1.INTRODUCTION

Wireless power is beginning to show great potential in the consumer market. The ability to power an electronic device without the use of wires provides a convenient solution for the users of portable devices and also gives designers the ability to develop more creative answers to problems. This technology’s benefits can be seen in the many portable devices, from cell phones to electric cars that normally operate on battery power. Inductive coupling is the method by which efficient and versatile wireless power can be achieved. For ease of use and the benefit of both designers and consumers, the Wireless Power Consortium (WPC) has developed a standard that creates interoperability between the device providing power (power transmitter, charging station) and the device receiving power (power receiver, portable device). Established in 2008, the WPC is a group of Asian, European, and American companies in diverse industries, including electronics manufacturers and original equipment manufacturers (OEMs). The WPC standard defines the type of inductive coupling (coil configuration) and the communications protocol to be used for low-power wireless devices. Any device operating under this standard will be able to pair with any other WPC-compliant device. One key benefit to this approach is that it makes use of the coils for communications between the power transmitter and the power receiver.

The area of wireless power transmission is very interesting. The technology is in its infancy but the overall benefits from its maturation could be significant to society as a whole. World population is expected to continue to grow exponentially. Five sixths of the world’s population lives in developing nations. Most developing nations such as China, India, and Pakistan are rapidly improving their standard of living. All of these trends point to an energy demand that will grow at even a larger rate. Wireless power transmission could one day allow us to generate solar power on a satellite and beam it down to Earth, transmit power to a water treatment plant for a disaster relief operation or power a flying communication relay station from a terrestrial station. There are a few engineering hurtles yet to overcome to make this technology viable to today’s investors, but with the rising demand for energy and the rapid improvements being made it is just a matter of time before wireless power transmission becomes an industry of its own.

1.1 History Of Wireless Power Transfer

The discussion of wireless power transmission as an alternative to transmission line power distribution started in the late 19th century. Both Heinrich Hertz and Nicolai Tesla theorized the possibility of wireless power transmission. Tesla demonstrated it in 1899 by powering fluorescent lamps 25 miles from the power source without using wires. Despite the novelty of Tesla's demonstration and his personal efforts to commercialize wireless power transmission, he soon ran out of funding because it was much less expensive to lay copper than to build the equipment necessary to transmit power through radio waves.

1.2 Principle Of Wireless Power Transfer

EM induction is the production of an electric current across a conductor when it moves through a magnetic field. Energy transferred by EM induction is magnetic. EM induction can be used as a means of power transmission wirelessly in WPT. Faraday's law states that a changing current in one coil creates an electromotive force (emf), which induces a current in another coil. This principle of induction is used in electric generators (mechanical to electrical energy conversion) or a motor (electrical to mechanical energy conversion) or transformers (AC to AC conversion). The important point to be noted is that the two coils (source and destination) do not need to be in contact, but can be a short distance away. Thus, EM induction is used for short distance WPT. Some examples of WPT using EM induction are recharging mats, pads, or desks that can recharge several devices kept on their surfaces, at once. EM method of WPT is used to charge devices, but can only work for small distances. Hence, WiTricity is used that increases the distance for WPT using EM induction by using resonant coupling between the source and destination coils. EM induction that is enhanced with resonance is also called WiTricity. WiTricity is a new technology for transmitting energy wirelessly via resonant coupling in the non-radiative near-field.

1.3 Need For Wireless Power Transfer

There are so many places where a power source is needed for many appliances to work, but batteries cannot be there. Examples of such situations include remote underwater locations for temperature and tide sensors, concrete reinforcements for corrosion detectors, or even inside our own body for diagnostic endoscopes, etc. In such instances, ability to deliver power wirelessly where it is needed becomes an enabler to a much larger impact from countless electrical devices. Wireless Power Transmission (WPT) is the transmission of electrical energy from a power source to an electrical load without a conductive physical connection or interconnecting wires. Transmission of power wirelessly is very different from data communication wirelessly. Radio waves are used to send and receive cell phone, TV, radio, and Wi-Fi data. The radio waves spread in all directions until they reach the antenna that is tuned to the right frequency. Spreading power in a similar way would be not only inefficient but also dangerous. Therefore, WPT is done utilizing technologies like inductive coupling. WPT is increasingly being used to make everyday products like cell phones, laptop computers, mobile robots, and electric vehicles, capable of re-charging themselves without ever being plugged in. WPT enables flat screen TVs hang on the wall without any wires to power source. Medical devices and implants no longer need wires or batteries. Pacemakers do not have to be surgically replenished with batteries every few years. WT technologies continue to evolve, so they can be safely and efficiently over larger and larger distances and deliver large amount of power.

Wireless power transmission is an underdeveloped field of study. There are many promising applications for the ability to transport power over great distances and boundaries without the need for transmission lines. Current technology employs the use of microwaves because of the economic and energy efficiency that can be leveraged by products already in production. There is some effort to develop new technology that would accommodate propagation by electromagnetic waves in and around the visual light spectrum; however those technologies are just emerging

2.BLOCK DIAGRAM

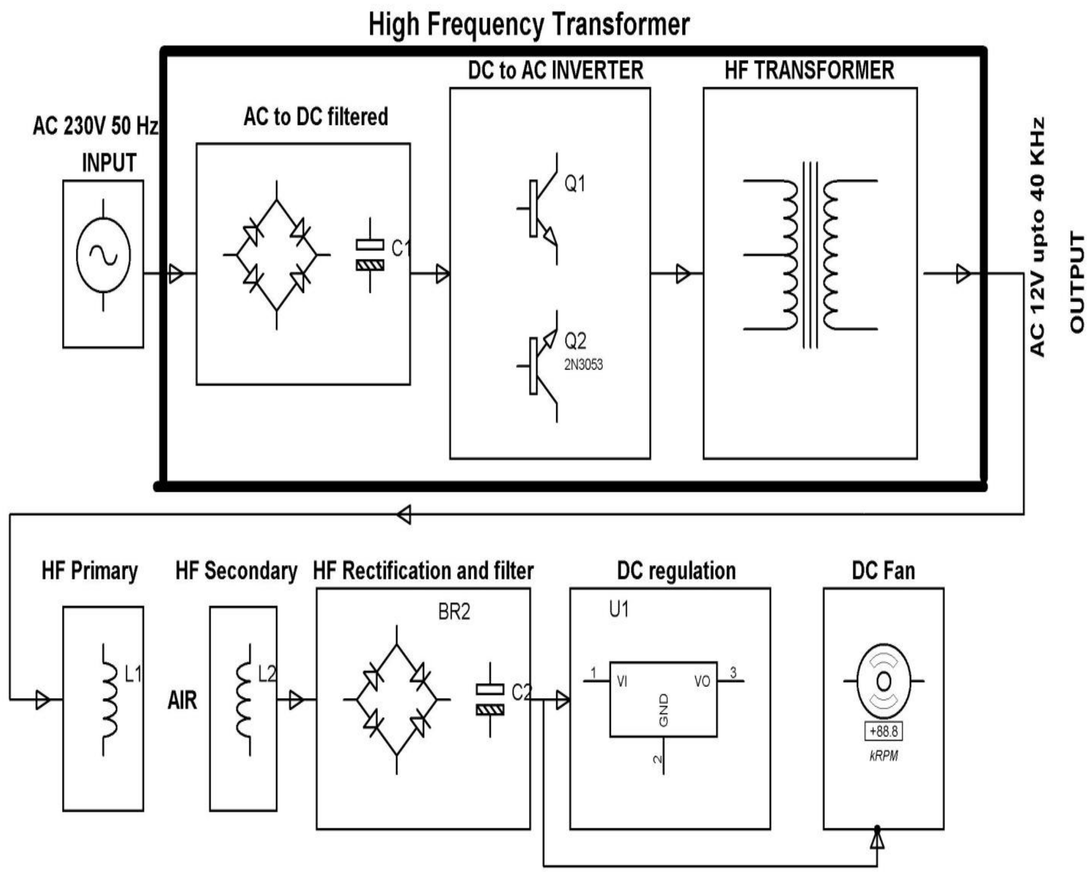


Fig: 2.1 Block diagram

3.HARDWARE REQUIREMENTS

1. HIGH FREQUENCY TRANSFORMER
2. VOLTAGE REGULATOR
3. FILTER
4. RECTIFIER
5. TRANSISTOR
6. LED
7. BRUSH LESS DC MOTOR
8. IN4007
9. RESISTOR
10. CAPACITOR
11. ELECTROMAGNETIC COIL

3.1 High Frequency Transformer

The transformer is one of the simplest of electrical devices. Its basic design, materials, and principles have changed little over the last one hundred years, yet transformer designs and materials continue to be improved. Transformers are essential in high voltage power transmission providing an economical means of transmitting power over large distances.

The simplicity, reliability, and economy of conversion of voltages by transformers was the principal factor in the selection of alternating current power transmission in the "War of Currents" in the late 1880's. In electronic circuitry, new methods of circuit design have replaced some of the applications of transformers, but electronic technology has also developed new transformer designs and applications.

Transformers come in a range of sizes from a thumbnail-sized coupling transformer hidden inside a stage microphone to gigawatt units used to interconnect large portions of national power grids, all operating with the same basic principles and with many similarities in their parts.

Transformers alone cannot do the following:

- Convert DC to AC or vice versa
- Change the voltage or current of DC
- Change the AC supply frequency.

The high-frequency transformers are calculated with the help of the effective core volume V_e and the minimum core-cross-section A_{min}. For a required power output $P_{out} = V_{out} \cdot I_{out}$ and a chosen switching frequency a suitable core volume V_e must be determined. Then an optimal ΔB is selected depending on the chosen switching frequency and also regarding the temperature rise of the transformer.

The program makes suggestions for

- Very well-suited cores (Green writing), whose volume lies between the value which was calculated by us to be suitable for the required power transfer, and 50% over that value. This volume is chosen such that the transformer temperature rise during operation is under 30K and the coil with a current density S = 3A/mm^2 fits into the available winding area.
- Well suited cores (Brown writing), whose volume lies between 50% and 100% over the value recommended by us,
- Suitable cores (Black writing), whose volume is greater than 100% over the value recommended by us (thus being uneconomically large),
- Inappropriately small cores (Gray writing), whose volume is below the value recommended by us. However, this does not mean that the core would be unsuitable. By reducing the primary number of turns N_1 you can adapt the magnetic flux density and the winding area to your request. However in this case they will have a higher temperature rise than the cores indicated in green.

You can change the suggested value for the primary number of turns N_1 according to your desires (the modification must be concluded with "return"). In each case a new value for ΔB will be displayed in the corresponding column. This also results in a change of the number of secondary turns N_2 such that the ratio N_1/N_2 will not be affected. The turn's ratio N_1/N_2 can only be changed on the simulation side.

The wire-diameter proposed by us as well as the wire-cross-section is always calculated for a current density of S = 3A/mm^2. If you change the number of primary turns, it can happen that the wire cross-section proposed by us no longer fits into the winding area, especially if you choose a smaller core (Gray writing), than the one suggested by us.

3.1.1 Design Of HF Transformers

High frequency transformers transfer electric power. The physical size is dependent on the power to be transferred as well as the operating frequency. The higher the frequency the smaller the physical size. Frequencies are usually between 20 and 100kHz. Ferrite is mainly used as the core material.

The first step to calculate a high frequency transformer is usually to choose an appropriate core with the help of the data book which provides certain tables for this purpose. In the second step, the primary number of turns is calculated because this determines the magnetic flux-density within the core. Then the wire-diameter is calculated, which is dependent on the current in the primary and secondary coils.

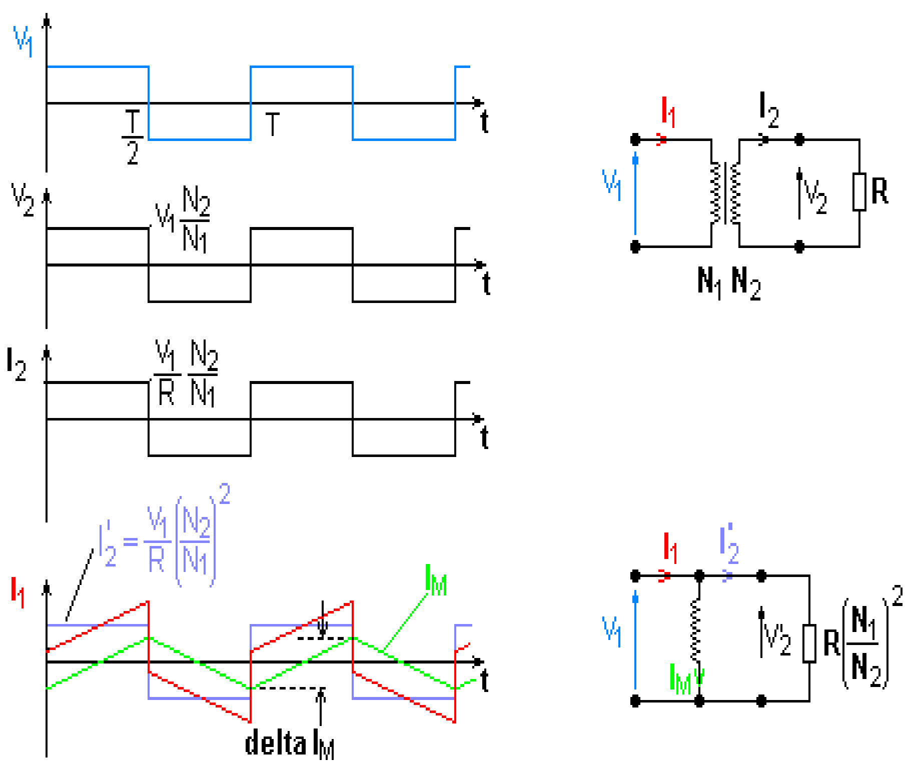


Fig: 3.1 HF Transformer characteristics

It is assumed that there is a square-wave voltage V_1 at the primary side of the transformer. This causes an input current I_1, which consists of the back transformed secondary current I_2 and the magnetizing current I_M. A core without an air-gap is used in order to keep the magnetizing current as small as possible.

The square-wave voltage at the input of the transformer causes a triangular shaped magnetising current I_M which is almost independent of the secondary current (see also the equivalent circuit). The magnetising current is approximately proportional to the magnetic flux Φ i.e. to the magnetic flux density B. The input voltage V_1 determines the magnetic flux in the transformer core corresponding to Faraday's Law $V = N \cdot d(\Phi)/dt$.

