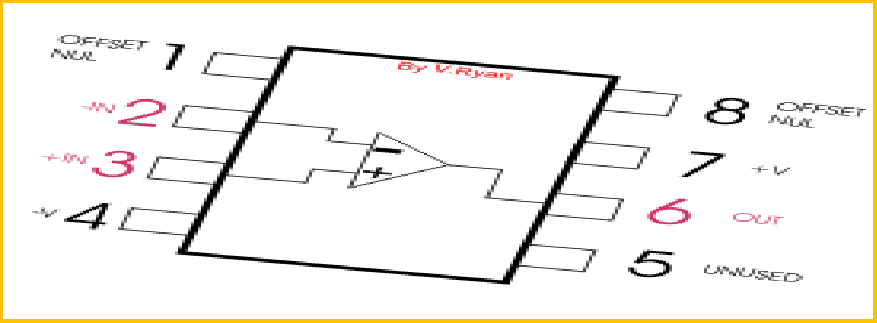
ANALOG ELECTRONICS – II
STUDY MATERIAL



Name of the Course: Diploma in Electronics & Telecomm. Engg.

Course code : ETT 401 Semester : 4th

Designed & Developed

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CHAPTER- 1. OPTO ELECTRONICS.

1.1 Define the concept of Photodiode: A photodiode is a semiconductor device that converts light into current. The current is generated when photons are absorbed in the photodiode. A small amount of current is also produced when no light is present. Photodiodes may contain optical filters, builtin lenses, and may have large or small surface areas. Photodiodes usually have a slower response time as its surface area increases. The common, traditional solar cell used to generate electric solar power is a large area photodiode.

Photoconductivity cells and Photovoltaic cells. When used in zero bias or *photovoltaic mode*, the flow of photocurrent out of the device is restricted and a voltage builds up. This mode exploits the photovoltaic effect, which is the basis for solar cells – a traditional solar cell is just a large area photodiode.

Photoconductive mode: In this mode the diode is often reverse biased (with the cathode driven positive with respect to the anode). This reduces the response time because the additional reverse bias increases the width of the depletion layer, which decreases the junction's capacitance. The reverse bias also increases the dark current without much change in the photocurrent

1.2 Define the concept of Light sensing Devices ,Photo active Devices & Light Sensors.

Light Sensor : A **Light Sensor** generates an output signal indicating the intensity of light by measuring the radiant energy that exists in a very narrow range of frequencies basically called “light”, and which ranges in frequency from “Infra-red” to “Visible” up to “Ultraviolet” light spectrum.

The Light Sensor is a passive devices that convert this “light energy” whether visible or in the infra-red parts of the spectrum into an electrical signal output. Light sensors are more commonly known as “Photoelectric Devices” or “Photo Sensors” because the convert light energy (photons) into electricity (electrons).

1.3 Explain construction & working of LDR, LED, LCD, Phototransistor, Infrared transmitter and receiver.

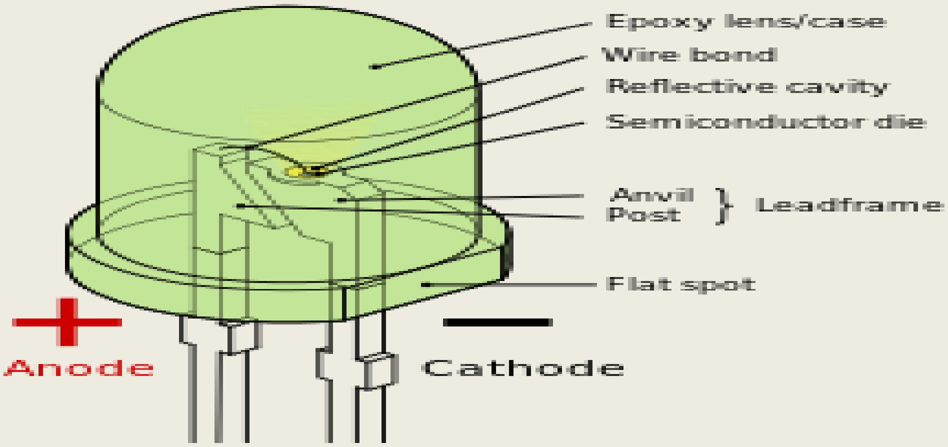
Light Dependent Resistor:

Typical LDR

As its name implies, the **Light Dependent Resistor** (LDR) is made from a piece of exposed semiconductor material such as cadmium sulphide that changes its electrical resistance from several thousand Ohms in the dark to only a few hundred Ohms when light falls upon it by creating hole-electron pairs in the material.

Light-Emitting Diode (LED):

A **light-emitting diode** (**LED**) is a two-lead semiconductor light source. It is a pn-junction diode, which emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.



Liquid-Crystal Display (**LCD**): A **liquid-crystal display** (**LCD**) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly.

LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images which can be displayed or hidden, such as preset words, digits, and 7-segment displays as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements.

