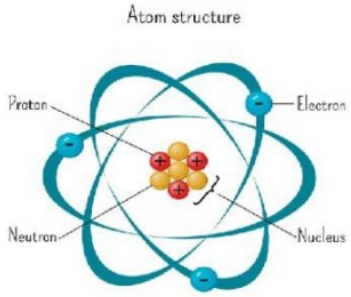
WEEK 3 – SESSION 1

BASIC ELECTRONICS

Electricity

Electricity is a form of energy involving the flow of electrons. All matter is made up of atoms, which has a centre called a nucleus. The nucleus contains positively charged particles called protons and uncharged particles neutrons. The nucleus of an atom is surrounded by negatively charged particles called electrons. The negative charge of an electron is equal to the positive charge of a proton and the number of electron in an atom is equal to the number of protons.



When the balancing force between protons and electrons is upset by an outside force, an atom may gain or lose electron. When electrons are lost from an atom, the free movements of these electrons constitutes an electric current.

Electricity is defined as a set of phenomena caused by the existence, interaction, and motion of electric charges.

Electrical quantities-voltage, current and resistance:

Voltage:

Voltage can be described as a force that generates the flow of electrons through a circuit. it is the difference in the electric potential between two points. It is the work done in moving a charge from one pole to another through a wire.

The SI unit of voltage is Volts (V).

Current:

Electric Current is the rate of flow of electrons in a conductor.

The SI Unit of electric current is the Ampere

Resistance:

Resistance is the opposition that a substance offers to the flow of electric current.

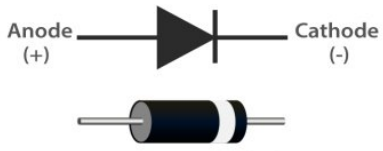
The SI unit of Resistance is Ohms (Ω).

Active components:

Active electronic components are those that can control the flow of electricity. Active components are those components which generates or supply energy to the circuit in some form.

Diodes:

A diode is a two-terminal electronic component that conducts electricity primarily in one direction. It has high resistance on one end and low resistance on the other end.



Types of Diodes

1. Light Emitting Diode
2. Laser diode
3. Avalanche diode
4. Zener diode
5. Schottky diode
6. Photodiode
7. PN junction diode

P-N Junction Diode

The P-N junction diode is also known as rectifier diodes. These diodes are used for the rectification process and are made up of semiconductor material. The P-N junction diode includes two layers of semiconductors. One layer of the semiconductor material is doped with P-type material and the other layer with N-type material. The combination of these both P and N-type layers form a junction known as the P-N junction. Hence, the name P-N junction diode.

P-N junction diode allows the current to flow in the forward direction and blocks the flow of current in the reverse direction.

In case of a p-n junction there are two bias conditions. Such as:

1. Forward biasing
2. Reverse biasing

Forward Biasing of p-n Junction Diode

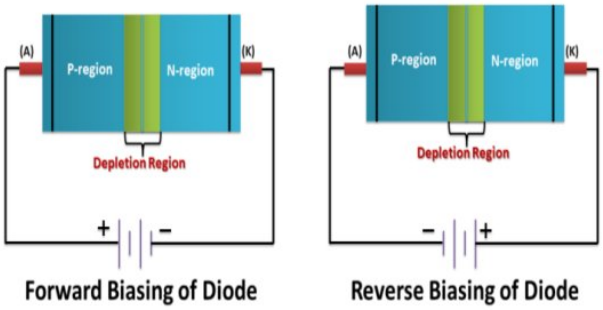
A p-n junction is said to be forward biased when the external DC voltage applied in such a direction that it cancels the potential barrier, hence, permitting the current flow.

In order to forward bias a p-n junction, the positive terminal of the battery is connected to the p-type and negative terminal of the battery is connected to the n-type as shown in the figure below.

Reverse Biasing of p-n Junction Diode

A pn junction is said to be reverse biased when the external DC voltage applied to the junction is in such a direction that it increases the potential barrier.