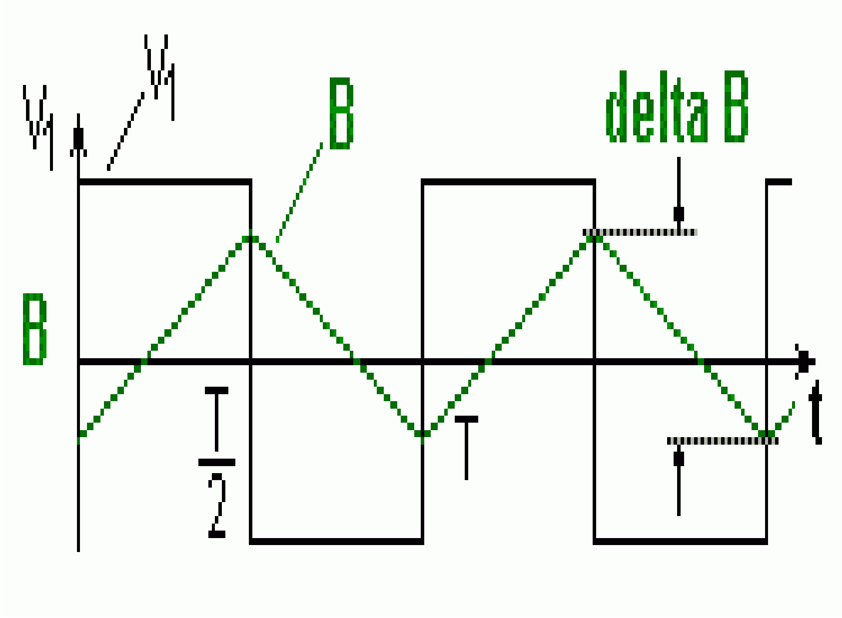


Fig: 3.2 Input voltage&magnetic flux density of transformer

A transformer is an electrical device that transfers energy from one circuit to another purely by magnetic coupling. Relative motion of the parts of the transformer is not required for transfer of energy. Transformers are often used to convert between high and low voltages, to change impedance, and to provide electrical isolation between circuits.

3.1.2 High Frequency Operation

The universal transformer emf equation indicates that at higher frequency, the core flux density will be lower for a given voltage. This implies that a core can have a smaller cross-sectional area and thus be physically more compact without reaching saturation. It is for this reason that the aircraft manufacturers and the military use 400 hertz supplies. They are less concerned with efficiency, which is lower at higher frequencies (mostly due to increased hysteresis losses), but are more concerned with saving weight. Similarly, fly back transformers which supply high voltage to cathode ray tubes operate at the frequency of the horizontal oscillator, many times higher than 50 or 60 hertz, which allows for a more compact component.

Transformers for use at power or audio frequencies have cores made of many thin laminations of silicon steel. By concentrating the magnetic flux, more of it is usefully linked by both primary and secondary windings. Since the steel core is conductive, it, too, has currents induced in it by the changing magnetic flux. Each layer is insulated from the adjacent layer to reduce the energy lost to eddy current heating of the core. A typical laminated core is made from E-shaped and I-shaped pieces, leading to the name "EI transformer".

Certain types of transformer may have gaps inserted in the magnetic path to prevent magnetic saturation. These gaps may be used to limit the current on a short-circuit, such as for neon sign transformers.

A steel core's magnetic hysteresis means that it retains a static magnetic field when power is removed. When power is then reapplied, the residual field will cause a high inrush current until the effect of the remanent magnetism is reduced, usually after a few cycles of the applied alternating current. Over current protection devices such as fuses must be selected to allow this harmless inrush to pass. On transformers connected to long overhead power transmission lines, induced currents due to geomagnetic disturbances during solar storms can cause saturation of the core, and false operation of transformer protection devices.

Distribution transformers can achieve low off-load losses by using cores made with amorphous (non-crystalline) steel, so-called "metal glasses" - the high cost of the core material is offset by the lower losses incurred at light load, over the life of the transformer.

3.1.3 Uses Of Transformers

- Electric power transmission over long distances.
- High-voltage direct-current HVDC power transmission systems
- Large, specially constructed power transformers are used for electric arc furnaces used in steelmaking.
- Rotating transformers are designed so that one winding turns while the other remains stationary. A common use was the video head system as used in VHS and Beta video tape players. These can pass power or radio signals from a stationary mounting to a rotating mechanism, or radar antenna.
- Sliding transformers can pass power or signals from a stationary mounting to a moving part such as a machine tool head. An example is the linear variable differential transformer,
- Some rotary transformers are precisely constructed in order to measure distances or angles. Usually they have a single primary and two or more secondary’s, and electronic circuits measure the different amplitudes of the currents in the secondary’s, such as in synchros and resolvers.
- Small transformers are often used to isolate and link different parts of radio receivers and audio amplifiers, converting high current low voltage circuits to low current high voltage, or vice versa.
- Balanced-to-unbalanced conversion. A special type of transformer called a balun is used in radio and audio circuits to convert between balanced circuits and

unbalanced transmission lines such as antenna down leads. A balanced line is one in which the two conductors (signal and return) have the same impedance to Ground: twisted pair and "balanced twin" are examples. Unbalanced lines include Coaxial cables and strip-line traces on printed circuit boards. A similar use is for Connecting the "single ended" input stages of an amplifier to the high-powered "push-pull" output stage.

3.2 Voltage Regulator 7805

3.2.1 Features

- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

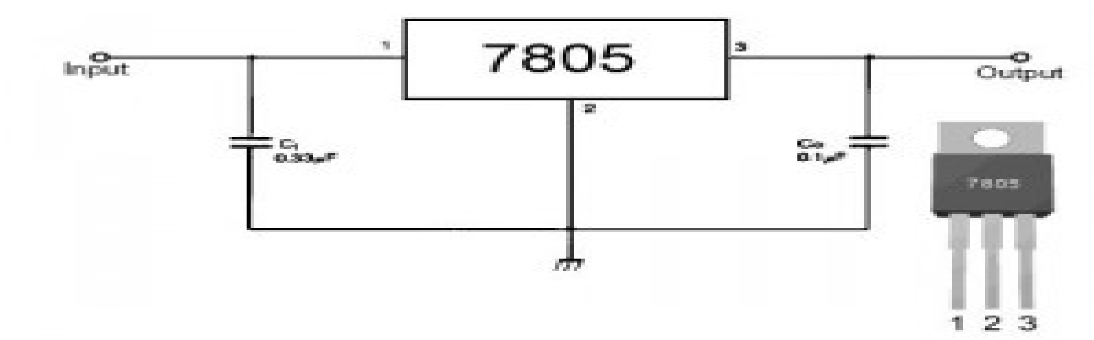


FIG: 3.3 MODEL OF VOLTAGE REGULATOR

3.2.2 Description

The LM78XX/LM78XXA series of three-terminal positive regulators are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a Wide range of applications. Each type employs internal current limiting, thermal shutdown and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output Current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

A voltage regulator is an electrical regulator designed to automatically maintain a constant voltage level. A voltage regulator may be a simple "feed-forward" design or may include negative feedback control loops. It may use an electromechanical mechanism, or electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages.

Electronic voltage regulators are found in devices such as computer power supplies where they stabilize the DC voltages used by the processor and other elements. In automobile alternators and central power station generator plants, voltage regulators control the output of the plant. In an electric power distribution system, voltage regulators may be installed at a substation or along distribution lines so that all customers receive steady voltage independent of how much power is drawn from the line.

The output voltage can only be held roughly constant; the regulation is specified by two measurements:

- load regulation is the change in output voltage for a given change in load current (for example: "typically 15mV, maximum 100mV for load currents between 5mA and 1.4A, at some specified temperature and input voltage").
- line regulation or input regulation is the degree to which output voltage changes with input (supply) voltage changes - as a ratio of output to input change (for example

"typically 13mV/V"), or the output voltage change over the entire specified input voltage range (for example "plus or minus 2% for input voltages between 90V and 260V, 50-60Hz").

Other important parameters are:

- Temperature coefficient of the output voltage is the change in output voltage with temperature (perhaps averaged over a given temperature range), while...
- Initial accuracy of a voltage regulator (or simply "the voltage accuracy") reflects the error in output voltage for a fixed regulator without taking into account temperature or aging effects on output accuracy.
- Dropout voltage is the minimum difference between input voltage and output voltage for which the regulator can still supply the specified current. A Low Drop-Out (LDO) regulator is designed to work well even with an input supply only a Volt or so above the output voltage.
- Absolute maximum ratings are defined for regulator components, specifying the continuous and peak output currents that may be used (sometimes internally limited), the maximum input voltage, maximum power dissipation at a given temperature, etc.
- Output noise (thermal white noise) and output dynamic impedance may be specified as graphs versus frequency, while output ripple noise (mains "hum" or switch-mode "hash" noise) may be given as peak-to-peak or RMS voltages, or in terms of their spectra.
- Quiescent current in a regulator circuit is the current drawn internally, not available to the load, normally measured as the input current while no load is connected (and hence a source of inefficiency; some linear regulators are, surprisingly, more efficient at very low current loads than switch-mode designs because of this).
- Transient response is the reaction of a regulator when a (sudden) change of the load current (called the load transient) or input voltage (called the line transient) occurs. Some regulators will tend to oscillate or have a slow response time which in some

cases might lead to undesired results. This value is different from the regulation parameters, as that is the stable situation definition. The transient response shows the behavior of the regulator on a change. This data is usually provided in the technical documentation of a regulator and is also dependent on output capacitance.

3.2.3 Electronic Voltage Regulators

A simple voltage regulator can be made from a resistor in series with a diode (or series of diodes). Due to the logarithmic shape of diode V-I curves, the voltage across the diode changes only slightly due to changes in current drawn. When precise voltage control is not important, this design may work fine.

Feedback voltage regulators operate by comparing the actual output voltage to some fixed reference voltage. Any difference is amplified and used to control the regulation element in such a way as to reduce the voltage error. This forms a negative feedback control loop; increasing the open-loop gain tends to increase regulation accuracy but reduce stability (avoidance of oscillation, or ringing during step changes). There will also be a trade-off between stability and the speed of the response to changes. If the output voltage is too low (perhaps due to input voltage reducing or load current increasing), the regulation element is commanded, up to point, to produce a higher output voltage–by dropping less of the input voltage (for linear series regulators and buck switching regulators), or to draw input current for longer periods (boost-type switching regulators); if the output voltage is too high, the regulation element will normally be commanded to produce a lower voltage. However, many regulators have over-current protection, so that they will entirely stop sourcing current (or limit the current in some way) if the output current is too high, and some regulators may also shut down if the input voltage is outside a given range.

3.2.4 Electromechanical Regulators

In electromechanical regulators, voltage regulation is easily accomplished by coiling the sensing wire to make an electromagnet. The magnetic field produced by the current attracts a moving ferrous core held back under spring tension or gravitational pull. As voltage increases, so does the current, strengthening the magnetic field produced by the coil and pulling the core towards the field. The magnet is physically connected to a mechanical power switch, which opens as the magnet moves into the field. As voltage decreases, so does the current, releasing spring tension or the weight of the core and causing it to retract. This closes the switch and allows the power to flow once more.

If the mechanical regulator design is sensitive to small voltage fluctuations, the motion of the solenoid core can be used to move a selector switch across a range of resistances or transformer windings to gradually step the output voltage up or down, or to rotate the position of a moving-coil AC regulator.

3.2.5 Internal Block Diagram

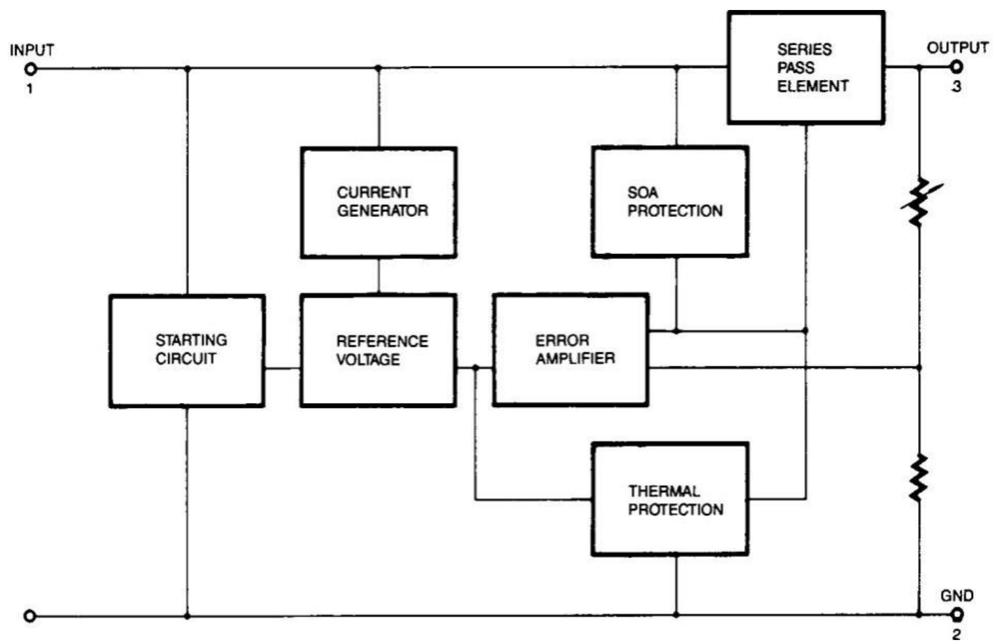


Fig 3.4 Block diagram of voltage regulator

3.3 Filter

Electronic filters are electronic circuits which perform signal processing functions, specifically to remove unwanted frequency components from the signal, to enhance wanted ones, or both. Electronic filters can be:

- Passive or active
- Analog or digital
- High-pass, low-pass, bandpass, band-reject (band reject; notch), or all-pass.
- Discrete-time (sampled) or continuous-time
- Linear or non-linear
- Infinite impulse response (IIR type) or finite impulse response (FIR type)

The most common types of electronic filters are linear filters, regardless of other aspects of their design. See the article on linear filters for details on their design and analysis.

Capacitive filter is used in this project. It removes the ripples from the output of rectifier and smoothens the D.C. Output received from this filter is constant until the mains voltage and load is maintained constant. However, if either of the two is varied, D.C. voltage received at this point changes. Therefore a regulator is applied at the output stage.

The simple capacitor filter is the most basic type of power supply filter. The use of this filter is very limited. It is sometimes used on extremely high-voltage, low-current power supplies for cathode-ray and similar electron tubes that require very little load current from the supply. This filter is also used in circuits where the power-supply ripple frequency is not critical and can be relatively high.

3.4 Rectifier

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), current that flows in only one direction, a process known as rectification. Rectifiers have many uses including as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid state diodes, vacuum tube diodes, mercury arc valves, and other components.

The output from the transformer is fed to the rectifier. It converts A.C. into pulsating D.C. The rectifier may be a half wave or a full wave rectifier. In this project, a bridge rectifier is used because of its merits like good stability and full wave rectification.

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which is in only one direction, a process known as rectification. Rectifiers have many uses including as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid state diodes, vacuum tube diodes, mercury arc valves, and other components.

A device which performs the opposite function (converting DC to AC) is known as an inverter. When only one diode is used to rectify AC (by blocking the negative or positive portion of the waveform), the difference between the term diode and the term rectifier is merely one of usage, i.e., the term rectifier describes a diode that is being used to convert AC to DC. Almost all rectifiers comprise a number of diodes in a specific arrangement for more efficiently converting AC to DC than is possible with only one diode. Before the development of silicon semiconductor rectifiers, vacuum tube diodes and copper (I) oxide or selenium rectifier stacks were used.

Early radio receivers, called crystal radios, used a "cat's whisker" of fine wire pressing on a crystal of galena (lead sulphide) to serve as a point-contact rectifier or "crystal detector". Rectification may occasionally serve in roles other than to generate direct current per se. For example, in gas heating systems flame rectification is used to detect presence of flame. Two metal electrodes in the outer layer of the flame provide a current path, and rectification of an applied alternating voltage will happen in the plasma, but only while the flame is present to generate it.

3.4.1 Half-wave Rectification

In half wave rectification, either the positive or negative half of the AC wave is passed, while the other half is blocked. Because only one half of the input waveform reaches the output, it is very inefficient if used for power transfer. Half-wave rectification can be achieved with a single diode in a one-phase supply, or with three diodes in a three-phase supply.

