RTB | RWANDA TVET BOARD

RQF LEVEL 5

GENPE501

RENEWABLE ENERGY

Power Electronic Fundamentals

TRAINEE'S MANUAL

October, 2024

POWER ELECTRONIC FUNDAMENTALS

RTB | RWANDA TVET BOARD

KOICA Korea International Cooperation Agency

TQUM TVET Quality Management Project

2024

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ACRONYMS

AC: Alternative Current
BJT: Bipolar Junction Transistor
DC: Direct Current
FET: Field-Effect Transistor
IEE: Inspire Educate and Empower
IEEE: Institute of Electrical and Electronics Engineers
MOSFET: Metal-Oxide-Semiconductor Field-Effect Transistor
PCB: Printed Circuit Board
PPE: Personal Protective Equipment
RQF: Rwanda Qualification Framework
RTB: Rwanda TVET Board
RTB: Rwanda TVET Board
SMPS: Switched-Mode Power Supplies
SOP: Standard Operating Procedure
TQUM Project: TVET Quality Management Project
TVET: Technical and Vocational Education and Training

INTRODUCTION

This trainee's manual includes all the knowledge and skills required in Renewable Energy specifically for the module of **" Power Electronics Fundamentals"**. Trainees enrolled in this module will engage in practical activities designed to develop and enhance their competencies. The development of this training manual followed the Competency-Based Training and Assessment (CBT/A) approach, offering ample practical opportunities that mirror real-life situations.

The trainee's manual is organized into Learning Outcomes, which is broken down into indicative content that includes both theoretical and practical activities. It provides detailed information on the key competencies required for each learning outcome, along with the objectives to be achieved.

As a trainee, you will start by addressing questions related to the activities, which are designed to foster critical thinking and guide you towards practical applications in the labor market. The manual also provides essential information, including learning hours, required materials, and key tasks to complete throughout the learning process.

All activities included in this training manual are designed to facilitate both individual and group work. After completing the activities, you will conduct a formative assessment, referred to as the end learning outcome assessment. Ensure that you thoroughly review the key readings and the 'Points to Remember' section.

MODULE CODE AND TITLE: GENPE501 POWER ELECTRONIC FUNDAMENTALS

Learning Outcome 1: Perform preliminary activities
Learning Outcome 2: Implement a power rectifier
Learning Outcome 3: Implement a power inverter
Learning Outcome 4: Implement DC to DC converter

Learning Outcome 1: Perform Preliminary Activities

Indicative contents
1.1 Introduction to Power Conversion System **1.2 Preparing Electronics workplace** **1.3 Describing Power Electronics components** **1.4 Soldering Power electronic components** **1.5 Selecting equipment, tools, and materials**

Key Competencies for Learning Outcome 1: Describe Power electronics components and prepare the workplace for soldering process

Knowledge	Skills	Attitudes
• Description of power conversion system • Identification of workshop code of practice • Description of power electronics components • Description of Power converters • Identification of types of PCB • Identification of soldering steps • Description of tools, materials and equipment	• Cleaning of workplace • Selecting power converter • Applying soldering technics • Selecting equipment, tools, and materials	• Having Time management in cleaning the workplace • Having self confidence in applying soldering techniques • Being attentive while selection of tools, materials and equipment • Being careful in applying techniques

Duration:5 hrs

Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Describe properly power conversion system according their types
2. Identify clearly workshop code of practice according to the work to be done
3. Clean the workplace properly according to the electronic workshop code standards.
4. Describe effectively electronic components according to their function and selection criteria
5. Describe properly power converters according their types.
6. Select clearly power electronics components according to their types
7. Identify properly types of PCB according to their use
8. Identify clearly soldering steps according to the work to be done
9. Apply properly soldering technics according to the types of components
10. Describe properly tools, materials and equipment according to their types
11. Select properly tools, materials and equipment according to the work to be done

Resources

Equipment	**Tools**	**Materials**
• Screwdriver machine • DC power supply • Oscilloscope • Digital multimeter • soldering station • Personal protective equipment (PPE)	• Magnifying glass • soldering iron • Desoldering pump • Electrician toolbox • simulation software	• power electronic passive and active components • Integrated circuits (IC) • electronic relay • glue stick • thermal paste • soldering paste • Desoldering wire • soldering wire • battery/cells alcohol • jumper wires • Breadboard • power cables

Indicative content 1.1: Introduction to Power Conversion System

Duration: 1 hr

Theoretical Activity 1.1.1: Description of power conversion system

Tasks:

1: Answer the following questions:

i. What do you understand by a term power electronics?
ii. What is power conversion system?
iii. What do understand by Power converter?
iv. List down 5 areas of applications of power electronics

2: Write the answers on flipchart/ paper

3: Present the findings to the trainer and whole class

4: Ask for clarification if any

5: Read the key readings 1.1.1.in the manual

Key readings 1.1.1: Description of power conversion system

- **Definition of key concepts related to power conversion system**

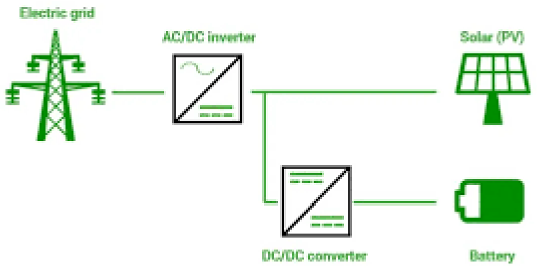
✓ **Power electronics**

Is the branch of electrical engineering that deals with the processing of high voltages and currents to deliver power that supports a variety of need.

Power Electronics refers to the process of controlling the flow of current and voltage and converting it to a form that is suitable for user loads. Electronics and power electronics relate to similar devices; the distinction lies with the devices' respective voltage and current ratings (in short, electronics relates to low-voltage devices and power electronics relates to high-voltage devices). Power electronic devices change voltage levels, current levels, or frequency.

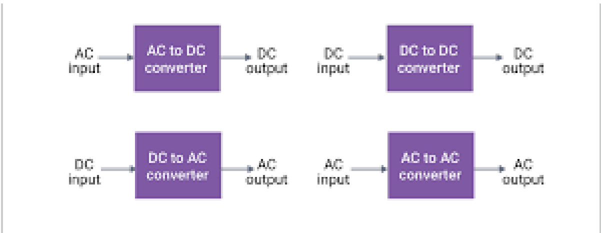
✓ **Power conversion**

Power conversion is the process of converting electric energy from one form to another. A power converter is an electrical or electro-mechanical device for converting electrical energy



✓ Power converter

Power converter is an electronic device or system that converts electrical power from one form to another, typically altering the voltage, current, or frequency of the input power.



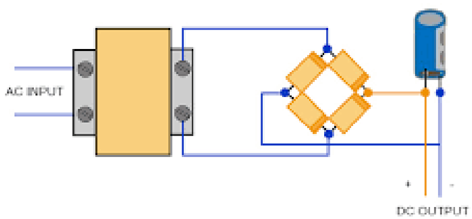
Common types of power converters include AC to DC converters, DC to AC converters (inverters), and DC to DC converters.

AC to DC converters

As you may know, electricity is generated at power plants from hydro, nuclear, and thermal sources. These power plants are often located in mountainous and coastal areas, making it more advantageous to send AC voltage to urban areas.

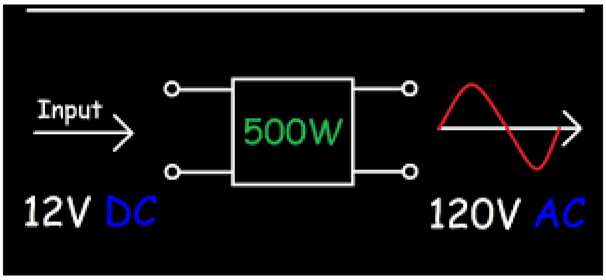
Simply put, transmitting high AC voltage at low current minimizes transmission (energy) loss.

However, since the high AC voltage cannot be used in the home as-is, it is transformed (stepped down) in stages via several substations before finally reaching 100V or 200V at the outlet. These transformed voltages are also sent via AC since AC is easier to transmit.



DC to AC converter

DC to AC Converters is mainly designed to change a DC power supply to an AC power supply. In this context, the DC power supply is comparatively stable and provides a positive voltage source, whereas AC oscillates around a 0V base stage, typically in a sinusoidal or square mode.

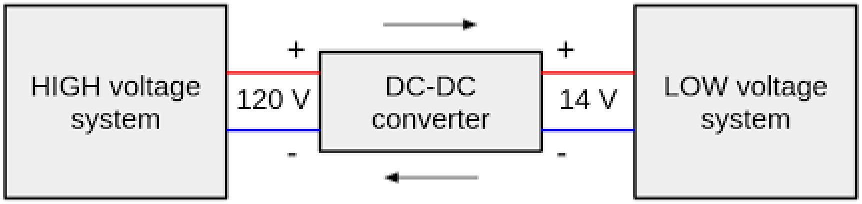


- **AC to AC converters**

AC-AC power converters in which the frequency is converted directly to another frequency, without any intermediate DC conversion connection (as in the case of inverters), are called cyclo-converters.

- **DC to DC converters**

A DC-to-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another



✓ **Power Electronic Applications**

- **Power Conversion**

The ability of power conversion to convert electrical power from one form to another is the key application of power electronics. The rectifier is a major component of the power conversion, and it converts AC to DC.

- **Wind Power Generation**

The rectifier is responsible for converting the variable frequency and variable voltage electricity from the wind turbine into DC power. Subsequently, the multiple boost DC-DC converter is employed to elevate the DC voltage level and maintain it relatively constant regardless of the wind speed. This continuous DC voltage is then inverted to AC voltage to synchronize the output voltage phasor with the grid voltage phasor. Similarly, in electric vehicles, power electronics are utilized to convert DC power from the batteries into AC power for the motor.

- **Motor Control System**

Power electronics are widely used in motor control systems such as industrial automation, robotics, and power generation systems. They are utilized to regulate the speed and torque of electric motors, resulting in enhanced efficiency and reduced energy consumption.

- **Lighting System**

This system controls the brightness of LEDs and inductive loads, such as fluorescent lamps. This enables more efficient lighting with reduced energy consumption.

Furthermore, power electronics play a crucial role in the operation of various consumer electronics, such as computers, mobile devices, and home appliances. They are responsible for regulating voltage and current levels, ensuring that these devices function safely and efficiently.

✓ **Advantages of Power Electronics**

The primary advantage of power electronics is that it enables engineers to work with high voltage and high current systems and configure them to operate at their most efficient level. By converting AC to DC power with very low losses, power electronics increase energy efficiency while maintaining stable, reliable power to electronic systems and devices. Considering the growing industry trend towards sustainable electronics, this is an advantage of power electronics that can't be understated.

Compared with electronics where noise and distortion are high, power electronics has significantly lower noise and distortion.

- Power electronics is used in space shuttle power supplies
- Since there is very low loss in power electronic devices so its efficiency is very high.
- Power electronic converter systems are highly reliable.
- Since there is no moving parts in power electronic systems so it has long life and also its maintenance cost is very less.
- The power electronic systems have fast dynamic response in comparison to electromechanical converter systems.
- Since the power electronic system has small size and also it has less weight, so they occupy less floor space and hence their installation cost is also less

✓ **Disadvantages of Power Electronics**

- The power electronic converter circuits tend to generate harmonics in the supply system as well as in the load circuit.
- AC to DC and DC to AC converters operate at a low input power factor under certain operating conditions. To avoid a low power factor, some special measures must be adopted.
- The overload capacity of power electronic controllers is very low.
- It is very difficult to regenerate power in power electronic converter systems.

Points to Remember

- **Power electronics:** refers to the process of controlling the flow of voltage and current and converting it to a form that is suitable for user loads
- **Power conversion** is the process of converting electric energy from one form to another.
- **Power converter** is an electronic device or system that converts electrical power from one form to another, typically altering the voltage, current, or frequency of the input power.
- **Applications of power electronic are:** Lighting system, Power factor correction, Motor speed control, Uninterruptible power supply and Renewable energy systems

Application of learning 1.1.

You are an electronic technician who repairs different home electronic equipment. A new customer has contacted you to inquire about the details on Power conversion system. They are interested in understanding the advantages, disadvantages and application of the components involved.

Indicative content 1.2: Preparation of Electronics Workplace

Duration: 1 hrs

Theoretical Activity 1.2.1: Identification of workshop code of practice

Tasks:

1: Answer the following questions:

i. What do you understand by a term electronic workshop?
ii. What is electronic workshop code of practice
iii. Write down the rules that guide someone in workshop
iv. What are the key components to check while preparing the workplace?
v. Enumerate the tools, materials and equipment used to clean the workpla ce

2: Write the answers on flipchart/ paper

3: Present the findings to the trainer and whole class

4: Ask for clarification if any

5: Read the key readings 1.2.1.in the manual

Key readings 1.2.1. Identification of workshop code of practice

- **Definition of workshop**

A workshop is a building or room where people perform their jobs.

An electronic workshop: is a room, group of rooms, or building in which work, especially electronic work, is carried on.

- **Preparation of Electronics workplace**

Preparing an electronics workplace involves setting up a space that's conducive to working with electronic components, instruments, and devices safely and effectively. Here's a guide on how to prepare an electronics workplace:

- ✓ **Workspace Design:**

Workbench: Have a sturdy, spacious workbench with ample space for tools, components, and instruments.

Ergonomic Setup: Ensure the workbench and chair are at appropriate heights for comfortable working.

Organization: Use shelves, drawers, or organizers to keep tools, components, and instruments sorted and easily accessible.

- ✓ **Lighting**
  - Ensure proper lighting to see small components and read labels clearly.
  - Consider task lighting, such as adjustable desk lamps, to illuminate specific areas while working.
- ✓ **Electrical Safety**
  - Install grounded electrical outlets for plugging in equipment and instruments.
  - Use surge protectors to safeguard sensitive electronics from power surges.
  - Clearly label circuit breakers or fuses for the workspace.
- ✓ **Ventilation**
  - Maintain a well-ventilated workspace, especially when working with soldering equipment or chemicals.
  - Consider using a fume extractor if dealing with soldering or other fumes.
- ✓ **Tools and Equipment**
  - Have a comprehensive set of tools including soldering irons, multimeters, oscilloscopes, wire strippers, screwdrivers, pliers, etc.
  - Invest in high-quality tools to ensure precision and durability.
- ✓ **Storage and Organization**
  - Use storage containers, cabinets, or drawers to organize small components, cables, and tools.
  - Label storage units to easily find necessary components.
- ✓ **Safety Equipment**
  - Have fire extinguishers and a first aid kit readily available.
  - Use safety goggles and gloves when handling hazardous materials or working with tools.
- ✓ **Grounding and ESD Protection**

Implement electrostatic discharge (ESD) protection measures to prevent damage to sensitive components. This includes ESD mats, wrist straps, and ESD-safe containers.

- ✓ **Workspace Cleanliness**
  - Keep the workspace clean to prevent dust or debris from damaging equipment or components.
  - Regularly clean workbenches, tools, and surrounding areas.
- ✓ **Documentation and Reference Materials**
  - Keep technical manuals, datasheets, and reference books nearby for quick access.
  - Maintain a notebook or digital system for recording project details, schematics, and notes.
- ✓ **Workplace Rules and Procedures**
  - Establish safety protocols and rules for working in the electronics workspace.
  - Train individuals on safe handling of equipment and materials.

Creating an efficient and safe electronics workspace involves organizing, equipping, and maintaining the area to optimize productivity and ensure safety while working with electronic components.

- **Electronic Workshop code of practice**

A code of practice for an electronic workshop serves as a set of guidelines and procedures to ensure safety, efficiency, and best practices for working with electronic components and equipment. Here are some key components that can be included in an electronic workshop code of practice:

- ✓ **General Safety Guidelines**
  - Always wear appropriate personal protective equipment (PPE) such as safety goggles, gloves, and lab coats.
  - Prohibit eating, drinking, or smoking in the workshop area.
  - Ensure all workers are aware of emergency procedures, including the location of fire extinguishers, first aid kits, and emergency exits.
- ✓ **Equipment Use and Maintenance**
  - Regularly inspect and maintain all electronic equipment to ensure proper functionality and safety.
  - Ensure that only qualified personnel use specific tools or equipment after receiving adequate training.
- ✓ **Work Area Organization**
  - Keep workbenches and pathways clear of clutter and unnecessary materials to prevent accidents.
  - Store tools and components in designated areas with clear labeling for easy access.
- ✓ **Electrostatic Discharge (ESD) Procedures**
  - Implement procedures to prevent ESD damage, including the use of ESD mats, wrist straps, and protective packaging for sensitive components.

- ✓ **Chemical Handling and Waste Disposal**
  - Handle chemicals according to safety data sheets and guidelines, ensuring proper ventilation and protective gear.
  - Dispose of hazardous waste in accordance with local regulations and guidelines.
- ✓ **Soldering and Heat Safety**
  - Use soldering irons and other heat-producing tools in a controlled manner, and ensure they are turned off when not in use.
  - Provide heat-resistant mats and use fume extraction systems if soldering in enclosed spaces.
- ✓ **Emergency Procedures**
  - Establish clear protocols for handling accidents, injuries, or equipment malfunctions.
  - Conduct regular safety drills to ensure all personnel are familiar with emergency procedures.
- ✓ **Training and Education**
  - Provide comprehensive training for all personnel on the use of equipment, safety procedures, and handling of electronic components.
  - Encourage ongoing education and skill development to keep up with new technologies and safety measures.
- ✓ **Documentation and Record-Keeping**
  - Maintain records of equipment maintenance, safety inspections, and any incidents that occur in the workshop.
  - Document project details, schematics, and any changes made to equipment or systems.
- ✓ **Regular Inspections and Reviews**
  - Conduct periodic inspections to ensure compliance with safety protocols and to identify any potential hazards.
  - Regularly review and update the code of practice to incorporate any changes in regulations or best practices.

Practical Activity 1.2.2: Cleaning the workplace

Task:

1: Read the given task

As electronic technician you are asked to clean the workshop benches and floor using brush, water, soap and vacuum cleaner.

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 2.1.3 and ask clarification where necessary

5: Perform the task provided in application of learning 1.2

Key readings 1.2.1: Cleaning the workplace

- **Cleaning techniques**

Cleaning is the most important and primary aspect of housekeeping. It is a process of removing dirt, dust and grime by using different methods such as:

- ✓ **Dusting**

the act of making something clean by brushing or wiping away dirt and dust from the surface

- ✓ **Brushing**
  To clean with or as if with a brush
- ✓ **Sweeping**
  To clean with or as if with a broom
- ✓ **Mopping**
  To clean with or as if with a mop
- ✓ **washing**
  The act or action of one that cleanses with water cleaning tools

- **Cleaning tools, materials and equipment**
  - ✓ **CLEANING TOOLS**

- **Brushes**

an implement with a handle and a block of bristles, hair, or wire, used especially for cleaning, applying a liquid or powder to a surface, or arranging the hair.

- **Sponge**

a piece of a soft, light, porous absorbent substance originally consisting of the fibrous skeleton of an aquatic invertebrate but now usually made of synthetic material, used for washing and cleaning.

- **soft cloth**

Soft cloth is an excellent way to lift organic matter and inorganic matter off an anything's surface. A soft cloth cleans the hard-to-get places most effectively.

- **Brooms**

A broom is a cleaning tool consisting of usually stiff fibers attached to, and roughly parallel to, a cylindrical handle, the broomstick.

- **Mop**

A mop is a piece of equipment for washing floors. It consists of a sponge or many pieces of string attached to a long handle.

- ✓ **CLEANING EQUIPMENT**
- **Air blower machines**

Are a simple and effective electrical device used in homes and industries to blow away dust from every nook and corner.

- **Vacuum cleaner**

A vacuum cleaner, also known simply as a vacuum, is a device that uses suction, and often agitation, to remove dirt and other debris from carpets and hard floors.

- ✓ **Cleaning materials**
  - **Cleaning solution**

Cleaning solution means liquid solvents or solutions used to remove ink and debris from the operating surfaces of the printing press and its parts.

- **Soap**

A salt of a fatty acid (sometimes other carboxylic acids) used for cleaning and lubricating products as well as other applications.

Isopropanol or isopropyl alcohol

Is a clear, colourless, bitter liquid commonly found in "rubbing alcohol," skin lotion, hair tonics, aftershave lotion, denatured alcohol, solvents, cements, cleaning products, and de-icers.

Points to Remember

- **Cleaning techniques**

The cleaning techniques are dusting, brushing, sweeping, mopping, blowing, washing

- **Cleaning tools, materials and equipment**
  - ✓ **Tools:** brushes, sponge, soft cloth, Brooms
  - ✓ **Equipment:** Air blower machines, vacuum cleaner
  - ✓ **Materials:** soap, cleaning solution, water

Application of learning 1.2.

BCD Group wants to re-install their workshop, but the working area has many dusts they want to clean it first, you are hired as one of technician to prepare the working area.

Indicative content 1.3: Description of Power Electronics Components

Duration: 1 hrs

Theoretical Activity 1.3.1: description of power electronics

Tasks:

1: Answer the following questions:

a) What do you understand by power electronics components?

b) Enumerate the examples of power electronics components

c) Explain briefly the function of power electronics components

2: Present the findings to the whole class

3: Ask for clarification if any

4: Read the key readings 1.3.1.

Key readings 1.3.1: Description of Power Electronics components

- **Power electronic component**
  - ✓ **Definition of Power electronic component**

Power electronic component is a device or unit that enables the conversion, control, and management of electrical power in various applications

- ✓ **Power electronics components**

Power electronics consists of

- Power semiconductor devices
- Passive components
- Control circuit
- Protection devices

- **Power semiconductor devices**

I. Power Diodes.

II. Power transistors (BJT's)

III. Power MOSFETS.

IV. IGBT's.

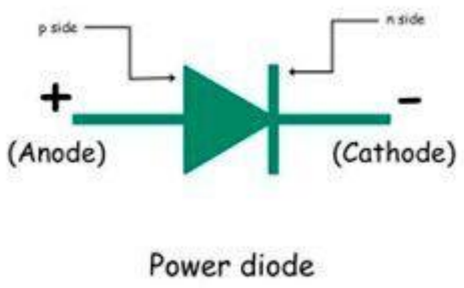
V. Thyristors

I. Power diodes

Definition of Power Diodes

A power diode is a three-layer two-terminal uncontrolled power electronic device with high power ratings and low switching speed. Power diodes offer unidirectional flow of kiloamperes of current and are used in high-power applications

A diode operates as a switch to accomplish a variety of activities, including switching in rectifiers, freewheeling in switching regulators, charge revision of capacitors and energy transmission between components, trapped energy recovery, voltage isolation, and energy feedback from the load to the power source.



Characteristics of Diode

The characteristics of an ideal diode deviate from the ideals of zero forward and infinite reverse impedance, as seen in Fig. 3.1 A voltage drop occurs in the forward direction due to a potential barrier brought on by the distribution of charges close to the junction and other factors.

For currents in the usual range, this is in the region of 1V for silicon. In the opposite direction, a very small current that is essentially independent of the voltage flows within the typical working range of voltage. For practical purposes, Fig. 3.2 frequently serves as a representation of the static features.

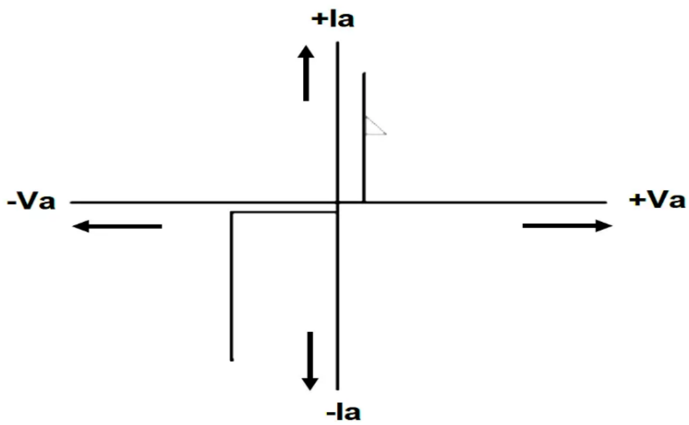


Fig 3.1 Ideal diode VI Characteristics

A threshold voltage Vo and a linear incremental or slope resistance, r, are used to represent the forward characteristic in Fig. 3. Regardless of voltage within the usual operating range, the reverse characteristic is constant throughout the whole range of potential leakage currents.

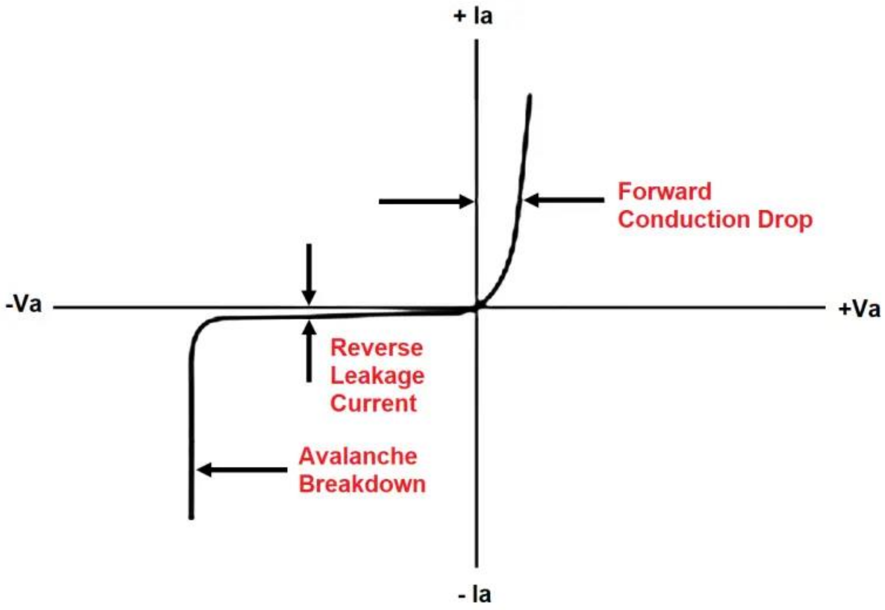
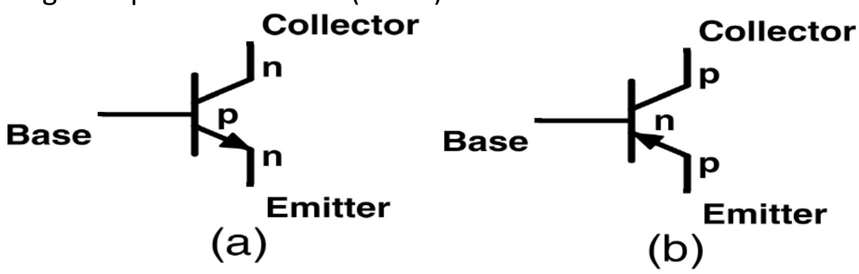


Fig 3.2 Practical Diode VI Characteristics

II. Power transistors

Power transistors are devices that have controlled turn-on and turn-off characteristics. These devices are used a switching device and are operated in the saturation region resulting in low on-state voltage drop. They are turned on when a current signal is given to base or control terminal.

The transistor remains on so long as the control signal is present. The switching speed of modern transistors is much higher than that of thyristors and is used extensively in dc-dc and dc-ac converters. However, their voltage and current ratings are lower than those of thyristors and are therefore used in low to medium power applications. Power transistors are classified as follows o Bipolar junction transistors (BJTs) o Metal-oxide semiconductor filed-effect transistors (MOSFETs) o Static Induction transistors (SITs) o Insulated-gate bipolar transistors (IGBTs)



Symbol of transistor

- **Advantages of BJT'S**

✓ BJT's have high switching frequencies since their turn-on and turn-off time are low.

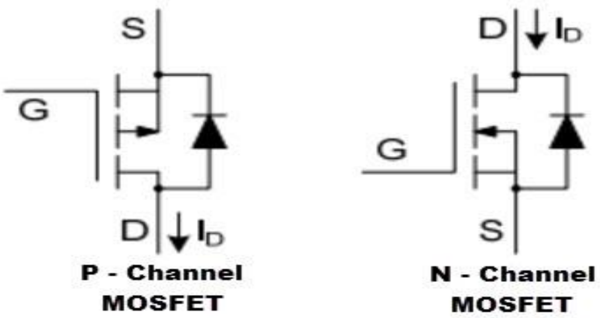
- ✓ The turn-on losses of a BJT are small.
- ✓ BJT has controlled turn-on and turn-off characteristics since base drive control is possible.
- ✓ BJT does not require commutation circuits

- **Demerits of BJT**

- ✓ Drive circuit of BJT is complex.
- ✓ It has the problem of charge storage which sets a limit on switching frequencies.
- ✓ It cannot be used in parallel operation due to problems of negative temperature coefficient.

III. **Power MOSFETS (METAL OXIDE SEMI CONDUCTOR FIELD EFFECT TRANSISTOR)**

One kind of MOSFET which handles high levels of power is known as Power MOSFET. As compared to normal MOSFETs in the less voltage range, these MOSFETS works much better by exhibiting high speed of switching. Its operating principle is the same as general MOSFETs.



These are three-terminal silicon devices that work through applying a signal toward the gate terminal so that it controls current conduction among source & drain terminals. The current conduction capacities are equal to thousands of amperes including breakdown voltage ratings from 10Volts-1000Volts.

Operating Principle

Like normal MOSFETs, these types of MOSFETs will switch & control the flow of current in between the two terminals like source & drain through changing the voltage on the gate terminal. Once the voltage is applied to the gate terminal, then a channel can be formed in between the source & the gate terminals which allows the flow of current.

By enhancing the VGS voltage (gate-source), the channel will become superior & the ID (drain current) will increase. Here, the main relationship among the two voltages like gate & drain will depend on the below equation.

ID = K (VGS – VT)2

Where,

'ID' is a drain current

‘K’ is a device constant
‘VGS’ is a gate voltage
‘VT’ is a threshold voltage

Power MOSFET Testing

The testing of power MOSFET can be done by using a multimeter through the following methods. Let’s test for N-channel & P-channel power MOSFETs.

- **Testing N-Channel MOSFET**

✓ Fix the digital multimeter to the range of diode
✓ Place the power MOSFET on a wooden table
✓ Using a meter probe or a screwdriver, short the drain & gate terminals of the transistor. This will primarily remain the inside capacitance of the device will discharge completely.
✓ Place the black probe of the meter toward the source whereas the red color probe is toward drain of the transistor.
✓ So an open circuit sign can be observed on the digital multimeter.
✓ After that, keep the black color probe toward the source and remove the red color probe from drain & connect it toward the gate terminal of the MOSFET for a moment, again place it back on the drain terminal.
✓ So at this moment, the digital multimeter will display a short circuit.

From the above two results, we can conclude that the MOSFET is okay.

For proper confirmation, repeat these steps several times

To repeat the above steps every time, you must reset the transistor by shorting the drain & gate terminals through a meter probe.

Testing P-Channel MOSFETs

For P channel MOSFET, the above five steps are the same except the meter polarities will vary.

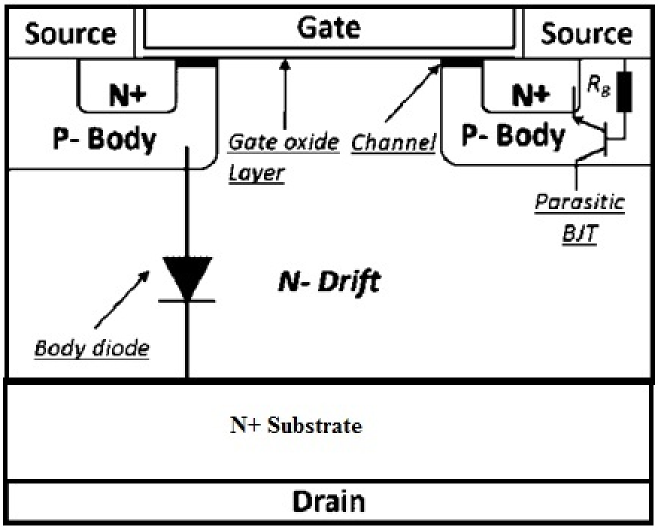
Next, without touching the RED color probe from the source, detach the black color probe from the drain & contact the gate terminal of the transistor for a moment & place it back toward the drain of the MOSFET.

So this time, the multimeter will display continuity otherwise a less value on the multimeter.

So that we can conclude that MOSFET is in okay condition without any troubles. Any other type of reading will specify a faulty MOSFET.

Power MOSFET Construction

Generally, the power MOSFETs are enhancement types. A drift layer is used to enhance the voltage rating for enhancement MOSFET. The structure of the power MOSFET is the vertical shape and it includes four layers. This type of structure is mainly used to decrease the region of the flow of current. So this structure will decrease the on-state resistance & on-state loss.



In the MOSFET structure, the middle layer like p-type is called as body whereas n- layer is called as the drift region. This layer is doped lightly as evaluated to the other layers like source & drain. This drift region will decide the breakdown voltage for this MOSFET. In the power MOSFET construction, both the first & last layers are n+ layers. Here the source layer is the primary layer whereas the drain layer is the last layer.

The structure of n+ p n- n+ is the n channel MOSFET in enhancement mode. But the structure of a p-channel MOSFET includes quite opposite doping shape. In this construction, the gate terminal is not connected directly to p-type as there is an oxide layer in between the metal & semiconductor which works as a dielectric layer.

It forms a metal oxide semiconductor capacitance on the MOSFET's input which is high like above 1000 pF. The oxide layer provides excellent insulating properties by offering the silicon dioxide layer to separate the terminal from the body to the gate

The advantages of power MOSFET

- The next breakdown does not occur.
- Very simple Gate driving circuit
- Very simple to switch ON & OFF
- It uses a high switching frequency to operate
- Thermal stability is good due to the positive temperature coefficient of power MOSFET
- Less on-state resistance
- Less expensive
- Small size
- It is a voltage-controlled device
- Needs small power to hold it within the activated condition.

- Switching speed is fast
- For commutation, an extra circuit is not necessary

The disadvantages of power MOSFET

- The on-state voltage is extremely high beyond the MOSFET. Thus, the dissipation of on-state power is high.
- The blocking capacity of this MOSFET is not symmetric so they can block high forward voltage instead of high reverse voltage. So, we need to fix a diode for guarding the MOSFET.
- They require special care while using or else they can be damaged because of the fixed electricity.

The applications of power MOSFET

- UPS (Uninterrupted Power Supplies)
- Relay driver
- SMPS (Switch Mode Power Supplies)
- Industries
- High frequency-based inverters
- Used within power amplifiers
- In motor controlling
- Display driver

From the above information finally, we can conclude that the main difference between power MOSFET and MOSFET is, a MOSFET handles with less power so used for experimental purposes whereas the power MOSFET handles with huge power. So it is very dangerous to handle. These are used mostly in power electronic devices.

IV. Insulated Gate Bipolar Transistor

The IGBT is a power switching transistor which combines the advantages of MOSFETs and BJTs for use in power supply and motor control circuits

The IGBT Transistor takes the best parts of these two types of common transistors, the high input impedance and high switching speeds of a MOSFET with the low saturation voltage of a bipolar transistor, and combines them together to produce another type of transistor switching device that is capable of handling large collector-emitter currents with virtually zero gate current drive.

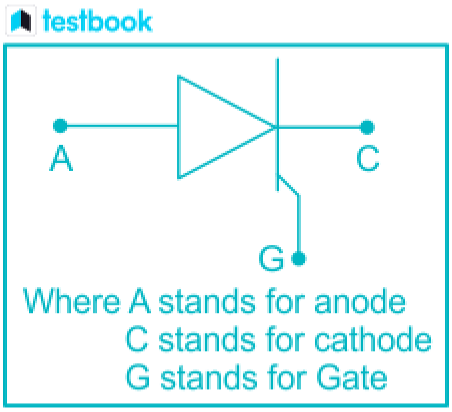
The Insulated Gate Bipolar Transistor, (IGBT) combines the insulated gate (hence the first part of its name) technology of the MOSFET with the output performance characteristics of a conventional bipolar transistor, (hence the second part of its name).

The result of this hybrid combination is that the “IGBT Transistor” has the output switching and conduction characteristics of a bipolar transistor but is voltage-controlled like a MOSFET.
One of the main advantages of the IGBT transistor is the simplicity by which it can be driven “ON” by applying a positive gate voltage, or switched “OFF” by making the gate signal zero or slightly negative allowing it to be used in a variety of switching applications. It can also be driven in its linear active region for use in power amplifiers.

With its lower on-state resistance and conduction losses as well as its ability to switch high voltages at high frequencies without damage makes the Insulated Gate Bipolar Transistor ideal for driving inductive loads such as coil windings, electromagnets and DC motors.

V. Thyristor

A thyristor is a three-junction (J1, J2, J3), Four layer of alternating P-type and N-type materials (PNPN) Semiconductor device, which has an Anode, Cathode, and Gate (three terminals). It typically has three electrodes: an anode, a cathode, and a gate (the control electrode). The silicon-controlled rectifier (SCR) is the most prevalent type of thyristor. The primary function of a thyristor is to control electric power and current by acting as a switch. A small current on its gate terminal controls the larger current of the anode-to-cathode path. For such a small and lightweight component, it offers adequate protection to circuits with large voltages and currents.



Where,
A indicates Anode terminal (Positive terminal)
C indicates Cathode terminal (Negative terminal)
G indicates Gate terminal (Current control terminal)

The most common type of thyristor is the silicon-controlled rectifier (SCR Thyristor). When the cathode is negatively charged relative to the anode, no current flows until a pulse is applied to the gate. Then, the SCR conducts current until the voltage between the cathode and anode is reversed or reduced below a certain threshold or holding value. Using this type of thyristor, large amounts of power can be switched or controlled using a small triggering current or voltage.

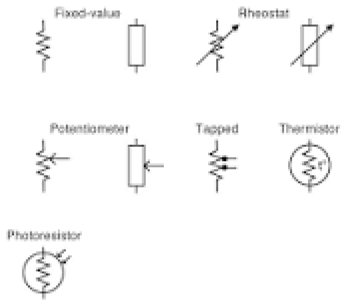
A thyristor is the most important type of power semiconductor device. They are mostly used in power electronic circuits. They are operated as bi-stable switches from non-conducting to conducting state. Thyristors are high-speed electronic switches that can be used to replace electromechanical relays in many circuits as they have no moving parts, no contact arcing, or suffer from corrosion or dirt. But in addition to simply switching large currents “ON” and “OFF”, thyristors can be made to control the mean value of an AC load current without dissipating large amounts of power.

1.2.2 Passive components

A passive component is an electronic component which can only receive energy, which it can either dissipate, absorb or store it in an electric field or a magnetic field. Passive elements do not need any form of electrical power to operate.

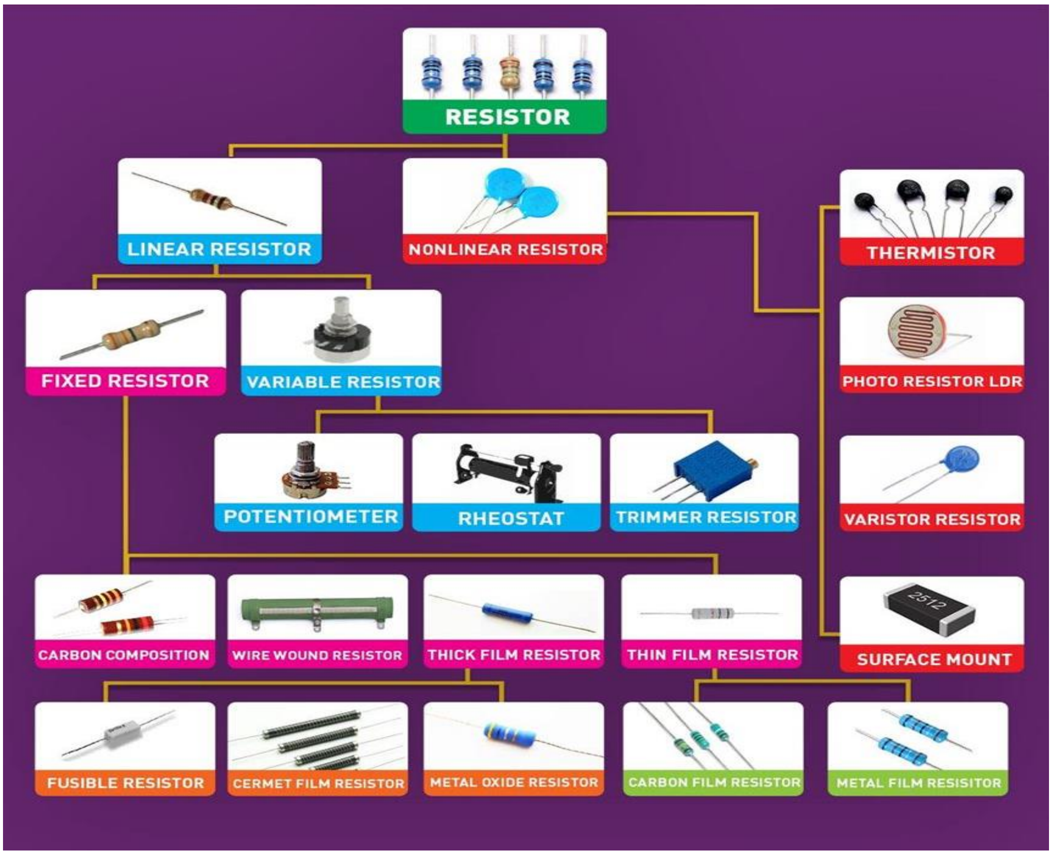
Resistors, capacitors, inductors are examples of passive components

1. **RESISTORS**



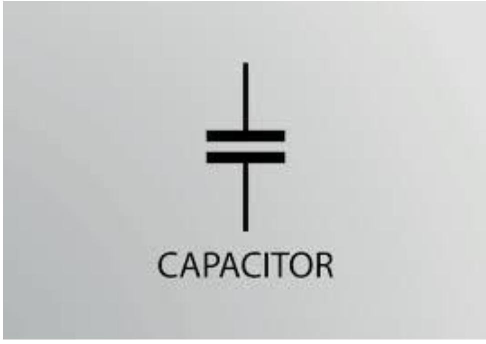
A resistor is an electrical component that limits or regulates the flow of electrical current in an electronic circuit. Resistors can also be used to provide a specific voltage for an active device such as a transistor.

TYPES OF RESISTORS



2. **Capacitor**

A capacitor is an electrical component or a device that stores electrical energy by accumulating electric charges on opposite surfaces which are separated by an insulating layer and the capability to store these charges at a given potential refers to capacitance.



Classification of Capacitors

The kinds of capacitors accessible reach from a little sensitive managing capacitor utilizing an oscillator or radio circuits. It is up to enormous force metal-can type capacitors that in use within high voltage power amendment and smoothing circuits.

Following is the classification of the capacitor types, According to structure:

- **Fixed Capacitors**
- **Variable Capacitors**
- **Trimmer Capacitor**

Following is the classification of the capacitor types, According to polarization:

- **Polarized**
- **Unpolarized**

A polarized capacitor is a significant part of the electronic circuit and frequently named as an electrolytic capacitor. These capacitors are in use to accomplish high capacitive density.

Unpolarized capacitors are favoured over capacitors with full energy. Since it doesn't get annihilates by invert voltage and can be in use in pure AC circuits. They additionally discover applications in DC circuits as they don't have positive and negative closures. The recurrence of the unpolarized capacitor is high and the spillage current is low.

Types of Capacitors

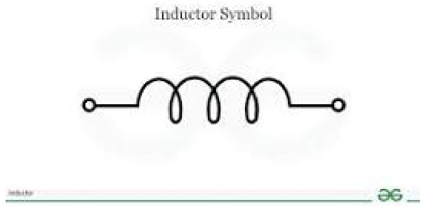
Capacitors are ordered into 2 mechanical gatherings. Fixed Capacitors comprising of fixed capacitance worth. And variable capacitance with variable capacitance esteem. Underneath are a short portrayal of different capacitor types and their properties.

- Ceramic Capacitors
- Film Capacitors
- Power Film Capacitors
- Electrolytic Capacitors
- Ceramic capacitors
- Film capacitors
- Paper capacitors
- Electrolytic capacitors

3. **INDUCTOR**

An inductor is a passive electronic component that temporarily stores energy in a magnetic field when electric current flows through the inductor's coil. In its simplest form, an inductor consists of two terminals and an insulated wire coil that either loops around air or surrounds a core material that enhances the magnetic field.

Symbol of inductor



Types of Inductors

- ➢ Air-core inductor.
- ➢ Radio-frequency inductor.
- ➢ Ferromagnetic-core inductor.
- ➢ Laminated-core inductor.
- ➢ Ferrite-core inductor.
- ➢ Powdered-iron-core inductor.
- ➢ Toroidal-core inductor.
- ➢ Variable inductor.

Theoretical Activity 1.3.2: Description of Power converters

Tasks:

1: Answer the following questions:

i. What do you understand by power converter?

ii. Enumerate the types of power electronic converter

2: Present the findings to the whole class

3: Ask for clarification if any

4: Read the key readings 1.3.2.

Key readings 1.3.2.: Description of Power converters

1. A power converter

Is an electrical circuit that changes the electric energy from one form into the desired form optimized for the specific load.

Power converters are necessary because electrical power sources, such as the grid, batteries, or generators, often do not directly provide the type or characteristics of electricity that various electronic devices and systems require. For example, the mains electricity supplied in homes is alternating current (AC) with a fixed voltage and frequency. However, many electronic devices, such as laptops and smartphones, require direct current (DC) at a lower voltage, which necessitates the use of a power converter.

1.1. How does a Power Converter work?

Power converter's function using semiconductor components that control and modify electrical power. These components include diodes, transistors, and thyristors, among others. The design and operation of these components within the power converter circuit determine how the input power is transformed into the desired output power.

These switches rapidly connect and disconnect the power source from the load, thereby effectively controlling the flow of electrical energy. Rapid switching, known as Pulse Width Modulation (PWM), enables precise control over the output by varying the duty cycle of the switches, which is the ratio of the on-time to the off-time.

The operation of a power converter can be explained through the following steps:

1. Energy Storage: Power converters often use inductors and capacitors as energy storage elements. Inductors store energy in the form of a magnetic field when current flows through them, while capacitors store energy in the form of an electric field between their plates.

2. Switching: The semiconductor switches in the converter turn on and off at high frequencies, which can range from tens of kilohertz to several megahertz, depending on the application. This switching action shapes the flow of energy from the input to the output.

3. Control Circuitry: The switching elements are controlled by a circuit that determines the timing and sequence of their operation. This control circuitry is designed to respond to the input conditions and the desired output specifications. It uses feedback from the output to adjust the switching parameters in real time to maintain the correct output voltage or current.

4. Filtering: After the switching process, the resulting waveform may contain ripples or high-frequency components that are not suitable for the load. Filters, which are typically composed of inductors and capacitors, smooth out these ripples, producing a more stable and continuous output waveform.

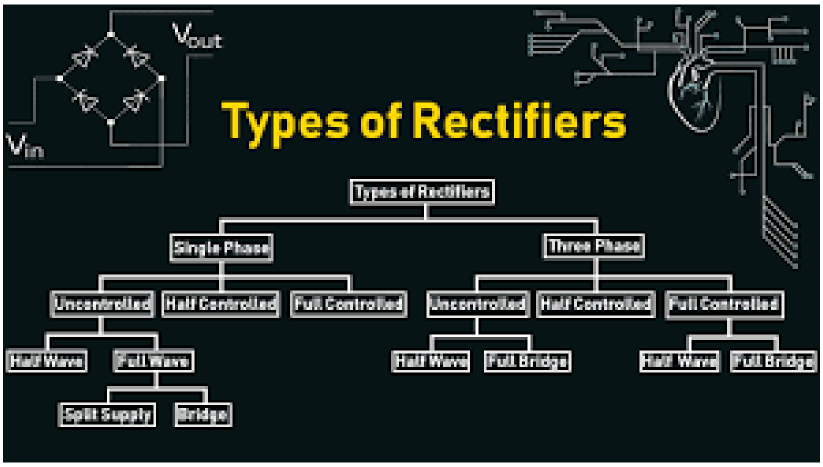
5. Transformation: During the conversion process, the characteristics of the electrical energy are transformed. For example, in a DC-DC converter, the voltage level is changed while maintaining the direct current nature of the power. In an AC-DC converter (rectifier), the alternating current is converted into direct current, and in a DC-AC converter (inverter), the reverse occurs.

2. Types of Power Converters

2.1 AC to DC Converters(Rectifier)

An AC to DC converter, also known as a **rectifier**, is an electronic circuit that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. This process is critical in many electronic devices that require a steady DC voltage for their operation.

TYPES OF RECTIFIERS



1. Single phase rectifier

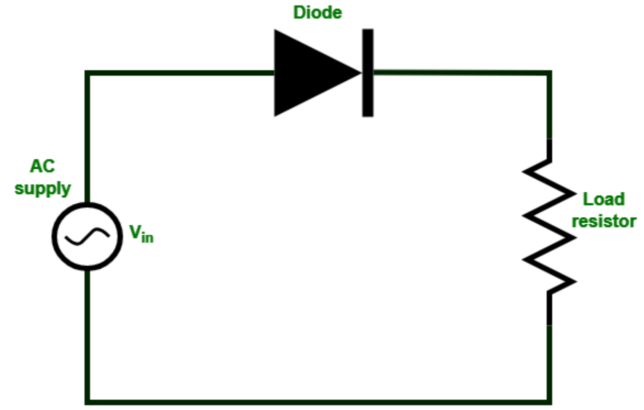
1.1 Half Wave Rectifier

Half Wave Rectifier

A Half-wave rectifier is a device that converts Alternating Current (AC) to Direct Current (DC). In a Half-wave rectifier, only one half-cycle of AC is converted to DC and the other half-cycle is blocked. Therefore, the output waveform produced by a half-wave rectifier consists of ripples of positive half-cycle of the input waveform and it is called pulsating DC. In a half-wave rectifier, a p-n junction diode is used as a rectifier. It has a relatively simple circuit consisting of a p-n junction diode connected in series to a load.

Half Wave Rectifier Circuit

Given below is the Circuit diagram of the Half Wave Rectifier. The components of the Half Wave Rectifier are P-N Junction diode, Ac supply and the load.



- **Construction of Half Wave Rectifier**
  To Construct a half-wave rectifier, the Components are Assembled as the Following

✓ Function generator serves as input AC source for us. The positive end of the function generator (red coloured end) is connected to the positive side of the diode(black side of diode without line).

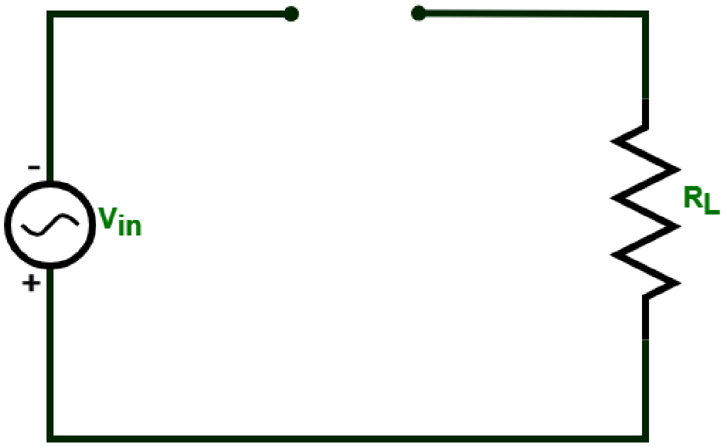
✓ Next, the negative terminal of the diode (marked by a grey line or indicator) is connected to the one end of the resistor.

✓ Now, the other end of the resistor is connected to the remaining terminal of the function generator. This completes the circuit loop and allows the AC signal from the function generator to flow through the diode and resistor.

- **Working of Half Wave Rectifier**
  In a half-wave rectifier, the AC supply is connected in series to a p-n junction diode and load resistor. An Alternating current (AC) consists of two half-cycles: Positive half-cycle and Negative half-cycle. Let us take a look at the working of the half-wave circuit at each half-cycle separately.

✓ In a positive half-cycle, the Diode is forward-biased and hence acts like a short circuit. Therefore in a positive half-cycle, current flows through the circuit and produces whole AC input as such in DC output. In the real world, the output voltage is less than the input voltage considering the Diode voltage drop.

✓ In a negative half-cycle, the Diode is reverse-biased and hence acts like an open circuit. Therefore, in a negative half-cycle current does not flow through the circuit. And output does not consist of input negative half-cycle.



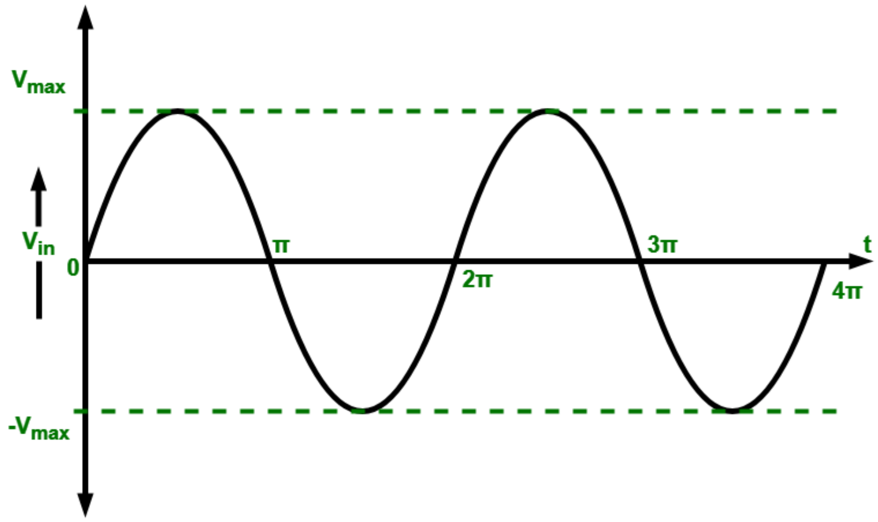
This step is repeated in each half-cycle and AC is converted into DC. The waveform of input AC and corresponding rectified DC are shown in the figures below.

Half Wave Rectifier Waveforms

Given below is the Input and output waveform of the half wave rectifier

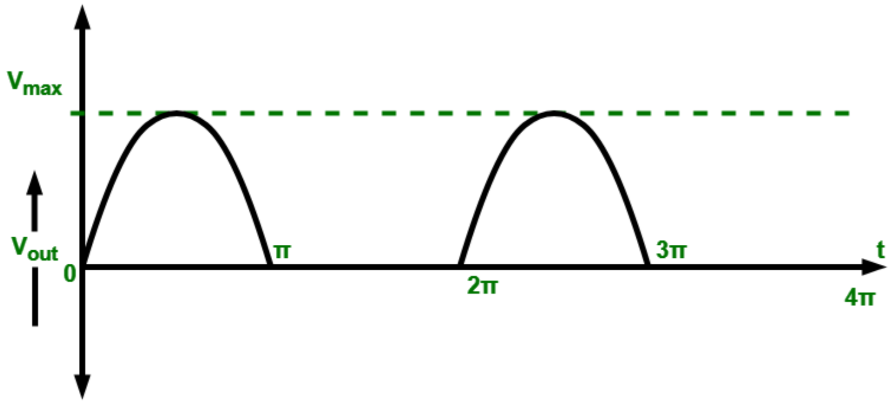
AC Input Waveform

The below figure shows AC input with a maximum voltage of Vmax. This is the Ac Waveform given as the input for the half wave rectifier which is converted to the Dc.



DC Output Waveform

The below figure shows the output waveform of the DC output waveform of a half-wave rectifier. From the input first a positive half cycle comes and in the positive half cycle diode lets pass the input voltage through it. You can see the positive half cycle in the output waveform as such from the input waveform. Then a negative half-cycle comes, but it does not allow to pass the negative half-cycle and we can see that the negative half-cycle is not present in the output waveform. At that time output voltage is zero. Then again a positive half cycle comes which is passed through the diode and it is visible in the output waveform. After that a negative half cycle comes and it is blocked by the diode and is not present in the output. This process continues to convert AC to DC.

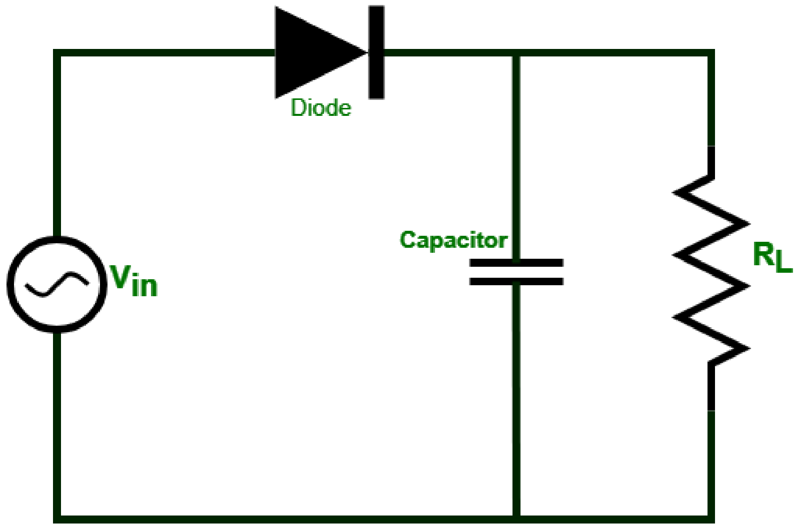


Half Wave Rectifier with Filter

we can see that the output of a half-wave rectifier is pulsating DC and pulsating DC cannot be used for many real-world applications. So, To avoid or reduce the ripples in pulsating DC filters are used. Generally, capacitors and inductors are used as filters in half-wave rectifier circuits. These capacitors or inductors reduce ripples in output DC and help in many real-world applications. Although we can reduce ripples in the output of the half-wave rectifier, it is not possible to completely remove ripples in output DC.

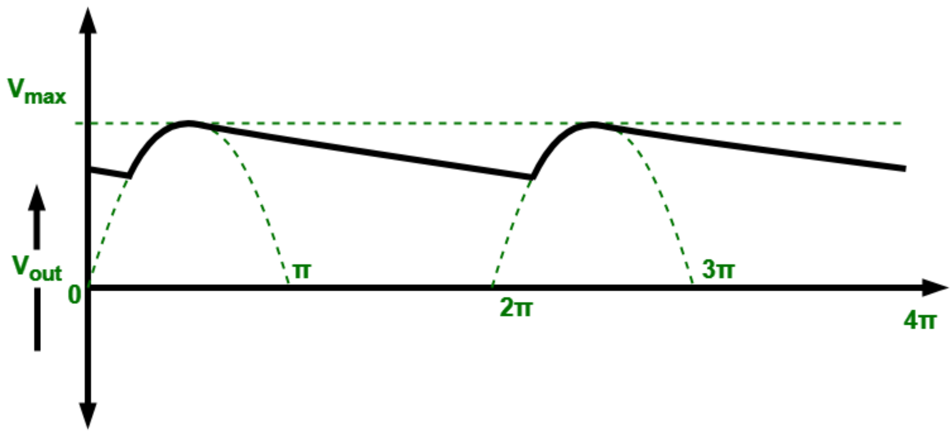
Half Wave Rectifier Capacitor Filter

Here’s the circuit diagram of a half-wave rectifier with a capacitor filter.



Working of Half Wave Rectifier with Filter

In a Half-wave rectifier with a filter, the Diode is connected in series to a capacitor and Load resistor which in turn are connected parallelly as shown in the above circuit diagram. In this circuit, the capacitor charges in the positive half-cycle and discharges during the negative half-cycle and reduces ripples in the output. In a positive half cycle, the diode acts as a short circuit and the capacitor charges from the input source. In the negative half cycle when the diode acts as an open circuit, the capacitor discharges providing current flow into the Load. Thus, adding a capacitor to the circuit helps to maintain DC output even when AC is in negative half cycle. Given below is the output waveform of the Half wave rectifier with Filter.



Thus, a capacitor helps to reduce ripples in the DC output of a half-wave rectifier.

2. Full Wave Rectifier

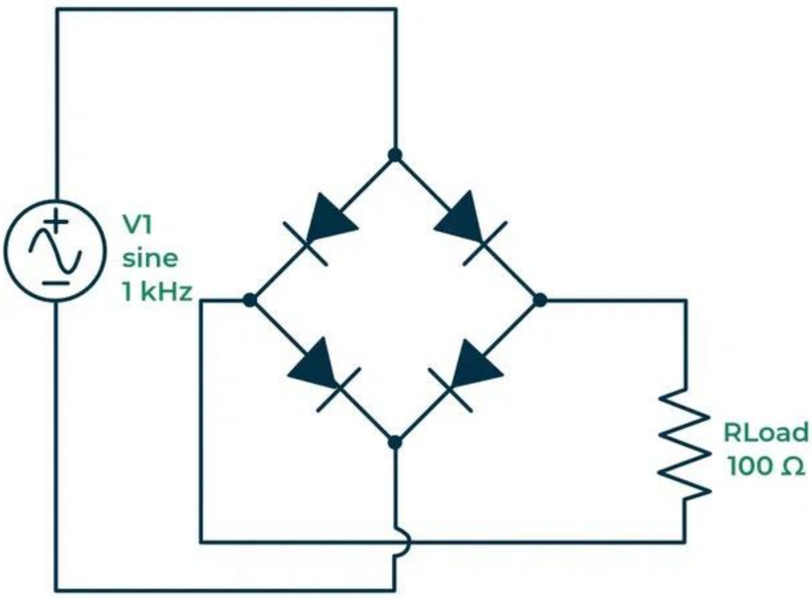
A full wave rectifier converts both positive and negative half cycles of the AC (alternating current) into DC (direct current). It provides double output voltage compared to the halfwave rectifier

A full wave rectifier is made up of more than one diode.

