communicate with other devices on a network.

THE ROLE OF THE OPERATING SYSTEM (OS)

Now that we've explored the main parts of a computer, it's time to introduce a crucial element that ensures all these parts work together seamlessly—the Operating System (OS).

Imagine if all the components of a computer were like different musicians in a band. Each one has its role, but without a conductor, the music wouldn't flow. That's exactly what the OS does! It's the conductor, making sure everything is in harmony.

Whether you're clicking on icons, running programs, or saving files, the OS is hard at work behind the scenes, orchestrating everything for smooth performance. Let's explore how this essential piece of software brings it all together!

Operating System

1. A program that acts as an intermediary between a user of a computer and the computer hardware.
2. An operating System is a collection of system programs that together control the operations of a computer system.

Some examples of operating systems are UNIX, Mach, MS-DOS, MS-Windows, Windows/NT, Chicago, OS/2, MacOS, VMS, MVS, and VM.

Operating system goals:

- Execute user programs and make solving user problems easier.
- Make the computer system convenient to use.
- Use the computer hardware in an efficient manner.

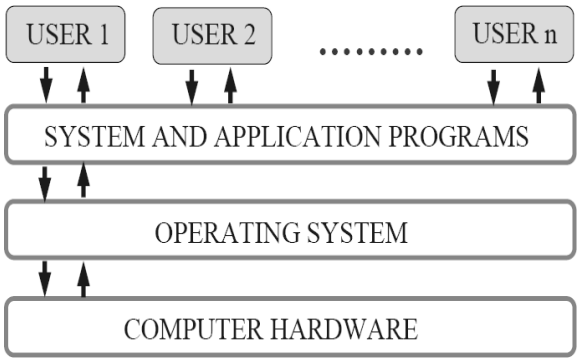
Computer System Components

1. **Hardware** – provides basic computing resources (CPU, memory, I/O devices).
2. **Operating system —** controls and coordinates the use of the hardware among the various application programs for the various users.

3. **Applications programs —** Define the ways in which the system resources are used to solve the computing problems of the users (compilers, database systems, video games, business programs).

4. **Users** (people, machines, other computers).

Abstract View of System Components



Operating System Definitions

Resource allocator – manages and allocates resources.

Control program – controls the execution of user programs and operations of I/O devices.

Kernel – The one program running at all times (all else being application programs).

Components of OS: OS has two parts. (1) Kernel. (2) Shell.

(1) Kernel is an active part of an OS i.e.; it is the part of OS running at all times. It is a program which can interact with the hardware. Ex: Device driver, dll files, system files etc.

(2) Shell is called as the command interpreter. It is a set of programs used to interact with the application programs. It is responsible for execution of instructions given to OS (called commands).

Operating systems can be explored from two viewpoints: the user and the system.

User View: From the user's point view, the OS is designed for one user to monopolize its resources, to maximize the work that the user is performing and for ease of use.

System View: From the computer's point of view, an operating system is a control program that manages the execution of user programs to prevent errors and improper use of the computer. It is concerned with the operation and control of I/O devices.

Functions of Operating System:

Process Management

A *process* is a program in execution. A process needs certain resources, including CPU time, memory, files, and I/O devices, to accomplish its task.

The operating system is responsible for the following activities in connection with process management.

1. Process creation and deletion.
2. process suspension and resumption.
3. Provision of mechanisms for:
   - process synchronization
   - process communication

Main-Memory Management

Memory is a large array of words or bytes, each with its own address. It is a repository of quickly accessible data shared by the CPU and I/O devices.

Main memory is a volatile storage device. It loses its contents in the case of system failure.

The operating system is responsible for the following activities in connections with memory management:

1. Keep track of which parts of memory are currently being used and by whom.
2. Decide which processes to load when memory space becomes available.
3. Allocate and de-allocate memory space as needed.

File Management

A file is a collection of related information defined by its creator. Commonly, files represent programs (both source and object forms) and data.

The operating system is responsible for the following activities in connections with file management:

1. File creation and deletion.
2. Directory creation and deletion.
3. Support of primitives for manipulating files and directories.
4. Mapping files onto secondary storage.

5. File backup on stable (nonvolatile) storage media.

I/O System Management

The I/O system consists of:

1. A buffer-caching system
2. A general device-driver interface
3. Drivers for specific hardware devices

Secondary-Storage Management

Since main memory (*primary storage*) is volatile and too small to accommodate all data and programs permanently, the computer system must provide *secondary storage* to back up main memory.

Most modern computer systems use disks as the principle on-line storage medium, for both programs and data. The operating system is responsible for the following activities in connection with disk management:

1. Free space management
2. Storage allocation
3. Disk scheduling

Networking (Distributed Systems)

1. A *distributed* system is a collection processor that do not share memory or a clock. Each processor has its own local memory.
2. The processors in the system are connected through a communication network.
3. Communication takes place using a *protocol.*
4. A distributed system provides user access to various system resources.
5. Access to a shared resource allows:
6. Computation speed-up
7. Increased data availability
8. Enhanced reliability

Protection System

1. *Protection* refers to a mechanism for controlling access by programs,

processes, or users to both system and user resources.

2. The protection mechanism must:
3. distinguish between authorized and unauthorized usage.
4. specify the controls to be imposed.
5. provide a means of enforcement.

Command-Interpreter System

Many commands are given to the operating system by control statements which deal with:

1. process creation and management
2. I/O handling
3. secondary-storage management
4. main-memory management
5. file-system access
6. protection
7. networking

The program that reads and interprets control statements is called variously:

1. command-line interpreter
2. shell (in UNIX)

Its function is to get and execute the next command statement.

Operating-System Structures

- System Components
- Operating System Services
- System Calls
- System Programs
- System Structure
- Virtual Machines

- System Design and Implementation
- System Generation

Common System Components

- Process Management
- Main Memory Management
- File Management
- I/O System Management
- Secondary Management
- Networking
- Protection System
- Command-Interpreter System

Evolution of OS:

1. Mainframe Systems

Reduce setup time by batching similar jobs Automatic job sequencing – automatically transfers control from one job to another. First rudimentary operating system. Resident monitor

1. initial control in monitor
2. control transfers to job
3. when job completes control transfers pack to monitor.

2. Batch Processing Operating System:
    1. This type of OS accepts more than one jobs and these jobs are batched/ grouped together according to their similar requirements. This is done by computer operator. Whenever the computer becomes available, the batched jobs are sent for execution and gradually the output is sent back to the user.
    2. It allowed only one program at a time.
    3. This OS is responsible for scheduling the jobs according to priority and the resource required.
3. Multiprogramming Operating System:
    1. This type of OS is used to execute more than one jobs simultaneously by a

single processor. it increases CPU utilization by organizing jobs so that the CPU always has one job to execute.

2. The concept of multiprogramming is described as follows:
   - All the jobs that enter the system are stored in the job pool(in disc). The operating system loads a set of jobs from job pool into main memory and begins to execute.
   - During execution, the job may have to wait for some task, such as an I/O operation, to complete. In a multiprogramming system, the operating system simply switches to another job and executes. When that job needs to wait, the CPU is switched to *another* job, and so on.
   - When the first job finishes waiting and it gets the CPU back.
   - As long as at least one job needs to execute, the CPU is never idle.

   Multiprogramming operating systems use the mechanism of job scheduling and CPU scheduling.

3. Time-Sharing/multitasking Operating Systems

Time sharing (or multitasking) OS is a logical extension of multiprogramming. It provides extra facilities such as:

a. Faster switching between multiple jobs to make processing faster.
b. Allows multiple users to share computer system simultaneously.
c. The users can interact with each job while it is running.

These systems use a concept of virtual memory for effective utilization of memory space. Hence, in this OS, no jobs are discarded. Each one is executed using virtual memory concept. It uses CPU scheduling, memory management, disc management and security management. Examples: CTSS, MULTICS, CAL, UNIX etc.

4. Multiprocessor Operating Systems

Multiprocessor operating systems are also known as parallel OS or tightly coupled OS. Such operating systems have more than one processor in close communication that sharing the computer bus, the clock and sometimes memory and peripheral devices. It executes multiple jobs at same time and makes the processing faster.

Multiprocessor systems have three main advantages:

Increased throughput: By increasing the number of processors, the system performs more work in less time. The speed-up ratio with **N** processors is less than **N**.

1. **Economy of scale:** Multiprocessor systems can save more money than multiple single-processor systems, because they can share peripherals, mass storage, and power supplies.
2. **Increased reliability:** If one processor fails to done its task, then each of the remaining processors must pick up a share of the work of the failed processor. The failure of one processor will not halt the system, only slow it down.

The ability to continue providing service proportional to the level of surviving hardware is called **graceful degradation.** Systems designed for graceful degradation are called **fault tolerant.**

The multiprocessor operating systems are classified into two categories:

1. Symmetric multiprocessing system
2. Asymmetric multiprocessing system

In symmetric multiprocessing system, each processor runs an identical copy of the operating system, and these copies communicate with one another as needed.

In asymmetric multiprocessing system, a processor is called master processor that controls other processors called slave processor. Thus, it establishes master-slave relationship. The master processor schedules the jobs and manages the memory for entire system.

5. Distributed Operating Systems

1. In distributed system, the different machines are connected in a network and each machine has its own processor and own local memory.
2. In this system, the operating systems on all the machines work together to

manage the collective network resource.

3. It can be classified into two categories:
    1. Client-Server systems
    2. Peer-to-Peer systems

Advantages of distributed systems.

1. Resources Sharing
2. Computation speeds up – load sharing
3. Reliability
4. Communications
5. Requires networking infrastructure.
6. Local area networks (LAN) or Wide area networks (WAN)

6. Desktop Systems/Personal Computer Systems

a. The PC operating system is designed for maximizing user convenience and responsiveness. This system is neither multi-user nor multitasking.

b. These systems include PCs running Microsoft Windows and the Apple Macintosh. The MS-DOS operating system from Microsoft has been superseded by multiple flavors of Microsoft Windows and IBM has upgraded MS-DOS to the OS/2 multitasking system.

c. The Apple Macintosh operating system has been ported to more advanced hardware, and now includes new features such as virtual memory and multitasking.

7. Real-Time Operating Systems (RTOS)

a. A real-time operating system (RTOS) is a multitasking operating system intended for applications with fixed deadlines (real-time computing). Such applications include some small embedded systems, automobile engine controllers, industrial robots, spacecraft, industrial control, and some large-scale computing systems.

b. The real time operating system can be classified into two categories:

1. hard real time system and 2. soft real time system.

c. A **hard real-time** system guarantees that critical tasks be completed on time. This goal requires that all delays in the system be bounded, from the retrieval of stored data to the time that it takes the operating system to finish any request made of it. Such time constraints dictate the facilities that are available in hard real-time systems.

d. A **soft real-time** system is a less restrictive type of real-time system. Here, a critical real-time task gets priority over other tasks and retains that priority until it completes. Soft real time system can be mixed with other types of systems. Due to less restriction, they are risky to use for industrial control and robotics.

Operating System Services

Following are the five services provided by operating systems to the convenience of the users.

Program Execution

The purpose of computer systems is to allow the user to execute programs. So the operating system provides an environment where the user can conveniently run programs. Running a program involves the allocating and deallocating memory, CPU scheduling in case of multiprocessing.

I/O Operations

Each program requires an input and produces output. This involves the use of I/O. So the operating systems are providing I/O makes it convenient for the users to run programs.

File System Manipulation

The output of a program may need to be written into new files or input taken from some files. The operating system provides this service.

Communications

The processes need to communicate with each other to exchange information during execution. It may be between processes running on the same computer or running on the

different computers. Communications can be occur in two ways: (i) shared memory or (ii) message passing

Error Detection

An error is one part of the system may cause malfunctioning of the complete system. To avoid such a situation operating system constantly monitors the system for detecting the errors. This relieves the user of the worry of errors propagating to various part of the system and causing malfunctioning.

Following are the three services provided by operating systems for ensuring the efficient operation of the system itself.

Resource allocation

When multiple users are logged on the system or multiple jobs are running at the same time, resources must be allocated to each of them. Many different types of resources are managed by the operating system.

Accounting

The operating systems keep track of which users use how many and which kinds of computer resources. This record keeping may be used for accounting (so that users can be billed) or simply for accumulating usage statistics.

Protection

When several disjointed processes execute concurrently, it should not be possible for one process to interfere with the others, or with the operating system itself. Protection involves ensuring that all access to system resources is controlled. Security of the system from outsiders is also important. Such security starts with each user having to authenticate him to the system, usually by means of a password, to be allowed access to the resources.

System Call:

- System calls provide an interface between the process and the operating system.
- System calls allow user-level processes to request some services from the operating system which process itself is not allowed to do.

- For example, for I/O a process involves a system call telling the operating system to read or write particular area and this request is satisfied by the operating system.

Computer hardware refers to the physical components of a computer system, including the central processing unit (CPU), motherboard, memory, hard drive, graphics card, sound card, and other peripherals such as a keyboard, mouse, and monitor. These components work together to allow a computer system to perform tasks and run programs. A computer can be a desktop, laptop, tablet, or smartphone, and is usually connected to the internet, allowing for access to a wide range of software applications and online resources.

At a basic level, a computer works through a series of interconnected hardware and software components, each designed to perform specific functions. When a user inputs a command, such as typing on a keyboard, the computer receives the input and processes it through the Central Processing Unit, or CPU, which acts as the brain of the computer. The CPU fetches instructions from memory and executes them, performing calculations and logical operations at incredibly high speeds.

The computer's Random Access Memory, or RAM, acts as a temporary storage space for data, holding information that is being actively used by the CPU. Meanwhile, the hard drive or solid-state drive (SSD) stores data and programs for long-term use. When the user opens a program or file, the computer retrieves the necessary data from the hard drive and loads it into RAM for processing.

The computer's input/output devices, such as the keyboard, mouse, and monitor, allow users to interact with the computer and receive feedback on its operations. For example, when a user clicks on an icon with a mouse, the computer registers the input and performs the corresponding action, displaying the results on the monitor.

To summarize, the complex interplay of hardware and software components enables a computer to perform a vast array of tasks, from basic word processing to complex scientific simulations. As technology continues to advance, computers are becoming ever more powerful and versatile, and their capabilities are limited only by the imagination of their users.

Digital Measures

Digital *bits* are usually combined into groups of eight bits to form a *byte*. Bytes are sufficiently large to store characters and numbers. Computer memory and storage devices are measured in powers of two. A *megabyte*, abbreviated MB, is 2^{10} or 1,024 bytes. A *gigabyte* is 1,024 megabytes.