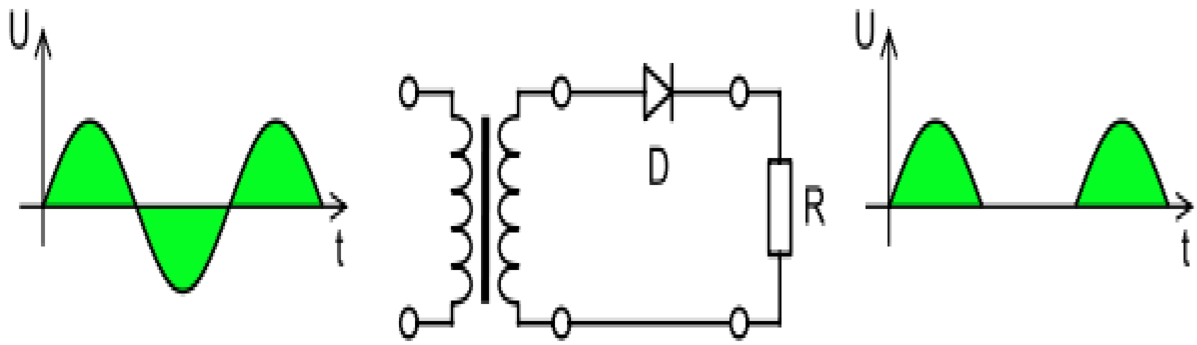


Fig: 3.5 Half wave rectifier using one diode

The output DC voltage of a half wave rectifier can be calculated with the following two ideal equations

$$V_{rms} = \frac{V_{peak}}{2}$$

$$V_{dc} = \frac{V_{peak}}{\pi}$$

3.4.2 Full-wave Rectification

A full-wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output. Full-wave rectification converts both polarities of the input waveform to DC (direct current), and is more efficient. However, in a circuit with a non-centre tapped transformer, four diodes are required instead of the one needed for half-wave rectification. Four diodes arranged this way are called a diode bridge or bridge rectifier.

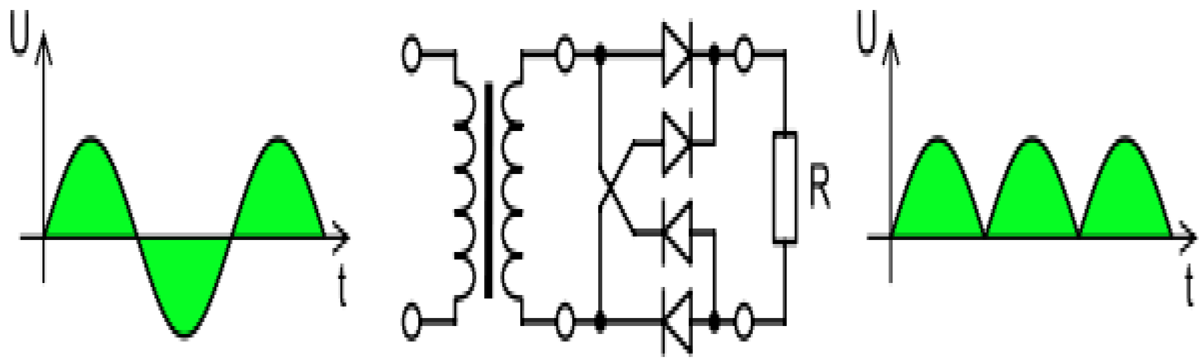


Fig: 3.6 Full-wave rectifier using 4 diodes

For single-phase AC, if the transformer is centre-tapped, then two diodes back-to-back (i.e. anodes-to-anode or cathode-to-cathode) can form a full-wave rectifier. Twice as many windings are required on the transformer secondary to obtain the same output voltage compared to the bridge rectifier above.

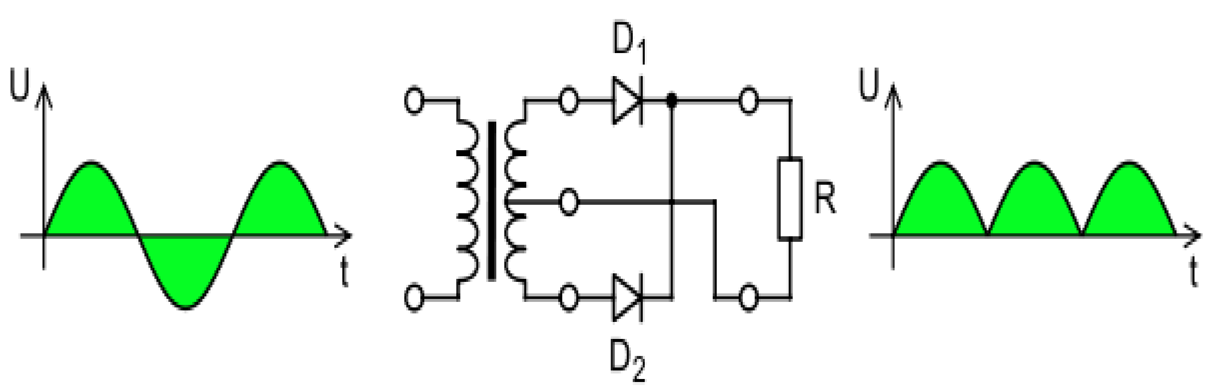


Fig: 3.7 Full-wave rectifier using a center tap transformer and 2 diodes

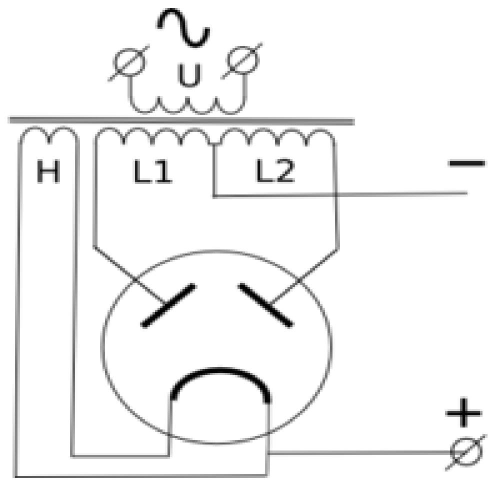


Fig: 3.8 Full-wave rectifier, with vacuum tube having two anodes

A very common vacuum tube rectifier configuration contained one cathode and twin anodes inside a single envelope; in this way, the two diodes required only one vacuum tube. The 5U4 and 5Y3 were popular examples of this configuration.

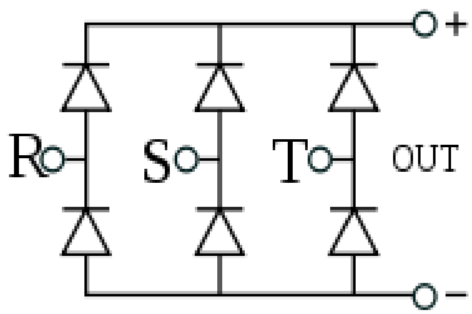


Fig: 3.9 Three-phase bridge rectifier

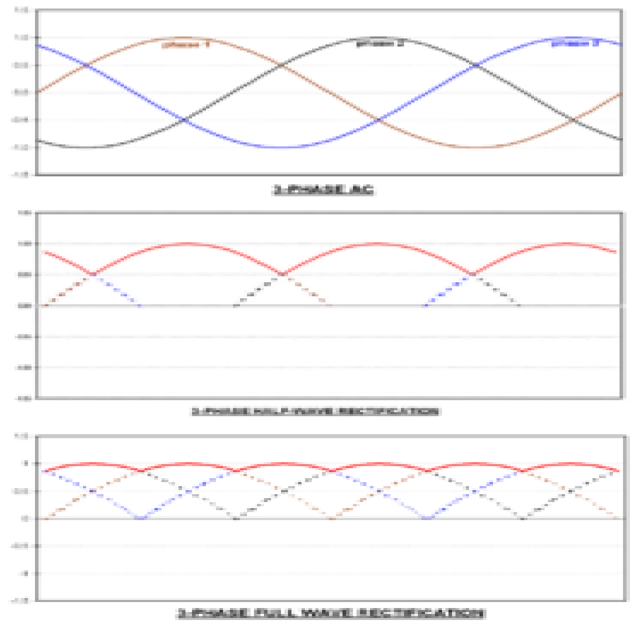


Fig: 3.10 3-phase ac input, half & full wave rectified dc output waveforms

For three-phase AC, six diodes are used. Typically there are three pairs of diodes, each pair, though, is not the same kind of double diode that would be used for a full wave single-phase rectifier. Instead the pairs are in series (anode to cathode). Typically, commercially available double diodes have four terminals so the user can configure them as single-phase split supply use, for half a bridge, or for three-phase use.

Fig: 3.11 Disassembled automobile alternator

Most devices that generate alternating current (such devices are called alternators) generate three-phase AC. For example, an automobile alternator has six diodes inside it to function as a full-wave rectifier for battery charging applications.

The average and root-mean-square output voltages of an ideal single phase full wave rectifier can be calculated as:

$$V_{dc} = V_{av} = \frac{2V_p}{\pi}$$

$$V_{rms} = \frac{V_p}{\sqrt{2}}$$

Where:

V_{dc},V_{av} - the average or DC output voltage,

V_p - the peak value of half wave,

V_{rms} - the root-mean-square value of output voltage.

π = ~ 3.14159

3.4.3 Peak Loss

An aspect of most rectification is a loss from the peak input voltage to the peak output voltage, caused by the built-in voltage drop across the diodes (around 0.7 V for ordinary silicon p-n-junction diodes and 0.3 V for Schottky diodes). Half-wave rectification and full-wave rectification using two separate secondaries will have a peak voltage loss of one diode drop. Bridge rectification will have a loss of two diode drops. This may represent significant power loss in very low voltage supplies. In addition, the diodes will not conduct below this voltage, so the circuit is only passing current through for a portion of each half-cycle, causing short segments of zero voltage to appear between each "hump".

3.4.4 Rectifier Output Smoothing

While half-wave and full-wave rectification suffice to deliver a form of DC output, neither produces constant-voltage DC. In order to produce steady DC from a rectified AC supply, a smoothing circuit or filter is required.[2] In its simplest form this can be just a reservoir capacitor or smoothing capacitor, placed at the DC output of the rectifier. There will still remain an amount of AC ripple voltage where the voltage is not completely smoothed.

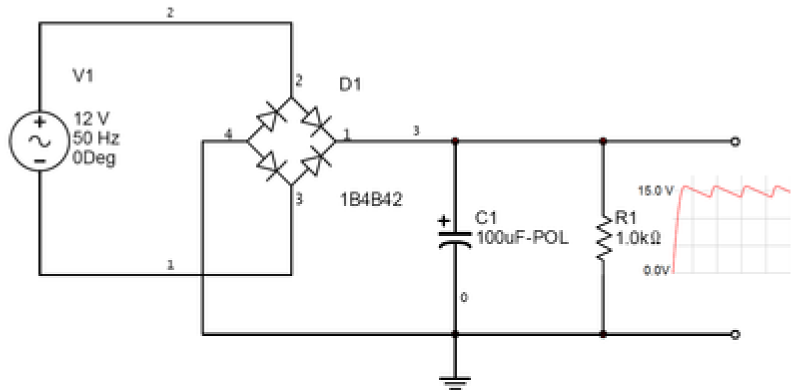


Fig: 3.12 RC-filter rectifier

Sizing of the capacitor represents a trade-off. For a given load, a larger capacitor will reduce ripple but will cost more and will create higher peak currents in the transformer secondary and in the supply feeding it. In extreme cases where many rectifiers are loaded onto a power distribution circuit, it may prove difficult for the power distribution authority to maintain a correctly shaped sinusoidal voltage curve.

For a given tolerable ripple the required capacitor size is proportional to the load current and inversely proportional to the supply frequency and the number of output peaks of the rectifier per input cycle. The load current and the supply frequency are generally outside the control of the designer of the rectifier system but the number of peaks per input cycle can be affected by the choice of rectifier design.

A half-wave rectifier will only give one peak per cycle and for this and other reasons is only used in very small power supplies. A full wave rectifier achieves two peaks per cycle and this is the best that can be done with single-phase input. For three-phase inputs a three-phase bridge will give six peaks per cycle and even higher numbers of peaks can be achieved by using transformer networks placed before the rectifier to convert to a higher phase order.

To further reduce this ripple, a capacitor-input filter can be used. This complements the reservoir capacitor with a choke (inductor) and a second filter capacitor, so that a steadier DC output can be obtained across the terminals of the filter capacitor. The choke presents a high impedance to the ripple current.

A more usual alternative to a filter, and essential if the DC load is very demanding of a smooth supply voltage, is to follow the reservoir capacitor with a voltage regulator. The reservoir capacitor needs to be large enough to prevent the troughs of the ripple getting below the voltage the DC is being regulated to. The regulator serves both to remove the last of the ripple and to deal with variations in supply and load characteristics. It would be possible to use a smaller reservoir capacitor (these can be large on high-current power supplies) and then apply some filtering as well as the regulator, but this is not a common strategy. The extreme of this approach is to dispense with the reservoir capacitor altogether and put the rectified waveform straight into a choke-input filter. The advantage of this circuit is that the current waveform is smoother and consequently the rectifier no longer has to deal with the current as a large current pulse, but instead the current delivery is spread over the entire cycle. The downside is that the voltage output is much lower – approximately the average of an AC half-cycle rather than the peak.

3.4.5 Applications

FIG: 3.13 Application of rectifier

A rectifier diode (silicon controlled rectifier) and associated mounting hardware. The heavy threaded stud helps remove heat.

The primary application of rectifiers is to derive DC power from an AC supply. Virtually all electronic devices require DC, so rectifiers find uses inside the power supplies of virtually all electronic equipment.

Converting DC power from one voltage to another is much more complicated. One method of DC-to-DC conversion first converts power to AC (using a device called an inverter), then use a transformer to change the voltage, and finally rectifies power back to DC.

Rectifiers also find a use in detection of amplitude modulated radio signals. The signal may be amplified before detection, but if un-amplified, a very low voltage drop diode must be used. When using a rectifier for demodulation the capacitor and load resistance must be carefully matched. Too low a capacitance will result in the high frequency carrier passing to the output and too high will result in the capacitor just charging and staying charged.

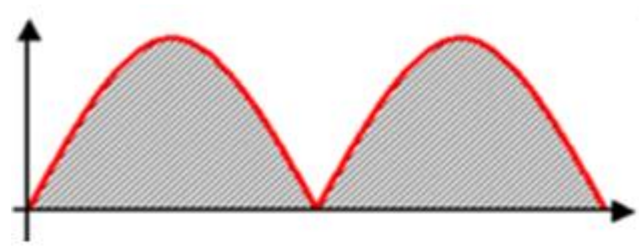


Fig: 3.14 Output voltage of a full-wave rectifier with controlled thyristors

Rectifiers are also used to supply polarised voltage for welding. In such circuits control of the output current is required and this is sometimes achieved by replacing some of the diodes in bridge rectifier with thyristors, whose voltage output can be regulated by means of phase fired controllers.

Thyristors are used in various classes of railway rolling stock systems so that fine control of the traction motors can be achieved. Gate turn-off thyristors are used to produce alternating current from a DC supply, for example on the Eurostar Trains to power the three-phase traction motors.

3.4.6 Electromechanical

Early power conversion systems were purely electro-mechanical in design, since electronic devices were not available to handle significant power. Mechanical rectification systems usually rely on some form of rotation or resonant vibration in order to move quickly enough to match the frequency of the input power source, and cannot operate beyond several thousand cycles per second.