There are two types of full wave rectifier.

2.1 Bridge Rectifier

A Bridge Rectifier is a device used to convert AC into DC. Its main purpose is rectification ensuring that electric current flows in one direction. It is composed of diodes arranged in a bridge structure. It can rectify both the negative and positive halves of an AC waveform. As AC electricity enters the bridge rectifier it rectifies both segments of the AC cycle to produce a supply of DC power at the output. This transformation holds importance for electronic devices as it ensures a stable and reliable source of electrical energy.



Construction

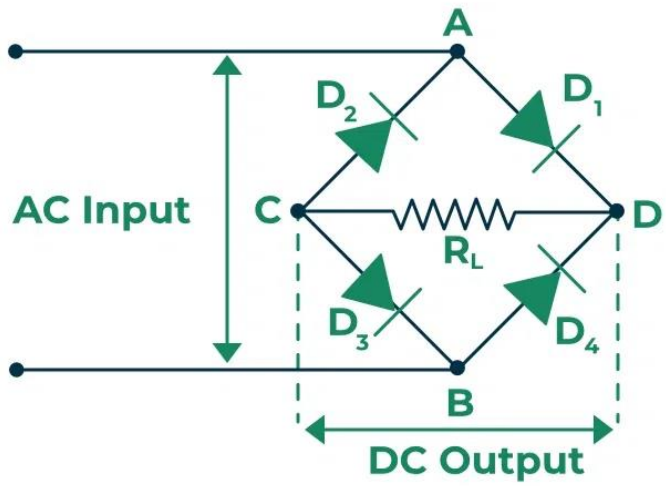
Constructing a Bridge Rectifier involves assembling components, in a particular manner to create a device capable of converting alternating current (AC) into direct current (DC).

Diodes: The fundamental elements of a Bridge Rectifier are diodes. Four diodes are arranged in a pattern forming the bridge configuration. Typically these diodes are made from semiconductor materials such as silicon.

Arrangement: The four diodes are interconnected to construct a bridge structure, the name "Bridge Rectifier." They serve as the four arms of the bridge with the AC input connected to two corners and the DC output taken from the two corners.

Terminal Connections: Each diodes anode (side) and cathode (side) are linked to the AC input and DC output terminals of the bridge. This arrangement ensures that current flows in one direction through the diodes facilitating the conversion of AC, to DC.

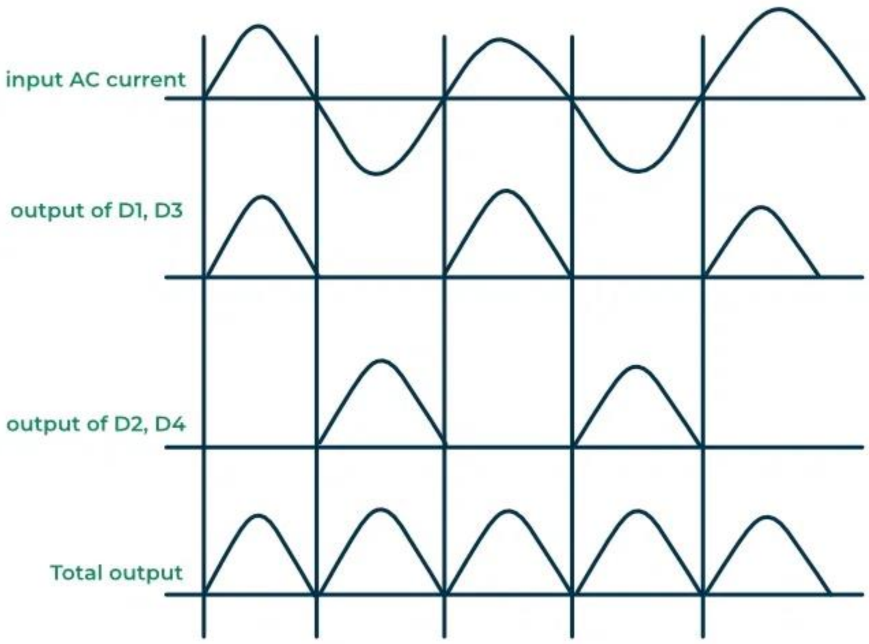
Mounting: To ensure component protection and practicality it is common for these diodes and their connections to be mounted on a circuit board or housed within an enclosure that offers safety and compactness.



Working

A bridge rectifier diagram is similar, to a representation that illustrates the arrangement of components within a specific circuit. Its purpose is to convert alternating AC which is characterized by wave patterns into direct current (DC) that provides a consistent flow of electricity**.**

The diagram typically features four arrows positioned in a bridge formation ensuring the direction of electrical flow. One end represents AC power while the other end signifies DC power, which is commonly utilized in our devices. Additionally, there might be symbols incorporated in the diagram, for safety measures.



waveforms-of-bridge-rectifier

The functioning of a Bridge Rectifier is relatively simple yet crucial, in converting alternating (AC) to direct current (DC). It operates in four steps:

AC Input: Firstly the Bridge Rectifier connects to an AC power source, which supplies electricity that constantly changes direction resembling ocean waves. This type of AC power is commonly obtained from outlets.

Diode Action: Strategically arranged within the Bridge Rectifier are four diodes that form a bridge configuration. When the AC voltage is positive on one side, two diodes allow the current to flow through them in one direction. Conversely when the AC voltage reverses the other two diodes become active. Enable the current to pass through them in the previous direction**.**

Conversion: As a result of this alternating action of the diodes, the negative and positive halves of the AC waveform get separated. The diodes effectively "Cut off" the portions permitting only the positive portions to pass through.

DC Output: Consequently, what we obtain as an output from the Bridge Rectifier is a stream of current (DC). This DC output represents a flow of electricity in a direction akin, to a steady river stream.

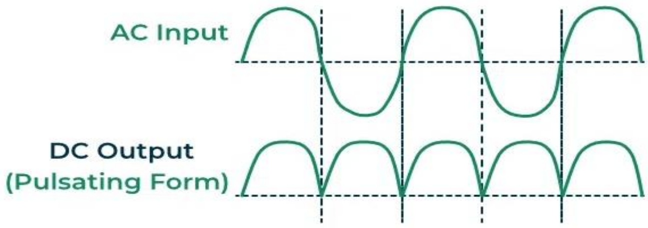


Figure 3 Input-Output Waveforms of a Bridge Rectifier

Characteristics of Bridge Rectifier

The Bridge Rectifier has three main characteristics given below:

1. Ripple Factor
2. Peak Inverse Voltage (PIV)
3. Efficiency

Types of Bridge Rectifier

Bridge rectifiers are commonly available in various types, each with its specific characteristics and applications. The primary types of bridge rectifiers include:

1. Single-phase Bridge Rectifier

- The single-phase bridge rectifier is the most basic and widely used type.
- It is suitable for converting single-phase AC power into DC power.
- Commonly used in power supplies for electronic devices and general-purpose rectification.

2. Three-phase Bridge Rectifier

- Three phase bridge rectifiers have the purpose of transforming three phase AC power into DC power. They are commonly used in settings where there is a need, for power capacity and improved efficiency.
- Used in various motor drives, industrial power supplies, and heavy machinery.

3. Center-tap Bridge Rectifier

- This type of bridge rectifier includes a center-tapped secondary winding in the transformer.
- It is capable of handling higher voltage and current levels.
- Commonly used in power supply circuits for amplifiers and other high-power applications.

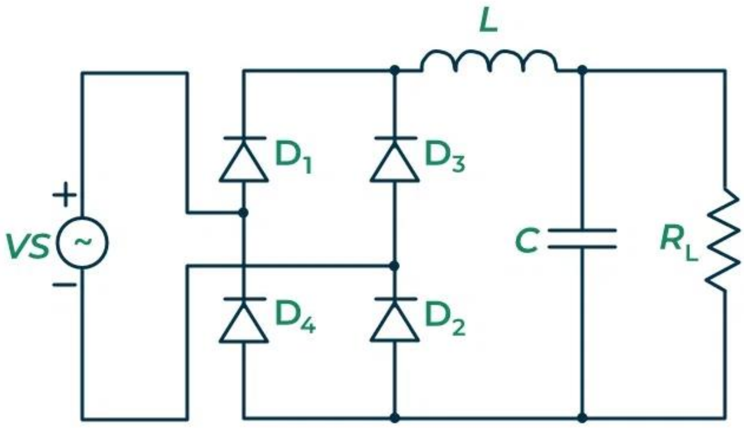
4. Half-wave Bridge Rectifier

- The half wave bridge rectifier utilizes two diodes to convert the AC input, into DC.
- It is a method although not as efficient, as the full wave bridge.
- This type of rectifier is commonly found in low power applications and battery chargers.

5. Full-wave Bridge Rectifier

- The full-wave bridge rectifier employs four diodes to provide full-wave rectification.
- It is highly efficient and widely used for most AC-to-DC conversion applications.
- Commonly found in power supplies, battery chargers, and electronic circuits.

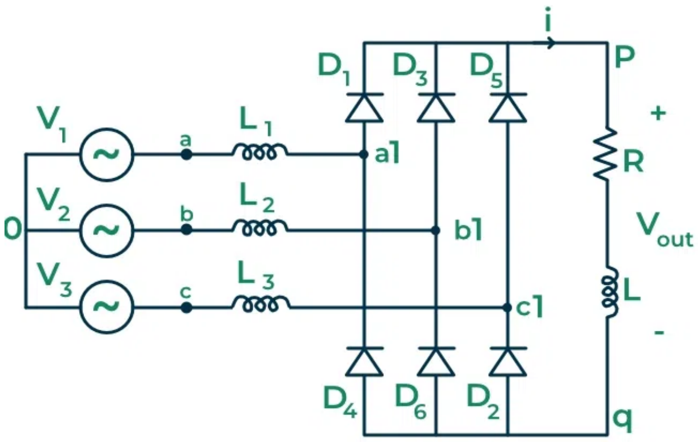
Single-Phase Bridge Rectifier



Working

A single-phase bridge rectifier is a common configuration for converting alternating current (AC) to direct current (DC). It consists of four diodes arranged in a bridge circuit. During the positive half of the AC input cycle, two diodes conduct, allowing the current to flow through them and produce a positive DC output. During the negative half of the cycle, the other two diodes conduct, again producing a positive DC output. This continuous switching of diodes ensures that the output voltage remains in one polarity, resulting in a smooth and constant DC output.

Three-Phase Bridge Rectifier

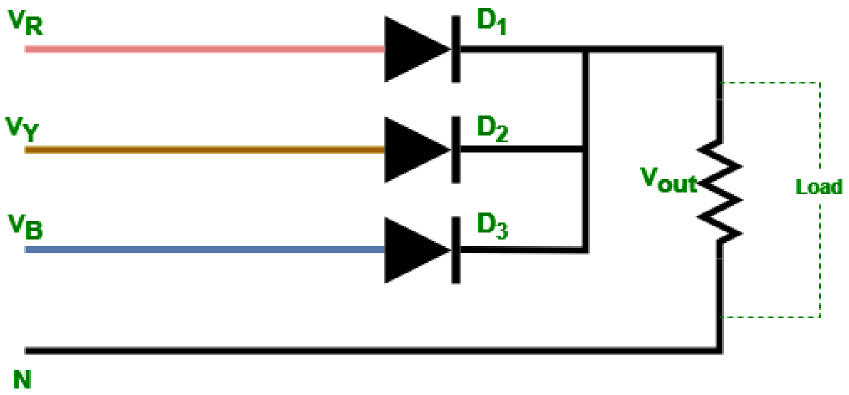


Working

In three-phase systems, where three AC phases are 120 degrees out of phase with each other, a three-phase bridge rectifier is used. This rectifier employs six diodes to rectify all three phases simultaneously. As each phase alternates, the diodes direct the current flow such that there is always at least one path for current conduction. This leads to a smoother DC output with reduced ripple compared to single-phase rectifiers.

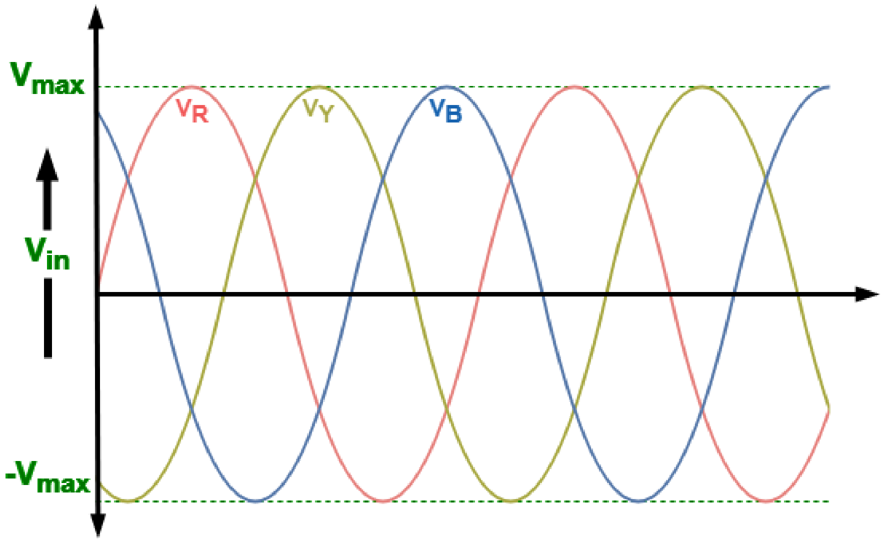
Three Phase Half Wave Rectifier

Three-phase connection is used in households and industries with high power requirements. The main advantage of three phases over a single phase is that they are more efficient. A three-phase AC connection consists of three single phases (Red, Yellow and Blue colored wires are used to represent each of the three phases) AC with a phase difference of 120° connected to the load. So at any time voltage of any one of the phases will be greater than zero and therefore machines operate at a better efficiency. To convert a Three-phase AC supply to DC a three-phase half-wave rectifier is used. To convert a three-phase AC supply to DC, a diode is connected in series to each of the three-phase inputs, such an arrangement is called a three-phase rectifier. So it requires three diodes to convert three-phase AC to DC. The circuit diagram of a three-phase rectifier is given below.



Working of Three Phase Half Wave Rectifier

The below figure shows the input of a three-phase AC supply. You can see that the input of three-phase AC is like that of three single-phases separated by an equal time gap. So when we place a half-wave rectifier in each phase wire, the half-wave rectifier allows it to pass the positive half cycle and prevents the flowing of current in the negative half cycle. Thus it can convert AC to DC.

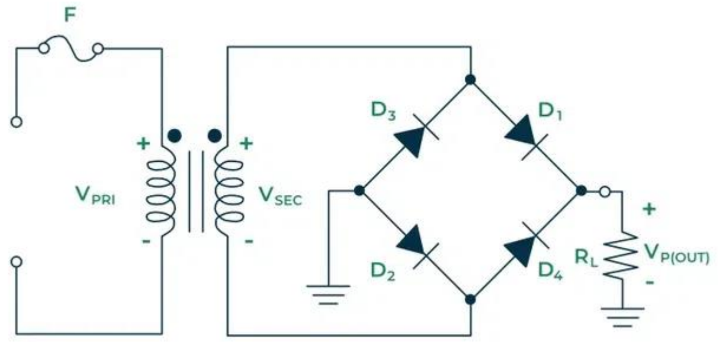


If we consider the red phase alone, In the positive half cycle diode acts as a short circuit and it allows to pass current through it. In a negative half cycle, the diode acts as an open circuit and blocks the flow of current. You can see that in the output waveform given below, red phase voltage is present when it is in the positive half cycle and it is not visible in the negative half cycle.

Similarly, other phases are also rectified by using a diode.

From the output of a three-phase rectifier, You can see that its voltage does not fall into zero like in that of a single-phase rectifier as it uses three phases and at any time any of the three phases will have a positive half-cycle. Thus it has a better supply than that of a single-phase rectifier.

Centre-Tap Bridge Rectifier



Working

The center tap bridge rectifier is a modified version of the single-phase bridge. Along, with the four diodes it incorporates a transformer that has a winding with a center tap. During the cycle one diode allows current to pass through the load. In contrast during the cycle the other diode conducts to ensure that the output remains positive. This configuration enables full wave rectification for both halves of the AC cycle producing a DC output.

Applications of Bridge Rectifier

- Used in power adapters for laptops, phones, and other electronic devices.
- Convert AC power from outlets into DC power to charge batteries.
- Provide DC power for motors and control systems in factories.
- Used in vehicles for charging batteries and powering car accessories.
- Found in appliances like refrigerators, washing machines, and air conditioners.
- Used in LED drivers and lighting control circuits.
- Convert AC signals into DC for audio and radio amplifiers.
- An essential component in various electronic devices and circuits.
- Convert AC power generated by solar panels into DC for use or storage.
- Part of uninterruptible power supplies (UPS) to provide emergency power during outages.
- Used to provide DC power for welding equipment.
- Found in medical equipment like X-ray machines and MRI scanners.
- Used in power supplies for telecom equipment and data centers.

Advantages of Bridge Rectifier

- Bridge Rectifiers are incredibly efficient when it comes to converting alternating AC) into current (DC) ensuring a consistent and stable power supply.
- Their design is compact and space efficient because they only require four diodes, which makes them suitable, for a range of applications.
- Bridge Rectifiers perform full wave rectification meaning they utilize both the negative portions of the AC waveform resulting in a DC output.
- Compared to center tap rectifiers, Bridge Rectifiers eliminate the need for a center tapped transformer simplifying wiring and reducing costs.
- Bridge Rectifiers are readily available and extensively used in electronics making them easily accessible, for projects.

Disadvantages of Bridge Rectifier

- Typically Bridge Rectifiers have a voltage drop compared to other methods of rectification which can result in a small power loss.
- When used in high power applications Bridge Rectifiers generate heat. May require measures, like heat sinks or cooling systems to maintain optimal performance.
- When dealing with AC voltages Bridge Rectifiers may not be as efficient because the voltage drop becomes significant relative to the input voltage.
- For frequency AC inputs Bridge Rectifiers may not be the best choice, as the speed at which the diodes switch can become a limiting factor.
- In current applications it might be necessary to make special arrangements or add extra diodes to handle the load effectively.

4. **Controlled Rectifier**

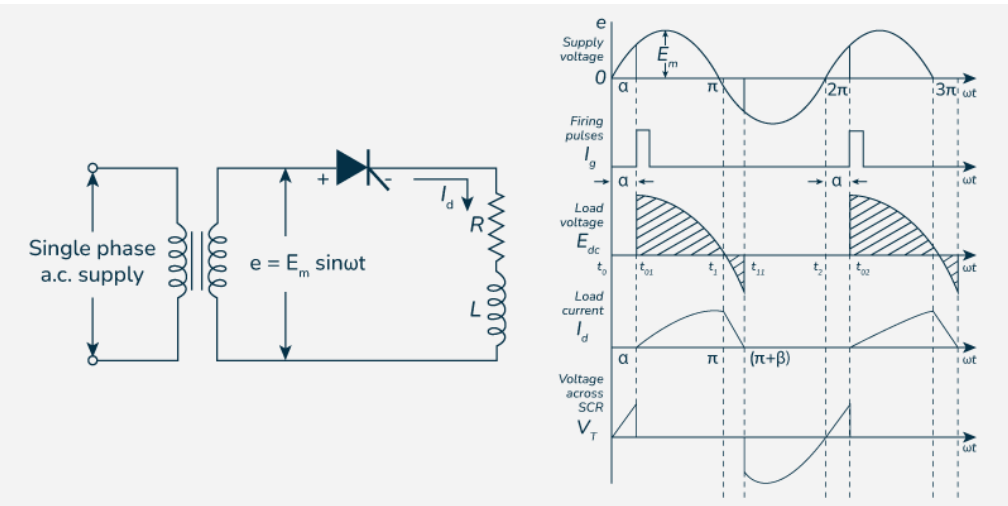
A rectifier whose voltage can be controlled means can be varied is known as a controlled rectifier. For controlling we use SCRs, MOSFET, and IGBT to make the uncontrolled rectifier into a controlled rectifier. These are proffered over the uncontrolled counterparts.

As the SCRs gets on or off at the gate signals then the complete control is established in the rectifier. The gate output is responsible for the controlling of the output voltage .

The controlled rectifier is further classified into the following types:

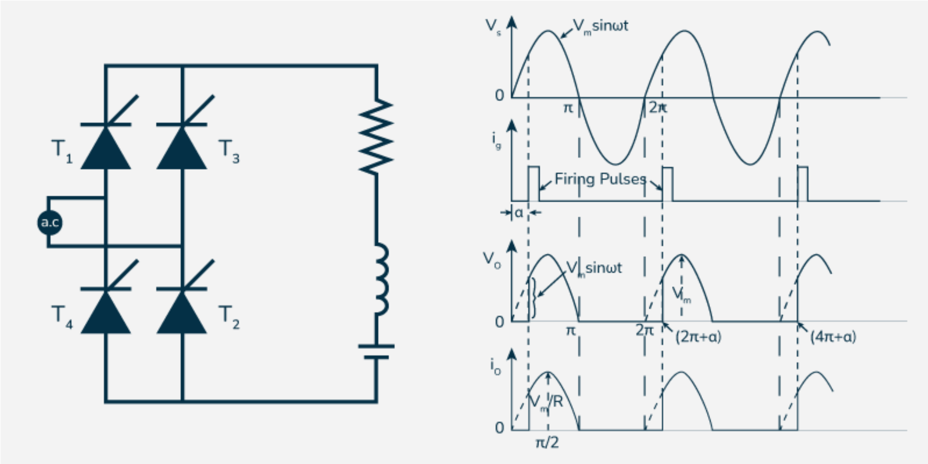
Half-Wave Controlled Rectifier

In a Half wave-controlled rectifier, input AC voltage control only one half cycle of the voltage. It is regulated by using a thyristor to control the current flow. Thyristor turned on when the input AC voltage half-cycle comes allowing current to flow hence one-cycle-half waveforms are generated at the output resulting into generation of DC waveform only on one half cycle as shown below. Therefore, half wave-controlled rectifier cannot regulate output DC waveform as compared to full wave controlled rectifier.



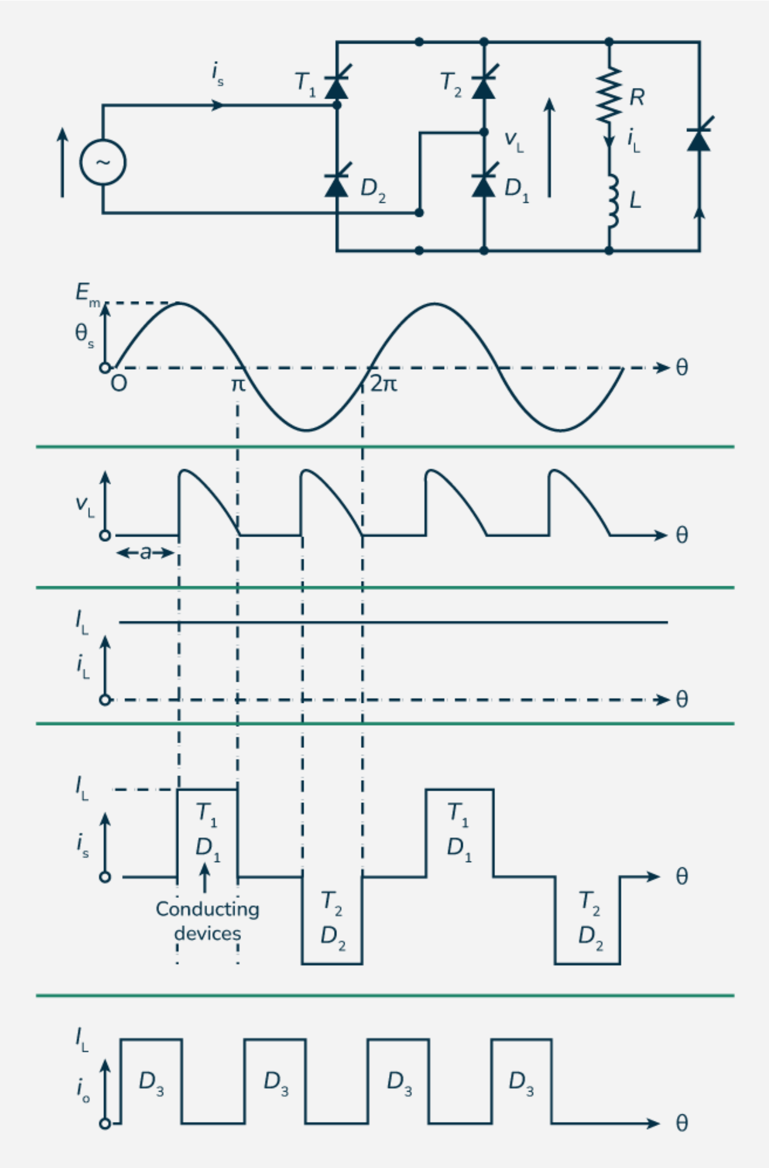
Full Wave Controlled Rectifier

In full wave control rectification, both half-cycles are controlled. Thyristors are employed in to regulate currents flowing in either direction. The administering of control signals to turn ON the thyristors; which conduct during both half-cycles of the input AC voltages, results into flowing across them leading to production of DC with complete cycle waveshape output. Constructed with HTML tags. Is well as bursts than perplexing; even though the number of words has not been changed.



Controlled Bridge Rectifier

A control bridge rectifier is a circuit that converts alternating current to direct current using four diodes in bridge configuration. It uses thyristors or similar devices to regulate the output voltage. The bridge rectifier's output voltage and current can be regulated or adjusted as necessary by addition of these extra control components. This feature brings about a finer control of the DC output and is what makes the control bridge rectifiers appropriate for applications requiring variable DC outputs such as motor speed control, power supplies, and battery charging systems.



Benefits

- Controlled Output: The output voltage can be precisely controlled thanks to the thyristors' adjustable firing angle.
- Complete Utilization of AC Input: By utilizing the entire AC input, efficiency is increased.
- Versatility: Adaptable DC output allows for use in a wide range of applications.

Uses

- DC motor drives
- DC power supply that are changeable
- Circuits for charging batteries
- Control systems for industry

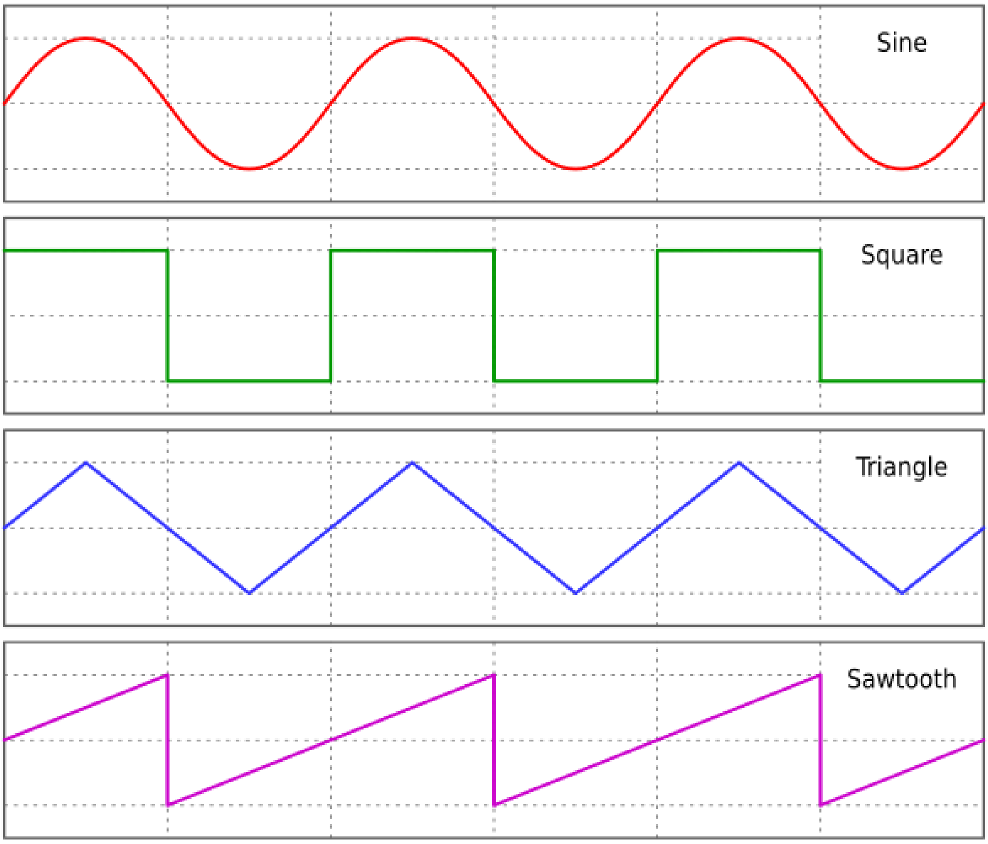
2.2 DC to AC Converters

DC to AC converters is commonly known as **inverters**. These are electronic devices that convert direct current into alternating current. Inverters are used in a variety of applications including renewable energy systems, where they convert DC from solar panels or batteries to AC for use in homes and businesses, as well as in electric vehicles, where they convert DC from the battery to AC for the electric motor.

One of the most common techniques used in DC to AC converters is Pulse Width Modulation (PWM). Pulse Width Modulation (PWM) is a method in which the inverter switches the DC input on and off at a high frequency, varying the duration of the 'on' time (pulse width) to control the power delivered to the load. By adjusting the pulse width, PWM can simulate various voltage levels of an AC waveform. High-frequency switching requires the use of solid-state electronics, such as transistors or other types of power switches.

Another technique for DC to AC conversion is using H-bridge inverters. An H-bridge is a circuit configuration commonly used in inverters to facilitate the polarity reversal necessary for AC generation. It consists of four switches that can be controlled to connect the load to the power supply in either polarity. When two diagonally opposite switches in the H-bridge are closed, current flows in one direction through the load. By opening those switches and closing the opposite pair, the current flow is reversed, creating the alternating nature of the output current.

There are **three types of output waveforms** an inverter can produce:
Square Wave: The simplest form of output, not often used due to its high harmonic content which can be damaging to sensitive electronics.
Modified Sine Wave: A compromise between complexity and quality, with a waveform that more closely resembles a sine wave but still has significant harmonic distortion.
Pure Sine Wave: The most desirable form of AC output, closely matching the power supplied by utilities, is ideal for all types of appliances, especially sensitive electronics.



2.3 DC to DC Converters

DC to DC converters are electronic devices or circuits that convert direct current (DC) electrical power from one voltage level to another. They are essential in many electronic applications where the voltage supplied by batteries or power supplies does not match the voltage required by the electronic components or circuits.

There are **several types of DC-to-DC converters**, each suited for different applications. The most common types include:

1. **Linear Regulators**

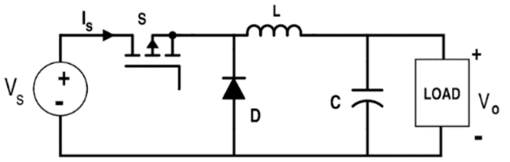
These are the simplest form of DC-to-DC converters and operate by dissipating excess voltage as heat to maintain a constant output voltage. They are known for their simplicity, low noise output, and fast response to changes in load, but they are inefficient for large differences between input and output voltages because they waste a lot of power as heat.

2. Switched-Mode Power Supplies (SMPS)

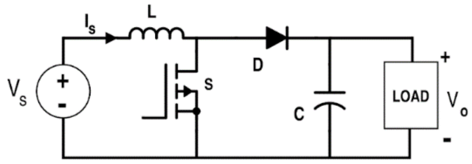
These converters use a switching element that turns on and off rapidly, combined with inductors and capacitors, to regulate the output voltage.

The primary types of SMPS (Switched-Mode Power Supplies) include:

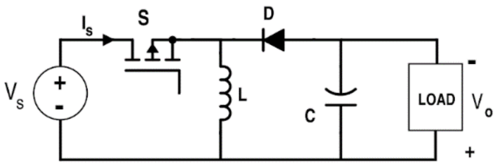
Buck Converters: Also known as step-down converters, which reduce the input voltage to a lower output voltage.
Boost Converters: Also known as step-up converters, they increase the input voltage to a higher output voltage.
Buck-Boost Converters: These can either increase or decrease the input voltage depending on the design and requirements.
Cuk Converters: Like buck-boost converters, these converters differ in that their output reverses polarity.



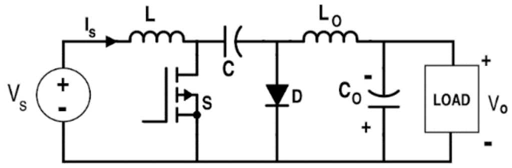
Buck Converter



Boost Converter



Buck-Boost Converter



Cuk Converter

SMPS are more efficient than linear regulators, especially when there is a significant difference between input and output voltages, because they transfer energy via a switch without dissipating it as heat.

3. Isolated Converters
These provide electrical isolation between their input and output, which is critical for safety and noise reduction in sensitive electronic systems. Types of isolated converters include flyback, forward, push-pull, half-bridge, and full-bridge converters.

2.4 AC to AC Converters

An AC-to-AC converter is a type of power electronic device that is designed to convert AC electrical power from one waveform to another. This conversion can involve changes in the amplitude, frequency, or phase of the AC signal.

AC to AC converters is used in various applications where the modification of AC power is required. For example, they are essential in applications such as variable-frequency drives for controlling the speed of AC motors, power supplies for devices that require different voltage levels or frequencies than what is provided by the main power grid, and in uninterruptible power supplies (UPS) that may need to regulate and condition the power before delivering it to sensitive equipment.

AC-AC Voltage Controller Converter (AC Choppers)

AC choppers are a type of converter that directly controls the voltage amplitude of the AC supply without changing the frequency. They achieve this by selectively chopping parts of the input voltage waveform using switches such as thyristors, triacs, or transistors. By controlling the conduction angle or the duration for which the switch is on during each half-cycle of the AC waveform, the average output voltage can be varied. This method is often referred to as phase control. AC choppers are commonly used in light-dimming circuits, speed control of single-phase AC motors, and heating applications.

3. **AC Cycloconverter**

Cycloconverters are converters that change the input AC frequency to a lower output frequency without an intermediate DC link. They are essentially direct frequency converters that use controlled semiconductor switches to synthesize the low-frequency output from segments of the input AC waveform.

Cycloconverters are mainly classified into two types: step-down cycloconverters, which produce an output frequency lower than the input frequency, and step-up cycloconverters, which are less common due to their complexity and are used to produce a higher output frequency. Cycloconverters are suitable for applications requiring large power and low frequency, such as in driving large motors for rolling mills.

3.1 Matrix Converter

Matrix converters, direct AC-AC converters, utilize an array of controlled bi-directional switches to connect the input phases to the output phases. Unlike other converters, matrix converters do not require any intermediate energy storage components like capacitors or inductors. The switches are arranged in a matrix form, and by appropriately timing the switching actions, the converter can produce an output voltage with adjustable magnitude and frequency. Matrix converters are capable of bidirectional power flow, which makes them suitable for regenerative braking applications where energy can be fed back into the power supply. They are used in high-performance drive applications, such as machine tools and aircraft power systems.

Factors to Consider While Selecting Power Converters

When selecting power converters, several critical factors must be taken into consideration to ensure that the chosen converter is suitable for the intended application.

Firstly, the input and output voltage requirements are fundamental parameters. The converter must be able to accept the available input voltage and provide the necessary output voltage for the load.

Secondly, the current demands of the load are equally important. The converter must be able to supply the maximum current required by the load without overheating or becoming unstable. It is also beneficial to consider future scalability in case the system's power requirements increase.

Thirdly, efficiency is a key factor, especially for battery-powered or energy-sensitive applications.

Additionally, the converter's form factor and footprint must be compatible with the application's space constraints. The miniaturization of electronics has made this an increasingly important consideration.

Finally, while cost is always a consideration, it should be balanced against the aforementioned factors to ensure that neither quality nor suitability is compromised for the sake of upfront savings.

Practical Activity 1.3.3: Select power converter

Task:

Task 1: referring to key reading 1.2.1 you are requested:

As electronic technician you are asked to select a power converter according to the work you are going to perform

Task 2: Perform the given tasks.

Task 3: Present your work to the trainer and whole class.

Task 4: Read key reading 1.3.3 and ask clarification where necessary

Task 5: Perform the task provided in application of learning 1.3.

Key readings 1.3.3: Select power converter

Selecting power converter

How to select power converter

When choosing a power converter, there are a few key factors you need to take into consideration such as:

- The specific application or use case for the converter
- The voltage requirements of the application
- The amperage (or current) requirements of the application

Other considerations may also come into play depending on your unique situation. But, these are some of the most common and important ones to keep in mind. Let's briefly explore each one in turn so that you can be sure you're making the best choice for your needs.

Use Case for the Converter

The first factor to consider is the specific application or use case for the converter. As we discussed, there are many different applications that may require an AC/DC converter. And each one will have different power requirements. So, it's important to know exactly what you need the converter for before making a purchase. This way, you can be sure you're choosing a model that is best suited for your needs.

This will also help you consider specific ratings that matter for your use case. Consider whether your application requires a UL Listed vs UL recognized power supply, for example.

Voltage Requirements

Next, you'll need to consider the voltage requirements of your application. Voltage refers to the amount of pressure behind the electrical current. It's essentially how much 'power' is behind the current flowing through wires. Most small electronic devices like laptops and smartphones operate on low-voltage currents (usually between three and twelve volts). But if you're looking for a converter for more industrial use - like in the medical field or in a crypto mining operation - you will need a more powerful voltage.

However, some industrial applications like X-ray machines may require much higher voltages. Going back to the use-case consideration, medical equipment also has specific safety ratings you need to take heed of when choosing your converter. As such, you'll want to seek out a specialized medical power supply. Learn more in our blog post explaining what medical power supplies are. For now, let's move on to the final consideration when choosing an AC DC power converter: amperage requirements.

Amperage Requirements
In addition to voltage, you also need to consider amperage or current. Amperage refers to the amount of electrical current flowing through wires. It's essentially how much 'power' is being used by an electronic device.

Just like the voltage requirements, amperage requirements will vary depending on the application. Small electronic devices usually have lower amperage requirements than industrial applications - just like with voltage. Do some research on the device you're looking to convert power for to determine the ideal amperage of your adaptor.

Other Considerations When Choosing an AC DC Converter
There are a few other considerations you may need to consider when choosing an AC/DC converter such as:

- The size of the unit
- The efficiency rating
- The warranty
- Efficiency
- Cost
- Size
- Reliability
- Compatibility

How do you choose the right power converter for your device?
1 Identify your power requirements
The first step to choose a power converter is to determine the input and output specifications of your device, such as voltage, current, power, frequency, and waveform. You can find this information in the datasheets, manuals, or labels of your device and the power source. For example, if you want to power a laptop that requires 19 V DC and 3.42 A from a wall outlet that provides 120 V AC and 60 Hz, you will need a power converter that can convert the AC input to the DC output with the appropriate voltage and current ratings.

2 Choose the type of power converter
The next step is to choose the type of power converter that suits your device and application. There are two main types of power converters: AC-DC and DC-DC. AC-DC converters, also known as rectifiers, convert alternating current (AC) to direct current (DC), while DC-DC converters change the voltage or current level of a DC source. Depending on your device, you may need one or both types of

converters. For example, if you want to power a LED light that requires 12 V DC and 0.5 A from a solar panel that provides 24 V DC and 1 A, you will need a DC-DC converter that can step down the voltage and limit the current.

3 Compare the performance and features of power converters

The third step is to compare the performance and features of different power converters that meet your power requirements and type. Some of the key performance metrics are efficiency, ripple, regulation, and transient response. Efficiency is the ratio of output power to input power, and it indicates how much power is lost as heat during the conversion. Ripple is the amount of variation or noise in the output voltage or current, and it affects the stability and quality of the power supply. Regulation is the ability of the converter to maintain a constant output voltage or current despite changes in the input or load. Transient response is the speed and accuracy of the converter to adjust to sudden changes in the input or load. Some of the features that you may look for are protection circuits, isolation, feedback, and synchronization. Protection circuits prevent damage from overvoltage, overcurrent, short circuit, or reverse polarity. Isolation separates the input and output circuits electrically, which improves safety and reduces interference. Feedback is a mechanism that monitors and controls the output voltage or current using a sensor and a controller. Synchronization is a function that allows multiple converters to operate in phase with each other or with an external signal.

4 Evaluate the cost and availability of power converters

The fourth step is to evaluate the cost and availability of different power converters that meet your performance and features criteria. Cost is an important factor that affects your budget and profitability, and it depends on the complexity, quality, and quantity of the converter. Availability is another factor that affects your delivery time and flexibility, and it depends on the supply and demand of the converter. You can find the cost and availability information from the manufacturers, distributors, or online platforms that sell power converters. You can also compare the prices and reviews of different brands and models of power converters.

5 Consider the size and reliability of power converters

The fifth step is to consider the size and reliability of different power converters that meet your cost and availability criteria. Size is a factor that affects the space and weight of your device, and it depends on the design, components, and cooling system of the converter. Reliability is a factor that affects the lifespan and performance of your device, and it depends on the quality, testing, and maintenance of the converter. You can find the size and reliability information from the datasheets, specifications, or ratings of the power converters. You can also check the warranty and support policies of the power converters.

6 Test and verify the power converter for your device

The final step is to test and verify the power converter for your device before using it in your application. Testing and verification are essential to ensure that the power converter meets your expectations and requirements, and to avoid any problems or failures in the future. You can test and verify the power converter using a multimeter, an oscilloscope, a load bank, or a power analyser. You can also simulate the power converter using software tools, such as PSpice, LTspice, or Simulink. You should test and verify the power converter under various input and output conditions, such as voltage, current, frequency, load, temperature, and humidity.

Points to Remember

- When selecting a power converter, you consider the following factors

1. The specific application or use case for the converter
2. The voltage requirements of the application
3. The amperage (or current) requirements of the application

Application of learning 1.3.

BCD Group repair different home appliances like radios, TV, and photovoltaic home system wants to hire technician who can explain to the clients' different types of power converters, you are one of those technicians and your job is to describe and select AC to DC converter and DC to AC basing on client's needs and requirements.

Indicative content 1.4: Soldering Power Electronic Components

Duration: 1hrs

Theoretical Activity 1.4.1: Soldering Power electronic components

Tasks:

1: Read carefully the following questions:

I. What is printed circuit board?

II. What are the function of PCB

III. Outline different types of PCB do you know?

2: Provide the answer for the asked questions and write them on papers.

3: Present the findings/answers to the whole class

4: Ask clarification if any.

Key readings 1.4.1.: Soldering Power electronic components

2. Printed Circuit Boards (PCB)

A Printed Circuit Board (PCB) is a crucial component in electronic devices that provides the physical support and electrical connections for electronic components.

2.1 Structure and Composition of PCB

- **Substrate:** The base layer of a PCB is typically made from a non-conductive material such as fiberglass (FR4) or plastic. This provides mechanical support and insulation.
- **Conductive Layers:** Copper traces are used to create electrical pathways on the board. These traces are etched onto the substrate and connect various components.
- **Solder Mask:** A protective layer of solder mask is applied over the copper traces to prevent accidental soldering and short circuits. It also provides insulation.
- **Silkscreen Layer**: This layer is used for printing component labels, symbols, and other information on the board to help with assembly and troubleshooting.

2.2. Functions of PCB

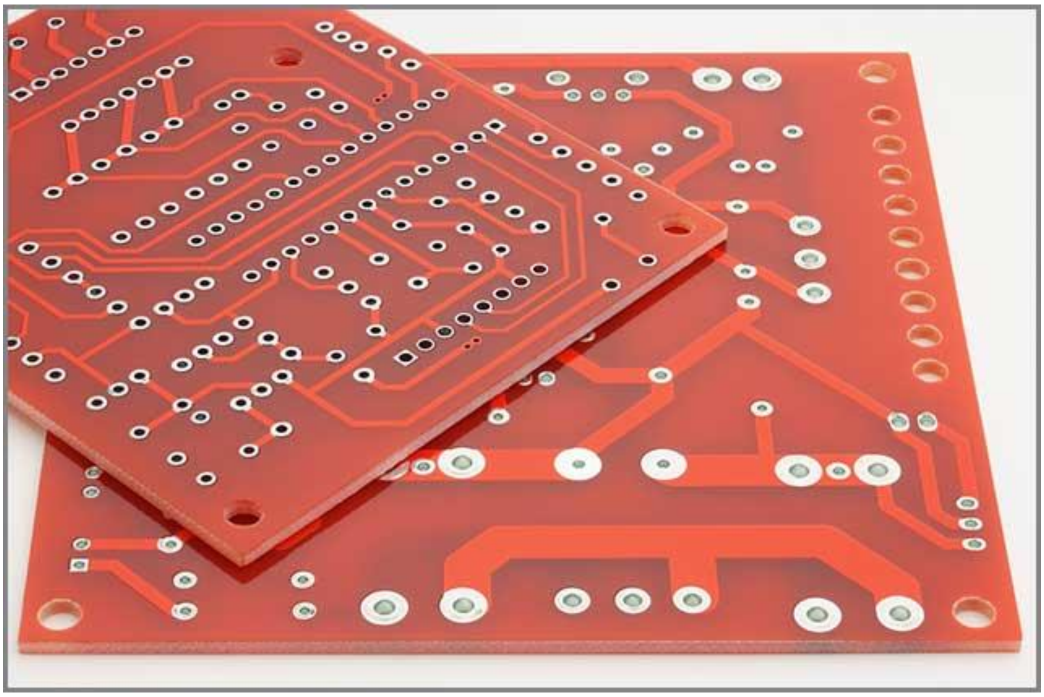
- **Mechanical Support:** PCBs provide a sturdy platform to mount electronic components. This allows for precise and stable placement of components.
- **Electrical Connections:** The copper traces create electrical pathways that connect different components, allowing signals and power to flow between

them.

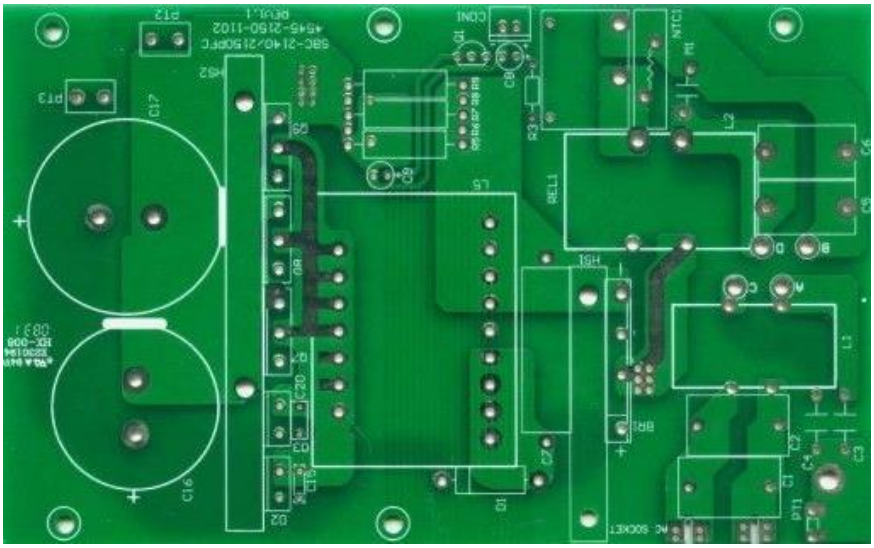
- **Heat Dissipation:** Certain PCBs, especially those with metal cores, are designed to dissipate heat away from high-power components to prevent overheating.
- **Signal Integrity:** PCBs help maintain signal integrity by controlling the layout and routing of traces, which minimizes signal interference and loss.

2.3 Types of PCBs

- **Single-Sided PCBs:** A single-sided PCB is a type of PCB where the components and conductive copper are mounted on one side and the conductive wiring is on the other side.

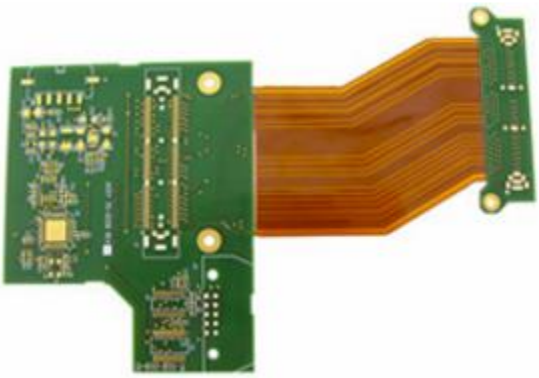


- **Double-Sided PCBs:** Components and traces are on both sides of the board, with connections made via plated-through holes.

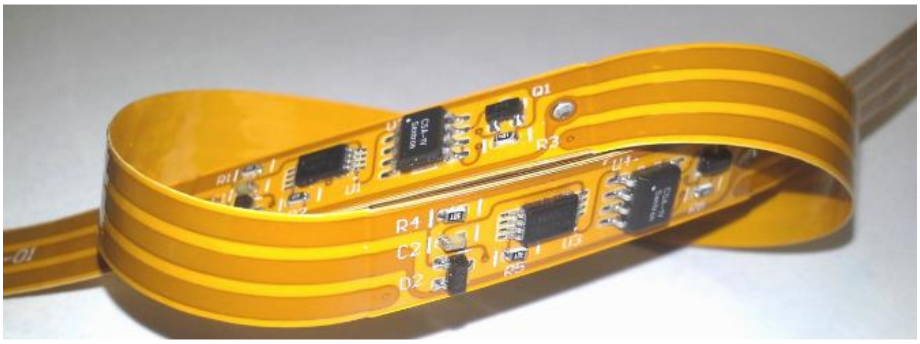


- **Multi-Layer PCBs:** Consist of multiple layers of conductive material separated by insulating layers, allowing for complex and high-density circuits.

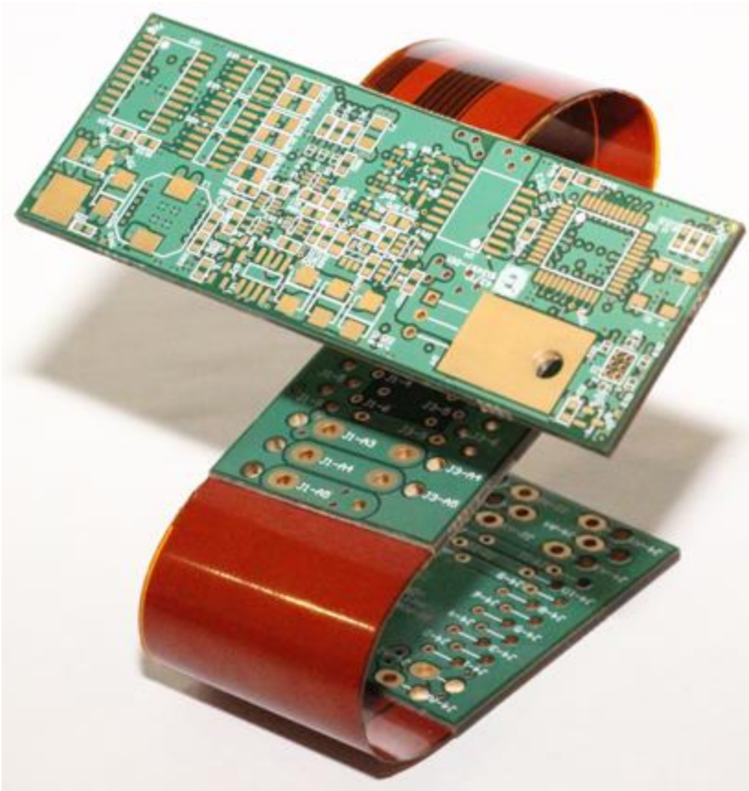
- **Rigid PCB**: it is a form of circuit board which is solid and inflexible in its structure and therefore cannot be bent or flexed.



- **Flexible PCBs:** Made from flexible materials, allowing them to bend and fit into tight spaces.



- **Rigid-Flex PCBs:** Combine rigid and flexible layers, useful in designs that require both rigidity and flexibility.



2.4 Applications of PCBs

PCBs are used in virtually all electronic devices, including:

- **Consumer Electronics:** Smartphones, computers, TVs, and home appliances.
- **Automotive Electronics:** Control units, sensors, and entertainment systems.
- **Medical Devices:** Monitors, diagnostic equipment, and therapeutic devices.
- **Industrial Equipment:** Machinery control systems, sensors, and automation

Practical Activity 1.4.2: Apply soldering technics

Task:

1: Read carefully the following questions:

Perform the soldering of MOSFETs on PCB using hand soldering technic.

2: Perform the given tasks by respecting the given instructions.

4: Present your work to the trainer.

5: Read key reading 1.4.2 and ask clarification where necessary

6: Perform the task provided in application of learning 1.4.

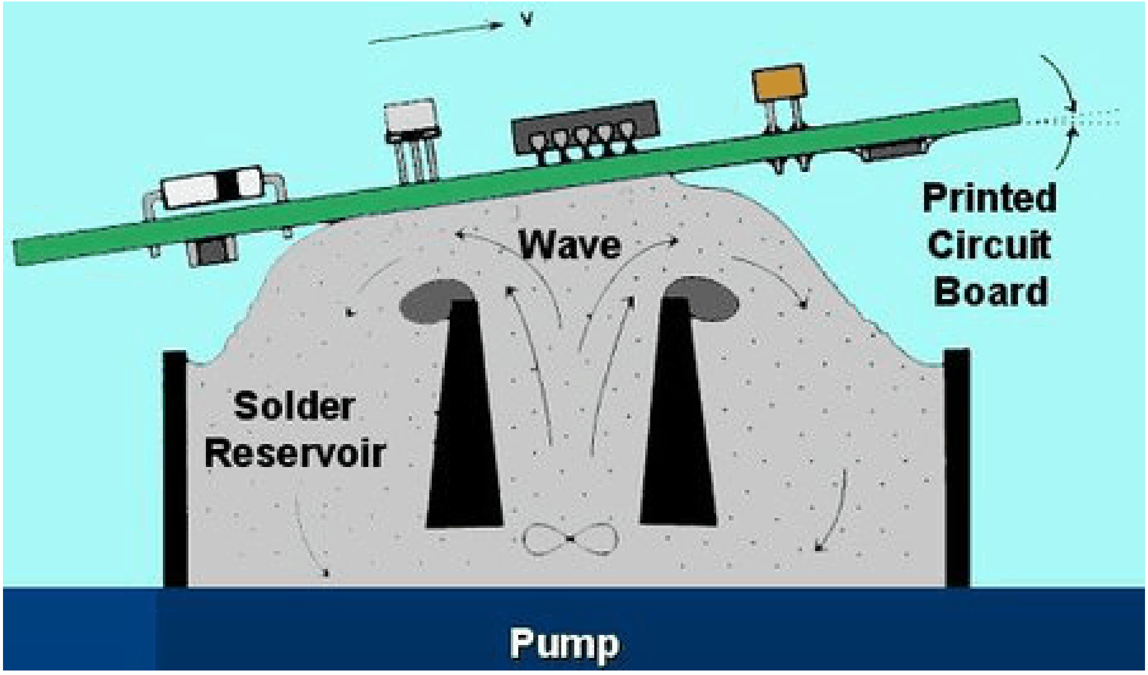
Key readings 1.4.2: Apply soldering technics

1. Soldering technics

1.1 Wave soldering

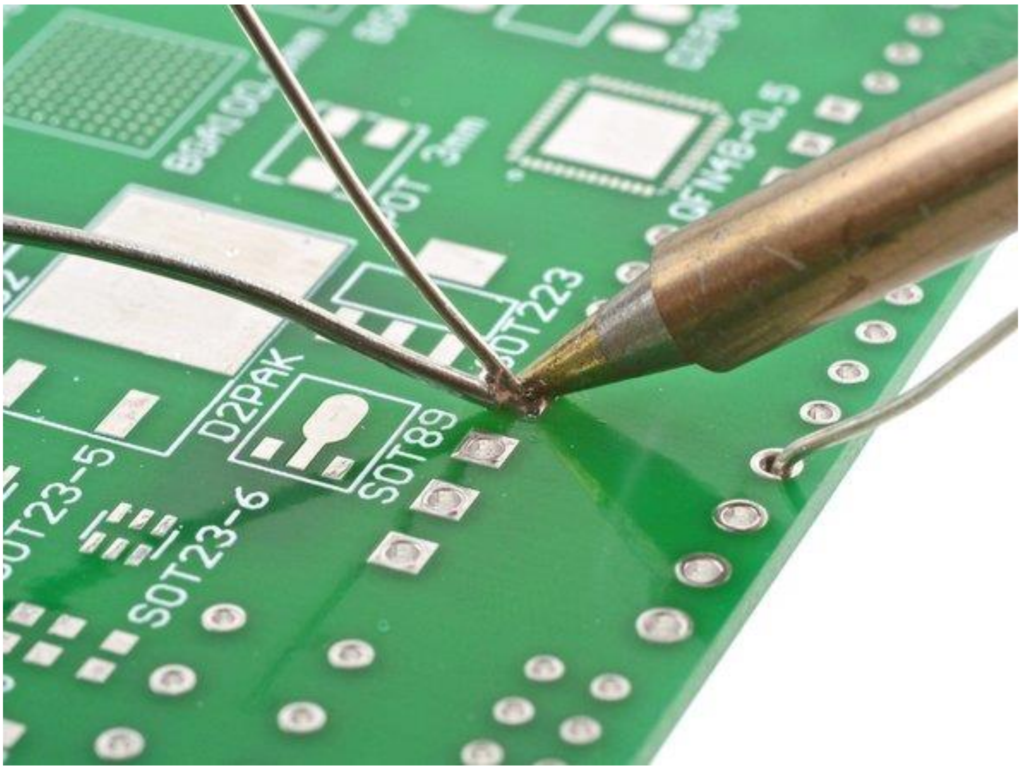
Wave Soldering is the process of soldering through hole components onto a PCB by passing the exposed leads of the components placed on a board over a wave of molten solder.

Applications: Efficient for large production runs and when many through-hole components are used.



1.2 Hand soldering

Hand soldering involves using a soldering iron to manually apply solder to individual joints.



1.3 Selective soldering

Selective soldering is an automated soldering process by which components are soldered to a PCB all at once or in very quick succession only specific areas of a PCB via means of automation.

1.4 Reflow soldering

Solder reflow is a critical process in the electronics industry, primarily used to attach surface-mount components to printed circuit boards (PCBs). It involves applying solder paste to specific locations on a PCB, placing the components on the paste, and then heating the assembly in a reflow oven.

Points to Remember

Soldering technics:

- **Wave soldering:** Wave Soldering is the process of soldering through hole components onto a PCB by passing the exposed leads of the components placed on a board over a wave of molten solder.
- **Hand soldering:** Hand soldering involves using a soldering iron to manually apply solder to individual joints.
- **Selective soldering:** Selective soldering is an automated soldering process by which components are soldered to a PCB all at once or in very quick succession only specific areas of a PCB via means of automation.
- **Reflow soldering:** Solder reflow is a critical process in the electronics industry, primarily used to attach surface-mount components to printed circuit boards

(PCBs).

Practical Activity 1.4.3: Applying steps of soldering PCB

Task:

1: Read carefully the following questions:

Perform the soldering of a MOSFET on PCB according to the steps of soldering on PCB.

2: Perform the given tasks by respecting the given instructions.

4: Present your work to the trainer.

5: Read key reading 1.4.2 and ask clarification where necessary

6: Perform the task provided in application of learning 1.4.

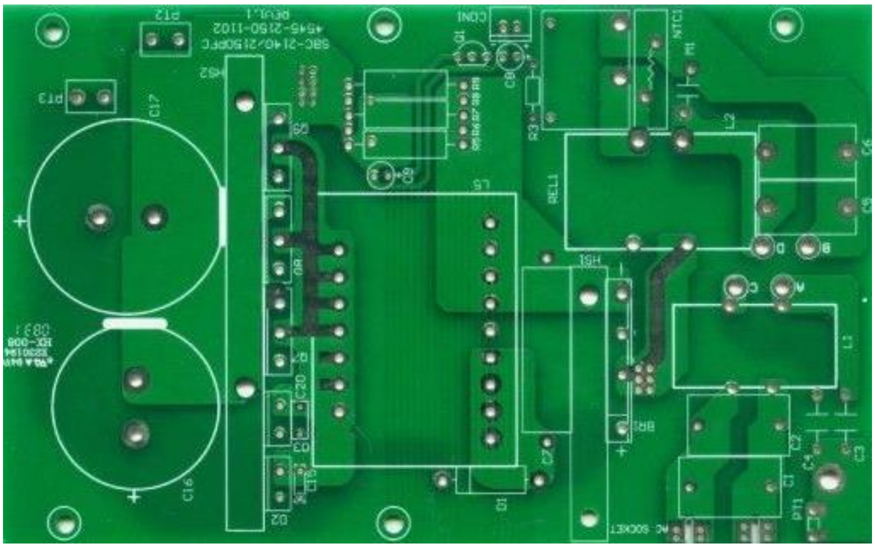
Key readings 1.4.3: Applying steps of soldering PCB

1. Steps of soldering PCB

Here's a general guide to the process:

1.1 Preparation

- **Gather Tools and Materials:** Soldering iron, solder (typically lead-free or leaded), soldering flux, PCB, electronic components, tweezers, solder wick, and a soldering iron tip cleaner.