Hardware Components of a Computer

Central Processing Unit (CPU)

The CPU, or central processing unit, is the primary component of a computer's hardware that performs most of its processing tasks. It is essentially the brain of the computer and controls all of its functions. The CPU performs calculations, logical operations, and manages data flow between other parts of the computer, such as RAM and the hard drive. It executes instructions stored in memory and runs software programs, which allows the computer to perform specific tasks such as word processing, gaming, and browsing the internet. The speed and efficiency of a CPU determine how fast a computer can perform tasks and run applications. Higher-end CPUs are typically faster and more powerful, allowing for faster processing speeds and better performance.

Logic Gates

Logic gates are electronic circuits that perform logical operations, such as AND, OR, NOT, and XOR, on binary inputs. These operations are based on Boolean algebra, a branch of mathematics that deals with binary logic. Each logic gate has one or more inputs and one output, that depends on the logic of the inputs.

In a CPU, logic gates are incorporated into the arithmetic logic unit (ALU), which is responsible for performing mathematical and logical operations on data. The ALU contains many logic gates, as well as other circuits and registers that allow it to perform a wide range of operations.

Graphics Processing Unit (GPU)

A GPU, or graphics processing unit, is a specialized type of processor designed for handling graphical and visual data. GPUs are particularly important for gaming, video editing, and other applications that require high-quality graphics and fast processing speeds. A GPU works by offloading some of the processing tasks that would normally be handled by the CPU, allowing for more efficient and faster performance.

When a computer runs a graphics-intensive application, such as a video game or 3D rendering software, the GPU takes over much of the processing load, freeing up the CPU to handle other tasks. GPUs are optimized for performing calculations related to graphics and visual data, which allows them to process large amounts of data quickly and efficiently. They are typically more powerful than the integrated graphics processors found in most CPUs and are often used in desktop computers and high-end laptops.

A computer motherboard, also known as a mainboard, is a flat board that connects all the components of the computer, including the CPU, RAM, storage devices, expansion cards, and other peripherals.

Its purpose is to provide a communication pathway and physical connection between different computer parts. It is essentially the backbone of the computer system, serving as the central hub to which all other parts of the computer connect.

The motherboard also houses the BIOS or UEFI firmware that allows the computer to boot up and run its essential software. BIOS (Basic Input/Output System) or UEFI (Unified Extensible Firmware Interface) firmware is the software that is built into the motherboard of a computer. It is responsible for controlling the fundamental hardware operations of the system, such as booting up the computer and managing the communication between the operating system and the hardware.

What is unique about firmware is that it is stored in non-volatile memory, usually in a ROM or flash memory chip, and is not erased when the computer is turned off. This means that the firmware remains intact even if there is a power outage or if the computer is reset. Firmware can be updated or flashed to make changes to the way a computer operates. It is also unique in that it is specific to the hardware it is controlling, meaning that firmware for one computer may not be compatible with another.

RAM, or random-access memory, is a type of computer memory that is used to temporarily store data and program instructions that are currently in use by the computer's CPU. RAM is volatile, meaning that it requires power to maintain its contents, and is cleared when the computer is turned off. RAM is important for computer performance because it provides fast access to data and program instructions, allowing the CPU to work efficiently.

ROM, or read-only memory, is a type of computer memory that is used to store permanent data and program instructions that are essential to the computer's operation, such as the BIOS or

UEFI firmware. ROM is non-volatile, meaning that it does not require power to maintain its contents, and is not erased when the computer is turned off. ROM is important for computer operation because it provides essential instructions and data that the computer needs to function properly.

RAM and ROM are both used in a computer to store and access data and program instructions. RAM is used to temporarily store data while the computer is running, while ROM is used to store permanent data and program instructions that are necessary for the computer to function. Together, RAM and ROM provide a complete memory system for a computer, allowing it to perform a wide range of tasks and run a variety of software applications.

Data on a computer can be stored in various ways, such as on hard drives, solid-state drives (SSD), and removable media like USB flash drives or CDs/DVDs.

Hard drives are mechanical storage devices that use spinning disks to read and write data, with the data being accessed by magnetic read/write heads. Hard drives store data even when a computer is turned off and typically have a larger storage capacity than SSDs, making them ideal for storing large amounts of data.

Solid-state drives (SSD) use electronic circuits to store data instead of mechanical spinning disks. They are faster than hard drives because there are no moving parts that need to be accessed. Their storage capacity is generally smaller compared to hard drives. They are ideal for use as the primary or boot drive because they offer faster boot times and faster application load times, making them ideal for people who need the speed more than large storage capacity.

Removable media like USB flash drives, CDs/DVDs and memory cards are used for storing and sharing data, especially when portability is needed. They can be inserted into a USB or memory card port on a computer or mobile device, and data can be added, deleted, or modified as needed. They are not ideal for use as a primary storage device, but they’re a great way to back up or transfer data between computers or as temporary storage to free up computer memory.

Input and Output

Computer input devices are tools that allow users to interact with a computer system. They are used to transmit signals and data into the computer itself, facilitating communication between man and machine. Here are some examples of input devices:

Keyboard: A keyboard is a common input device that is used to enter characters, numbers, and other text into a computer. Almost all PCs and laptops come with an integrated keyboard.

Mouse: A mouse is another popular input device that is used to control the movement of a cursor on a screen. It allows the user to select and click on items on the screen.

Scanner: A scanner is a device that captures images or text from printed documents and converts them into a digital format that can be displayed on a computer screen.

Microphone: A microphone allows the user to input audio data into a computer. It is commonly used for recording voiceovers, podcasts, and other types of audio content.

Computer output devices take digital data from a computer system and present it to the user in various forms, such as sound, text, images, or video. Here are some examples of output devices:

Monitor: A monitor is a common output device that displays visual data that a computer is processing. It can be a Cathode Ray Tube (CRT), Liquid Crystal Display (LCD), or Light-Emitting Diode (LED) display.

Printer: A printer is an output device that produces a hard copy of a digital file. It can be used to print text or images.

Speaker: A speaker is an output device that converts digital signals into sound. It is used to play music, voice recordings or other audio files.

Projector: A projector is an advanced output device which projects an image or video onto a large screen or wall. It is commonly used in presentations or home theatre systems.

Input and output devices are fundamental to the operation of computer systems. Generically, these are often called peripheral devices because they operate outside the core components of the computer itself. Peripherals are often wired devices that connect to a computer's Universal Serial Bus (USB), High-Definition Multimedia Interface (HDMI), or similar port. Some peripheral devices may use Bluetooth technology to connect peripherals to a computer wirelessly.

Bluetooth allows devices to communicate with each other wirelessly over short distances. It is commonly used for peripherals such as wireless mice, keyboards, and headphones, as well as for file transfers between devices such as smartphones and computers. Bluetooth works by using radio waves to establish a connection between two devices and exchanging data between them. The devices must be within close proximity to each other, usually within a few meters,

for the Bluetooth connection to work. This technology provides a convenient and efficient way for users to connect and use peripherals with their computers without the need for cables or wires.

Introduction to Software

Computer software is a collection of programs, data, and instructions that tell a computer what to do. This includes operating systems, applications, utilities, and any other programs that are used on a computer or other electronic device. Software is designed to be interpreted by a machine, and it can be stored and executed on a variety of computing devices, such as desktops, laptops, tablets, smartphones, and servers. The software is responsible for managing hardware resources, performing complex calculations, manipulating data, providing user interfaces, and enabling communication among various components of a system.

Types of Software

Operating Systems

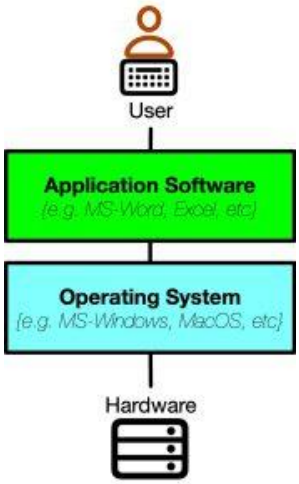
A computer operating system is a collection of software programs that manages computer hardware resources and provides common services for computer programs. Examples of commonly used operating systems include Microsoft Windows, macOS, Linux, and Android.

We need an operating system because it provides a common interface for users to interact with the computer's hardware and software. Without an operating system, we would have to interact directly with the computer's hardware, which would be tedious and difficult. The operating system also manages system resources, such as memory and processing power, to ensure that different programs can run simultaneously without interfering with each other. Additionally, the operating system provides security features to protect against malware and unauthorized access to the system.

We need an operating system because it provides a common interface for users to interact with the computer's hardware and software. Without an operating system, we would have to interact directly with the computer's hardware, which would be tedious and difficult. The operating system also manages system resources, such as memory and processing power, to ensure that different programs can run simultaneously without interfering with each other. Additionally, the operating system provides security features to protect against malware and unauthorized access to the system.

How Computers Work: Hardware and Software – YouTube

Application Software



Application software, or "apps," are programs that are designed to perform specific tasks or functions for users. They are usually developed for a specific platform or operating system, such as Windows, iOS, or Android, and can be downloaded and installed onto a device from an app store or website. Examples of application software include:

Adobe Photoshop: a graphics editing program used for photo manipulation, image enhancement, and graphic design.

Google Chrome: a web browser used for accessing the internet and viewing websites.

Spotify: a music streaming service used for listening to music and creating playlists.

Zoom: a video conferencing program used for online meetings and virtual events.

QuickBooks: an accounting software used for managing finances and bookkeeping for small businesses.

Snapchat: a social media app used for sharing photos and videos with friends.

Uber: a transportation app used for booking rides and getting around in urban areas.

Minecraft: a video game used for building, exploring, and creating virtual worlds.

TikTok: a social media app used for creating and sharing short videos.

Office Software

Office software apps refer to a suite of productivity software programs used for creating and editing documents, spreadsheets, presentations, and email. Examples of office software include Microsoft Office, Google Workspace, LibreOffice, and Apple iWork.

Using office software instead of stand-alone apps allows for more streamlined and efficient workflows, as all the tools needed for productivity work are housed in one platform. This makes it easier to switch between tasks and to collaborate with others on shared documents, spreadsheets, and presentations. Additionally, office software often provides more advanced features and customization options, such as formatting and styling tools, mail merge functions, and the ability to create automated workflows.

Example: MS Office Integration

When a user creates a chart in Microsoft Excel and wants to insert it into a Microsoft PowerPoint presentation, the user can easily copy and paste the chart from Excel into

PowerPoint, or they can use the “Insert” feature in PowerPoint to import the chart directly from Excel. If the user needs to make changes to the data in the chart, they can do so in Excel and the changes will automatically be updated in the chart in PowerPoint. This integration between Excel and PowerPoint, two different components of the Microsoft Office suite, allows for seamless collaboration and efficient workflow.

Productivity Software

Productivity software is a type of software designed to increase productivity and efficiency in completing tasks. It includes tools such as project management software, time tracking software, and collaboration software. Examples of productivity software include:

Trello: a project management tool that uses boards and cards to organize tasks and projects.

Evernote: a note-taking app that allows users to create and organize notes, to-do lists, and reminders.

Asana: a project management tool that helps teams track tasks and progress towards goals.

Slack: a messaging and collaboration app that allows teams to communicate and share files in real-time.

Microsoft Teams: a collaboration platform with messaging, video conferencing, and file sharing capabilities.

Google Drive: a cloud storage and collaboration platform that allows users to create and share documents, spreadsheets, and presentations.

Rescue Time: a time-tracking tool that helps users understand how they spend their time on their computer or mobile device.

Grammarly: a writing assistant that checks for spelling and grammar errors, suggests writing improvements, and offers suggestions for clarity and tone.

Zoom: a video conferencing tool that allows users to connect with others remotely for meetings, webinars, and virtual events.

Hootsuite: a social media management tool that allows users to manage multiple social media accounts, schedule posts, and track engagement metrics.

Utilities

Computer utility apps are a type of software designed to optimize the performance and functionality of a computer or electronic device. Examples of computer utility apps include:

Antivirus and malware software: These apps are designed to detect and remove viruses, malware, and other malicious software from a computer or device.

Disk cleanup and optimization: These apps are used to free up space on a computer's hard drive by deleting unnecessary files and optimizing system performance.

Backup and recovery: These apps are used to back up important files and data to prevent loss in case of a system failure, and to recover data if a system failure does occur.

System maintenance: These apps are used to perform routine maintenance tasks on a computer, such as updating software, scanning for errors, and optimizing performance.

File compression and extraction: These apps are used to compress large files for easier storage and transfer, and to extract files from compressed archives.

Disk defragmentation: This app is used to optimize a computer's hard drive by rearranging fragmented files and improving system performance.

So, computer utility apps are used to maintain and optimize the performance and functionality of a computer or electronic device, ensuring that it operates smoothly and efficiently.

Enterprise Systems

Enterprise information systems (EIS) are integrated software solutions designed to support and automate various business functions and processes within an organization. These systems help organizations manage and analyze vast amounts of data to make informed decisions and improve overall efficiency. There are several types of enterprise information systems, each specialized for different aspects of business operations.

Enterprise Resource Planning (ERP) Systems: ERP systems integrate core business processes, such as finance, accounting, inventory management, human resources, and supply chain management. They provide a centralized database and real-time visibility into all facets of the organization. Examples of popular ERP systems include SAP, Oracle ERP, and Microsoft Dynamics 365.

Customer Relationship Management (CRM) Systems: CRM systems streamline customer interactions, sales, and marketing processes. They help organizations manage customer data, track leads, and improve customer satisfaction and loyalty. Popular CRM systems include Salesforce, Microsoft Dynamics CRM, and HubSpot.

Supply Chain Management (SCM) Systems: SCM systems optimize the flow of materials, information, and finances involved in the supply chain. They enable organizations to plan, execute, and control the entire supply chain, from procurement to product delivery. Examples of SCM systems are SAP SCM, Oracle SCM, and JDA Software.

Human Resources Management Systems (HRMS): HRMS systems automate HR processes, including recruitment, employee onboarding, payroll management, benefits administration, performance evaluation, and training. They centralize employee data and streamline HR operations. Examples of HRMS systems include Workday, Oracle HCM Cloud, and ADP.

Business Intelligence (BI) Systems: BI systems collect, analyze, and present data from various sources to provide actionable insights and support decision-making. They include tools for data visualization, reporting, and advanced analytics. Examples of popular BI systems are Tableau, Microsoft Power BI, and Qlik.

Knowledge Management (KM) Systems: KM systems capture, store, and share organizational knowledge and information. They facilitate collaboration, knowledge discovery, and knowledge sharing. Examples of KM systems include Microsoft SharePoint, Confluence, and IBM Knowledge Center.