Due to the complexity of mechanical systems, they have traditionally needed a high level of maintenance to keep operating correctly. Moving parts will have friction, which requires lubrication and replacement due to wear. Opening mechanical contacts under load results in electrical arcs and sparks that heat and erode the contacts.

3.4.7 Synchronous Rectifier

To convert AC currents into DC current in electric locomotives, a synchronous rectifier may be used. It consists of a synchronous motor driving a set of heavy-duty electrical contacts. The motor spins in time with the AC frequency and periodically reverses the connections to the load just when the sinusoidal current goes through a zero-crossing. The contacts do not have to switch a large current, but they need to be able to carry a large current to supply the locomotive's DC traction motors.

3.4.8 Vibrator

In the past, the vibrators used in battery-to-high-voltage-DC power supplies often contained a second set of contacts that performed synchronous mechanical rectification of the stepped-up voltage.

3.4.9 Motor-generator Set

A motor-generator set, or the similar rotary converter, is not a rectifier in the sense that it doesn't actually rectify current, but rather generates DC from an AC source. In an "M-G set", the shaft of an AC motor is mechanically coupled to that of a DC generator. The DC generator produces multiphase alternating currents in its armature windings, and a commutator on the armature shaft converts these alternating currents into a direct current output; or a homopolar generator produces a direct current without the need for a commutator. M-G sets are useful for producing DC for railway traction motors, industrial motors and other high-current applications, and were common in many high power D.C. uses (for example, carbon-arc lamp projectors for outdoor theaters) before high-power semiconductors became widely available.

3.4.10 Electrolytic

The electrolytic rectifier was an early device from the 1900s that is no longer used. When two different metals are suspended in an electrolyte solution, it can be found that direct current flowing one way through the metals has less resistance than the other direction. These most commonly used an aluminum anode, and a lead or steel cathode, suspended in a solution of tri-ammonium ortho-phosphate.

The rectification action is due to a thin coating of aluminium hydroxide on the aluminium electrode, formed by first applying a strong current to the cell to build up the coating. The rectification process is temperature sensitive, and for best efficiency should not operate above 86 °F (30 °C). There is also a breakdown voltage where the coating is penetrated and the cell is short-circuited. Electrochemical methods are often more fragile than mechanical methods, and can be sensitive to usage variations which can drastically change or completely disrupt the rectification processes.

Similar electrolytic devices were used as lightning arresters around the same era by suspending many aluminium cones in a tank of tri-ammonium oroth-phosphate solution. Unlike the rectifier, above, only aluminium electrodes were used, and used on A.C., there was no polarization and thus no rectifier action, but the chemistry was similar.

The modern electrolytic capacitor, an essential component of most rectifier circuit configurations was also developed from the electrolytic rectifier.

Plasma type

Mercury arc

A rectifier used in high-voltage direct current power transmission systems and industrial processing between about 1909 to 1975 is a mercury arc rectifier or mercury arc valve. The device is enclosed in a bulbous glass vessel or large metal tub. One electrode, the cathode, is submerged in a pool of liquid mercury at the bottom of the vessel and one or more high purity graphite electrodes, called anodes, are suspended above the pool. There may be several auxiliary electrodes to aid in starting and maintaining the arc. When an electric arc is established between the cathode pool and suspended anodes, a stream of electrons flows from the cathode to the anodes through the ionized mercury, but not the other way. [In principle, this is a higher-power counterpart to flame rectification, which uses the same one-way current transmission properties of the plasma naturally present in a flame].

These devices can be used at power levels of hundreds of kilowatts, and may be built to handle one to six phases of AC current. Mercury arc rectifiers have been replaced by silicon semiconductor rectifiers and high power thyristor circuits, from the mid 1970s onward. The most powerful mercury arc rectifiers ever built were installed in the Manitoba Hydro Nelson River Bipole HVDC project, with a combined rating of more than one million kilowatts and 450,000 volts.

3.4.11 Argon Gas Electron Tube

The General Electric Tungar rectifier was an argon gas-filled electron tube device with a tungsten filament cathode and a carbon button anode. It was useful for battery chargers and similar applications from the 1920s until low-cost solid-state rectifiers (the metal rectifiers at first) supplanted it. These were made up to a few hundred volts and a few amperes rating, and in some sizes strongly resembled an incandescent lamp with an additional electrode.

The 0Z4 was a gas-filled rectifier tube commonly used in vacuum tube car radios in the 1940s and 1950s. It was a conventional full wave rectifier tube with two anodes and one cathode, but was unique in that it had no filament (thus the "0" in its type number). The electrodes were shaped such that the reverse breakdown voltage was much higher than the forward breakdown voltage. Once the breakdown voltage was exceeded, the 0Z4 switched to a low-resistance state with a forward voltage drop of about 24 volts.

3.4.12 Vacuum Tube (valve)

Since the discovery of the Edison effect or thermionic emission, various vacuum tube devices have been developed to rectify alternating currents. Low-power devices are used as signal detectors, first used in radio by Fleming in 1904. Many vacuum-tube devices also used vacuum rectifiers in their power supplies, for example the All American Five radio receiver. Vacuum rectifiers were made for very high voltages, such as the high voltage power supply for the cathode ray tube of television receivers, and the kenotron used for power supply in X-ray equipment. However, vacuum rectifiers generally had low current capacity owing to the maximum current density that could be obtained by electrodes heated to temperatures compatible with long life. Another limitation of the vacuum tube rectifier was that the heater power supply often required special arrangements to insulate it from the high voltages of the rectifier circuit.

3.4.13 Metal Rectifier

Once common until replaced by more compact and less costly silicon solid-state rectifiers, these units used stacks of metal plates and took advantage of the semiconductor properties of selenium or copper oxide.[8] While selenium rectifiers were lighter in weight and used less power than comparable vacuum tube rectifiers, they had the disadvantage of finite life expectancy, increasing resistance with age, and were only suitable to use at low frequencies. Both selenium and copper oxide rectifiers have somewhat better tolerance of momentary voltage transients than silicon rectifiers.

Typically these rectifiers were made up of stacks of metal plates or washers, held together by a central bolt, with the number of stacks determined by voltage; each cell was rated for about 20 volts. An automotive battery charger rectifier might have only one cell: the high-voltage power supply for a vacuum tube might have dozens of stacked plates. Current density in an air-cooled selenium stack was about 600 mA per square inch of active area (about 90 mA per square centimeter).

3.4.14 Silicon And Germanium Diodes

In the modern world, silicon diodes are the most widely used rectifiers and have largely replaced earlier germanium diodes.

Recent developments

High-speed rectifiers

Researchers at Idaho National Laboratory (INL) have proposed high-speed rectifiers that would sit at the center of spiral nanoantennas and convert infrared frequency electricity from AC to DC. Infrared frequencies range from 0.3 to 400 terahertz.

3.5 Transistor

A transistor is a semiconductor device used to amplify and switch electronic signals. It is made of a solid piece of semiconductor material, with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals changes the current flowing through another pair of terminals. Because the controlled (output) power can be much more than the controlling (input) power, the transistor provides amplification of a signal. Today, some transistors are packaged individually, but many more are found embedded in integrated circuits.

The transistor is the fundamental building block of modern electronic devices, and is ubiquitous in modern electronic systems. Following its release in the early 1950s the transistor revolutionized the field of electronics, and paved the way for smaller and cheaper radios, calculators, and computers, among other things.

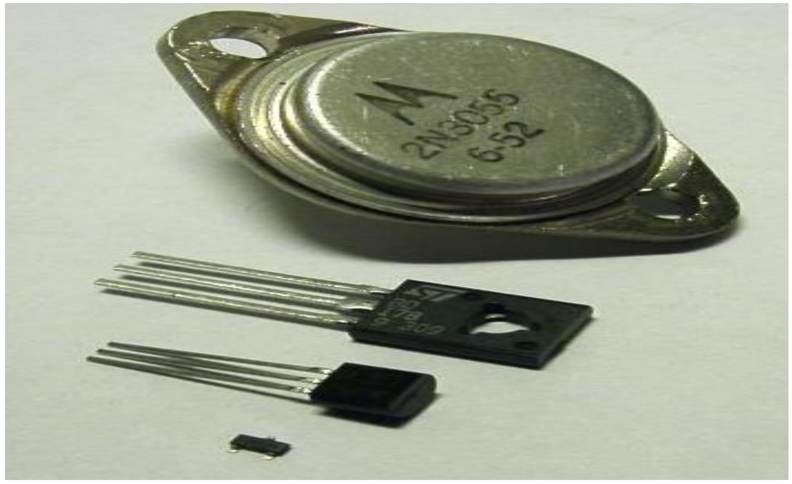


Fig:3.15 Model of transistor

The transistor's low cost, flexibility, and reliability have made it a ubiquitous device. Transistorized mechatronic circuits have replaced electromechanical devices in controlling appliances and machinery. It is often easier and cheaper to use a standard microcontroller and write a computer program to carry out a control function than to design an equivalent mechanical control function.

The essential usefulness of a transistor comes from its ability to use a small signal applied between one pair of its terminals to control a much larger signal at another pair of terminals. This property is called gain. A transistor can control its output in proportion to the input signal; that is, it can act as an amplifier. Alternatively, the transistor can be used to turn current on or off in a circuit as an electrically controlled switch, where the amount of current is determined by other circuit elements.

The two types of transistors have slight differences in how they are used in a circuit. A bipolar transistor has terminals labeled base, collector, and emitter. A small current at the base terminal (that is, flowing from the base to the emitter) can control or switch a much larger current between the collector and emitter terminals. For a field-effect transistor, the terminals are labeled gate, source, and drain, and a voltage at the gate can control a current between source and drain.

The image to the right represents a typical bipolar transistor in a circuit. Charge will flow between emitter and collector terminals depending on the current in the base. Since internally the base and emitter connections behave like a semiconductor diode, a voltage drop develops between base and emitter while the base current exists. The amount of this voltage depends on the material the transistor is made from, and is referred to as V_{BE}.

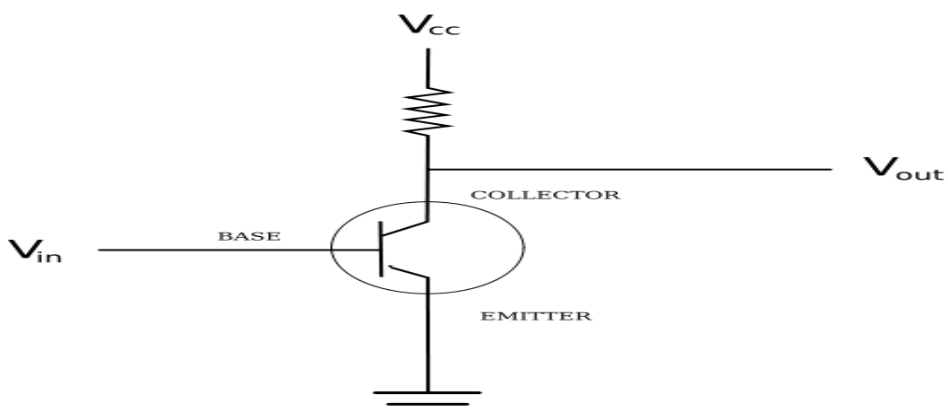


Fig:3.16 Block diagram of transistor

3.5.1 Transistor as a switch

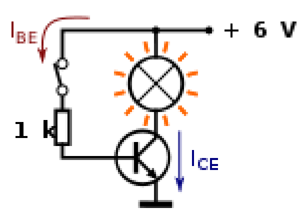


Fig:3.17 BJT used as an electronic switch

Transistors are commonly used as electronic switches, both for high-power applications such as switched-mode power supplies and for low-power applications such as logic gates.

In a grounded-emitter transistor circuit, such as the light-switch circuit shown, as the base voltage rises the base and collector current rise exponentially, and the collector voltage drops because of the collector load resistor. The relevant equations:

$V_{RC} = I_{CE} \times R_C$, the voltage across the load (the lamp with resistance R_C)

$V_{RC} + V_{CE} = V_{CC}$, the supply voltage shown as 6V

If V_{CE} could fall to 0 (perfect closed switch) then Ic could go no higher than V_{CC} / R_C, even with higher base voltage and current. The transistor is then said to be saturated. Hence, values of input voltage can be chosen such that the output is either completely off,[13] or completely on. The transistor is acting as a switch, and this type of operation is common in digital circuits where only "on" and "off" values are relevant.

3.6 LED

LEDs are semiconductor devices. Like transistors, and other diodes, LEDs are made out of silicon. What makes an LED give off light are the small amounts of chemical impurities that are added to the silicon, such as gallium, arsenide, indium, and nitride. When current passes through the LED, it emits photons as a byproduct. Normal light bulbs produce light by heating a metal filament until its white hot. Because LEDs produce photons directly and not via heat, they are far more efficient than incandescent bulbs. Not long ago LEDs were only bright enough to be used as indicators on dashboards or electronic equipment. But recent advances have made LEDs bright enough to rival traditional lighting technologies. Modern LEDs can replace incandescent bulbs in almost any application.

LEDs are based on the semiconductor diode. When the diode is forward biased (switched on), electrons are able to recombine with holes and energy is released in the form of light. This effect is called electroluminescence and the color of the light is determined by the energy gap of the semiconductor. The LED is usually small in area (less than 1 mm2) with integrated optical components to shape its radiation pattern and assist in reflection.

Fig:3.18 LEDS

LEDs present many advantages over traditional light sources including lower energy consumption, longer lifetime, improved robustness, smaller size and faster switching. However, they are relatively expensive and require more precise current and heat management than traditional light sources.

Applications of LEDs are diverse. They are used as low-energy and also for replacements for traditional light sources in well-established applications such as indicators and automotive lighting. The compact size of LEDs has allowed new text and video displays and sensors to be developed, while their high switching rates are useful in communications technology. So here the role of LED is to indicate the status of the components like relays and power circuit etc…

3.6.1 LED Circuits

To build LED circuits, it helps to be familiar with Ohm's law, and the concepts of voltage, resistance, and current. LEDs do not have resistance like a resistor does. LEDs have a dynamic resistance that is their resistance changes depending on how much current passes through them. But it's easiest to think of them as having NO resistance. This means that if you just connect an LED to a battery, you'll have a short circuit..

So an LED circuit needs some resistance in it, so that it isn't a short circuit. Actually we need a very specific amount of resistance. Among the specifications for LEDs, a "maximum forward current" rating is usually given. This is the most current that can pass through the LED without damaging it, and also the current at which the LED will produce the most light. A specific value of resistor is needed to obtain this exact current. There is one more complication. LEDs consume a certain voltage. This is known as the "forward voltage drop", and is usually given with the specs for that LED. This must be taken into account when calculating the correct value of resistor to use. So to drive an LED using a voltage source and a resistor in series with the LED, use the following equation to determine the needed resistance:

Ohm's = (Source Voltage - LED Voltage Drop) / Amps

For example, to drive an LED from your car's 12v system, use the following values:

Source Voltage = 13.4 volts (12v car systems aren't really 12v in most cases

Voltage Drop = 3.6 volts (Typical for a blue or white LED)

Desired Current = 30 milliamps (again, a typical value)

So the resistor we need is:

(13.4 - 3.6) / (30 / 1000) = 327 ohms

3.7 Brushless DC Motor

Brushless DC motors (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous electric motors powered by direct-current (DC) electricity and having electronic commutation systems, rather than mechanical commutators and brushes. The current-to-torque and frequency-to-speed relationships of BLDC motors are linear.