In order to reverse bias a pn junction, the negative terminal of the battery is connected to the p-type and positive terminal is connected to the n-type

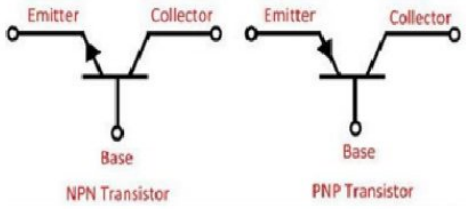


WEEK 3 – SESSION 2

Transistors

The transistor is a semiconductor device which transfers a weak signal from low resistance circuit to high resistance circuit. The words **trans** mean **transfer property** and **istor** mean **resistance property offered to the junctions.** In other words, it is a switching device which regulates and amplifies the electrical signal likes voltage or current

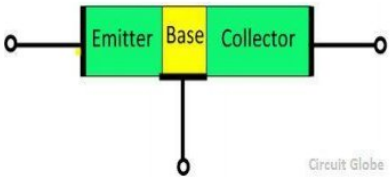
Transistor Symbols are shown below.



There are two types of transistor, namely NPN transistor and PNP transistor. The transistor which has two blocks of n-type semiconductor material and one block of P-type semiconductor material is known as NPN transistor. Similarly, if the material has one layer of N-type material and two layers of P-type material then it is called PNP transistor.

Transistor Terminals

The transistor has three terminals namely, emitter, collector and base. The terminals of the diode are explained below in details.



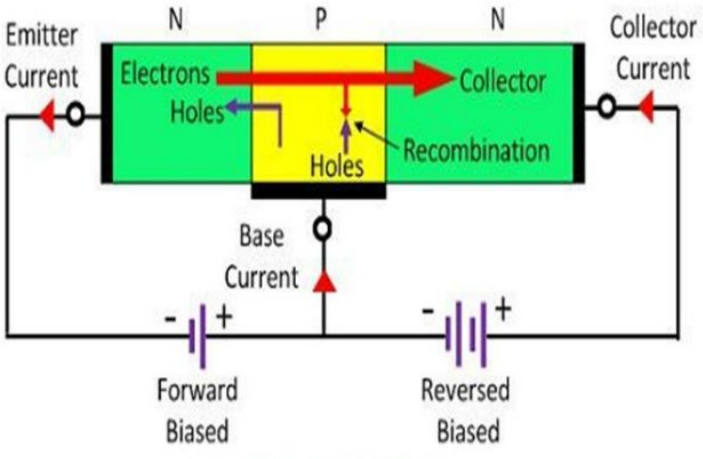
Emitter – The section that supplies the large section of majority charge carrier is called emitter. The emitter is always connected in forward biased with respect to the base so that it supplies the majority charge carrier to the base.

Collector – The section which collects the major portion of the majority charge carrier supplied by the emitter is called a collector. The collector-base junction is always in reverse bias. Its main function is to remove the majority charges from its junction with the base.

Base – The middle section of the transistor is known as the base. The base forms two circuits, the input circuit with the emitter and the output circuit with the collector. The emitter-base circuit is in forward biased and offered the low resistance to the circuit. The collector-base junction is in reverse bias and offers the higher resistance to the circuit. The base of the transistor is lightly doped and very thin due to which it offers the majority charge carrier to the base

Working of Transistor

Usually, silicon is used for making the transistor because of their high voltage rating, greater current and less temperature sensitivity. The emitter-base section kept in forward biased constitutes the base current which flows through the base region. The magnitude of the base current is very small. The base current causes the electrons to move into the collector region or create a hole in the base region.



The base of the transistor is very thin and lightly doped because of which it has less number of electrons as compared to the emitter. The few electrons of the emitter are combined with the hole of the base region and the remaining electrons are moved towards the collector region and

constitute the collector current. Thus we can say that the large collector current is obtained by varying the base region.