Enterprise Content Management (ECM) Systems: ECM systems manage the creation, storage, retrieval, and distribution of an organization's documents and content. They ensure document security, compliance, and improve collaboration. Examples of ECM systems are OpenText Content Suite, Microsoft SharePoint, and IBM FileNet.

These enterprise information systems work together to provide a comprehensive view of an organization's operations and facilitate effective decision-making. By integrating various business functions and processes, EIS enable organizations to streamline their operations,

reduce manual work, and improve overall efficiency. We will explore these systems in greater detail later in the text.

Mobile Applications

Mobile applications, or mobile apps, are software applications that are designed to be used on mobile devices such as smartphones and tablets. Mobile apps can be downloaded and installed from app stores such as the Apple App Store and Google Play Store. Mobile apps have become popular due to their convenience and accessibility, as they allow users to access information and perform tasks on the go.

Some examples of popular mobile applications for business include:

Slack: A messaging and collaboration app designed for teams to communicate and share files in real-time.

Trello: A project management app that allows teams to organize and prioritize tasks and projects.

Salesforce: A CRM app that allows sales teams to manage customer relationships and track sales leads on the go.

Dropbox: A file-sharing app that allows users to access and share files from anywhere.

LinkedIn: A professional networking app that allows users to connect with colleagues, find job opportunities, and share industry news.

Mobile apps provide businesses with increased flexibility and productivity, allowing employees to stay connected and productive even when they are on the go.

Cloud Computing

Cloud computing is a type of computing where resources and services are accessed over the internet. This includes servers, storage, and applications, which are provided by third-party providers and hosted on remote servers. Cloud computing allows users to access computing

resources and services from anywhere with an internet connection, and it has become increasingly popular in recent years due to its flexibility and cost-effectiveness.

Advantages of cloud computing:

Cost-Effective: Cloud computing eliminates the need for businesses to invest in expensive on-premises hardware and software, reducing upfront costs.

Scalability: Cloud computing allows for easy and quick scalability, meaning businesses can easily increase or decrease the resources they need based on demand.

Accessibility: Cloud computing allows for remote access, allowing users to access computing resources and applications from anywhere with an internet connection.

Disaster Recovery: Cloud computing providers typically have robust disaster recovery measures in place, ensuring that data and applications are backed up and protected in the event of a disaster.

Potential Disadvantages of cloud computing:

Security Concerns: Cloud computing hosts data and applications on remote servers, which can lead to security concerns if proper security measures are not in place.

Dependence on Internet Connection: Cloud computing relies on a stable and reliable internet connection, which can be a limitation for businesses in areas with poor internet connectivity.

Limited Control: Cloud computing providers control and manage the cloud infrastructure, meaning businesses have limited control over their data and applications.

Provider Dependence: Businesses rely on cloud computing providers to maintain and manage the cloud infrastructure, which can be a concern if the provider experiences downtime or other issues.

Virtualization

Virtualization is a technology that enables multiple operating systems to run on a single physical machine, by creating virtual versions of the computing resources such as the CPU, memory, and storage. Virtualization makes it possible to run multiple applications and operating systems on a single physical server, which can lead to increased efficiency and cost savings.

In business, virtualization is used to consolidate multiple physical servers into a single physical machine, which can reduce hardware costs and improve resource utilization. Virtualization also allows for better management and flexibility of computing resources, as virtual machines can be easily created, moved, and deleted as needed.

Advantages of virtualization include:

Cost savings: Virtualization can reduce hardware and maintenance costs by consolidating multiple physical servers into a single machine.

Improved efficiency: Virtualization can improve resource utilization and reduce downtime by allowing virtual machines to be easily moved and managed.

Flexibility: Virtualization allows for easy creation and deployment of virtual machines, making it easier to scale resources up or down as needed.

Disadvantages of virtualization include:

Increased complexity: Virtualization adds an additional layer of complexity to the IT infrastructure, which can make it more difficult to manage and troubleshoot.

Performance issues: Running multiple virtual machines on a single physical machine can lead to performance issues if resources are not properly allocated or if the physical machine is not powerful enough.

Security concerns: Virtualization can create new security vulnerabilities if virtual machines are not properly isolated or if there are vulnerabilities in the virtualization software.

Open-Source Software

Open-source software is software that is distributed with its source code, allowing anyone to access, modify, and distribute the code. This is in contrast to proprietary software, where the source code is kept secret and can only be modified and distributed by the software vendor.

Open-source software is used in business for a variety of purposes, including server management, software development, content management, and collaboration. It can help to reduce costs, increase flexibility and customization, and improve security and reliability.

Some popular examples of open-source software include the Linux operating system, the Apache web server, the MySQL database management system, the WordPress content management system, and the Git version control system.

The pros of open-source software include increased flexibility and customization, reduced costs, improved security and reliability, and a global community of developers contributing to the code. The cons of open-source software include potential compatibility issues, lack of support, and the need for technical expertise to manage and modify the code.

Ultimately, the choice between open-source office software and Microsoft Office depends on the specific needs and preferences of the user. Those looking for a cost-effective option with basic office capabilities may prefer open-source software, while larger organizations or those requiring more advanced features may opt for Microsoft Office.

Microsoft Office vs. OpenOffice

When comparing OpenOffice open-source software with Microsoft Office, there are several key differences to consider.

Cost: Open-source office software, such as LibreOffice and OpenOffice, is generally free to use, while Microsoft Office requires a subscription or one-time purchase.

Features: While both options provide word processing, spreadsheet, and presentation capabilities, Microsoft Office may offer more advanced features and integrations with other Microsoft products.

Compatibility: Microsoft Office is the industry standard for office software, meaning that files created in Microsoft Office may not always be fully compatible with open-source office software, and vice versa.

Support: Microsoft Office has a dedicated support team and a large user base, while open-source office software may have limited support options and documentation.

Community: Open-source office software has a global community of developers contributing to the code, while Microsoft Office is proprietary software controlled by Microsoft.

Software Programming

Programming software involves the process of designing, coding, testing, and maintaining software applications. It requires knowledge of programming languages, software development tools, and principles of software engineering.

The software development process typically involves the following stages:

1. **Requirements gathering**: Identifying the needs and requirements of the software application through collaboration with stakeholders and end-users.
2. **Design**: Creating a detailed plan and design for the software, including architecture, user interface, and functionality.
3. **Implementation**: Writing the actual code for the software application using programming languages and software development tools.
4. **Testing**: Testing the software application for bugs, errors, and performance issues.
5. **Deployment**: Launching the software application in production environments.
6. **Maintenance**: Ongoing support and maintenance of the software application, including updates, bug fixes, and enhancements.

Effective software development requires strong teamwork, communication, and project management skills. It involves a continuous cycle of feedback and improvement to ensure that the software application meets the needs of stakeholders and end-users.

Algorithm

An algorithm is a set of instructions or rules that a computer follows to complete a task or solve a problem.

For example, an algorithm to access a SQL database and move data into a user's Outlook address book might look like:

1. Import software library modules for connecting to the SQL database and interacting with Outlook.
2. Establish a connection to the SQL database and retrieve necessary data using SQL queries.
3. Iterate through the retrieved data and extract the required fields such as names, phone numbers, and email addresses.

4. Create a new Outlook application object.
5. Retrieve the contacts folder in Outlook.
6. Create a new contact item
7. Set the properties of the name, phone number, and email address of the contact item using the appropriate methods and properties.
8. Save the contact item using the Save method.
9. Repeat steps 6-8 for all the retrieved data.
10. Close the connection to the SQL database and Outlook.

This algorithm would then be used to guide a programmer to select appropriate commands in the programming language they were using to translate the algorithm to something a computer would understand.

Low-Level Programming Languages

Low-level programming languages are programming languages that are closer to the hardware and machine language than high-level programming languages. They are typically used to develop system software, device drivers, and firmware. Examples of low-level programming languages include Assembly language and machine language.

Advantages of using low-level programming languages include:

Better performance: Low-level programming languages can directly access hardware resources, allowing for better performance than high-level programming languages.

Control: Low-level programming languages provide more control over the system hardware, which can be useful for developing system software and device drivers.

Memory efficiency: Low-level programming languages can be memory-efficient since they require less memory to run compared to high-level programming languages.

Disadvantages of using low-level programming languages include:

Steep learning curve: Low-level programming languages can be difficult to learn and require a deep understanding of hardware architecture.

Time-consuming: Developing software in low-level programming languages can be time-consuming since it requires writing more lines of code to accomplish tasks.

Prone to errors: Low-level programming languages are prone to errors such as memory leaks and buffer overflows, which can result in security vulnerabilities.

In the end, the choice of programming language depends on the specific requirements of the project and the expertise of the development team.

Example: Assembly Language

High-Level Programming Languages

High-level programming languages are programming languages that are designed to be easier to read and write than low-level programming languages. They are typically used to develop application software, such as desktop and mobile applications, web applications, and games. Examples of high-level programming languages include Java, Python, C++, and JavaScript.

Advantages of using high-level programming languages include:

Ease of use: High-level programming languages are designed to be easier to read and write than low-level programming languages, making them more accessible to beginner programmers.

Abstraction: High-level programming languages provide an abstraction from the hardware and machine language, allowing programmers to focus on the functionality of their code rather than the details of the hardware.

Portability: High-level programming languages are typically portable across different operating systems and hardware architectures, making it easier to write software that can run on a variety of devices.

Disadvantages of using high-level programming languages include:

Performance issues: High-level programming languages can be slower than low-level programming languages because they require additional processing time to perform abstractions and translations between the software and the hardware.

Limited control: High-level programming languages provide less control over the hardware than low-level programming languages, which can be a disadvantage for developing system software and device drivers.

Memory inefficiency: High-level programming languages can be memory-inefficient because they require more memory to run compared to low-level programming languages.

Weighing these factors, the choice of programming language depends on the specific requirements of the project and the expertise of the development team. High-level programming languages are typically preferred for developing application software, while low-level programming languages are preferred for developing system software and device drivers.

Example: Python Code

Compiled versus Scripted Languages

Compiled code is code that has been translated into machine code by a compiler, resulting in a standalone executable file that can be run directly on a computer without the need for any additional software. In summary, a compiler works by taking source code written in a high-level programming language and translating it into machine code that can be run on a computer. The process involves several stages, including lexical analysis, parsing, semantic analysis, code generation, and optimization. The resulting executable file can be run directly on the computer without the need for any additional software, offering faster execution and better performance compared to scripts.

Script, on the other hand, is code that needs to be interpreted by an interpreter or runtime environment in real-time to be executed. Scripts are usually written in high-level programming languages and require the presence of the interpreter or runtime environment to be executed. Compiled code results in faster execution and better performance, while scripts offer more flexibility and ease of use for developers.

Example: Javascript

Software Engineering

Software engineering is the process of designing, developing, testing, and maintaining software applications using various engineering principles and practices. It involves programming,

project management, and problem-solving skills to create high-quality software that meets the needs of users and stakeholders. Software engineers use various tools and methodologies to ensure that the software is reliable, scalable, and maintainable.

The software engineering process typically involves requirements gathering, design, implementation, testing, deployment, and maintenance. Software engineering is a broad field that covers various specializations, such as web development, mobile app development, and system software development.

Software Engineering for Large Scale Projects

Developing large scale software projects can be challenging due to various factors such as complexity, team size, and coordination. Some of the main challenges include:

Project management: Managing a large team requires proper planning, coordination, and communication. Project managers must ensure that everyone is working towards the same goal and that timelines are being met.

Scaling: As the project grows, it becomes more complex and difficult to manage. Developers must ensure that the system is scalable and can handle large amounts of data and users.

Integration: Large projects often involve integrating multiple systems and technologies. This can be challenging as developers must ensure that all the components work seamlessly together.

Testing: Large projects require extensive testing to ensure that the software is stable and reliable. Testing involves various techniques such as unit testing, integration testing, and user acceptance testing.

To address these challenges, software engineers use various tools and methodologies such as Agile, DevOps, and continuous integration and delivery. These approaches emphasize collaboration, flexibility, and automation to ensure that software projects are delivered on time and within budget.

Additionally, modular design and code can help to simplify the development process and make it easier to manage and integrate different components. Successful development of large scale software projects requires a combination of technical expertise, project management skills, and effective communication and collaboration.

Waterfall versus Agile Software Engineering Approaches

The waterfall method of software development is a linear approach where each stage of the development process is completed in a sequential order. The stages typically include requirements gathering, design, implementation, testing, and deployment. Once a stage is completed, the project moves onto the next stage without any revisiting of the previous stage.

Advantages of the waterfall method include clear goal-setting and defined stages that can be easily tracked and measured. However, the disadvantages include the lack of flexibility for changes or adjustments during the development process, and the risk of potential errors or issues being discovered at a later stage in the process that may require significant rework and delay.

Agile methodology, on the other hand, is an iterative and flexible approach to software development that emphasizes collaboration, customer involvement, and adaptability. Instead of completing each stage before moving on to the next, the agile approach involves ongoing feedback and adjustments throughout the development process.

Advantages of agile methodology include the ability to respond quickly to changes, a focus on customer satisfaction, and increased collaboration and communication among team members. The disadvantages may include a lack of defined goals and timelines, a potential for scope creep, and a need for more frequent updates and assessments.

In light of the advantages and disadvantages of each, the choice of methodology depends on the specific needs and requirements of the project, the development team's expertise, and the stakeholders' preferences. Some projects may benefit from a more structured approach like waterfall, while others may require the flexibility and adaptability of agile methodology.

Computer Networking

Computer networking is a field responsible for the creation and maintenance of computer networks, which, in turn, are responsible for the interconnection of devices and systems, allowing the exchange of data and information. In essence, it is the physical and logical infrastructure that links devices, computers, servers, and other devices within a network,

enabling them to communicate and access resources that exist in other devices, with the primary goal of enhancing cooperation and the sharing of resources.

A computer network can be made up of two or more devices and could cover a small room or span multiple levels of a building, connecting computers, printers, routers, switches, servers, modems, and other hardware components used to create a working network.

To understand computer networking, it important to start from the basics, and in this case, that means understanding the different types of computer networks. Computer networks come in different types depending on their coverage areas or the nature of information exchanged in them.

Types of Computer Networks

There are several types of computer networks, each with unique features and purposes. These types include LAN, WAN, and VPN and are described below.

Local Area Network (LAN): A LAN is a network that connects devices within a limited geographical area, such as a home or office building. LANs are the most common type of network and are used for sharing data, printers, and internet access among devices. LANs are typically designed to be fast and reliable, with low latency and high bandwidth. Ethernet and Wi-Fi are the most common technologies used to connect devices in a LAN. Equipment needed for a LAN includes Ethernet cables or Wi-Fi routers, switches, network interface cards, and printers. The advantages of a LAN include fast data transfer, low latency, and the ability to share resources among devices. The disadvantages of a LAN include limited geographical coverage and the need for additional equipment such as routers, switches, and cables.