- **Clean the PCB:** Ensure the PCB is clean and free from dust or oils. You can use isopropyl alcohol and a brush for this.

1.2. Assembling the materials

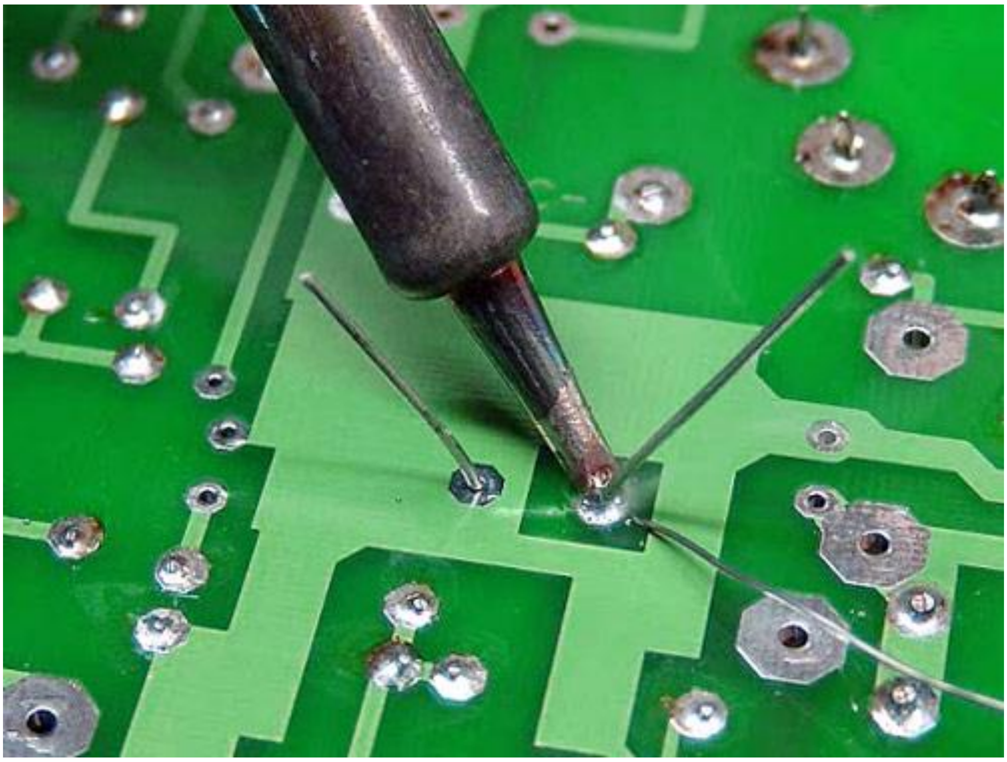
- **Identify Component Placement:** Check the PCB design or schematic to know where each component goes.
- **Insert Components**: Place each component into its respective holes or slots on the PCB. For through-hole components, insert the leads through the holes; for surface-mount components, place them on the surface pads.
- **Temporary Securing:** For through-hole components, bend the leads slightly to hold the component in place. For surface-mount components, you might use a small amount of solder or double-sided tape to keep the component steady.

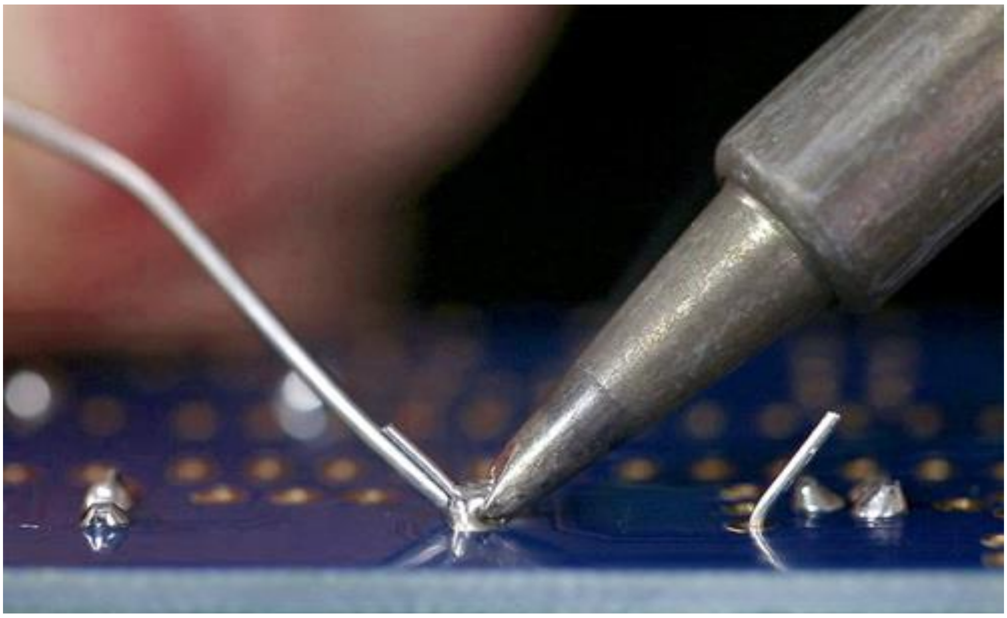
1.3. Tinning: Tinning involves applying a thin uniform coating of solder to the two surfaces that will be coming into contact with each other.

1.4. Soldering

- **Heat the Soldering Iron:** Preheat your soldering iron to the appropriate temperature (usually around 350°C or 662°F).

- **Apply Solder:** For each connection:
- **Through-Hole Components:** Heat the solder pad and the component lead simultaneously with the soldering iron. Feed solder into the joint and remove the soldering iron, allowing the solder to cool and solidify.
- **Surface-Mount Components:** Heat the pad and the component lead or body, then apply solder to the joint. Be careful to avoid creating solder bridges between adjacent pads.





- **Inspect Joints**: Make sure each joint is well-soldered, with a clean, shiny appearance and no cold solder joints or bridges.

1.5. Cleaning:

- **Remove Residual Flux:** Use isopropyl alcohol and a brush or cloth to clean off any residual flux or soldering debris from the PCB.

1.6. Inspection and Testing

- **Visual Inspection:** Check for solder bridges, cold solder joints, and component alignment.
- **Test the PCB:** Conduct functional tests to ensure that the PCB works as intended. You might use a multimeter to check for shorts and continuity.

1.7. Finishing(Final Adjustments)

- **Rework if Necessary:** If you find any issues during testing, reheat and adjust the solder joints or components as needed.

Final Clean-Up: Ensure the PCB is clean and free from any solder splashes or debris.

Points to Remember

- **Steps of soldering PCB:**

✓ Preparation
✓ Assembling the materials
✓ Tinning:
✓ Soldering:
✓ Cleaning
✓ Inspection and Testing
✓ Finishing (Final Adjustments)

Application of learning 1.4.

MPXY ltd is company which build power inverters used in solar panel systems. The company has different department, including Sales Department, Marketing Department, Design Department, Production Department, HR Department and Finance Department. The Company need to hire five (5) electronic technicians who will work in Production Department and their daily responsibility is to solder specified power electronic components on PCB. The company prepared the practical examination for shortlisted candidates, and you are one of them. The exam was to appropriately solder MOSFET, IGBT and full wave bridge rectifier components on PCB using hand soldering technic .

Indicative content 1.5: Selecting Equipment, Tools, and Materials

Duration: 1 hrs

Theoretical Activity 1.5.1: Selecting equipment, tools and materials

Task:

1: Answer the following questions:

i. Define a tool and give two examples?
ii. Define a material and give two examples?
iii. Define a equipment and give 2 examples?
iv. What are the criteria to follow when selecting tools, materials and equipment?
v. Classify different types of tools

2: Write the answers on flipchart/ paper
3: Present the findings to the trainer and whole class
4: Ask for clarification if any
5: Read the key readings 1.5.1.in the manual

Key readings 1.5.1: Selecting equipment, tools and materials

1. **Tools:** a device or implement, especially one held in the hand, used to carry out a particular function. A tool is any instrument or simple piece of equipment that you hold in your hands and use to do a particular kind of work

   Example: soldering iron, screwdriver, pliers.

1.1.Universal screwdriver

1.2. Screwdriver is a tool, manual or powered, for screwing and unscrewing (inserting and removing) screws. A typical simple screwdriver has a handle and a shaft, ending in a tip the user puts into the screw head before turning the handle. Something that is universal relates to everyone in the world or everyone in a particular group or society.

1.3. Flat screwdriver: Is screwdriver with a wedge-shaped flat tip ,used to tighten or loosen screws that have a straight, linear notch in their heads**.**

1.4. Soldering iron: Soldering is a process used for joining metal parts to form mechanical or electrical bonds. It typically uses a low melting point metal alloy (solder) which is melted and applied to the metal parts to be joined and this bonds to the metal parts and forms a connection when the solder solidifies

1.5. Pliers: Pliers are a tool with two handles at one end and two hard, flat, metal parts at the other. Pliers are used for holding or pulling out things such as nails, or for bending or cutting wire. Attach the chain to the bag with the pliers

2. **Materials:** are the matters or substance that objects are made from. A material is a chemical substance or mixture of substances that constitute an object.
   Example: electronic components, soldering tin, glue.

2.1.Electronic components:

An electronic component is any basic discrete electronic device or physical entity part of an electronic system used to affect electrons or their associated fields. Electronic components have a number of electrical terminals or leads.

2.2. Soldering tin:

Solder is a fusible metal alloy used to create a permanent bond between metalwork pieces. Solder is melted in order to wet the parts of the joint, where it adheres to and connects the pieces after cooling. Metals or alloys suitable for use as solder should have a lower melting point than the pieces to be joined.

2.3. Glue: Is a solution of glue used for sticking things together

3. **Equipment:** it is defined as the necessary items for a particular purpose.

Equipment consists of the things, which are used for a particular purpose

Example: digital multimeter. DC power supply, soldering station, …

3.1. Personal protective equipment (PPE) is protective clothing, helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury or infection. The hazards addressed by protective equipment include physical, electrical, heat, chemicals, biohazards, and airborne particulate matter

3.2.digital multimeter:

A digital multimeter (DMM) is a versatile electronic device used to measure various electrical properties, including voltage, current, and resistance. The device displays the measurements on a digital screen, making it easy to read and understand the results accurately

3.3.DC power supply:

A direct current (DC) power supply is a device that converts alternating current (AC) to direct current (DC), or from one voltage to another. Most electronic devices and circuits are powered by a DC power supply. The majority of DC power supplies are in the form of wall adapters. It plugs into a standard AC outlet and outputs a fixed quantity of DC voltage, typically 5 or 12 volts

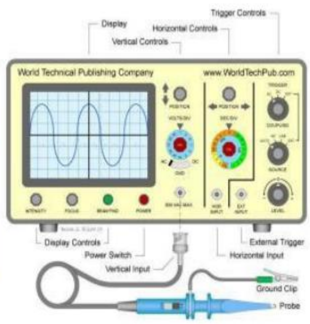
3.4. Soldering station:

A soldering station is a multipurpose power soldering device designed for electronic components soldering. This type of equipment is mostly used in electronics and electrical engineering.

3.5.Oscilloscope(CRO):

An oscilloscope displays time-varying signals like voltage waveform patterns on a screen

which help in visualizing the circuit functions.



3.6.Function generator :

A function generator is usually a piece of electronic test equipment or softwareused to generate different types of electrical waveforms over a wide range of frequencies. Some

of the most common waveforms produced by the function generator are the sine wave, square wave, triangular wave and sawtooth shapes.

4. the criteria to follow when selecting types of tools, materials, and equipment are
    - work to be done
    - Size
    - Ease to use
5. Classification of tools are

5.1. Repairing tools

- Soldering irons
- Screwdrivers
- Pliers
- Cable cutters
- Crimping tools
- Cutting tools

5.2. Cleaning tools

- Brushes
- Sponge
- Soft cloth

Practical Activity 1.5.2: select tools, materials and equipment

Task:

1: Read the given task

As electronic technician, select the required tools, materials, and equipment to be used when replacing protection fuse in Adjustable DC power supply(1.5-20V,30A) .

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 1.5.2 and ask clarification where necessary

5: Perform the task provided in application of learning 1.5

Key readings 1.5.2: select tools, materials and equipment

1. **Multimeter:**

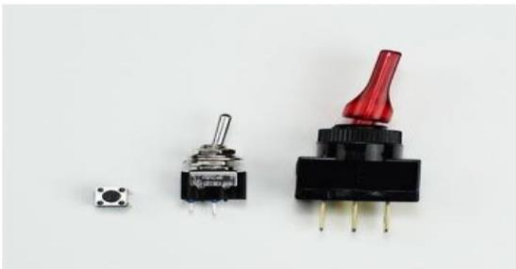
A multimeter is quite important as it measures voltage, current, resistance, and other aspects of electricity and circuits. Usually, these are small in size, run on batteries, and carry large digital displays. There is also a knob to select the measurement function and a pair of test leads for connecting the device to the circuit.

2. **Switch :**

Switches can come in many forms such as pushbutton, rocker, momentary and others.

Their basic function is to interrupt electric current by turning a circuit on or off.

The symbol of switch is



3. **Fuses:**

In electronics and electrical engineering, a fuse is an electrical safety device that operates

Points to Remember

- **Materials:** are the matters or substance that objects are made from. A material is a chemical substance or mixture of substances that constitute an object.
- Example: electronic components, soldering tin, glue.
- **Equipment:** it is defined as the necessary items for a particular purpose.
- Equipment consists of the things, which are used for a particular purpose
- Example: digital multimeter. DC power supply, soldering station,
- **Tools:** a device or implement, especially one held in the hand, used to carry out a particular function. A tool is any instrument or simple piece of equipment that you hold in your hands and use to do a particular kind of work

  Example: soldering iron, screwdriver, pliers.

Application of learning 1.5.

United Electronic Technician Ltd Company has assigned different tasks to its technicians. You, as electronic lab technician, are requested to repair a UPS industry at MEGA Industry. As electronic technician, select the required tools, materials, and equipment using to repair devices

Learning outcome 1 end assessment

Theoretical assessment

I. Read the following statements and choose the collect answer:

1:List two types of full-wave rectifiers.

2: Rectifier can take the form of ______

A. Node
B. Rheostat
C. Vacuum tube diodes
D. Resistors

3: Which process straightens the direction of the current?

A. Amplification
B. Lithification
C. Straightfication
D. Rectification

4: Choose the correct answer: Rectifiers allow current to flow in _____

A. Single direction
B. Multi-direction

5: Which of the following is used in a rectifier?

A. Inductor
B. Capacitor
C. Resistor
D. Diode

6: Choose YES or NO: Can rectifier circuits be single-phase?

A. YES
B. NO

7: Power rectifiers are used in ______

A. Laptops
B. Televisions
C. Video game systems
D. All the above options

8:. Bridge Rectifier is a _____

A. Half-wave rectifier
B. Full-wave rectifier

II. Answer the following questions

9. What 2 types of diode used in power electronics application

10: Explain the Types of power electronic converters

11:.what is the difference between Full wave controlled rectifier and Full Wave Bridge controlled rectifiers.

12: Including the examples of material /tools/ equipment used in each types of cleaning ,explain the techniques for cleaning working area?

Practical assessment

KDSTec LTD is a company working on renewable energy project, especially on solar panel systems. Their produces different types of power conversion systems. The company is looking for different skilled technicians who will contribute in achieving the company's goals. the company prepare the examination for the shortlisted candidates and you are one of them. The examination took place into the electronic workshop. You are given different materials, tools and equipment, and you are tasked to prepare a workspace and solder different power electronic components such as MOSFET, power rectifiers and IGBT on a PCB.

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Learning Outcome 2: Implement a Power Rectifier

Indicative contents
1.1 Evaluating power rectifier requirements **1.2 Designing power rectifier diagram** **1.3 Assembling power rectifier** **1.4 Testing power rectifier**

Key Competencies for Learning Outcome 2: Implement power rectifier circuit

Knowledge	Skills	Attitudes
• Identification of power rectifier parameters • Description of components specification • Identification of power rectifier symbols • Description of power rectifier diagrams	• Calculating power rectifier parameters • Selecting of power rectifiers • Designing of power rectifier diagram • Interpretating of wiring diagram • Placing power rectifier components • Soldering power rectifier components • wiring of power rectifier components • Testing of DC output voltage and functionality of power rectifier	• Time management • Creative • Responsible • Innovative • Motivated • Open-minded • Problem solver • Teamwork and Collaboration

Duration: 20 hrs

Learning outcome 2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify properly power rectifier parameters according to their types
2. Determine clearly power converter parameters according to their types
3. Describe clearly the components specification according to the type of power converter
4. Identify clearly the symbols of power rectifier according to their application
5. Describe properly power rectifier diagram according to their type
6. Calculate accurately power rectifier parameters
7. Select properly the power rectifier according to their types
8. Design correctly the power rectifier diagram according to their types
9. Interpret clearly wiring diagram based working principle of the circuit
10. Solder correctly power rectifier components according to the type of PCB
11. Assemble correctly the power rectifier components according to the type of PCB
12. Test properly the power rectifier according to the output

Resources

Equipment	Tools	Materials
● Office UPS ● 12V battery charger ● Screwdriver machine ● DC power supply ● Oscilloscope ● Digital multimeter ● soldering station ● Glue gun ● Personal protective equipment (PPE)	● Magnifying glass ● Pliers set ● Electrician toolbox ● soldering iron ● Desoldering pump ● Simulation software	● Connectors ● IC socket ● power electronic passive and active components ● Integrated circuits (IC) ● electronic relay ● glue stick ● foam cleaner ● thermal paste ● soldering paste ● desoldering wire

kit • 3D Printing machine		• soldering wire • battery/cell • Isopropyl alcohol • jumper wires • breadboard • Copper Board • power cables

Indicative content 2.1: Evaluating Power Rectifier Requirements

Duration: 5 hrs

Theoretical Activity 2.1.1: identification of the power rectifier parameters

Tasks:

1: Answer the following questions:

Explain the following terms

a. Peak Inverse Voltage

b. Output DC voltage

c. Efficiency

d. Input AC voltage

e. Forward Current

f. Reverse Recovery Time

2: Write the answers on flipchart/ paper

3: Present the findings to the trainer and whole class

4: Ask for clarification if any

5: Read the key readings 2.1.1.in the manual

Key readings 2.1.1.: Identification of the power rectifier parameters

1. **Peak Inverse Voltage (PIV) or Peak Reverse Voltage (PRV)**

   The maximum voltage that a diode can withstand under reverse bias conditions is called the peak reverse voltage. During the positive half cycle, the diodes D1 and D3 are in a conducting state, while D2 and D4 are in a non-conducting state. Similarly, during the negative half cycle, the diodes D1 and D3 are in a non-conducting state, and the diodes D2 and D4 are in a conducting state.

   Peak inverse voltage is the maximum voltage a diode can withstand in the reverse-biased direction before breakdown. The peak inverse voltage of the full-wave rectifier is double that of a half-wave rectifier. The PIV across D1 and D2 is 2Vmax.

2. **Output DC voltage**

   If you measure the output voltage of a rectifier as the Root Mean Square (RMS) voltage you are getting a reading which reflects the amount of power that the source can deliver as compared to the **equivalent DC voltage.**

   The forward voltage is the amount of voltage needed to get current to flow across a diode. This is important to know because if one is trying to get a signal through diode that is less than the forward voltage, one will be disappointed. Although a perfect diode could block any amount of voltage, the fact is, just like humans, every diode has its price. If the voltage in the reverse direction gets high enough, current will flow. The next type of semiconductor is made by tacking on another type P or type N junction to the diode structure. It is called a BJT, for bipolar junction transistor, or transistor for short. When one uses a transistor as a switch, one should always consider if one is driving the device into saturation. Saturation occurs when one is putting enough current into the base to get the transistor to move the maximum amount through the collector.

3. **Rectifier efficiency**

   The measurement of the efficiency of the Bridge Rectifier shows the optimum performance of the rectifier. The definition of rectifier efficiency is the ratio of the DC output power to the AC input power.

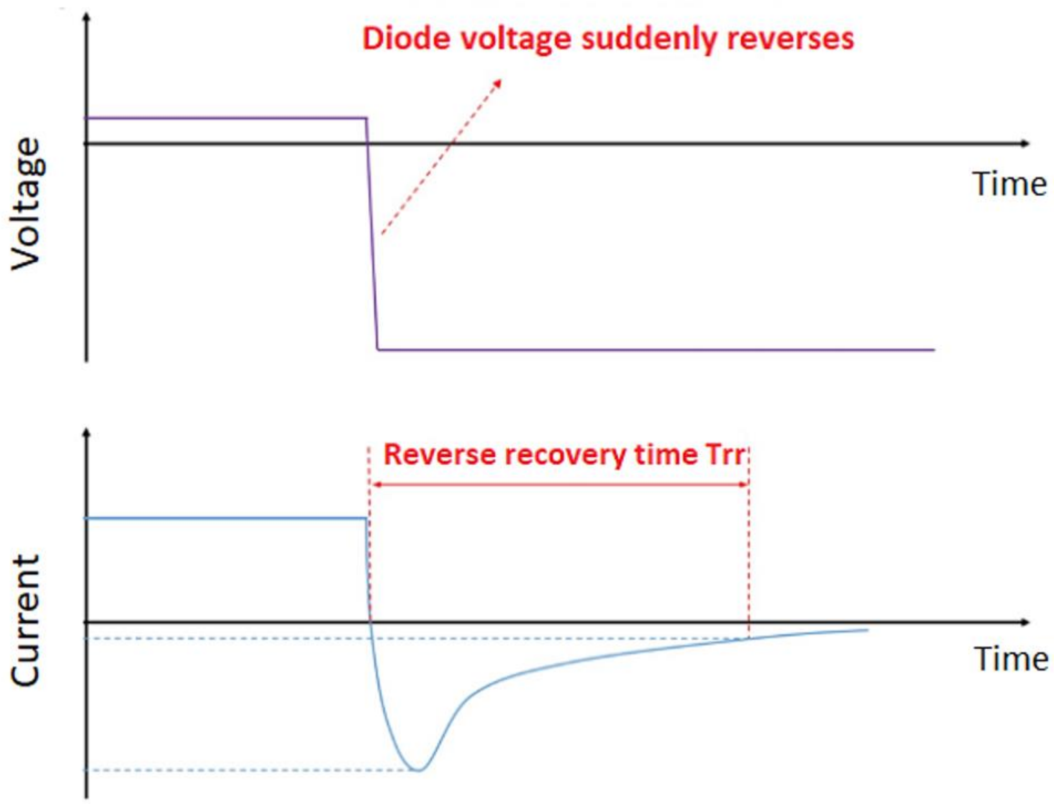
4. **Forward Current**

   Maximum Average Forward Rectified Current (IF) is the maximum allowable average forward current in the normal operating temperature range. That is the amount of current that flows through the diode in the forward direction, which is the direction in which the diode does not block its flow. The opposite current is called reverse current and is designed to be many orders of magnitude smaller than the forward current.

5. **reverse recovery time.**

   If a diode is initially driven in forward bias, and the polarity suddenly switches to reverse bias, the diode will remain conducting for some time.

   The time required for conduction to settle into the reverse bias state is the diode’s reverse recovery time.



The reverse recovery time appears to behave somewhat like a discharging capacitor, where the conducted current eventually decays to zero. The behaviour can be most clearly seen on a graph of diode forward bias current vs. time.

6. **Operating temperature range**
   It is the range of temperatures within which the inverter can operate safely and efficiently. Exceeding this range can cause overheating or damage.
7. **Connections and interfaces**
   The type connectors used for connecting the inverter to the DC source and the AC load. Common connectors include terminal blocks, MC4 connectors (for solar applications), and various plug types. *Interfaces are used by a user* for monitoring and configuration.
8. **Efficiency**
   The ratio of output power to input power, expressed as a percentage. Higher efficiency means more effective conversion from DC to AC with less wasted energy. Typical efficiencies range from 80% to 95%.
9. **Input DC voltage**
   The range of direct current (DC) voltages the inverter can accept from the DC source (e.g., battery bank). Common ranges include 12V, 24V, or 48V, depending on the inverter and application.

10. Output Frequency

This is the frequency of the AC power output, usually 50 Hz or 60 Hz, depending on the region. It should match the frequency requirements of your appliances or equipment.

11. Total Harmonic Distortion (THD)

It is a measure of the distortion in the output waveform compared to a pure sine wave. Lower THD values indicate a cleaner, more stable output, which is important for sensitive electronics.

Practical Activity 2.1.2: Calculation of power rectifiers parameters

Task:

1: Read the given question

Calculate the Peak inverse voltage, output DC Voltage, efficiency forward current and reverse recovery time of power rectifier.

2: follow carefully as trainer's demonstration

3: Perform the given tasks by applying the knowledge learn from trainer's demonstration.

4: Ask clarification where necessary

5: Read key reading 2.1.2

Key readings 2.1.2.: Calculation of power rectifiers parameters

Calculation of:

1. **Peak Inverse Voltage**

Peak inverse voltage is the maximum voltage a diode can withstand in the reverse-biased direction before breakdown. The peak inverse voltage of the full-wave rectifier is double that of a half-wave rectifier. The PIV across D1 and D2 is

2Vmax.

2. **DC Output Voltage**

The following formula gives the average value of the DC output voltage:

$$V_{dc} = I_{av}R_L = \frac{2}{\pi} I_{max}R_L$$

3. **RMS Value of Current**

The RMS value of the current can be calculated using the following formula:

$$I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

4. **Form Factor**

The form factor of the full wave rectifier is calculated using the formula:

$$\mathbf{K_f = \frac{RMS value of current}{Average value of current} = \frac{I_{rms}}{I_{dc}} = \frac{I_{max}/\sqrt{2}}{2I_{max}/\pi} = \frac{\pi}{2\sqrt{2}} = 1.11}$$

5. Rectification Efficiency

The rectification efficiency of the full-wave rectifier can be obtained using the following formula:

$$\mathbf{\eta = \frac{DC Output Power}{AC Output Power}}$$

6. Ripple Factor of Half Wave Rectifier

Ripple factor determines how well a halfwave rectifier can convert AC voltage to DC voltage.

Ripple factor can be quantified using the following formula:

$$\boldsymbol{\gamma = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1}}$$

7. RMS value of Half Wave Rectifier

The RMS value of the load current for a half-wave rectifier is given by the formula:

$$\mathbf{I_{rms} = \frac{I_m}{2}}$$

8. Form factor of a Halfwave Rectifier

The form factor is the ratio between RMS value and average value and is given by the formula:

$$\text{Form Factor} = \frac{\text{RMS Value}}{\text{Average Value}}$$

Practical Activity 2.1.3: Selection of power rectifiers

Task:

1: Read the given task

Go to the workshop and select single phase bridge rectifier.

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 2.1.3 and ask clarification where necessary

5: Perform the task provided in application of learning 2.1

Key readings 2.1.3.: Selection of power rectifiers

Here's a step-by-step guide to help you select a rectifier:

1. Determine the Type of Rectifier:

Half-Wave or Full-Wave: Half-wave rectifiers are simpler but less efficient, while full-wave rectifiers are more efficient as they utilize both halves of the AC waveform.

Bridge or Center-Tapped: Bridge rectifiers are more common due to their efficiency. Center-tapped rectifiers are used for specific applications requiring higher current capabilities.

2. Identify Input Specifications:

AC Voltage: Determine the peak and RMS values of the input voltage.

Frequency: Know the frequency of the input AC power supply.

3. Determine Output Requirements:

DC Voltage: Determine the required output voltage level.

DC Current: Determine the load current requirements.

Ripple Voltage: Specify the acceptable ripple voltage (lower ripple for sensitive electronics).

Regulation: Decide if voltage regulation is needed and to what degree.

4. Consider Load Characteristics:

Steady State vs. Transient Loads: Consider if the load is constant or fluctuates. Some rectifiers handle transient loads better than others.

Inrush Current: If the load requires a high inrush current at startup, choose a rectifier capable of handling this transient demand.

5. Efficiency and Power Loss:

Consider the rectifier's efficiency and power loss characteristics, especially if the application demands high efficiency.

6. Temperature and Cooling:

Consider the operating temperature range of the rectifier. Choose a rectifier with an appropriate temperature rating.

Plan for adequate cooling if the rectifier is expected to operate in high-temperature environments.

7. Reliability and Longevity:

Choose rectifiers from reputable manufacturers known for producing reliable and durable components.

Check the rectifier's MTBF (Mean Time Between Failures) value, provided by the manufacturer.

8. Safety and Compliance:

Ensure the rectifier complies with safety standards and certifications relevant to your region or industry (e.g., UL, CE).

Consider safety features like overcurrent protection, overvoltage protection, and thermal shutdown.

9. Budget and Cost Considerations:

Compare prices and features from different manufacturers.

Consider long-term costs, including maintenance and energy efficiency.

10. Consult Manufacturer Datasheets:

Review manufacturer datasheets for detailed specifications, including voltage ratings, current ratings, operating temperature range, and application notes.

11. Consult with Experts:

If you are uncertain, consult with electrical engineers or experts who specialize in power electronics for specific applications.

By carefully considering these factors, you can select a rectifier that meets the requirements of your specific application, ensuring reliable and efficient operation.

Theoretical Activity 2.1.4: Identification of components specification

Task:

1: Read the given task

a. Define a term specification

b. Identify the specification of the following components

i. Rectifier Diodes

ii. Transformer

iii. Capacitors

iv. Resistors

v. Heat Sink

vi. Fuse

vii. PCB

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 2.1.3 and ask clarification where necessary

5: Perform the task provided in application of learning 1.2

Key readings 2.1.4: Identification of components specification

1. Introduction to specification

1.1. Definition

A component specification contains detailed information about a component's functionalities, interfaces, dependencies, and interactions with other components. It's essentially a contract that defines what the component does (its responsibilities) and how others can use it (its interfaces).

The specifications can range from high-level overviews to intricate low-level details, depending on the project's scope and the development phase. High-level specifications often describe what the component does and its relationship with other components, while low-level specifications dive into the specific details of implementation.

One of the key benefits of component specification is that it enables modularity in software design. This means the software system can be divided into discrete, interchangeable components, each with a specific function. Modularity simplifies the development process, enhances code readability, and promotes reusability of components.

2. Specification of electronic components

2.1. Specification of rectifier diodes

Performance specifications for rectifier diodes include average rectified current, reverse current, forward voltage, peak forward surge current, reverse recovery time, and junction operating temperature.

Rectifier diodes are generally planar silicon diodes, used in various power supply rectifier circuits. When selecting a rectifier diode, the main considerations should be its maximum rectification current, maximum reverse operating current, cut-off frequency and reverse recovery time, and other parameters.

The rectifier diode used in the rectifier circuit and pulse rectifier circuit of the switching regulator should be selected with a higher operating frequency and shorter reverse recovery time (for example, RU series, EU series, V series, 1SR series, etc.) or choose a fast recovery diode. There is also a Schottky rectifier diode.

2.2. Specification of transformers

Different features to look out for in an Electrical Power Transformer are listed below.

- **Phase**

The two types are single-phase and three-phase. In a single phase, a single pair of coils is used. A primary coil and a secondary coil are used to generate the desired voltage. It has a less complicated design when compared to the three-phase transformers. Also, it produces an AC power supply of 1000 watts for the appliances.

In a three-phase, three single-phase transformers are winded over a central core. The three-phase structure includes six coils, out of which three are primary and the other three are secondary. The usage of three-phase transformers reduces the risk level to a larger extent and also withstands more power loads.

- **kVA Rating**
  kVA stands for Kilovolt-Ampere and this rating is used to rate a transformer. The kVA rating for the single-phase transformers will not be the same for the three-phase transformers. The kVA of a transformer should be equal to or greater than the rating of the load. In other words, a 1 KW load would require a 1 kVA transformer.
- **Primary Voltage and Secondary Voltage**
  Primary voltage refers to the voltage that is applied to the primary winding of a transformer. If the primary has fewer turns compared to the secondary, the step-up transformer is used to increase the voltage. And, if the primary has more turns compared to the secondary, the step-down transformer is used to decrease the voltage.
  Secondary voltage is the coil winding that supplies output voltage. The output voltage varies with variations in the load resistance and even with constant voltage input.
- **Full Load Current**
  The full load current is defined as the maximum allowable current to the winding. For calculating the full load current, the voltage, kVA rating, and the type (single-phase or three-phase) are required.
- **Coolant type**
  To dissipate the excess heat from the transformers, four types of cooling methods are used.
  Oil Natural Air Natural (ONAN): In this method, the heat produced from the core and winding is shifted to the oil.
  Oil Natural Air Forced (ONAF): Forced air is used to dissipate heat from the dissipating surface.
  Oil Forced Air Forced (OFAF): Oil flow is forced through heat exchangers. Airflow is also forced towards the heat exchanger.
  Oil Forced Water Forced (OFWF): It's Similar to the OFAF method. The only difference here is, forced water is used to dissipate heat from the dissipating surface.

- **Dimensions**
  The dimensions of the Electrical power transformer include two main factors: the height of the window (Hw) and the width of the window (Ww). Two other important entities are the width of the largest stamping (a) and the diameter of the circumscribing circle.
- **Weight**
  For any transformer, the weight can be calculated by multiplying the transformer's capacity in kilovolt amperes (kVA) with a basic impulse insulation level (BIL). The weight of core, winding, and oil for insulation can also be calculated.
- **Terminals**
  In a transformer, H terminal denotes high voltage, and the X terminal denotes low voltage. These terminals can either be primary or secondary based on which is the source and which is the load.
- **Serial Number**
  The serial number format printed in the transformers is usually used t0 identify information like the year of manufacturing, the month of manufacturing, date of manufacturing, and the place of manufacturing.

✓ **Specification of capacitors**

- Consider the capacitance, voltage rating, ripple current rating, and temperature when selecting a capacitor.
- The physical size of a capacitor depends on the capacitance value. As the capacitance increases, the size becomes larger.
- The capacitance variation is temperature dependent. In case you need control over capacitance for a broad temperature range, select the capacitor with the smallest temperature coefficient.

2.4. Specification of resistors

- **Range of resistance value:** The resistors are manufactured with specified values.
- **Tolerance:** A manufactured resistor has a certain tolerance to which the resistance may differ from the nominal value.
- **Power rating:** Power rating is the maximum power supported by the resistor. This rating is measured in watts (W) to explain how much heat energy a resistor can dissipate without overheating and sustaining damage.
- **Operating temperature:** The operating temperature is the temperature that the resistor can continue to operate before being damaged.
- **Operating voltage:** The operating voltage of a resistor specifies the maximum voltage above which the resistor may damage.
- **Thermal stability:** The thermal stability of a resistor is indicated by temperature coefficient which is usually expressed in parts per million per degree centigrade. The smaller value of temperature coefficient will have less variation in the

resistance value.

Points to Remember

- **Peak Inverse Voltage (PIV) or Peak Reverse Voltage (PRV)** refer to the maximum voltage a diode or other device can withstand in the reverse-biased direction before breakdown.
- We calculate **efficiency** by taking DC Power Output / AC power input
- Root mean squre current is calculated $I_{rms} = \frac{I_{max}}{\sqrt{2}}$
- **specification** a detailed precise presentation of something or of a plan or proposal for something

Application of learning 2.1.

A half-wave rectifier is used to supply 50V D.C. to a resistive load of 800 Ω. The diode has a resistance of 25 Ω. Calculate A.C voltage required.

Indicative content 2.2: Designing Power Rectifier Diagram

Duration: 5 hrs

Theoretical Activity 2.2.1: Identification of power rectifier symbols

Tasks:

1: Answer the following questions:

Draw a symbol of the following components

i. an ordinary diode

ii. transformer

2: Write the answers on flipchart/ paper

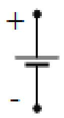
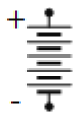
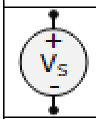
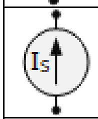
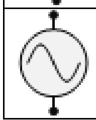
3: Present the findings to the trainer and whole class

4: Ask for clarification if any

5: Read the key readings 2.2.1.in the manual

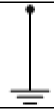
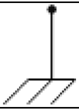
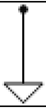
Key readings 2.2.1.: Identification of power rectifier symbols

Power Supply Schematic Symbols

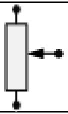
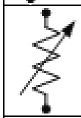
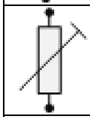
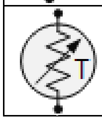
Schematic Symbol	**Symbol Identification**
	Single Cell
	DC Battery Supply
	DC Voltage Source
	DC Current Source
	AC Voltage Source

Electrical Grounding Schematic Symbols

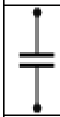
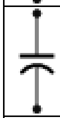
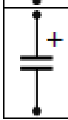
Schematic Symbol	**Symbol Identification**

	Earth Ground
	Chassis Ground
	Digital Ground

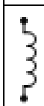
Resistor Schematic Symbols

Schematic Symbol	**Symbol Identification**
	Fixed Resistor (IEEE Design)
	Potentiometer (IEC Design)
	Rheostat (IEEE Design)
	Trimmer Resistor
	Thermistor (IEEE Design)

Capacitor Schematic Symbols

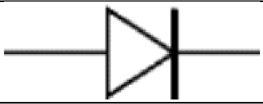
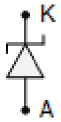
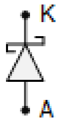
Schematic Symbol	**Symbol Identification**
	Fixed Value Capacitor
	Fixed Value Capacitor
	Polarized Capacitor

Inductor Schematic Symbols

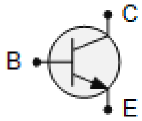
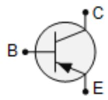
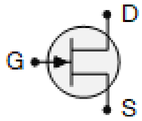
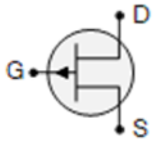
Schematic Symbol	**Symbol Identification**
	Open Inductor

Semiconductor Diode Symbols

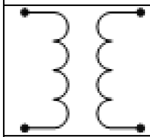
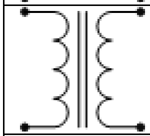
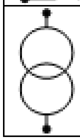
Schematic	**Symbol**

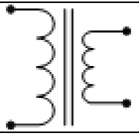
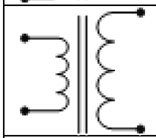
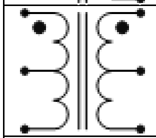
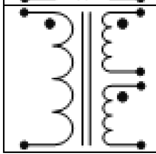
Symbol	Identification
	Semiconductor Diode
	Zener Diode
	Schottky Diode

Transistor Symbols

Schematic Symbol	Symbol Identification
	NPN Bipolar Transistor
	PNP Bipolar Transistor
	N-JFET Transistor
	P-JFET Transistor

Schematic Transformer Symbols

Schematic Symbol	Symbol Identification
	Air-core Transformer
	Iron-core Transformer
	Power Transformer

	Step-down Transformer
	Step-up Transformer
	Center-tapped Transformer
	Multi-load Transformer

Theoretical Activity 2.2.2: Description of power rectifier diagrams

Tasks:

1: Answer the following questions:

i. What do you understand by an electrical diagram?

ii. Identify 3 types of electrical diagrams

2: Write the answers on flipchart/ paper

3: Present the findings to the trainer and whole class

4: Ask for clarification if any

5: Read the key readings 2.2.2.in the manual

Key readings 2.2.2: Description of power rectifier diagrams

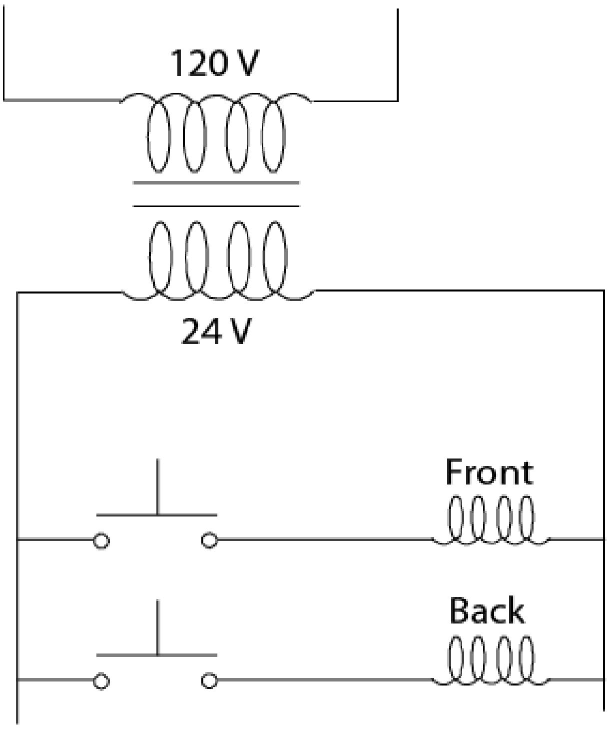
1. An electrical diagram

Are drawings which are used to represent electrical circuits, these circuits are represented by using lines, symbols and numbers.

2. There are four basic types of electrical diagrams

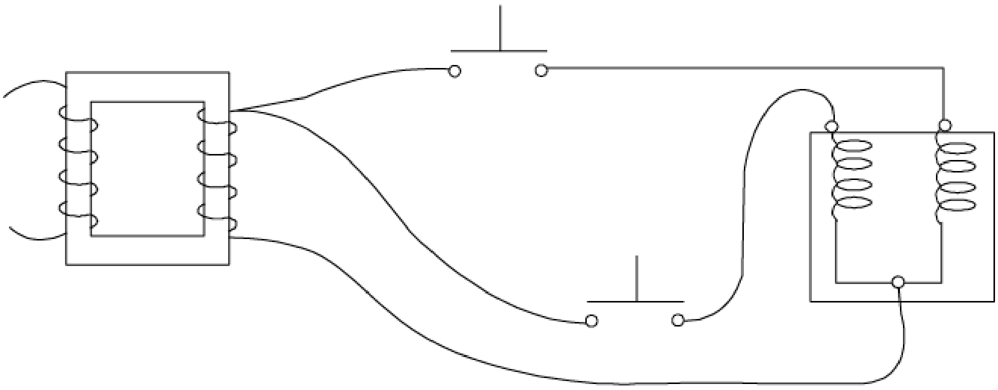
2.1. Schematic Diagrams

The schematic diagram often called a ladder diagram, is intended to be the simplest form of an electrical circuit. This diagram shows the circuit components on horizontal lines without regard to their physical location. It is used for troubleshooting because it is easy to understand the operation of the circuit. The loads are located on the far right of the diagram, and the controls for each load are located to the left. To understand the sequence of operation, the drawing is read from the upper left corner and then from left to right, and from top to bottom.



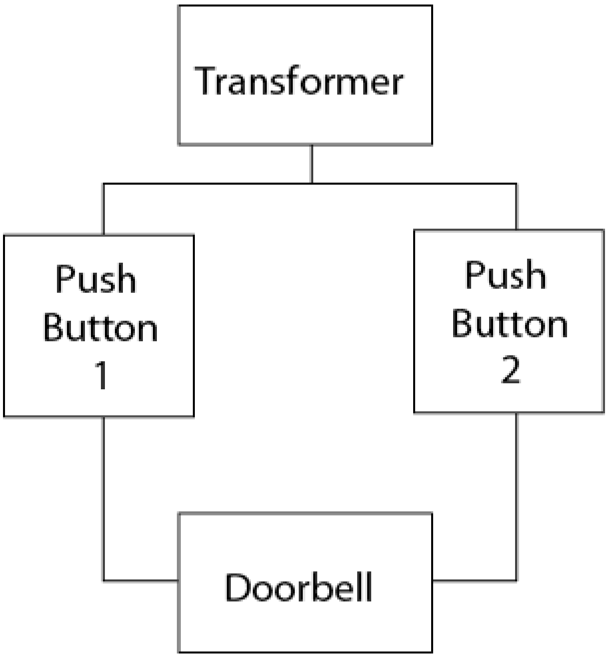
2.2. Wiring diagrams

The wiring diagram shows the relative layout of the circuit components using the appropriate symbols and the wire connections. Although a wiring diagram is the easiest to use for wiring an installation, it is sometimes difficult to understand circuit operation and is not as applicable for troubleshooting.



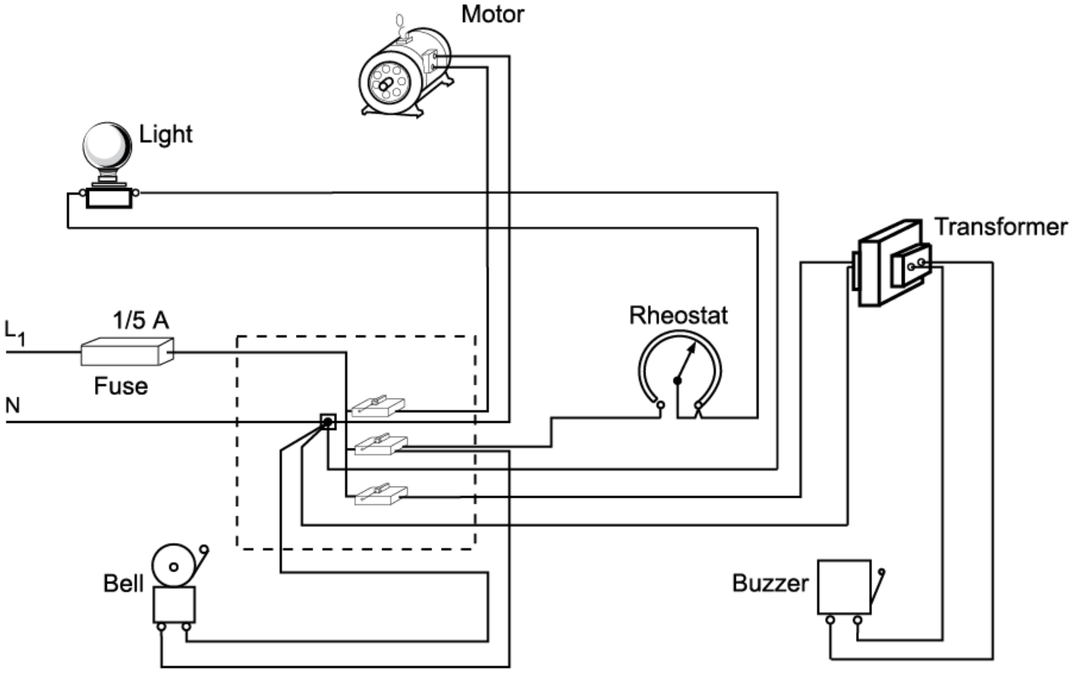
2.3. Block diagrams

The block diagram also called a functional block diagram, is used to describe the sequence of circuit operations. This diagram indicates by functional descriptions, showing which components must operate first to get an outcome. They do not refer to specifics like device symbols or related wire connections.



2.4. Pictorial diagrams

A pictorial diagram shows the circuit components in more detail, as they really look, and indicates how the wiring is attached. These diagrams can be used to locate components in a complex system.



Practical Activity 2.2.3: Draw single phase and three phase power

Task:

1: Read the given task

Draw a single-phase and three phase half wave, full wave, center-tap and controlled rectifier circuit and label each component.

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 2.2.3 and ask clarification where necessary

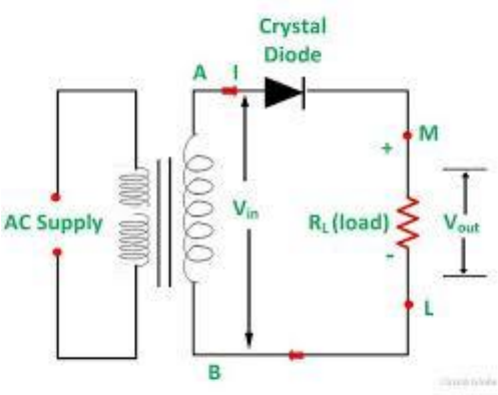
5: Perform the task provided in application of learning 2.2

Key readings 2.2.3: Draw single phase and three phase power rectifier

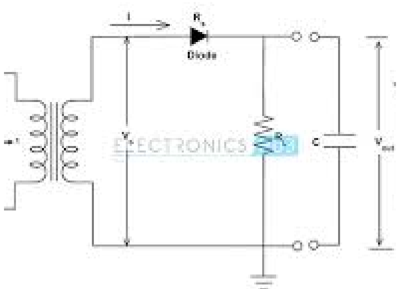
1. **Drawing of single-phase rectifier**

1.1. Half wave rectifier

i. **Half wave rectifier**

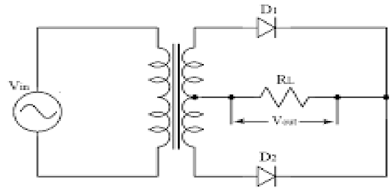


ii. **Half wave rectifier with smoothing capacitor**

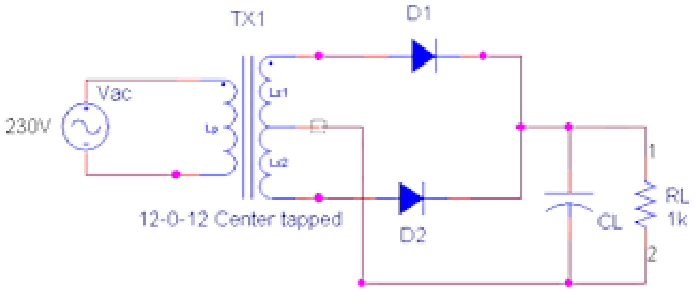


1.2. Full wave rectifier

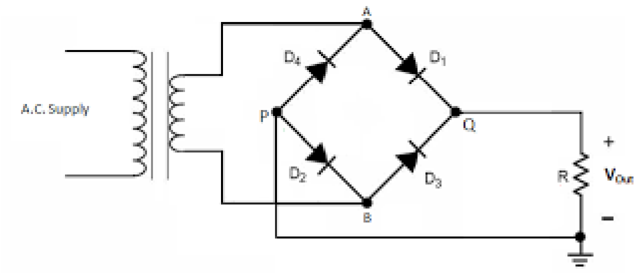
a. **Centre tap full wave rectifier**



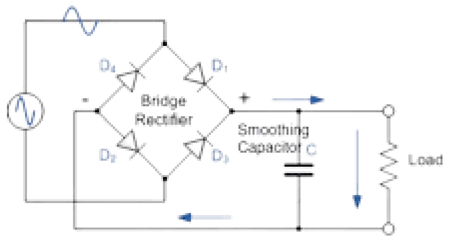
b. **centre tapped full wave rectifier with filter**



c. **full wave bridge rectifier**

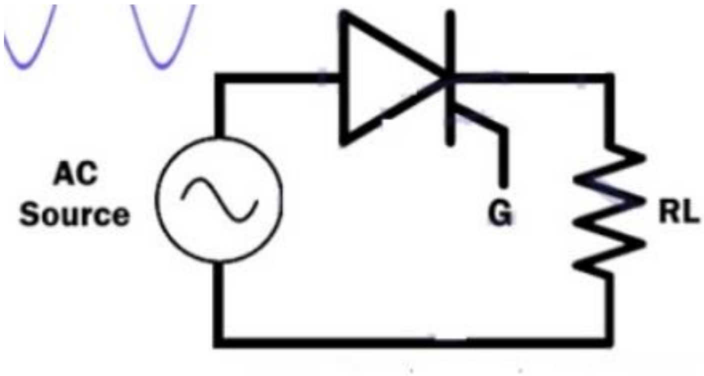


d. **full wave bridge rectifier with filter**



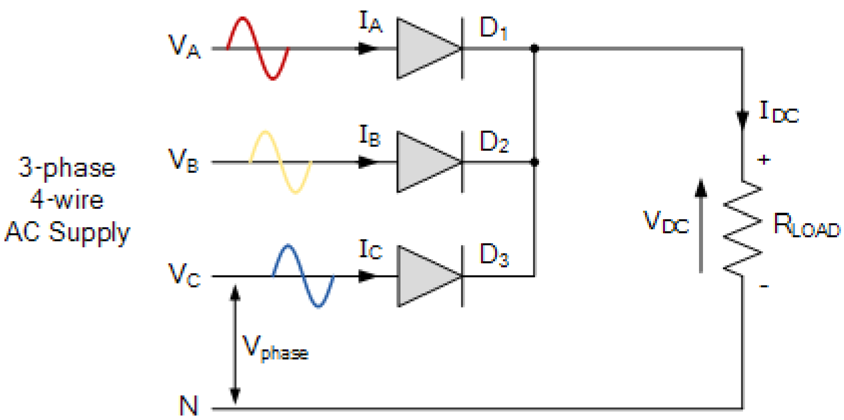
2. **Controlled rectifier**

2.1. Single phase Controlled rectifier

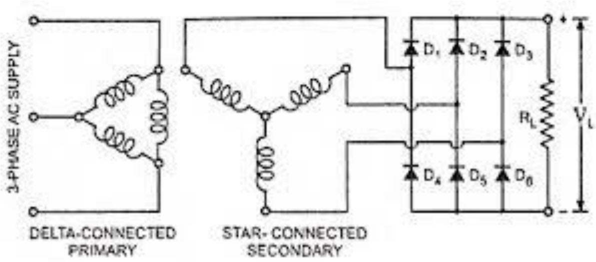


3. **Three phase rectifiers**

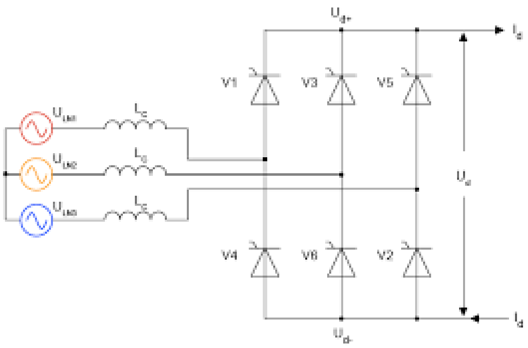
3.1. Three phase Half wave rectifier



3.2. Three phase full wave rectifier



3.3. Three phase Controlled rectifier



Points to Remember

1. The circuit of the full wave rectifier consists of

a step-down transformer, four diodes that are connected, and resistive load (RL), DC pass filter

2. DC pass filter is type of filter with capacitor gives more efficiency for converting AC to DC compared to a half-wave rectifier

Application of learning 2.2.

A company that repairs different home appliances like radios, TV, and photovoltaic home system wants to hire technician who can repair a radio of the client, the radio power supply was faulty, you are asked to draw a single-phase full wave rectifier and demonstrate each component of it.

Indicative content 2.3: Assembling Power Rectifier

Duration: 5 hrs

Practical Activity 2.3.1: assembling of single-phase power rectifier

Task:

1: Read the given task

Go to the workshop to connect a single-phase and full wave, half wave rectifier circuit on PCB board.

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 2.3.1 and ask clarification where necessary

5: Perform the task provided in application of learning 2.3

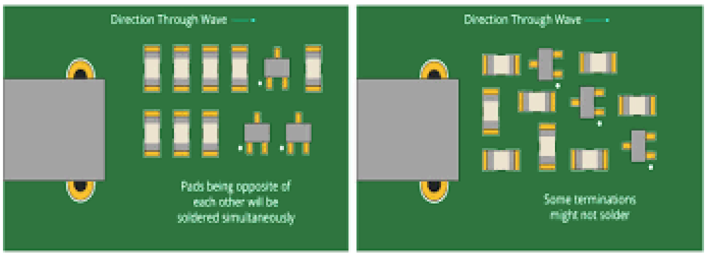
Key readings 2.3.1: assembling of single-phase power rectifier

1. **Placing the components on PCB**

Steps of Placing Half Wave Rectifier Components on PCB

Step 1 – Considering the placement

Before beginning any procedure, it is important to plan up well. Same is the case with PCB component placement. You need to understand very well where and how each Half Wave Rectifier Components needs to be placed. You also need to identify the mechanical constraints on the component location, such as the location of the connectors, the locations of heat sinks, the keep-out zones, etc. Also, the perimeter of the board must be kept free to give enough space for gripping the PCB during assembling, and room to score smaller boards to allow them to be removed from a larger multi-arrayed panel. A good recommendation is to keep all components at least 0.050” from the PCB edge. Further, taller and more fragile components should be kept at least 0.125” from the edge to prevent damage and allow room for tooling access when the board is routed or scored from the panel. Another important aspect to consider is to simplify routing and grounding in a way that the noise between power components, high-speed digital components, and analog components is minimized. Also, the power supplies and associated components should be grouped together, as far as possible from noise-sensitive section of the circuit.



Properly oriented components　　Poorly oriented components

Step 2 – Locating active components

The next step is to locate the active components on the board, such as the BGAs, quad packs, and other large high pin count components.

Step 3 – Locating passive components

Once the active components are in place, the next step is to locate the passive components on the board. The bypass or decoupling capacitors on the power pins should be located as close to the IC as practical to minimize the parasitic inductance. The lowest value capacitor should be placed closest to the power pin. The bypass capacitors should be located on the opposite side, directly under the power pin. And each power pin should have its own bypass capacitor. The polarized components like electrolytic capacitors and diodes should be arranged such that they all face in one direction. Lastly, the inductors should be placed apart, because placing them too close together can cause inductive coupling, changing their value, thanks to their property of generating magnetic fields.

2. **Soldering half wave rectifier components on PCB**

Steps of soldering halfwave rectifier on PCB

Step 1: Prepare

Tools

A Pencil Soldering Iron, A Soldering Station, Circuit Holding Hands., A Soldering Fume Extractor Unit, A DE soldering Station and Gun)

Materials as transformer (step-down), a diode, a capacitor, a resistor and Wire solder

Step 2: Clean surface on which Solder needs to adhere.

- Buff the copper foil of a PC board with steel wool before soldering.

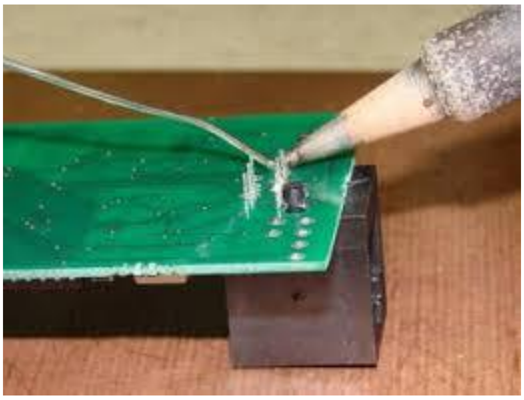
- Remove any oil, paint, wax, etc. with a solvent, steel wool, or fine sandpaper.

Step 3: To solder, heat the connection with the tip of the soldering iron for a few seconds, then apply the solder.

- Heat the connection, not the solder.
- Hold the soldering iron like a pen, near the base of the handle.
- Both parts that are being soldered must be hot to form a good connection.

Step 4: Keep the soldering tip on the connection as the solder is applied.

- Solder will flow into and around well-heated connections.
- Use just enough solder to form a strong connection.



Step 5: Remove the tip from the connection as soon as the solder has flowed where you want it to be. Remove the solder, then the iron.

Step 6: Don't move the connection while the solder is cooling.

Step 7: Don't overheat the connection, as this might damage the electrical component you are soldering.

Step 8: Inspect the joint closely. It should look shiny (note: lead-free solder may appear dull, this is OK).

If the connection looks bad, reheat it and try again and follow the below steps:

i. Wipe the tip of the iron on a damp sponge to clean it. The tip should now be shiny.
ii. Unplug the soldering iron when it is not in use.

Steps of Connecting full wave rectifier on PCB

1. **Placing the components on PCB**

1.1. Steps of Placing full Wave Rectifier Components on PCB

Step 1 – Considering the placement

Before beginning any procedure, it is important to plan up well. Same is the case with PCB component placement. You need to understand very well where and how each Half Wave Rectifier Components needs to be placed. You also need to identify the mechanical constraints on the component location, such as the location of the connectors, the locations of heat sinks, the keep-out zones, etc. Also, the perimeter of the board must be kept free to give enough space for gripping the PCB during assembling, and room to score smaller boards to allow them to be removed from a larger multi-arrayed panel. A good recommendation is to keep all components at least 0.050” from the PCB edge. Further, taller and more fragile components should be kept at least 0.125” from the edge to prevent damage and allow room for tooling access when the board is routed or scored from the panel. Another important aspect to consider is to simplify routing and grounding in a way that the noise between power components, high-speed digital components, and analog components is minimized. Also, the power supplies and associated components should be grouped together, as far as possible from noise-sensitive section of the circuit.

Step 2 – Locating active components

The next step is to locate the active components on the board, such as the BGAs, quad packs, and other large high pin count components.

Step 3 – Locating passive components

Once the active components are in place, the next step is to locate the passive components on the board. The bypass or decoupling capacitors on the power pins should be located as close to the IC as practical to minimize the parasitic inductance. The lowest value capacitor should be placed closest to the power pin. The bypass capacitors should be located on the opposite side, directly under the power pin. And each power pin should have its own bypass capacitor. The polarized components like electrolytic capacitors and diodes should be arranged such that they all face in one direction. Lastly, the inductors should be placed apart, because placing them too close together can cause inductive coupling, changing their value, thanks to their property of generating magnetic fields.