Fig:3.19 Brushless DC motor

BLDC motors may be described as stepper motors, with fixed permanent magnets and possibly more poles on the rotor than the stator, or reluctance motors. The latter may be without permanent magnets, just poles that are induced on the rotor then pulled into alignment by timed stator windings. However, the term stepper motor tends to be used for motors that are designed specifically to be operated in a mode where they are frequently stopped with the rotor in a defined angular position; this page describes more general BLDC motor principles, though there is overlap.

3.7.1 Brushless Versus Brushed Motor

Limitations of brushed DC motors overcome by BLDC motors include lower efficiency and susceptibility of the commutator assembly to mechanical wear and consequent need for servicing, at the cost of potentially less rugged and more complex and expensive control electronics. BLDC motors develop maximum torque when stationary and have linearly decreasing torque with increasing speed as shown in the adjacent figure.

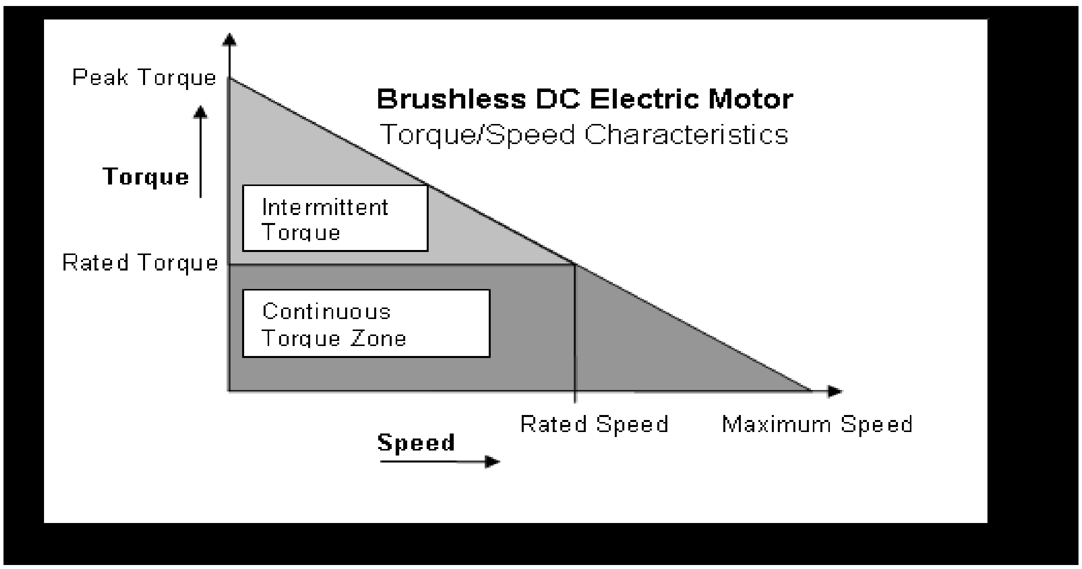


Fig:3.20 Brushless DC Electric Motor Torque-Speed Characteristics

A DC motor has permanent magnets which rotate and a fixed armature, eliminating the problems of connecting current to the moving armature. An electronic controller replaces the brush/commutator assembly of the brushed DC motor, which continually switches the phase to the windings to keep the motor turning. The controller performs similar timed power distribution by using a solid-state circuit rather than the brush/commutator system.

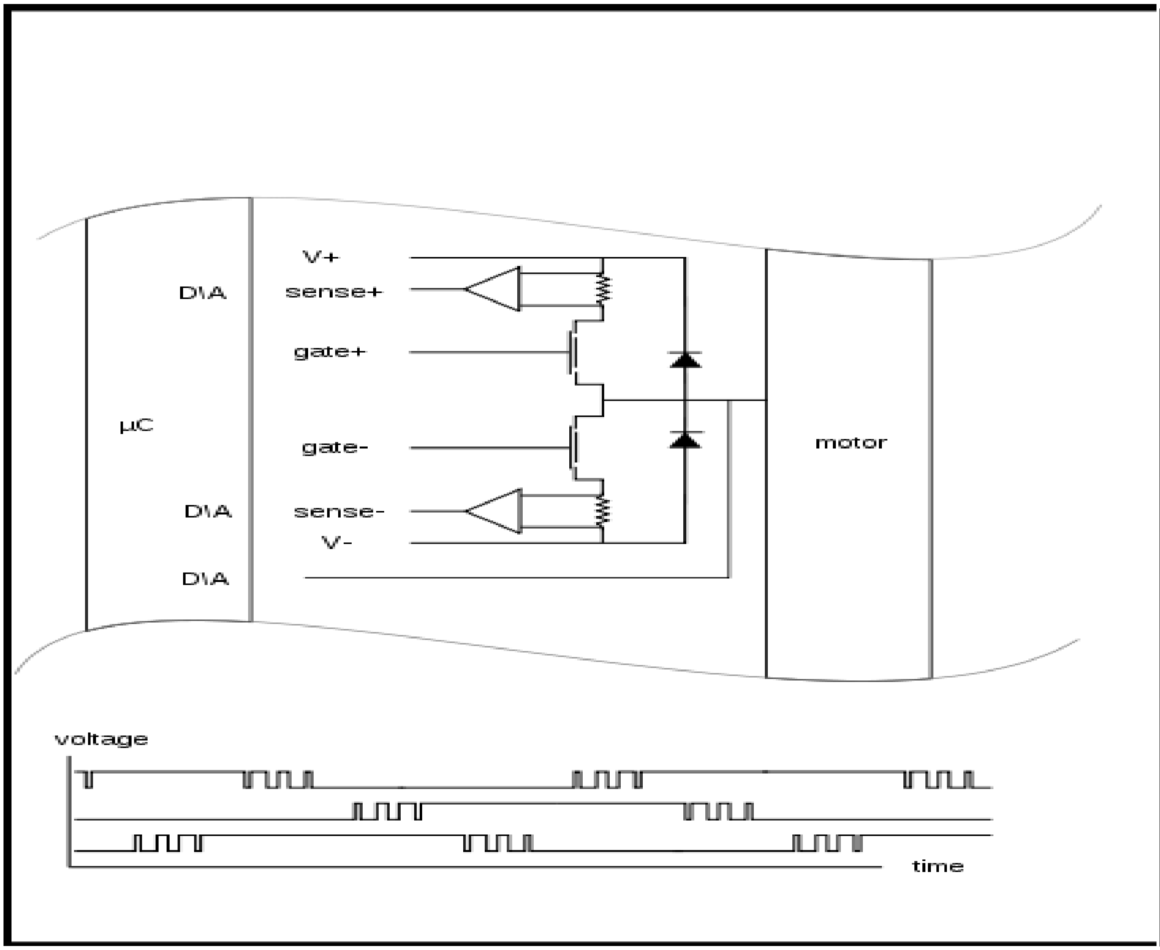


Fig:3.21 Multiple transitions between high and low voltage levels

The interface circuitry between a digital controller and motor. The waveforms show multiple transitions between high and low voltage levels, approximations to a trapezoid or sinusoid which reduce harmonic losses. The circuit compensates for the induction of the windings, regulates power and monitors temperature.

BLDC motors offer several advantages over brushed DC motors, including more torque per weight and efficiency, reliability, reduced noise, longer lifetime (no brush and commutator erosion), elimination of ionizing sparks from the commutator, more power, and overall reduction of electromagnetic interference (EMI). With no windings on the rotor, they are not subjected to centrifugal forces, and because the windings are supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling. This in turn means that the motor's internals can be entirely enclosed and protected from dirt or other foreign matter.

The maximum power that can be applied to a BLDC motor is exceptionally high, limited almost exclusively by heat, which can weaken the magnets. (Magnets demagnetize at high temperatures, the Curie point, and for neodymium-iron-boron magnets this temperature is lower than for other types.) A BLDC motor's main disadvantage is higher cost, which arises from two issues. First, BLDC motors require complex electronic speed controllers to run. Brushed DC motors can be regulated by a comparatively simple controller, such as a rheostat (variable resistor). However, this reduces efficiency because power is wasted in the rheostat. Second, some practical uses have not been well developed in the commercial sector. For example, in the Radio Control (RC) hobby, even commercial brushless motors are often hand-wound while brushed motors use armature coils which can be inexpensively machine-wound. (Nevertheless, see "Applications", below.)

BLDC motors are often more efficient at converting electricity into mechanical power than brushed DC motors. This improvement is largely due to the absence of electrical and friction losses due to brushes. The enhanced efficiency is greatest in the no-load and low-load region of the motor's performance curve. Under high mechanical loads, BLDC motors and high-quality brushed motors are comparable in efficiency.

AC induction motors require induction of magnetic field in the rotor by the rotating field of the stator; this results in the magnetic and electric fields being out of phase. The phase difference requires greater current and current losses to achieve power. BLDC motors are microprocessor-controlled to keep the stator current in phase with the permanent magnets of the rotor, requiring less current for the same effect and therefore resulting in greater efficiency.

In general, manufacturers use brush-type DC motors when low system cost is a priority but brushless motors to fulfill requirements such as maintenance-free operation, high speeds, and operation in explosive environments where sparking could be hazardous.

3.7.2 Applications

- Consumer electronics
- Transport
- Heating and ventilation
- Industrial engineering
- Model engineering

3.8 IN4007

Diodes are used to convert AC into DC these are used as half wave rectifier or full wave rectifier. Three points must he kept in mind while using any type of diode.

1. Maximum forward current capacity
2. Maximum reverse voltage capacity
3. Maximum forward voltage capacity

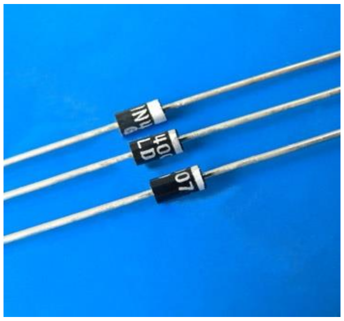


Fig:3.22 IN4007 diodes

The number and voltage capacity of some of the important diodes available in the market are as follows:

- Diodes of number IN4001, IN4002, IN4003, IN4004, IN4005, IN4006 and IN4007 have maximum reverse bias voltage capacity of 50V and maximum forward current capacity of 1 Amp.
- Diode of same capacities can be used in place of one another. Besides this diode of more capacity can be used in place of diode of low capacity but diode of low capacity cannot be used in place of diode of high capacity. For example, in place of IN4002; IN4001 or IN4007 can be used but IN4001 or IN4002 cannot be used in place of IN4007.The diode BY125made by company BEL is equivalent of diode from IN4001 to IN4003. BY 126 is equivalent to diodes IN4004 to 4006 and BY 127 is equivalent to diode IN4007.

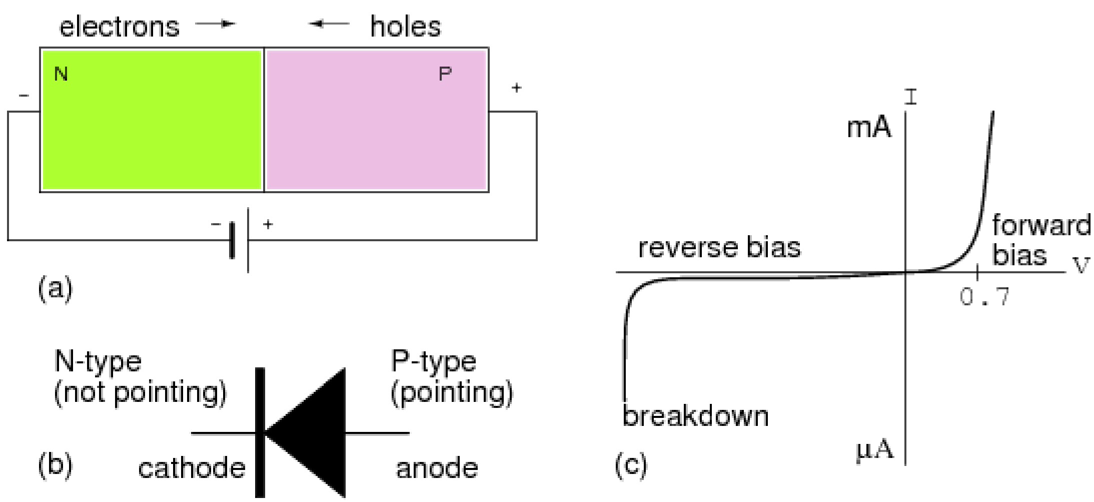


Fig:3.23 PN junction diode

3.8.1 PN Junction Operation

Now that you are familiar with P- and N-type materials, how these materials are joined together to form a diode, and the function of the diode, let us continue our discussion with the operation of the PN junction. But before we can understand how the PN junction works, we must first consider current flow in the materials that make up the junction and what happens initially within the junction when these two materials are joined together.

3.8.2 Current Flow in the N-Type Material

Conduction in the N-type semiconductor, or crystal, is similar to conduction in a copper wire. That is, with voltage applied across the material, electrons will move through the crystal just as current would flow in a copper wire. This is shown in figure 1-15. The positive potential of the battery will attract the free electrons in the crystal. These electrons will leave the crystal and flow into the positive terminal of the battery. As an electron leaves the crystal, an electron from the negative terminal of the battery will enter the crystal, thus completing the current path. Therefore, the majority current carriers in the N-type material (electrons) are repelled by the negative side of the battery and move through the crystal toward the positive side of the battery.

3.8.3 Current Flow in the P-Type Material

Current flow through the P-type material is illustrated. Conduction in the P material is by positive holes, instead of negative electrons. A hole moves from the positive terminal of the P material to the negative terminal. Electrons from the external circuit enter the negative terminal of the material and fill holes in the vicinity of this terminal. At the positive terminal, electrons are removed from the covalent bonds, thus creating new holes. This process continues as the steady stream of holes (hole current) moves toward the negative terminal.

3.9 Resistors

A resistor is a two-terminal electronic component designed to oppose an electric current by producing a voltage drop between its terminals in proportion to the current, that is, in accordance with Ohm's law:

$$V = IR$$

Resistors are used as part of electrical networks and electronic circuits. They are extremely commonplace in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel/chrome).

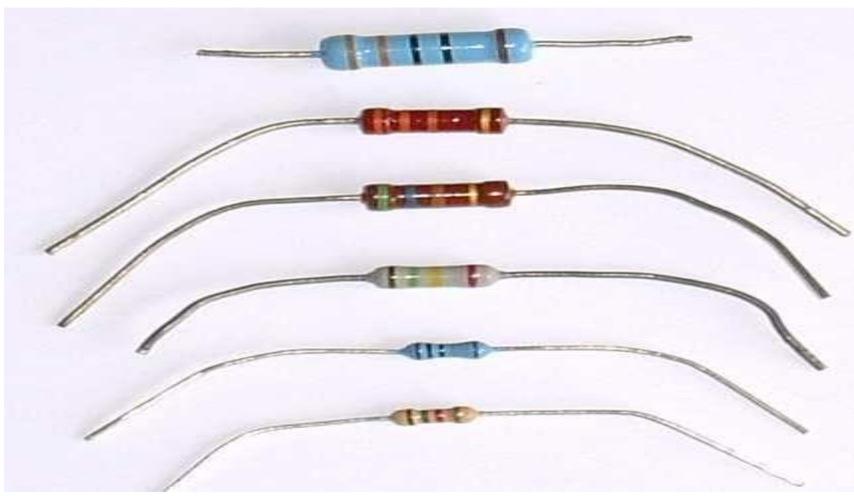


Fig:3.24 Resistors

The primary characteristics of resistors are their resistance and the power they can dissipate. Other characteristics include temperature coefficient, noise, and inductance. Less well-known is critical resistance, the value below which power dissipation limits the maximum permitted current flow, and above which the limit is applied voltage. Critical resistance depends upon the materials constituting the resistor as well as its physical dimensions; it's determined by design.