Wide Area Network (WAN): A WAN is a network that connects devices over a large geographical area, such as multiple LANs across different cities or countries. WANs are used for sharing data and resources among devices in different locations. The internet is the most extensive WAN, connecting billions of devices across the world. Equipment needed for a WAN includes routers and switches, leased lines or satellite links, and internet service providers (ISPs). The advantages of a WAN include the ability to connect devices over long distances, access to remote resources, and cost savings. The disadvantages of a WAN include high latency, slow data transfer, and vulnerability to security breaches.

Virtual Private Network (VPN): A VPN is a network that connects devices over the internet, providing a secure and private connection. VPNs are used for accessing remote networks

securely, enabling data transfer between devices in different locations. Equipment needed for a VPN includes VPN servers and clients, and secure protocols such as SSL (Secure Sockets Layer) and IPSec (Internet Protocol Security). The advantages of a VPN include secure data transfer, private connection, and remote access. The disadvantages of a VPN include slow data transfer due to encryption and the need for specialized equipment and software.

Networking Equipment: Functions of Routers, Switches, Modems, Hotspots, and Access Points

Routers. Routers are networking devices that connect LANs or WANs, directing traffic between them. They function as gatekeepers, determining which devices have access to the network and how the traffic flows. Routers use IP addresses to identify devices and use routing tables to determine the best path for data to travel between networks. They also provide security features such as firewalls and VPNs, protecting networks from cyber threats.

Switches. Switches are networking devices that connect devices within a LAN, providing a high-speed connection with low latency. Switches use MAC addresses to identify devices and allow for efficient data transfer between them. They use forwarding tables to direct data to the appropriate device and can be managed or unmanaged. Managed switches offer more control over the network, allowing administrators to configure and monitor network performance.

Modems. Modems are networking devices that connect devices to the internet or other WANs. They convert digital signals from devices into analog signals that can be transmitted over telephone lines or cable connections. Modems use various modulation techniques, such as QAM (Quadrature Amplitude Modulation) and QPSK (Quadrature Phase-Shift Keying), to encode and decode data, allowing for efficient data transfer over long distances.

Hotspots. Hotspots are wireless access points that provide internet access to devices within a limited geographical area, such as a coffee shop or hotel room. Hotspots can be public or private and use various technologies such as Wi-Fi or Bluetooth. They require a wireless router or other networking device to provide internet access.

Access Points. Access points are networking devices that connect devices to a wireless LAN, providing wireless connectivity within a limited geographical area such as a home or office. Access points use various technologies such as Wi-Fi or Bluetooth and allow for efficient data transfer between devices. They are often used in conjunction with routers and switches to create a LAN. Access points can be managed or unmanaged, with managed access points providing more control over the network.

Network Software

To create a network, various software and tools are required, depending on the type and size of the network. Some examples of software used to create a network include:

Network Operating System (NOS): This software is used to manage and control the network. It provides various services such as file sharing, print sharing, and user authentication. Examples of NOS include Windows Server, Linux, and Unix.

Network Configuration Tools: These tools are used to configure network settings such as IP addresses, subnet masks, and DNS servers. Some examples of network configuration tools include Cisco Network Assistant, SolarWinds Network Configuration Manager, and NetSetMan.

Network Monitoring and Analysis Tools: These tools are used to monitor network performance, analyze network traffic, and troubleshoot network issues. Examples of network monitoring and analysis tools include Wireshark, Nagios, and PRTG Network Monitor.

Virtual Private Network (VPN) Software: This software is used to create secure connections between remote devices and networks, allowing users to access resources on the network securely. Examples of VPN software include OpenVPN, NordVPN, and ExpressVPN.

Firewall Software: This software is used to protect the network from unauthorized access and other security threats. Examples of firewall software include Windows Firewall, Norton Security, and McAfee Firewall.

Together, these software and tools are essential components in creating and maintaining a network. They provide the necessary functionality to manage, configure, monitor, and protect the network, ensuring that it is secure, efficient, and reliable.

Network Security

Network security refers to the protection of a network and its components from unauthorized access, theft, and damage. Network security concerns can include data breaches, malware, unauthorized access, denial-of-service attacks, and insider threats. These security concerns can lead to the theft of sensitive information, operational disruption, reputational damage, and financial losses. Therefore, it is crucial to protect a network against these security concerns to ensure that it remains secure and operational.

Here are some ways in which we can protect networks against security concerns:

Implement Strong Passwords and Authentication: Weak passwords are a common cause of security breaches. Passwords should be complex, unique, and changed regularly. Implementing multi-factor authentication adds an additional layer of security by requiring a second form of verification, such as a fingerprint or code.

Install Security Software: Anti-virus and anti-malware software can protect against the most common security threats. Firewall software can prevent unauthorized access and detect suspicious activities. Intrusion detection and prevention systems can monitor the network and alert administrators of potential attacks.

Regularly Update Software and Hardware: Software and hardware manufacturers regularly release updates to fix security vulnerabilities. It is essential to keep all devices and software up-to-date to ensure that the network remains secure.

Conduct Regular Security Audits: Conducting regular security audits can help identify vulnerabilities and areas that need improvement. These audits can help to identify gaps in security and make improvements to prevent potential security breaches.

Educate Employees: Employees are often the weakest link in network security. Implementing training programs can help employees understand the importance of network security and how to identify and prevent security breaches.

Physical Security: Physical security measures can prevent unauthorized access to network components. Server rooms and data centers should be locked and secured, and only authorized personnel should have access.

In conclusion, network security is essential in today's digital age. Protecting a network from security concerns requires an understanding of the risks and implementing appropriate security measures. By implementing strong passwords and authentication, security software, regular

updates, security audits, employee education, and physical security measures, a network can be protected from potential security breaches. As technology continues to advance, it is crucial to remain vigilant and adapt to new security threats to ensure that networks remain secure and operational.

The Internet and World Wide Web

The Internet is a global network of computer networks that enables the exchange of information and resources between millions of devices worldwide. The history of the Internet dates back to the 1960s when the US Department of Defense's Advanced Research Project Agency (ARPA) developed a packet-switching system called ARPANET. The primary purpose of ARPANET was to share information between military and academic institutions. In 1983, ARPANET switched from the Network Control Protocol (NCP) to the Transmission Control Protocol/Internet Protocol (TCP/IP), which formed the foundation of the modern internet.

The World Wide Web (WWW), often referred to simply as the 'web,' is an information system that allows documents to be linked and accessed over the internet. The web was invented by British computer scientist Tim Berners-Lee in 1989 while working at CERN (European Organization for Nuclear Research) in Switzerland. Berners-Lee developed the Hypertext Transfer Protocol (HTTP) and the HyperText Markup Language (HTML) that form the basis of the web. In 1993, the first web browser, Mosaic, was released, which allowed users to access web pages with ease.

The web quickly grew in popularity, and by the mid-1990s, it had become a global phenomenon. The web provided a platform for individuals and businesses to share information and communicate with each other, transforming the way we live and work. Today, the web is an essential tool for businesses, governments, and individuals, and it has become an integral part of our daily lives.

The Importance of the Internet to Business Today

The internet has had a significant impact on businesses worldwide, providing them with opportunities for growth and expansion. Here are some reasons why the internet is essential to businesses today:

Global Reach. The internet provides businesses with the ability to reach customers and clients worldwide, breaking down geographical barriers. Companies can now market their products and services to a global audience through their website, social media, email marketing, and online advertising.

E-commerce. The rise of e-commerce has revolutionized the way businesses sell products and services. Companies can now set up online stores and sell their products directly to customers, cutting out the middleman. E-commerce has enabled small businesses to compete with big corporations, providing them with a platform to reach a global audience.

Communication. The internet has transformed the way businesses communicate with each other, their employees, and their customers. Email, instant messaging, video conferencing, and other messaging apps have made it easier for businesses to communicate with employees and customers in different locations. This has increased efficiency and productivity, reduced costs associated with travel, and improved customer service.

Data Analysis. The internet has also provided businesses with access to vast amounts of data that can be used to improve their operations. Big data analytics tools can be used to extract insights from this data, enabling businesses to make informed decisions and improve their operations. This has led to the development of new business models and the creation of innovative products and services.

In conclusion, the internet has transformed the way businesses operate, providing them with opportunities for growth and expansion. It has enabled businesses to reach a global audience, sell products and services online, improve communication, and make data-driven decisions. As technology continues to evolve, the importance of the internet to businesses will only continue to grow. Businesses that embrace the internet and stay up-to-date with the latest trends and technologies will have a significant advantage over their competitors.

Internet of Things

The internet of things (IoT) refers to the network of interconnected physical devices and objects that are embedded with sensors and software, allowing them to collect and exchange data over the internet. This includes anything from smart home appliances and wearables to industrial sensors and autonomous vehicles.

The concept of IoT has been around since the 1990s, but it has only become practical in recent years with the development of affordable and reliable sensors, wireless connectivity, and cloud computing. The importance of IoT lies in its potential to revolutionize the way we live and work by enabling greater automation, efficiency, and data-driven decision-making. For example, smart homes can adjust lighting and temperature based on user preferences, while factories can optimize production processes and reduce waste through real-time monitoring and analytics. However, IoT also raises concerns around privacy, security, and data ownership, as the vast amounts of data generated by IoT devices can be sensitive and personal.

IP address configuration

In networking, the configuration of IP addresses is foundational to enabling devices to communicate within an organizational network. Understanding how IP address configuration works is paramount for network administrators and IT professionals tasked with designing, managing, and securing complex networks. On this page, we will explore the intricacies of IP address configuration, providing insights into its principles, methodologies, and practical scenarios within organizational networks. This includes:

- The basics of IP addressing
- IP address configuration methods
- Use cases and scenarios in organizational networks
- IP address configuration best practices and considerations

The basics of IP addressing

1. **IPv4 and IPv6 addresses:** IP address configuration revolves around two main versions: IPv4 and IPv6. IPv4, the more widely used version, utilizes a 32-bit address scheme, allowing for approximately 4.3 billion unique addresses. On the other hand, IPv6 employs a 128-bit address scheme, offering an exponentially larger pool of unique addresses to accommodate the growing number of connected devices.

2. **IP address components:** An IP address comprises two main components: The network and host portions. In IPv4, the address is divided into four octets, each representing a binary number. For example, the IPv4 address "192.168.1.1" is divided into four octets: 192, 168, 1, and 1. In IPv6, the address is represented as eight groups of four hexadecimal digits.

IP address configuration methods

Static IP addressing:

Static IP addressing involves manually assigning a fixed IP address to a device. This method ensures consistency in addressing, making it easier to manage and troubleshoot specific devices within the network. It is commonly used for servers, printers, and network infrastructure components.

For instance, consider an organization has a critical server that hosts a database accessed by multiple departments. To ensure seamless access and stability, the network administrator assigns a static IP address (e.g., 192.168.1.10) to the server. With this, the server's IP address remains constant, simplifying configuration and access control.

Dynamic IP addressing (DHCP):

Dynamic Host Configuration Protocol (DHCP) automates the IP address assignment process by dynamically allocating IP addresses to devices when they join the network. DHCP servers manage a pool of available addresses and lease them to devices for a specific duration. This method is efficient for large networks with numerous devices requiring IP connectivity.

In a corporate office, employees connect their laptops to the network. Instead of manually configuring each device with a unique IP address, the organization employs DHCP. When a laptop joins the network, the DHCP server assigns an available IP address and ensures seamless connectivity without manual intervention.

Automatic private IP addressing (APIPA):

Automatic private IP addressing (APIPA) is a feature in Windows operating systems that allows devices to self-assign IP addresses when DHCP is unavailable. Devices configured with APIPA select an IP address from the reserved range of 169.254.0.1 to 169.254.255.254. While APIPA enables basic communication on a local network, it does not provide connectivity beyond the immediate subnet.

Assume, an employee brings a personal device to a coffee shop with Wi-Fi but without DHCP services. The device, unable to obtain an IP address from a DHCP server, automatically configures itself with an APIPA address. This allows the device to communicate with other devices on the same subnet, such as the coffee shop's router.

Use cases and scenarios in organizational networks

Segmentation for security:

IP address configuration plays a pivotal role in network segmentation and is a crucial strategy for enhancing security. By dividing a large network into smaller segments, organizations can control access and limit the impact of security incidents. Different segments can have distinct IP address ranges and facilitate efficient traffic management.

For example, in a financial institution, customer-facing systems can be segmented from internal databases. The customer-facing segment uses a different IP address range (e.g., 203.0.113.0/24), ensuring that external traffic is isolated from sensitive internal systems. This segmentation helps prevent unauthorized access and contains potential security breaches.

Virtual LANs (VLANs):

VLANs enable the logical segmentation of a network, allowing devices in different physical locations to join the same virtual network. IP address configuration within VLANs permits

seamless communication between devices within the same VLAN while providing isolation from devices in other VLANs.

For instance, on a university campus, different departments have their VLANs to streamline network management. The computer science department, for instance, operates in the VLAN 10 with an IP address range of 172.16.10.0/24, while the engineering department operates in VLAN 20 with an IP address range of 172.16.20.0/24. IP address configuration within VLANs ensures efficient communication within departments while maintaining network security.

Remote access and VPNs:

In the era of remote work, IP address configuration becomes crucial for facilitating secure remote access. VPNs use IP addresses to create secure tunnels over the internet, allowing remote devices to connect to the organizational network securely.

Consider an employee working from home that establishes a VPN connection to the corporate network. Through IP address configuration, the VPN assigns the employee's device an IP address within the corporate network's address range. This allows the remote device to communicate securely with internal servers and resources as if it were physically present in the office.

Quality of service (QoS):

IP address configuration is instrumental in implementing quality of service (QoS) policies, ensuring that critical applications receive the necessary network resources and priority. Organizations can optimize network performance for essential applications by assigning specific IP addresses or ranges to high-priority traffic.

A call center within an organization relies on VoIP for communication. To prioritize voice traffic and minimize latency, the network administrator configures QoS policies assigning a specific IP address range (e.g., 192.168.2.0/24) to VoIP devices. This ensures that voice traffic receives preferential treatment over less time-sensitive data.

IPv6 transition:

As the world exhausts IPv4 addresses, organizations are transitioning to IPv6. IP address configuration becomes critical in managing both IPv4 and IPv6 addresses during this transition period. Dual-stack configurations enable devices to communicate using both IPv4 and IPv6 protocols.