Bipolar Junction Transistor (BJT)

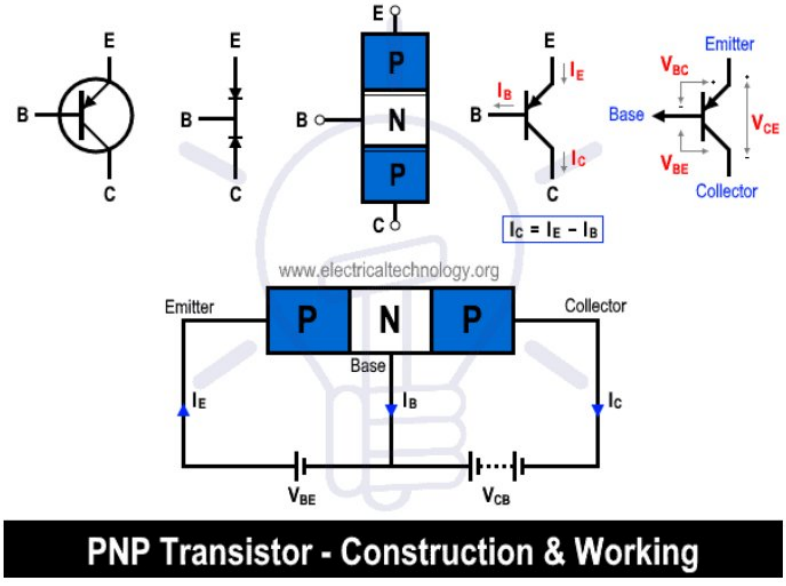
A bipolar junction transistor is a three-terminal semiconductor device that consists of two p-n junctions which are able to amplify or magnify a signal. It is a current controlled device. The three terminals of the BJT are the base, the collector, and the emitter. A signal of small amplitude applied to the base is available in the amplified form at the collector of the transistor. This is the amplification provided by the BJT. Note that it does require an external source of DC power supply to carry out the amplification process.

Types of BJT

This three-layer device formed by back to back connection has specific names. It can be weather **PNP** or **NPN**. Both connections are disused here briefly.

PNP Construction

In PNP bipolar transistor, the N-type semiconductor is sandwiched between two P-type semiconductors. PNP transistors can be formed by connecting cathodes of two diodes. The cathodes of the diodes are connected together at a common point known as **base**. While the anodes of the diodes that are on the opposite sides are known as the **collector** and the **emitter**.

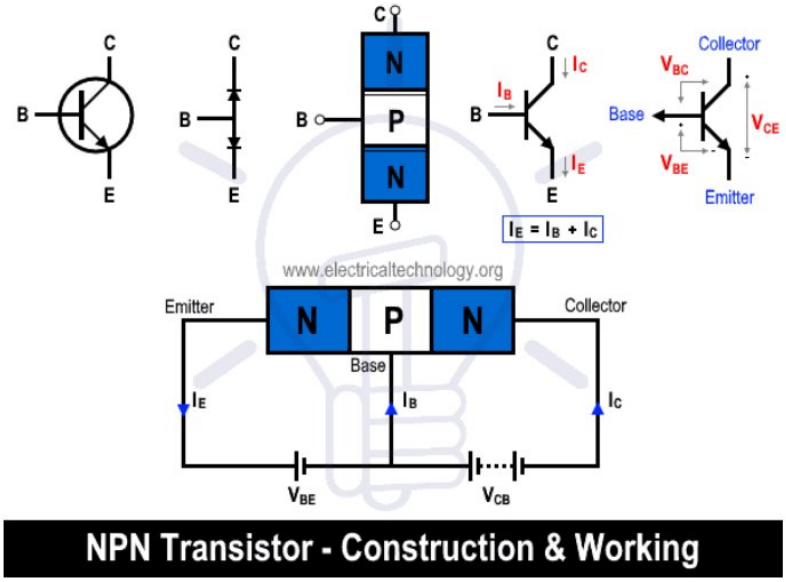


PNP Transistor - Construction & Working

The emitter-base junction is forward bias while collector-base junction is reverse bias. So, in PNP type current flows from emitter to collector. The emitter, in this case, is at high potential to both collector and base.