Resistors can be integrated into hybrid and printed circuits, as well as integrated circuits. Size, and position of leads (or terminals) are relevant to equipment designers; resistors must be physically large enough not to overheat when dissipating their power.

A resistor is a two-terminal passive electronic component which implements electrical resistance as a circuit element. When a voltage V is applied across the terminals of a resistor, a current I will flow through the resistor in direct proportion to that voltage. The reciprocal of the constant of proportionality is known as the resistance R, since, with a given voltage V, a larger value of R further "resists" the flow of current I as given by Ohm's law:

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

Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel-chrome). Resistors are also implemented within integrated circuits, particularly analog devices, and can also be integrated into hybrid and printed circuits.

The electrical functionality of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than 9 orders of magnitude. When specifying that resistance in an electronic design, the required precision of the resistance may require attention to the manufacturing tolerance of the chosen resistor, according to its specific application. The temperature coefficient of the resistance may also be of concern in some precision applications. Practical resistors are also specified as having a maximum power rating which must exceed the anticipated power dissipation of that resistor in a particular circuit: this is mainly of concern in power electronics applications. Resistors with higher power ratings are physically larger and may require heat sinking. In a high voltage circuit, attention must sometimes be paid to the rated maximum working voltage of the resistor.

The series inductance of a practical resistor causes its behavior to depart from ohms law; this specification can be important in some high-frequency applications for smaller values of resistance. In a low-noise amplifier or pre-amp the noise characteristics of a resistor may be an issue. The unwanted inductance, excess noise, and temperature coefficient are mainly dependent on the technology used in manufacturing the resistor.

They are not normally specified individually for a particular family of resistors manufactured using a particular technology.[1] A family of discrete resistors is also characterized according to its form factor, that is, the size of the device and position of its leads (or terminals) which is relevant in the practical manufacturing of circuits using them.

3.9.1 Units

The ohm (symbol: Ω) is the SI unit of electrical resistance, named after Georg Simon Ohm. An ohm is equivalent to a volt per ampere. Since resistors are specified and manufactured over a very large range of values, the derived units of milliohm (1 mΩ = 10^{-3} Ω), kilohm (1 kΩ = 10^{3} Ω), and megohm (1 MΩ = 10^{6} Ω) are also in common usage.

The reciprocal of resistance R is called conductance G = 1/R and is measured in Siemens (SI unit), sometimes referred to as a mho. Thus a Siemens is the reciprocal of an ohm: $S = \Omega^{-1}$. Although the concept of conductance is often used in circuit analysis, practical resistors are always specified in terms of their resistance (ohms) rather than conductance.

3.9.2 Theory of operation

Ohm's law

The behavior of an ideal resistor is dictated by the relationship specified in Ohm's law:

$$V = I \cdot R$$

Ohm's law states that the voltage (V) across a resistor is proportional to the current (I) passing through it, where the constant of proportionality is the resistance (R).

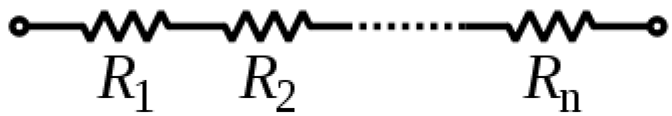
Equivalently, Ohm's law can be stated:

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

This formulation of Ohm's law states that, when a voltage (V) is present across a resistance (R), a current (I) will flow through the resistance. This is directly used in practical computations. For example, if a 300 ohm resistor is attached across the terminals of a 12 volt battery, then a current of 12 / 300 = 0.04 amperes (or 40 milliamperes) will flow through that resistor.

3.9.3 Series and parallel resistors

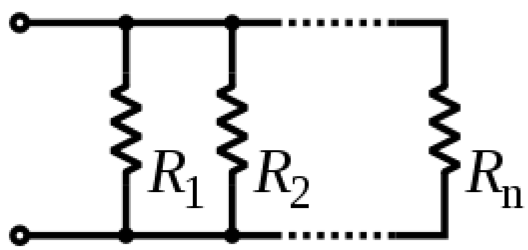
In a series configuration, the current through all of the resistors is the same, but the voltage across each resistor will be in proportion to its resistance. The potential difference (voltage) seen across the network is the sum of those voltages, thus the total resistance can be found as the sum of those resistances:



$$R_{eq} = R_1 + R_2 + \cdots + R_n$$

As a special case, the resistance of N resistors connected in series, each of the same resistance R, is given by NR.

Resistors in a parallel configuration are each subject to the same potential difference (voltage), however the currents through them add. The conductances of the resistors then add to determine the conductance of the network. Thus the equivalent resistance (R_{eq}) of the network can be computed:



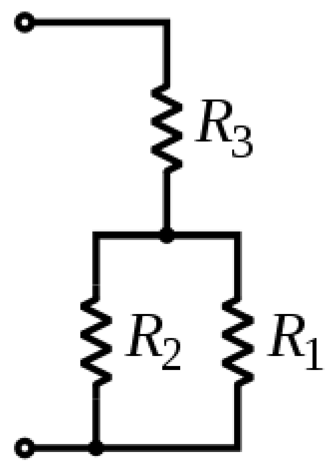
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

The parallel equivalent resistance can be represented in equations by two vertical lines "‖" (as in geometry) as a simplified notation. For the case of two resistors in parallel, this can be calculated using:

$$R_{\mathrm{eq}} = R_1 \| R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

As a special case, the resistance of N resistors connected in parallel, each of the same resistance R, is given by R/N.

A resistor network that is a combination of parallel and series connections can be broken up into smaller parts that are either one or the other. For instance,



$$R_{\mathrm{eq}} = (R_1 \| R_2) + R_3 = \frac{R_1 R_2}{R_1 + R_2} + R_3$$

However, some complex networks of resistors cannot be resolved in this manner, requiring more sophisticated circuit analysis. For instance, consider a cube, each edge of which has been replaced by a resistor. What then is the resistance that would be measured between two opposite vertices? In the case of 12 equivalent resistors, it can be shown that the corner-to-corner resistance is ⅚ of the individual resistance. More generally, the Y-Δ transform, or matrix methods can be used to solve such a problem.[2][3]

One practical application of these relationships is that a non-standard value of resistance can generally be synthesized by connecting a number of standard values in series and/or parallel. This can also be used to obtain a resistance with a higher power rating than that of the individual resistors used. In the special case of N identical resistors all connected in series or all connected in parallel, the power rating of the individual resistors is thereby multiplied by N.

3.9.4 Power dissipation

The power P dissipated by a resistor (or the equivalent resistance of a resistor network) is calculated as: $P = I^2R = IV = \frac{V^2}{R}$

The first form is a restatement of Joule's first law. Using Ohm's law, the two other forms can be derived.

The total amount of heat energy released over a period of time can be determined from the integral of the power over that period of time:

$$W = \int_{t_1}^{t_2} v(t)i(t)\,dt.$$

Practical resistors are rated according to their maximum power dissipation. The vast majority of resistors used in electronic circuits absorb much less than a watt of electrical power and require no attention to their power rating. Such resistors in their discrete form, including most of the packages detailed below, are typically rated as 1/10, 1/8, or 1/4 watt. Resistors required to dissipate substantial amounts of power, particularly used in power supplies, power conversion circuits, and power amplifiers, are generally referred to as power resistors; this designation is loosely applied to resistors with power ratings of 1 watt or greater. Power resistors are physically larger and tend not to use the preferred values, color codes, and external packages described below.

If the average power dissipated by a resistor is more than its power rating, damage to the resistor may occur, permanently altering its resistance; this is distinct from the reversible change in resistance due to its temperature coefficient when it warms. Excessive power dissipation may raise the temperature of the resistor to a point where it can burn the circuit board or adjacent components, or even cause a fire. There are flameproof resistors that fail (open circuit) before they overheat dangerously.

Note that the nominal power rating of a resistor is not the same as the power that it can safely dissipate in practical use. Air circulation and proximity to a circuit board, ambient temperature, and other factors can reduce acceptable dissipation significantly. Rated power dissipation may be given for an ambient temperature of 25 °C in free air. Inside an equipment case at 60 °C, rated dissipation will be significantly less; a resistor dissipating a bit less than the maximum figure given by the manufacturer may still be outside the safe operating area and may prematurely fail.

3.10 Capacitors

A capacitor or condenser is a passive electronic component consisting of a pair of conductors separated by a dielectric. When a voltage potential difference exists between the conductors, an electric field is present in the dielectric. This field stores energy and produces a mechanical force between the plates. The effect is greatest between wide, flat, parallel, narrowly separated conductors.

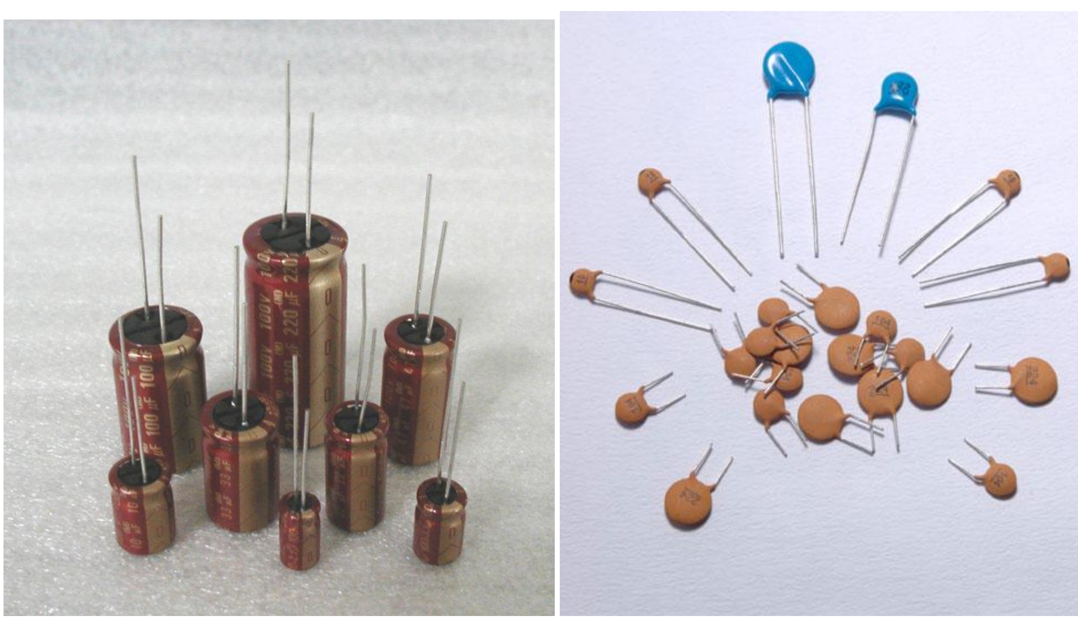


Fig:3.25 Capacitors

An ideal capacitor is characterized by a single constant value, capacitance, which is measured in farads. This is the ratio of the electric charge on each conductor to the potential difference between them. In practice, the dielectric between the plates passes a small amount of leakage current. The conductors and leads introduce an equivalent series resistance and the dielectric has an electric field strength limit resulting in a breakdown voltage.

The properties of capacitors in a circuit may determine the resonant frequency and quality factor of a resonant circuit, power dissipation and operating frequency in a digital logic circuit, energy capacity in a high-power system, and many other important aspects.

A capacitor (formerly known as condenser) is a device for storing electric charge. The forms of practical capacitors vary widely, but all contain at least two conductors separated by a non-conductor. Capacitors used as parts of electrical systems, for example, consist of metal foils separated by a layer of insulating film.

Capacitors are widely used in electronic circuits for blocking direct current while allowing alternating current to pass, in filter networks, for smoothing the output of power supplies, in the resonant circuits that tune radios to particular frequencies and for many other purposes.

A capacitor is a passive electronic component consisting of a pair of conductors separated by a dielectric (insulator). When there is a potential difference (voltage) across the conductors, a static electric field develops in the dielectric that stores energy and produces a mechanical force between the conductors. An ideal capacitor is characterized by a single constant value, capacitance, measured in farads. This is the ratio of the electric charge on each conductor to the potential difference between them.

The capacitance is greatest when there is a narrow separation between large areas of conductor, hence capacitor conductors are often called "plates", referring to an early means of construction. In practice the dielectric between the plates passes a small amount of leakage current and also has an electric field strength limit, resulting in a breakdown voltage, while the conductors and leads introduce an undesired inductance and resistance.

3.10.1 Theory of operation

Main article: Capacitance

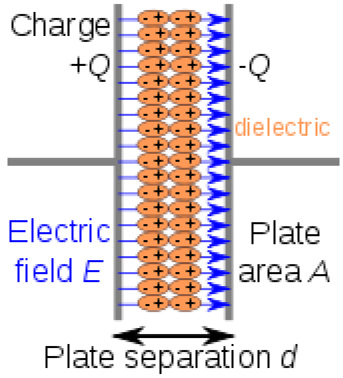


Fig:3.26 Operation of capacitors

Charge separation in a parallel-plate capacitor causes an internal electric field. A dielectric (orange) reduces the field and increases the capacitance.

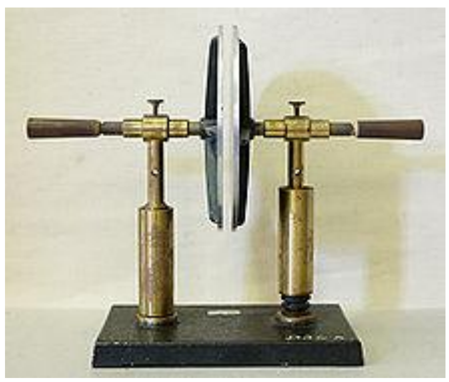


Fig:3.27 Simple demonstration of a parallel-plate capacitor

A capacitor consists of two conductors separated by a non-conductive region[8]. The non-conductive region is called the dielectric or sometimes the dielectric medium. In simpler terms, the dielectric is just an electrical insulator. Examples of dielectric mediums are glass, air, paper, vacuum, and even a semiconductor depletion region chemically identical to the conductors. A capacitor is assumed to be self-contained and isolated, with no net electric charge and no influence from any external electric field. The conductors thus hold equal and opposite charges on their facing surfaces, and the dielectric develops an electric field. In SI units, a capacitance of one farad means that one coulomb of charge on each conductor causes a voltage of one volt across the device. The capacitor is a reasonably general model for electric fields within electric circuits. An ideal capacitor is wholly characterized by a constant capacitance C, defined as the ratio of charge ±Q on each conductor to the voltage V between them:

$$C = \frac{Q}{V}$$

Sometimes charge build-up affects the capacitor mechanically, causing its capacitance to vary. In this case, capacitance is defined in terms of incremental changes:

$$C = \frac{\mathrm{d}q}{\mathrm{d}v}$$

3.10.2 Energy storage

Work must be done by an external influence to "move" charge between the conductors in a capacitor. When the external influence is removed the charge separation persists in the electric field and energy is stored to be released when the charge is allowed to return to its equilibrium position. The work done in establishing the electric field, and hence the amount of energy stored, is given by:[11]

$$W = \int_{q=0}^{Q} V\,\mathrm{d}q = \int_{q=0}^{Q} \frac{q}{C}\mathrm{d}q = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}VQ.$$

3.10.3 Current-voltage relation

The current i(t) through any component in an electric circuit is defined as the rate of flow of a charge q(t) passing through it, but actual charges, electrons, cannot pass through the dielectric layer of a capacitor, rather an electron accumulates on the negative plate for each one that leaves the positive plate, resulting in an electron depletion and consequent positive charge on one electrode that is equal and opposite to the accumulated negative charge on the other. Thus the charge on the electrodes is equal to the integral of the current as well as proportional to the voltage as discussed above. As with any antiderivative, a constant of integration is added to represent the initial voltage v (t_0). This is the integral form of the capacitor equation,[12]

$$v(t) = \frac{q(t)}{C} = \frac{1}{C}\int_{t_0}^{t} i(\tau)\mathrm{d}\tau + v(t_0)$$

.