Let's assume an organization decides to implement IPv6 alongside its existing IPv4 infrastructure. Network devices are configured with dual-stack capabilities, allowing them to communicate using both IPv4 and IPv6 addresses. This phased transition ensures compatibility with both protocol versions during the coexistence period.

IP address configuration best practices and considerations

IP address planning:

Thorough IP address planning is essential for avoiding conflicts and ensuring efficient address utilization. Organizations should allocate IP address ranges based on their network requirements, considering factors such as the number of devices, future scalability, and network segmentation needs.

Documentation and monitoring:

Maintaining accurate documentation of IP address assignments is crucial for effective network management. Network administrators should create and update documentation that includes details such as device names, associated IP addresses, and lease duration. Regular monitoring helps identify and address issues promptly.

Security measures:

Implementing security measures at the IP address level is critical for safeguarding organizational networks. This includes deploying firewalls, intrusion detection systems, and access control lists (ACLs) to control the flow of traffic based on IP addresses and enhance overall network security.

Automation and IPAM:

Automation tools and IP Address Management (IPAM) solutions streamline IP address configuration and management. These tools automate the assignment of IP addresses, reducing the risk of human errors and enhancing overall efficiency in large-scale networks.

Regular audits and cleanup:

Periodic audits of IP address allocations help identify and reclaim unused or obsolete addresses. Regular cleanup activities ensure that the IP address space is utilized efficiently, reducing the likelihood of address conflicts and optimizing network performance.

MODEM

A modem is a device that allows two or more devices to communicate using telephone lines. Modems are necessary for the internet to work. They convert digital information from one device into analog signals.

So that the data can be transmitted over the telephone line and then converted back into digital information once it reaches its destination. The word 'modem" itself was driven from Modular-demodulator. Which is a type of hardware that converts data.

So, how does it convert data? Its purpose is to convert digital data into analog systems so that it can travel through wires from one modem point to another. Hence, it used telephone cables to transmit information—i.e. the early shape of the internet.

However, the invention of the Modem dates back to the early 1950s. Later, over the years, until the late 1990s, the technology went through many evolution phases. The final setup was around 56k dial-up products.

Working of MODEM

The Modem works on a simple and basic technological base. Understanding the Modem's working process is a lot easier than today's technology. That's why it's important to understand that the basic pillars of a Modem include the following:

- Devices that connect through a coax cable connection, i.e., the telephone wire
- Uses an IP or online address provided by an ISP (internet service provider)
- The Modem takes digital signals from the cable and ISP, then converts them into analog signals and vice versa
- It uses the Wide Area Network (WAN) as a base to assign a public IP address, which helps it identify computers on a network

But to simply put, a modem converts digital data into analog and vice versa to establish communication between two ends (server to computer and back).

Types of Modems

Modems come in many shapes and sizes. However, there are three main types of modems, and they are used universally. While the dial-up Modem might be outdated, these three main types are still thoroughly used, which are:

- Cable Modem
- DSL Modem
- Fiber Modem

A cable modem is the one we discussed earlier, used through telephone lines or WAN. Whereas DSL or Digital Subscriber Line is a broadband-based modem. Lastly, a fiber modem is one that employs fiber optics and cables to transmit data.

Modem Vs Router

The Modem is cable-based, whereas routers are generally referred to as wireless internet-providing devices. But their differences are far more than those two simple lines. Yet, you can still define their differences in two lines, such as:

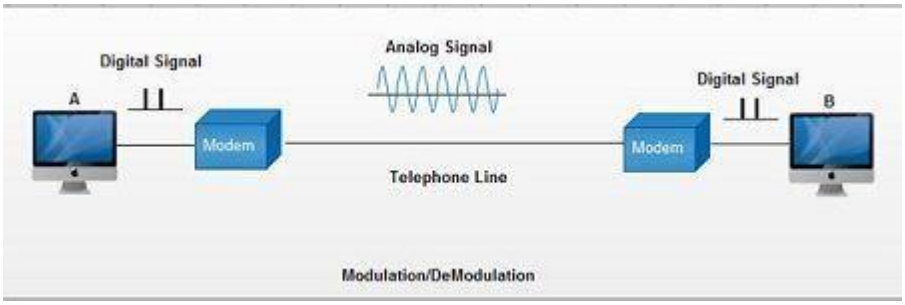
- The Modem connects you and brings the internet to your home
- Routers bring the internet to your devices and connect them to the internet

These are the two main differences between the two technologies. Another key difference is the fact that a Modem comes with a public IP address, whereas routers assign a local IP address. Lastly, modems use a WAN network, whereas router creates their own LAN (local area network).

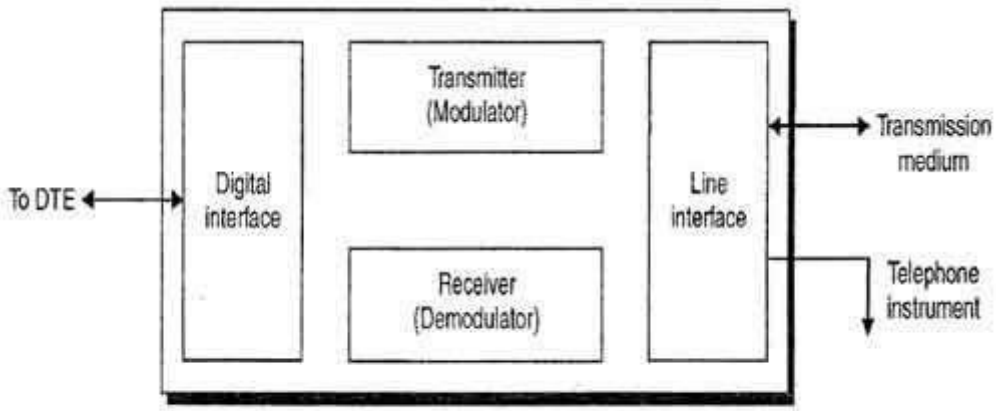
Modem is abbreviation for Modulator – Demodulator. Modems are used for data transfer from one computer network to another computer network through telephone lines. The computer network works in digital mode, while analog technology is used for carrying massages across phone lines.

Modulator converts information from **digital mode to analog mode** at the transmitting end and demodulator converts the same from **analog to digital at receiving end**. The process of converting analog signals of one computer network into digital signals of another computer network so they can be processed by a receiving computer is **referred to as digitizing.**

When an analog facility is used for data communication between two digital devices called Data Terminal Equipment (DTE), modems are used at each end. DTE can be a terminal or a computer.



The modem at the transmitting end converts the digital signal generated by DTE into an analog signal by modulating a carrier. This modem at the receiving end demodulates the carrier and hand over the demodulated digital signal to the DTE.



Building blocks of a modem

The transmission medium between the two modems can be dedicated circuit or a switched telephone circuit. If a switched telephone circuit is used, then the modems are connected to the local telephone exchanges. Whenever data transmission is required connection between the modems is established through telephone exchanges.

Ready to Send

To begin with the Data Terminal Equipment or DTE (better known as a computer) sends a Ready to Send or RTS signal to the Data Communication Equipment or DCE (better known as a modem). This is sometimes known as a wakeup call and results in the modem sending a Data Carrier Detect or DCD signal to the receiving modem. There then follows a series of signals passed between the two until the communication channel has been established. This process is known as handshaking and helps to explain why, even now, some companies like CompuServe use the symbol of two hands grasping each other to mean being on- line. Of course, after that all it takes is for the second modem to send a Data Set Ready or DSR signal to its computer and wait for the Data Terminal Ready or DTR reply. When that happens the first modem sends a Clear to Send or CTS signal to the computer that started the whole process off and data can then be transmitted. It is as simple as that.

Types of Modems

• Modems can be of several types and they can be categorized in a number of ways.

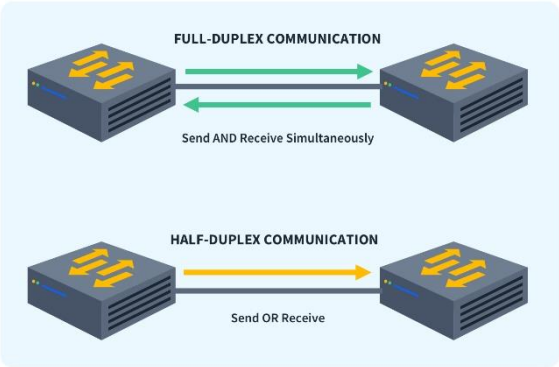
• Categorization is usually based on the following basic modem features:

1. Directional capacity: half duplex modem and full duplex modem.
2. Connection to the line: 2-wire modem and 4-wire modem.
3. Transmission mode: asynchronous modem and synchronous modem.

Half duplex and full duplex Modems

Half duplex

1. A **half-duplex modem** permits transmission in one direction at a time.
2. If a carrier is detected on the line by the modem, I gives an indication of the incoming carrier to the DTE through a control signal of its digital interface.
3. As long as they camel' IS being received; the modem does not give permission to the DTE to transmit data.



Full duplex

• A **full duplex modem** allows simultaneous transmission in both directions.

• Therefore, there are two carriers on the line, one outgoing and the other incoming.

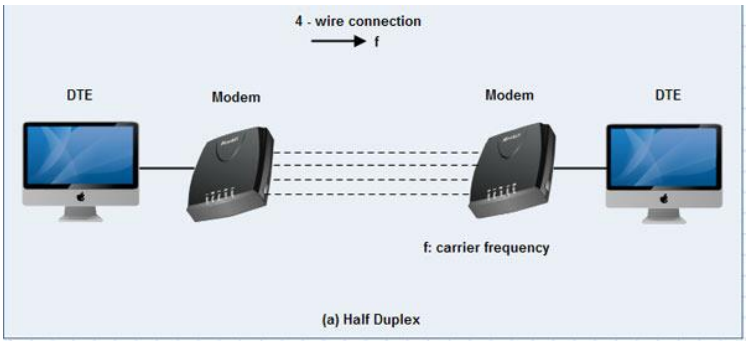
Wire and 4-wire Modems

• The line interface of the modem can have a 2-wire or a 4-wire connection to transmission medium. 4-wire Modem

• In a 4-wire connection, one pair of wires is used for the outgoing carrier and the other pair is used for incoming carrier.

• Full duplex and half duplex modes of data transmission are possible on a 4- wire connection.

• As the physical transmission path for each direction is separate, the same carrier frequency can be used for both the directions.



2-wire Modem

• 2-wire modems use the same pair of wires for outgoing and incoming carriers.

• A leased 2-wireconrlection is usually cheaper than a 4-wire connection as only one pair of wires is extended to the subscriber's premises.

• The data connection established through telephone exchange is also a 2-wire connection.

• In 2-wire modems, half duplex mode of transmission that uses the same frequency for the incoming and outgoing carriers can be easily implemented.

• For full duplex mode of operation, it is necessary to have two transmission channels, one for transmit direction and the other for receive direction.

• This is achieved by frequency division multiplexing of two different carrier frequencies. These carriers are placed within the bandwidth of the speech channel.

Asynchronous & Synchronous Modems

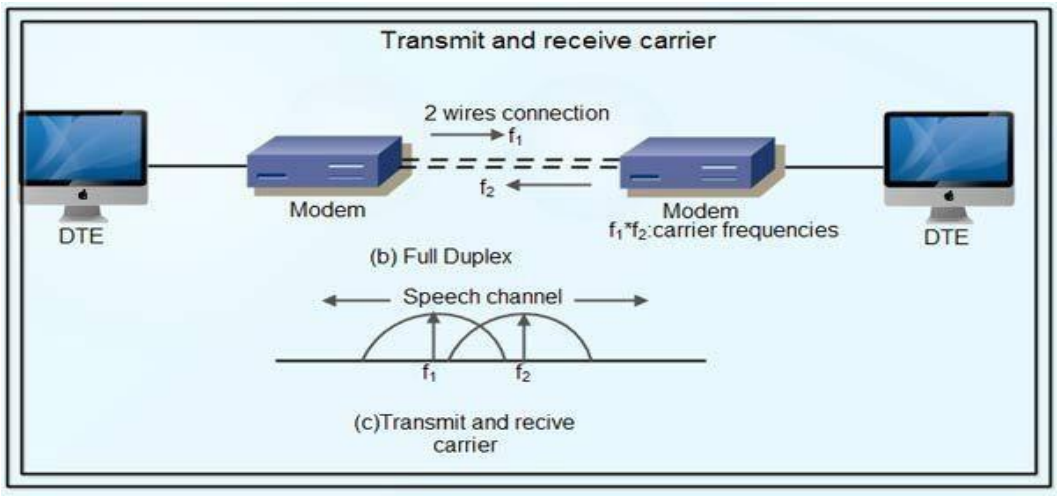
Asynchronous Modem

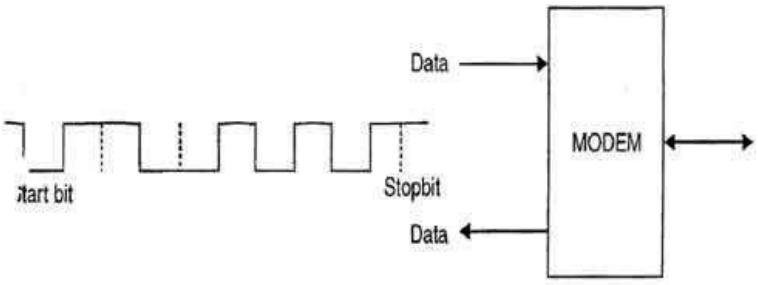
• Asynchronous modems can handle data bytes with start and stop bits.

• There is no separate timing signal or clock between the modem and the DTE.

• The internal timing pulses are synchronized repeatedly to the leading edge of the start pulse

.





Asynchronous modem

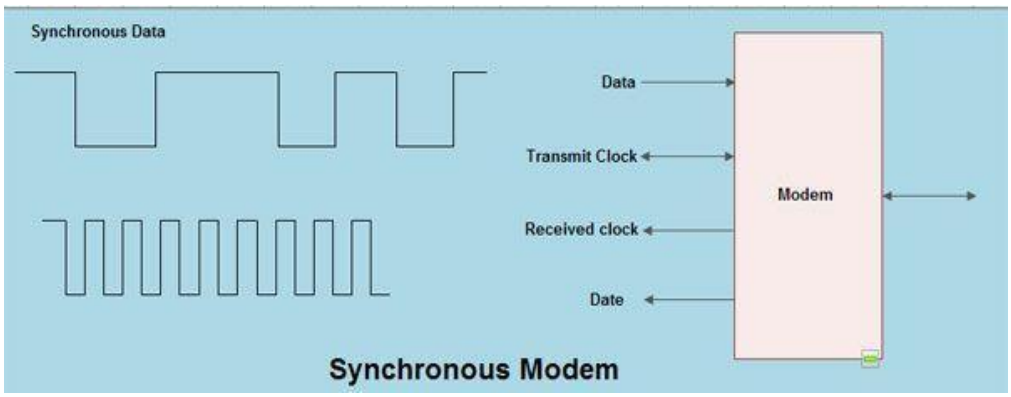
Synchronous Modem

• Synchronous modems can handle a continuous stream of data bits but requires a clock signal.