2. **Steps of soldering full wave bridge rectifier on PCB**

Prepare

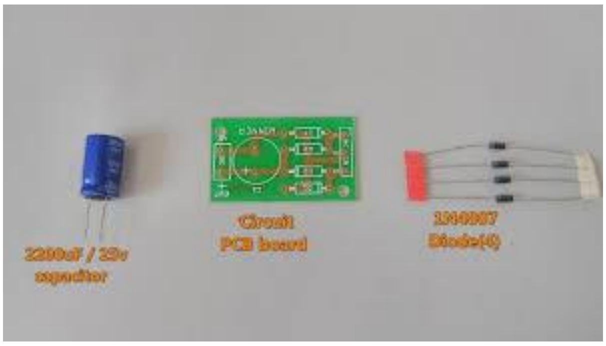
Tools

A Pencil Soldering Iron, A Soldering Station, Circuit Holding Hands., A Soldering Fume Extractor Unit, A DE soldering Station and Gun)

Materials as transformer (step-down), 4 diodes, and a resistor, Wire solder, PCB

Step 1: Clean surface on which Solder needs to adhere.

- Buff the copper foil of a PC board with steel wool before soldering.
- Remove any oil, paint, wax, etc. with a solvent, steel wool, or fine sandpaper.

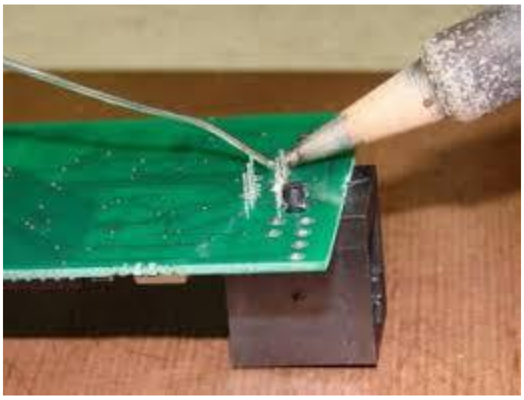


Step 2: To solder, heat the connection with the tip of the soldering iron for a few seconds, then apply the solder.

- Heat the connection, not the solder.
- Hold the soldering iron like a pen, near the base of the handle.
- Both parts that are being soldered must be hot to form a good connection.

Step 3: Keep the soldering tip on the connection as the solder is applied.

- Solder will flow into and around well-heated connections.
- Use just enough solder to form a strong connection.



Step 4: Remove the tip from the connection as soon as the solder has flowed where you want it to be. Remove the solder, then the iron.

Step 5: Don't move the connection while the solder is cooling.

Step 6: Don't overheat the connection, as this might damage the electrical component you are soldering.

Step 7: Inspect the joint closely. It should look shiny (note: lead-free solder may appear dull, this is OK).

- If the connection looks bad, reheat it and try again.

i. Wipe the tip of the iron on a damp sponge to clean it. The tip should now be shiny.

ii. Unplug the soldering iron when it is not in use.

4. Steps of soldering full wave bridge rectifier on PCB

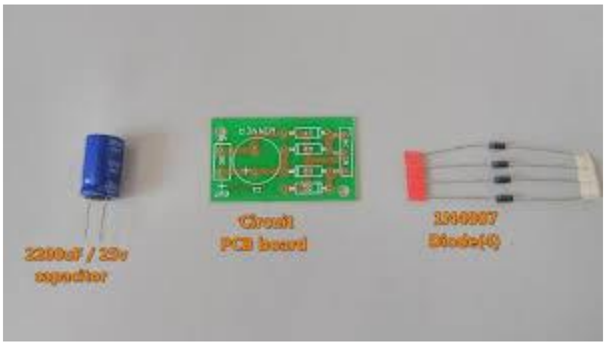
1. Prepare Tools

A Pencil Soldering Iron, A Soldering Station, Circuit Holding Hands., A Soldering Fume Extractor Unit, A DE soldering Station and Gun)

2.**Prepare materials** as transformer (step-down), 4 diodes, and a resistor, Wire solder, PCB

Step 1: Clean surface on which Solder needs to adhere.

- Buff the copper foil of a PC board with steel wool before soldering.
- Remove any oil, paint, wax, etc. with a solvent, steel wool, or fine sandpaper.

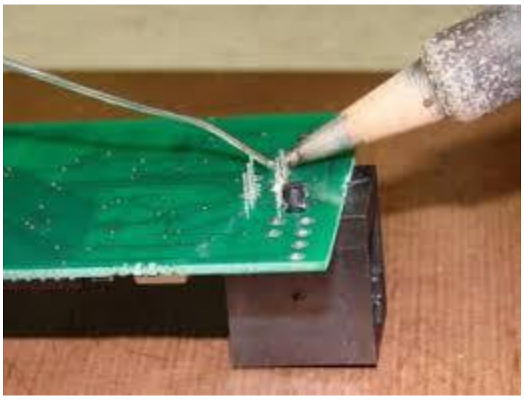


Step 2: To solder, heat the connection with the tip of the soldering iron for a few seconds, then apply the solder.

- Heat the connection, not the solder.
- Hold the soldering iron like a pen, near the base of the handle.
- Both parts that are being soldered must be hot to form a good connection.

Step 3: Keep the soldering tip on the connection as the solder is applied.

- Solder will flow into and around well-heated connections.
- Use just enough solder to form a strong connection.



Step 4: Remove the tip from the connection as soon as the solder has flowed where you want it to be. Remove the solder, then the iron.

Step 5: Don't move the connection while the solder is cooling.

Step 6: Don't overheat the connection, as this might damage the electrical component you are soldering.

Step 7: Inspect the joint closely. It should look shiny (note: lead-free solder may appear dull, this is OK).

- If the connection looks bad, reheat it and try again.

i. Wipe the tip of the iron on a damp sponge to clean it. The tip should now be shiny.

ii. Unplug the soldering iron when it is not in use.

4. Steps of soldering centre tap bridge rectifier on PCB

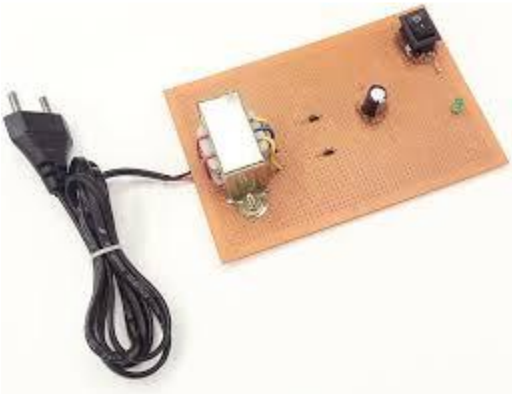
1. **Prepare Tools**

A Pencil Soldering Iron, A Soldering Station, Circuit Holding Hands., A Soldering Fume Extractor Unit, A DE soldering Station and Gun)

2.Prepare materials as transformer (step-down), 4 diodes, and a resistor, Wire solder, PCB

Step 1: Clean surface on which Solder needs to adhere.

- Buff the copper foil of a PC board with steel wool before soldering.
- Remove any oil, paint, wax, etc. with a solvent, steel wool, or fine sandpaper.

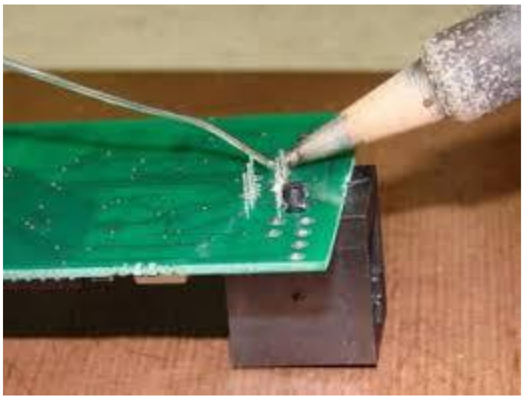


Step 2: To solder, heat the connection with the tip of the soldering iron for a few seconds, then apply the solder.

- Heat the connection, not the solder.
- Hold the soldering iron like a pen, near the base of the handle.
- Both parts that are being soldered must be hot to form a good connection.

Step 3: Keep the soldering tip on the connection as the solder is applied.

- Solder will flow into and around well-heated connections.
- Use just enough solder to form a strong connection.



Step 4: Remove the tip from the connection as soon as the solder has flowed where you want it to be. Remove the solder, then the iron.

Step 5: Don't move the connection while the solder is cooling.

Step 6: Don't overheat the connection, as this might damage the electrical component you are soldering.

Step 7: Inspect the joint closely. It should look shiny (note: lead-free solder may appear dull, this is OK).

If the connection looks bad, reheat it and try again.

i. Wipe the tip of the iron on a damp sponge to clean it. The tip should now be shiny.

ii. Unplug the soldering iron when it is not in use.

Practical Activity 2.3.2: Assembling of three-phase power rectifier

Task:

1: Read the given task

Go to the workshop to connect a three-phase full wave, half wave rectifier circuit on PCB board.

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 2.3.2 and ask clarification where necessary

5: Perform the task provided in application of learning 2.3

Key readings 2.3.2: Assembling of three-phase power rectifier

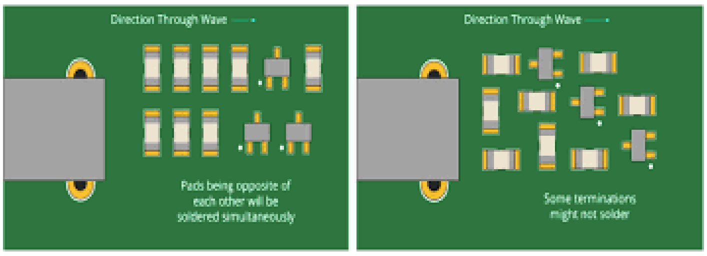
Connecting three phase half wave rectifiers on PCB

1. **Placing the components on PCB**

Steps of Placing three phase Half Wave Rectifier Components on PCB

Step 1 – Considering the placement

Before beginning any procedure, it is important to plan up well. Same is the case with PCB component placement. You need to understand very well where and how each Half Wave Rectifier Components needs to be placed. You also need to identify the mechanical constraints on the component location, such as the location of the connectors, the locations of heat sinks, the keep-out zones, etc. Also, the perimeter of the board must be kept free to give enough space for gripping the PCB during assembling, and room to score smaller boards to allow them to be removed from a larger multi-arrayed panel. A good recommendation is to keep all components at least 0.050" from the PCB edge. Further, taller and more fragile components should be kept at least 0.125" from the edge to prevent damage and allow room for tooling access when the board is routed or scored from the panel. Another important aspect to consider is to simplify routing and grounding in a way that the noise between power components, high-speed digital components, and analog components is minimized. Also, the power supplies and associated components should be grouped together, as far as possible from noise-sensitive section of the circuit.



Properly oriented components — Poorly oriented components

Step 2 – Locating active components

The next step is to locate the active components on the board, such as the BGAs, quad packs, and other large high pin count components.

Step 3 – Locating passive components

Once the active components are in place, the next step is to locate the passive components on the board. The bypass or decoupling capacitors on the power pins should be located as close to the IC as practical to minimize the parasitic inductance. The lowest value capacitor should be placed closest to the power pin. The bypass capacitors should be located on the opposite side, directly under the power pin. And each power pin should have its own bypass capacitor. The polarized components like electrolytic capacitors and diodes should be arranged such that they all face in one direction. Lastly, the inductors should be placed apart, because placing them too close together can cause inductive coupling, changing their value, thanks to their property of generating magnetic fields.

2. Soldering three phase half wave rectifier components on PCB

2.1. Steps of soldering three phase halfwave rectifier on PCB

Step 1: Prepare

1. Tools

A Pencil Soldering Iron, A Soldering Station, Circuit Holding Hands., A Soldering Fume Extractor Unit, A DE soldering Station and Gun)

3. **Materials** as transformer (step-down), a diode, a capacitor, a resistor and Wire solder

Step 2: Clean surface on which Solder needs to adhere.

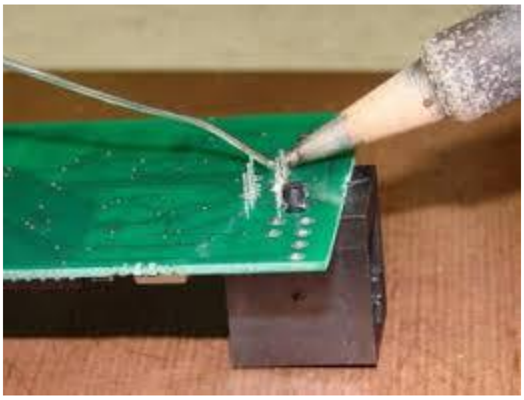
- Buff the copper foil of a PC board with steel wool before soldering.
- Remove any oil, paint, wax, etc. with a solvent, steel wool, or fine sandpaper.

Step 3: To solder, heat the connection with the tip of the soldering iron for a few seconds, then apply the solder.

- Heat the connection, not the solder.
- Hold the soldering iron like a pen, near the base of the handle.
- Both parts that are being soldered must be hot to form a good connection.

Step 4: Keep the soldering tip on the connection as the solder is applied.

- Solder will flow into and around well-heated connections.
- Use just enough solder to form a strong connection.



Step 5: Remove the tip from the connection as soon as the solder has flowed where you want it to be. Remove the solder, then the iron.

Step 6: Don't move the connection while the solder is cooling.

Step 7: Don't overheat the connection, as this might damage the electrical component you are soldering.

Step 8: Inspect the joint closely. It should look shiny (note: lead-free solder may appear dull, this is OK).

- If the connection looks bad, reheat it and try again.

iii. Wipe the tip of the iron on a damp sponge to clean it. The tip should now be shiny.

iv. Unplug the soldering iron when it is not in use.

Connecting full wave rectifier on PCB

1. **Placing the components on PCB**

Steps of Placing three phase full Wave Rectifier Components on PCB

Step 1 – Considering the placement

Before beginning any procedure, it is important to plan up well. Same is the case with PCB component placement. You need to understand very well where and how each Half Wave Rectifier Components needs to be placed. You also need to identify the mechanical constraints on the component location, such as the location of the connectors, the locations of heat sinks, the keep-out zones, etc. Also, the perimeter of the board must be kept free to give enough space for gripping the PCB during assembling, and room to score smaller boards to allow them to be removed from a larger multi-arrayed panel. A good recommendation is to keep all components at least 0.050” from the PCB edge. Further, taller and more fragile components should be kept at least 0.125” from the edge to prevent damage and allow room for tooling access when the board is routed or scored from the panel. Another important aspect to consider is to simplify routing and grounding in a way that the noise between power components, high-speed digital components, and analog components is minimized. Also, the power supplies and associated components should be grouped together, as far as possible from noise-sensitive section of the circuit.

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The next step is to locate the active components on the board, such as the BGAs, quad packs, and other large high pin count components.

Step 3 – Locating passive components

Once the active components are in place, the next step is to locate the passive components on the board. The bypass or decoupling capacitors on the power pins should be located as close to the IC as practical to minimize the parasitic inductance. The lowest value capacitor should be placed closest to the power pin. The bypass capacitors should be located on the opposite side, directly under the power pin. And each power pin should have its own bypass capacitor. The polarized components like electrolytic capacitors and diodes should be arranged such that they all face in one direction. Lastly, the inductors should be placed apart, because placing them too close together can cause inductive coupling, changing their value, thanks to their property of generating magnetic fields.

3. **Steps of soldering three phase full wave bridge rectifier on PCB**

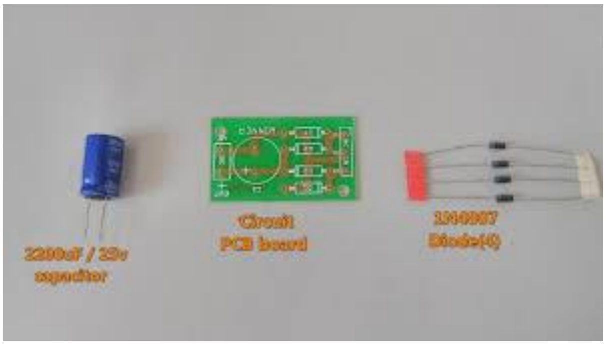
   1. **Prepare** tools

   A Pencil Soldering Iron, A Soldering Station, Circuit Holding Hands., A Soldering Fume Extractor Unit, A DE soldering Station and Gun)

2. **Prepare materials** as transformer (step-down), 4 diodes, and a resistor, Wire solder, PCB

Step 1: Clean surface on which Solder needs to adhere.

- Buff the copper foil of a PC board with steel wool before soldering.
- Remove any oil, paint, wax, etc. with a solvent, steel wool, or fine sandpaper.

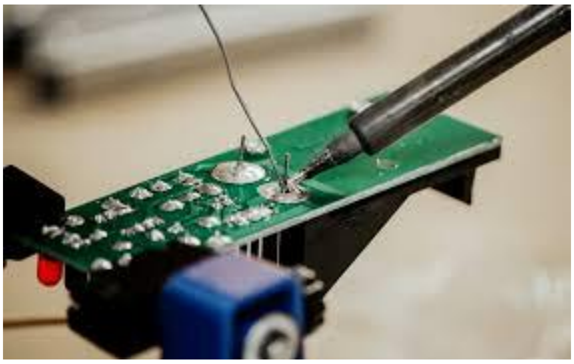


Step 2: To solder, heat the connection with the tip of the soldering iron for a few seconds, then apply the solder.

- Heat the connection, not the solder.
- Hold the soldering iron like a pen, near the base of the handle.
- Both parts that are being soldered must be hot to form a good connection.

Step 3: Keep the soldering tip on the connection as the solder is applied.

- Solder will flow into and around well-heated connections.
- Use just enough solder to form a strong connection.



Step 4: Remove the tip from the connection as soon as the solder has flowed where you want it to be. Remove the solder, then the iron.

Step 5: Don't move the connection while the solder is cooling.

Step 6: Don't overheat the connection, as this might damage the electrical component you are soldering.

Step 7: Inspect the joint closely. It should look shiny (note: lead-free solder may appear dull, this is OK).

- If the connection looks bad, reheat it and try again.

Step 8: Wipe the tip of the iron on a damp sponge to clean it. The tip should now be shiny.

Step 9: Unplug the soldering iron when it is not in use.

4. Steps of soldering Fully controlled 3-phase Bridge Rectifier on PCB

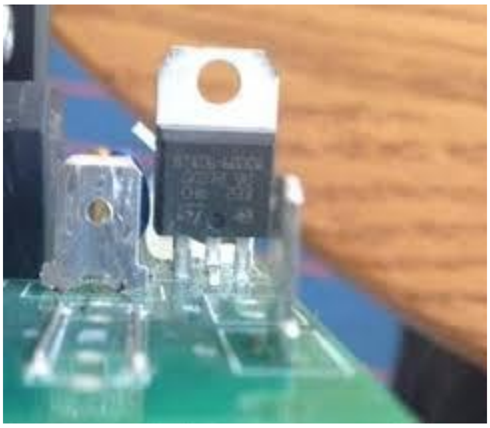
1. Prepare Tools

A Pencil Soldering Iron, A Soldering Station, Circuit Holding Hands., A Soldering Fume Extractor Unit, A DE soldering Station and Gun)

Step 9: Prepare materials as transformer (step-down), 6 thyristors, and a resistor, Wire solder, PCB

Step 1: Clean surface on which Solder needs to adhere.

- Buff the copper foil of a PC board with steel wool before soldering.
- Remove any oil, paint, wax, etc. with a solvent, steel wool, or fine sandpaper.

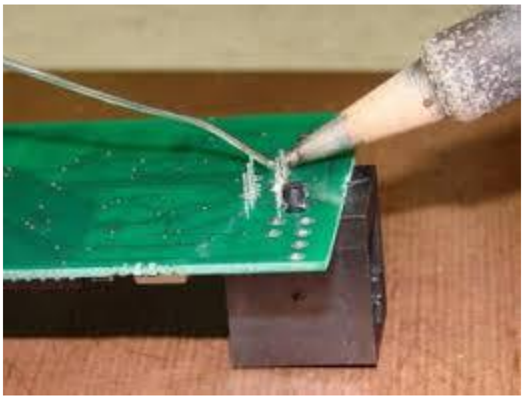


Step 2: To solder, heat the connection with the tip of the soldering iron for a few seconds, then apply the solder.

- Heat the connection, not the solder.
- Hold the soldering iron like a pen, near the base of the handle.
- Both parts that are being soldered must be hot to form a good connection.

Step 3: Keep the soldering tip on the connection as the solder is applied.

- Solder will flow into and around well-heated connections.
- Use just enough solder to form a strong connection.



Step 4: Remove the tip from the connection as soon as the solder has flowed where you want it to be. Remove the solder, then the iron.

Step 5: Don't move the connection while the solder is cooling.

Step 6: Don't overheat the connection, as this might damage the electrical component you are soldering.

Step 7: Inspect the joint closely. It should look shiny (note: lead-free solder may appear dull, this is OK).

- If the connection looks bad, reheat it and try again.

Step 8: Wipe the tip of the iron on a damp sponge to clean it. The tip should now be shiny.

Step 9: Unplug the soldering iron when it is not in use.

Points to Remember

- **Steps of Placing Half Wave Rectifier Components on PCB**
    1. Considering the placement
    2. Locating active components
    3. Locating passive components

Application of learning 2.3

BCD company LTD is a company that offer photovoltaic home installation and provide radios, and TVs to their client. This company want to hire a technician who can build a battery charging system, you are asked to assemble a single-phase full wave and half wave rectifier on PCB.

Indicative content 2.4: Testing Power Rectifiers

Duration: 5 hrs

Theoretical Activity 2.4.1: Description of testing techniques

Tasks:

1: Answer the following questions:

i. What are the testing techniques?

ii. What is the purpose of testing electrical circuit?

iii. Outline the testing tools and equipment

2: Write the answers on flipchart/ paper

3: Present the findings to the trainer and whole class

4: Ask for clarification if any

5: Read the key readings 2.4.1..in the manual

Key readings 2.4.1.: Description of testing techniques

1. **Testing**

An electrical test is an evaluation of the parametric, functional, or timing performance of a component when electrical power is applied

2. **Main purpose of testing**

The main purpose of electrical testing is to ensure that all the electrical appliances, wiring and installations in a business are functioning to their full capacity and will continue to run trouble free.

3. **TESTING TECHNIQUES**

3.1 Functional Testing.

Functional testing verifies that each function of the electronic hardware is operating in accordance with its specification.

3.2 Continuity testing

Continuity testing checks for a complete path for current flow in an electrical circuit, typically using a multimeter or continuity tester.

3.3 Visual inspection

Visual Inspection. Visual inspection is the simplest form of testing electronic components

4. **Testing equipment**

The following items are used for basic measurement of voltages, currents, and components in the circuit under test.

1. Voltmeter

2. Ohmmeter
3. Ammeter
4. Multimeter)
5. LCR meter
6. Oscilloscope
7. Frequency counter

4.1 VOLTMETER

A voltmeter is an instrument used for measuring electric potential difference between two points in an electric circuit. It is connected in parallel.

4.2 AMMETER

An ammeter (abbreviation of ampere meter) is an instrument used to measure the current in a circuit. Electric currents are measured in amperes (A), hence the name. For direct measurement, the ammeter is connected in series with the circuit in which the current is to be measured.

4.3 Ohmmeter

An ohmmeter is an electrical instrument that measures electrical resistance Multimeters also function as ohmmeters when in resistance-measuring mode.

4.4 Multimeter

Electrical, Multimeters. A digital multimeter (DMM) is a versatile electronic device used to measure various electrical properties, including voltage, current, and resistance. The device displays the measurements on a digital screen, making it easy to read and understand the results accurately.

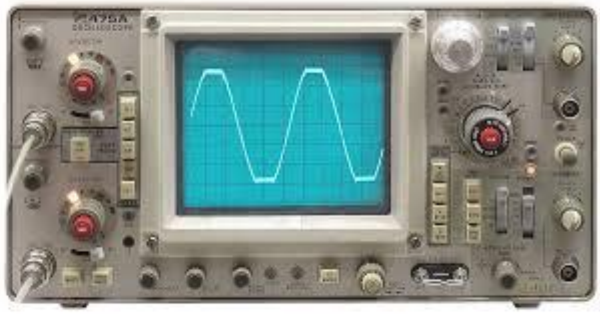
Figure 1 A Typical Digital Multimeter

4.5 LCR Meter

An LCR meter is a type of electronic test equipment used to measure the inductance (L), capacitance (C), and resistance (R) of an electronic component. In the simpler versions of this instrument the impedance was measured internally and converted for display to the corresponding capacitance or inductance value.

4.6 Oscilloscopes

Oscilloscopes (or scopes) test and display voltage signals as waveforms, visual representations of the variation of voltage over time. The signals are plotted on a graph, which shows how the signal changes. The vertical (Y) access represents the voltage measurement and the horizontal (X) axis represents time.



4.7 Frequency counter

A frequency counter is an electronic instrument, or component of one, that is used for measuring frequency. Frequency counters usually measure the number of cycles of oscillation or pulses per second in a periodic electronic signal. Such an instrument is sometimes called a cymometer, particularly one of Chinese manufacture

Practical Activity 2.4.2: Testing a power inverter

Task:

1: Read the given task

As electronic technician you are asked to Show the output signal of a full wave rectifier on oscilloscope.

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 2.4.2 and ask clarification where necessary

5: Perform the task provided in application of learning 2.4

Key readings 2.4.2: Testing a power inverter

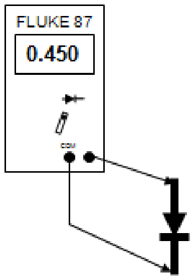
1. **How to test the rectifier?**

A bridge rectifier is composed of diodes. There are two ways to test a diode.

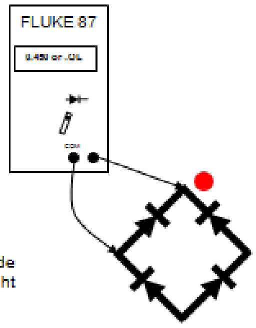
1.1. Through a Diode Test

First, make sure to disconnect the white wires and black wires from the bridge rectifier.

Then, you need to have your multi-tester dial set in Diode Test Mode. (Dial setting no. 14)

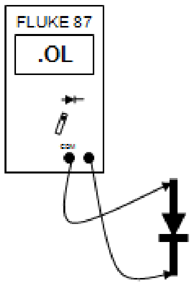


Forward: 400mv ±50mv



Check each diode individually. Eight readings total.

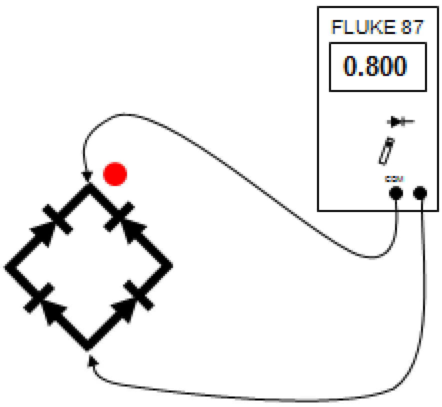
Forward: 450mv ±
Reverse: Open

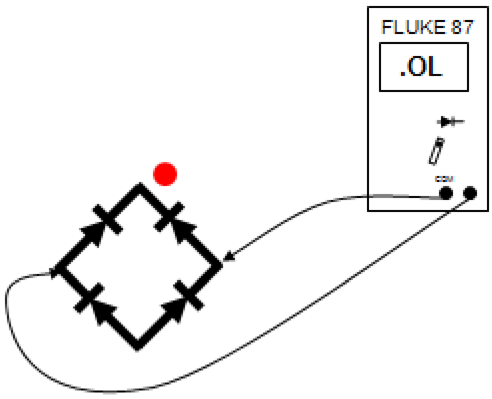


Reverse: Open

Check for Open or Shorted Diodes

Testing the Rectifier Diodes





Forward (as shown): 800mv ±
Reverse: Open

Both Directions: Open

Check for Diodes in the wrong Position

1.2. For through Resistance Check,

You need to have your multi-tester dial set in Ohmmeter. (dial setting no. 12)

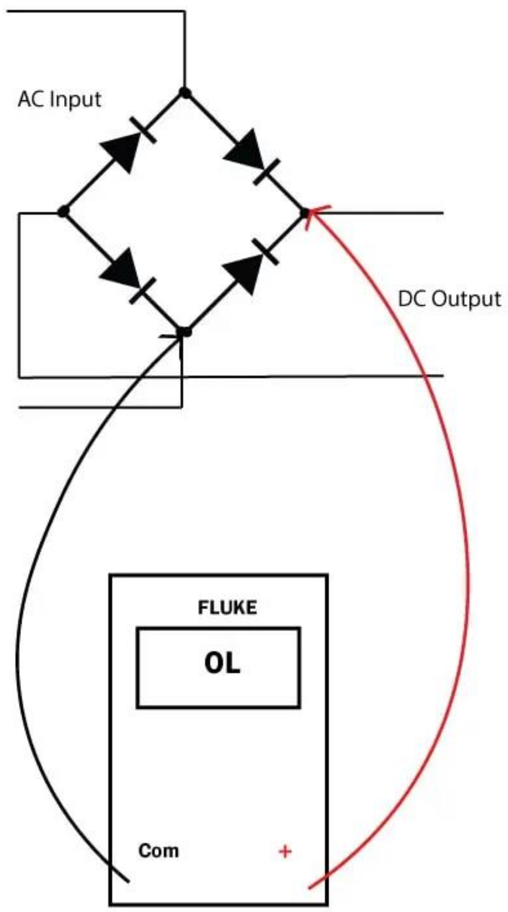
Then, check the resistance of each adjacent terminals. (top & right/ top & left/ bottom & right/ bottom & left)

You should get a resistance reading of around 97 ohms or as long as all resistance readings are approximately the same, the rectifier is good.

2. How to Test a Bridge Rectifier with a Digital Multimeter:

Let's explore the step-by-step process of testing a bridge rectifier using a digital multimeter. This simple yet effective method can help you diagnose potential problems quickly.

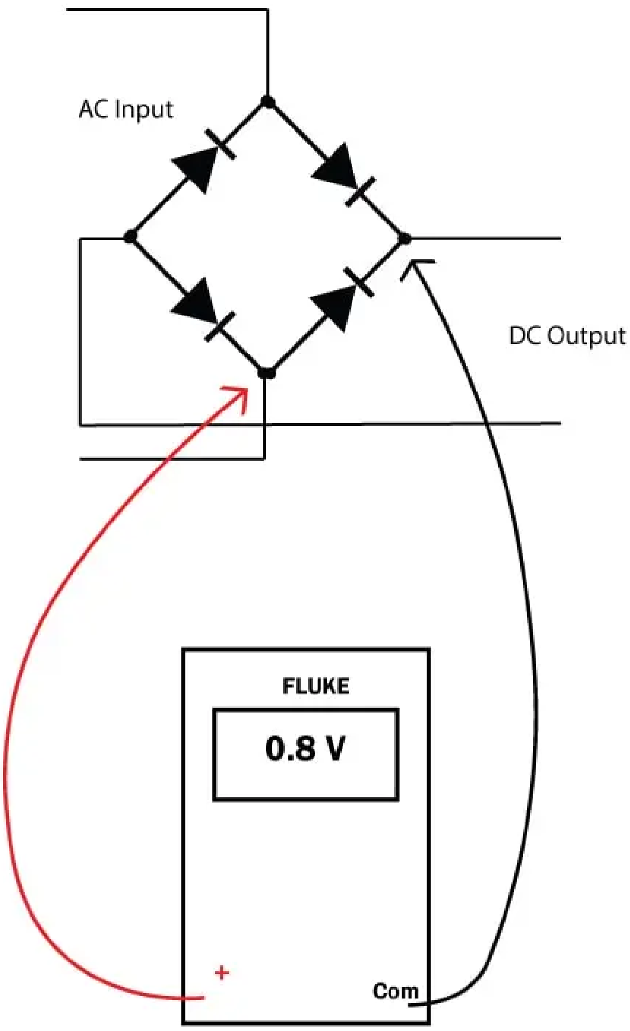
Testing Bridge rectifier with digital multimeter



Reversed Biase

Testing Bridge rectifier with digital multimeter

Forward Biase



Solutions on Common Power rectifier's faults, symptoms and their causes

Power rectifiers are critical components in converting alternating current (AC) to direct current (DC). However, like all electronic components, they can experience various faults. Below are some common faults in power rectifiers, along with possible solutions:

1. Open Circuit or Burned-Out Diodes

Fault: A diode in the rectifier may fail due to overheating or overcurrent, resulting in an open circuit.

Causes: Excessive current, voltage surges, poor cooling, or faulty components upstream.

Symptoms: No DC output, low output voltage, or inconsistent voltage levels.

Solution:

- Inspect and replace any damaged or failed diodes.
- Ensure proper current rating and adequate heat dissipation.
- Check circuit design to avoid exceeding the diode's maximum ratings.

2. Short-Circuited Diodes

Fault: A diode may become short-circuited, which can cause the rectifier to malfunction.

Causes: High voltage spikes, reverse current conditions, or improper mounting leading to mechanical stress.

Symptoms: High current draw, reduced or no DC output, overheating of the rectifier.

Solution:

- Replace the shorted diode.
- Inspect the circuit for any factors causing excessive stress or voltage spikes and make necessary adjustments.

3. Leakage Current

Fault: Small amounts of current flow through the rectifier even when it should be turned off.

Causes: Faulty diodes, improper insulation, or age-related degradation of materials.

Symptoms: Slow drain of the DC output, low current efficiency.

Solution:

- Check for shorted or degraded diodes and replace them.
- Ensure proper insulation and consider using diodes with higher reverse voltage ratings if required.

4. Excessive Ripple in DC Output

Fault: The rectifier produces DC output with noticeable ripple (AC components), which can affect the stability of the system.

Causes: Insufficient filtering (capacitors), faulty diodes, or incorrect circuit design.

Symptoms: Fluctuations in DC output, poor performance of downstream equipment.

Solution:

- Add or replace the filter capacitor to smooth the output.
- Check the health of diodes and replace any faulty ones.

- If using a bridge rectifier, verify that all diodes are functioning correctly.

5. Overvoltage or Undervoltage

Fault: The rectifier provides an output voltage that is either too high or too low.

Causes: Faulty voltage regulation, incorrect transformer ratings, or a malfunctioning rectifier circuit.

Symptoms: Output voltage deviating from expected levels.

Solution:

- Verify transformer ratings and ensure they match the rectifier's design requirements.
- Check the rectifier circuit for faulty diodes, incorrect component values, or faulty voltage regulators.

6. Thermal Runaway

Fault: The rectifier overheats due to excessive current, improper cooling, or incorrect circuit design.

Causes: High ambient temperature, inadequate heat sinks, or excessive load conditions.

Symptoms: Overheating components, potential thermal damage, failure of diodes.

Solution:

- Improve heat dissipation (larger heat sinks, forced air cooling).
- Ensure the rectifier is operated within its specified current and voltage limits.
- Use components rated for higher temperature environments if necessary.

7. Reverse Polarity

Fault: A rectifier may be installed incorrectly, resulting in reverse polarity, where the DC output is opposite to the intended direction.

Causes: Incorrect wiring during installation or maintenance.

Symptoms: The connected load does not work correctly or gets damaged.

Solution:

- Correct the polarity of connections to ensure proper DC output.
- Use diodes with reverse-polarity protection if necessary.

8. Low Current Output

Fault: The rectifier is not supplying enough current for the load.

Causes: Overloaded rectifier, under-specification of diodes, or inadequate voltage regulation.

Symptoms: Devices or systems powered by the rectifier operate poorly or fail to start.

Solution:

- Check the rectifier's current capacity and ensure it is correctly rated for the load.
- Inspect the diodes for degradation and replace them if necessary.
- Check for shorts or high resistance in the output wiring.

9. Surge or Spikes in Output Voltage

Fault: The rectifier produces large voltage spikes or surges, which can damage sensitive electronics.

Causes: Inadequate filtering, faulty diodes, or malfunctioning voltage regulation components.

Symptoms: High voltage spikes, erratic behavior in connected devices.

Solution:

- Add proper surge protection and filtering components (e.g., MOVs or varistors).
- Verify the rectifier's output waveform and replace any faulty components.

Final Tips:

- **Routine Maintenance:** Regularly inspect and clean components to avoid dust accumulation or corrosion that may affect performance.
- **Proper Sizing:** Ensure rectifiers, transformers, and other components are appropriately rated for the required load and operating conditions.
- **Testing:** Use an oscilloscope or multimeter to check for ripple, voltage levels, and component integrity during troubleshooting.

Points to Remember

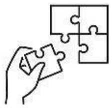
- **Setting Up Your Digital Multimeter for Continuity Testing you need to**
  Selecting the Correct Mode

Activating Continuity Mode

- **To test the rectifier**

  Through a Diode Test

  For through Resistance Check



Application of learning 2.4

BCD Group repair different home appliances like radios, TV, and photovoltaic home system wants to hire technician who can repair the clients' radios, you are one of those technicians and your job is to test the power supply of a SONITEC 50HZ, radio with a faulty rectifier.

Learning outcome 2 end assessment

Theoretical assessment

1. Choose the correct answer: Rectifiers allow current to flow in _____

a) Single direction

b) Multi-direction

2. Which of the following is used in a rectifier?
   a. Inductor
   b. Capacitor
   c. Resistor
   d. Diode
3. Power rectifiers are used in ______
   a) Laptops
   b) Televisions
   c) Video game systems
   d) All the above options
4. Bridge Rectifier is a _____
   a) Half-wave rectifier
   b) Full-wave rectifier
5. A simple diode rectifier has 'ripples' in the output wave which makes it unsuitable as a DC source. To overcome this one can use
   a. A capacitor in series with a the load resistance
   b. A capacitor in parallel to the load resistance
   c. Both of the mentioned situations will work
   d. None of the mentioned situations will work
6. The minimum number of diodes required in a centre tap full wave rectifier is:
   a) 3
   b) 1
   c) 4
   d) 2
7. Give two types of full-wave rectifiers.
8. What are the five uses of a rectifier?
9. How many diodes used in a bridge rectifier
10. Explain what is a dc power supply?
11. Explain what is a rectifier?
12. Explain what is PIV of a diode in a rectifier circuit?
13. Explain what is the importance of peak inverse voltage?
14. Explain why half-wave rectifiers are generally not used in dc power supply?

15. An a.c. supply of 230 V is applied to a half-wave rectifier circuit through a transformer of turn ratio 10 : 1. Find (i) the output d.c. voltage and (ii) the peak inverse voltage. Assume the diode to be ideal.

Practical assessment

AAAA company repair different home appliances like radios, TV, and photovoltaic home system wants to hire technician who can repair that equipment, you are one of those technicians and you are assigned the following task:

1. Draw a diagram of a bridge rectifier on A4 paper
2. Solder a bridge rectifier on a PCB
3. Test the output wave form on an oscilloscope

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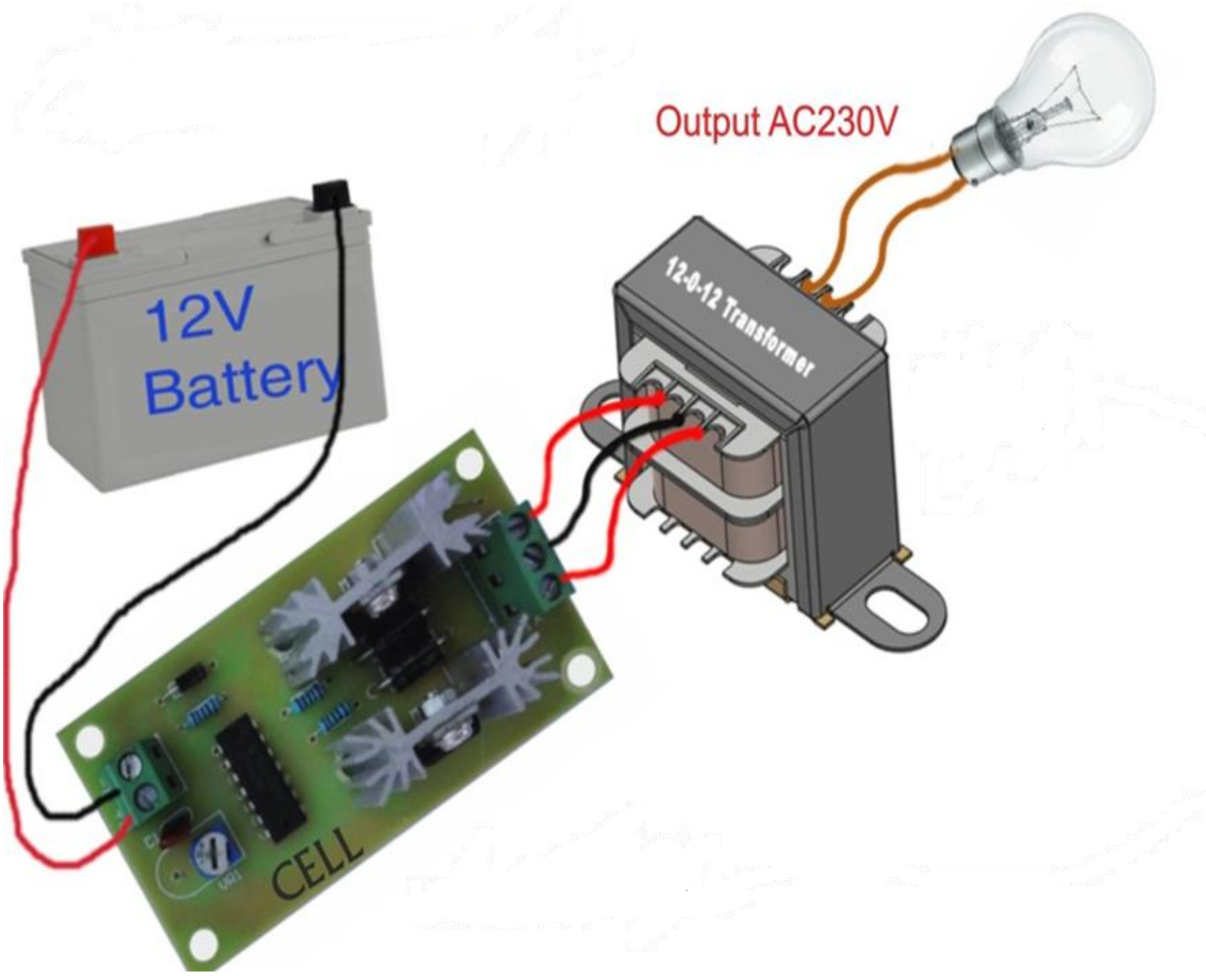

Output AC230V
12V
Battery
12-0-12 Transformer
CELL

Indicative contents
1.1 Evaluating power inverter requirements **1.2 Designing power inverter diagram** **1.3 Assembling power inverter** **1.4 Testing power inverter**

Key Competencies for Learning Outcome 3: Design and implement a power inverter

Knowledge	Skills	Attitudes
• Identification of the parameters and types of power inverter, • Identification of symbols and type of diagrams used in designing power inverter diagram, • Identification of testing techniques	• Determine the power inverter parameters, • Gather component specifications, • Design the power inverter diagram, • Interpret power inverter diagram, • Placing power rectifier components • wiring of power inverter's components, • Soldering power inverter's components • Test a power inverter	• Being Self-confident and goal oriented in selecting power inverter, • Having Teamwork and Collaboration in gathering and analysing component's specifications, • Being patient in gathering and analysing component's specifications, • Having Teamwork and Collaboration in designing a power inverter, • Being accountable and professional in designing and assembling a power inverter, • Being accurate, creative and innovative in designing a power inverter, • Being Flexible in assembling a power inverter, • Having time management in assembling a power inverter, • Being Problem solver in testing and assembling power inverter, • Having Safety Consciousness in testing

		power inverter

Duration: 20 hrs

Learning outcome 3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify clearly the parameters and types of inverters based on the output signal,
2. Determine accurately the power inverter parameters according to the load
3. Gather correctly the specifications of power components based on the type and parameters of a power inverter
4. Analyse correctly the specifications of power components based on the type and parameters of a power inverter
5. Identify correctly symbols and type of diagrams used in designing power inverter diagram based on design diagram,
6. Design accurately the power inverter diagram based on the circuit symbol and the types of diagrams according to the use of the design diagram,
7. Assemble correctly the power inverter components according to the assembling steps
8. Identify clearly testing techniques based on the test to be performed,
9. Test properly the power inverter according to required parameters
10. Interpret clearly power inverter diagram according to the working principle of the circuit

Resources

Equipment	**Tools**	**Materials**
● Oscilloscope, ● Personal Computer (laptop, desktop), ● PPE, ● Digital multimeter, ● Soldering station, ● 12V Battery	● Soldering iron, ● Electrician toolbox, ● Desoldering pump, ● Pliers set, ● Screwdriver set, ● Technician Knife, ● Magnifying glass, ● Tweezer, ● Spanner set, ● Tape measure, ● electronic simulation software.	● power electronic passive and active components, ● isopropyl alcohol, ● printed Circuit Board, ● Connectors, ● soldering wire, ● power cables, ● foam cleaner, ● thermal past soldering paste, ● glue stick, ● Integrated circuits (IC),

Indicative content 3.1: Evaluating Power Inverter Requirements

Duration: 4 hrs

Theoretical Activity 3.1.1: Identification of the parameters

Tasks:

1: Answer the following questions:

i. What do you understand by a power inverter?

ii. Outline the parameters of the power inverter.

2: Write the answers on flipchart/paper.

3: Present the findings to the trainer and whole class

4: Ask for clarification if any.

5: Read the key readings 3.1.1 in manual.

Key readings 3.1.1.: Identification of the parameters

1. Definition of power inverters

Power inverters are devices that convert direct current (DC) to alternating current (AC), and their performance and suitability for specific applications are defined by key parameters**.**

2. Power inverter parameters

2.1 Peak Inverse Voltage

Peak Inverse Voltage (PIV) or Peak Reverse Voltage (PRV) refer to the maximum voltage a diode or other device can withstand in the reverse-biased direction before breakdown.

2.2 Output AC voltage

The alternating current (AC) voltage the inverter provides. Common values are 120V, 230V, or 240V, depending on the region and application.

2.3 Output AC power

This is the maximum amount of power the inverter can handle, typically expressed in watts (W) or kilowatts (kW). It's crucial to choose an inverter with a power rating that matches or exceeds the power requirements of your devices.

2.4 Operating temperature range

It is the range of temperatures within which the inverter can operate safely and efficiently. Exceeding this range can cause overheating or damage.

2.5 Connections and interfaces

The type connectors used for connecting the inverter to the DC source and the

AC load. Common connectors include terminal blocks, MC4 connectors (for solar applications), and various plug types. *Interfaces are used by a user* for monitoring and configuration.

2.6 Efficiency

The ratio of output power to input power, expressed as a percentage. Higher efficiency means more effective conversion from DC to AC with less wasted energy. Typical efficiencies range from 80% to 95%.

2.7 Input DC voltage

The range of direct current (DC) voltages the inverter can accept from the DC source (e.g., battery bank). Common ranges include 12V, 24V, or 48V, depending on the inverter and application.

2.8 Output Frequency

This is the frequency of the AC power output, usually 50 Hz or 60 Hz, depending on the region. It should match the frequency requirements of your appliances or equipment.

2.9 Total Harmonic Distortion (THD)

it is a measure of the distortion in the output waveform compared to a pure sine wave. Lower THD values indicate a cleaner, more stable output, which is important for sensitive electronics.

2.10 Mounting Options

How the inverter can be installed, whether it’s wall-mounted, rack-mounted, or portable.

Practical Activity 3.1.2: Calculating power inverter parameters

Task:

1: Read carefully the following question:

You have a power inverter connected to a solar panel system with the following specifications:

- ✓ Input Voltage (V_{in}): 48 V
- ✓ Input Current (I_{in}): 10 A
- ✓ Output Voltage (V_{out}): 220 V
- ✓ Output Current (I_{out}): 1 A
- ✓ Power Factor (PF): 0.9
- ✓ Efficiency (η): 90%

a) Calculate the input power (P_{in}).

b) Calculate the output power (P_{out}).

c) Verify the efficiency using the calculated input and output power.

d) Calculate the total harmonic distortion (THD) if the fundamental current is 1 A, and the harmonic currents are 0.1 A and 0.05 A.

2: Follow carefully the trainer's demonstration

4: Perform the given task by applying the knowledge learnt from the trainer's demonstration.

5: Ask clarification where necessary

6: Read key reading 3.1.2

Key readings 3.1.2: Determination power inverter parameters

1. Determination of power inverter parameters

Determining the parameters of a power inverter involves selecting the right specifications to match the needs of your application.

Here is a step-by-step guide to help you determine the appropriate parameters for a power inverter:

1.1 Define Your Requirements

1.1.1 Load Requirements

- **Type of Load**: Identify whether your load is resistive (e.g., heating elements), inductive (e.g., motors), or capacitive (e.g., power factor correction).
- **Power Rating:** Determine the total power required by your load in watts (W). Consider both continuous and peak power needs.

1.1.2. Input Power Source

- **Input Voltage:** Identify the voltage of your power source (e.g., 12V DC, 24V DC, 48V DC, or 230V AC).
- **Input Current:** Calculate the maximum current from the input source, considering the inverter's efficiency and load requirements.

1.2 Determine Key Inverter Parameters

1.2.1 Input Specifications

- ✓ **Input Voltage Range:** Ensure the inverter can accept the input voltage of your source. For example, if you have a 12V battery, you need an inverter that can operate at 12V DC.
- ✓ **Input Current:** Based on the power requirement and input voltage, calculate the current the inverter will need to handle.

Example of Calculation:

If your load requires 1000W and you have a 12V DC input, assuming 90% efficiency:

Input Power = Output Power/Efficiency=1000 W/0.90=1111 W

Input Current=Input PowerInput /Voltage=1111 W/12 V≈92.6 A

1.2.2 Output Specifications

- ✓ **Output Voltage:** Choose the output voltage based on the requirements of your load. Common output voltages are 120V AC or 230V AC for home appliances or 5V DC for electronics.
- ✓ **Output Power:** The inverter should be rated for the maximum continuous power your load requires. It should also handle any peak power demands (e.g., for motor startup).

Example:

For a load that requires 1000W continuously, select an inverter with at least a 1000W rating. It's a good practice to choose an inverter with a margin, such as 1200W, to handle peak loads and ensure reliability.

- ✓ **Output Waveform:** Decide on the type of output waveform:

  Pure Sine Wave: Best for sensitive electronics and appliances.

  Modified Sine Wave: Suitable for simple loads but may not work well with all electronics.

  Square Wave: Least expensive and only suitable for very basic loads.
- ✓ **Efficiency:** Check the inverter's efficiency rating, which indicates how much input power is converted into usable output power. Typical efficiencies range from 80% to 95%. Higher efficiency means less wasted energy and heat.
- ✓ **Thermal Management**

Cooling: Ensure the inverter has appropriate cooling mechanisms (passive or active) to manage heat dissipation. Check the thermal resistance and operating temperature range.

- ✓ **Protection Features:**

  Overload Protection: Ensures the inverter can handle temporary overloads without damage.

  Short Circuit Protection: Prevents damage from short circuits in the output.

  Over/Under Voltage Protection: Safeguards against input voltage fluctuations.

  Thermal Shutdown: Protects the inverter from overheating.

Example Calculation:

Assume you have a 24V DC input and need to power a load of 1500W. The inverter's efficiency is 90%.

Calculate Input Power:

Input Power=Output Power/Efficiency=1500 W/0.90=1667 W

Calculate Input Current:

Input Current=Input Power/Input Voltage=1667 W/24 V≈69.5 A

Select an Inverter:

Power Rating: Choose an inverter with a continuous power rating of at least 1500W (preferably with a margin, like 2000W).

Input Voltage: Ensure the inverter supports 24V DC input.

Efficiency: Look for an inverter with high efficiency (around 90% or higher).

Practical Activity 3.1.3: Selection of power inverters

Task:

1: Read carefully the given task:

You want to buy a power inverter that will be connected to the to the 12V battery. Select a power inverter which will be used to supply the power to one AC lamp of 40W and one Desktop computer.

2: Perform the given tasks by respecting the given instructions.

4: Present your work to the trainer.

5: Read key reading 3.1.3 and ask clarification where necessary

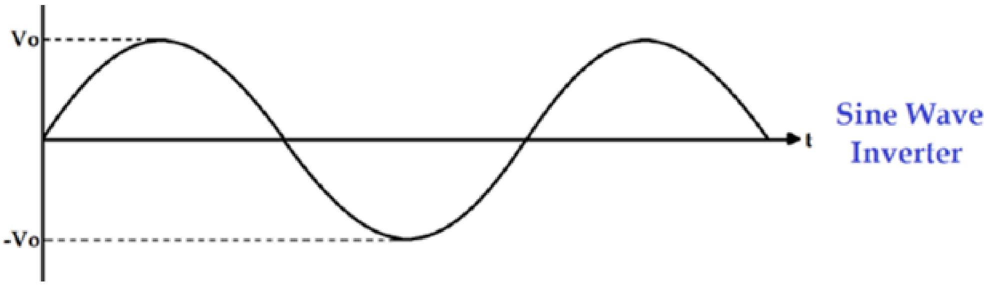
6: Perform the task provided in application of learning 3.1

Key readings 3.1.3: Selection of power inverters

1. Types of power inverters

1.1 Pure sine wave inverter

The output waveform of the voltage is a sine wave and it gives us a very similar output to the utility supply. This is ideal for sensitive electronic devices.



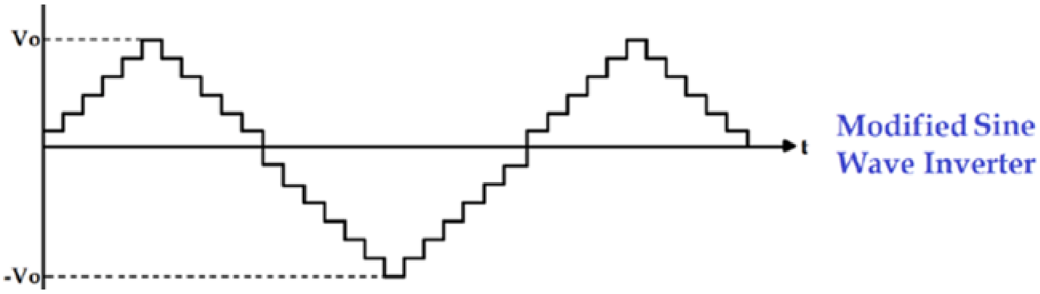
Applications: High-end electronics, medical equipment, home appliances, and any device that requires stable and clean power.

Advantages: Provides the cleanest and most reliable power, reduces interference, and is compatible with all devices.

Disadvantages: Typically, more expensive compared to other types.

1.2 Modified sine wave inverter

The output of this inverter is neither pure sine wave nor the square wave. The output of such inverter is the some of two square waves. The output signal is a stepped waveform that approximates a sine wave but is not as smooth.



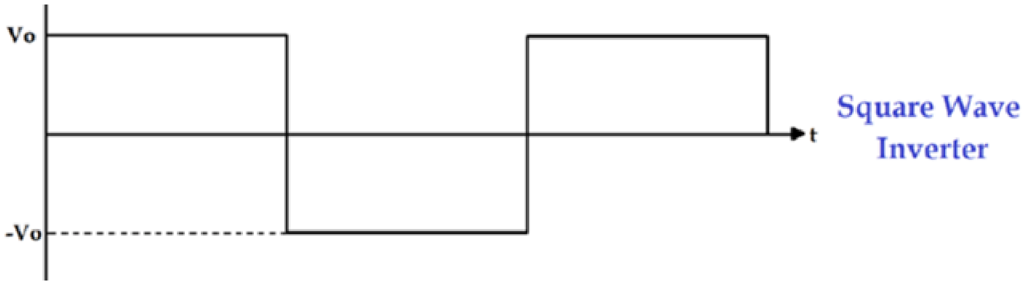
Applications: Power tools, basic household appliances, and other devices that are less sensitive to waveform quality.

Advantages: Generally, less expensive than pure sine wave inverters.

Disadvantages: May cause interference with some electronic devices and can be less efficient for certain types of loads.

1.3 Square wave inverter

The output waveform of the voltage for this inverter is a square wave. This type of inverter is least used among all other types of inverter because all appliances are designed for sine wave supply. If we supply square wave to sine wave-based appliance, it may get damaged or losses are very high. The cost of this inverter is very low but the application is very rare. It can be used in simple tools with a universal motor.



Advantages: Inexpensive and simple design.

Disadvantages: Not suitable for most electronic devices; can cause overheating and potential damage.

Based on the load or output phase, power inverters can be classified as follows

- ✓ Single-phase Inverter
- ✓ Three-phase Inverter

1) single-phase inverter

Generally, residential and commercial load uses single phase power. The single-phase inverter is used for this type of application. The single-phase inverter is further divided into two parts;

- ✓ Single Phase Half-Bridge Inverter
- ✓ Single Phase Full-Bridge Inverter

1.4 Single phase power inverters

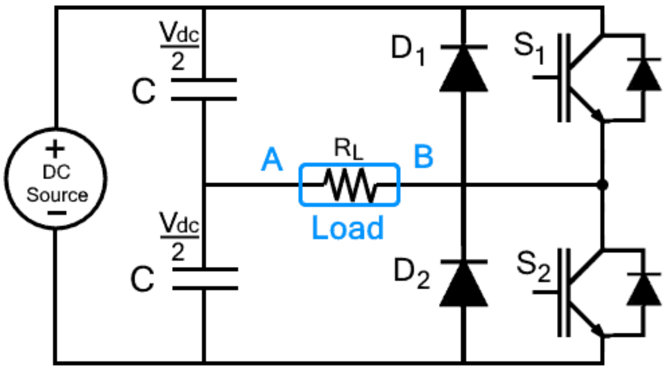
1.4.1 Half H-Bridge power inverter

Half H-bridge is one of the inverter topologies which convert DC into AC. The typical Half-bridge circuit consists of two control switches, 3 wire DC supply, two feedback diodes, and two capacitors connecting the load with the source. Control switch can be any electronic switch i.e. MOSFET, BJT, IGBT, or thyristor, etc.

The circuit is designed in such a way that both switches must not turn-on at a single time & only one of the two switches will conduct. Each switch will operate for half period (T/2), providing half of the applied voltage the load ($\pm V_{dc}/2$). When both the switches are off, the reserved voltage across the load will be V_{dc} instead of $V_{dc}/2$. This is called a half-bridge inverter.

Some of the conventions in the given circuit are such that

- ✓ Current through $\mathbf{S_1}$ is $\mathbf{i_1}$, while the current flowing through $\mathbf{S_2}$ is $\mathbf{i_2}$.
- ✓ Output voltage and current are $\mathbf{V_o}$ and $\mathbf{i_o}$
- ✓ **T** is the time period and switches are considered unidirectional.



Operation of Half H-Bridge Inverter with R Load

The circuit with this load will be operated in just two modes.

Mode 1: (0<t<T/2)

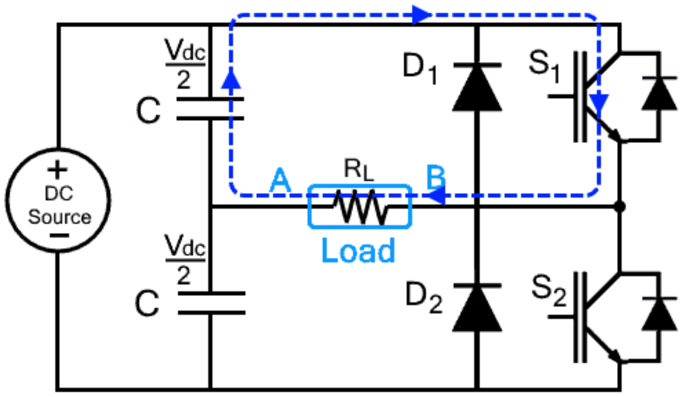
In this mode, S_1 is turned-on from time interval t=0 to t=T/2 while S_2 is turned off. As soon as S_1 is turned on, the voltage across the load will appear. The output voltage across the load will be

$\mathbf{V_o = V_{dc}/2}$

The current flowing through the switch $\mathbf{S_1}$ will be

$\mathbf{I_o = V_{dc}/2R_L}$

Where $\mathbf{R_L}$ is the load resistance. The current flow in clockwise direction as shown in the figure.