NPN Construction

NPN type is exactly opposite to PNP type. In NPN bipolar transistor, the P-type semiconductor is sandwiched between two N-type semiconductors. When the anodes of two diodes are connected together it forms an NPN transistor. The current will flow from the collector to emitter because the collector terminal is more positive than emitter in NPN connection.

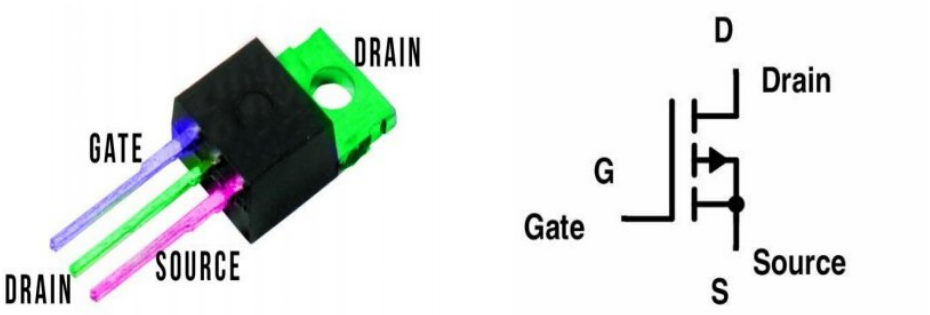


The difference between PNP and NPN symbol is the arrow mark at the emitter which shows the direction of flow of current. The current will either flow from emitter to collector or from collector to emitter. The arrow mark in PNP transistor is inward, which shows the flow of current from emitter to collector. In case of NPN collector, the arrow mark is outward; this shows the flow of current from collector to emitter.

MOSFET

Metal Oxide Silicon Field Effect Transistors commonly known as MOSFETs are electronic devices used to switch or amplify voltages in circuits. It is a voltage controlled device and is constructed by three terminals. The terminals of MOSFET are named as follows:

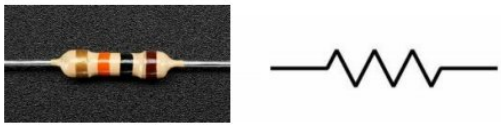
- Source
- Gate
- Drain



Passive components

Resistors:

A resistor is a primary type of physical component that opposes the flow of current. The amount of that oppose is called its resistance, which is measured in ohms.



Capacitors

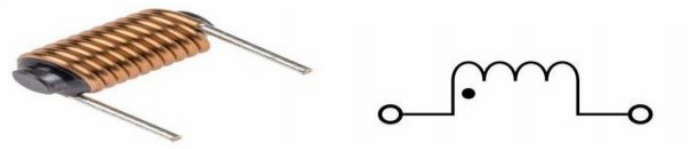
The capacitor is a component which has the ability or capacity to store energy in the form of an electrical charge.

A unit of capacitance is farad.

Inductors:

An inductor is a component in an electrical circuit which stores energy in its magnetic field.

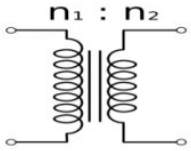
Units of inductance is Henry.



Transformers:

A transformer is defined as a passive electrical device that transfers electrical energy from one circuit to another through the process of electromagnetic induction. It is used to increase or decrease voltage levels between circuits.

A transformer can be represented as below.



Where, n1-number of turns in primary and n2- number of turns in secondary.

The three main parts of transformer are:

Primary winding of transformer:

This produces magnetic flux when it is connected to an electrical source.

Magnetic core of transformer:

The magnetic flux produced by the primary winding, that will pass through this low reluctance path linked with secondary winding and create a closed magnetic circuit.

Secondary winding of transformer:

The flux produced by primary winding passes through the core, will link with the secondary winding. This winding also wounds on the same core and gives the desired output of the transformer.

Sensors:

A sensor is a device that detects the change in the environment and responds to some output on the other system.

Transducers:

A transducer is an electronic device that converts energy from one form to another. The process of converting energy from one source to another is known as transducer.

Some examples of transducers are loudspeakers, microphones, LEDs, etc..