• The data bits are always synchronized to the clock signal.

• There are separate clocks for the data bits being transmitted and received.

• For synchronous transmission of data bits, the DTE can use its internal clock and supply the same to the modem.



Modulation techniques used for Modem:

The basic modulation techniques used by a modem to convert digital data to analog signals are:

• Amplitude shift keying (ASK).

• Frequency shift keying (FSK).

• Phase shift keying (PSK).

• Differential PSK (DPSK).

These techniques are known as the binary continuous wave (CW) modulation.

• Modems are always used in pairs. Any system whether simplex, half duplex or full duplex requires a modem at the transmitting as well as the receiving end.

• Thus a modem acts as the electronic bridge between two worlds - the world of purely digital signals and the established analog world.

UNIT – V

SOLAR POWER SYSTEMS AND INVERTERS

SOLAR PANEL

Solar panel, a component of a photovoltaic system that is made out of a series of photovoltaic cells arranged to generate electricity using sunlight. Solar panels are those devices which are used to absorb the sun's rays and convert them into electricity or heat.

A solar panel is actually a collection of solar (or photovoltaic) cells, which can be used to generate electricity through photovoltaic effect. These cells are arranged in a grid-like pattern on the surface of solar panels.

Thus, it may also be described as a set of photovoltaic modules, mounted on a structure supporting it. A photovoltaic (PV) module is a packaged and connected assembly of 6×10 solar cells.

When it comes to wear-and-tear, these panels are very hardy. Solar panels wear out extremely slow. In a year, their effectiveness decreases only about one to two per cent (at times, even lesser).

Most solar panels are made up using crystalline silicon solar cells.

Installation of solar panels in homes helps in combating the harmful emissions of greenhouse gases and thus helps reduce global warming. Solar panels do not lead to any form of pollution and are clean. They also decrease our reliance on fossil fuels (which are limited) and traditional power sources.

These days, solar panels are used in wide-ranging electronic equipments like calculators, which work as long as sunlight is available.

However, the only major drawback of solar panels is that they are quite costly. Also, solar panels are installed outdoors as they need sunlight to get charged.

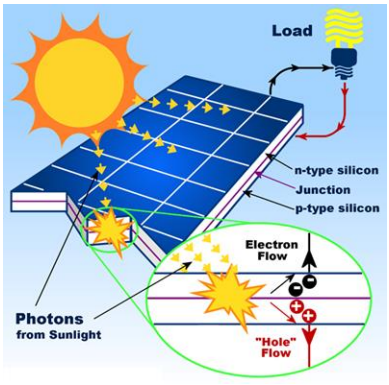
SOLAR CELLS

When sunlight strikes a solar cell, an electron is freed by the photoelectric effect. The two dissimilar semiconductors possess a natural difference in electric potential (voltage), which causes the electrons to flow through the external circuit, supplying power to the load. The flow of electricity results from the characteristics of the semiconductors and is powered entirely by light striking the cell.

The main component of a solar panel is a solar cell, which converts the Sun's energy to usable electrical energy. The most common form of solar panels involves crystalline silicon-type solar cells. These solar cells are formed using layers of elemental silicon and elements such as phosphorus and boron. The elements added to the silicon layers form an *n*-type layer, which has an excess of electrons, and a *p*-type layer, which has a deficit of electrons. These two layers form a *p*-*n* junction.

When light falls on a solar cell, electrons are excited from a lower-energy ground state, in which they are bound to specific atoms in the solid, to a higher excited state, in which they can move through the solid. In the absence of the junction-forming layers, these free electrons are in random motion, and so there can be no oriented direct current. The addition of junction-forming layers, however, induces a built-in electric field that produces the photovoltaic effect. In effect, the electric field gives a collective motion to the electrons that flow past the electrical contact layers into an external circuit where they can do useful work.

WORKING OF SOLAR PANELS



Solar panels collect clean renewable energy in the form of sunlight and convert that light into electricity which can then be used to provide power for electrical loads. Solar panels are comprised of several individual solar cells which are themselves composed of layers of silicon,

phosphorous (which provides the negative charge), and boron (which provides the positive charge). Solar panels absorb the photons and in doing so initiate an electric current. The resulting energy generated from photons striking the surface of the solar panel allows electrons to be knocked out of their atomic orbits and released into the electric field generated by the solar cells which then pull these free electrons into a directional current. This entire process is known as the Photovoltaic Effect. An average home has more than enough roof area for the necessary number of solar panels to produce enough solar electricity to supply all of its power needs excess electricity generated goes onto the main power grid, paying off in electricity use at night.

In a well-balanced grid-connected configuration, a solar array generates power during the day that is then used in the home at night. Net metering programs allow solar generator owners to get paid if their system produces more power than what is needed in the home. In off-grid solar applications, a battery bank, charge controller, and in most cases, an inverter are necessary components. The solar array sends direct current (DC) electricity through the charge controller to the battery bank. The power is then drawn from the battery bank to the inverter, which converts the DC current into alternating current (AC) that can be used for non-DC appliances. Assisted by an inverter, solar panel arrays can be sized to meet the most demanding electrical load requirements. The AC current can be used to power loads in homes or commercial buildings, recreational vehicles and boats, remote cabins, cottages, or homes, remote traffic controls, telecommunications equipment, oil and gas flow monitoring, RTU, SCADA, and much more.

THE BENEFITS OF SOLAR PANELS

Using solar panels is a very practical way to produce electricity for many applications. The obvious would have to be off-grid living. Living off-grid means living in a location that is not serviced by the main electric utility grid. Remote homes and cabins benefit nicely from solar power systems. No longer is it necessary to pay huge fees for the installation of electric utility poles and cabling from the nearest main grid access point. A solar electric system is potentially less expensive and can provide power for upwards of three decades if properly maintained.

Besides the fact that solar panels make it possible to live off-grid, perhaps the greatest benefit that you would enjoy from the use of solar power is that it is both a clean and a renewable source of energy. With the advent of global climate change, it has become more important that we do whatever we can to reduce the pressure on our atmosphere from the emission of

greenhouse gases. Solar panels have no moving parts and require little maintenance. They are ruggedly built and last for decades when properly maintained.

Last, but not least, of the benefits of solar panels and solar power is that, once a system has paid for its initial installation costs, the electricity it produces for the remainder of the system's lifespan, which could be as much as 15-20 years depending on the quality of the system, is absolutely free! For grid-tie solar power system owners, the benefits begin from the moment the system comes online, potentially eliminating monthy electric bills or, and this is the best part, actually earning the system's owner additional income from the electric company.

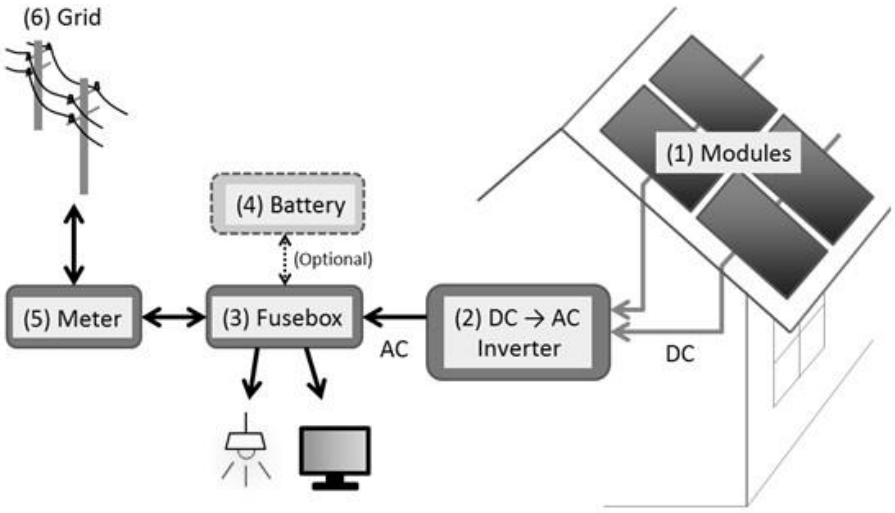
SOLAR INVERTER AND WORKS

In any solar system, inverter plays an essential role like a brain. The main function of this is to alter DC power to AC power which is generated from the solar array. It allows for monitoring the system so this system operators can observe how this system is working. If you are considering a solar panel system for your home, one of the key decisions you make is the type of inverter to install. Inverters convert direct current (DC) energy which is generated from the solar panels into usable alternating current (AC) energy. After the panels themselves, inverters are the most important equipment in the solar power system. The inverter gives analytical information to assist in identifying operations & maintenance to fix issues of the system. This article discusses an overview of a solar system.

A solar inverter can be defined as an electrical converter that changes the uneven DC (direct current) output of a solar panel into an AC (alternating current). This current can be used for different applications like in a viable electrical grid otherwise off-grid electrical network. In a PV system, it is a dangerous BOS (balance of system) component that allows the utilization of normal AC powered apparatus. These inverters have some functions with PV arrays like tracking of utmost PowerPoint & protection of anti-islanding. If we are using a solar system for a home, the selection & installation of the inverter is important. So, an inverter is an essential device in the solar power system.

SOLAR INVERTER AND IT'S WORKING

The working principle of the inverter is to use the power from a DC Source such as the solar panel and convert it into AC power. The generated power range will be from 250 V to 600 V. This conversion process can be done with the help of a set of IGBTs (Insulated Gate Bipolar Transistors). When these solid-state devices are connected in the form of H-Bridge, then it oscillates from the DC power to AC power.



solar-inverter-working

A step-up transformer is employed so that the AC power can be obtained & can be fed to the grid. A few designers have started designing inverters without transformer which have high efficiency as compared with the inverters which have a transformer.

In any solar inverter system, a pre-programmed microcontroller is used to execute different algorithms exactly. This controller increases the output power from the solar panel with the help of the MPPT (Maximum Power Point Tracking) algorithm.

TYPES OF SOLAR INVERTERS

The classification of solar inverters can be done based on the application which includes the following.

Types-of-solar-inverters

String Inverter

This kind of solar panel is arranged in the form of a string and many strings are allied to a single string inverter. Every string holds the DC power where it is altered into AC power used like electricity. Based on the installation size, you may have many string inverters where each string gets DC power from some strings. These inverters are good for installations where the panels are arranged on a single plane to avoid facing in different directions.

String inverters can also be used with power optimizers as they are module-level power electronics that are mounted at the module level, consequently, every solar panel has one. Manufacturers of the solar panels use power optimizers with their devices & sell as one solution called a smart module so that installation can be made easier. Power optimizers give many benefits like microinverters, but they are less expensive. So it can be a good choice among using inverters like strictly string otherwise micro inverters.

Central Inverters

These are related to string inverters however they are larger & support additional strings of solar panels. Rather than running strings openly to the inverter, the strings are allied together in a general combiner box so that the DC power runs toward the middle inverter wherever it is transformed to AC power. These inverters needless connections of components, however, they need a pad as well as combiner box as they are suitable for huge installations through reliable production across the array.

The range of these inverters is from MWs to the hundreds of KWs and they handle up to 500kW for each area. These are not used in homes but used generally for huge commercial installations & utility-scale solar farms.

Microinverters

These inverters are a good choice for commercial as well as residential purposes. Same as power optimizers, these are also module-level electronics because one inverter is mounted on every panel. Microinverters alter power from DC to AC exact at the panel, so they don't need a string type inverter.

Also, due to the conversion of panel-level, if the performance of panels is shaded then the residual panels won't be exposed. These inverters monitor the function of every single panel, whereas string inverters illustrate the act of every string to make the inverters good at installation by using these inverters there are many benefits as they optimize every solar panel independently. It transmits more energy particularly if you have an incomplete shade situation.

Battery based Inverter

The growth in battery-based inverters is increased day by day. These are uni-directional and include both an inverter & battery charger. The operation of this can be done with the help of a battery. These inverters are separate grid-tied, grid-interactive and off-grid, based on the UL design & rating. The main benefit of this is, they give nonstop operation for critical loads based on the grid condition. In all occurrences, these inverters handle power between the grid & the array while charging the batteries, and they monitor the status of battery & controls how they are charged.

Hybrid Inverter

This inverter is also known as a multi-mode inverter and allows plugging batteries into the solar power system. It interfaces the battery through a method known as DC coupling. Electronics manage the charging & discharging of the battery. So there is a quite incomplete choice on these inverters.

Advantages of Solar Inverter

The main benefits of solar inverter include the following.

- Solar energy decreases the greenhouse effect as well as abnormal weather change.
- By using solar products, we can save money by reducing electricity bills
- The solar inverter is used to change DC to AC and this is a reliable source of energy.

- These inverters empower small businesses by reducing their energy needs & requirements.
- These are multifunctional devices as they preprogrammed to alter DC to AC which assists large energy consumers.
- Easy to set up & more reasonable compared with generators.
- Maintenance is easy as they work well even with usual maintenance.

Disadvantages of Solar Inverter

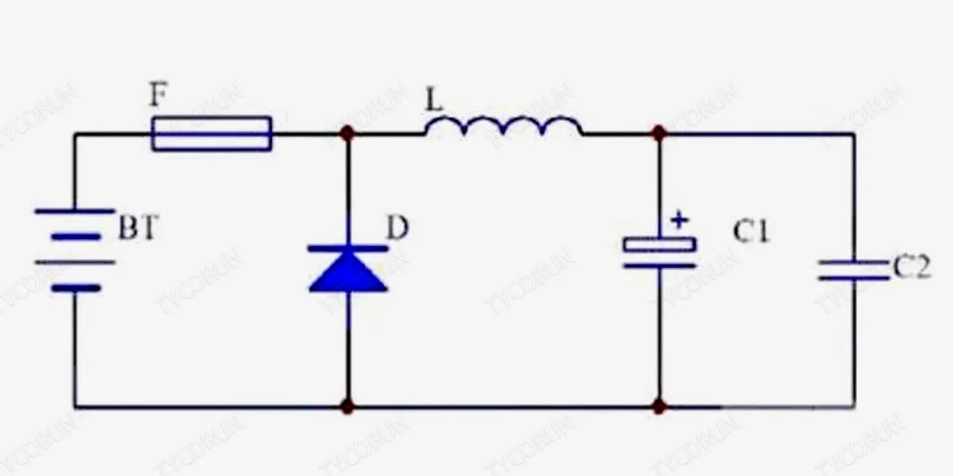
- The main drawbacks of solar inverter include the following.
- This kind of inverters is expensive to afford.
- Sunlight is necessary to generate sufficient electricity.
- It requires a huge space for installation.
- It requires a battery to work at night time to provide proper electricity to the home, commercial, etc.