Mode 2: (T/2<t<T)

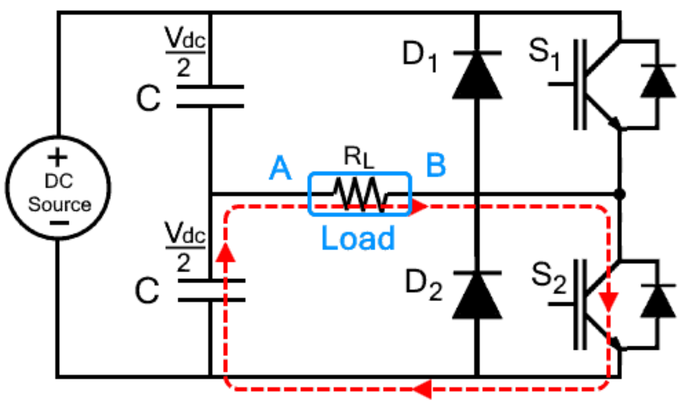
In this mode, switch S_2 is turned-on from the time interval t=T/2 to t=T while S_1 is switched off. Immediate switching of modes is avoided because it causes a short circuit. Due to this reason, S_2 is turned-on with some delay after S_1 is completely turned off. In this case, the output voltage will be negative as the current enters in the load from the opposite direction where output voltage will be

$\mathbf{V_o = -V_{dc}/2}$

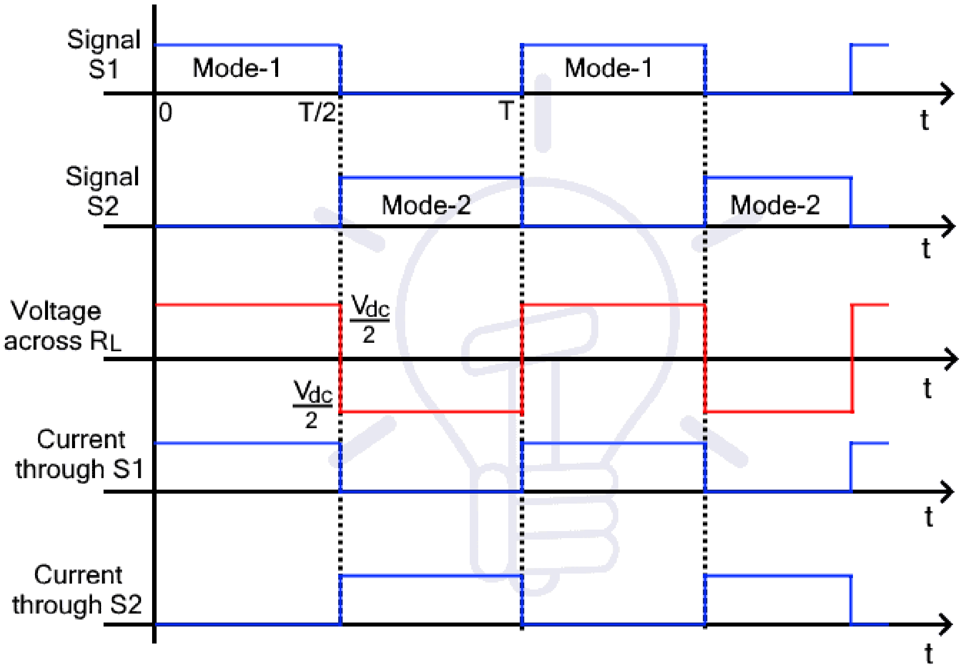
The current through S_2 will be

$\mathbf{I_o = V_{dc}/2R_L}$

The current flows in the reverse direction through the load as shown in the figure. Hence it shows that the half H-bridge has converted the applied DC into AC.



Waveform of Half H-Bridge with R Load

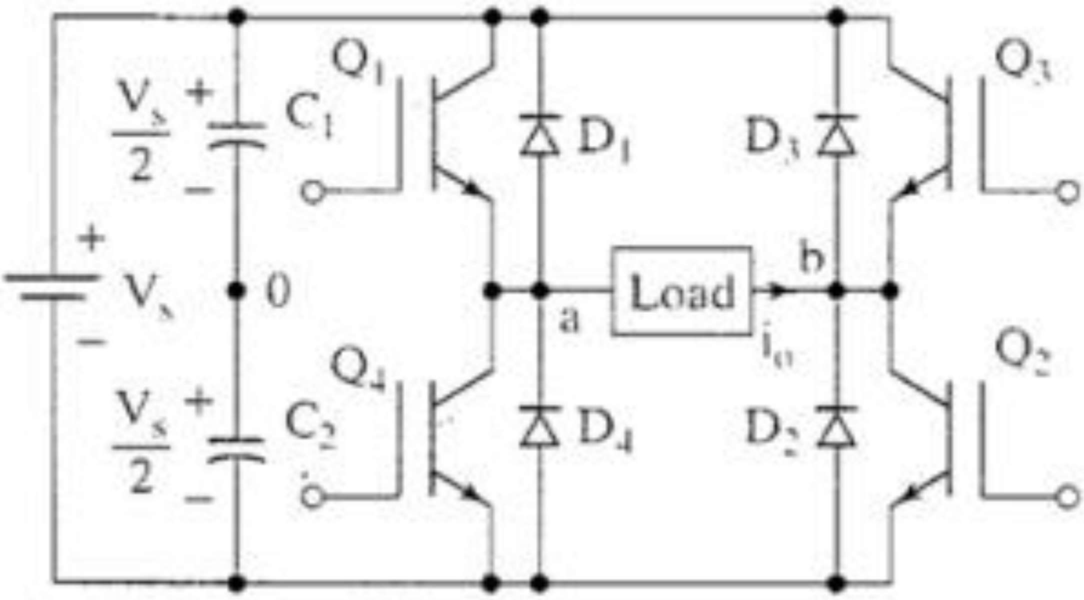


1.4.2 Single Phase Full Bridge Inverter

A single-phase bridge DC-AC inverter is shown in Figure below. The analysis of the single-phase DC-AC inverters is done taking into account following assumptions and conventions.

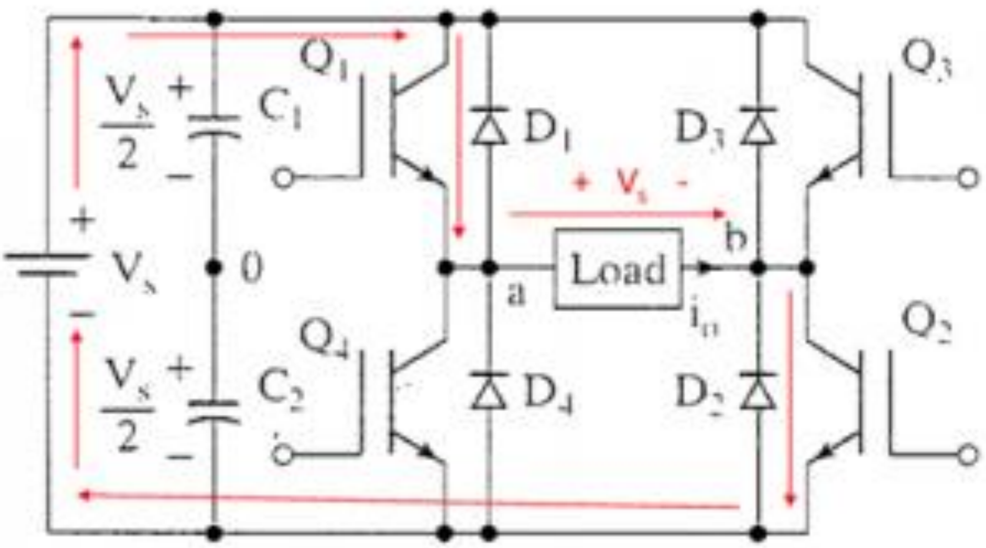
i) The current entering node a in Figure below is considered to be positive.

ii)The switches S1, S2, S3 and S4 are unidirectional, i.e. they conduct current in one direction.



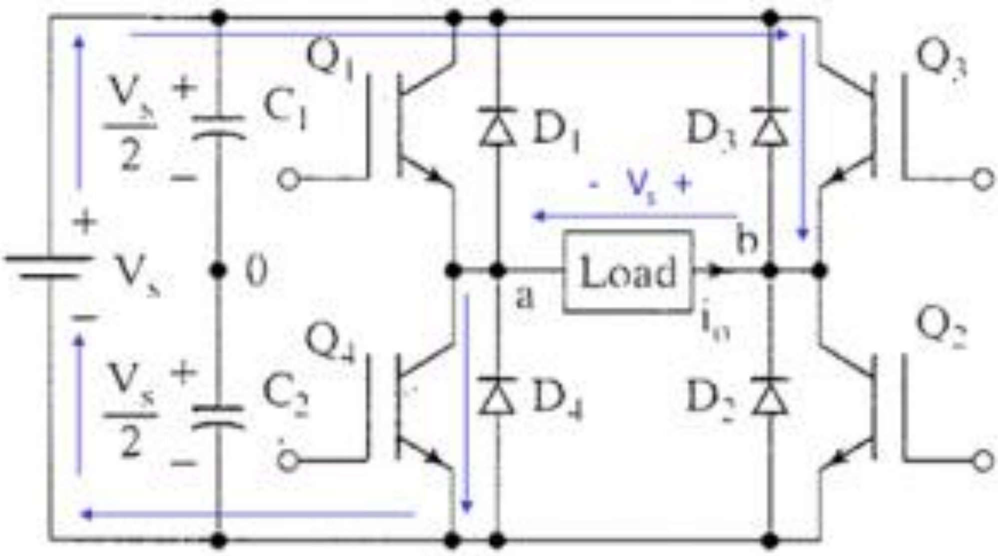
When the switches S1 and S2 are turned on simultaneously for a duration $0 \le t \le T1$, the the input voltage Vin appears across the load and the current flows from point a to b.

Q1 – Q2 ON, Q3 – Q4 OFF ==> v o = Vs



If the switches S3 and S4 turned on duration T1 ≤ t ≤ T2, the voltage across the load the load is reversed and the current through the load flows from point b to a.

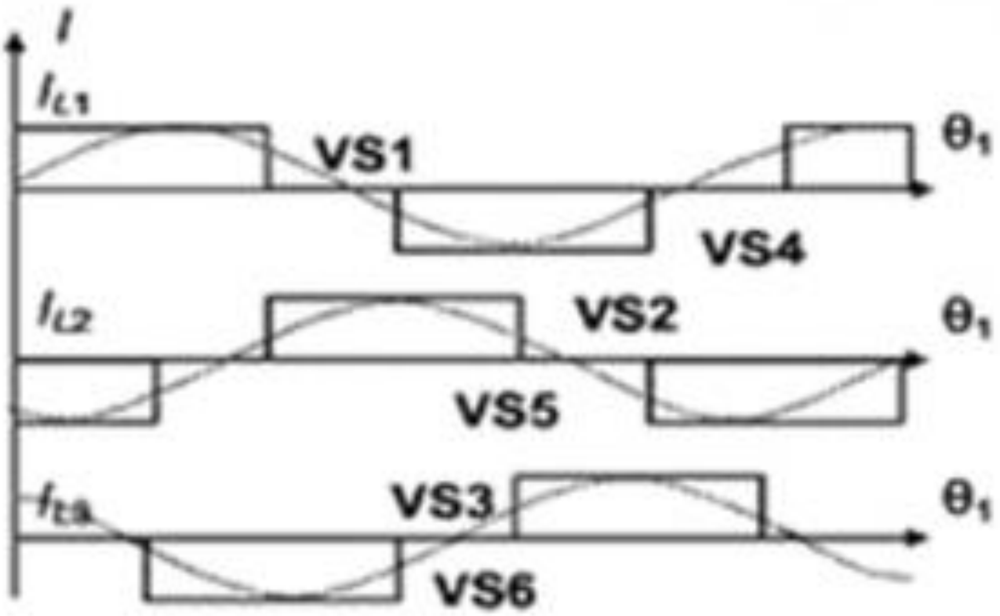
Q1 – Q2 OFF, Q3 – Q4 ON ==> v o = -Vs



Then the control circuits are used to generate the necessary gate signals to produce the required PWM waveform.

It is necessary to avoid short circuits. This happens by closing both Q1 and Q2 at the same time. To avoid this, it is necessary to turn off one set of IGBT before turning on the next. The Diodes provide a necessary path for inductive current in order to limit potential voltage build-up during the transition period. The capacitor provides smoothing to even out any variation in the DC supply.

The voltage and current waveforms across the resistive load are shown in Figure below.

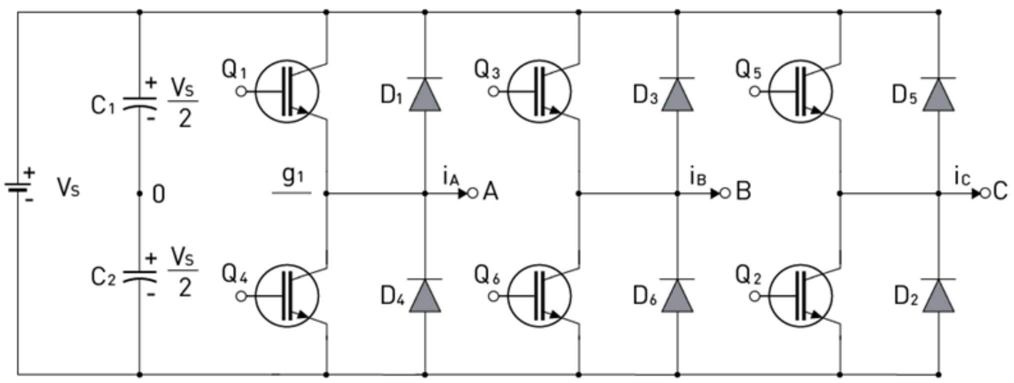


1. 5 Three-phase Inverter

A three phase inverter is a device that converts dc source into three phase ac output. This conversion is achieved through a power semiconductor switching topology.

Circuit Topology

Commonly the full-bridge topology is used for three-phase inverters.



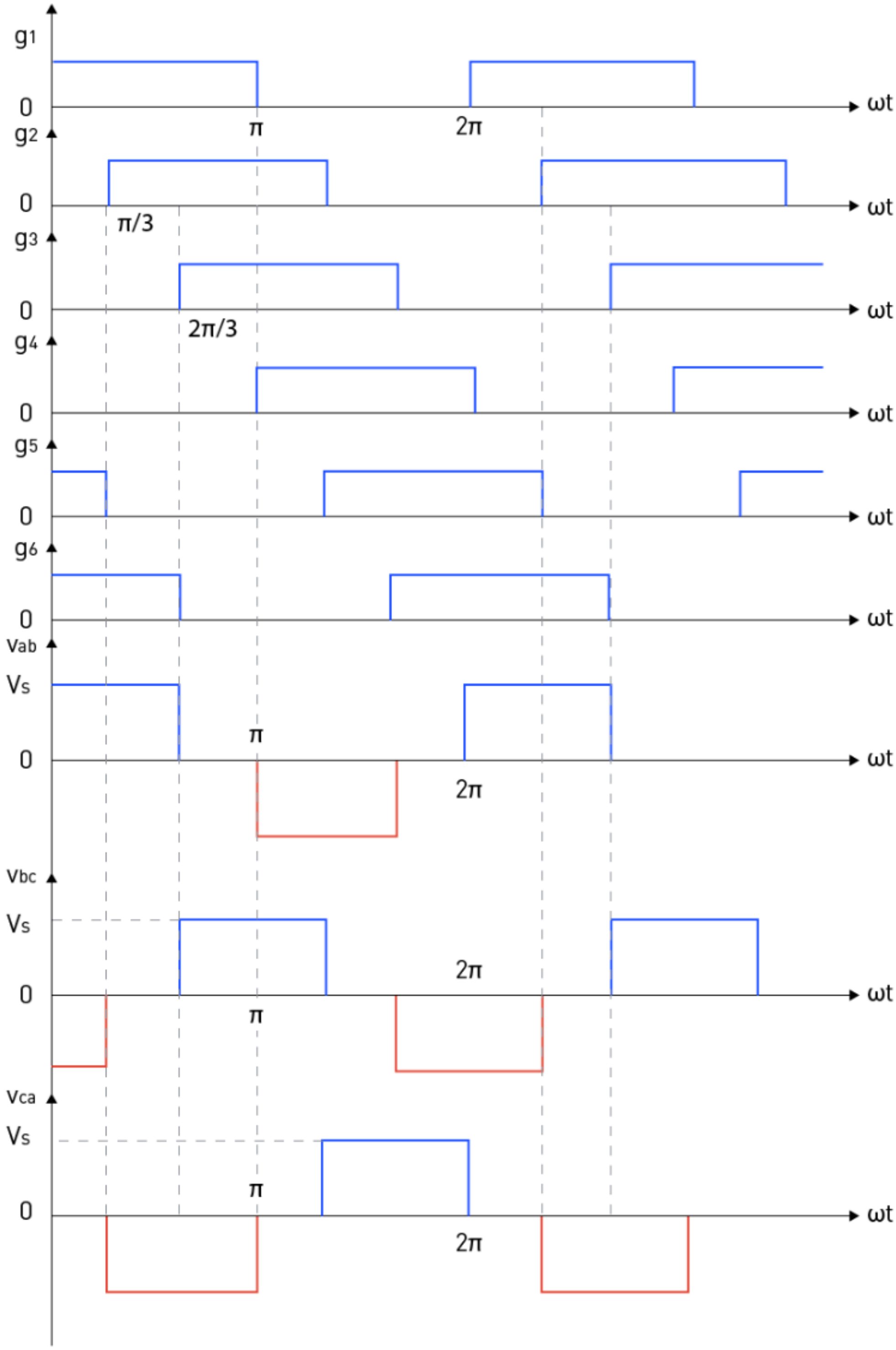
Modes of Conduction in 3-Phase Inverter

There are basically two modes of conduction:

- ✓ 180 degree conduction mode
- ✓ 120 degree conduction mode

1.5.1 180 Degree Conduction Mode

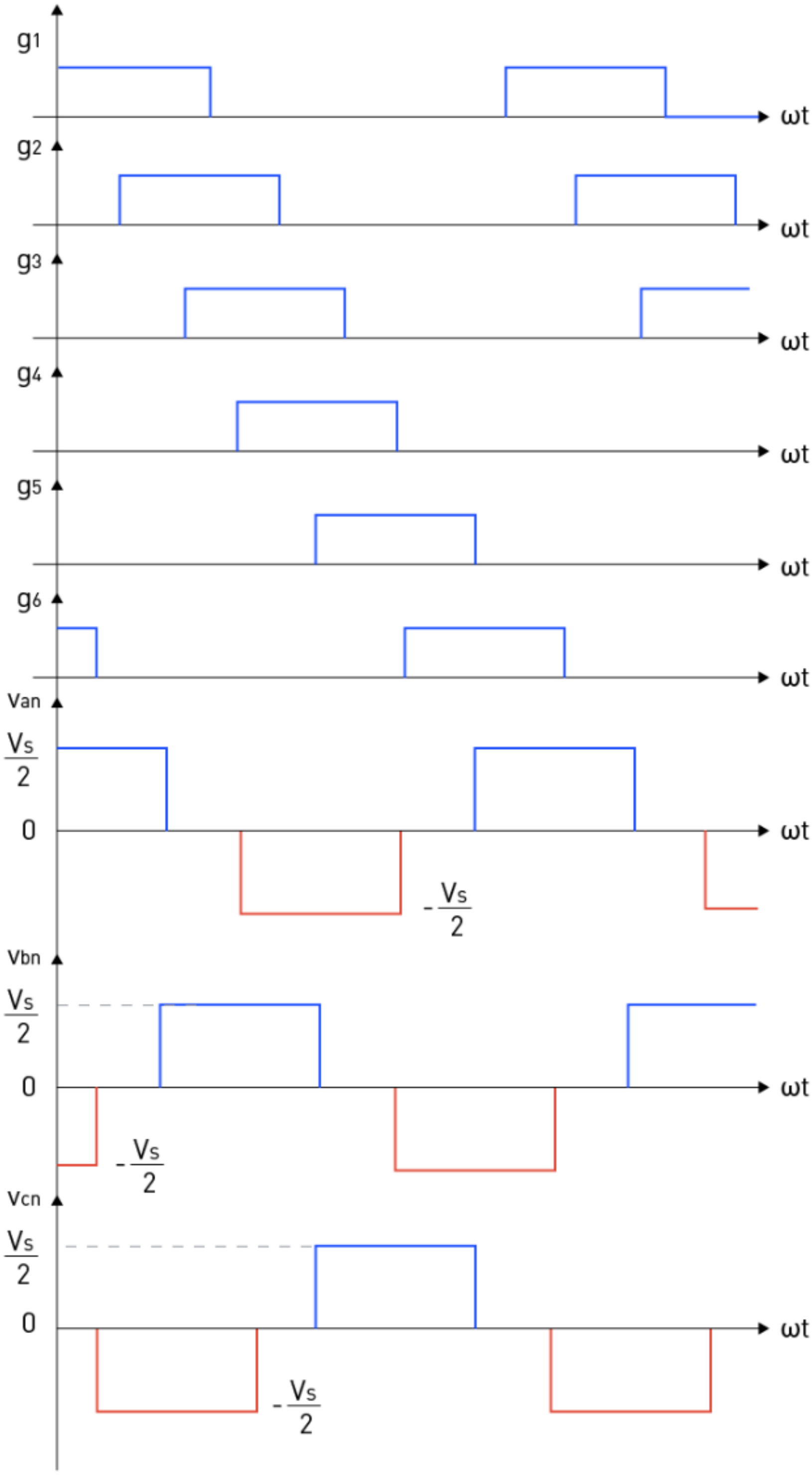
In this conduction mode each device conducts for 180 degrees with activation occurring at 60 degree intervals . The output terminals labeled A, B and C are connected in either star or a three phase delta configuration to the load. this balanced load arrangement is illustrated in the diagram.
During 0 to 60 degree phase angle range, switches S1 , S5 and S6 are in conduction mode . In this period, terminals A and C are connected to the positive point of the power source , while terminal B is linked to the source’s negative point . Additionally, there is an R/2 resistance between the two ends of the neutral and the positive terminals , while on R resistance is present between the neutral and the negative terminal.
This configuration ensures that the three phase inverter operates with a specific switching pattern, producing a balanced output across its terminals while controlling the flow of current through the load . Such precise control is essential for various applications , including motor drives and power systems , where maintaining balanced and controlled three phase ac power is crucial.



180 Degree Conduction Waveform

1.5.2 120 degree conduction mode

In this conduction mode , each electronic device operates for 120 degrees , making it suitable for a delta connected load . This mode generates a six step waveform across one of its phases , where only specific devices conduct at any given instant , precisely at 120 degree intervals. In the load connection , the ‘A’ terminal connects to the positive end of the source , while the ‘B’ terminal links to the source negative terminal . The ‘C’ terminal remains in a floating state , meaning it is not connected to either the positive or negative side of the source .The phase voltages across the load correspond to the voltages , providing a controlled and balanced output across the phases.



2. Selection criteria for power inverters?

When selecting a power inverter, there are several key criteria to consider to ensure it meets your needs. Here are the most important factors:

2.1 Power Rating:

- ✓ **Continuous Output Power**: Ensure the inverter can handle the continuous load you plan to use.
- ✓ **Surge Power**: Check the surge rating for starting high-demand appliances, which can require significantly more power.

2.2 Input Voltage

Match the inverter's input voltage with your power source, such as 12V, 24V, or 48V systems.

2.3 Output Waveform:

- ✓ **Pure Sine Wave**: Best for sensitive electronics; provides a clean output.
- ✓ **Modified Sine Wave**: More affordable but may not work well with all devices, especially those with sensitive circuits.

2.4 Efficiency

Look for an inverter with high efficiency (typically above 85%) to minimize energy loss.

2.5 Size and Portability

Consider the physical dimensions and weight, especially if you need a portable solution for camping or travel.

2.6 Cooling System

Inverters can generate heat, so check if it has adequate cooling (fan or passive) to prevent overheating.

2.7 Safety Features

Look for features like over-voltage protection, under-voltage protection, short circuit protection, and thermal shutdown.

2.8 Number of Outlets

Ensure it has enough outlets for your devices, and check the types (AC, USB, etc.).

2.9 Warranty and Support

A good warranty and responsive customer support can be crucial for troubleshooting and repairs.

2.10 Price

Balance your budget with the features and quality of the inverter to find the best value for your needs.

3. Applications of power inverters

- ✓ **Renewable Energy Systems**: In solar power systems, inverters convert the DC generated by solar panels into AC for home use or to feed into the grid.
- ✓ **Backup Power Systems**: Inverters are used in uninterruptible power supplies (UPS) and backup generators to provide AC power during outages.
- ✓ **Electric Vehicles**: Inverters convert the DC from the vehicle's battery to AC to power the electric motor

- ✓ **Telecommunications**: They provide AC power for communication equipment in remote locations.
- ✓ **Consumer Electronics**: Inverters are used in devices that require a stable AC supply from battery-operated devices, like portable power stations.
- ✓ **Industrial Applications**: They control AC motors and drives in various industrial processes, enabling variable speed operation.
- ✓ **Home Appliances**: Some inverters are designed for use with specific appliances, allowing for greater energy efficiency and mobility.

Theoretical Activity 3.1.4: Identification of datasheet information

Tasks:

1: Answer the following questions:

i. What is a datasheet?

ii. Outline information that can be found on a datasheet

2: Write the answers on flipchart/paper.

3: Present the findings to the trainer and whole class.

4: Ask clarification if any.

5: Read the key readings 3.1.1 in manual.

Key readings 3.1.4.: Identification of datasheet information

1. A datasheet of electronic components

It is a detailed document provided by the manufacturer that includes essential information about a specific electronic component. This document is crucial for engineers, designers, and technicians to understand the component's specifications, functionality, and proper usage.

1.1 Information found on a datasheet

1.1.1 Component Overview

- ✓ **Description:** A brief overview of what the component is and its primary function (e.g., a transistor, resistor, capacitor).
- ✓ **Features:** Key features and benefits of the component, such as high speed, low power consumption, or high precision.

1.1.2 Electrical Characteristics

- ✓ **Absolute Maximum Ratings:** The maximum limits of voltage, current, and power that the component can handle without being damaged. Exceeding these limits may cause failure.
- ✓ **Recommended Operating Conditions:** The optimal conditions under which the component operates reliably, including voltage, current, and temperature

ranges.

1.1.3 Pin Configuration and Function

- ✓ **Pinout Diagram:** A graphical representation showing the arrangement of pins and their functions, often crucial for components like integrated circuits (ICs).
- ✓ **Pin Descriptions:** Detailed descriptions of each pin's function (input, output, ground, power supply, etc.).

1.1.4 Mechanical and Physical Characteristics

- ✓ **Dimensions:** Physical dimensions of the component, including package size and lead spacing.
- ✓ **Package Types:** Information on the type of package (e.g., through-hole, surface mount) and any specific mounting details.

1.1.5 Electrical Performance Graphs and Curves

- ✓ **Performance Curves:** Graphs showing how the component behaves under various conditions, such as voltage vs. current, gain vs. frequency, or resistance vs. temperature.
- ✓ **Timing Diagrams:** For digital components, these show the timing relationships between signals and states.

1.1.6 Application Information

- ✓ **Typical Application Circuits:** Example circuits demonstrating how the component is used in practical applications.
- ✓ **Design Considerations:** Recommendations for circuit design to ensure proper operation of the component.

1.1.7 Reliability and Environmental Data

- ✓ **Life Expectancy:** Expected operational life or reliability of the component under specified conditions.
- ✓ **Temperature and Environmental Ratings:** Information on operating and storage temperature ranges, humidity, and other environmental factors.

1.1.8 Testing Procedures

How the component was tested to verify its performance and reliability.

1.1.9 Manufacturer Information

- ✓ **Contact Details:** Information for contacting the manufacturer or distributor for support or additional information.
- ✓ **Ordering Information:** Details on part numbers, packaging options, and how to order the component.

Practical Activity 3.1.5: Gathering components specifications

Task:

1: Read carefully the given task:

Gather the specifications of the following electronic components as used in the power inverter design:

- ✓ IGBTs
- ✓ Fuses and circuit breakers
- ✓ chopper
- ✓ Capacitors
- ✓ Resistors
- ✓ Heat Sink
- ✓ Fuse
- ✓ PCB

2: Perform the given tasks by respecting the given instructions.

4: Present your work to the trainer.

5: Read key reading 3.1.5 and ask clarification where necessary

6: Perform the task provided in application of learning 3.1

Key readings 3.1.5.: Gathering components specifications

Gathering component specifications involves a systematic approach to ensure you obtain the right data for selecting and using components effectively.

1.1 .Steps of gathering component specifications

- ✓ **Identify the Component**

  Determine the Component Type

  Function: Define what you need the component to do (e.g., resistor, capacitor, transistor, microcontroller).

  Basic Type: Identify the specific type within that category (e.g., NPN transistor, ceramic capacitor, 555 timer IC).

- ✓ **Source the Datasheet**

  Manufacturer's Website

  Find the Manufacturer: Use the part number to search for the component on the manufacturer's website.

  Download the Datasheet: Manufacturers typically provide datasheets in PDF format.

- ✓ **Electronic Component Distributors**
- ✓ **Search Online**: Distributors like Digi-Key, Mouser, RS Components, and Element14 have extensive component databases.

- ✓ **Datasheets and Technical Information**: Distributors often provide datasheets and additional technical details on their product pages.
- **Technical Libraries and Databases**
- ✓ **Engineering Libraries**: University or corporate engineering libraries may have datasheets and technical documents.
- ✓ **Online Databases**: Websites like Octopart or Datasheet4U aggregate datasheets from various sources.
- **Review the Datasheet**

Read the Component Overview

- ✓ **Description**: Understand the basic function and application of the component.
- ✓ **Features**: Note the key features and benefits.

Examine Electrical Specifications

- ✓ **Absolute Maximum Ratings**: Identify the maximum limits for voltage, current, and power to prevent damage.
- ✓ **Recommended Operating Conditions**: Check the optimal voltage, current, and temperature ranges for reliable operation.
- ✓ **Typical Characteristics**: Review typical values like resistance, capacitance, or gain.

Analyze Pin Configuration and Function

- ✓ **Pinout Diagram**: Refer to the diagram to understand pin layout and connections.
- ✓ **Pin Descriptions**: Check descriptions for each pin to ensure correct usage.

Example:

- **Pin 1**: Gate
- **Pin 2**: Drain
- **Pin 3**: Source

Review Thermal Characteristics

- ✓ **Junction Temperature**: Maximum temperature the component can handle.
- ✓ **Thermal Resistance**: Measures how well the component dissipates heat.

Check Switching and Dynamic Characteristics

- ✓ **Turn-On/Off Times**: For components like MOSFETs, review how quickly they switch states.
- ✓ **Gate Charge**: For MOSFETs, the total gate charge affects switching performance.

Example:

- ✓ **Turn-On Time**: 50ns
- ✓ **Gate Charge**: 20Nc

Review Application Information

- ✓ **Typical Application Circuits**: See how the component is used in practical applications.
- ✓ **Design Considerations**: Follow recommendations to ensure proper operation in your circuit.

- **Verify Compliance and Reliability**
  Review Reliability Data
- ✓ **Life Expectancy**
  Look for data on the component's expected operational life and reliability.
- **Cross-Reference with Other Sources**
  Compare with Alternatives
- ✓ **Cross-Reference**: If needed, compare specifications with similar components to ensure the best fit.

1.2 Insulated Gate Bipolar Transistors (IGBTs)

Insulated Gate Bipolar Transistors (IGBTs) are semiconductor devices used for switching and amplification. They combine the advantages of both MOSFETs and BJTs.

- **Define Application Requirements**
- ✓ **Voltage Requirements:** Determine the maximum operating voltage and transient voltages your application will experience.
- ✓ **Current Requirements:** Identify the maximum continuous and peak current that the IGBT will need to handle.
- ✓ **Switching Frequency:** Determine the frequency at which the IGBT will be switching to ensure it can handle the required switching speed.
- ✓ **Thermal Management:** Assess the cooling requirements and thermal dissipation needs for your application.
- **Gather Key Specifications**
  Voltage Rating (V_CE):
- ✓ **Description**: Maximum voltage the IGBT can handle between the collector and emitter.
- ✓ **Typical Values** : 600V, 1200V, 1700V, etc.
- ✓ **Considerations:** Ensure the rating exceeds the maximum voltage in your application.

Current Rating (I_C):

- ✓ **Description**: Maximum continuous current the IGBT can handle.
- ✓ **Typical Values:** 10A, 30A, 100A, etc.
- ✓ **Considerations:** Factor in the derating due to temperature and cooling conditions.

Gate-Emitter Voltage (V_GE):

- ✓ **Description:** Voltage required to fully turn the IGBT on.
- ✓ **Typical Values:** 15V (standard), with some devices offering lower or higher values.
- ✓ **Considerations:** Ensure compatibility with your gate drive circuit.

Gate-Emitter Threshold Voltage (V_GE(th)):

- ✓ **Description:** Minimum gate-emitter voltage needed to start conduction.
- ✓ **Typical Values:** 2V to 5V.
- ✓ **Considerations:** Important for precise gate drive control.

Collector-Emitter Saturation Voltage (V_CE(sat)):

- ✓ **Description:** Voltage drop across the IGBT when it is fully on.
- ✓ **Typical Values:** 1.5V to 3V.
- ✓ **Considerations:** Lower values indicate better efficiency and less power loss.

Total Gate Charge (Q_G):

- ✓ **Description:** Total charge required to switch the IGBT on and off.
- ✓ **Typical Values:** From a few nanocoulombs (nC) to microcoulombs (µC).
- ✓ **Considerations:** Affects the speed and power requirements of the gate drive circuitry.

Switching Speed:

- ✓ **Description:** Time required to turn the IGBT on and off.
- ✓ **Typical Values:** Turn-on time (ns to µs), Turn-off time (ns to µs).
- ✓ **Considerations**: Ensure the IGBT can handle your application’s switching frequency.

Thermal Resistance (R_th):

- ✓ **Description:** Resistance to heat flow from junction to ambient or case.
- ✓ **Typical Values**: °C/W.
- ✓ **Considerations:** Lower values are preferable for better thermal management.

Power Dissipation (P_D):

- ✓ **Description:** Maximum power the IGBT can dissipate without overheating.
- ✓ **Typical Values:** Depends on the package and cooling.
- ✓ **Considerations:** Ensure adequate cooling and heat dissipation in your design.

Package Type:

- ✓ **Description:** Physical package that affects thermal performance and mounting.
- ✓ **Typical Packages**: TO-220, D2PAK, modules.
- ✓ **Considerations**: Choose a package that fits your thermal and mounting needs.

Safe Operating Area (SOA):

- ✓ **Description**: The range of voltage and current within which the IGBT can operate safely.

- ✓ **Typical Values:** Defined in the datasheet's SOA curves.
- ✓ **Considerations**: Ensure your operating conditions fall within the SOA limits.

Isolation:

- **Description**: Electrical isolation between the gate and other terminals.
- **Typical Values:** Varies, check the datasheet for isolation specifications.
- **Considerations:** Important for protecting gate drive circuitry and safety

Review Datasheets

Obtain datasheets from manufacturers or suppliers for the specific IGBT models you're considering. Compare specifications to your application requirements and ensure compatibility.

Consult Application Notes

Review application notes and technical papers related to IGBTs for insights on real-world performance and design considerations.

Seek Expert Advice

If needed, consult with engineers or technical support from IGBT manufacturers to ensure the chosen device meets all your application's requirements.

1.3 Fuses

1.3.1. Define Application Requirements

- ✓ **Voltage Rating:** Determine the maximum voltage the fuse will encounter in your circuit.
- ✓ **Current Rating:** Identify the maximum current the fuse needs to protect against.
- ✓ **Blowing Characteristics:** Decide on the type of fuse response needed (fast-blow, slow-blow, etc.).
- ✓ **Environment:** Consider environmental factors such as temperature, humidity, and vibration.

1.3.2 Gather Key Specifications

1.3.2.1 Voltage Rating (V):

- ✓ **Description:** The maximum voltage the fuse can safely interrupt without arcing or causing damage.
- ✓ **Typical Values:** Common ratings include 250V, 600V, 1000V, etc.
- ✓ **Considerations:** Ensure the voltage rating of the fuse is higher than the maximum

voltage in your circuit.

1.3.2.2 Current Rating (I):

- ✓ **Description:** The maximum current the fuse can carry continuously without blowing.
- ✓ **Typical Values:** Ranges from milliamps (mA) to thousands of amps (kA), depending on the fuse type.
- ✓ **Considerations:** Choose a rating that is slightly higher than the normal operating current to avoid nuisance blowing.

1.3.2.3 Breaking Capacity (I_CU):

- ✓ **Description:** The maximum current the fuse can safely interrupt without causing damage.
- ✓ **Typical Values:** Varies widely, e.g., 10kA, 100kA, etc.
- ✓ **Considerations:** Ensure the fuse's breaking capacity exceeds the potential fault current in your circuit.

1.3.2.4 Fuse Type (Characteristic):

- ✓ **Description:** Indicates how the fuse reacts to overcurrent conditions.
- ▪ **Fast-Blow:** Opens quickly to protect sensitive components.
- ▪ **Slow-Blow (Time-Delay):** Withstands temporary overcurrent conditions and opens after a delay.
- ✓ **Typical Values:** Specific to application needs.
- ✓ **Considerations:** Choose based on the protection required and the nature of the load.

1.3.2.5 Package/Physical Size:

- ✓ **Description:** The physical dimensions and form factor of the fuse.
- ✓ **Typical Values:** Varied, including cylindrical, rectangular, surface-mount, etc.
- ✓ **Considerations:** Ensure the fuse fits the designated mounting location in your circuit.

1.3.2.6 Temperature Rating:

- ✓ **Description:** The range of temperatures within which the fuse can operate reliably.
- ✓ **Typical Values:** Often specified as a range, e.g., -55°C to +125°C.
- ✓ **Considerations:** Ensure the fuse can handle the operating temperature of your environment.

1.3.2.7 Fuse Speed (Opening Time):

- ✓ **Description:** Time it takes for the fuse to open under overload conditions.
- ✓ **Typical Values:** Fast (milliseconds), Medium, Slow (seconds).
- ✓ **Considerations:** Match the speed to the protection requirements of the circuit.

1.3.2.8 Mounting Style:

- ✓ **Description:** How the fuse is installed in the circuit.
- ▪ **Through-Hole:** For PCB mounting.
- ▪ **Surface-Mount:** For compact designs.

- **Panel-Mount:** For larger, industrial applications.
- ✓ **Typical Styles:** Axial lead, radial lead, surface-mount.
- ✓ **Considerations:** Ensure the mounting style is compatible with your circuit design.

1.3.3. Review Datasheets

- ✓ Obtain datasheets from manufacturers for the specific fuses you are considering.
- ✓ Compare specifications to your application requirements and verify they meet all necessary criteria.

1. 4. Gathering specifications of chopper

1.4.1 Define Application Requirements

- ✓ **Input Voltage Range:** Determine the range of voltages that the chopper will handle.
- ✓ **Output Voltage and Current:** Identify the required output voltage and current for your application.
- ✓ **Switching Frequency:** Define the frequency at which the chopper will operate.
- ✓ **Efficiency:** Consider the efficiency requirements for your power conversion.
- ✓ **Thermal Management:** Assess the cooling needs and heat dissipation requirements.

1.4.2 Gather Key Specifications

1.4.2.1 Input Voltage Range:

- ✓ **Description:** The range of input voltages the chopper can handle.
- ✓ **Typical Values:** 5V to 400V or more, depending on the chopper type and application.
- ✓ **Considerations:** Ensure the chopper's input voltage range covers your application's requirements.

1.4.2.2 Output Voltage:

- ✓ **Description:** The voltage output the chopper provides to the load.
- ✓ **Typical Values:** 5V, 12V, 24V, etc., depending on the application.
- ✓ **Considerations:** Ensure the output voltage is adjustable if required, or matches your application's needs.

1.4.2.3 Output Current:

- ✓ **Description**: The maximum current the chopper can supply to the load.
- ✓ **Typical Values:** Ranges from a few amps to hundreds of amps.
- ✓ **Considerations:** Ensure the current rating meets or exceeds the requirements of your load.

1.4.2.4 Switching Frequency:

- ✓ **Description**: The frequency at which the chopper operates.
- ✓ **Typical Values:** Can range from a few kHz to several MHz.
- ✓ **Considerations:** Higher frequencies can reduce the size of passive components but may require more sophisticated control and cooling.

1.4.2.5 Efficiency:

- ✓ **Description:** The ratio of output power to input power, indicating how effectively the chopper converts power.
- ✓ **Typical Values:** Typically 80-95%, depending on the design and application.
- ✓ **Considerations:** Higher efficiency reduces heat generation and power loss.

1.4.2.6 Duty Cycle:

- ✓ **Description:** The ratio of the on-time to the total cycle time of the switching device.
- ✓ **Typical Values**: Usually expressed as a percentage.
- ✓ **Considerations:** Ensure the duty cycle can be adjusted or matches your application requirements.

1.4.2.6 Thermal Resistance:

- ✓ **Description**: The resistance to heat flow from the chopper's junction to ambient or heatsink.
- ✓ **Typical Values**: Specified in °C/W.
- ✓ **Considerations:** Lower thermal resistance improves heat dissipation and reliability.

1.4.2.7 Control Method:

- ✓ **Description**: The method used to control the chopper, such as PWM (Pulse Width Modulation) or other techniques.
- ✓ **Typical Methods:** PWM is commonly used for its simplicity and effectiveness.
- ✓ **Considerations**: Ensure the control method aligns with your control circuitry and application requirements.

1.4.2.8 Protection Features:

- ✓ **Description**: Built-in features to protect against overcurrent, overheating, and other fault conditions.
- ✓ **Typical Features:** Overcurrent protection, thermal shutdown, short-circuit protection.
- ✓ **Considerations:** Verify that the chopper includes the necessary protection for your application.

1.4.2.9 Packaging and Form Factor:

- ✓ **Description**: The physical size and mounting style of the chopper.
- ✓ **Typical Packages:** TO-220, D2PAK, surface-mount, module packages.
- ✓ **Considerations:** Ensure the package fits your design and thermal management needs.

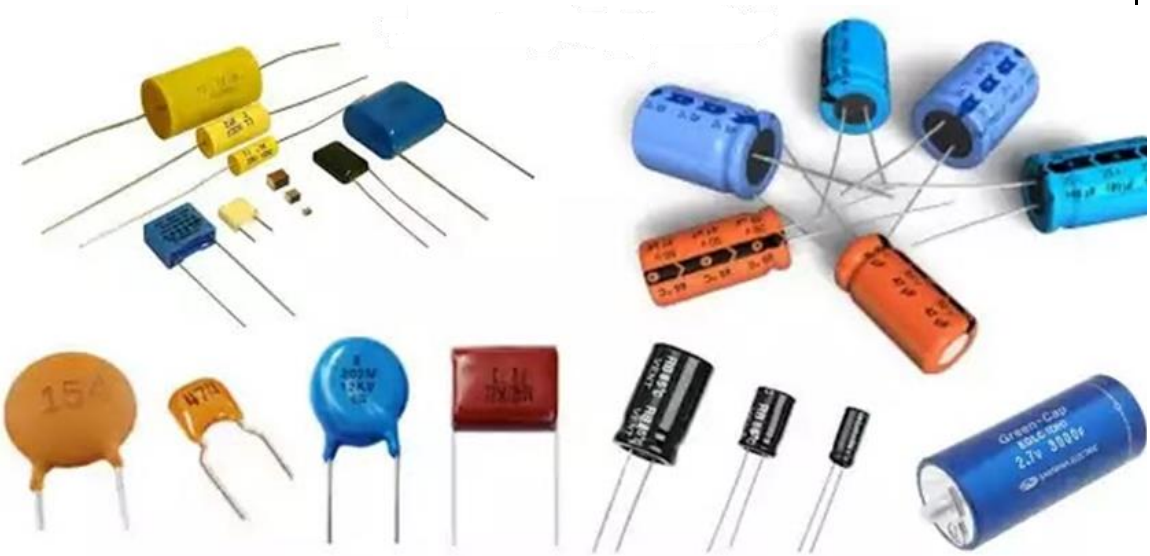
1.4.2.10 Ripple and Noise:

- ✓ **Description**: The amount of AC ripple and noise on the output.
- ✓ **Typical Values**: Specified in mV or as a percentage of the output voltage.
- ✓ **Considerations**: Lower ripple and noise are critical for sensitive applications.

1.4.3 Review Datasheets

Obtain datasheets from manufacturers for the specific choppers you're considering. Compare specifications to your application's requirements and verify they meet all necessary criteria.

1.5. Gathering specifications of Capacitors



1.5.1 Define Application Requirements

- ✓ **Voltage Rating:** Determine the maximum voltage the capacitor will experience.
- ✓ **Capacitance Value:** Identify the capacitance needed for your application.
- ✓ **Tolerance:** Consider the allowable variation in capacitance.
- ✓ **Temperature Range**: Assess the operating temperature range for the capacitor.
- ✓ **Size and Mounting:** Determine physical size and mounting style constraints.
- ✓ **Frequency Response:** Evaluate the capacitor's performance at your operating frequency.

1.5.2 Gather Key Specifications

1.5.2.1 Capacitance (C):

- ✓ **Description:** The ability of the capacitor to store charge, measured in farads (F).
- ✓ **Typical Values:** PicoFarads (pF), NanoFarads (nF), MicroFarads (µF), and higher.
- ✓ **Considerations:** Ensure the capacitance value matches the requirements of your circuit.

1.5.2.2 Voltage Rating (V):

- ✓ **Description:** The maximum voltage the capacitor can handle without breakdown.
- ✓ **Typical Values:** Ranges from a few volts (e.g., 6V, 25V) to thousands of volts (e.g., 500V, 1000V).
- ✓ **Considerations:** The voltage rating should be higher than the maximum voltage the capacitor will experience in the circuit.

1.5.2.3 Tolerance:

- ✓ **Description:** The acceptable deviation from the nominal capacitance value.
- ✓ **Typical Values:** ±1%, ±5%, ±10%, ±20%.
- ✓ **Considerations:** Choose tolerance based on the precision required for your application.

1.5.2.4 Temperature Coefficient (TC) / Temperature Range:

- ✓ **Description:** How capacitance changes with temperature. Also, the operational temperature range.

- ✓ **Typical Values**: -55°C to +125°C or higher for extreme conditions. TC is often expressed in parts per million per degree Celsius (ppm/°C).
- ✓ **Considerations:** Ensure the capacitor can operate reliably within the temperature range of your application.

1.5.2.5 Equivalent Series Resistance (ESR):

- ✓ **Description**: The internal resistance of the capacitor that affects its performance, especially at high frequencies.
- ✓ **Typical Values:** Measured in ohms (Ω), varying from milliohms (mΩ) to several ohms.
- ✓ **Considerations:** Lower ESR is desirable for high-frequency and power applications.

1.5.2.6 Leakage Current:

- ✓ **Description:** The small amount of current that flows through the capacitor when it is charged.
- ✓ **Typical Values:** Varies by type; typically, low for ceramic capacitors and higher for electrolytic capacitors.
- ✓ **Considerations:** Low leakage is important for precision applications and when the capacitor is used in high-impedance circuits.

1.5.2.7 Dielectric Type:

- ✓ **Description:** The material used between the capacitor plates, which affects performance.
- ✓ **Typical Types**: Ceramic, electrolytic, tantalum, film, aluminum, etc.
- ✓ **Considerations**: Choose based on the application's needs for stability, tolerance, and frequency response.

1.5.2.8 Size and Package:

- ✓ **Description:** The physical dimensions and mounting style of the capacitor.
- ✓ **Typical Packages:** Radial leaded, axial leaded, surface-mount (SMD), etc.
- ✓ **Considerations:** Ensure the capacitor fits within your design's spatial constraints and mounting requirements.
- ✓ **Ripple Current Rating:**
- ✓ **Description:** The maximum alternating current (AC) the capacitor can handle without overheating.
- ✓ **Typical Values:** Measured in amps (A), depends on the capacitor type and construction.
- ✓ **Considerations**: Ensure the capacitor can handle the ripple current in your application, particularly in power supply circuits.

1.5.2.9 Lifetime and Reliability:

- ✓ **Description**: Expected operational life and reliability of the capacitor under specified conditions.
- ✓ **Typical Values:** Hours of operation at rated temperature and voltage.

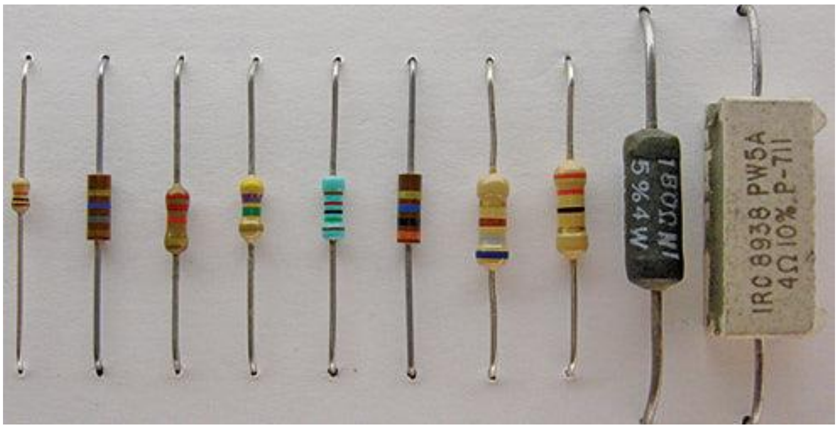
- ✓ **Considerations**: Ensure the capacitor meets the expected lifetime requirements for your application.

1.5.3. Review Datasheets

Obtain datasheets from capacitor manufacturers or suppliers.

Compare specifications with your application requirements to ensure compatibility and performance.

1.6 Gathering specifications of resistors



1.6.1. Define Application Requirements

- ✓ **Resistance Value**: Determine the specific resistance needed for your application.
- ✓ **Power Rating**: Identify how much power the resistor needs to dissipate.
- ✓ **Tolerance:** Consider the acceptable variation in resistance.
- ✓ **Temperature Coefficient:** Assess how resistance changes with temperature.
- ✓ **Size and Mounting Style:** Determine the physical size and mounting constraints.
- ✓ **Environmental Factors:** Consider operating conditions such as humidity and vibration.

1.6.2. Gather Key Specifications

1.6.2.1 Resistance Value (R):

- ✓ **Description:** The measure of opposition to current flow, expressed in ohms (Ω).
- ✓ **Typical Values:** From milli-ohms (mΩ) to mega-ohms (MΩ), depending on the application.
- ✓ **Considerations:** Ensure the resistor value matches the design requirements of your circuit.

1.6.2.2 Power Rating (P):

- ✓ **Description:** The maximum power the resistor can safely dissipate without overheating.
- ✓ **Typical Values:** Common ratings include 1/8W, 1/4W, 1/2W, 1W, 2W, 5W, etc.
- ✓ **Considerations:** Select a power rating that exceeds the maximum power dissipation in your application to ensure reliable operation.

1.6.2.3 Tolerance:

- ✓ **Description**: The allowable deviation from the nominal resistance value.
- ✓ **Typical Values:** ±1%, ±5%, ±10%, ±20%, and so on.

- ✓ **Considerations:** Choose a tolerance that matches the precision requirements of your circuit.

1.6.2.4 Temperature Coefficient (TC):

- ✓ **Description:** The change in resistance with temperature, typically expressed in ppm/°C (parts per million per degree Celsius).
- ✓ **Typical Values:** ±25 ppm/°C, ±50 ppm/°C, ±100 ppm/°C, etc.
- ✓ **Considerations:** A lower TC value means the resistor's resistance changes less with temperature, which is crucial for precision applications.

1.5.2.5 Temperature Range:

- ✓ **Description:** The range of temperatures within which the resistor can operate reliably.
- ✓ **Typical Values:** Often -55°C to +155°C, but can vary.
- ✓ **Considerations:** Ensure the resistor can operate within the temperature range of your application.

1.5.2.6 Resistance Type:

- ✓ **Description:** The construction and material of the resistor, affecting performance.
- ✓ **Typical Types:** Carbon film, metal film, wirewound, ceramic, thick film, thin film.
- ✓ **Considerations:** Choose based on factors like precision, stability, and power dissipation requirements.

1.5.2.7 Mounting Style:

- ✓ **Description:** The physical form and mounting type of the resistor.
- ✓ **Typical Types:** Through-hole (axial, radial leads), surface-mount (SMD).
- ✓ **Considerations:** Ensure the resistor fits your design’s physical constraints and mounting requirements.

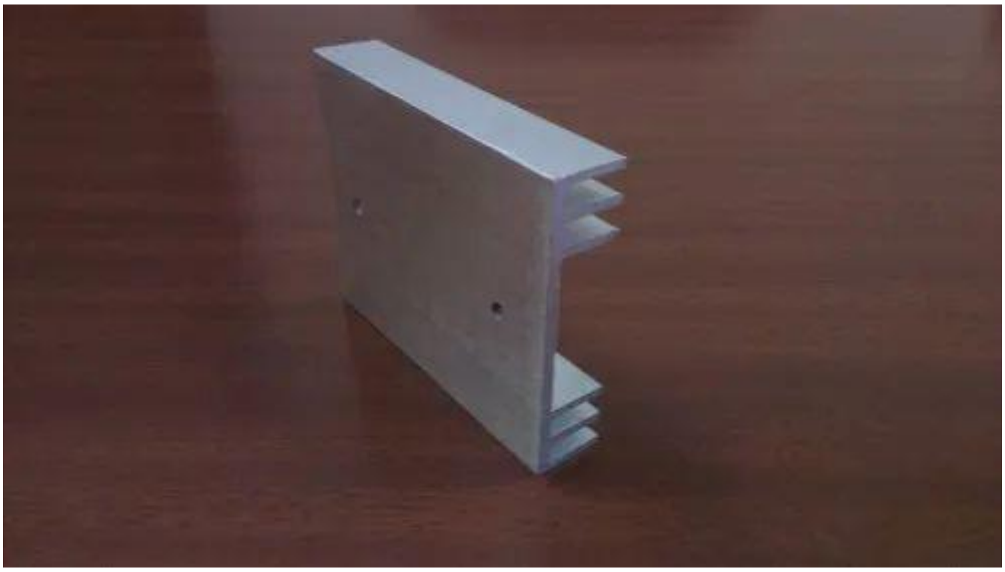
1.5.2.8 Noise:

- ✓ **Description:** The amount of electrical noise generated by the resistor.
- ✓ **Typical Values:** Measured in nanovolts per square root Hertz (nV/√Hz).
- ✓ **Considerations:** Low noise is important for precision analog circuits and signal processing.

1.6.3. Review Datasheets

Obtain datasheets from manufacturers for the specific resistors you’re considering. Compare specifications to your application’s requirements to verify compatibility and performance.

1.7. Gathering specifications of heat sink



1.7.1. Define Application Requirements

- ✓ **Heat Dissipation Needs:** Determine the amount of heat (in watts) that needs to be dissipated.
- ✓ **Component Dimensions:** Consider the size and shape of the component that the heat sink will be attached to.
- ✓ **Space Constraints:** Assess the available space for mounting the heat sink.
- ✓ **Airflow:** Evaluate whether the heat sink will be used in a natural convection environment or with forced airflow (e.g., fans).

1.7.2. Gather Key Specifications

1.7.2.1 Thermal Resistance (R_θ):

- ✓ **Description:** The heat sink's ability to conduct heat away from the component, measured in °C/W.
- ✓ **Typical Values:** Ranges from 0.1°C/W to several °C/W, depending on the design.
- ✓ **Considerations:** Lower thermal resistance indicates better heat dissipation performance. Ensure the thermal resistance is low enough to maintain the desired temperature.

1.7.2.2 Heat Dissipation Capacity:

- ✓ **Description:** The maximum amount of heat the heat sink can effectively dissipate.
- ✓ **Typical Values**: Specified in watts (W).
- ✓ **Considerations:** Ensure the heat sink can handle the maximum power dissipation required by your component.

1.7.2.3 Size and Dimensions:

- ✓ **Description:** The physical dimensions of the heat sink, including height, width, and depth.
- ✓ **Typical Values**: Varies widely, e.g., 10mm x 10mm to 100mm x 100mm or larger.
- ✓ **Considerations:** Ensure the heat sink fits within the available space and can be mounted properly.

1.7.2.4 Mounting Type:

- ✓ **Description:** The method used to attach the heat sink to the component or housing.
- ✓ **Typical Types:** Clip-on, screw-mounted, adhesive, or press-fit.
- ✓ **Considerations:** Choose a mounting method that suits your application's requirements and ensures good thermal contact.

1.7.2.5 Material:

- ✓ **Description:** The material used to construct the heat sink, which affects thermal conductivity and weight.
- ✓ **Typical Materials:** Aluminum, copper, or composites.
- ✓ **Considerations:** Aluminum is commonly used for its good thermal conductivity and lightweight properties, while copper offers higher thermal conductivity but is heavier and more expensive.

1.7.2.6 Fin Design and Density:

- ✓ **Description:** The shape and spacing of the fins on the heat sink, which affect airflow and heat dissipation.
- ✓ **Typical Designs:** Straight fins, pinned fins, or extruded fins**.**
- ✓ **Considerations:** Higher fin density increases surface area and improves heat dissipation but may also affect airflow and space requirements.

1.7.2.7 Surface Finish:

- ✓ **Description:** The finish of the heat sink surface, affecting thermal contact and aesthetics.
- ✓ **Typical Finishes:** Anodized, painted, or natural**.**
- ✓ **Considerations:** Anodized finishes improve thermal contact and prevent oxidation, which is important for long-term reliability.

1.7.2.8 Compatibility:

- ✓ **Description:** Ensure the heat sink is compatible with the component in terms of size, mounting, and thermal interface.
- ✓ **Typical Considerations:** Check that the heat sink's footprint matches the component's mounting area and that any thermal pads or compounds used are appropriate.

1.7.2.9 Weight:

- ✓ **Description:** The weight of the heat sink, which can affect mounting and handling.
- ✓ **Typical Values:** Ranges from a few grams to several kilograms.
- ✓ **Considerations:** Ensure the weight of the heat sink is manageable for your application and mounting setup.

1.7.2.10 Airflow Considerations:

- ✓ **Description:** Whether the heat sink is designed for natural convection or forced airflow (e.g., with a fan).
- ✓ **Typical Designs**: Passive (natural convection) or active (with fan).

- ✓ **Considerations:** Active heat sinks (with fans) provide higher heat dissipation but require power and space for the fan.

1.7.2.11 Thermal Interface Material (TIM):

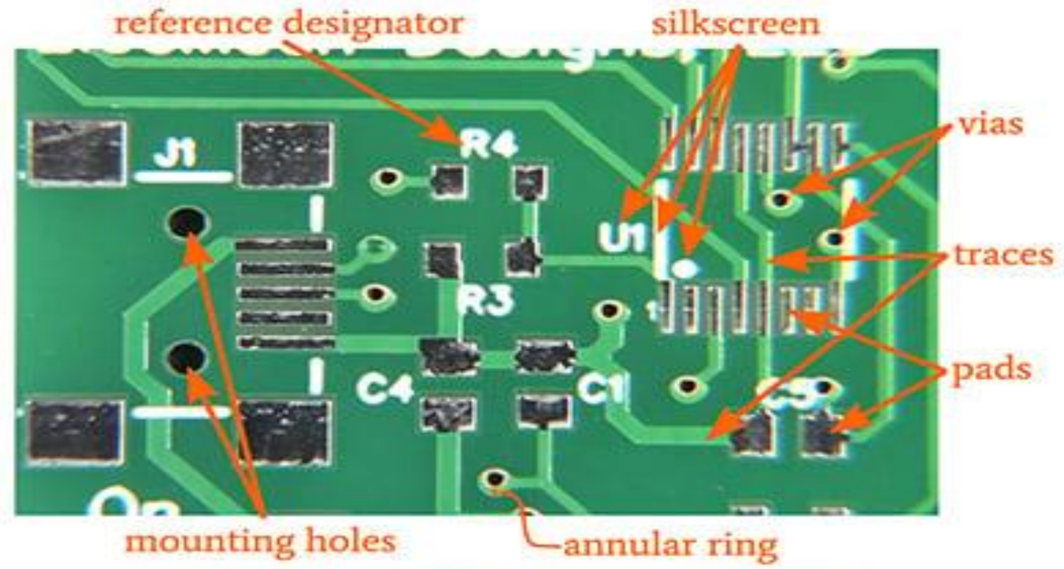
- ✓ **Description:** Material used between the heat sink and the component to improve thermal conductivity.
- ✓ **Typical Materials:** Thermal pads, thermal grease, or thermal epoxy.
- ✓ **Considerations**: Ensure the TIM is compatible with both the heat sink and the component for optimal thermal performance.

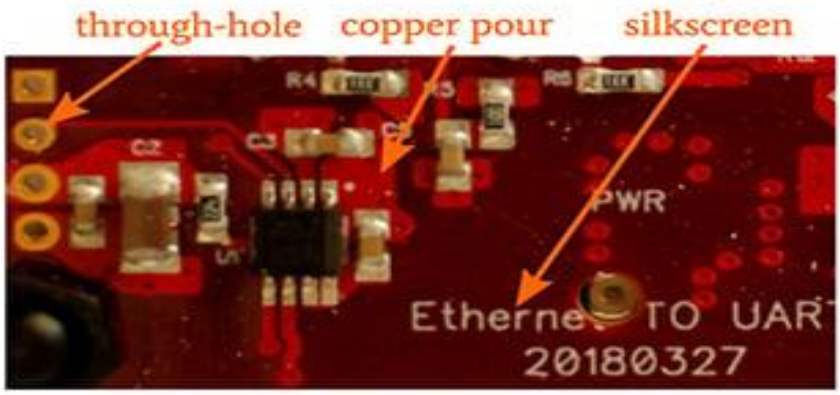
1.7.3. Review Datasheets

Obtain datasheets from manufacturers or suppliers for the specific heat sinks you're considering.

Compare specifications to your application's requirements to verify compatibility and performance.

1. 8. Gathering specifications of PCB





1.8.1. Define Application Requirements

- **Circuit Design:** Determine the complexity and requirements of the circuit to be implemented on the PCB.
- **Environmental Conditions**: Consider the operating environment, including

temperature, humidity, and exposure to chemicals or vibrations.

1.8.2. Gather Key Specifications

1.8.2.1 Board Dimensions:

- ✓ **Description:** The physical size and shape of the PCB.
- ✓ **Typical Values:** Custom sizes based on design; common sizes include 50mm x 50mm to 300mm x 300mm or larger.
- ✓ **Considerations:** Ensure the PCB fits within the enclosure and meets design constraints.