WEEK 3 – SESSION 3

Integrated circuits digital electronics

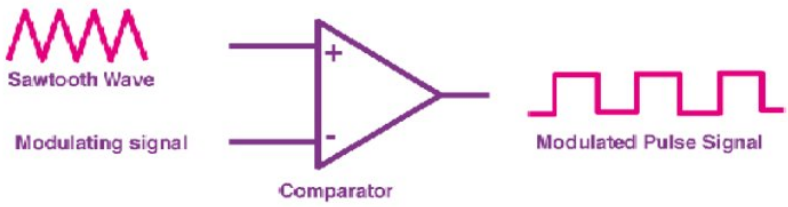
If multiple electronic components are interconnected on a single chip of semiconductor material, then that chip is called integrated circuit(IC).

PWM

Pulse width modulation reduces the average power delivered by an electrical signal by converting the signal into discrete parts. In the PWM technique, the signal's energy is distributed through a series of pulses rather than a continuously varying (analogue) signal.

How is a Pulse Width Modulation Signal generated?

A pulse width modulating signal is generated using a comparator. The modulating signal forms one part of the input to the comparator, while the non-sinusoidal wave or saw tooth wave forms the other part of the input. The comparator compares two signals and generates a PWM signal as its output waveform.



If the saw tooth signal is more than the modulating signal, then the output signal is in a "High" state. The value of the magnitude determines the comparator output which defines the width of the pulse generated at the output.

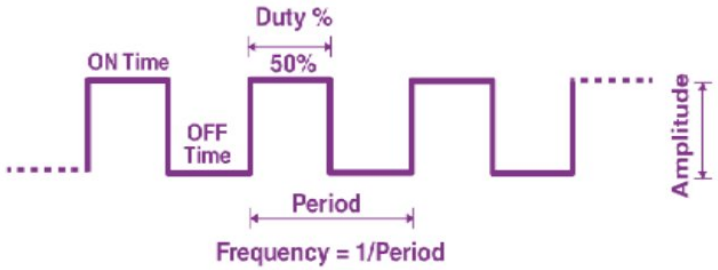
Duty Cycle of PWM

As we know, a PWM signal stays "*ON*" for a given time and stays "*OFF*" for a certain time. The percentage of time for which the signal remains "*ON*" is known as the duty cycle. If the signal is always "*ON,*" then the signal must have a 100 % duty cycle. The formula to calculate the duty cycle is given as follows:

Duty Cycle = Turn on Time + Turn off Time

The average value of the voltage depends on the duty cycle. As a result, the average value can be varied by controlling the width of the "ON" of a pulse.

Frequency of PWM



The frequency of PWM determines how fast a PWM completes a period. The frequency of a pulse is shown in the figure above.

The frequency of PWM can be calculated as follows:

Frequency = 1/Time Period
Time Period = On Time + OFF time

Applications of Pulse Width Modulation

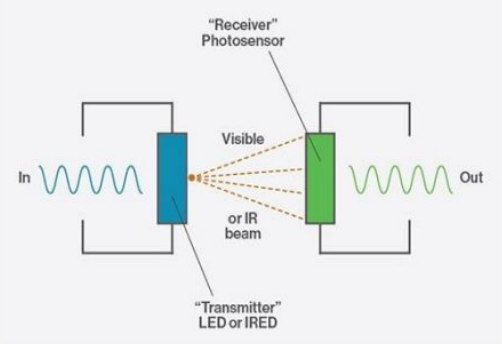
Due to the high efficiency, low power loss, and the PWM technique's ability to precisely control the power, the technique is used in a variety of power applications. Some of the applications of PWM are as follows:

- The pulse width modulation technique is used in telecommunication for encoding purposes.
- The PWM helps in voltage regulation and therefore is used to control the speed of motors.
- The PWM technique controls the fan inside a CPU of the computer, thereby successfully dissipating the heat.
- PWM is used in Audio/Video Amplifiers