Taking the derivative of this, and multiplying by C, yields the derivative form,[13]

$$i(t) = \frac{\mathrm{d}q(t)}{\mathrm{d}t} = C\frac{\mathrm{d}v(t)}{\mathrm{d}t}.$$

The dual of the capacitor is the inductor, which stores energy in the magnetic field rather than the electric field. Its current-voltage relation is obtained by exchanging current and voltage in the capacitor equations and replacing C with the inductance L.

3.10.4 Parallel plate model

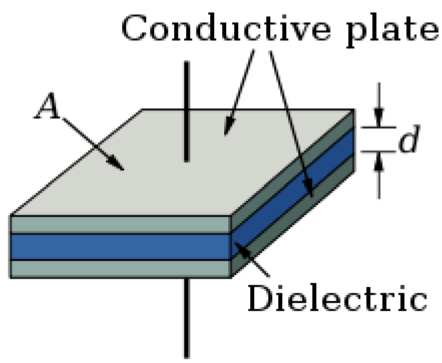


Fig:3.28 Parallel plate

Dielectric is placed between two conducting plates, each of area A and with a separation of d. The simplest capacitor consists of two parallel conductive plates separated by a dielectric with permittivity ε (such as air). The model may also be used to make qualitative predictions for other device geometries. The plates are considered to extend uniformly over an area A and a charge density $\pm\rho = \pm Q/A$ exists on their surface. Assuming that the width of the plates is much greater than their separation d, the electric field near the centre of the device will be uniform with the magnitude $E = \rho/\varepsilon$. The voltage is defined as the line integral of the electric field between the plates

$$V = \int_0^d E\mathrm{d}z = \int_0^d \frac{\rho}{\varepsilon}\mathrm{d}z = \frac{\rho d}{\varepsilon} = \frac{Qd}{\varepsilon A}.$$

Solving this for C = Q/V reveals that capacitance increases with area and decreases with separation

$$C = \frac{\varepsilon A}{d}.$$

The capacitance is therefore greatest in devices made from materials with a high permittivity.

3.11 Electromagnetic Coil

A coil is a series of loops. A coiled coil is a structure where the coil itself is in turn also looping, these objects are used commonly and are very important, some of their functions may be in bikes, cars trains and planes. Often used in conjunction with a thread.

Electromagnetic coils

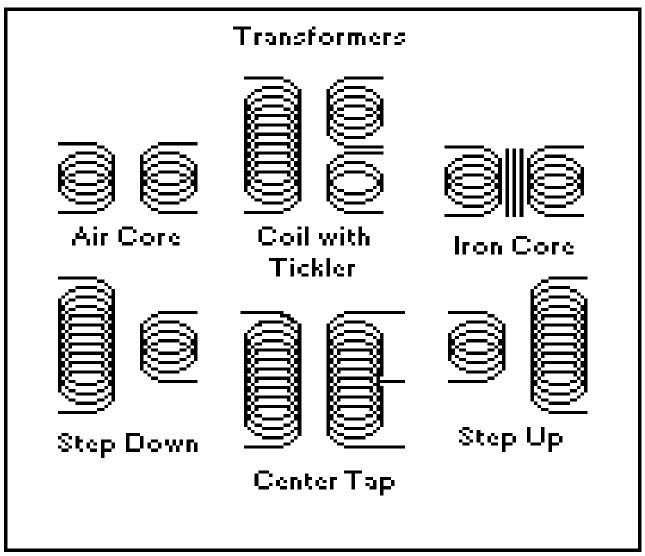


Fig:3.29 Diagram of typical transformer configurations

An electromagnetic coil (or simply a "coil") is formed when a conductor (usually an insulated solid copper wire) is wound around a core or form to create an inductor or electromagnet. One loop of wire is usually referred to as a turn, and a coil consists of one or more turns. For use in an electronic circuit, electrical connection terminals called taps are often connected to a coil. Coils are often coated with varnish and/or wrapped with insulating tape to provide additional insulation and secure them in place. A completed coil assembly with taps etc. is often called a winding. A transformer is an electromagnetic device that has a primary winding and a secondary winding that transfers energy from one electrical circuit to another by magnetic coupling without moving parts. The term tickler coil usually refers to a third coil placed in relation to a primary coil and secondary coil. A coil tap is a wiring feature found on some electrical transformers, inductors and coil pickups, all of which are sets of wire coils. The coil tap(s) are points in a wire coil where a conductive patch has been exposed (usually on a loop of wire that extends out of the main coil body). As self induction is larger for larger coil diameter the current in a thick wire tries to flow on the inside. The ideal use of copper is achieved by foils. Sometimes this means that a spiral is a better alternative. Multilayer coils have the problem of interlayer capacitance, so when multiple layers are needed the shape needs to be radically changed to a short coil with many layers so that the voltage between consecutive layers is smaller (making them more spiral like).

3.11.1 Analysis

The inductance of single-layer air-cored cylindrical coils can be calculated to a reasonable degree of accuracy with the simplified formula

$$\mu\mathrm{H} = \frac{R^2 N^2}{9R + 10L}$$

where Henry [μH] (microhenries) are units of inductance, *R* is the coil radius (measured in inches to the center of the conductor), *N* is the number of turns, and *L* is the length of the coil in inches. The online Coil Inductance Calculator calculates the inductance of any coil using this formula. Higher accuracy estimates of coil inductance require calculations of considerably greater complexity.

Note that if the coil has a ferrite core, or one made of another metallic material, its inductance cannot be calculated with this formula.

Coil examples

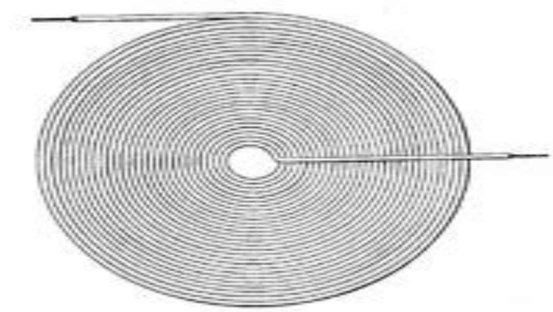


Fig:3.30 Nikola tesla's flat spiral coil.

Some common electromagnetic coils include:

- A bifilar coil is a coil that employs two parallel windings.
- A Barker coil is used in low field NMR imaging.
- A Balun is set of transformer coils for transmission lines.
- A Braunbeck coil is used in geomagnetic research.
- A degaussing coil is used in the process of removing permanent magnetism (magnetic hysteresis) from an object.
- A choke coil (or choking coil) is low-resistance inductor used to block alternating current while passing direct current.
- A Flat coil is used in thin electric motors.
- A Garrett coil is used in metal detectors.
- A Helmholtz coil is a device for producing a region of nearly uniform magnetic field.
- A hybrid coil (or bridge transformer) is a single transformer that effectively has three windings.
- An induction coil (or ignition coil) is an electrical device in common use as the ignition system (ignition coil or spark coil) of internal-combustion engines.
- A loading coil is, in electronics, a coil (inductor) inserted in a circuit to increase its inductance. Archaically called Pupin coils.

- A multiple coil magnet is an electromagnet that has several coils of wire connected in parallel.
- A Maxwell coil is a device for producing almost a constant magnetic field.
- A Micro coil use in security devices.
- A Oudin coil is a disruptive discharge coil.
- The polyphase coils are connected together in a polyphase system such as a generator or motor.
- A relay coil is the copper winding part of a relay that produces a magnetic field that actuates the mechanism.
- A Repeating coil is a voice-frequency transformer.
- A Rogowski coil is an electrical device for measuring alternating current.
- A Rook coil is a high Q coil wave wound cylindrical coil often used for crystal sets.
- A single coil is a type of pickup for the electric guitar.
- A solenoid is a mechanical device, based on a coil of wire, that usually converts energy into linear motion, however solenoids also come in a rotary motion (normally up to a turn of 90 degrees).
- A Spider coil is a high Q wave wound flat coil often used for crystal sets, that somewhat resembles a spider's web.
- A telephone cord is usually manufactured in a coiled fashion, as to allow maximum length while taking up minimum space when not in use.
- A Tesla coil is category of disruptive discharge coils, usually denoting a resonant transformer that generates very high voltages at radio frequencies.
- A Universal coil or a Dual Lateral coil is a self supporting coil used for high voltage applications.
- A voice coil which is mounted to the moving cone of a loudspeaker.

4. DIAGRAM AND DESCRIPTION

4.1 Schematic Diagram

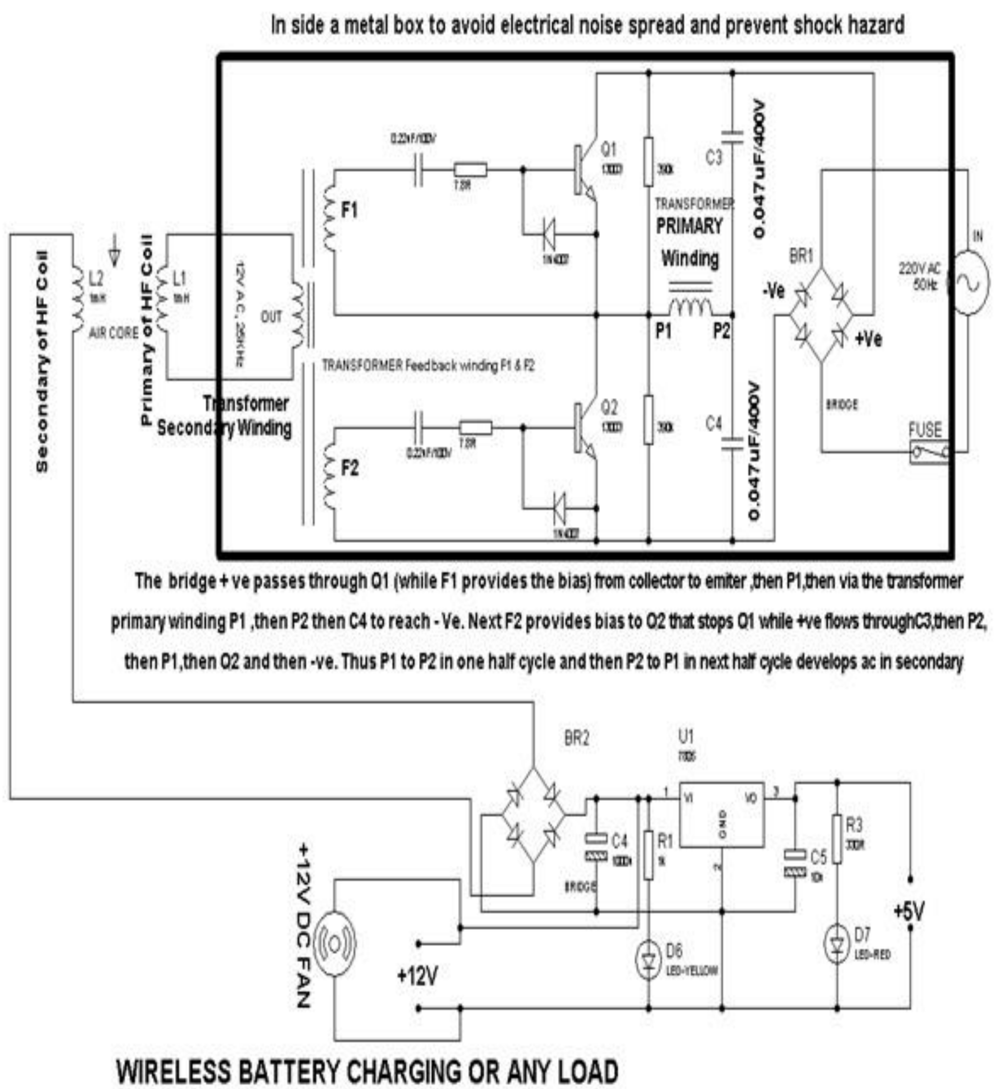


Fig:4.1 Schematic diagram

4.2 Description

Electronic transformer works on half bridge and double line frequency. The AC power is given as an input to the bridge rectifier where it is converted into DC through resistor capacitor gets charged .in one half cycle Q1 (collector to emitter) starts conducting, F1 provides biasing for this Q1 transistor. Current flows from P1 to P2 of primary coil. Then current passes through capacitor C4 and reaches ground. In another half cycle Q2 (collector to emitter) starts conducting and F2 provides bias for this transistor. Then current flows through C3 and then P2 to P1 reaches Q2 and then negative. So in one half cycle flow of current is from P1 to P2,in another half cycle flow of current is from P2 to P1. Biasing for F1, F2 is done automatically i.e. we can't say that when which coil gets bias. so current flowing in the primary coil in both half cycles generates A.C in secondary coil. As the transistors are fast switching devices frequency of A.C becomes 25KHz.This is fed copper windings L1 which are connected to secondary of transformer.L1 transfers the 25 KHz A.C. to L2 by means of EMF (Principle of transformer).

Voltage induced L2 coil is fed to 4 diodes forming a Bridge Rectifier that delivers dc which is then filtered by an electrolytic capacitor of about 1000microf. The filtered dc being unregulated IC LM7805 is used to get 5v constant at its pin no 3 irrespective of input dc varying from 9v to 14v.

The regulated 5volts dc is further filtered by a small electrolytic capacitor of 10 micro F for any noise so generated by the circuit which can be used for battery charging. One LED is connected of this 5v point in series with a resistor of 330ohms to the ground i.e. negative voltage to indicate 5v power supply availability. The 5v dc is used for other applications as on when required. The output of bridge rectifier i.e., +12V is taken to drive the 12V DC Fan.

4.2.1 Note

The electronic design considerations

The topology of the circuit is the classic half-bridge. The control circuit could have been realized using an IC (so fixing the operating frequency), but there is a more economical solution which consists of a self-oscillating circuit where the two transistors are drive-in opposing phase by feedback from the output circuit.

Circuit description

The line voltage is rectified by the full-bridge rectifier, generating a semi-sinusoidal voltage at double the

line frequency.

The frequency of oscillation then depends mainly upon the size and maximum flux density of the ferrite core used in the feedback transformer, and the storage time of the transistors. When the cycle has started, the current in the feedback transformer increases until the core saturates. At this point the feedback drive of the active transistors is therefore removed, and, once its storage time has passed, it turns off. In this application the oscillation frequency would be around 25kHz.The dependence upon the storage time is minimized by the RC network at the base of the transistor, which increases the rate of charge extraction from the base at turn-off. The network also serves to decouple the base from the oscillation caused by the base transformer at turn-off, preventing spurious turn-on of the device.