1.8.2.2 Layer Count:

- ✓ **Description:** The number of conductive layers in the PCB.
- ✓ **Typical Values:** Single-layer, double-layer, multi-layer (4, 6, 8 layers, etc.).
- ✓ **Considerations:** Multi-layer boards are used for more complex circuits or to save space.

1.8.2.3 Material:

- ✓ **Description**: The substrate material of the PCB, affecting electrical properties and thermal management.
- ✓ **Typical Materials:** FR-4 (fiberglass), CEM1, CEM3, ceramic, high-frequency materials (e.g., Rogers).
- ✓ **Considerations:** Choose based on electrical performance, thermal requirements, and cost.

1.8.2.4 Copper Thickness:

- ✓ **Description:** The thickness of the copper layer used for traces and pads.
- ✓ **Typical Values:** Ranges from 1 oz/ft^2 to 10 oz/ft^2 or more (thicker copper for higher current).
- ✓ **Considerations:** Ensure the copper thickness supports the current carrying capacity and thermal dissipation needed.

1.8.2.5 Trace Width and Spacing:

- ✓ **Description:** The width of the conductive traces and the spacing between them.
- ✓ **Typical Values:** Trace width can range from a few mils to several millimeters, depending on current requirements and design rules.
- ✓ **Considerations:** Ensure trace width and spacing meet electrical and manufacturing requirements.

1.8.2.6 Drill Sizes and Hole Tolerances:

- ✓ **Description:** Sizes of plated and non-plated holes for component leads and vias.
- ✓ **Typical Values:** Hole sizes can range from 0.3mm to several millimeters.
- ✓ **Considerations:** Ensure hole sizes and tolerances match component leads and manufacturing capabilities.

1.8.2.7 Surface Finish:

- ✓ **Description:** The coating applied to the PCB to protect the copper and enhance solderability.
- ✓ **Typical Finishes:** HASL (Hot Air Solder Leveling), ENIG (Electroless Nickel/Immersion Gold), OSP (Organic Solderability Preservative), Immersion Silver.
- ✓ **Considerations:** Choose based on soldering process, component requirements, and cost.

1.8.2.8 Impedance Control:

- ✓ **Description:** Control over the impedance of signal traces, crucial for high-speed or RF designs.
- ✓ **Typical Values:** Impedance controlled traces for specific values (e.g., 50Ω, 75Ω).
- ✓ **Considerations:** Ensure impedance control meets signal integrity requirements for high-speed or high-frequency applications.

1.8.2.9 PCB Thickness:

- ✓ **Description**: The overall thickness of the PCB.
- ✓ **Typical Values:** Ranges from 0.2mm to 3.2mm or more.
- ✓ **Considerations**: Choose based on mechanical support, thermal dissipation, and enclosure constraints.

1.8.2.10 Solder Mask:

- ✓ **Description:** A protective layer applied over the PCB to prevent solder from bridging between traces.
- ✓ **Typical Colors**: Green, red, blue, black.
- ✓ **Considerations**: Ensure the solder mask is compatible with the PCB's operational environment and meets design requirements.

1.8.2.11 Silkscreen Layer:

- ✓ **Description:** The layer used for marking component values, logos, and other information on the PCB.
- ✓ **Typical Colors:** White, yellow, or other colors.
- ✓ **Considerations:** Ensure silkscreen does not overlap with pads or vias and is legible for assembly.

1.8.2.12 Vias and Pads:

- ✓ **Description:** Vias are used for electrical connections between layers, and pads are areas for component leads.
- ✓ **Typical Sizes:** Varies based on design requirements.
- ✓ **Considerations**: Ensure via and pad sizes are appropriate for component leads and the manufacturing process.

1.8.2.13 Thermal Management:

- ✓ **Description:** Features designed to manage heat dissipation, such as thermal pads, heatsinks, or copper pours.
- ✓ **Typical Features:** Thermal vias, large copper areas, heat spreaders.
- ✓ **Considerations:** Ensure adequate thermal management for components that

generate significant heat.

1.8.3. Review Design Files

Obtain and review design files such as Gerber files, Bill of Materials (BoM), and schematic diagrams.

Verify that the design files align with your specifications and requirements.

Points to Remember

- **Power inverter parameters are:**
  - ✓ Peak Inverse Voltage
  - ✓ Output AC voltage
  - ✓ Output AC power
  - ✓ Operating temperature range
  - ✓ Connections and interfaces
  - ✓ Efficiency
  - ✓ Input DC voltage
  - ✓ Output Frequency
  - ✓ Total Harmonic Distortion (THD)
  - ✓ Mounting Options.
- **Types of power inverters:**
  - ✓ Pure sine wave inverter
  - ✓ Modified sine wave inverter.
  - ✓ Square wave inverter
- **Procedures of determination of power inverter parameters**

✓ Define Your Requirements

✓ Determine Key Inverter Parameters:

- **Procedure of Gathering component specifications**

✓ Identify the Component

✓ Source the Datasheet

✓ Review the Datasheet:

✓ Verify Reliability

✓ Cross-Reference with Other Sources

✓ Compare with Alternatives

Application of learning 3.1.

MHK ltd is a new company working in Rwanda. This company is distributing electricity of solar panels for home application (for Rwandan people). Suppose you are working in the Design Department, and you tasked to evaluate the requirements of the power inverters that will be used in that project.

Indicative content 3.2: Designing Power Inverter Diagram

Duration: 4 hrs

Theoretical Activity 3.2.1: Identification of types of Symbols and diagrams

Tasks:

1: Answer the following questions:

i. Identify main drawing symbols used in power inverter diagram

ii. Outline electrical diagrams you know.

2: Write the answers on flipchart/paper.

3: Present the findings to the trainer and whole class.

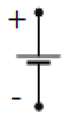
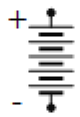
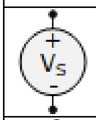
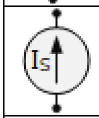
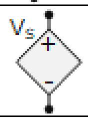
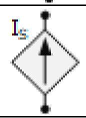
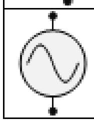
4: Ask for clarification if any.

5: Read the key readings 3.2.1

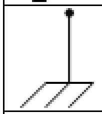
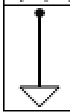
Key readings 3.2.1.: Identification of types of Symbols and diagrams

1. Schematic diagrams

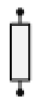
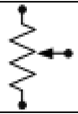
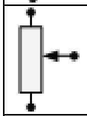
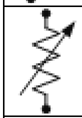
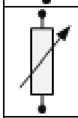
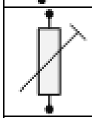
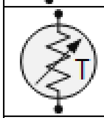
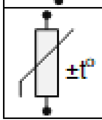
1.1 Power Supply Schematic Symbols

Schematic Symbol	Symbol Identification	Description of Symbol
	Single Cell	A single DC battery cell of 0.5V
	DC Battery Supply	A collection of single cells forming a DC battery supply
	DC Voltage Source	A constant DC voltage supply of a fixed value
	DC Current Source	A constant DC current supply of a fixed value
	Controlled Voltage Source	A dependent voltage source controlled by an external voltage or current
	Controlled Current Source	A dependent current source controlled by an external voltage or current
	AC Voltage Source	A sinusoidal voltage source or generator

1.2 Electrical Grounding Schematic Symbols

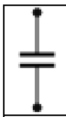
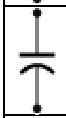
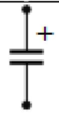
Schematic Symbol	Symbol Identification	Description of Symbol
	Earth Ground	Earth ground referencing a common zero potential point
	Chassis Ground	Chassis ground connected to the power supplies earthing pin
	Digital Ground	A common digital logic circuit ground line

1.3 Resistor Schematic Symbols

Schematic Symbol	Symbol Identification	Description of Symbol
	Fixed Resistor (IEEE Design)	A fixed value resistor whose resistive value is indicated next to its schematic symbol
	Fixed Resistor (IEC Design)	
	Potentiometer (IEEE Design)	Three terminal variable resistance whose resistive value is adjustable from zero to its maximum value
	Potentiometer (IEC Design)	
	Rheostat (IEEE Design)	Two terminal fully adjustable rheostat whose resistive value varies from zero to a maximum value
	Rheostat (IEC Design)	
	Trimmer Resistor	Small variable resistors for mounting onto pcb’s
	Thermistor (IEEE Design)	Thermal resistor whose resistive value changes with changes in surrounding temperature
	Thermistor (IEC Design)	

1.4 Capacitor Schematic Symbols

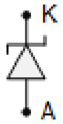
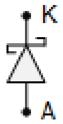
Schematic Symbol	Symbol Identification	Description of Symbol

	Fixed Value Capacitor	A fixed value parallel plate non-polarised AC capacitor whose capacitive value is indicated next to its schematic symbol
	Fixed Value Capacitor	
	Polarized Capacitor	A fixed value polarised DC capacitor usually an electrolytic capacitor which must be connected to the supply as indicated
	Variable Capacitor	An adjustable capacitor whose capacitance value can be varied by means of adjustable plates

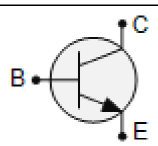
1.5 Inductor and Coil Schematic Symbols

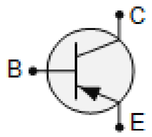
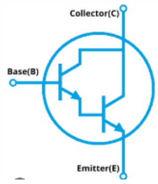
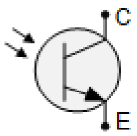
Schematic Symbol	Symbol Identification	Description of Symbol
	Open Inductor	An open inductor, coil or solenoid that generates a magnetic field around itself when energised

1.6 Semiconductor Diode Symbols

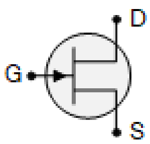
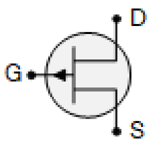
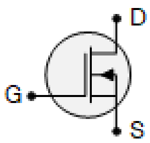
Schematic Symbol	Symbol Identification	Description of Symbol
	Semiconductor Diode	Semiconductor pn-junction diode used for rectification and high current applications
	Zener Diode	Zener diode used in its reverse voltage breakdown region for voltage limiting and regulation applications
	Schottky Diode	Schottky diode consisting of an n-type semiconductor and metal electrode junction for low voltage applications

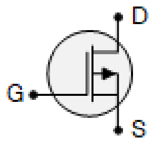
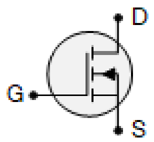
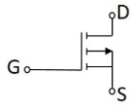
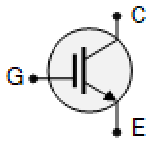
1.7 Schematic Semiconductor Symbols for Bipolar Junction Transistors

Schematic Symbol	Symbol Identification	Description of Symbol
	NPN Bipolar Transistor	Characterised as being a lightly doped p-type base region between two n-type emitter and collector regions with the arrow indicating direction of conventional current flow out

	PNP Bipolar Transistor	Characterised as being a lightly doped n-type base region between two p-type emitter and collector regions. Arrow indicates direction of conventional current flow in
	Darlington Pair Transistor	Two bipolar transistor npn or pnp connected in a series common collector configuration to increase overall current gain. Available in PNP and Sziklai pair configuration
	Phototransistor	NPN Phototransistor sealed in a protective case with glass lens or window for detecting external visible and near infrared light sources. Some models have a base (B) lead available to enable biasing and sensitivity control

1.8 Schematic Symbols for Field Effect Transistors

Schematic Symbol	Symbol Identification	Description of Symbol
	N-JFET Transistor	N-channel junction field effect transistor having an n-type semi-conductive channel between the Source (S) and Drain (D) terminals with the Gate (G) arrow pointing inwards to indicate direction of conventional current flow
	P-JFET Transistor	P-channel junction field effect transistor having a p-type semi-conductive channel between Source (S) and Drain (D) terminals with the Gate (G) arrow pointing outwards to indicate direction of conventional current flow
	N-channel D-MOSFET Transistor	Depletion N-channel Metal-Oxide Semiconductor FET (nMOSFET) has a Gate terminal insulated from the main conductive channel and which is *normally-on* and conducting when $V_G = 0$ volts

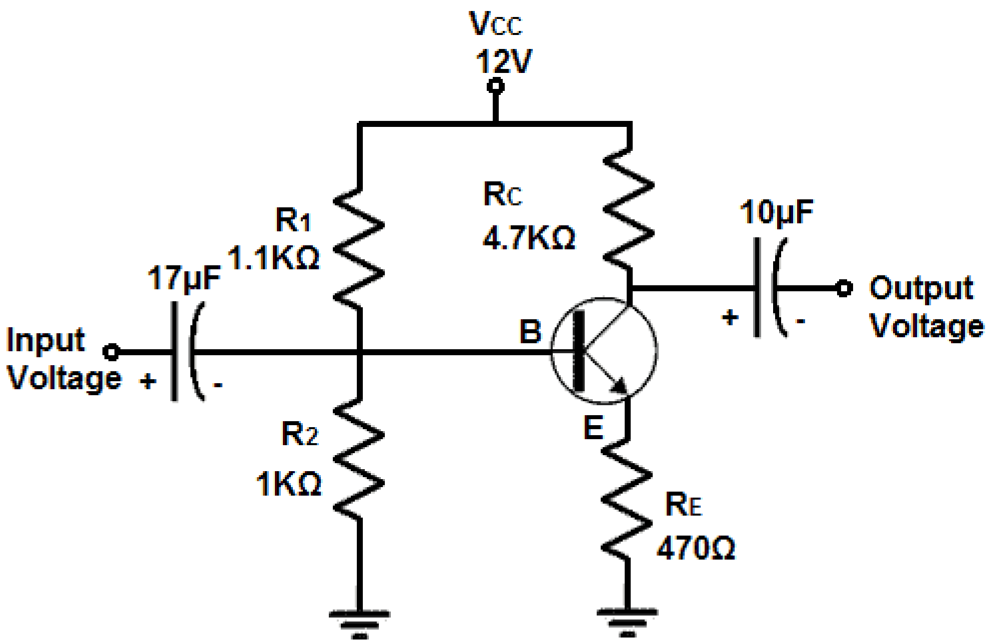
	P-channel D-MOSFET Transistor	Depletion P-channel Metal-Oxide Semiconductor FET (pMOSFET) has a Gate terminal insulated from the main conductive channel and which is *normally-on* and conducting when V_G = 0 volts
	N-channel E-MOSFET Transistor	Enhancement N-channel Metal-Oxide Semiconductor FET (nMOSFET) has a Gate terminal insulated from the main channel and which is *normally-off* and closed when V_G = 0 volts
	P-channel E-MOSFET Transistor	Enhancement P-channel Metal-Oxide Semiconductor FET (pMOSFET) has a Gate terminal insulated from the main channel and which is *normally-off* and closed when V_G = 0 volts
	IGBT Transistor	Insulated Gate Bipolar Transistor (IGBT) is a cross between a BJT and IGFET offering high input MOS characteristics and large bipolar output current-carrying capability and low saturation voltage

2. Types of diagrams

2.1 Schematic Diagram

A simplified representation of an electrical circuit using symbols to represent components and lines for connections.

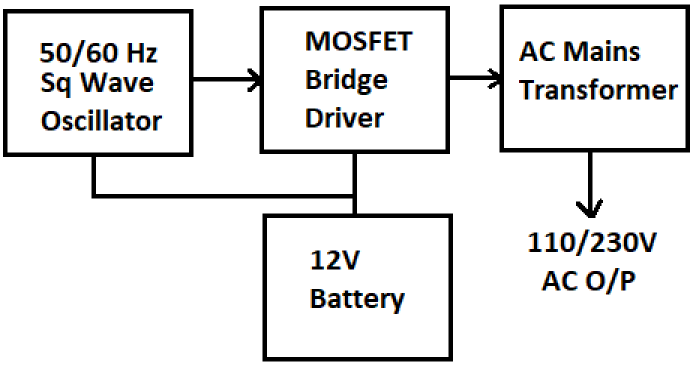
Ex:



2.2 Block Diagram

A high-level representation that illustrates the main components of a system and their interconnections without detailed circuitry.

Ex: block diagram of power inverter



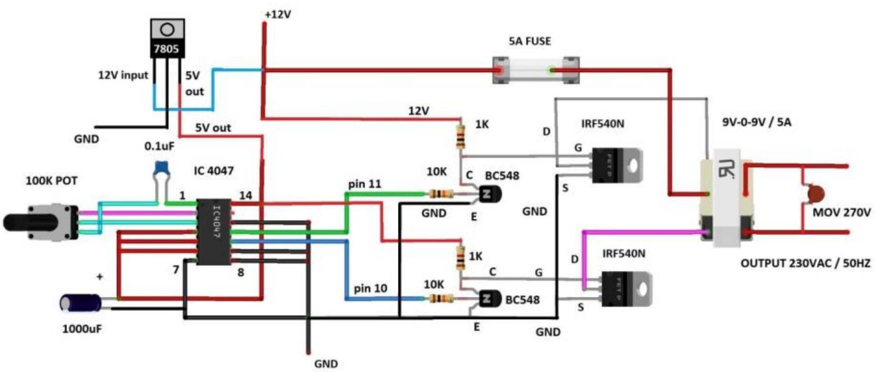
2.3 Wiring Diagram

It is a detailed representation of the physical connections and layout of an electrical system, often used for installation and troubleshooting.

2.4 Pictorial Diagram

It Offers a visual representation of components in a circuit, resembling a more realistic illustration.

Example:



Practical Activity 3.2.2: Designing a power inverter Diagram

Task:

1: Read carefully the given task:

Design a 12V DC to 220V AC inverter circuit diagram.

Components Required

No	Item
1	IC CD4047
2	IRFZ44 power MOSFET
3	12V-240V Output Transformer
4	22KΩ Variable Resistor
5	100Ω/10W Resistors (2)
6	0.22µF Capacitors
7	12V Sealed Lead Acid Battery

2: Perform the given tasks by respecting the given instructions.

4: Present your work to the trainer.

5: Read key reading 3.2.2 and ask clarification where necessary

6: Perform the task provided in application of learning 3.2

Key readings 3.2.2: Designing a power inverter Diagram

Steps to pass through in order to design a power inverter diagram

Designing a power inverter schematic involves several key components and considerations. Here's a basic outline to guide you through creating a simple inverter circuit that converts DC to AC:

Step1: **Select the type of a power inverter diagram**

- ✓ Block diagram
- ✓ Wiring diagram
- ✓ Pictorial diagram
- ✓ Schematic diagram

Step2: List down the components needed

i. **Power Source**: A DC source (12V battery).

ii. **Oscillator Circuit**: Generates a square wave signal (can use a 555 timer IC or a transistor-based oscillator).

iii. **Transistors**: Typically, two N-channel MOSFETs (IRF540N) and BJTs(BC549) are used to switch the current.

iv. **Transformer**(12 to 240V): To step up the voltage and isolate the circuit (often a center-tapped transformer).

v. **Diodes**: For protection against back EMF.

vi. **Capacitors**: For smoothing and filtering (C1 10uF (non-polar), C2 10nF (non-polar) and C3 1000uf (25V electrolytic))

vii. **Resistors**: For biasing and current limiting (VR 20k pot, R1, R3, R4 1kΩ(1/4watt), R2 4.7kΩ(1/4watt))

viii. **Load**: The AC device you want to power.

Step3: Get all symbols an inverter's components

Find the symbol for every component used in the design

Step4: Draw the inverter diagram

i. **Oscillator Circuit**:

- ✓ Use a 555 timer IC in astable mode to create a square wave.
- ✓ Connect resistors and capacitors to set the frequency (typically 50/60 Hz).

ii. **Transistor Switching**:

- ✓ Connect the output of the oscillator to the gate/base of the transistors (MOSFETs/BJTs).
- ✓ Ensure that the transistors are configured in a push-pull arrangement.
- ✓ Connect the collector/drain to one end of the transformer.

iii. **Transformer**:

- ✓ Use a center-tapped transformer for better efficiency.
- ✓ Connect the center tap to ground.
- ✓ Connect the other ends to the collectors/drains of the transistors.

iv. **Diode Protection**:

- o Place diodes in parallel with the transistors to protect against back EMF.

v. **Output Circuit**:

- ✓ The secondary winding of the transformer will provide the AC output.
- ✓ Add capacitors to smooth the output if necessary.

vi. **Load Connection**:

✓ Connect your AC load to the output of the transformer.

Points to Remember

- **Types of diagrams**

✓ Schematic Diagram
✓ Block Diagram
✓ Wiring Diagram
✓ Pictorial Diagram

- **Steps for designing a power diagram:**

✓ Select the type of a power inverter diagram
✓ list down the components needed
✓ Get all symbols an inverter's components
✓ Draw a power inverter diagram

Application of learning 3.2.

As a technician, you are given the following power inverter's components. Design a 12V DC to 220V AC inverter circuit diagram.

The given components are

✓ 555 timer IC
✓ T1 step-up Transformer (12 to 240V)
✓ C1 10uF (non-polar)
✓ C2 10nF (non-polar)
✓ C3 1000uf (25V electrolytic)
✓ Q1 BC549
✓ Q2 IRF540N
✓ Q3 IRF540N
✓ VR 20k pot
✓ R1, R3, R4 1kΩ(1/4watt)
✓ R2 4.7kΩ(1/4watt)
✓ 12V battery

Indicative content 3.3: Assembling Power Inverter

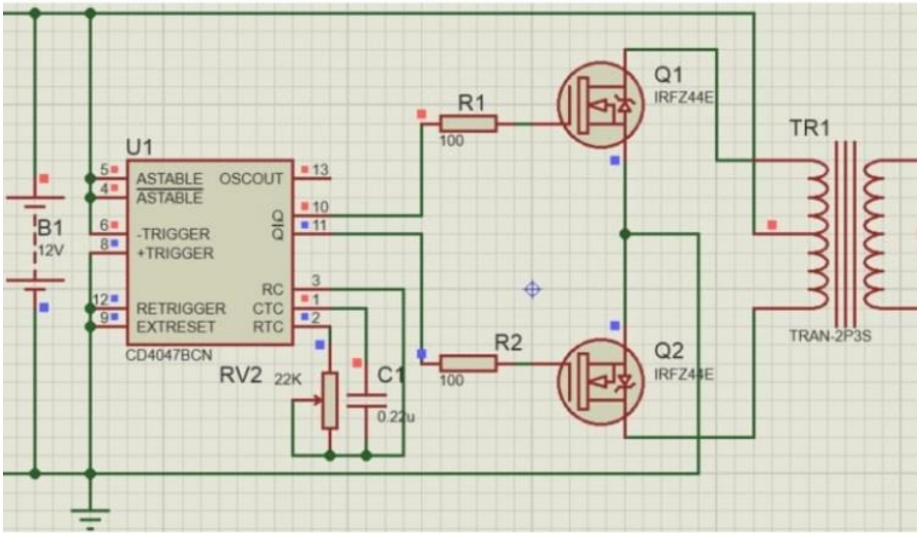
Duration: 8 hrs

Practical Activity 3.3.1: Assemble a power inverter

Task:

1: Read carefully the following questions:

Make an assembling of a power inverter having the following circuit diagram on a PCB:



2: Perform the given tasks by respecting the given instructions.

4: Present your work to the trainer.

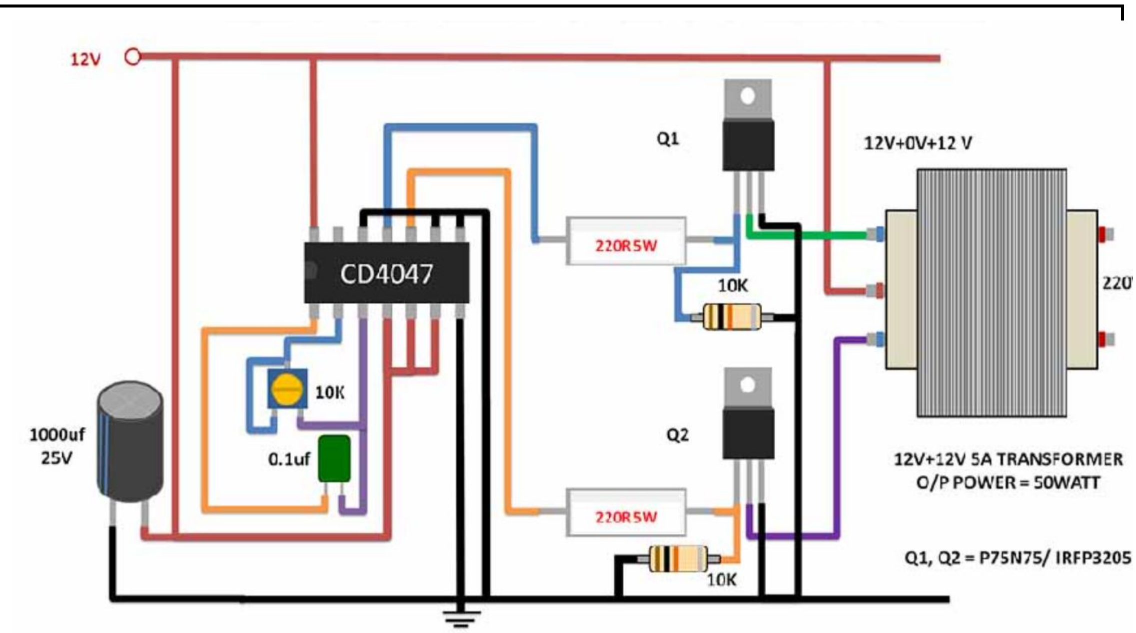
5: Read key reading 3.3.1 and ask clarification where necessary

6: Perform the task provided in application of learning 3.2

Key readings 3.3.2: Assemble a power inverter

Assembling a power inverter involves several important steps to ensure proper operation, safety, and efficiency. The process can vary depending on the type of inverter (e.g., DC to AC, modified sine wave, or pure sine wave inverter), but the general assembly steps are similar across different designs.

Sample diagram to illustrate the power inverter to be assembled and components specifications.



List of components to be assembled while designing the above power inverter:

1.Transformer 12V-0V-12V(50W) to 220V on output

2.Two Power MOSFET IRFP3205

3.Power resistor (two)220R 5W

4.Resitors (two fixed) 10K

5.Variable resistor 10K

6.Capacitors (ceramic 0.1Uf and Electrolytic 1000uf/25V)

7.Integrated Circuit (CMOS multivibrator) CD 4047

8.PCB board

9. Wires and cables

Here's a step-by-step guide on how to assemble a basic power inverter:

Step 1: Gather Required Components

Before starting the assembly, make sure you have all the components you will need. Here's a basic list for assembling a **DC to AC power inverter**:

Example Components:

- **DC source** (e.g., battery or solar panel)
- **Power transistors** (e.g., Power MOSFET IRFP3205)
- **Pulse Width Modulation (PWM) controller** (e.g., CD 4047)
- **Transformer** (for stepping up or stepping down voltage)
- **Rectifier diodes** (for DC-AC conversion)
- **Heat sinks** (for power transistors)
- **Resistors** (for voltage regulation and current control)
- **PCB (Printed Circuit Board)** or breadboard (for prototyping)
- **Fuses and protection circuits** (for safety)

Step 2: Assemble the Power Stage

The power stage typically includes the **DC-AC conversion** circuitry, which involves power transistors, a transformer, and a rectifier.

Example:

- **Power Transistors (MOSFETs)**: Use two MOSFETs in a **H-bridge** configuration to switch the DC voltage into an alternating waveform. The MOSFETs should be placed on the PCB with proper heat sinking.
- **PWM Controller**: Use a PWM controller like the **CD 4047** to generate the appropriate control signals for switching the MOSFETs.
- **Transformer**: Connect the output from the MOSFETs to a transformer. The transformer steps up (or steps down) the voltage from DC to AC. For example, if you need 230V AC from a 12V DC input, use a **12V to 230V transformer**.

Step 3: Connect the Rectifier and Filtering Stages

To ensure smooth and efficient operation, you'll need to include **filtering** to reduce ripple and noise from the inverter's output.

Example:

- **Rectifier**: Use **diodes** to form a bridge rectifier if needed, to rectify the AC output from the transformer into smooth DC before feeding it into the filter. However, many inverters use direct switching in the AC output, depending on the design.
- **Filter Capacitors**: Install **capacitors** (e.g., **electrolytic capacitors**) at the output to smooth the waveform and reduce ripple.
- **Inductors**: Use inductors to further filter high-frequency noise or spikes from the switching components.

Step 4: Assemble the Control and Protection Circuit

The control circuit is responsible for regulating the operation of the inverter, ensuring that the correct signals are sent to the switching transistors. The protection circuit ensures the inverter operates safely by preventing issues like overvoltage, overcurrent, and overheating.

Example:

- **PWM Control**: Use the **PWM controller** to generate the switching signals for the power transistors (MOSFETs or IGBTs). This controls the timing of the MOSFET switching and determines the output waveform.
- **Protection**: Install **fuses** or **circuit breakers** on both the input and output sides to prevent overcurrent damage. **Overtemperature protection** can be added with temperature sensors near critical components.
- **Voltage Regulation**: Use **Zener diodes** or **voltage regulators** for controlling the output voltage and ensuring it remains stable.

Step 5: Assemble the Power Supply and Input Section

The input section connects the **DC source** (such as a battery) to the inverter. This section often includes a **battery charger** (if applicable) or a direct DC input circuit.

Example:

- **Battery Connection**: Connect the **12V battery** (for a 12V system) to the inverter input via **fuses** or **protection diodes** to prevent reverse polarity.
- **DC Input Filtering**: Use **filter capacitors** and **inductors** at the input to reduce noise and stabilize the input voltage.

Step 6: Mount Components on the PCB or Breadboard

- **PCB Assembly**: If you're using a **PCB**, solder all the components in their correct positions. Ensure that the **MOSFETs** are installed on heatsinks to dissipate heat efficiently.
- **Breadboard (for Prototyping)**: For a **breadboard prototype**, carefully insert components, ensuring all connections are stable and proper.

Example:

- **Place the Power Components**: Attach the **MOSFETs** and **transformer** to the board.
- **Install Capacitors and Inductors**: Place **filtering capacitors** and **inductors** near the power stage.
- **Cooling**: Attach a **cooling fan** (if necessary) to the power components to avoid overheating.

Step 7: Enclosure and Final Assembly

Once the inverter is functioning correctly, enclose the assembly in a **protective casing** to prevent physical damage and ensure safety.

Example:

- **Enclosure**: Use a **metal** or **plastic case** to house the inverter. Make sure to leave openings for ventilation or mount cooling fans.
- **Wire Management**: Securely fasten all wires to prevent short circuits or accidental disconnections.
- **Safety Features**: Include **ventilation holes**, **earth grounding**, and **accessible fuse points** for safety

Points to Remember

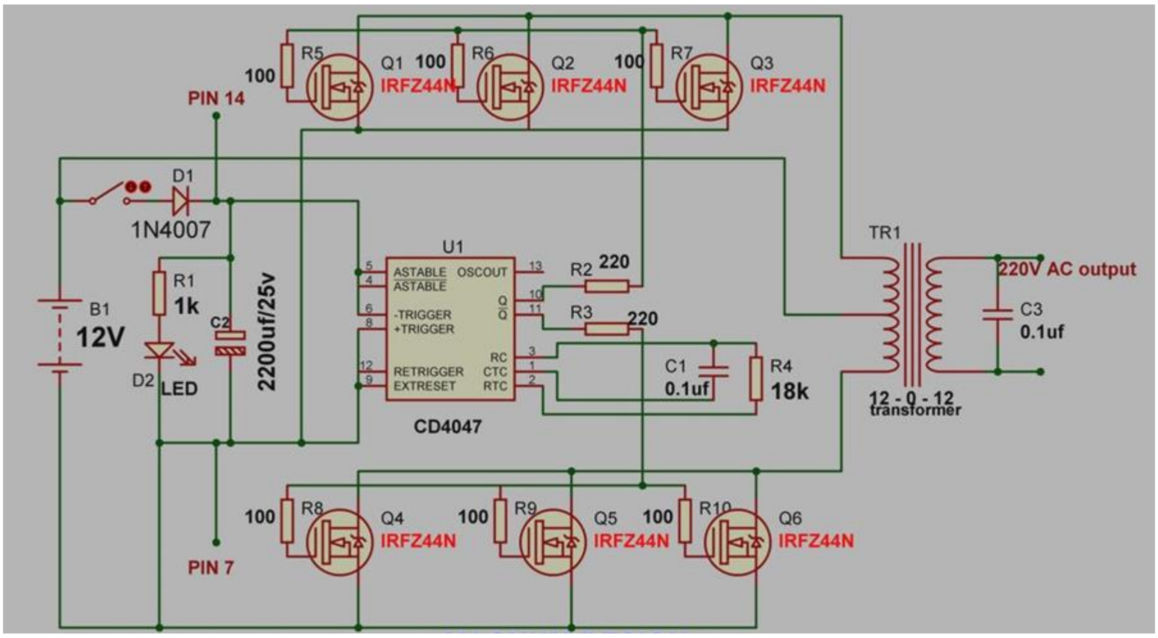
- **steps for assembling a power:**

✓ Gather all required materials, tools and equipment for assembly
✓ Read the Instructions
✓ Prepare the Workspace.
✓ Prepare the Circuit Board:
✓ Component Placement:
✓ Solder Components

- ✓ Install Heat Sinks
- ✓ Wire Connections:
- ✓ Final Inspection

Application of learning 3.3

ENNG Tech ltd is a company that offers different electrical services and products. The company is looking for technician who will work in Production department and he will responsible for assembling a power inverter. Suppose you are the one who is chosen and you are given the following schematic diagram:



Indicative content 3.4: Testing a Power Inverter

Duration: 4 hrs

Theoretical Activity 3.4.1: Describe testing techniques

Tasks:

1: In small groups, you are requested to answer the following questions concerning the testing a power inverter:

i. What is the purpose of testing electrical circuit?
ii. How do we measure an electric current?
iii. How do we measure an electrical potential difference/voltage.
iv. Outline testing tools and equipment

2: Provide the answer for the asked questions and write them on papers.

3: Present the findings/answers to the whole class

4: For more clarification, read the key readings 3.4.1.

5: In addition, ask questions where necessary.

Key readings 2.1.1.: Describe testing techniques

1. Testing techniques

1.1 Continuity testing

In electronics, a continuity test is the checking of an electric circuit to see if current flows
(that it is in fact a complete circuit). A continuity test is performed by placing a small
voltage (wired in series with an LED or noise-producing component such as a piezoelectric
speaker) across the chosen path. If electron flow is inhibited by broken conductors,83
damaged components, or excessive resistance, the circuit is "open". Devices that can be
used to perform continuity tests include multimeters which measure current and
specialized continuity testers which are cheaper, more basic devices, generally with a
simple light bulb that lights up when current flows. An important application is the
continuity test of a bundle of wires so as to find the two ends belonging to a

particular one
of these wires; there will be a negligible resistance between the "right" ends, and only
between the "right" ends.

1.2 Voltage measurement

Instruments for measuring voltages include the voltmeter, the potentiometer, and
the oscilloscope. Analog voltmeters, such as moving-coil instruments, work by measuring
the current through a fixed resistor, which, according to Ohm's Law, is proportional to the
voltage across the resistor. The potentiometer works by balancing the unknown voltage
against a known voltage in a bridge circuit. The cathode-ray oscilloscope works by
amplifying the voltage and using it to deflect an electron beam from a straight path, so that
the deflection of the beam is proportional to the voltage. To measure voltage is to
determine the “differential” voltage between two separate points in an electrical circuit.
For example, to measure the voltage across a single resistor, you measure the voltage at
both ends of the resistor. The difference between the voltages is the voltage across the
resistor. Usually, differential voltage measurements are useful in determining the voltage
that exists across individual elements of a circuit, or if the signal sources are noisy.

1.3 Current measurement

Current can be measured using an ammeter. Electric current can be directly measured with
a galvanometer, but this method involves breaking the electrical circuit, which is
sometimes inconvenient. Current can also be measured without breaking the circuit by
detecting the magnetic field associated with the current. There are two main ways to
measure current one is based on electromagnetics and is associated with the early moving
coil meter, and the other is based on the main theory of electricity, Ohm’s law.

Electronic components testing

Repairing an electronic device begins with testing these electronic components through multimeter. Multimeters can measure resistance, current, voltage capacitance and identification of transistor pinout such as NPN and PNP. They can test devices powered by either AC or DC voltages and work in or out of circuit.

1.4 Functionality testing

Functional Testing is defined as a type of testing which verifies that each function of the device/circuit operates in conformance with the requirement specification. It is performed by feeding input to the circuit/device and test/measure the output.

Resistance tests how much current is lost as electricity flows through a component or circuit. It’s measured in ohms, and it is slightly more complicated to test than continuity.

Whereas continuity works on a range of zero to one (or OL), resistance can come in different strengths so you need to know how much resistance a given part should have

Practical Activity 3.4.2: Testing a power inverter

Task:

1: Read carefully the following questions:

You have finished assembling of a new power inverter and you want to verify whether it functions correctly and meets the desired specifications. Carry out a thorough testing process.

2: Perform the given tasks by respecting the given instructions.

4: Present your work to the trainer.

5: Read key reading 3.4.2 and ask clarification where necessary

6: Perform the task provided in application of learning 3.4

Key readings 3.4.2: Testing a power inverter

Testing a power inverter after assembling it is crucial to ensure it operates correctly and safely.

The following are steps for testing a power inverter:

1. preparation:

i) Gather all required Tools and equipment

- Multimeter (for voltage testing)
- Oscilloscope(for analysing waveform)
- Load (small appliance or light bulb)
- Battery (for powering the inverter)
- Safety Gear (gloves, goggles)

ii) Considerations:

- **Heat Loss:** Inverters can generate heat; ensure they have adequate ventilation during testing.
- **Load Type**: Resistive loads are best for accurate measurements.
- **Safety:** Ensure all connections are secure, and follow safety guidelines to prevent accidents.

iii) Safety Precautions:

- Always work in a safe environment and follow electrical safety guidelines.
- Make sure the load is suitable for the inverter's capacity.

iv) Expected Results:

- **Voltage**: Should match the inverter's rated output (e.g., 120V or 230V).
- **Waveform**: Depending on the inverter type, you might see a pure sine wave, modified sine wave, or a square wave

2. Test output AC voltage

Testing output AC voltage involves measuring the alternating current (AC) voltage produced by a device, such as a power inverter, to ensure it meets specified performance standards. This is crucial for verifying that the inverter is functioning correctly and delivering the expected output for connected loads.

Measure output AC Voltage:

- Connect the inverter to a DC power source (like a battery).
- Turn on the inverter
- Set your multimeter to the AC voltage setting.
- Connect the multimeter probes to the output terminals of the inverter.

- Record the voltage reading.

3. Test output ac waveform

Testing the waveform refers to the process of analyzing the shape and characteristics of an electrical signal, particularly the output of devices like inverters. This is crucial for understanding the quality of the AC output and ensuring it meets the required specifications for the intended applications.

- Connect the inverter to a DC power source (like a battery).
- Turn on the inverter
- Connect the oscilloscope probes to the inverter's AC output.
- Ensure the oscilloscope is set to the appropriate voltage range.
- Power on the oscilloscope.
- Observe and adjust the time base and voltage scale to get a clear view of the waveform.
- Take note of the waveform shape (sine, square, modified sine, etc.).
- Look for distortions or irregularities that may indicate issues.
- Measure frequency and peak voltage if needed.

4. Load testing

Load testing is a type of performance testing used to evaluate how a system, device, or application performs under various levels of demand. The primary goal is to determine the behavior of the system when subjected to expected and peak load conditions.

- Connect the inverter to a DC power source (like a battery).
- Turn on the inverter
- Connect a small load (like a light bulb) to the inverter to see if it can handle the demand.
- Measure the output voltage again while under load to ensure it remains stable.
- **Check for Overheating**: Feel the inverter during operation. It should be warm but not excessively hot. If it overheats, turn it off immediately.

5. Efficiency

Testing the efficiency of a power inverter involves measuring the input power and the output power to calculate how effectively the inverter converts DC power to AC power. Steps:

- Connect the inverter to a DC power source (like a battery).
- Turn on the inverter.
- Ensure that the voltage and current are within the inverter's specifications.
- Measure Input Power: Use the multimeter to measure the input voltage

(V_in) and input current (I_in).

- Calculate the input power (P_in) using the formula:

$P_{in}=V_{in}\times Iin$

- Connect the Load: Connect a resistive load to the AC output of the inverter.
- Measure Output Power: Measure the output voltage (V_out) and output current (I_out) using the multimeter or an AC power meter.
- Calculate the output power (P_out) using the formula:

$Pout=Vout\times Iout\times Power\ Factor$

Note: The power factor is important for AC measurements; for resistive loads, it's usually close to 1.

- Calculate Efficiency:

Use the formula for efficiency:

$Efficiency(\%)=(Pout/Pin)\times 100$

- Repeat for Different Loads:

It's a good idea to test the inverter with different loads to see how efficiency changes under various conditions.

- Record Conditions: Note the input and output voltages, currents, and power ratings during each test for reference.

6. Functionality testing

A **functionality test** is a type of testing conducted to verify that a device or system operates according to its specified requirements and performs its intended functions correctly. This kind of testing is essential in various fields, including electronics, software development, and mechanical systems.

Steps for Functionality Testing:

i) Initial Setup:

- Place the inverter in a well-ventilated area.
- Connect the inverter to a stable DC power source, ensuring it's within specified voltage and current ratings.

ii) Check Input Voltage: Use a multimeter to measure the input voltage to ensure it falls within the inverter's operating range.

iii) Connect the Load: Attach a suitable AC load to the inverter output. Start with a lower load to begin testing.

iv) Power On the Inverter: Turn on the inverter and observe any indicator lights or displays to confirm it powers on correctly.

v) Measure Output Voltage and Current: With the load connected, use a multimeter to measure the output voltage (V_out) and output current (I_out). Check that V_out matches the inverter's rated output.

vi) Check Output Waveform (if using an oscilloscope):

- Analyze the output waveform to ensure it is a clean sine wave (for pure sine wave inverters) or acceptable shape for modified sine wave inverters.
- Look for any distortion or noise in the waveform.

vii) Test Under Load Conditions:

Gradually increase the load to the inverter's rated capacity and Monitor:

- Output voltage and current stability.
- Any unusual sounds, overheating, or odors.
- The inverter's response time to load changes.

viii) Safety Features Check: Test built-in safety features like overload and short-circuit protection. This can be done by applying a small overload condition (cautiously) and ensuring the inverter shuts down or signals appropriately.

ix) Performance Monitoring: If available, use a power meter to measure input and output power, allowing you to calculate efficiency. This can provide insight into how well the inverter is functioning.

x) Document Findings: Record all measurements and observations, including input/output voltages, currents, power ratings, and any operational anomalies for future reference.

xi). Review Results: If all readings are within specifications and the inverter operates correctly under load, it is functioning properly. If you encounter issues, recheck your assembly and connections.

Solutions on common Power inverter's faults and symptoms

Power inverters can experience various faults that may affect their performance or even cause failure. Below are common faults in power inverters, their causes, symptoms, and solutions:

1. Inverter Does Not Turn On

Fault: The inverter does not start or powers up correctly.

Causes: Blown fuse or circuit breaker ,Low or no DC input voltage, Faulty power switch or control circuitry.

- Overload or short circuit in the system.

Symptoms:

- No LED indicators or display on the inverter.
- Inverter fails to start when the power button is pressed.
- No output AC voltage.

Solution:

- Check and replace any blown fuses or tripped circuit breakers.
- Verify that the DC input voltage is within acceptable limits.
- Inspect the control circuitry and connections for any faults.
- Ensure the inverter is not overloaded or shorted.

2. Low Output Voltage

Fault: The AC output voltage from the inverter is lower than expected.

Causes:

- Insufficient DC input voltage.
- Faulty transformer (in step-up or step-down inverters).
- Poor connection or loose wiring.
- Inverter overload or under load conditions.

Symptoms:

- Connected equipment does not operate properly or is underpowered.
- Inverter output voltage is significantly lower than rated.
- Inverter may enter a protection mode.

Solution:

- Check the DC voltage to ensure it meets the inverter's required input range.
- Inspect and replace the transformer if needed.
- Tighten or re-secure all connections and wiring.
- Reduce load to prevent overloading or check inverter specifications.

3. Inverter Overheating

Fault: The inverter overheats, causing it to shut down or reduce performance.

Causes:

- Inadequate ventilation or cooling.
- Overloading the inverter beyond its power rating.
- High ambient temperature.
- Dust or debris clogging cooling fans or vents.

Symptoms:

- Inverter shuts down unexpectedly after a short period of operation.
- Overheating warning light or indicator.
- Inverter emits excessive heat.

Solution:

- Ensure the inverter is installed in a well-ventilated area.
- Clean vents and fans to allow for proper airflow and cooling.
- Reduce the load or use a higher-rated inverter to prevent overloading.
- Install additional cooling systems (e.g., fans or heat sinks) if required.

4. Inverter Produces No Output (No AC Power)

Fault: The inverter produces no AC output despite being powered on.

Causes:

- Faulty internal components (e.g., power transistors, capacitors, or diodes).
- Open circuit or poor connection in the output wiring.
- Fault in the DC to AC conversion circuit.
- Inverter protection mode triggered due to overcurrent, undervoltage, or overheating.

Symptoms:

- No AC power output from the inverter.
- No waveform present on the AC output terminals (measured with an oscilloscope).
- Inverter enters protection mode.

Solution:

- Inspect and replace any faulty internal components like transistors or capacitors.
- Check the output wiring for open circuits, loose connections, or shorts.
- Test the inverter with a load that meets the specified ratings to avoid protection triggers.
- Reset the inverter by turning it off and back on.

5. Excessive Ripple or Distortion in Output Voltage

Fault: The inverter generates an output with high ripple or waveform distortion.

Causes:

- Faulty or inadequate filtering components (e.g., capacitors or inductors).
- Low-quality inverters (e.g., modified sine wave inverters producing distortion).
- Defective or worn-out components in the inverter's inverter stage.

Symptoms:

- Flickering lights or unstable power in connected loads.
- Audio distortion in sensitive electronics.
- Voltage measurements showing high-frequency fluctuations.

Solution:

- Inspect and replace the filtering components (capacitors, inductors).
- Switch to a higher-quality inverter with a pure sine wave output for sensitive equipment.
- Test the inverter with known loads to ensure proper waveform generation.

6. Inverter Keeps Shutting Down (Protection Mode)

Fault: The inverter frequently shuts down or enters protection mode.

Causes:

- Overload condition (more power drawn than the inverter can supply).
- Low DC input voltage (e.g., from a discharged battery).
- Inverter detects short-circuit or overcurrent at the output.
- Overheating due to poor ventilation or excessive load.

Symptoms:

- Inverter shuts down repeatedly after short operating periods.
- Protection LED or error code is displayed.
- No output voltage during shutdown periods.

Solution:

- Ensure the inverter is not overloaded by checking the connected load.
- Check the DC input voltage and ensure batteries or power sources are fully charged.
- Improve ventilation or cooling to prevent overheating.
- Inspect the output connections for short circuits.

7. Inverter Makes Unusual Noises

Fault: The inverter emits abnormal sounds like buzzing, clicking, or whining.

Causes:

- Loose components or vibration of internal parts.
- Mechanical failure in the cooling fan or transformer.
- Inverter overload causing stress on internal components.
- High-frequency noise due to a faulty pulse-width modulation (PWM) controller.

Symptoms:

- Persistent buzzing or clicking noises during operation.
- Inverter may still be functioning but producing irritating noise.
- Increased heat generation near the noise source.

Solution:

- Tighten any loose internal components.
- Check the cooling fan and replace it if it's malfunctioning or obstructed.
- Reduce load to prevent inverter stress.
- If the noise is due to the PWM controller, inspect and replace the controller circuit if necessary.

8. Inverter Battery Drain (for Battery-Powered Systems)

Fault: The inverter causes excessive battery drain, even when no significant load is applied.

Causes:

- Faulty or outdated battery management system (BMS).
- Inverter running inefficiently due to internal faults.
- High idle current draw from the inverter.

Symptoms:

- Rapid depletion of the battery charge.
- Inverter may operate at higher than normal power consumption levels.
- Batteries not holding charge effectively.

Solution:

- Ensure that the battery management system is working correctly and that batteries are not faulty.
- Check the inverter's idle current draw, and ensure it is within expected limits.
- Consider upgrading the inverter to a more efficient model if necessary.

Final Tips for Inverter Maintenance:

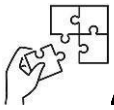
- **Routine Inspection:** Regularly inspect and clean the inverter, including checking for dust accumulation on vents and fans.
- **Proper Sizing:** Ensure the inverter is properly sized for the load and environment.
- **Monitoring:** Use monitoring tools (e.g., remote monitoring systems) to keep track of inverter performance and prevent issues before they arise.
- **Surge Protection:** Install surge protection devices to protect against voltage spikes or power surges that can damage the inverter.

Points to Remember

- **Testing a power inverter**

✓ Testing the waveform

- ✓ Testing output AC voltage
- ✓ Load testing
- ✓ Testing the efficiency
- ✓ A functionality test



Application of learning 3.4.

XXXV electrical technician, professional in making power inverter. He started working alone, but now the clients were increased. He needs another technician to help him in testing the new assembled power inverters. you are chosen and you are tasked to check whether the assembled power inverters functions correctly and meets the desired specifications as described in the design document.

Learning outcome 3 end assessment

Theoretical assessment

1. Answer with **True** or **False**
    a) A power inverter converts direct current (DC) to alternating current (AC).
    b) The efficiency of a power inverter is always 100%.
    c) The output voltage of a power inverter can be adjusted by changing the input voltage.
    d) A transformer is often used in inverters to step up or step down the output voltage.
    e) Power factor correction is not necessary in inverter design.
    f) A pure sine wave inverter produces an output that closely resembles a traditional AC power source.
    g) The switching frequency of an inverter has no impact on its size and efficiency.
    h) Overcurrent protection is an important consideration in power inverter design.
    i) All inverters are designed to handle the same amount of power regardless of their specifications.
2. What is the primary function of a power inverter?
3. Outline the key components of a power inverter?
4. What is the purpose of the oscillator in an inverter design?
5. What role do power transistors (e.g., MOSFETs, IGBTs) play in inverter design?
6. Outline the design factors that affect the efficiency of a power inverter?
7. What factors should be considered when selecting a transformer for an inverter?
8. What are the considerations for choosing switching devices (MOSFETs or IGBTs) in an inverter design?
9. How is the switching frequency determined in an inverter design?
10. How can you implement overcurrent protection in an inverter design?
11. If designing a 1000W inverter, how do you determine the required input current from a 12V battery?
12. How would you design a control circuit for a simple inverter?
13. What is the basic principle of operation of an inverter?
14. What are the main types of inverters, and what are their typical applications?
15. multiple choice questions

i) What is the input voltage range for a typical DC to AC inverter used in solar applications?

A) 12V to 48V
B) 120V to 240V
C) 48V to 120V
D) 5V to 15V

ii) Which type of inverter generates a waveform that approximates a sine wave?

A) Square Wave Inverter

B) Modified Sine Wave Inverter

C) Pure Sine Wave Inverter

D) All of the above

iii) In an inverter circuit, what does the term "efficiency" refer to?

A) The amount of power generated

B) The ratio of output power to input power

C) The speed of the switching device

D) The size of the inverter

iv) Which type of inverter topology is often used for high power applications?

A) Push-Pull

B) Half-Bridge

C) Full-Bridge

D) Both B and C

v) What is the main purpose of using a transformer in an inverter circuit?

A) To convert DC to AC

B) To step up or step down voltage

C) To filter out harmonics

D) To regulate frequency

vi) Which feature allows an inverter to maintain output voltage during fluctuating input conditions?

A) Feedback control

B) Voltage clamping

C) Harmonic distortion control

D) Phase shifting

Practical assessment

You are a professional in designing a single-phase power inverter for a small residential solar energy system. The inverter will convert DC power from solar panels and a battery bank into AC power for household appliances. Smith is a Rwandan people and he does not have electricity at home. He bought 24V battery. He want to install five lamps of 40W in his house. He is looking for a technician who can design a power inverter that will match with the battery and load. He contacts you and give you this task. Describe how you will perform that task.

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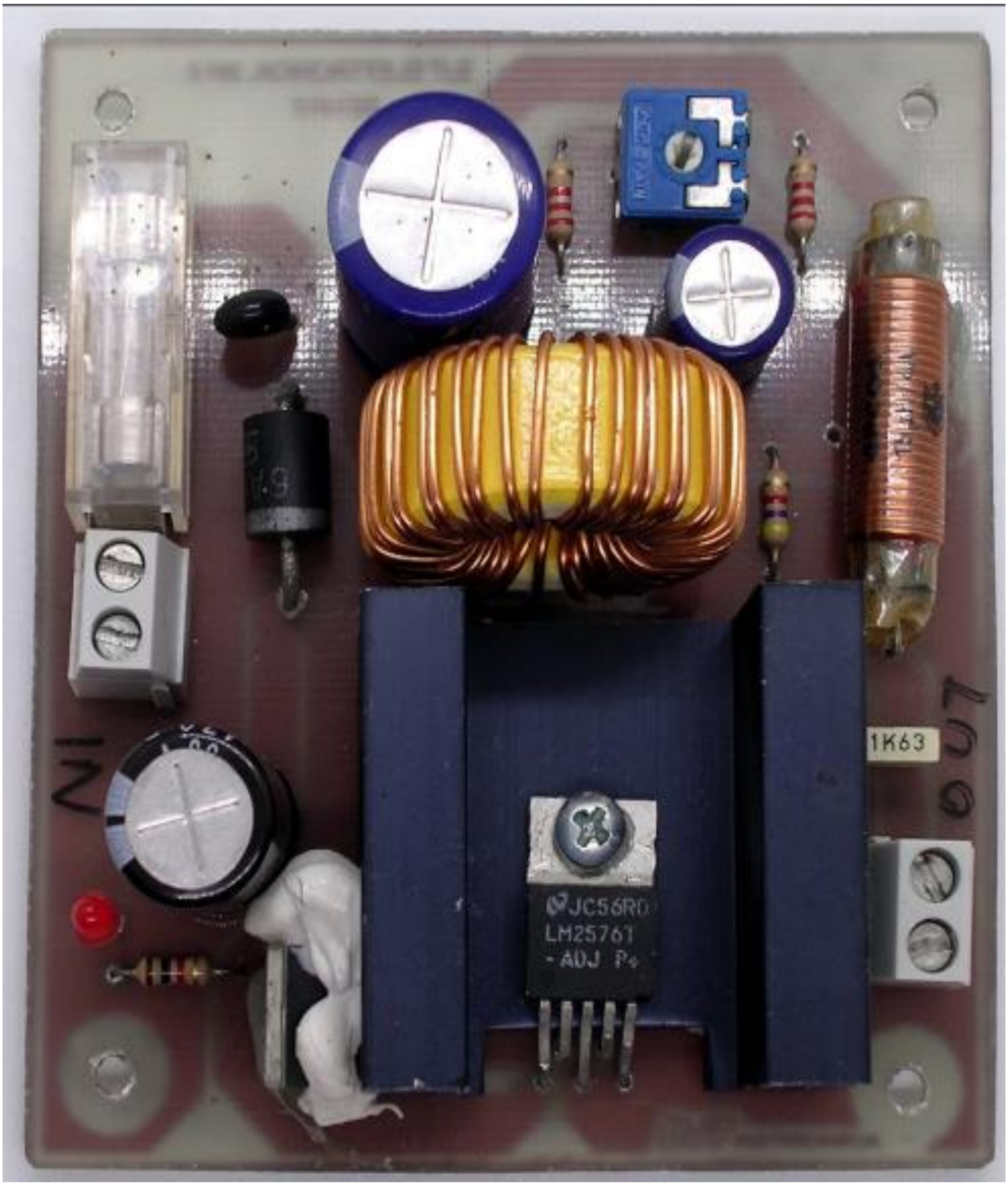

IN
OUT
1K63
JC56R0
LM2576T
-ADJ P+

Indicative contents
4.1 Evaluating DC To DC converter requirements **4.2 Designing To DC converter diagram** **4.3 Assembling DC To DC converter** **4.4 Testing To DC converter**

Key Competencies for Learning Outcome 4: Implement DC to DC Converter

Knowledge	Skills	Attitudes
• Identification of the DC To DC converter parameters • Description of components specification • Identification of DC to DC symbols • Description of DC to DC Converter diagram • Description of soldering technics	• Selecting of DC To DC converter parameters • Designing of DC to DC converter diagram • Interpretation of wiring diagram • Placing DC to DC components • Soldering DC to DC components • wiring of DC to DC components • Testing of DC output voltage and functionality of power converter	• Having Time management • Having self confidence in Placing, Wiring and Soldering of DC to DC converter • Being attentive while Testing DC To DC converter

Duration: 15hrs

Learning outcome 4 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify clearly DC to DC convert parameters according to their types
2. Describe clearly the components specification according to the type of DC to DC
3. Identify clearly the symbols of DC to DC according to their application
4. Describe properly DC to DC diagram according to their type
5. Select properly the DC to DC according to their types
6. Design correctly the DC to DC diagram according to their types
7. Assemble correctly the DC to DC components according to the type of PCB
8. Interpret clearly wiring diagram according to the working principle of the circuit
9. Solder properly power rectifier components according to the type of PCB
10. Test properly the power rectifier according to the output

Resources

Equipment	**Tools**	**Materials**
• Inverter • 12V battery • Battery Universal Charger • DC power supply • Oscilloscope • Digital multimeter • Air blower • Soldering station • Glue gun • Personal Computer • Personal protective equipment (PPE) kit • Screwdriver machine • 3D Printing machine	• Magnifying • glass • Pliers set • Electrician • Toolbox • Technician knife • Tape measure • Spirit level	• Connectors • IC socket • Power electronic passive and active component • Integreted circuit (IC) • glue stick • thermal paste • soldering paste • desoldering wire • soldering wire • battery/cells • isopropyl alcohol • jumper wires • breadboard • Copper Board

		- power cables - electronic simulation software

Indicative content 4.1: Evaluating DC To DC Converter Requirements

Duration: 4 hrs

Theoretical Activity 4.1.1: Identification of DC-To-DC converter

Tasks:

1: Answer the following questions:

- **i.** What do you understand DC to DC Converter
- **ii.** Define the following terms
  - a) Input DC voltage
  - b) Output DC voltage
  - c) Efficiency
  - d) Output Current
  - e) Power Rating

2: Write the answers on flipchart/ paper

3: Present the findings to the trainer and whole class

4: Ask for clarification if any

5: Read the key readings 4.1.1.in the manual

Key readings 4.1.1.: Identification of DC-To-DC converter requirements

1. **DC-DC Converters**

1.Introduction of DC TO DC Converter

A **DC to DC converter** is an essential electronic circuit that converts a source of direct current (DC) from one voltage level to another. This process is crucial for powering various electronic devices and systems, particularly when the input and output voltage levels need to be different. DC to DC converters are used in a wide variety of applications, including power supplies, battery charging, renewable energy systems (e.g., solar and wind), automotive systems, and portable electronics.

The key function of a DC to DC converter is to adjust the voltage while maintaining the same polarity (DC). It ensures efficient power conversion by stepping up (increasing) or stepping down (decreasing) the input voltage, depending on the needs of the system.

2. DC to DC Converter 's requirements/parameters

- **Input DC Voltage**

The voltage level supplied to the converter, often specified as a range (e.g., 10-15V).

✓ **Requirement**: Handle fluctuations in input voltage.

- ✓ **Consideration**: The converter must operate efficiently across a range of input voltages.
- ✓ **Example**: 9V to 18V input.

  Input DC Voltage: Is defined as the direct current (DC) voltage supplied to a DC-DC converter or any other electronic device. This voltage is the electrical potential difference that provides the necessary energy for the operation of the circuit

- **Output DC Voltage**

  The desired output voltage, which can be lower (buck) or higher (boost) than the input voltage.

- ✓ **Requirement**: Provide a stable output voltage at the desired level.
- ✓ **Consideration**: Voltage accuracy, ripple, and noise should be within acceptable limits for the application.
- ✓ **Example**: 5V ±5%, with ripple < 50mV.

  Output Voltage: Is defined as the direct current (DC) voltage that a DC-DC converter or other electronic device delivers to its load. This voltage represents the electrical potential difference available for use by connected devices or circuits after the conversion process

- **Output Current**

  The current delivered to the load at the output. It may also be specified as a maximum current rating.

  Output Current: is defined as the current that a DC-DC converter or other electronic device delivers to its load at the output terminal. It represents the flow of electric charge that powers connected devices or circuits

- ✓ **Requirement**: Supply sufficient current to the load without overheating or failure.
- ✓ **Consideration**: Consider both continuous and peak current demands.
- ✓ **Example**: 2A continuous, 3A peak
- **Power Rating**

  Power Rating in DC-DC Converters refers to the maximum output power that the converter can deliver to its load without exceeding its specified limits, such as thermal limits or component ratings. It is typically expressed in watts (W) or kilowatts (kW)

  The output power, calculated as:

- **Efficiency**

  The ratio of output power to input power, typically expressed as a percentage:

  The efficiency is a measure of how effectively a system converts input power into output power. In the context of DC-DC converters, it is defined as the ratio of the output power to the input power, typically expressed as a percentage.

- ✓ **Requirement**: Minimize energy loss during conversion.
- ✓ **Consideration**: High efficiency reduces heat generation and extends battery life.