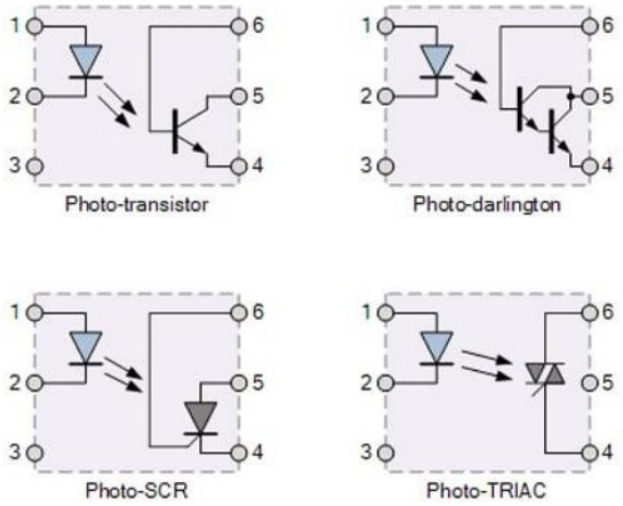
Optocoupler

An **optocoupler** (also called optoisolator) is a semiconductor device that allows an electrical signal to be transmitted between two isolated circuits. Two parts are used in an optocoupler: an **LED that emits infrared light** and a photosensitive device that detects light from the LED. Both parts are contained within a black box with pins for connectivity. The input circuit takes the incoming signal, whether the signal is AC or DC, and uses the signal to turn on the LED.

The photosensor is the output circuit that detects the light and depending on the type of output circuit, the output will be AC or DC. Current is first applied to the optocoupler, making the LED emit an infrared light proportional to the current going through the device. When the light hits the photosensor a current is conducted, and it is switched on. When the current flowing through the LED is interrupted, the IR beam is cut-off, causing the photosensor to stop conducting.



There are four configurations of optocouplers, the difference being the photosensitive device used. Photo-transistor and Photo-Darlington are typically used in DC circuits, and Photo-SCR and Photo-TRIAC are used to control AC circuits. In the photo-transistor optocoupler, the transistor could either be PNP or NPN. The Darlington transistor is a two transistor pair, where one transistor controls the other transistor's base. The Darlington transistor provides high gain ability.



The term optocoupler and optoisolator are often used interchangeably, but there is a slight difference between the two. The distinguishing factor is the voltage difference expected between the input and the output. The optocoupler is used to transmit analog or digital information between circuits while maintaining electrical isolation at potentials up to 5,000 volts. An optoisolator is used to transmit analog or digital information between circuits where the potential difference is above 5,000 volts.

AC to DC Converter

The power electronics converter which is used for converting AC to DC is called as rectifier circuit.

5-Simple Steps to Convert AC to DC

1. Stepping down the Voltage Levels

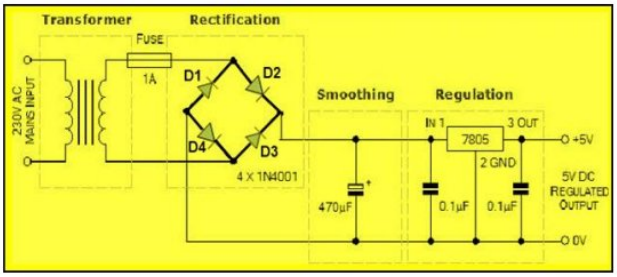
The step-up transformers are used for stepping up the voltage levels and step-down transformers are used for stepping down the voltage levels. Thus, by using a step-down transformer the available 230V AC power supply is converted into 12V AC. The output of this step-down transformer is RMS value and its peak value can be given by the product of the square root of two and RMS value, and is approximately equal to 17V.

Step-down Transformer

There are two windings in the step-down transformers, primary and secondary windings in which primary winding consists of more number of turns compared to the secondary winding (less number of turns). We know that, transformer works based on the principle of Faraday's laws of electromagnetic induction.

2. AC to DC Power Converter Circuit

Primarily, the 230V AC power is stepped-down to 12V AC (12V RMS value of which the peak value is 17V approximately), but 5V DC is the required power. So, this stepped-down output 17V AC power has to be converted into DC power and then it is to be stepped down to 5V DC. AC to DC converter namely rectifier is used for converting the 17V AC into DC and there are different types of rectifiers, such as half-wave, full-wave, and bridge rectifiers. Bridge rectifier is mostly preferred compared to the half wave, full wave, and bridge rectifiers.