1. Input overvoltage protection

When the DC side input voltage is higher than the maximum DC array access voltage allowed by the inverter, the inverter shall not start, or stop within 0.1s (when running), and a warning signal will be issued at the same time. After the DC side voltage returns to the allowable operating range of the inverter, the inverter should be able to start and operate normally.

2. Input reverse polarity protection

When the positive input terminal and negative input terminal of the inverter are reversely connected, the best solar inverter should be able to activate automatic inverter protection. After the polarity is connected correctly, the device should be able to work normally.



3. Input overcurrent protection

After the photovoltaic modules are connected in series and parallel, each string is connected to the DC side of the solar inverter. After MPPT disturbance is performed, when its input current is higher than the allowed maximum DC input current set by the inverter, the inverter Stops MPPT disturbance (while running) and issues an alert signal. After the DC side current returns to the allowable operating range of the inverter, the inverter should be able to start and operate normally.

4. Output overcurrent protection

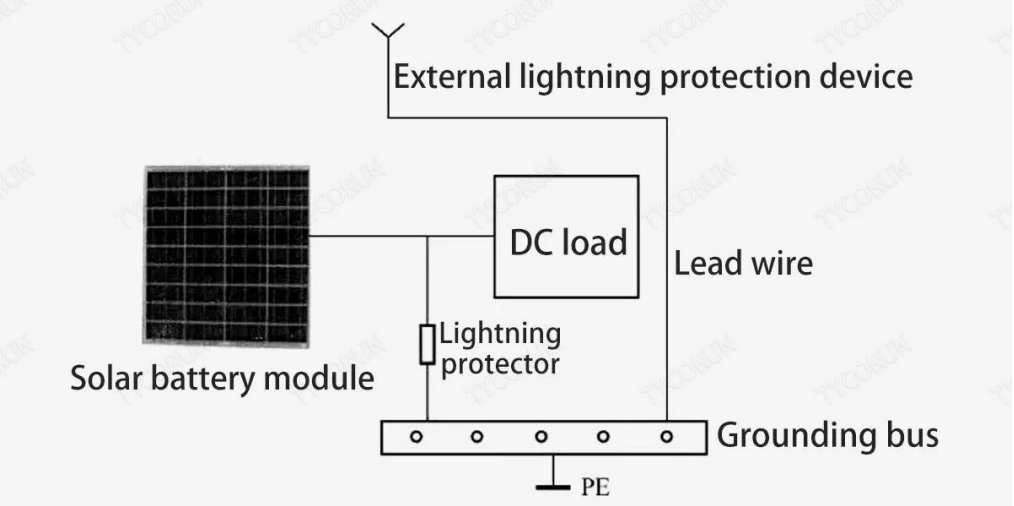
The AC output side of the grid-connected inverter should be equipped with inverter protection for overcurrent. When a short circuit is detected on the grid side, the grid-connected inverter should stop supplying power to the grid within 0.1s and issue a warning signal at the same time for inverter protection. After the fault is eliminated, the grid-connected inverter should work normally.

5. Output short circuit protection

When the inverter output is short-circuited, inverter protection for short circuit should be provided. The short-circuit inverter protection action time should not exceed 0.5s. After the short-circuit fault is eliminated, the equipment should be able to operate normally.

6. AC and DC surge protection

The inverter should have inverter protection against lightning, and the technical indicators of its lightning inverter protection device should be able to ensure the absorption of expected impact energy.

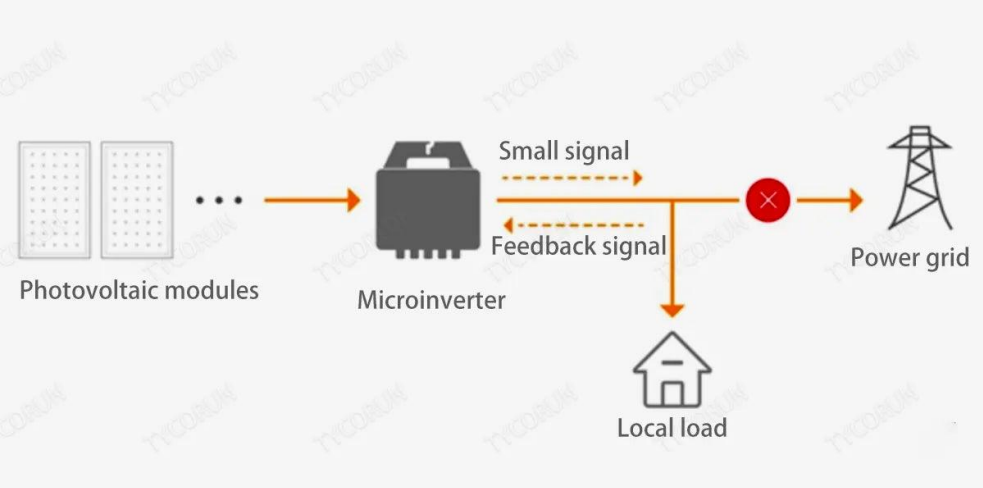


7. Anti-islanding protection

The anti-islanding inverter protection is mainly developed for the islanding phenomenon caused by abnormal voltage or frequency in solar power stations. When the anti-islanding device loses power on either the grid side or the photovoltaic side, it will quickly send a trip signal to the grid-connected circuit breaker, allowing the circuit breaker to open to protect the maintenance personnel on both sides of the photovoltaic system.

The anti-islanding protection device is based on the islanding phenomenon of distributed power sources (solar power generation, hydropower, etc.) in smart grids. Combined with microcomputer protection technology, it realizes the protection and control of microgrids and provides an effective solution for the prevention of islanding phenomena. Islanding refers to the islanding phenomenon caused by unstable voltage and insufficient reactive power or power loss in the power grid.

Once islanding occurs, it will cause serious harm to the power system and have a great impact on equipment safety. Inverter protection for anti-islanding will help improve the reliability of power grid operations.



8. Output over/under voltage, over/under frequency protection

On the AC output side of the grid-connected inverter, the grid-connected inverter should be able to accurately determine the over/under-voltage, over/under-frequency and other abnormal conditions of the power supply grid (wiring) for inverter protection.

The grid-connected inverter should perform operation according to the required time. And a warning signal should be issued when inverter protection is activated and cut off. When the grid voltage and frequency return to the allowable voltage and frequency range, the inverter should be able to start and operate normally.

9. Internal short circuit protection

When a short circuit occurs inside the grid-connected inverter, the electronic circuits, fuses and other inverter protection within the inverter should act quickly and reliably.

10. Over temperature protection

The grid-connected inverter should have inverter protection functions for overheating, such as alarm for excessive ambient temperature in the machine (such as excessive temperature in the chassis caused by fire) and inverter protection of key internal components (such as IGBT, Mosfet, etc.) from excessive temperature.

11. Automatically restore grid-connected protection

After the grid-connected inverter stops supplying power to the grid due to a grid failure, the grid-connected inverter should be able to automatically re-send power to the grid 20s to 5

minutes after the voltage and frequency of the grid return to the normal range for inverter protection. The power should be increased slowly without any impact on the power grid.

12. Insulation resistance monitoring

The inverter has a complete insulation resistance monitoring function for inverter protection. When the live part of the equipment is grounded, the insulation monitoring system should be able to immediately detect the fault status of the inverter, shut down and alarm.

The inverter detects the voltage of PV+ to ground and PV- to ground, and calculates the resistance of PV+ and PV– to ground respectively. If the resistance on either side is lower than the threshold, the inverter will stop working and an alarm will display "PV low insulation resistance".

13. Arc fault circuit interrupter (AFCI) protection

The inverter has a complete arc fault circuit interrupter (AFCI) inverter protection function. When the inverter is running, the leakage current is monitored in real time, and when the monitored residual current exceeds the limit, the inverter should disconnect from the grid within 0.3s and issue a fault signal.

14. Zero/low voltage ride-through protection

When an accident or disturbance in the power system causes a voltage sag in the voltage at the grid connection point of the solar power station, within a certain voltage drop range and time interval, the solar power station can ensure continuous operation without disconnecting from the grid. This function is implemented by the inverter.

The cause of the voltage sag is that when a short-circuit fault occurs in a certain branch of the power system, the current increases sharply. At this time, the inverter protection device in the faulty branch operates to isolate the fault point, and the voltage returns to normal.
From fault occurrence to detection and disconnection, which takes a while, it will cause the voltage of each branch to drop suddenly, resulting in a short-term voltage drop. At this time, if the solar power station is removed immediately, it will affect the stability of the power grid, and even other non-faulty branches will be disconnected, causing a large-scale power outage. At this time, the photovoltaic inverter needs to be able to support for a period of time (within 1 second) until the grid voltage returns to normal.

15. Intelligent anti-PID protection

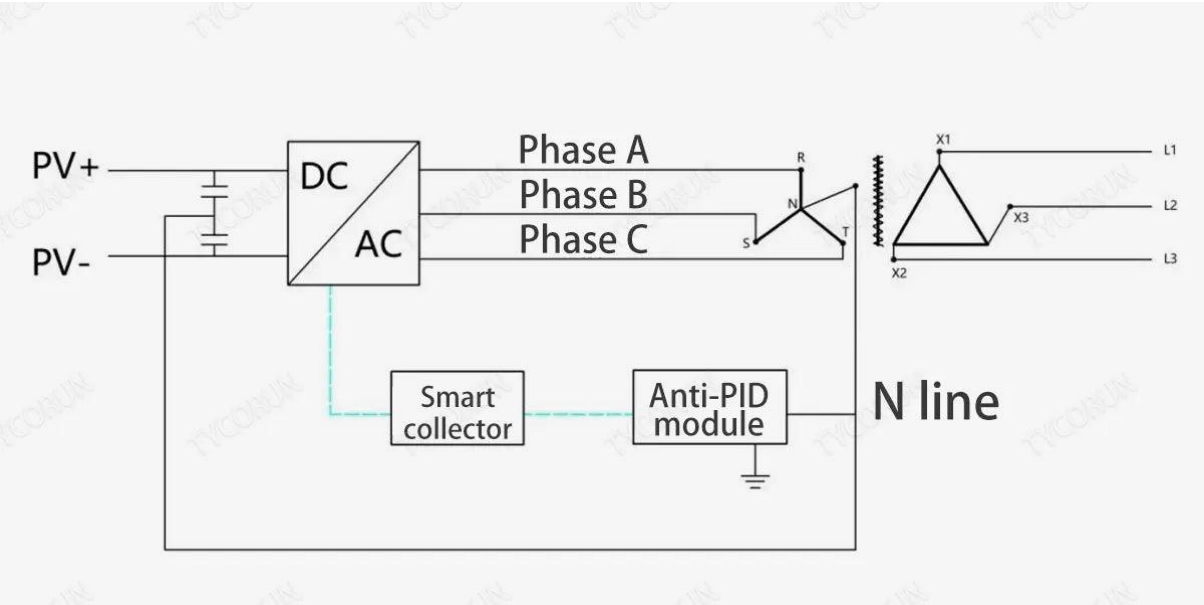
The PID (Potential Induced Degradation) effect of photovoltaic modules refers to a situation where the performance of the module will gradually decay after working for a long time.

The direct harm of the PID effect is that a large amount of charge accumulates on the surface of the LFP battery. It will cause passivation on the surface of the battery, which reduces the fill factor (FF), open circuit voltage, and short circuit current of the battery component, which will reduce the output power of the solar power station, thus reduce the power generation, and reduce the income of the photovoltaic power station. For the best batteries, you can check the battery stores near me.

The PID effect easily occurs in humid environments, and the activity level is positively related to the degree of humidity. At the same time, the degree of contamination of the component surface by conductive, acidic, alkaline, and ion-containing objects is also related to the occurrence of attenuation phenomena.

At present, the mainstream components themselves have the function of preventing PID effect. In addition, the inverter can also add this function. By raising the N line voltage on the AC output side, the PV negative electrode voltage is indirectly raised, so that the PV negative electrode of each inverter to the ground voltage is close to 0 or slightly higher than 0 potential to achieve the purpose of suppressing the PID effect for inverter protection.

The data collector in the system connects and communicates with the inverter and the external anti-PID module, automatically collects the negative pole status information of the inverter, and automatically performs lifting adjustment, thereby realizing the intelligent anti-PID inverter protection function.



SOLAR BATTERY

Solar batteries store excess electricity produced by solar panels so it can be used at the homeowner's convenience later on. This function allows solar panels – which famously only produce electricity when the sun is shining – to effectively provide round-the-clock clean energy.

Since solar and battery are a substantial investment, it's worth knowing exactly how these systems work together. So, let's take a closer look at how solar and battery work together.

Charging a solar battery

The process begins when sunlight hits the solar panels and is converted into electricity through the photovoltaic effect. From here, things get a little interesting.

Solar panels create a direct current (DC), which is the same current used to charge solar batteries. However, your home and local electricity grid use alternating current (AC) electricity. So, at some point, the DC current from your panels needs to be inverted into an AC current before powering your home – but exactly when and how many times the current is inverted depends on the type of battery you have.

- In a **DC-coupled battery system**, the DC electricity from the panels flows *directly into the battery*, where it either charges the battery or is flipped to AC electricity to power systems in the home by the battery's built-in multi-mode inverter.

- In an **AC-coupled battery system**, the DC electricity from the solar panels is immediately flipped to AC electricity by the solar inverter(s) and is directly used to power the home. Excess electricity is inverted *back* to a DC current by the battery inverter so it can be used to charge the battery.

Each time the current is inverted from AC to DC (or vice versa), a little bit of power is lost to heat. So, DC-coupled systems are typically more efficient because they require fewer inversions.

The kicker is that many existing solar-only systems already have solar inverters that flip solar electricity from DC to AC almost immediately after it is produced. In the case of microinverters, this inversion occurs on the panel itself, which makes adding a DC-coupled battery to an existing solar system incredibly difficult.

Despite differences in configuration, the big picture for AC- and DC-coupled battery systems is the same: Solar electricity is primarily used to power the home, and any excess is used to charge the battery.

What happens to solar power when batteries are full?

If your battery is charged to 100% capacity and you *still* have excess solar production, the excess power typically gets pushed (or "exported") to the local electricity grid to power nearby systems. In most cases, solar owners are compensated for exporting electricity to the grid in the form of on-bill credits.