4.2.2 Voltage rating

The required voltage rating of the devices is defined by the half-bridge topology. Supplying the circuit with 220V RMS A.C. mains, calculating peak value, and adding a safety margin, gives a maximum supply

voltage VCC of:

$V_{CC(max)} = 220V \times \sqrt{2} + 10\%$

= 310V + 10%.

≈ 350V.

To this figure must also be added the overvoltage generated by the input filter at turn-off. In practice,

devices are used with a rating of:

$V_{CE(max)}$ = 450 - 500V

4.2.3 Current rating

The nature of the half-bridge topology is such that in normal operation, half the supply voltage is dropped across each device, so from the above figures VCE in the steady state is 310V /2, 155V. Hence the collector current in the steady state can be calculated using.

$P_{OUT} = I_{C(RMS)} \cdot V_{CE(RMS)}$

$V_{CE(RMS)} = 1/2 \cdot V_{mains}$

$I_{C(RMS)} = 2 \cdot P_{OUT} / V_{mains}$

$I_{C(RMS)} = I_{C(peak)} / \sqrt{2}$

$I_{C(peak)} = 2 \cdot \sqrt{2} \cdot P_{OUT} / V_{mains}$

$= 2 \cdot \sqrt{2} \cdot 50W / 220V$

$I_{C(peak)} = 0.64A$

As stated above, when the circuit is first turned on, the low initial resistance the load causes a large current to flow through the transistors. This current can be up to ten times the current in the steady state, and the devices must be selected to withstand this. In this example then it is recommended that the device used is bipolar transistor, rated at 450V and around 2A i.e. Q1 and Q2. Storage and fall times are decided by the R 330k and C3, C4 & fall time, t fall, of the transistors influences the losses of the circuit, while the storage time, ts , is important as it affects the switching frequency of the converter. The nature of the processes used to produce bipolar transistors means that the storage time between batches of transistors may vary considerably. The transistors used must be manufactured, tested and selected to have storage times within certain limits. Transistors with too large a storage time may cause the circuit to oscillate below the operating limits of the output transformer, causing saturation of the core towards the end of each cycle. This will cause a spike in the collector current of the transistors every cycle, which will eventually cause them to overheat and be destroyed.

5. LAYOUT DIAGRAM

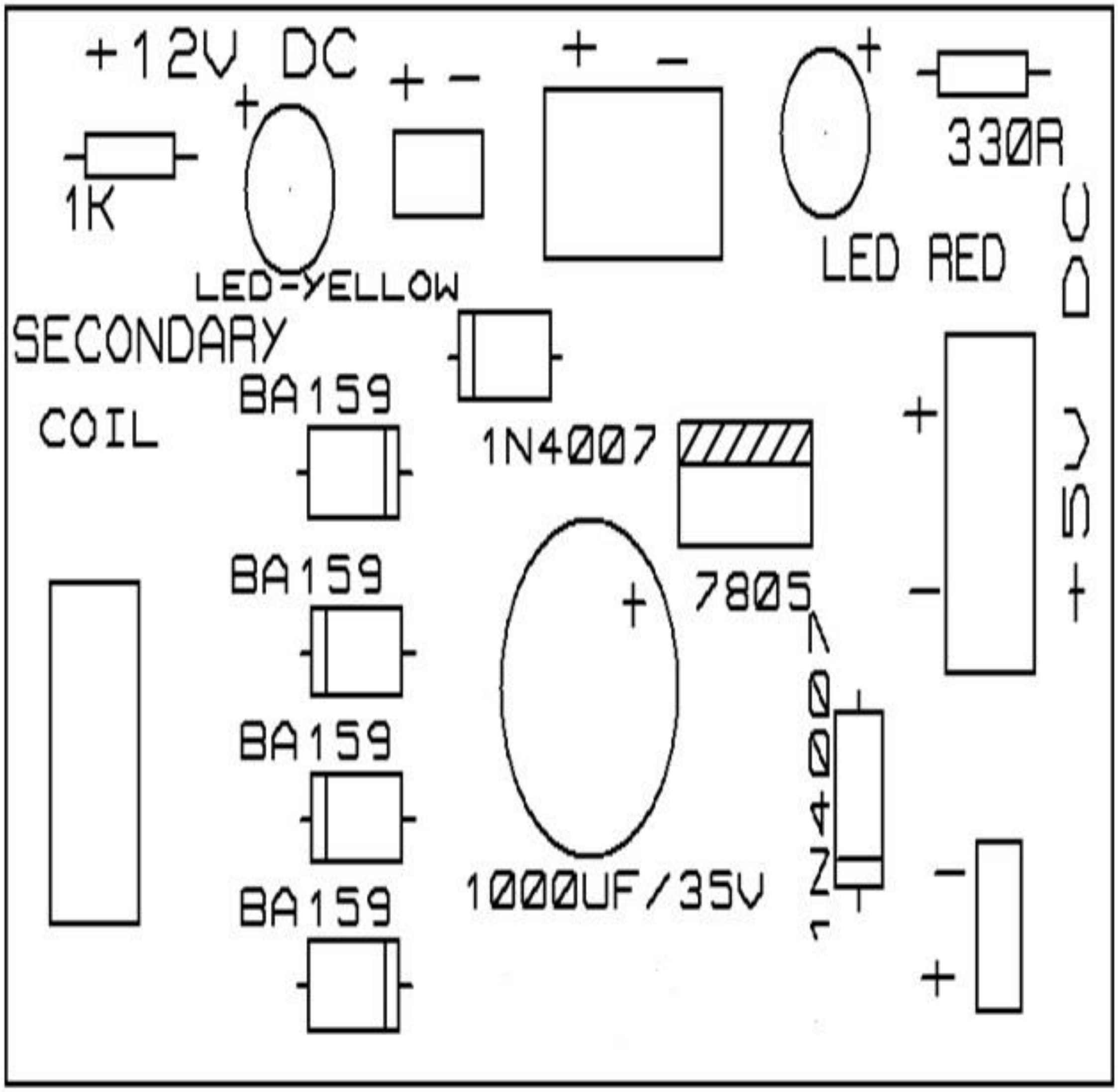


Fig:5.1 Layout diagram

6.HARDWARE TESTING

6.1 Continuity test

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, damaged components, or excessive resistance, the circuit is "open".

Devices that can be used to perform continuity tests include multi meters 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.

This test is the performed just after the hardware soldering and configuration has been completed. This test aims at finding any electrical open paths in the circuit after the soldering. Many a times, the electrical continuity in the circuit is lost due to improper soldering, wrong and rough handling of the PCB, improper usage of the soldering iron, component failures and presence of bugs in the circuit diagram. We use a multi meter to perform this test. We keep the multi meter in buzzer mode and connect the ground terminal of the multi meter to the ground. We connect both the terminals across the path that needs to be checked. If there is continuation then you will hear the beep sound.

6.2 Power on test

This test is performed to check whether the voltage at different terminals is according to the requirement or not. We take a multi meter and put it in voltage mode. Remember that this test is performed without ICs. Firstly, if we are using a transformer we check the output of the transformer; whether we get the required 12V AC voltage (depends on the transformer used in for the circuit). If we use a battery then we check if the battery is fully charged or not according to the specified voltage of the battery by using multimeter.

Then we apply this voltage to the power supply circuit. Note that we do this test without ICs because if there is any excessive voltage, this may lead to damaging the ICs. If a circuit consists of voltage regulator then we check for the input to the voltage regulator (like 7805, 7809, 7815, 7915 etc) i.e., are we getting an input of 12V and a required output depending on the regulator used in the circuit.
EX: if we are using 7805 we get output of 5V and if using 7809 we get 9V at output pin and so on.

This output from the voltage regulator is given to the power supply pin of specific ICs. Hence we check for the voltage level at those pins whether we are getting required voltage. Similarly, we check for the other terminals for the required voltage. In this way we can assure that the voltage at all the terminals is as per the requirement.

7. RESULTS

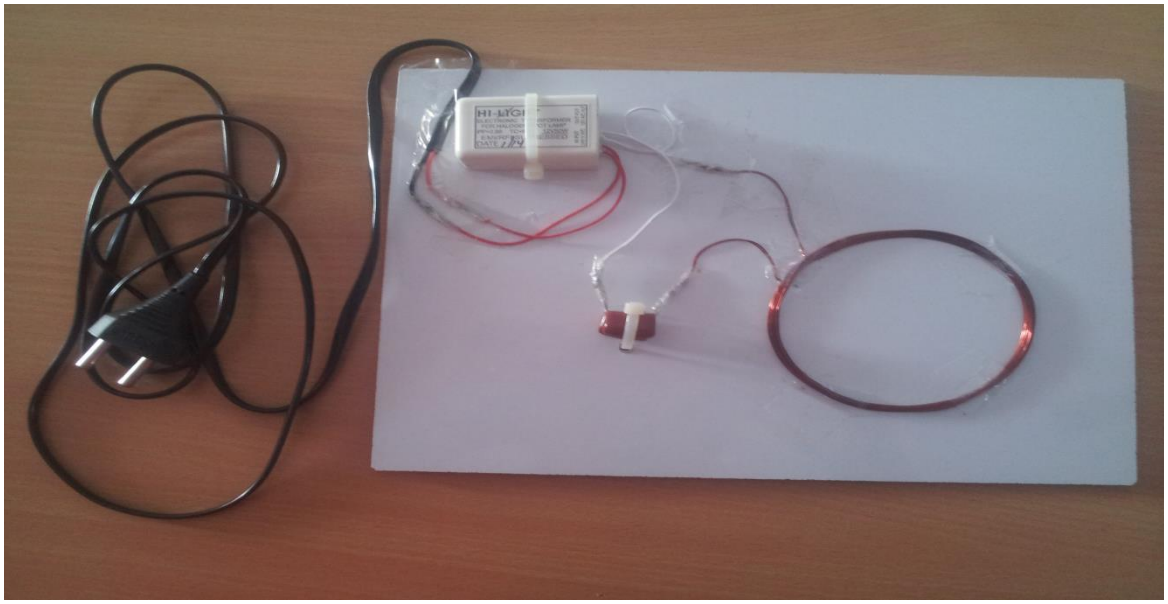


Fig:8.1 Primary circuit

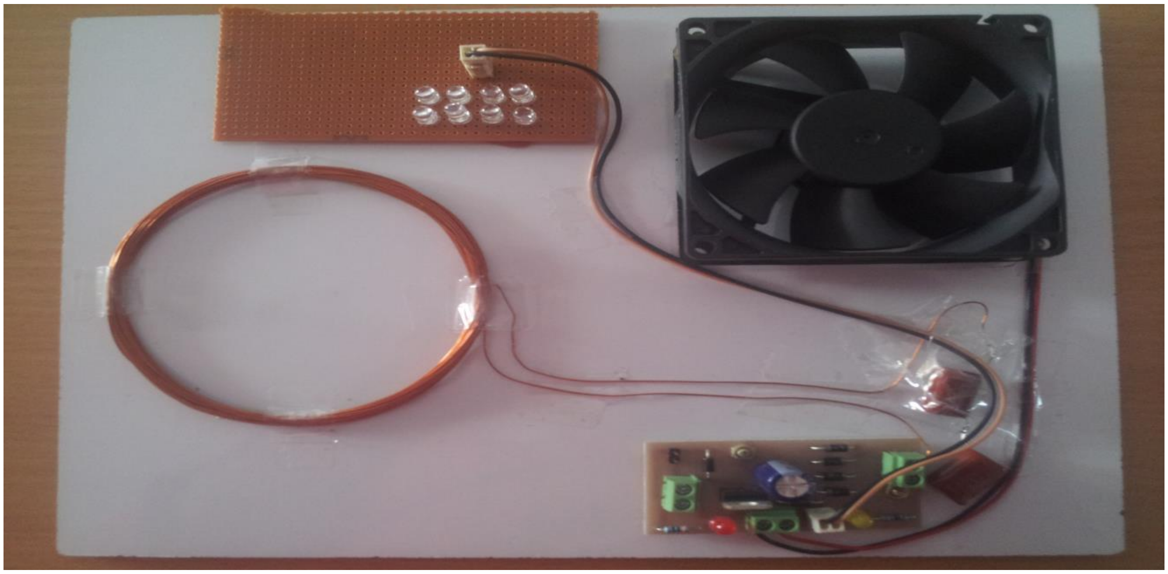


Fig:8.2 Secondary circuit

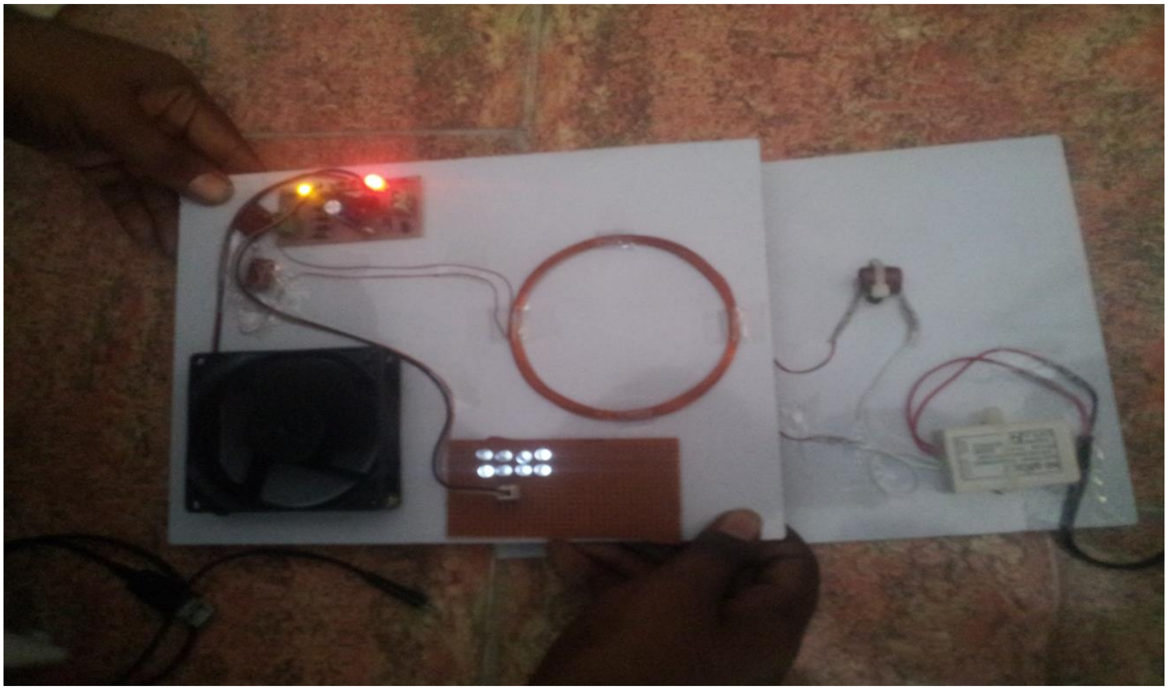


Fig:8.3 Final output

8.CONCLUSION

Electrical and electronic devices can now be placed into areas earlier inaccessible since WPT technologies can now bring power wirelessly to these devices anywhere. This is resulting in technology breakthroughs in areas of medicine such as endoscopy, pacemakers, defibrillator, etc. In many areas, batteries losing charge can be life threatening. Now that fear of losing charge is put to rest by the environment itself providing the ability to recharge using WPT anywhere, anytime. The emerging technologies enabled by WPT are impacting our lives in major ways, and a breathtaking future is ours to behold! Wireless power transmission is a promising area of study. The ability to transport power from a power generation facility on a satellite celestial body to Earth would help the human population keep pace with its energy demand.

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