AC to DC Converter Circuit

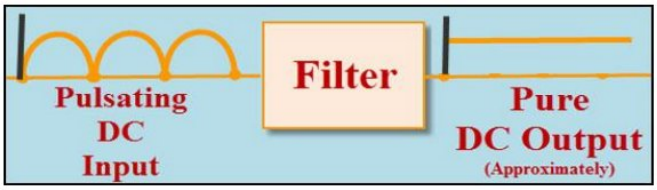
The rectifier which consists of four diodes and is connected in the form of bridge is called as a bridge rectifier. We know that, the diode conducts only in one direction (during forward bias only), remains in off state in another direction (during reverse bias). Diode generally are uncontrolled i.e., whenever the anode voltage becomes greater than the cathode, then it starts

conduction until anode voltage becomes less than the cathode. Hence, diodes are termed as uncontrolled rectifiers.

In the above circuit, during the positive half cycle of the power supply, diodes D2 & D4 conducts and during the negative half cycle of the power supply, diodes D1 & D3 conducts. Thus, the input AC power is rectified into output DC power; but DC output power consists of pulses, hence, it is termed as pulsating DC and is not pure DC. But, due to the internal resistance of the diodes a voltage drop of (2*0.7V) 1.4V occurs and thus, the peak voltage of the rectifier circuit is around 15V (17-1.4).

3. Obtaining Pure DC from Pulsating DC

The 15V DC can be regulated into 5V DC using a step-down converter, but before this, it is required to obtain pure DC power. The pure DC power can be obtained from pulsating DC using filter circuit (L-filter or C-filter or RC-coupled filter can be used to remove the ripples). The C-filter is frequently used for smoothing purposes.

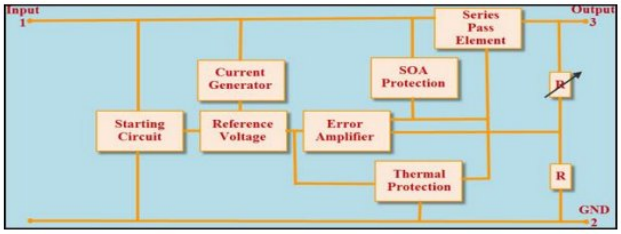


Smoothing Filter to obtain Pure DC

In the circuit, a capacitor is used to store energy while the input voltage is increasing from zero to its peak value and, energy from capacitor can be discharged while the input voltage is decreasing from its peak value to zero. Thus, the pulsating DC can be converted into pure DC using this charging and discharging process of the capacitor.

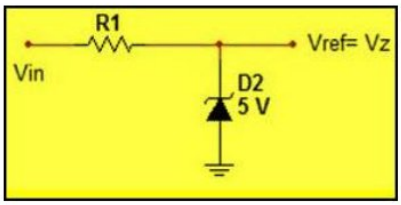
4. Regulating DC Voltage

The 15V DC output voltage can be regulated using DC voltage regulators such as IC 78XX in which the last two digits XX-represents the output voltage value. Here, let us consider the IC 7805, which is used for maintaining constant 5V DC output even though the input is varying DC voltage (7.2 to 35V DC).



IC 78XX DC Voltage Regulator Internal Diagram

The above figure represents the block diagram of IC7805 DC voltage regulator, it consists of an operating amplifier that acts as an error amplifier, zener diode which used to provide voltage reference, as shown in the below figure.



Zener Diode as Voltage Reference

The series pass element (transistor) is used to dissipate extra energy as heat and heat sink can be used for thermal protection.

5. Use a multi meter to check the DC voltage on the wires.

Turn your multi meter so the dial points at the DVC or "V-"option. Plug the leads into multi meter and hold the pins against the positive and negative sides of the capacitor filter. The reading on the display will be the DC voltage converted from the original AC supply.

References

1. Computer Hardware, Maintenance and Administration by Leelavathi Rajanna.
2. Google.com