- ✓ **Example**: ≥ 85% efficiency at full load.

Practical Activity 4.1.2: Selecting DC To DC converter

Task:

1: Read the given task
Go to the workshop, Select Buck Converter (Step-Down Converter), Boost Converter (Step-Up Converter) and buck- Boost converter according to their construction.

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 4.1.2 and ask clarification where necessary

5: Perform the task provided in application of learning 4.1.

Key readings 4.1.2: Selection of DC – DC Converter 's types

1. Buck Converter (Step-Down Converter):

Description: A buck converter steps down the input voltage to a lower output voltage. It's a type of switched-mode power supply.

Working Principle of a Buck Converter:

The basic operation of a Buck Converter involves switching the input DC voltage on and off at high frequency and using an inductor, capacitor, and diode to convert this pulsed voltage into a lower, smooth DC voltage.

Here's how it works:

1. **Switching Action**: The key component of the Buck Converter is a switching element (usually a **MOSFET** or **BJT**) that turns the input voltage on and off. This switching happens at a high frequency (typically tens to hundreds of kHz).

2. **Inductor Energy Storage**: When the switch is **on**, the current flows from the input to the load through the inductor. The inductor stores energy in its magnetic field during this time.

3. **Diode and Energy Transfer**: When the switch is **off**, the inductor resists the

sudden change in current by releasing the stored energy. The inductor's energy is transferred to the output capacitor and load via the **diode**, which ensures current flows in one direction.

4. **Capacitor Filtering**: The output capacitor smooths the voltage and reduces ripple by filtering out the high-frequency switching noise, producing a stable output DC voltage.

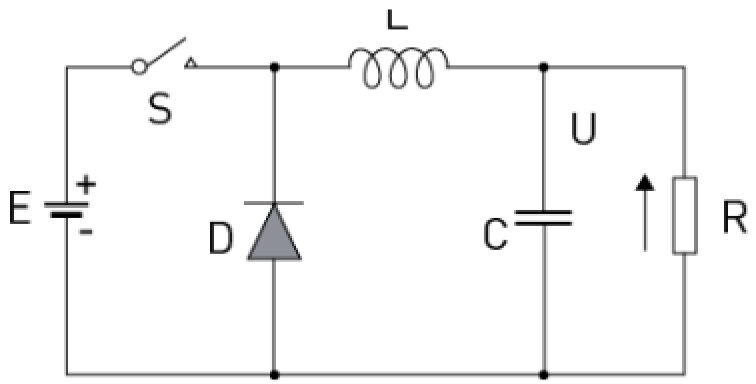
5. **Duty Cycle Control**: The **duty cycle** (the percentage of time the switch is on) determines the average output voltage. A higher duty cycle means the switch stays on for a longer period, delivering more energy to the load, whereas a lower duty cycle means less energy is delivered.

   The output voltage is proportional to the duty cycle.

   Vout=D×Vin

   Where:

- Vout is the output voltage.
- D is the duty cycle (ratio of time the switch is on to the total period).
- Vin is the input voltage.



In this Figure shows the circuit diagram of the buck converter, which consists of a source of DC power supply E, a switch S (typically a MOSFET or IGBT), a diode D, low frequency band pass LC filter and load R. The transistor is represented by a switch S with a small arrow, which marks the direction of the current that can be established through the switch.

Components of buck converter and related functions:

Component	Function
Switching Element	Controls current flow by switching the input voltage on/off (usually MOSFET).
Inductor	Stores and releases energy to smooth out current and control energy transfer.
Diode	Ensures unidirectional current flow and allows energy release when switch is off.
Output Capacitor	Filters ripple and smooths the output voltage.
Input Capacitor	Filters the input power to reduce noise and stabilize the input voltage.
Control Circuit	Maintains the desired output voltage by adjusting the switching duty cycle.

2. **Boost Converter (Step-Up Converter):**

- **Description**: A Boost Converter (also known as a Step-Up Converter) is a type of DC-to-DC converter that increases (boosts) the input voltage to a higher output voltage. It is used when the application requires a higher voltage than what is provided by the input power source.
  Working Principle of a Boost Converter
  The basic operation of a Boost Converter involves switching the input DC voltage on and off at high frequency and using an inductor, capacitor, and diode to convert the pulsed voltage into a higher, stable DC voltage.
  Key steps in the operation of a Boost Converter:

1. **Switching Action**: The core component is the **switching transistor** (usually a **MOSFET** or **BJT**), which turns the input voltage on and off at a high frequency (typically tens or hundreds of kHz).

2. **Inductor Energy Storage**:

- When the switch is **closed** (on), current flows from the input to the inductor, which begins to store energy in the form of a magnetic field. During this time, the output voltage is not significantly affected.

3. **Energy Transfer**:

- When the switch is **open** (off), the inductor resists the sudden change in current by collapsing its magnetic field and releasing the stored energy. This energy is transferred to the output capacitor and the load through the **diode**. The energy stored in the inductor increases the output voltage.

4. **Capacitor Filtering**:

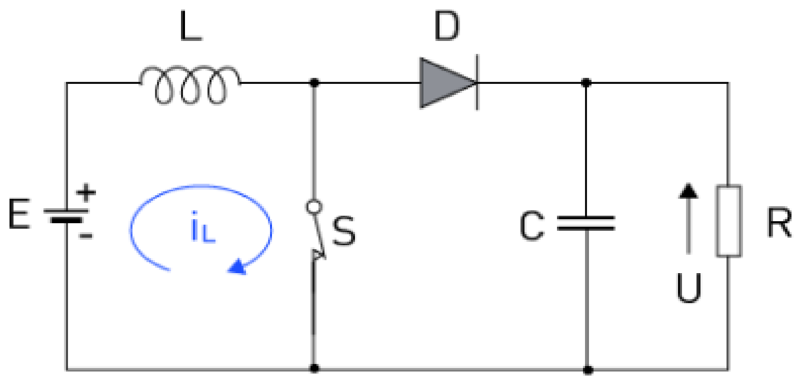
- The **output capacitor** smooths out the voltage spikes caused by the switching, providing a stable DC output voltage to the load. The capacitor also stores energy and helps regulate the output voltage during transient conditions.

5. **Duty Cycle Control**:

- The **duty cycle** of the switch (the proportion of time the switch is on versus off) controls the amount of energy transferred from the input to the output. A higher duty cycle leads to higher energy transfer, which increases the output voltage.

$$V_{out} = \frac{V_{in}}{1 - D}$$

- Vout is the output voltage.
- Vin is the input voltage.
- D is the duty cycle (the fraction of time the switch is on).



In this converter topology, the magnetic energy of the inductor is used to transfer energy from a lower voltage DC source to a higher load voltage. By turning on the switch S, the inductor is connected to the DC power supply E . The diode D is reverse-biased by the voltage at the load that is supplied with energy from the capacitor

Table to illustrate Boost Converter Components and Their Functions:

Component	Function
Switching Element (MOSFET/BJT)	Controls the flow of energy by switching the input voltage on and off at high frequency. It is the key element that initiates the boost process.
Inductor	Stores energy when the switch is on and releases it when the switch is off, boosting the voltage. It also smooths the current flow to the load.
Diode	Allows current to flow only in one direction (from the inductor to the output capacitor and load), preventing backflow of current and ensuring proper energy transfer.
Output Capacitor	Filters and smooths the output voltage by reducing ripple, ensuring a steady DC voltage at the output.
Input Capacitor	Helps filter noise and stabilize the input voltage, preventing spikes that could affect the converter's performance.
Control Circuit (PWM Controller)	Adjusts the duty cycle of the switching element to regulate the output voltage and maintain stability, often using feedback from the output voltage.

3. Buck-Boost Converter (DC-DC Converter)

- **Description**: A **Buck-Boost Converter** is a type of **DC to DC converter** that can either step-up (boost) or step-down (buck) the input voltage to a different output voltage. This converter is versatile because it can provide an output voltage that is either higher or lower than the input voltage, depending on the application's needs.

Working Principle of a Buck-Boost Converter

The Buck-Boost Converter operates by alternating between buck and boost modes of operation based on the relationship between the input and output voltages. The converter works in two stages, controlled by a switching transistor:

1. **Switching Action**: The key component, the **switching transistor** (often a MOSFET), alternates between on and off states at high frequency. During the "on" period, energy is stored in the inductor.
2. **Inductor Energy Storage**:

- When the switch is **on**, current flows from the input voltage source through the inductor. The inductor builds up magnetic energy during this period.
- When the switch is **off**, the inductor's magnetic field collapses, releasing the stored energy. This energy either steps up or steps down the voltage depending on the configuration.

3. **Energy Transfer to the Output**:

- During the "on" period, the energy stored in the inductor is transferred to the output capacitor through the diode.
- The **diode** ensures current only flows in the correct direction, preventing backflow

and ensuring efficient energy transfer.

4. **Output Voltage Control**:

- The output voltage is regulated by controlling the duty cycle of the switching element. The **duty cycle** (the proportion of time the switch is on) determines whether the converter operates in buck or boost mode.
- If the input voltage is higher than the output, the converter will operate in **buck mode** (voltage step-down), and if the input is lower, it will operate in **boost mode** (voltage step-up).

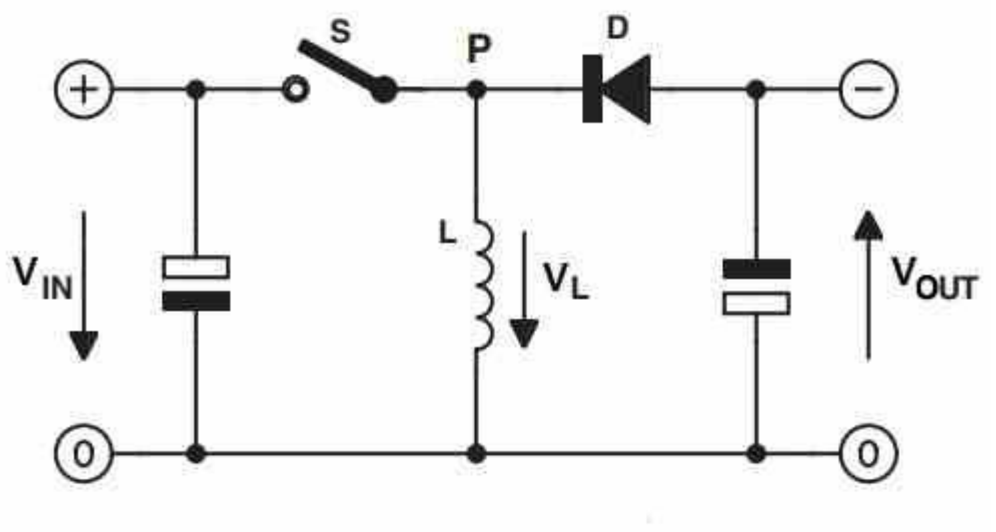
The output voltage for a Buck-Boost Converter is given by:

$$V_{out} = -D \times \frac{V_{in}}{1 - D}$$

Where:

- Vout is the output voltage.
- Vin is the input voltage.
- D is the duty cycle.

The negative sign indicates that the output voltage is inverted relative to the input voltage, which is a characteristic of many Buck-Boost Converters (though non-inverting versions are also possible).



Referring to the basic buck-boost topology diagram above, when the switch S is closed, the input voltage VIN is blocked by the diode D, since D is reverse biased. Therefore the voltage has no other option but to flow through the inductor L.The inductor L due to its inherent reluctance property initially tries to block the current. Due to this, initially the voltage drop across L is high. However, slowly as the reluctance of the coil decreases and the current through the inductor increases. During this phase the inductor L stores the energy (voltage and current) inside its winding. Ideally this the point when the switch S needs to be opened.when switch S is now opened, the voltage VL stored inside the inductor reverses direction, and it passes through the diode D which is now forward biased. In the process VL also passes through the output capacitor and charges it fully. During this phase the output capacitor stores energy inside it and gets fully charged, simultaneously the load across VOUT also gets the energy from the inductor for ts operation.

Next, at this point if the switch is closed again, the process repeats as explained above, however now the capacitor provides its stored energy to the load.Depending how how fast or how slow the switch S is closed and opened, the output DC can be a stepped up or boosted output, or it can be a stepped down or buck output.

Table illustrating the Buck-Boost Converter Components and Their Functions:

Component	Function
Switching Element (MOSFET/BJT)	Controls the flow of current by switching the input voltage on and off at high frequency. It regulates the energy transfer from the input to the output.
Inductor	Stores energy during the "on" period and releases it during the "off" period, helping to either step up or step down the voltage.
Diode (Freewheeling Diode)	Ensures current flows in only one direction (from the inductor to the output capacitor), allowing the stored energy to be transferred efficiently to the output.
Output Capacitor	Smooths the output voltage by filtering high-frequency switching ripple, providing a stable DC output.
Input Capacitor	Filters the input voltage to remove noise and stabilize the input supply, improving the converter's performance.
Control Circuit (PWM Controller)	Adjusts the duty cycle of the switching element based on feedback to maintain the desired output voltage, ensuring proper voltage regulation.

2.Components specification

When designing or selecting components for a power electronic device like a **DC-DC Converter** (e.g., Buck, Boost, or Buck-Boost Converter), the key components are crucial to ensure proper operation, efficiency, and reliability.

Below are the **important component specifications** for each of the mentioned components:

1. Inductor

- **Inductance Value**: The value of inductance determines how much energy the inductor can store. Typical values range from a few microhenries (µH) to millihenries (mH) depending on the application.

- **Example**: 10µH to 100µH for power conversion applications.

- **Saturation Current**: The current at which the inductor's core material saturates and loses its ability to store energy. It should be higher than the peak current in the converter.

- **Example**: 3A to 10A, depending on the power rating.

- **DC Resistance (DCR)**: Lower DCR results in lower losses. Choose an inductor with low resistance to minimize power dissipation.

- **Example**: < 100mΩ.

- **Current Ripple**: The amount of current ripple the inductor will produce; this should be minimized for better efficiency.

- **Core Material**: The material of the inductor core (ferrite, powdered iron, etc.) affects efficiency and operating frequency.

2. Capacitor

- **Capacitance Value**: The value of capacitance determines the capacitor's ability to store charge. Typically, electrolytic, ceramic, or tantalum capacitors are used in DC-DC converters.

- **Example**: 100µF to 470µF for output capacitors, and 10µF to 100µF for input capacitors.

- **Voltage Rating**: The capacitor's voltage rating must exceed the maximum input or output voltage.

- **Example**: 25V, 50V, or higher depending on application.

- **ESR (Equivalent Series Resistance)**: Low ESR is important for efficiency. High ESR leads to heat and voltage ripple.

- **Example**: Less than 100mΩ for low ESR capacitors used in high-efficiency converters.

- **Ripple Current Rating**: The maximum RMS current the capacitor can handle without damage.

- **Example**: 1A to 10A depending on the current in the circuit.

3. Diode

- **Forward Voltage Drop**: This is the voltage drop across the diode when it conducts. A lower forward voltage drop results in higher efficiency.

- **Example**: 0.4V to 0.8V for Schottky diodes.

- **Current Rating**: The diode should handle the peak current in the converter without failing.
  - **Example**: 5A to 20A depending on application.
- **Reverse Voltage Rating**: The diode must withstand the maximum voltage in reverse bias.
  - **Example**: 20V, 40V, or higher depending on the system.
- **Switching Speed**: Fast recovery diodes (like **Schottky** or **Ultrafast** diodes) are preferred to reduce switching losses.
  - **Example**: Recovery time of 50ns or less for high-speed switching.

4. Switching Device (Transistor)

- **Type**: Typically **MOSFETs** or **BJTs** are used, with **MOSFETs** being more common for high-efficiency converters due to their lower switching losses.
  - **Example**: **MOSFET** for switching in Buck or Boost Converters.
- **Voltage Rating**: The transistor must withstand the maximum voltage in the circuit.
  - **Example**: 20V, 50V, 100V, or higher depending on the application.
- **Current Rating**: The transistor must handle the peak current during operation.
  - **Example**: 5A to 30A.
- **Gate Charge**: For MOSFETs, low gate charge minimizes switching losses and improves efficiency.
  - **Example**: Low gate charge MOSFETs (< 10nC) are ideal for high-frequency switching.
- **Rds(on)**: Low on-resistance reduces conduction losses.
  - **Example**: < 50mΩ for low conduction losses.

5. Control Circuit (PWM Controller)

- **Control Method**: The PWM controller controls the duty cycle to regulate the output voltage. It can be **voltage-mode**, **current-mode**, or **hysteretic control**.
- **Switching Frequency**: The frequency of the PWM signal should be selected based on the application to balance efficiency, size, and noise.
  - **Example**: 100kHz to 1MHz.
- **Feedback Loop**: The controller adjusts the duty cycle based on feedback from the output voltage to maintain regulation.
- **Startup Circuit**: Features like soft start help minimize inrush currents during

startup.

6. Filter (LC or RC)

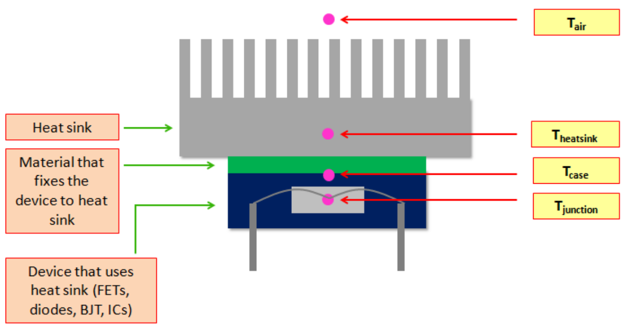
- **Inductor**: A low ESR inductor is often used to reduce high-frequency noise and ripple.
- **Capacitor**: Low ESR capacitors are used to filter out ripple and smooth the output voltage.
- **Values**: The filter components should be designed to match the expected ripple and noise requirements.
  - **Example (LC filter)**: L = 10µH to 100µH, C = 10µF to 100µF.

7. Feedback Loop

- **Type**: Typically, a **voltage feedback loop** is used to sense the output voltage and adjust the switching duty cycle to maintain regulation.
- **Compensation**: The loop may include compensation components (resistors and capacitors) to improve stability and transient response.
  - **Example**: Type II or Type III compensation for stable operation.
- **Feedback Accuracy**: The feedback should accurately regulate the output voltage across load and input variations.

8. Heatsink

- **Thermal Resistance**: Heatsinks should have a low thermal resistance to efficiently dissipate heat generated by power devices such as transistors, inductors, or diodes.
  - **Example**: 1°C/W to 10°C/W depending on the power dissipated.
- **Material**: Typically made from **aluminum** or **copper** for better thermal conductivity.

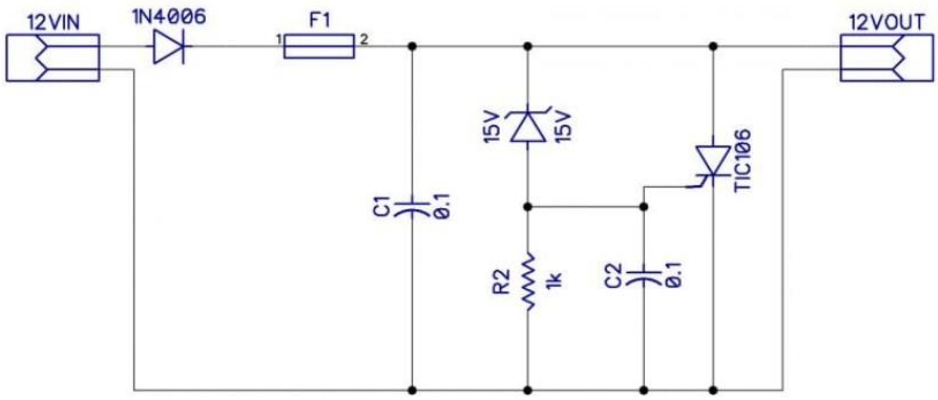


9. Input and Output Terminals

- **Voltage Rating**: The terminals should handle the input and output voltage without degradation.
- **Current Rating**: They must be rated for the maximum expected current.
- **Material**: Typically made from **gold-plated** or **tin-plated** copper for low resistance.

10. Protection Circuits

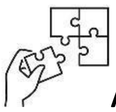
- **Overcurrent Protection**: A circuit that limits the current to a safe value to prevent component damage.
- **Overvoltage Protection**: Ensures the output voltage does not exceed a predefined threshold.
- **Thermal Protection**: The system can shut down or limit operation if the temperature exceeds safe limits.
- **Short-Circuit Protection**: Prevents damage to the converter by shutting it down in case of a short circuit.
- **Surge Protection**: Protects against high-voltage spikes or transients.



Points to Remember

- **Types of DC-DC Converters are:**
  Buck Converter (Step-Down Converter) and Boost Converter (Step-Up Converter)
- **Components specification**

- ✓ Inductor specification
- Inductance Value
- Saturation Current
- DC Resistance (DCR)
- Current Ripple
- Core Material
- ✓ Capacitor (C) specification
- Capacitance Value
- Voltage Rating
- ESR (Equivalent Series Resistance):
- Ripple Current Rating
- ✓ Diode specification
- Forward Voltage Drop
- Current Rating
- Reverse Voltage Rating
- Switching Speed



Application of learning 4.1.

A company that repair different industrial appliances like UPS system wants to hire technician who can select a new industrial UPS (Boost Converter (Step-Up Converter), to replace the faulty one, you are asked to analyse its circuit diagram drawing when selecting the better quality UPS to give to this company.

Indicative content 4.2: Designing DC TO DC converter Diagram

Duration: 4hrs

Theoretical Activity 4.2.1: Realization of symbols used in DC-DC converter

Tasks:

1: Answer the following questions:

- **i.** What are the step to follow while designing a DC-DC Converter?
- **ii.** List out 5 types of diagrams used when designing DC To DC converter.
- **iii.** Draw the symbols of the following important devices used when building DC-DC converter.
  - **a.** Power diode
  - **b.** Thyristor
  - **c.** Coil /inductor
  - **d.** Capacitor
  - **e.** Fuse

2: Write the answers on flipchart/ paper

3: Present the findings to the trainer and whole class

4: Ask for clarification if any

5: Read the key readings 4.2.1. in the manual

Key readings 4.2.1: Realization of symbols used in DC-DC converter

The **realization of symbols** used in **DC-DC converter design** is important for several reasons, especially in terms of communication, understanding, and implementation of the design. These symbols represent various components and their connections in a converter, and using standardized symbols ensures clarity and precision in designing and building these circuits.

Reasons for realizing and using power electronic device's symbols :

1. Standardization and Universality:

- Industry Standards:
- Simplification:

2. Clear Communication:

- Engineering Documentation
- Manufacturing and Assembly:

3. Design Understanding:

- Identifying Key Components:
- Functionality Mapping:

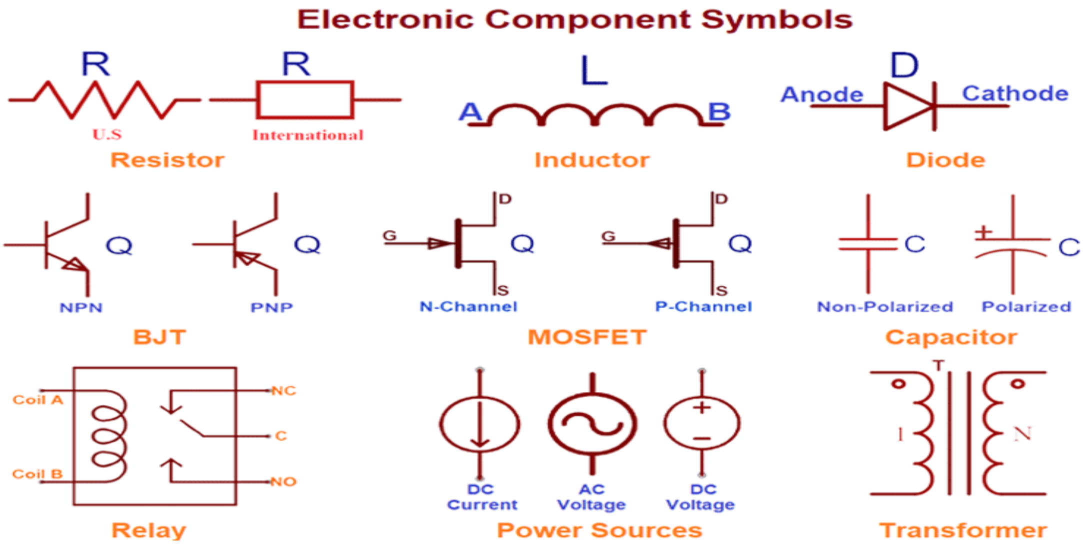
4. Ease of Troubleshooting:

- Pinpointing Issues:
- Simulation and Testing:

Key Symbols in DC-DC Converter Design:

Some of the key symbols used in DC-DC converter design include:

- **Inductor (L)**: A coil symbol that represents an inductor, which stores energy in a magnetic field.
- **Capacitor (C)**: Two parallel lines with one slightly curved (representing the two plates of a capacitor), used for storing electrical energy in an electric field.
- **Diode (D)**: A triangle pointing to a line (representing a diode), which only allows current to flow in one direction.
- **Switch (S)**: A line connecting two nodes, representing a switch that can either be open or closed to control the current flow.
- **Ground (GND)**: A symbol representing the common reference point for the circuit's voltage.
- **Voltage Source**: A circle with a plus and minus sign (for DC voltage), used to indicate the power supply.



1. **Step-by-Step guide for Designing a DC-DC Converter**

1.1: Define Your Requirements

Before diving into the design, clearly define the requirements for your DC-DC converter. Key parameters to consider include:

- **Input Voltage Range**: The range of voltages the converter will accept.
- **Output Voltage**: The desired output voltage.
- **Output Current**: The maximum current required by the load.
- **Efficiency**: Desired efficiency levels to minimize energy loss.
- **Load Regulation**: The ability of the converter to maintain steady output despite variations in load.
- **Transient Response**: How quickly the converter responds to changes in load or input voltage

1.2: Select the Topology

Choose the appropriate topology based on your requirements. For example, if you need to step down the voltage, a buck converter is suitable

1. 3: Calculate Component Values

Once you have selected the topology, you need to calculate the power basing on values of the key components, such as inductors, capacitors, and resistors.

1.4: Design the Control Loop

Pulse Width Modulation (PWM) controller is used to regulate the duty cycle, ensuring the output voltage remains constant despite changes in input voltage or load

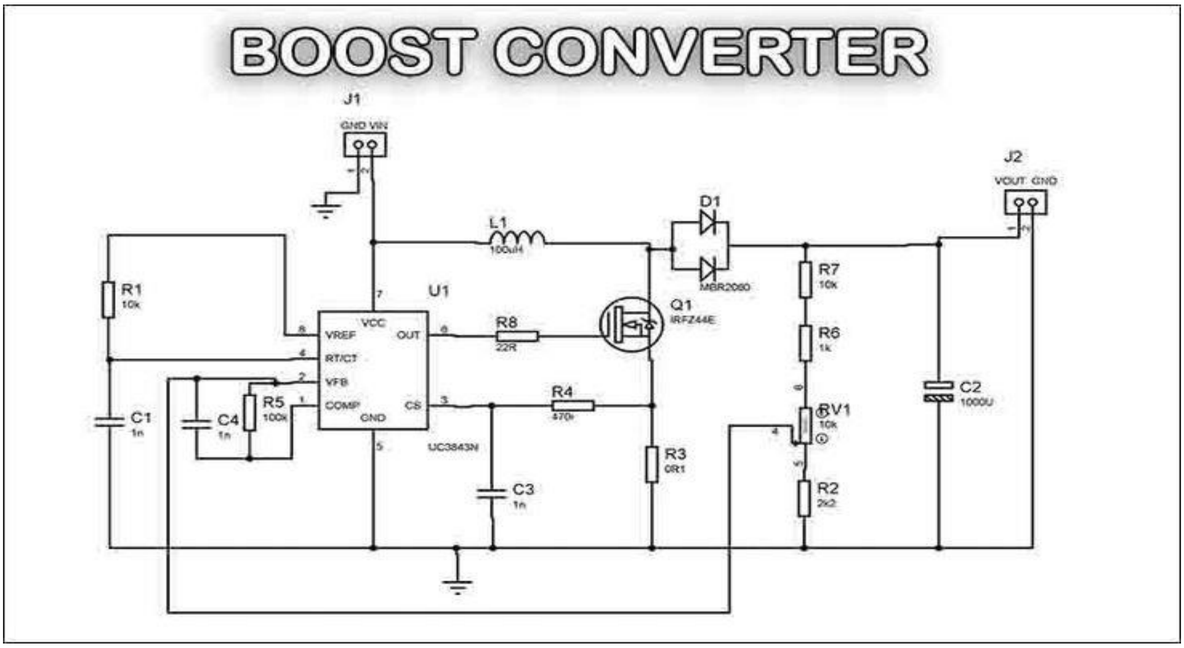
1. 5: Build and Test a Prototype

Once you are confident in your design, build a prototype. Use a printed circuit board (PCB) for best results, as it provides a reliable platform for testing. During testing, measure key parameters such as output voltage, efficiency, and thermal performance.

2. **Types of diagrams commonly used when design DC To DC converter**

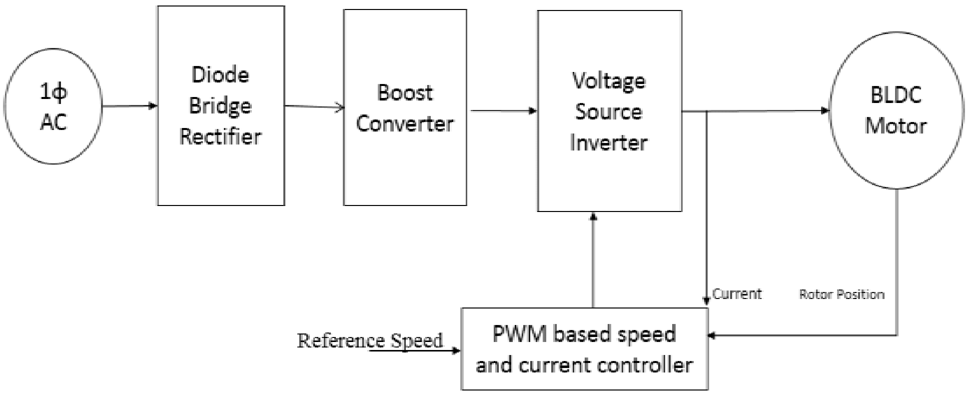
2.1. Schematic Diagram

- **Purpose**: Shows the electrical connections and components of the circuit.
- **Details**: Includes components like inductors, capacitors, diodes, transistors, and their interconnections. It provides a clear view of how the circuit functions.



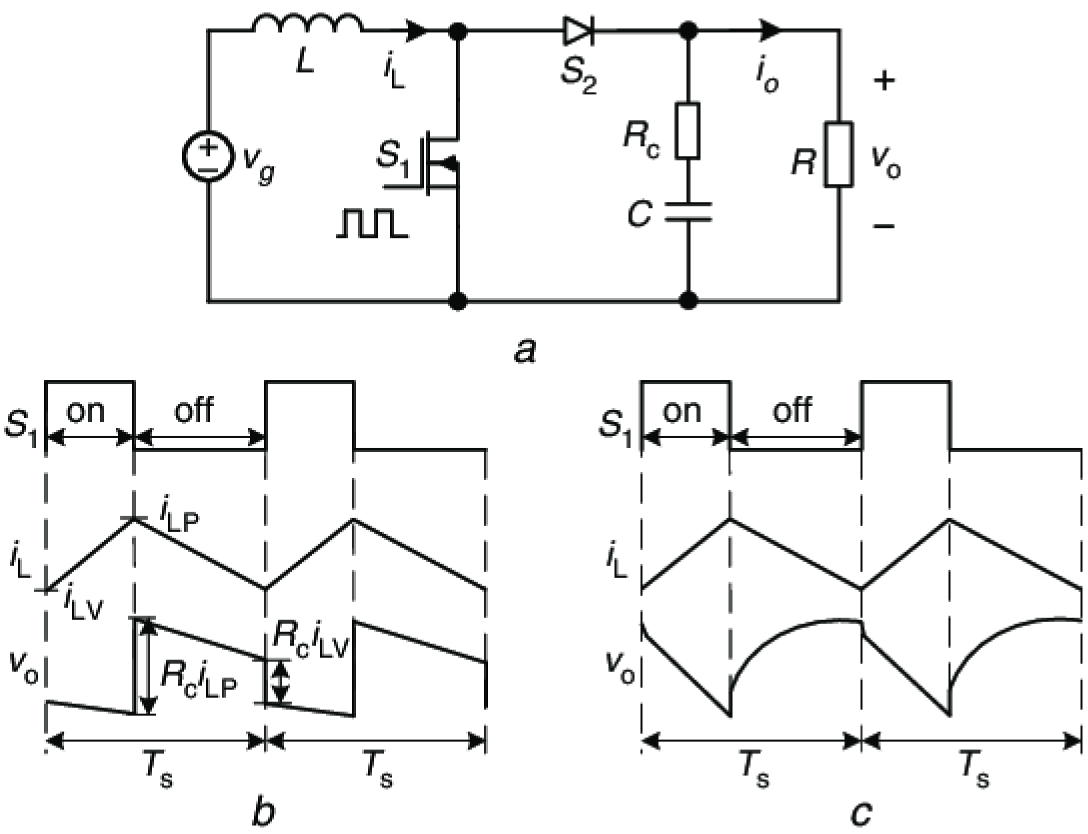
2.2. **Block Diagram**

- **Purpose**: Offers a high-level overview of the system.
- **Details**: Displays the main functional blocks of the converter (input, controller, power stage, output) without delving into specific components.



2.3. **Waveform Diagram**

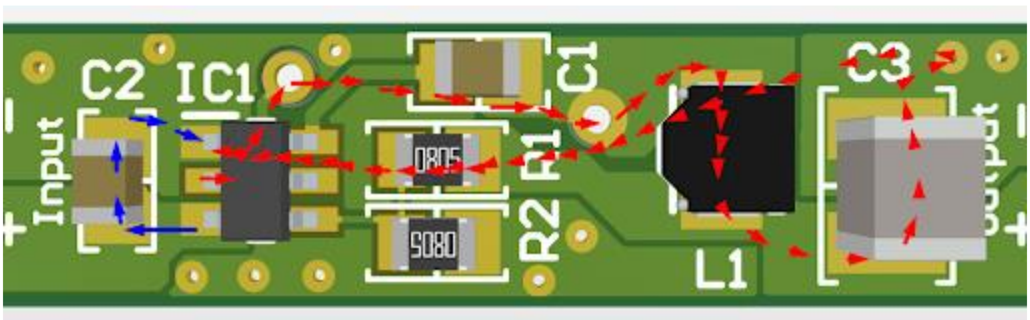
- **Purpose**: Illustrates the voltage and current waveforms at various points in the converter.
- **Details**: Shows the input and output waveforms, switching waveforms, and ripple voltages, helping to visualize performance during operation.

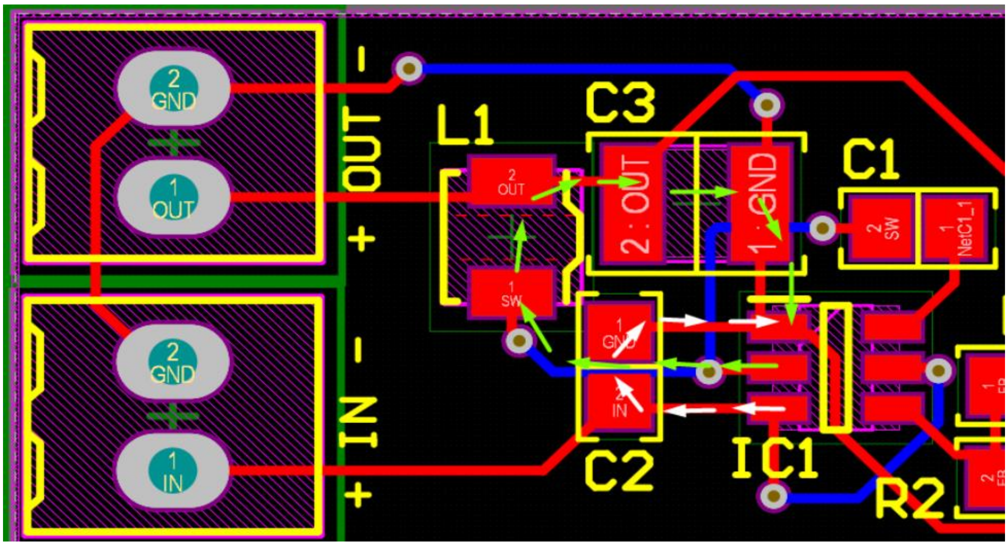


2.4. **PCB Layout Diagram**

- **Purpose**: Represents the physical arrangement of components on the printed circuit board.
- **Details**: Includes traces, pads, and component footprints, focusing on minimizing interference and optimizing thermal management.

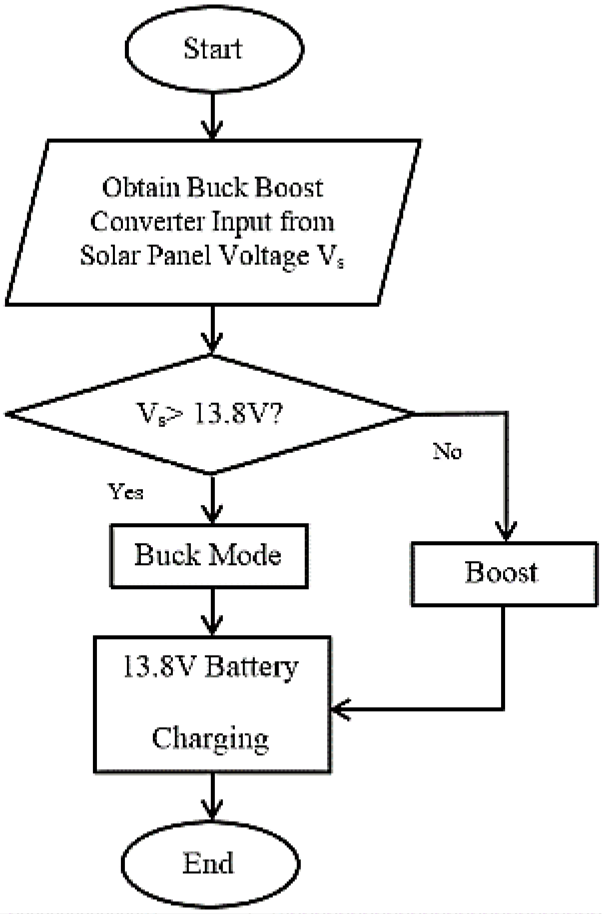
Input and output current loops of DC-DC design buck converter PCB layout:



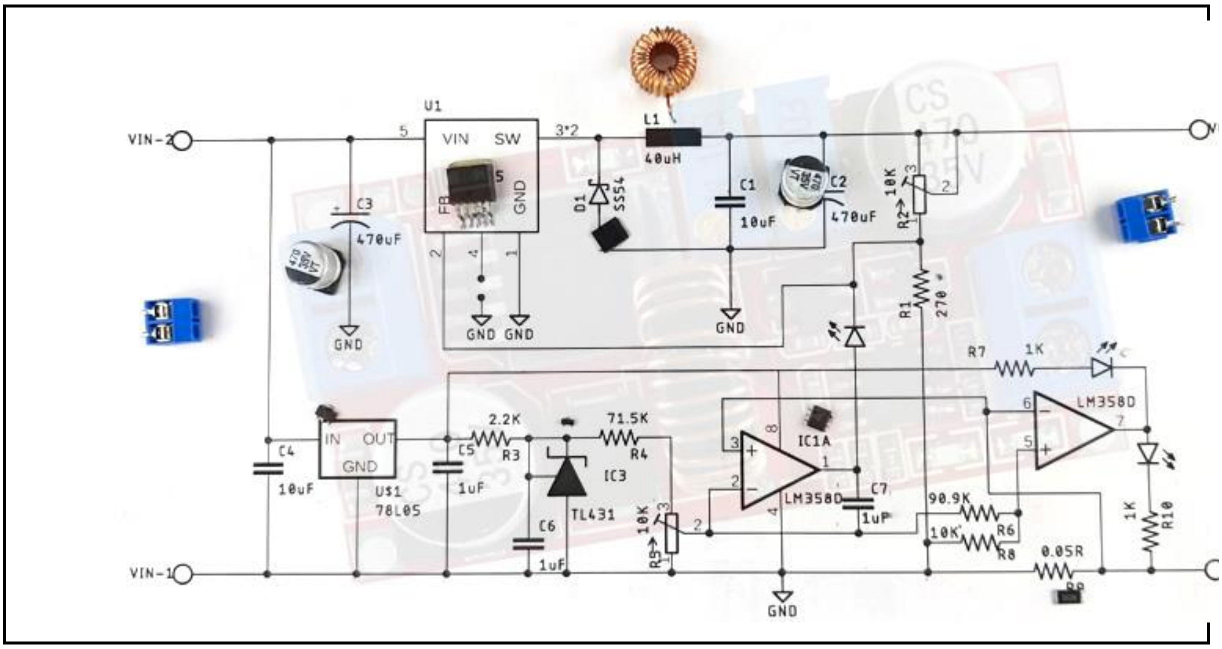


2.5. **Flowchart Diagram**

- **Purpose**: Outlines the control logic of the converter.
- **Details**: Shows the decision-making process for switching control, such as PWM (Pulse Width Modulation) control strategies



- **An electrical diagram** are drawings, which are used to represent electrical circuits, these circuits are represented by using lines, symbols and numbers.



Practical Activity 4.2.2: drawing a DC to DC Converter

Task:

1. Read the given task

Go to the workshop to Draw a Buck converter (Step-Down Converter) circuit and label each component.

2: Perform the given tasks by respecting the given instructions.

4: Present your work to the trainer.

5: Read key reading 4.2.1 and ask clarification where necessary

6: Perform the task provided in application of learning 4.2.

Key readings 4.2.2: drawing a DC-to-DC Converter

1.1 Designing a Buck Converter circuit

Designing a **Buck Converter circuit** involves creating a schematic that efficiently steps down the input voltage to a lower output voltage. Below are tips for drawing a clear and functional **Buck Converter circuit drawing tips:**

1. Start drawing the basic components:

2. Input Voltage Source (Vin):

- Label your input voltage clearly at the left side of the schematic.

- Represent the input voltage source with a DC voltage source symbol.
- Indicate proper voltage rating, e.g., **Vin = 12V**.

3. Switch (S):

- The switch typically controls the on/off cycles of the converter. Use a transistor or MOSFET symbol for the switch.
- Connect one terminal of the switch to the positive side of the input voltage (Vin).
- The other terminal will connect to the inductor (L).

4. Inductor (L):

- Place the inductor next to the switch.
- The inductor symbol is typically a series of coils or loops.
- Connect the inductor to the switch and to the next stage (diode or load).

5. Diode (D):

- Use a diode symbol (a triangle with a line at the tip) to show current direction.
- The anode of the diode connects to the inductor, while the cathode connects to the output voltage node.
- This diode allows current to flow when the switch is off, ensuring energy is transferred to the output.

6. Capacitor (C):

- Place a capacitor at the output of the inductor and diode, parallel to the load.
- The capacitor symbol is two parallel lines, one shorter than the other.
- The positive terminal of the capacitor connects to the output node (where you want to control the DC output voltage).

7. Output Voltage (Vout):

- Label the output voltage on the right side of the schematic.
- The capacitor helps filter out high-frequency noise and smoothens the output voltage.
- Include a load (could be represented as a resistor or another connected circuit) to show where the output is being used.

8. Grounding:

- Connect the ground symbols from the input source, capacitor, and load to a common ground point.

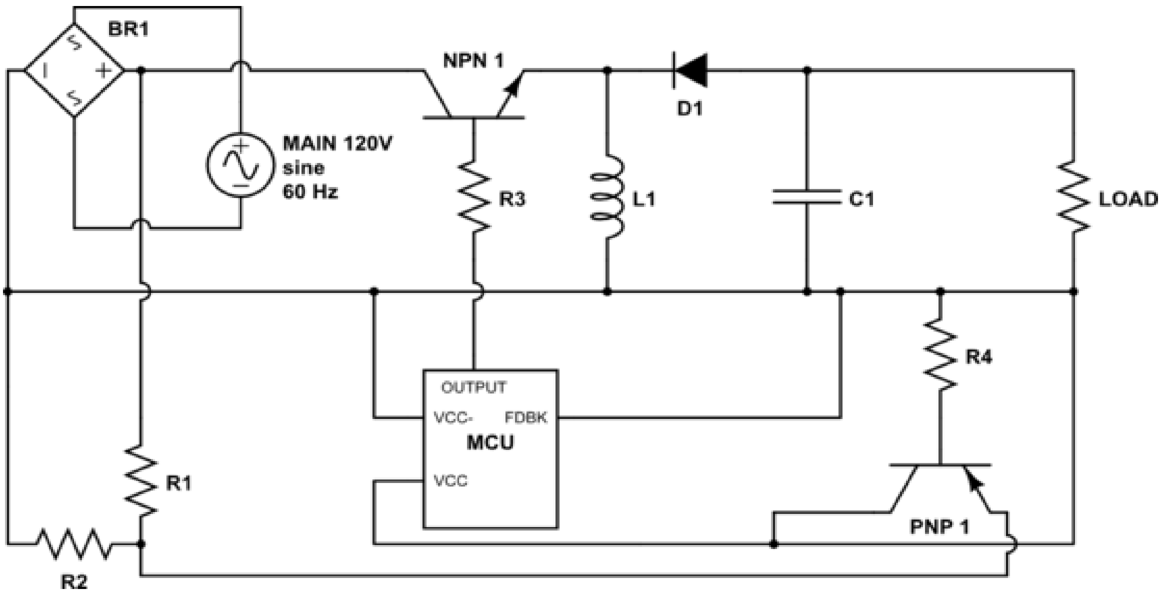
- Ensure the negative terminals of all components (like the diode, switch, and load) are connected to ground.

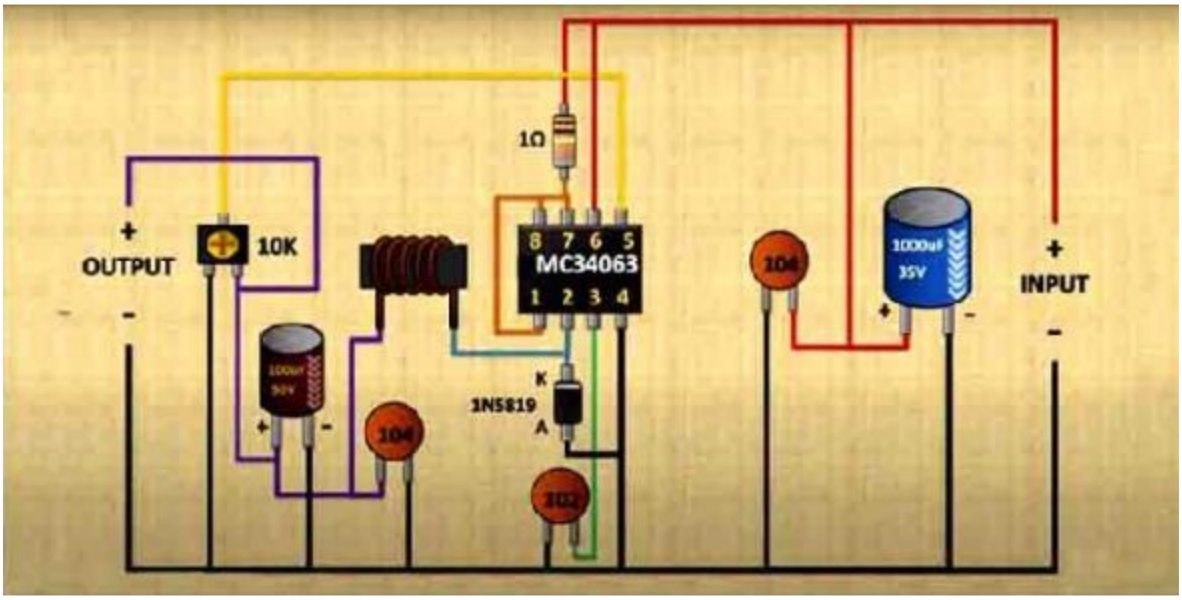
9. Feedback (Optional for Regulation):

- If designing a closed-loop controlled Buck Converter, you may need a feedback loop.
- This could include a voltage divider network (resistors) and a control IC (like PWM controller) to regulate the output voltage.
- The feedback is usually taken from the output (after the capacitor) and is sent to the control input of the switch for dynamic voltage regulation.

10. Labeling:

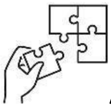
- Clearly label all components (Inductor L, Capacitor C, Switch S, Diode D, etc.).
- Include values for each component in your final schematic if possible (e.g., L = 100µH, C = 100µF).
- Label the input and output voltages and current if relevant.





Points to Remember

Designing a **Buck Converter circuit** involves creating a schematic that efficiently steps down the input voltage to a lower output voltage.



Application of learning 4.2.

A company that repair different Equipment like UPS industry system wants to hire technician who can repair a UPS of the industry, the UPS power supply was faulty, you are asked to draw a Buck converter (Step-Down Converter) and demonstrate each component of it.

Indicative content 4.3: Assembling DC TO DC Converter Diagram

Duration: 4 hrs

Practical Activity 4.3.1: Assembling of Boost Converter (Step-Up Converter)

Task:

1: Read the given task:

Go to the workshop to connect a Boost Converter (Step-Up Converter) circuit on PCB board.

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 4.3.1 and ask clarification where necessary

5: Perform the task provided in application of reading 4.3.1

Key readings 4.3.1: Assembling of Boost Converter (Step-Up Converter)

- **The method used to assemble a DC to DC Power Converter**

1.Preparation and Planning:

- Gather all necessary components required for the power converter assembly, including semiconductors, capacitors, inductors, resistors, transformers, heat sinks, PCB, enclosure, etc.
- Prepare a clean, well-lit workspace with the necessary tools and safety equipment.

2.Component Preparation:

- Check all components for damage or defects before assembly.
- Ensure components are properly prepped and ready for installation (e.g., leads trimmed, thermal paste applied to heat sinks, etc.).

3.PCB Assembly:

- If the power converter utilizes a printed circuit board, populate the PCB with the required components following the circuit diagram and considering their placement and orientation.
- Use proper soldering techniques to attach components to the PCB, ensuring proper connections and solder joints.

4.Sub-Assembly Creation:

- Create sub-assemblies of components that might be connected separately before the final integration.
- Perform individual tests or inspections on sub-assemblies to ensure their

functionality before integration.

5.Main Assembly:

- the Place sub-assemblies, such as the PCB, transformers, and heat sinks, into the enclosure or housing
- Connect all components as per the schematic or design plan, ensuring proper routing of wires and connections.
- Ensure all components are securely fixed within the enclosure to prevent movement and damage.

6.Wiring and Connections:

- Connect the electrical components using suitable wires, ensuring proper termination and isolation.
- Employ insulating materials or shielding where necessary to prevent electrical hazards and EMI.

7.Testing and Verification:

- Conduct a series of tests to verify the functionality of the assembled power converter, including input/output checks, load tests, and safety checks.
- Verify compliance with safety standards and regulations, ensuring the converter meets required criteria.

8.Documentation and Labelling:

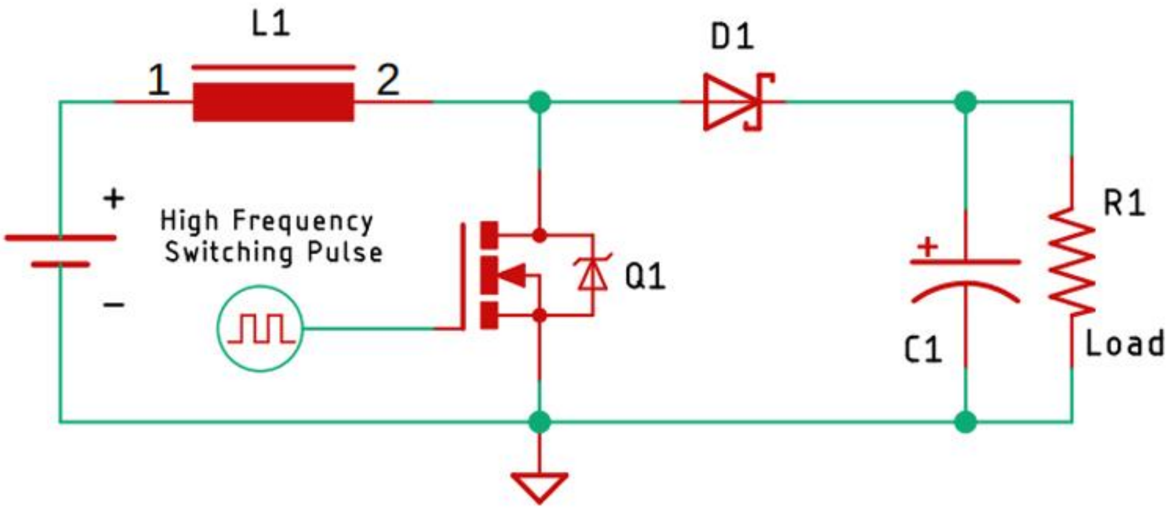
- Prepare assembly documentation, including assembly diagrams, instructions and part lists for future reference.
- Label components, terminals, warnings, and safety instructions as necessary for user guidance.

Designing a High Power, Efficiency Boost Converter using TL494

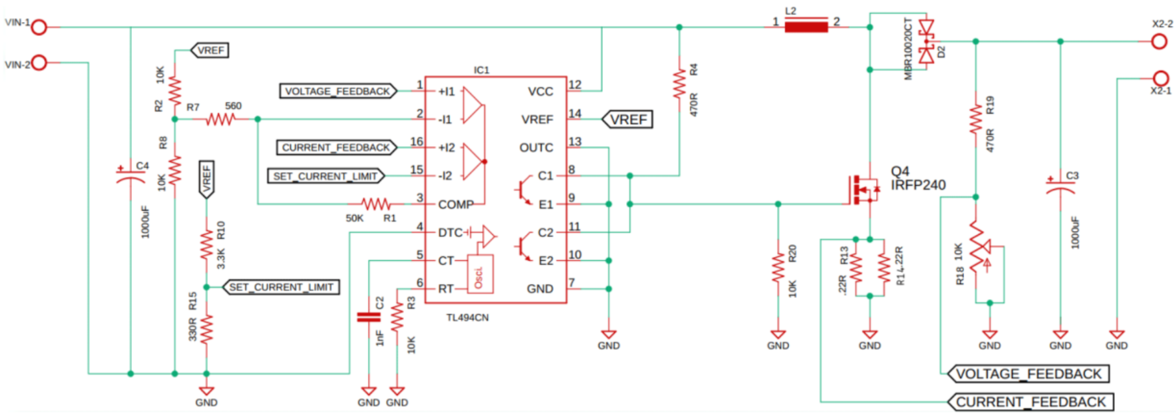
A boost converter is a DC-DC type switching converter that steps up the voltage while maintaining a constant power balance. The main feature of a boost converter is efficiency which means we can expect long battery life and reduced heat issues. .

design a **TL494 Boost converter,** and calculate and test a high-efficiency boost converter circuit based on the popular **TL494** IC, which has a minimum supply voltage of 7V and a maximum of 40V, and as we are using the **IRFP250 MOSFET** as a switch, this circuit can handle a maximum current of 19Amps, theoretically (Limited by Inductor Capacity

Circuit diagram of boost converter to be designed



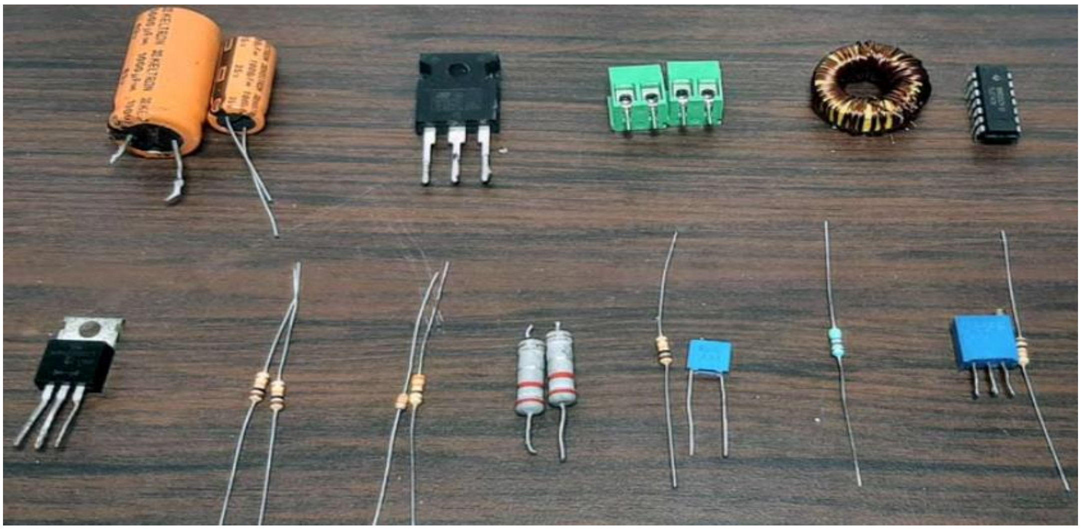
Schematic diagram to help in connection and component placing and soldering



Components to be used and its specifications:

1. TL494 IC - 1
2. IRFP250 MOSFET - 1
3. Screw Terminal 5X2 mm - 2
4. 1000uF, 35V Capacitor - 1
5. 1000uF,63V Capacitor - 1
6. 50K, 1% Resistor - 1
7. 560R Resistor - 1
8. 10K,1% Resistor - 4
9. 3.3K, 1% Resistor - 1

10. 330R Resistor - 1
11. 0.1uF Capacitor - 1
12. MBR20100CT Schottky Diode - 1
13. 150uH (27 x 11 x 14) mm Inductor - 1
14. Potentiometer (10K) Trim Pot - 1
15. 0.22R Current Sense Resistor - 2
16. Clad Board Generic 50x 50mm - 1
17. PSU Heat Sink Generic - 1
18. Jumper Wires Generic - 15



1. Component Placing:

- **Definition**: This is the process of positioning each component on the **PCB** (Printed Circuit Board) or **breadboard** before soldering. Proper placement ensures that the components are organized efficiently for easy connections and minimal interference.
- **Key Components Placement**:
  - **Input voltage (Vin)**: Place near the power source.
  - **MOSFET (Switch)**: Place near the input for controlling voltage flow.
  - **Inductor**: Position next to the MOSFET to store energy.
  - **Diode**: Place after the inductor to direct current flow.
  - **Capacitor**: Place at the output to filter the voltage.
  - **Load (Resistor or device)**: Position after the capacitor.
  - **Ground (GND)**: Ensure all components requiring ground are appropriately connected.

2. Component Connecting:

- **Definition**: This step involves physically linking the components with wires or traces on a PCB. The components must be correctly connected to form a functional circuit.
- **Key Connections**:
  - **Input Voltage**: Connect the positive terminal of **Vin** to the **drain** of the

MOSFET.

- **MOSFET**: Connect the **source** to ground, and the **gate** to the **PWM signal**.
- **Inductor**: Connect one side to the MOSFET drain and the other side to the diode anode.
- **Diode**: Connect the **anode** to the inductor and the **cathode** to the **output voltage** (Vout).
- **Capacitor**: Connect the positive terminal to **Vout** and the negative terminal to ground.
- **Load**: Connect the load across the **output voltage** and ground.
- **PWM Control**: Ensure the **PWM signal** controls the gate of the MOSFET.

3. Soldering:

- **Definition**: Soldering is the process of permanently attaching components to the PCB or breadboard by heating a metal (usually solder) to form electrical connections.
- **Key Soldering Steps**:
  - **Prepare the soldering iron**: Heat it to about 350°C (for lead-free solder).
  - **Solder small components**: Start with the smallest components (e.g., resistors, diodes) first.
  - **Solder large components**: Solder the **MOSFET**, **inductor**, **capacitor**, and **diode** carefully.
  - **Check connections**: Make sure all solder joints are clean and well-formed (not too much solder).
  - **Inspect for shorts**: Ensure there are no accidental bridges between adjacent pads or pins.

4. Finishing:

- **Definition**: This final step involves ensuring the circuit is working correctly and safely. It includes testing, debugging, and placing the completed circuit in an enclosure for protection.
- **Key Finishing Steps**:
  - **Testing**: Power the circuit and measure the output voltage (**Vout**) with a **multimeter**. Confirm that the output is higher than the input (as the Boost Converter is supposed to step up the voltage).
  - **Debugging**: If the circuit isn't working as expected, check for issues such as cold solder joints, missing connections, or faulty components. Use an oscilloscope to inspect the MOSFET's switching behavior.
  - **Safety Check**: Ensure that components are not overheating and that there are no short circuits.
  - **Enclosure**: Place the circuit in a protective **enclosure** to prevent damage and ensure safety during use.

- **Labeling**: Label the input and output terminals for easy identification and troubleshooting.

Points to Remember

- **The method used to assemble a DC to DC Power Converter**
  - Preparation and Planning
  - Component Preparation
  - PCB Assembly
  - Sub-Assembly Creation
  - Main Assembly
  - Wiring and Connections
  - Testing and Verification
  - Documentation and Labelling
  - **A boost converter** is a DC-DC type switching converter that steps up the voltage while maintaining a constant power balance. The main feature of a boost converter is efficiency which means we can expect long battery life and reduced heat issues.