Discharging a solar battery

Alright, the battery is now charged with DC electricity from your solar panels – now what?

When your home needs the power stored in your battery, a multi-mode inverter in your battery flips the current from DC to AC, and the current flows through a panel box to the systems that need power.

- In a DC-coupled system, this is the first and only inversion
- In an AC-coupled system, this is the *third* inversion

Today's lithium-ion batteries can discharge 85-100% of their stored capacity (depending on the type of battery) without incurring damage that shortens their lifespan. So, in theory, a 10

kWh battery can store and discharge 8.5 to 10 kWh of power in one cycle. However, in the real world, some of this capacity is lost to heat during inversion(s).

Now, exactly which systems the battery powers and when it powers them is up to the homeowner.

Common ways to use a solar battery

There are three main ways to use a solar battery: Critical backup mode, self-consumption mode, and a mix of both. The way you use your battery dictates the way it works. For example, a battery used strictly for backup power works differently than a battery used strictly for solar self-consumption.

Battery work in critical backup mode

Solar batteries are best known for their ability to provide backup power when the grid goes down. Not only does the battery itself provide power, but having a backup-enabled battery also allows the solar system to remain active (whereas solar-only systems are shut off during outages to protect lineworkers).

However, there are limits to which systems a battery can power in backup mode. Unless you invest in several batteries (30-40 kWh of capacity) that can power your entire home, you'll have to pick and choose which systems you want your battery to power during outages.

In fact, backup battery systems are typically configured to an additional electrical panel – known as a critical loads sub-panel – that dictates which systems get power during an outage.

Battery works in backup mode:

1. The battery maintains a full charge
2. Local power grid goes down
3. The battery system's backup gateway isolates the home from the grid
4. The battery feeds power to the home through the critical loads sub-panel

The battery can still charge like normal in backup mode, however, it will only power a pre-selected number of circuits in the home like refrigeration, kitchen appliances, lights, medical devices, water heating, Wi-Fi, TV, and device charging.

Battery work in solar self-consumption mode?

The other main reason to invest in home battery storage is to limit your interaction with the grid by storing and using your own solar production. This is a cost-saving strategy known as solar self-consumption and it's primarily used by homeowners that have time-of-use (TOU) rates and/or unfavorable compensation for their excess solar electricity.

The idea behind self-consumption mode is that it's more cost-effective to store and use excess solar energy than to export it to the grid.

In self-consumption mode, the battery is configured directly to your main electrical panel and can power any system in the house. But, instead of waiting for the grid to go down, the battery discharges power as soon as solar production isn't able to keep up with household demand and continues to do so until it has reached its maximum depth of discharge.

So, in self-consumption mode, your battery charges and discharges (cycles) most days, whereas in critical backup mode, it only discharges when the grid goes down.

Methods to Check Inverter Battery Voltage

Maintaining a full charge and maximizing backup time for your inverter battery voltage requires regular monitoring. Here are a few ways to measure the voltage in your inverter battery.

1. Inverter Display: For further instructions on figuring out the voltage readings, review the manual that came with your inverter. To determine whether the battery is fully charged, look for a "full" sign or a particular voltage range.
2. Multimeter: To get an exact reading on the voltage of the battery, use a multimeter. Check to see if the multimeter is in DC voltage mode.
3. Battery Indicator Light: To find out what color or symbol denotes a fully charged battery, see the instructions that came with your inverter.
4. Charging Time: Keep an eye on how long it takes. A built-in timer on almost all inverters lets you know when the battery needs charging.

Overload Protection Mechanisms:

Discover the constructed safety inverters which prevent from excessive current flows. As short-circuit protections to load shedding strategies, let this feature enlighten us the function of this chunk on the durability and reliability of solar inverters.

Strategies for Optimal Performance:

Monitoring Power Consumption:

Insert good mechanisms on the monitoring of electrical energy within the solar installation facility. For the PV system, comprehend the role of monitoring the power drawn in the sense of keeping away from overloading the system and supply the best electrical power.

Inverter Upgrades and Innovations:

Continually learn about the new tech in transformerless string inverters. Learn how new devices like smart inverters and grid-based systems assist to overcome the problems of overload by offering better of control and management.

Real-world Challenges and Solutions:

Short Circuits and Overloads:

Look at the issues that can be caused by short circuits as well as overloads. Learn about ways that a short circuit may occur and how to control and develop measures to prevent these challenges.

Common Scenarios Leading to Overloads:

Implement scenarios experience overloading, e.g., in which you will face the problems of change or renewable source addition to the existing array, such as impacts of weather conditions. Figure out how preparedness can prevent you from drowning in the list of things to do in case of potential crises.

Mitigating Power Losses:

Efficiency and Performance Optimization:

Discover techniques on how to increase power output while saving the cost for a solar inverter. Interactions like particle cleaning process to solar panel arrangement with shading issues not only minimize, but the loss of power as well.

Balancing Energy Demand:

Seek to find a refined equilibrium in energy derivation and provision. Spell out how often the load management strategies and energy economy practices help to create the peace between the solar array and inverter.

Example of Overloading in a Solar Inverter:

Let's imagine a case that a solar installation in a residence was installed first. This solar installation was composed of a PV panel with a capacity of 5 kiloWatt (kW) connected to a string inverter with the same capacity. In standard test conditions and with above-optimal settings, the inverter was linked to the solar panel and well-matched to minimize energy loss in the system. Now, just think of the fact that the house owner, who had the original installation of 4 kW, is now planning to expand the system by adding more solar panels to the existing array, reaching a total capacity of 7 kw. Though they do not replace the inverter of the original structure with the one that is designed for the enlarged capacity. Unfortunately, this kind of situation occurs when the solar inverters become overloaded, something that happens when the power demand from the increased solar array becomes bigger than the inverter's rated capacity. This situation can lead to several issues:

This situation can lead to several issues:

1. Power Losses: The 5kW inverter, which was initially designed just to handle the shade effect, may not be able to efficiently convert the surplus energy produced by the solar panels, causing some power losses to occur.
2. Inverter Strain: Regularly conducting this exceeds saturation can cause inverters more damage thus if any fault happens, the lifespan of inverter will decrease in accordance with the probability of inverter errors.
3. Reduced Efficiency: An inverter running at overload may lack its most efficient level of performance, which in turn may result in a decreased level of the solar power plant performance.
4. Potential Damage: Afterwards, the long-term overload situation might result in an overheated or other issues, causing wear and tear which may turn into the damage of the inverter and the related components.

Since this is the most likely result without correct sizing of the solar inverters based on the total capacity of the solar arrays, the corrective measure is to have the inverters appropriately sized according to the total capacity of the solar arrays. Developing regular tests and all future stages of upgrading the solar system is recommended, so its performance does not deter and it has increased efficiency.

An inverter itself does not directly cause battery overcharging. However, if the inverter is connected to a battery charger or charging system, the design and settings of the charger or charging system will determine whether the battery can be overcharged.

How to avoid overcharging the battery with an inverter?

Here are some recommendations to help you avoid overcharging the battery with a pure sine wave inverter:

a. Choose a suitable charger or charging system

Ensure that the charger or charging system you choose is compatible with your DC-AC inverter and has appropriate charging control features.

b. Regularly check the battery status

Periodically check the battery's charging status and voltage to ensure they are within the normal range.

c. Follow manufacturer's recommendations

Follow the recommendations and guidelines provided by DC to AC inverter and battery manufacturers to ensure proper usage and maintenance of the equipment.

d. Use smart chargers

Smart chargers have automatic charging cutoff features that can stop charging based on the battery's charging status, thus avoiding overcharging.

What Happens with Overcharging?

Impacts of overcharging the battery with a power inverter If the battery is overcharged, it may lead to the following issues:

a. Reduced battery lifespan

Overcharging intensifies internal chemical reactions in the battery, thereby shortening its lifespan.

b. Safety risks

Overcharging can cause the battery to overheat, potentially leading to fires or explosions.

c. Performance degradation

Overcharging can result in decreased battery performance, affecting the normal operation of the battery inverter.

Solar Inverter Failures: Causes, Consequences, and Impact on Energy Output

Solar inverters play a crucial role in converting the DC electricity generated by solar panels into AC electricity that can be used by homes and fed into the grid. Understanding the common failures in these systems is essential for maintaining efficiency and ensuring continuous power supply.

EEPROM Failure in Solar Inverters

EEPROM (Electrically Erasable Programmable Read-Only Memory) failure in solar inverters refers to the malfunctioning of the memory that stores the inverter's operational firmware and settings.

Possible Causes

- **Power Surges:** Sudden increases in voltage can damage the memory integrity.
- **Age:** Over time, EEPROM can degrade, losing its ability to retain data.
- **Quality Issues:** Lower quality components may fail prematurely under normal operating conditions.

Impact on Performance

EEPROM failures can cause the inverter to reset to factory settings or malfunction, leading to incorrect or suboptimal energy conversion and potential downtime.

Cost Implications

Replacing or repairing EEPROM is generally not expensive, but the associated downtime and reduced efficiency can lead to higher indirect costs.

GFCI Failure in Solar Inverters

GFCI (Ground-Fault Circuit Interrupter) failure in solar inverters occurs when this safety device, designed to protect electrical wiring and receptacles from ground faults, fails to operate correctly. A ground fault happens when there is an unintended electrical path between a power source and a grounded surface, which can occur if insulation breaks down or wiring is exposed. GFCIs detect these faults and quickly cut off power to prevent damage and reduce the risk of fire or electrocution.

Possible Causes

- **Moisture**: Exposure to moisture can damage the GFCI's electrical components.
- **Electrical Overload**: Excessive current can cause the GFCI to malfunction.
- **Wear and Tear**: Over time, GFCI components may degrade and fail to operate correctly.

Impact on Performance

Failure of the GFCI can lead to potential electrical hazards and system downtime if unnoticed.

Cost Implications

The component cost is low, but if a failure leads to system damage or safety incidents, the financial consequences can be significant.

3. FAC Failure in Solar Inverters

FAC (Frequency and Amplitude Control) failure in solar inverters refers to issues with managing the frequency and amplitude of the output AC (Alternating Current) waveform. Frequency in this context relates to how often the AC waveform cycles per second, measured in hertz, which needs to match the grid's frequency to ensure synchronization. Amplitude, on the other hand, refers to the waveform's height, correlating directly with the voltage level output by the inverter. Proper control of both is crucial for the effective delivery of power to the grid or local circuits.

Possible Causes

- **Sensor Malfunctions**: Faulty sensors can provide incorrect data, leading to improper adjustments.
- **Control Algorithm Errors:** Software issues can prevent effective frequency and amplitude control.
- **Component Wear:** Deterioration of critical components can disrupt waveform regulation.

Impact on Performance

This failure can result in the inverter producing electricity that is out of specification, potentially damaging connected devices or leading to disconnection from the grid.

Cost Implications

Rectifying FAC issues can be complex and costly, especially if software updates or hardware replacements are needed.

4. Isolation Failure in Solar Inverters

Isolation failure occurs when the inverter fails to adequately separate the DC and AC circuits, leading to potential leakage currents. Leakage current is an unwanted flow of electrical current that escapes from the power circuits of the inverter, potentially flowing through unintended paths such as the inverter's casing or grounding systems. This can occur when there is a failure in the electrical insulation or other barriers that normally contain the current flow within designed electrical pathways. Proper isolation is critical to ensure safety and prevent damage to the electrical system and connected devices.

Possible Causes

- **Insulation Breakdown**: Deterioration or damage to the insulation materials.
- **Component Failures**: Such as capacitors or relays failing, compromising isolation.
- **Design Flaws**: Poor inverter design can inherently lead to inadequate isolation.

Impact on Performance

Compromised isolation can lead to safety hazards, reduced efficiency, and regulatory non-compliance.

Cost Implications

Addressing isolation failures often requires substantial technical intervention, possibly involving complete inverter replacement.

5. Relay Failure in Solar Inverters

Relay failure in solar inverters occurs when the relays, which help switch electrical circuits on and off, malfunction. In a solar inverter, a relay is an electrically operated switch that controls the connection between the inverter and the electrical load or grid. It plays a crucial role in managing the flow of electricity, ensuring that power is safely and efficiently routed or isolated as needed. Relays in solar inverters are vital for both normal operation and protective functions, such as disconnecting the system during faults or maintenance to prevent damage and ensure safety.

Possible Causes

- **Mechanical Wear**: Continuous switching can wear out the relay contacts over time.
- **Coil Failure**: The coil in the relay can fail due to overheating or voltage spikes, causing it not to activate.
- **Poor Maintenance**: Lack of regular checks can lead to dirt and debris buildup, impacting relay functionality.

Impact on Performance

Relay failures can cause interruptions in power conversion processes, leading to inconsistent power supply or complete system shutdowns.

Cost Implications

While individual relays are not expensive to replace, frequent failures can lead to significant downtime costs and potential damage to other inverter components.

6. Solar Inverter Overload Problem

An overload in a solar inverter occurs when the power input from the solar panels exceeds the inverter’s capacity to handle or convert it safely into output power. This condition can stress the inverter's components, such as capacitors and cooling systems, beyond their operational limits. It typically happens during peak sunlight when the panels generate more electricity than usual or if the system configuration mistakenly exceeds the inverter's designed power rating.

Overloads can lead to inefficiencies, potential system shutdowns, or even damage if not managed properly.

Possible Causes

- **Excessive Solar Input**: High sunlight conditions can produce more power than anticipated.
- **Inadequate Inverter Capacity**: An undersized inverter for the solar panel setup.
- **Faulty Regulation**: Failure in the system's power regulation mechanisms.

Impact on Performance

Overloads can cause the inverter to shut down temporarily or, in severe cases, sustain permanent damage affecting long-term functionality.

Cost Implications

Costs related to resolving overload issues include potential inverter replacement and the opportunity cost of lost energy production during downtime.

7. Solar Inverter Grid Lost Fault

This fault occurs when the solar inverter loses synchronization with the grid, either due to a grid failure or anomalies in the grid's voltage or frequency. These anomalies might include voltage levels that are too high or too low, or frequency deviations from the standard 50 or 60 Hz, depending on regional standards. Such irregularities can pose risks to both the inverter and the broader grid infrastructure, prompting the inverter's safety mechanisms to disconnect to protect itself and maintain grid stability.

Possible Causes

- **Grid Instability**: Fluctuations or outages in the grid can disrupt the connection.
- **Inverter Sensitivity**: Some inverters may have high sensitivity settings that cause them to disconnect even with minor grid fluctuations.
- **Configuration Errors**: Improper settings related to grid integration can also lead to disconnections.