Practical Activity 4.3.2: Assembling a Buck converter (Step-Down Converter)

Task:

1: Read the given task

Go to the workshop to connect a Buck converter (Step-Down Converter) circuit on PCB board.

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 4.3.2 and ask clarification where necessary

5: Perform the task provided in application of reading 4.3.2

Key readings 4.3.2: Assembling a Buck converter (Step-Down Converter)

The method used to assemble a DC to DC Power Converter

1.1. Preparation and Planning:

- **Component Inventory:** Gather all necessary components required for the power converter assembly, including semiconductors, capacitors, inductors, resistors, transformers, heat sinks, PCB, enclosure, etc.
- **Assembly Area:** Prepare a clean, well-lit workspace with the necessary tools and

safety equipment.

1.2. Component Preparation:

- **Component Inspection:** Check all components for damage or defects before assembly.
- **Component Readiness:** Ensure components are properly prepped and ready for installation (e.g., leads trimmed, thermal paste applied to heat sinks, etc.).

1.3.PCB Assembly:

- **PCB Preparation:** If the power converter utilizes a printed circuit board, populate the PCB with the required components following the circuit diagram and considering their placement and orientation.
- **Soldering:** Use proper soldering techniques to attach components to the PCB, ensuring proper connections and solder joints.

1.4.Sub-Assembly Creation:

- **Sub-Assembly Construction:** Create sub-assemblies of components that might be connected separately before the final integration.
- **Pre-Assembly Testing:** Perform individual tests or inspections on sub-assemblies to ensure their functionality before integration.

1.5.Main Assembly:

- **Mounting Components:** the Place sub-assemblies, such as the PCB, transformers, and heat sinks, into the enclosure or housing
- **Component Integration:** Connect all components as per the schematic or design plan, ensuring proper routing of wires and connections.
- **Secure Fixtures:** Ensure all components are securely fixed within the enclosure to prevent movement and damage.

1.6.Wiring and Connections:

- **Wiring:** Connect the electrical components using suitable wires, ensuring proper termination and isolation.
- **Insulation and Shielding:** Employ insulating materials or shielding where necessary to prevent electrical hazards and EMI.

1.7.Testing and Verification:

- **Functional Testing:** Conduct a series of tests to verify the functionality of the assembled power converter, including input/output checks, load tests, and safety checks.
- **Compliance Testing:** Verify compliance with safety standards and regulations, ensuring the converter meets required criteria.

1.8.Documentation and Labelling:

- **Documentation:** Prepare assembly documentation, including assembly diagrams, instructions and part lists for future reference.
- **Labelling:** Label components, terminals, warnings, and safety instructions as necessary for user guidance.

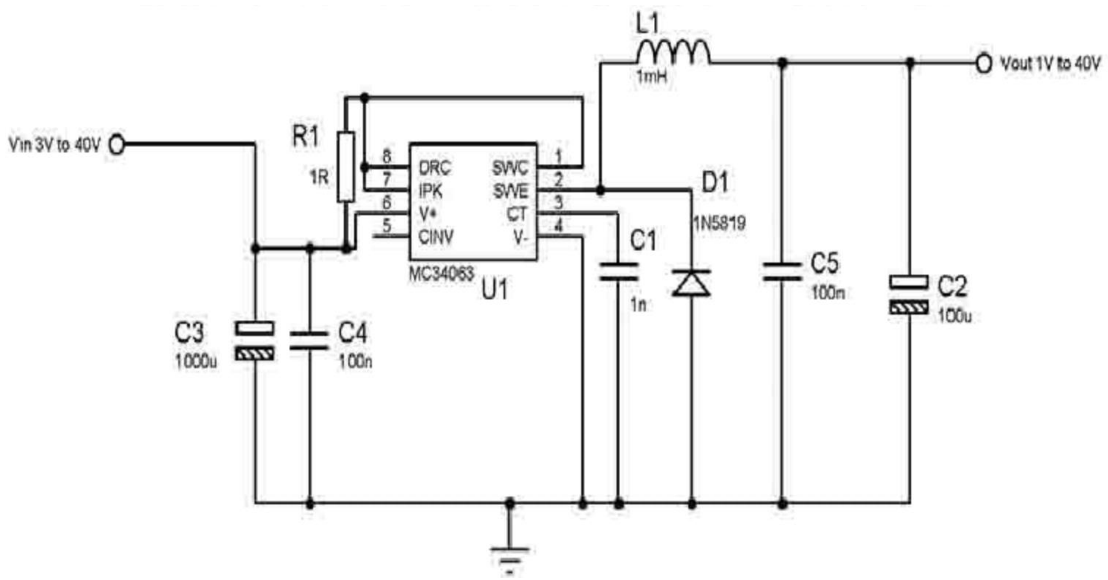
1.9.Final Checks and Packaging:

- **Final Inspection:** Perform a comprehensive inspection to ensure the assembly is correctly executed and ready for operation.

1. Buck Converter (Step-Down Converter):

. Buck converters, also known as step-down converters, are electronic circuits primarily used to step down voltage levels efficiently. These converters find extensive applications in power supplies, battery chargers, and other devices operating under sophisticated power management systems. This article will guide you through the process of building a Buck Converter for homemade using easily accessible components like the MC34063 IC, 330uH inductor, and 1N5819 diode

Circuit diagram of proposed circuit :



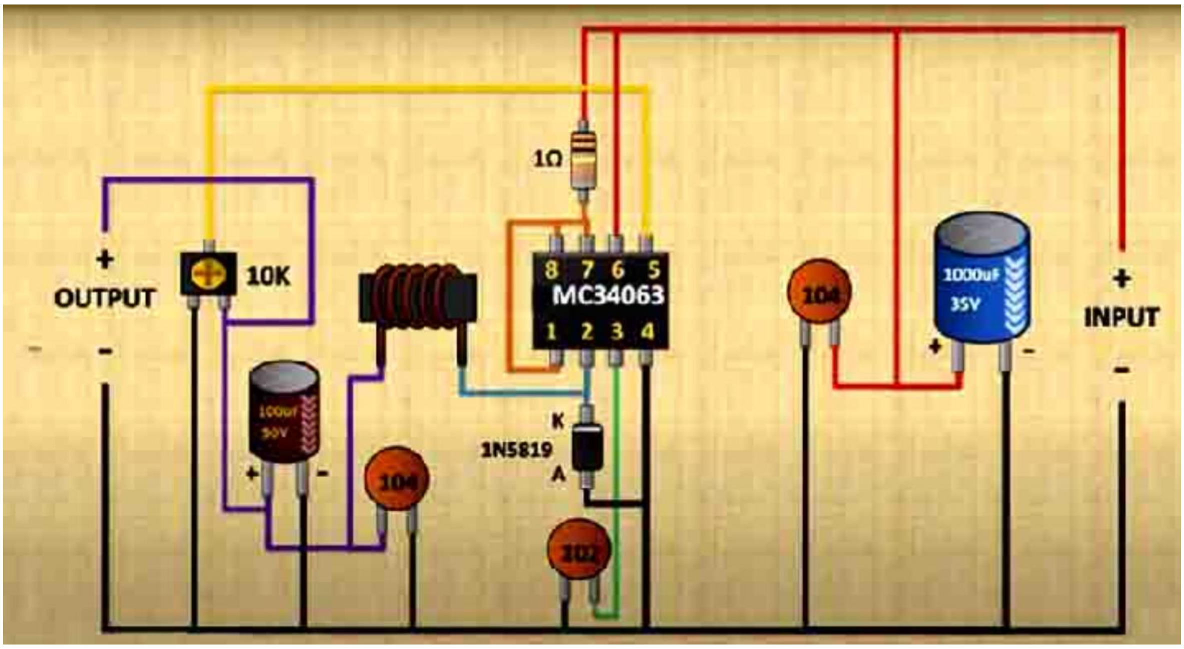
List of all components used in the proposed circuit and their specifications :

- 1x MC34063 IC
- 1x 1N5819 DIODE
- 1x 330uH INDUCTOR
- 1x 1nF CAPACITOR
- 2x 100nF CAPACITOR

- 1x 100uF CAPACITOR
- 1x 1000uF CAPACITOR
- 1x 10KVARIABLE RESISTOR
- 1x 1 OHM RESISTOR
- VERO BOARD
- JUMPER WIRES

Buck converter circuit implementation (components placing ,connecting ,soldering and finishing processes)

- ✓ **Placing**: Position components like the **MOSFET**, **inductor**, **diode**, and **capacitor** in a logical order on the PCB for effective operation.
- ✓ **Connecting**: Make electrical connections between components to form the Buck Converter circuit, ensuring each part of the circuit is linked correctly.
- ✓ **Soldering**: Use a soldering iron to create solid, permanent connections between components and PCB pads.
- ✓ **Finishing**: Power the circuit, check the output voltage, ensure proper operation, and then place the converter in an enclosure for protection.



Points to Remember

- **Buck converter circuit implementation**

✓ **Placing**: Position components like the **MOSFET**, **inductor**, **diode**, and **capacitor** in a logical order on the PCB for effective operation.

- ✓ **Connecting**: Make electrical connections between components to form the Buck Converter circuit, ensuring each part of the circuit is linked correctly.
- ✓ **Soldering**: Use a soldering iron to create solid, permanent connections between components and PCB pads.
- ✓ **Finishing**: Power the circuit, check the output voltage, ensure proper operation, and then place the converter in an enclosure for protection.

Practical Activity 4.3.3: Assembling of Buck-Boost Converter

Task:

1: Read the given task

Go to the workshop to connect a Buck-Boost Converter circuit on PCB board.

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 4.3.3 and ask clarification where necessary

5: Perform the task provided in application of reading 4.3.3

Key readings 4.3.3: Assembling of Buck-Boost Converter

The methods and processes to assemble a DC to DC Power Converter

By observing to the correct assembly methods, the circuit Designer will ensure that the implemented and assembled Buck-Boost converter operates efficiently, safely, and reliably. Each step—component placement, wiring, soldering, and finishing—has a direct impact on the device's performance, durability, and safety. Proper assembly methods ultimately reduce the risk of failure, improve operational efficiency, and contribute to the long-term success of the converter in its application.

3.Buck-Boost Converter circuit assembling process:

Buck-Boost Converter Assembling processes (component placing, wiring, soldering and finishing)

The assembly process of a Buck-Boost Converter involves several key stages, including component placing, wiring, soldering, and finishing. Here’s an outline of each stage:

1. Component Placing:

- **Identify Components**: Ensure you have all the necessary components for the Buck-Boost converter, such as inductors, capacitors, diodes, resistors, transistors, and the IC controller.
- **Placement on PCB**: Place the components onto the printed circuit board (PCB) according to the circuit design and schematic. This includes surface-mount

devices (SMD) or through-hole components depending on the design.

- **Preliminary Checks**: Verify the orientation and polarity of components, especially for polarized ones like electrolytic capacitors, diodes, and transistors.

2. Wiring (if necessary):

- **Point-to-Point Wiring**: For prototypes or non-standard designs, manually wire components that require interconnection between different parts of the circuit.
- **Connections for Power and Signal**: Ensure correct wiring for the power input, ground, and output paths. Ensure the proper routing of high-frequency signals, especially in power conversion circuits, to minimize noise and signal loss.
- **Wire Stripping and Preparation**: If using external wires for connections, strip insulation carefully, and prepare the wires for soldering by ensuring they are clean and free of oxidation.

3. Soldering:

- **Soldering Components**: Using a soldering iron or reflow soldering technique, attach components to the PCB. Ensure the joints are solid and free of cold solder joints.
- **Surface-Mount Soldering**: For SMD components, either use a reflow oven for mass assembly or hand solder them using fine-tipped soldering irons. Care must be taken to avoid overheating the components.
- **Through-Hole Soldering**: For through-hole components, insert the leads through the PCB holes and solder them from the opposite side.
- **Soldering Techniques**: Use flux to improve solder flow and clean the excess solder for neatness. Avoid bridging or shorting adjacent pads.
- **Inspection**: Check for solder bridges, cold solder joints, or other defects using a magnifying glass or microscope. This can be crucial in a power converter where any short or poor connection may cause failure.

4. Finishing:

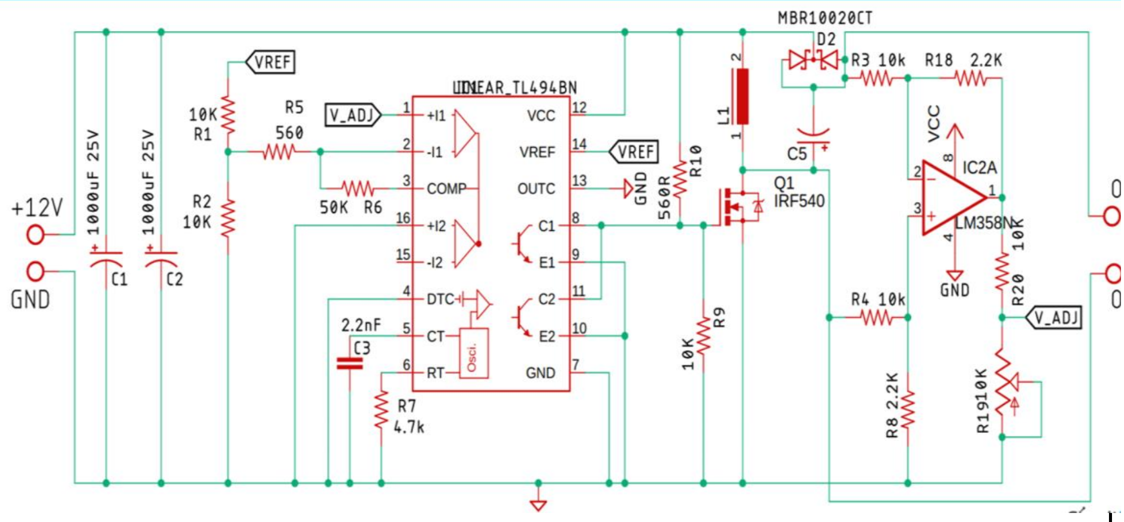
- **Cleaning**: Remove flux residues from the PCB using isopropyl alcohol or specialized cleaning solvents. This ensures long-term reliability of the assembly.
- **Visual Inspection**: Examine the completed assembly to ensure all components are properly placed, and there are no signs of damage, misplacement, or defects.
- **Testing**: Perform a functional test to ensure the converter is operating as intended. This can include verifying input and output voltage levels, checking for ripple, and ensuring the converter performs efficiently under load.
- **Heat Dissipation**: Verify that any heat sinks or thermal management components are properly installed and that the device is running within safe temperature limits.

Additional Considerations:

- **Safety**: When working with high voltages or currents, always follow appropriate safety protocols. Ensure proper insulation and grounding throughout the assembly process.

- **Documentation**: Keep detailed records of component selection, assembly steps, and testing results for future reference and troubleshooting.

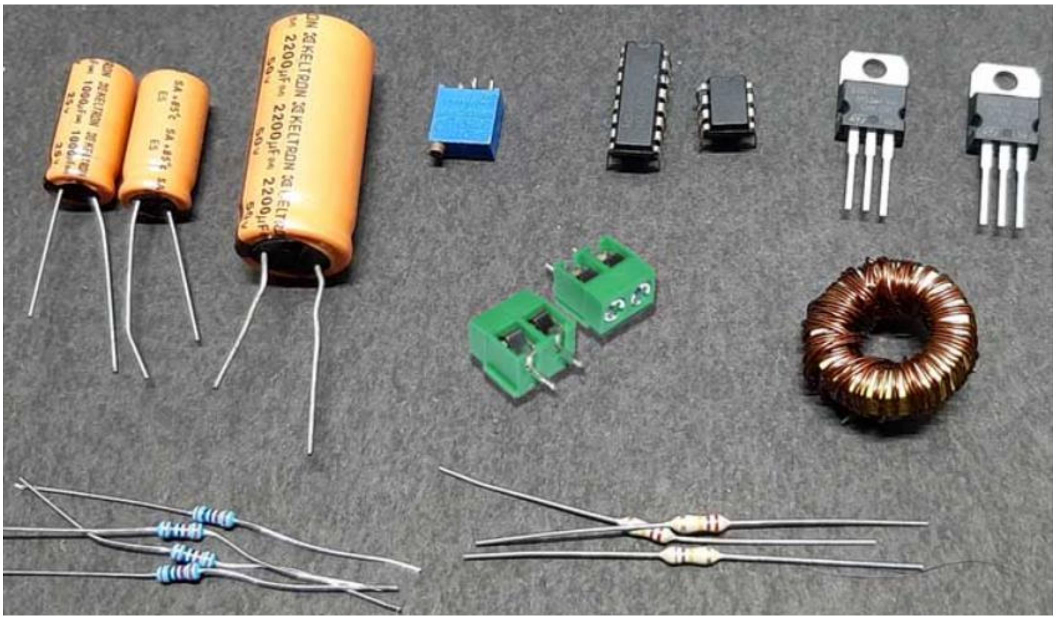
Circuit diagram of the proposed Buck-Boost converter's schematic diagram:



List of components to be used and related specifications :

1. IC TL494 PWM Controller - 1
2. IRFZ44N MOSFET - 1
3. 220 uH Inductor - 1
4. LM358 Op-amp - 1
5. MBR20100CT Diode - 1
6. 5.08mm Screw Terminal - 2
7. 1000uF,25V Capacitor - 2
8. 1000uF,63V Capacitor - 1
9. 2.2nF Capacitor - 1
10. R560 Resistor - 2
11. 2.2K Resistor, 1% - 2
12. 4.7K, 1% Resistor - 1
13. 10K, 1% Resistor - 6
14. 50K Resistor - 1
15. 10K Trim-Pot - 1
16. Cladboard for PCB

Selected components view:



The working principle:

The working principle of this circuit is very simple. The circuit is divided into three parts, the first one being the TL494 PWM controller. We are using the TL494 PWM controller to drive the MOSFET. This IC is configured to switch at 100KHz switching frequency which is suitable for this type of application. If you want to know more about the TL494 IC and its configuration, do check out our previous project on TL494 Based Buck Converter where we have discussed about TL494 IC in detail. Up next, we have the circuit which is responsible for the buck-boost operation**.** The final part of the circuit is a differential amplifier. A differential amplifier takes in two voltage values, finds the difference between these two values, and amplifies it. The resulting voltage can be obtained from the output pin. In one of the previous projects, we have built a voltage subtractor circuit where we used a differential amplifier and explained all of its details

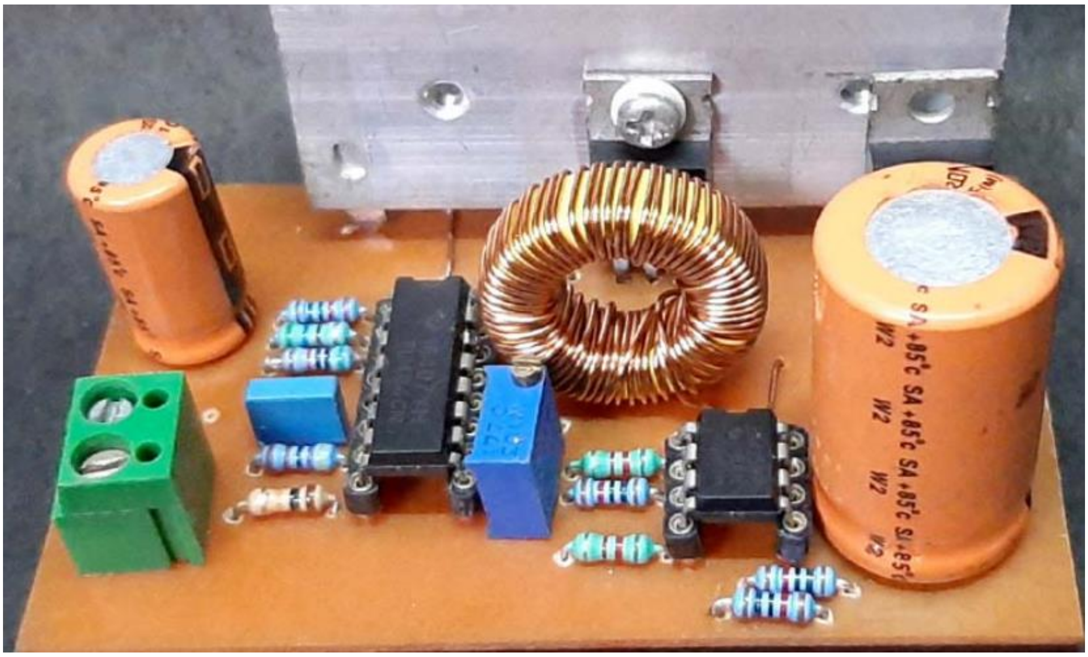
Finally, the resistors, R19 and R20 form a voltage divider that feeds back the voltage to pin 1 of the TL494 IC that regulates the PWM pulse depending upon the load condition.

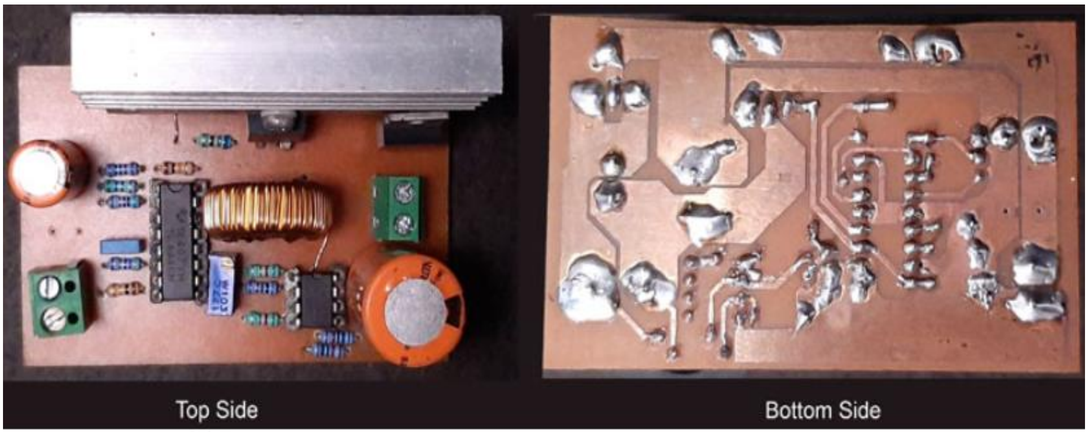
Final project and finishing procedures:

4. Finishing:

- **Cleaning**: Remove flux residues from the PCB using isopropyl alcohol or specialized cleaning solvents. This ensures long-term reliability of the assembly.
- **Visual Inspection**: Examine the completed assembly to ensure all components are properly placed, and there are no signs of damage, misplacement, or defects.
- **Testing**: Perform a functional test to ensure the converter is operating as intended. This can include verifying input and output voltage levels, checking for ripple, and ensuring the converter performs efficiently under load.

- **Heat Dissipation**: Verify that any heat sinks or thermal management components are properly installed, and that the device is running within safe temperature limits.





Buck boost converter assembling complexity and application basing on other types of converters (Buck converter and Boost converter):

Key Points of Comparison:

- **Complexity**:

✓ **Buck** converters are the simplest as they only step down the voltage, requiring fewer components and simpler control mechanisms.

✓ **Boost** converters are more complex due to the need for more sophisticated control to increase the voltage and manage higher current flows.

✓ **Buck-Boost** converters are the most complex because they need to handle both voltage stepping up and down, requiring more complex control and design considerations.

- **Applications**:

✓ **Buck** converters are widely used in low-voltage applications where the input voltage is higher than the desired output voltage, making them ideal for portable devices.

✓ **Boost** converters are used when the input voltage is lower than the required output voltage, often found in battery-operated devices or where voltage needs to be increased.

✓ **Buck-Boost** converters serve applications with varying input voltages, such as in renewable energy systems or UPS systems, where the voltage can fluctuate above or below the required output.

This comparison helps understand when and why each converter type is used based on their implementation complexity and specific applications.

Points to Remember

- **Buck-Boost** converters are the most complex because they need to handle both voltage stepping up and down, requiring more complex control and design considerations.

Application of learning 4.3

As Technician who have basic power electronics skills You have been assigned by XWXZ Tech Company the responsibility of assembling a Buck-Boost converter for a power supply that will regulate the output voltage to a stable 12V. The input voltage will vary between 9V and 18V, and the goal is to ensure that the output remains at 12V regardless of whether the input voltage is above or below 12V.

Components to be Provided for the Task:

You will be given the following components for the task. Please ensure you organize and identify them before starting the assembly process:

1. **Inductors**:

   L1: 100 µH, 1.5A

   L2: 100 µH, 1A

2. **Capacitors**:

   C1: 220 µF, 25V (Electrolytic)

C2: 100 µF, 25V (Electrolytic)

C3: 0.1 µF, 50V (Ceramic)

3. **Diodes**:

   D1: Schottky Diode, 1A, 40V (e.g., 1N5819)

   D2: Schottky Diode, 1A, 40V (e.g., 1N5819)

4. **Transistor** (Switching Device):

   MOSFET: N-channel MOSFET, 30V, 10A (e.g., IRF540N)

5. **Integrated Circuit (IC)**:

   PWM Controller IC: (e.g., LM2577, or any suitable Buck-Boost controller IC)

6. **Resistors**:

   R1: 10kΩ

   R2: 1kΩ

   R3: 100Ω

7. **PCB**: A pre-designed PCB suitable for a simple Buck-Boost converter circuit. Ensure that the PCB has all the necessary pads for the components listed above.

8. **Miscellaneous**:

   Heat sink (if needed for MOSFET or power components)

   Wires (for input/output connections)

   Soldering materials (soldering iron, solder wire, flux, etc.)

   Input Source: Variable DC power supply (9V to 18V)

   Multimeter: For measuring output voltage and performing basic checks.

Task Breakdown:

- **I**dentify all components based on the provided list and inspect them for any visible damage. Organize them in a way that allows easy access during the assembly.
- Place the components onto the PCB according to the schematic provided (or based on the PCB design if schematic is not available).
- **Action**: Use wires to make the required connections. Ensure the wires are securely attached to prevent loose connections during testing.

- Start soldering the components onto the PCB, starting with the smallest components (resistors and diodes) and moving to larger ones (capacitors, inductors, transistors).
- Carefully solder each component, ensuring that no cold solder joints or bridges are formed.
- Once all components are soldered, inspect the board for any mistakes such as misplaced components or solder bridges.
- Use a magnifying glass or microscope to inspect the PCB. Ensure that there are no shorts or poor solder joints.
- Use isopropyl alcohol and a brush to clean any flux residues left from the soldering process.

Indicative content 4.4: Testing DC TO DC Converter

Duration: 3hrs

Theoretical Activity 4.4.1: Description of DC-to-DC Converter testing methods

Tasks:

1: Answer the following questions:

i. List the method using to test DC-To-DC converter

2: Write the answers on flipchart/ paper

3: Present the findings to the trainer and whole class

4: Ask for clarification if any

5: Read the key readings 4.4.1. in the manual

Key readings 4.4.1.: Description of DC-to-DC Converter testing methods

1. The methods used to test DC To DC converter

1. Efficiency Test

Definition: This test measures the efficiency of the converter, which is the ratio of the output power to the input power. Efficiency is a key parameter, indicating how effectively the converter uses the supplied energy.

Formula:

$$\text{Efficiency}(\%) = \left(\frac{\text{Output Power}}{\text{Input Power}}\right) \times 100$$

Example:

- **Buck Converter**:
  - **Input**: 18V * 2A = 36W
  - **Output**: 12V * 2A = 24W
  - **Efficiency**: = (24W:36W)×100=66.7%
- **Boost Converter**:
  - **Input**: 5V * 1A = 5W
  - **Output**: 12V * 0.5A = 6W
  - **Efficiency**: =120% (Idealized efficiency should be less than 100%, but actual results are typically below this)
- **Buck-Boost Converter**:
  - **Input**: 9V * 1.5A = 13.5W

Output: 12V * 1A = 12W

Efficiency: =88.9%

2. Load Regulation Test

Definition: This test checks how well the converter maintains a constant output voltage as the load current varies. A good converter should have minimal voltage variation under different load conditions.

Example:

- **Buck Converter**:

  Test: Apply different loads (e.g., 1A, 2A, 3A) and measure the output voltage. The output should remain close to 12V with minimal variation.
- **Boost Converter**:

  Test: Gradually increase the load from 0.5A to 2A and ensure the output voltage remains stable at 12V.
- **Buck-Boost Converter**:

  Test: Vary the load from 1A to 3A and verify that the output voltage stays at 12V, regardless of input changes.

3. Line Regulation Test

Definition: This test measures how well the converter regulates the output voltage as the input voltage varies. The converter should ideally maintain a stable output voltage even when the input voltage changes.

Example:

- **Buck Converter**:

  Input Range: 18V to 24V

  Test: Measure the output voltage at 18V, 20V, 22V, and 24V. It should remain at 12V throughout this range, with minimal fluctuation.
- **Boost Converter**:

  Input Range: 5V to 8V

  Test: Measure the output at varying input voltages (e.g., 5V, 6V, 7V, 8V) and verify that the output voltage remains at 12V.
- **Buck-Boost Converter**:

  Input Range: 9V to 18V

  Test: Ensure the output remains at 12V while varying the input voltage between 9V and 18V.

4. Ripple & Noise Test

Definition: This test measures the amount of ripple and noise (undesired fluctuations) in the output voltage. High ripple or noise can negatively affect the performance of sensitive equipment powered by the converter.

Example:

- **Buck Converter**:

  Test: Use an oscilloscope to measure the output voltage. The ripple should be small, typically in the range of 20mV to 100mV for most converters.

- **Boost Converter**:
  Test: Measure the output voltage with an oscilloscope. Boost converters can sometimes produce higher ripple, so it's essential to verify that it's within acceptable limits.
- **Buck-Boost Converter**:
  Test: Measure the ripple and noise at different input voltages and loads. The ripple should be low and within the specified limits (e.g., 50mV peak-to-peak).

5. Thermal Test

Definition: This test checks the operating temperature of the converter, ensuring that components like the MOSFET, inductor, and capacitors do not overheat during operation.

Example:

- **Buck Converter**:
  Test: Operate the converter under full load (e.g., 3A) for an extended period and measure the temperature of the MOSFET and inductor. Ensure the temperature does not exceed the maximum rated value (e.g., 125°C for the MOSFET).
- **Boost Converter**:
  Test: After running the converter under full load (e.g., 2A), measure the temperature of key components. If it exceeds safe operating limits (e.g., 100°C), the design might need to be modified.
- **Buck-Boost Converter**:
  Test: Monitor the temperature of the inductor and switching components during operation to ensure safe thermal performance under varying load conditions.

6. Transient Response Test

Definition: This test checks how quickly the converter responds to sudden changes in load. A fast transient response is necessary for stable voltage regulation.

Example:

- **Buck Converter**:
  Test: Apply a sudden step change in load (e.g., from 1A to 2A) and observe the response of the output voltage. It should return to the nominal voltage (12V) within a short time (e.g., less than 100ms).
- **Boost Converter**:
  Test: Increase the load suddenly from 0.5A to 1A and measure how quickly the converter stabilizes the output voltage at 12V.
- **Buck-Boost Converter**:
  Test: Change the load from 1A to 2A and verify that the converter quickly

stabilizes at 12V without significant overshoot or undershoot.

7. Short-Circuit Protection Test

Definition: This test checks if the converter has built-in protection mechanisms to prevent damage when a short circuit occurs at the output.

Example:

- **Buck Converter**:
  Test: Short the output terminals and observe the converter's response. It should either shut down or enter a current-limiting mode to prevent damage.
- **Boost Converter**:
  Test: Short the output and verify that the converter either limits the current or shuts down to protect the components.
- **Buck-Boost Converter**:
  Test: Apply a short circuit to the output and ensure the converter either limits the current or shuts down safely.

8. Overvoltage and Undervoltage Protection Test

Definition: This test checks whether the converter has protection mechanisms to shut down or reduce power when the output voltage exceeds or falls below a set threshold.

Example:

- **Buck Converter**:
  Test: Increase the input voltage above the rated limit (e.g., 15V to 18V) and ensure the output voltage does not exceed a safe value, such as 12V.
- **Boost Converter**:
  Test: Reduce the input voltage below the rated minimum (e.g., 3V) and verify that the output does not drop below the minimum output voltage (e.g., 12V).
- **Buck-Boost Converter**:
  Test: Apply an input voltage too high (e.g., 20V) or too low (e.g., 8V) and ensure that the converter maintains a stable output at 12V, or shuts down when the protection limits are reached.

9. Start-Up and Shut-Down Test

Definition: This test verifies that the converter starts up and shuts down smoothly without causing any damage or producing excessive voltage spikes.

Example:

- **Buck Converter**:
  Test: Power on the converter and observe the startup behavior. It should smoothly ramp to the output voltage (12V). Similarly, when powering down, the output should gradually reduce to 0V.
- **Boost Converter**:

Test: Power the converter on and off, observing if the output voltage ramps up to 12V without overshoot. Shutdown should be smooth without damaging the circuit.

- **Buck-Boost Converter**:

  Test: Observe the startup and shutdown behavior. The converter should smoothly reach 12V from both high and low input voltage conditions.

10. Isolation Test (for Isolated Converters)

Definition: This test checks whether the converter provides electrical isolation between input and output (common in isolated DC-DC converters). It ensures that the isolated converter prevents any unwanted current flow between the two sides.

Example:

- **Isolated Converter**:

  Test: Measure the isolation between the input and output. It should be at a high voltage (e.g., >1000V) with no electrical continuity. A high-voltage insulation tester (megohmmeter) can be used to confirm proper isolation

Practical Activity 4.4.2: Testing DC to DC Converter.

Task:

1: Read the given task

Go to the workshop to perform the following DC-DC converter circuit test:

i. Short-Circuit Protection Test

ii. Overvoltage and Under voltage Protection Test

2: Perform the given tasks by respecting the given instructions.

3: Present your work to the trainer.

4: Read key reading 4.4.2 and ask clarification where necessary

5: Perform the task provided in application of reading 4.3.4.

Key readings 4.4.2.: Testing DC to DC Converter.

- **The common techniques used when testing DC To DC converter**

  Techniques for Testing Boost and Buck Converters

  Testing **Boost** and **Buck** converters involves verifying their operation under various conditions, ensuring they perform within expected parameters. There are several techniques to test these converters, ranging from simple measurements to more complex diagnostic methods.

  Below is an outline of common techniques used for testing converters, along with examples:

  1. Basic Voltage and Current Measurement

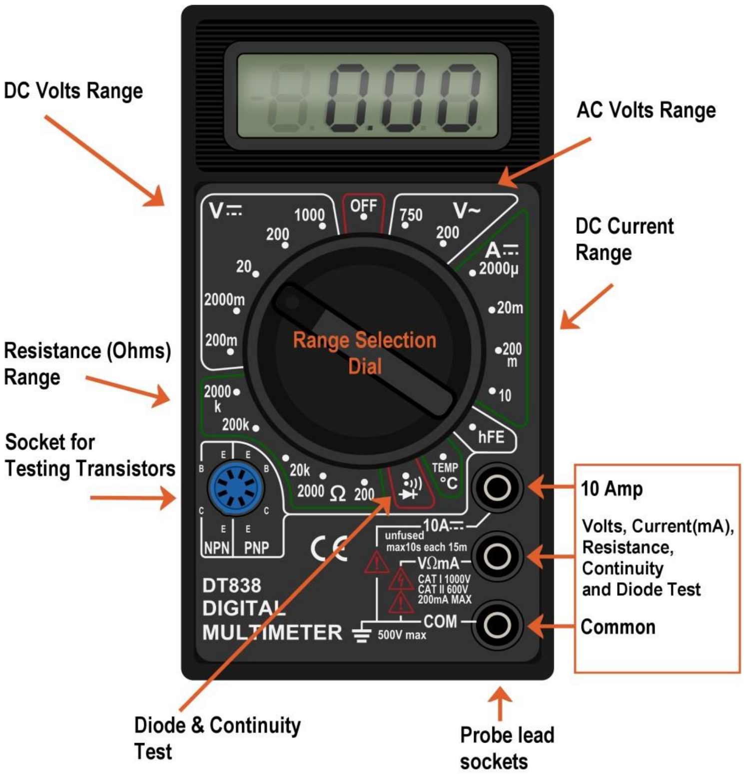
Technique: Using a **multimeter** to measure the output voltage and input/output current.

This is the most fundamental test, used to verify that the converter is providing the correct output voltage and drawing the expected input current.

- **Example**:

✓ **Buck Converter**: Apply 18V input, and measure the output voltage. The expected output should be 12V (a step-down conversion).

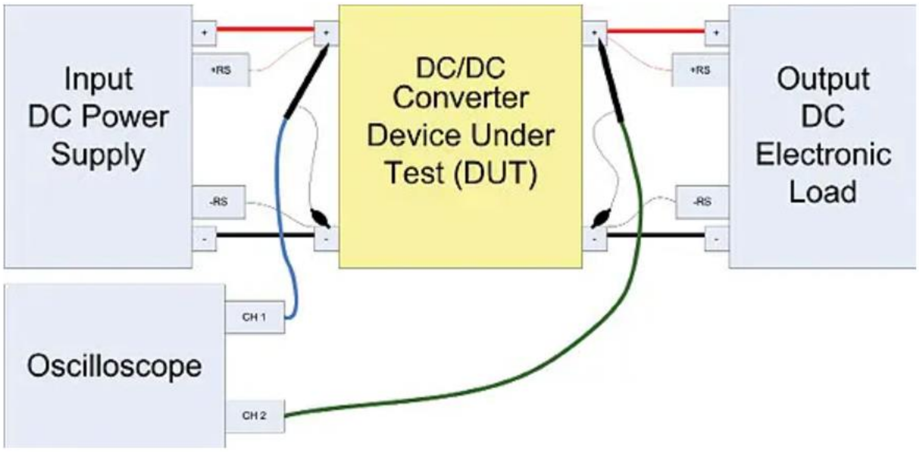
✓ **Boost Converter**: Apply 5V input, and measure the output voltage. The expected output should be 12V (a step-up conversion).



2. Output Ripple and Noise Measurement

Technique: Using an **oscilloscope** to measure voltage ripple and noise on the converter's output.

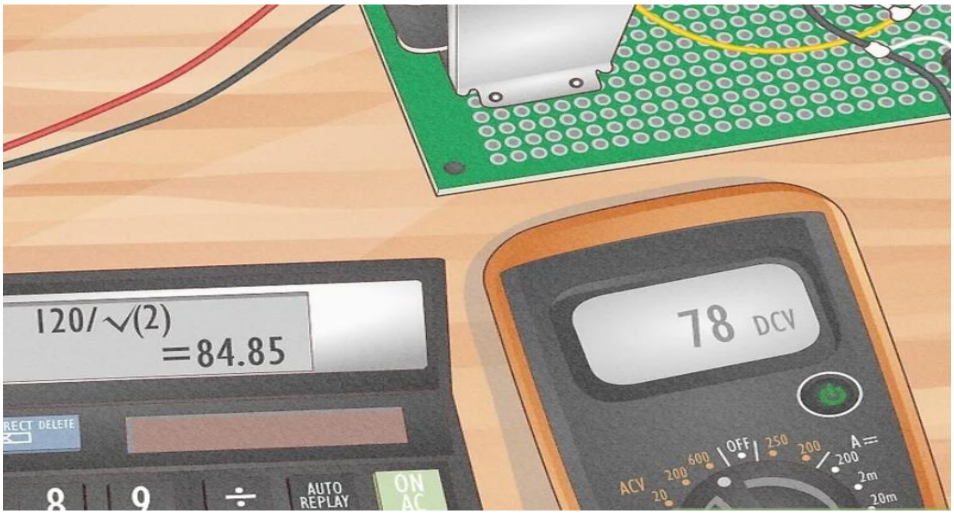
- **Purpose**: To ensure that the converter is stable and that the ripple or noise in the output voltage is within acceptable limits.



3. Efficiency Measurement

Technique: Using a **multimeter** or **power analyzer** to calculate efficiency by measuring input and output power.

- **Purpose**: To determine how efficiently the converter is converting power from input to output. Efficiency is a key indicator of performance and energy loss.



- **Example**:

o **Buck Converter**:

▪ **Input Power**: 18V * 2A = 36W

▪ **Output Power**: 12V * 2A = 24W

▪ **Efficiency**: 24W36W×100=66.7%\frac{24W}{36W} \times 100 = 66.7\%36W24W ×100=66.7%

o **Boost Converter**:

▪ **Input Power**: 5V * 2A = 10W

▪ **Output Power**: 12V * 0.833A = 10W

▪ **Efficiency**: 10W10W×100=100%\frac{10W}{10W} \times 100 = 100\%10W10W

×100=100% (ideal, though real-world efficiency would be lower due to losses).

4. Load Regulation Test

Technique: Using a **variable electronic load** and a **multimeter** or **oscilloscope** to monitor how the output voltage varies with changing load currents.

- **Purpose**: To check if the converter maintains a constant output voltage when the load current changes, ensuring good regulation.
- **Example**:
  - **Buck Converter**: Apply different loads (e.g., 1A, 2A, 3A) and measure the output voltage with a multimeter. The voltage should remain relatively constant (e.g., 12V) despite the load changes.
  - **Boost Converter**: Apply different loads (e.g., 0.5A, 1A, 1.5A) and check that the output voltage stays within the desired range (e.g., 12V).

5. Line Regulation Test

Technique: Varying the input voltage and monitoring the output voltage using a **multimeter** or **oscilloscope**.

- **Purpose**: To check if the converter can maintain a stable output voltage despite fluctuations in the input voltage.
- **Example**:
  - **Buck Converter**: Vary the input voltage from 18V to 24V and observe the output. The output should remain at the set voltage (e.g., 12V).
  - **Boost Converter**: Vary the input voltage from 5V to 8V and ensure that the output voltage remains stable at 12V.

6. Transient Response Test

Technique: Using an **oscilloscope** to observe how the converter reacts to sudden changes in load.

- **Purpose**: To evaluate how quickly the converter stabilizes its output voltage after a load transient (e.g., when the load current changes suddenly).
- **Example**:
  - **Buck Converter**: Apply a sudden load change (e.g., from 1A to 2A) and observe the output voltage on the oscilloscope. The voltage should recover quickly with minimal overshoot or undershoot.
  - **Boost Converter**: Similarly, apply a load change (e.g., from 0.5A to 1A) and observe how the converter's output responds. A good converter should have a fast and stable recovery.

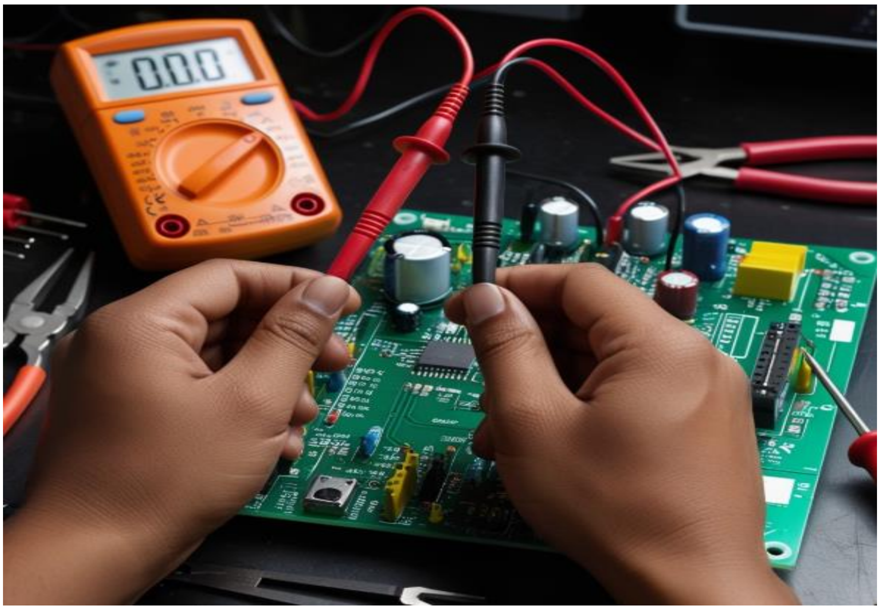
7. Short-Circuit Protection Test

Technique: Intentionally creating a **short circuit** at the output and observing the converter's response using a **multimeter** or **oscilloscope**.

- **Purpose**: To verify that the converter has short-circuit protection mechanisms, such as current limiting or shutdown, to prevent damage.
- **Example**:
  - **Buck Converter**: Short the output terminals and observe if the converter shuts down or enters current-limiting mode, preventing damage to components.
  - **Boost Converter**: Similarly, apply a short circuit at the output and ensure that the converter either limits the current or stops outputting.

8. Overvoltage and Undervoltage Protection Test

Technique: Adjusting the input voltage to extremes and monitoring the output voltage using a **multimeter** or **oscilloscope**.



- **Purpose**: To ensure that the converter can protect itself from overvoltage and undervoltage conditions by either shutting down or maintaining output within safe limits.
- **Example**:
  - **Buck Converter**: Increase the input voltage to above the rated value (e.g., 30V) and verify that the output does not exceed the rated output (e.g., 12V).
  - **Boost Converter**: Reduce the input voltage to below the rated value (e.g., 3V) and ensure that the output voltage does not drop below the desired level (e.g., 12V).

9. Thermal Testing

Technique: Thermocouples or temperature sensors can be used along with thermal paste. This method provides accurate point measurements. For devices with active cooling (e.g., fans or heat sinks), you can perform thermal testing by monitoring the cooling performance.

- **Purpose**: To ensure that the converter does not overheat during normal operation, which could lead to component failure.
- **Example**:
  - **Buck Converter**: After running the converter at full load, measure the temperature of the MOSFET and inductor. Temperatures should stay within safe operating limits (e.g., below 100°C for the MOSFET).
  - **Boost Converter**: Similarly, check that the temperature of components such as the switching transistor does not exceed the manufacturer's rated limits.

10. Start-Up and Shut-Down Testing

Technique: Monitoring the converter during **power-up** and **power-down** using a **multimeter** or **oscilloscope**.

- **Purpose**: To verify that the converter starts and shuts down smoothly, without causing large voltage spikes or transients that could damage connected equipment.
- **Example**:
  - **Buck Converter**: Power up the converter and observe the output voltage. It should smoothly ramp up to the expected output (e.g., 12V) without overshoot.

Boost Converter: Similarly, observe the voltage during start-up and shutdown. The output voltage should ramp smoothly to 12V without spikes.

Solutions on DC to DC converter 's faults and its symptoms

DC-to-DC converters are used to step up or step down DC voltage levels, providing a stable DC output despite fluctuations in input voltage or load. However, these converters are prone to certain faults. Below is a list of common faults in DC-to-DC converters, along with their symptoms, causes, and solutions.

1. No Output Voltage

Fault: The converter does not produce any output voltage.

Causes:

- Blown fuse or circuit protection triggered.
- Faulty switching components (e.g., MOSFET, IGBT).
- Open circuit in the power path or control circuitry.
- Input voltage too low or unstable.
- Failed feedback or control loop circuit.

Symptoms:

- Output voltage is 0V or fluctuates erratically.
- No LED indicators or error codes on the converter.

Solution:

- Check for blown fuses or tripped protection circuits and replace them.
- Test and replace faulty switching components like MOSFETs or diodes.
- Verify input voltage levels are within the specified range.
- Inspect and repair the feedback control loop or replace damaged feedback components.

2. Low or Reduced Output Voltage

Fault: The converter outputs a voltage that is lower than expected.

Causes:

- Input voltage is lower than required.
- Overloading or excessive current draw from the output.
- Faulty feedback loop or incorrect voltage reference.
- Insufficient filtering or a faulty output capacitor.
- Worn-out or damaged components like diodes or inductors.

Symptoms:

- Output voltage is below the expected or specified level.
- Devices powered by the converter fail to operate correctly.

Solution:

- Ensure the input voltage is within the specified range.
- Check for excessive load on the output and ensure the converter is not overloaded.
- Inspect the feedback circuitry and voltage reference components.
- Replace any damaged capacitors, diodes, or inductors in the power stage.
- Verify the converter's configuration and make necessary adjustments to maintain proper output voltage.

3. High Output Ripple or Noise

Fault: The output voltage exhibits excessive ripple or high-frequency noise.

Causes:

- Insufficient filtering (capacitors or inductors).
- Faulty or degraded output filter capacitors.
- Switching frequency interference or issues with the PWM controller.
- Poor layout design or inadequate grounding.

Symptoms:

- Fluctuating or noisy output voltage waveform.
- Devices powered by the converter experience malfunction, noise, or instability.

Solution:

- Check and replace the output filter capacitors or inductors.
- Increase filtering by adding additional capacitors at the output.
- Verify that the PWM controller is working correctly and producing a stable switching frequency.
- Improve the PCB layout, ensure proper grounding, and minimize parasitic inductance or capacitance.

4. Overheating

Fault: The converter heats up excessively or shuts down due to thermal overload.

Causes:

- Poor ventilation or insufficient cooling.
- Overloading or excessive current draw.
- Inadequate heat dissipation from heat sinks or components.
- High ambient temperatures affecting thermal performance.

Symptoms:

- The converter becomes very hot to the touch.
- The converter may shut down intermittently or fail to operate at all.

Solution:

- Ensure the converter has adequate cooling and ventilation (e.g., by adding heatsinks or fans).
- Reduce the load on the converter or switch to a higher-rated unit if the current demand exceeds the converter's specification.
- Clean dust from the converter's vents and ensure no obstructions.
- Ensure the operating environment temperature is within the specified range.

5. Input Under Voltage Protection

Fault: The converter stops working because the input voltage falls below the specified minimum.

Causes:

- Low or unstable input voltage.
- Poor connection or wiring in the input power source.
- Faulty or damaged input filter components.
- Discharged battery in battery-powered systems.

Symptoms:

- Converter fails to turn on or outputs zero voltage.
- Error code or under-voltage indication on the display or status LEDs.

Solution:

- Verify the input voltage is within the specified range for the converter.
- Inspect the input power source for stability and sufficient voltage.
- Check input wiring and connectors for loose connections or faults.
- Replace or charge the battery if used, ensuring it's within the acceptable voltage

range.

6. Overcurrent Protection (OCP) Triggered

Fault: The converter enters protection mode due to an overcurrent condition.

Causes:

- Excessive load or short circuit on the output.
- Faulty or damaged power stage components (e.g., inductors, transistors).
- Poor thermal management leading to excessive current draw.

Symptoms:

- The converter shuts down or enters protection mode when a load is applied.
- The output voltage drops or becomes unstable under load.

Solution:

- Reduce the load to prevent overcurrent conditions.
- Inspect the power stage for damaged components such as MOSFETs, diodes, or inductors.
- Check for short circuits in the output wiring or connected devices.
- Improve cooling or ventilation to avoid thermal overloads.
- Verify that the converter is correctly sized for the load demand.

7. Converter Oscillations or Instability

Fault: The converter shows unstable behavior, such as oscillations or erratic output voltage.

Causes:

- Incorrectly set feedback or control loop parameters.
- Faulty or degraded feedback components (e.g., resistors, capacitors).
- Poor layout design causing parasitic inductance or capacitance.
- External noise or electromagnetic interference (EMI).

Symptoms:

- Output voltage fluctuates, spikes, or oscillates unpredictably.
- Devices powered by the converter malfunction or experience flickering.

Solution:

- Check and adjust the feedback loop for stability, including compensator settings.
- Replace any faulty components in the feedback network.
- Optimize the PCB layout to reduce parasitic inductance and capacitance.
- Add external filtering (e.g., ferrite beads, capacitors) to mitigate EMI and reduce noise.

8. Converter Keeps Shutting Down (Protection Mode)

Fault: The converter repeatedly enters protection mode and shuts down.

Causes:

- Overvoltage or overtemperature conditions.
- Short circuit or open circuit in the output load.

- Internal fault in the power or control circuitry.
- Insufficient input voltage or poor-quality power supply.

Symptoms:

- The converter shuts down repeatedly or enters a reset state.
- The status LED shows a fault condition or error code.

Solution:

- Inspect for overvoltage or overtemperature conditions and ensure proper cooling.
- Check for short circuits or open circuits in the output path.
- Test internal components for damage and replace faulty parts.
- Ensure the input voltage is stable and within the required range.

9. Poor Efficiency or Power Loss

Fault: The converter has low efficiency, resulting in unnecessary power loss.

Causes:

- Faulty or inefficient switching components (e.g., MOSFETs, diodes).
- High switching losses due to poor design or inadequate components.
- Insufficient input or output filtering.

Symptoms:

- Excessive heat generation.
- Lower than expected output power or efficiency.

Solution:

- Replace worn-out or inefficient switching components (MOSFETs, diodes).
- Improve filtering by adding or upgrading input/output capacitors and inductors.
- Optimize switching frequency to minimize losses.
- Use components with lower conduction losses and higher efficiency ratings.

Points to Remember

- **Efficiency Test**

  Definition: This test measures the efficiency of the converter, which is the ratio of the output power to the input power. Efficiency is a key parameter, indicating how effectively the converter uses the supplied energy.

  Short-Circuit Protection Test

- **Definition:** This test checks if the converter has built-in protection mechanisms to prevent damage when a short circuit occurs at the output.
- **Basic Voltage and Current Measurement technique**:

  Using a **multimeter** to measure the output voltage and input/output current.

  This is the most fundamental test, used to verify that the converter is providing the correct output voltage and drawing the expected input current.

Application of learning 4.4.

Electronics maintenance and services (E.M.S) Company hired You to solve clients complains just you should test a **Buck Converter** used in a power supply application for a consumer electronics device. The converter is experiencing **voltage fluctuations**, and the device is being sent for troubleshooting. Your task is to perform various tests to identify any underlying problems and ensure that the converter is working within its specifications. You will be responsible for performing **voltage**, **current**, **load**, and **thermal testing**.

- **Required Tools**:
    - Multimeter (for voltage and current measurement)
    - Oscilloscope (for observing voltage fluctuations and ripple)
    - Electronic Load (to simulate different load conditions)
    - Infrared Thermometer or Thermal Camera (for thermal testing)
    - Power Supply (for input to the buck converter)
    - Notebook/Documentation (for recording results)

The task are mentioned below:

i. Measure the output voltage of the buck converter and check for voltage fluctuations.
   a. Check for excessive ripple or voltage spikes.

ii. Record the results, noting if there are any noticeable fluctuations or deviations from the nominal value.

iii. Measure the current drawn by the converter at different load conditions and verify it is within the expected range.

iv. Monitor the output voltage while varying the load to check for **voltage sag** or irregularities.

v. Check for excessive heating of the converter components, which could indicate problems such as inefficient power conversion or poor heat dissipation.

Learning outcome 4 end assessment

Theoretical assessment

I. CHOOSE THE CORRECT ANSWER

1. Which of the following is a primary component of a buck converter?

A) Capacitor

B) Inductor

C) Diode

D) All of the above

2. Which of the following is NOT a typical part of the assembly process for a buck or boost converter?

A) Component placement

B) Wiring and soldering

C) Enclosure design

D) Testing and troubleshooting

3. What is the main function of an inductor in a buck converter?

A) To provide smooth output voltage

B) To store energy and regulate current

C) To filter the input voltage

D) To convert AC to DC

4. What does the Efficiency Test for a converter measure?

A) The amount of power converted to heat

B) The ability of the converter to maintain stable voltage

C) The amount of energy input versus output

D) The ripple in the output signal

5. Which instrument is typically used to measure voltage ripple in a buck or boost converter?

A) Oscilloscope

B) Multimeter

C) Thermal Camera

D) Wattmeter

6. When assembling a boost converter, which of the following is the last step before testing the circuit?

A) Place the inductor

B) Solder the components onto the PCB

C) Apply the input voltage

D) Place the output capacitor

7. What type of diagram is used to represent the behavior of components such as transistors, resistors, and capacitors in a buck or boost converter circuit?

A) Block Diagram
B) Circuit Schematic
C) Timing Diagram
D) Functional Diagram

8. In a Thermal Test, which of the following is most commonly measured?

A) Output voltage ripple
B) Component temperatures
C) Frequency response
D) Input current fluctuations

9. Which of the following diagrams is most useful to understand how components are connected together in a circuit?

A) Block Diagram
B) Schematic Diagram
C) Timing Diagram
D) Component Layout Diagram

10. Which of the following components is responsible for the energy storage and regulation in both buck and boost converters?

A) Capacitor
B) Inductor
C) Diode
D) Transistor

II. Answer the following questions by **True or False**

1. Buck converters step up the input voltage to a higher output voltage.
2. Boost converters step down the input voltage to a lower output voltage.
3. Both buck and boost converters use inductors as a key component for energy storage.
4. The primary difference between a buck converter and a boost converter is that a buck converter increases the input voltage, while a boost converter decreases it.
5. In a buck converter, the output voltage is always higher than the input voltage.
6. A common method used to test the efficiency of a converter is the Efficiency Test, where the input power and output power are compared.
7. During thermal testing, excessive heating of components can be a sign of poor design or inefficient energy conversion.
8. In the assembly process of a buck converter, the first step is to place large components like capacitors and inductors before small components like ICs.
9. Soldering is a key part of assembling a buck or boost converter to connect the components to the PCB.
10. An oscilloscope is primarily used for measuring the resistance of components in a buck or boost converter circuit.
11. When assembling a buck converter, the circuit is usually tested before soldering any components onto the PCB.

12. A boost converter can operate without an inductor because it relies solely on capacitors to store energy.
13. In a buck converter, the output voltage remains constant regardless of changes in input voltage.
14. In a boost converter, the primary role of the diode is to allow current to flow when the switch is off, preventing backflow of current.

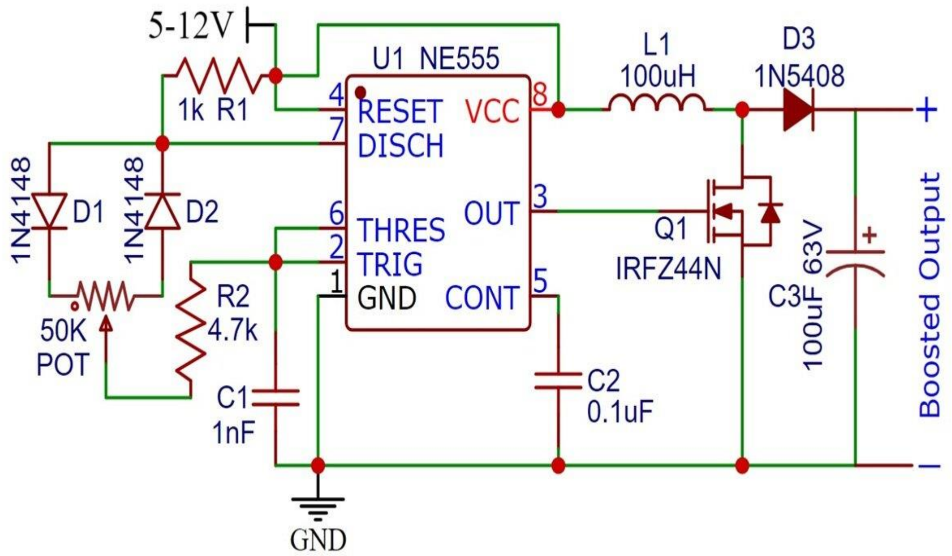
III. Match the following Testing Techniques in column A with relative Description in Column B

Column A	Column B
1. Efficiency Test 2. Load Regulation Test 3. Ripple & Noise Test 4. Thermal Test 5. Short-Circuit Protection Test 6. Transient Response Test 7. Line Regulation Test 8. Start-Up and Shut-Down Test 9. Overvoltage and Undervoltage Protection Test 10. Isolation Test	A) Measures how quickly the converter adjusts to sudden changes in load without significant voltage fluctuations. B) Ensures that the converter can handle fluctuations in input voltage and maintain a stable output. C) Measures the ability of the converter to start and shut down without causing excessive voltage spikes or damage. D) Measures how much power is lost in the form of heat compared to the total power supplied by the converter. E) Ensures that the converter shuts down or regulates the output if the voltage exceeds or falls below certain levels. F) Assesses the converter’s response to a short-circuit condition and ensures that the converter safely limits current. G) Measures the temperature of components and identifies potential overheating issues during operation. H) Tests for unwanted high-frequency noise or ripple in the output voltage of the converter. I) Tests whether the output voltage remains stable under varying load conditions. J) Ensures that the converter provides electrical isolation between the input and output circuits for safety.

Practical assessment

Power Tech Solutions (PTS)Ltd is a leading provider of advanced power electronics solutions. It specialized in designing and manufacturing efficient power conversion products for various industrial, automotive, and consumer electronics applications. The company is looking for a Skilled Technician to join its team in the assembly, testing, and validation of power conversion circuits, specifically boost converters, to support our growing product lines.

- **Job Role**:
  As a technician, you will be responsible for:
- ✓ drawing circuit's block diagram,
- ✓ assembling components onto printed circuit boards (PCBs),
- ✓ testing the implemented circuits, and
- ✓ generating comprehensive reports/documents on the performance of the boost converter.
- ✓ The circuit diagram chosen by the company is shown below you should write your request list of components basing on it.



- **Soft Skills needed**:
  - ✓ Attention to detail and ability to troubleshoot complex circuits.
  - ✓ Good documentation skills to prepare accurate and detailed reports.
  - ✓ Ability to work independently as well as in a team.

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