The Phototransistor:

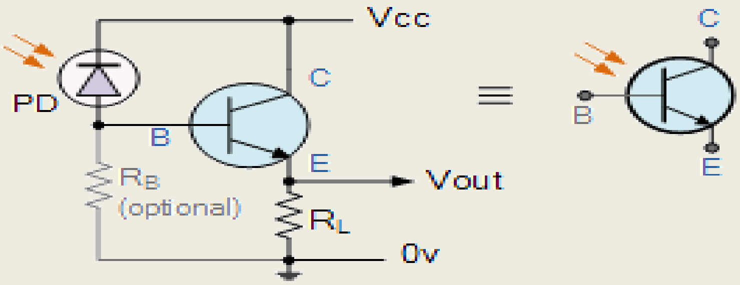


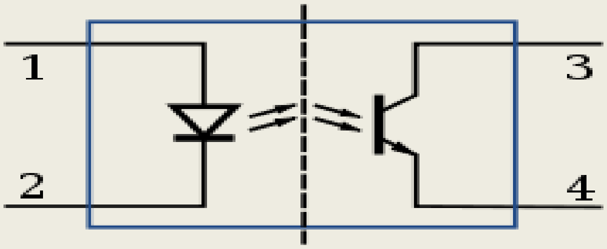
Photo-transistor

A **Phototransistor** which is basically a photodiode with amplification. The Phototransistor light sensor has its collector-base PN-junction reverse biased exposing it to the radiant light source.

Infrared (**IR**) is invisible radiant energy, electromagnetic radiation with longer wavelengths than those of visible light, extending from the nominal red edge of the visible spectrum at 700 nanometers

1.4 Explain Opto-isolator & optical sensors.

Opto-isolator: It is a device that uses light to couple a signal from its input to its output . The LED is on the ,left & the photo diode is on the right . Here the output from LED circuit is coupled via light to the photodiode circuit.



Schematic diagram of an opto-isolator showing source of light (LED) on the left, dielectric barrier in the center, and sensor (phototransistor) on the right.

Optical Sensor :

A **fiber optic sensor** is a sensor that uses optical fiber either as the sensing element ("intrinsic sensors"), or as a means of relaying signals from a remote sensor to the electronics that process the signals ("extrinsic sensors"). Fibers have many uses in remote sensing.

1.5 What is Laser and basic light theory & Laser theory .

A **laser** is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The term "laser" originated as an acronym for "**light amplification by stimulated emission of radiation**". A laser differs from other sources of light because it emits light *coherently*.Semiconductor lasers or laser diodes play an important part in our everyday lives by providing cheap and compact-size lasers. They consist of complex multi-layer structures requiring nanometer scale accuracy and an elaborate design. Their theoretical description is important not only from a fundamental point of view, but also in order to generate new and improved designs.

1.6 Describe working of Laser Diodes

A **laser diode**, or **LD**, is an electrically pumped semiconductor laser in which the active medium is formed by a p-n junction of a semiconductor diode similar to that found in a light-emitting diode.A laser diode is electrically a P-i-n diode. The active region of the laser diode is in the intrinsic (I) region, and the carriers, electrons and holes, are pumped into it from the N and P regions respectively. While initial diode laser research was conducted on simple P-N diodes, all modern lasers use the double-hetero structure implementation, where the carriers and the photons are confined in order to maximize their chances for recombination and light generation. Unlike a regular diode used in electronics, the goal for a laser diode is that all carriers recombine in the I region, and produce light. Thus, laser diodes are fabricated using direct band gap semiconductors. The laser diode epitaxial structure is grown using one of the crystal growth techniques, usually starting from an N doped substrate, and growing the I doped active layer, followed by the P doped cladding, and a contact layer. The active layer most often consists of quantum wells, which provide lower threshold current and higher efficiency.

CHAPTER -2 . INTEGRATED CIRCUITS :

***2*.1 Define the term IC and its uses &State the different types of ICs. An** integrated circuit **or** monolithic integrated circuit **(also referred to as an** IC**, a** chip**, or a** microchip**) is a set of electronic circuits on one small plate ("chip") of semiconductor material, normally silicon. This can be made much smaller than a discrete circuit made from independent components. ICs can be made very compact, having up to several billion transistors and other electronic components in an area the size of a fingernail.**

Need of Integrated Circuits.

The operations today performed by IC's were earlier performed by using vacuum tubes. Vacuum tubes consisted of electrodes inside a glass tube filled with vacuum. They were slower in operation, expensive and bigger in size. In order to make technical advancements it was necessary to increase the number of components which in turn would increase the cost and size. Also, previously all the components were individually connected whereas today different components in an IC are printed as a single unit using photolithography. Very thin paths of metal like copper and aluminum are laid directly on the same piece of material. These thin paths function like wires and electrically integrate all the different components of the integrated circuit.

Types of Integrated Circuits .There are mainly two types of IC ***s*** available.

1. **Digital Integrated Circuits:**

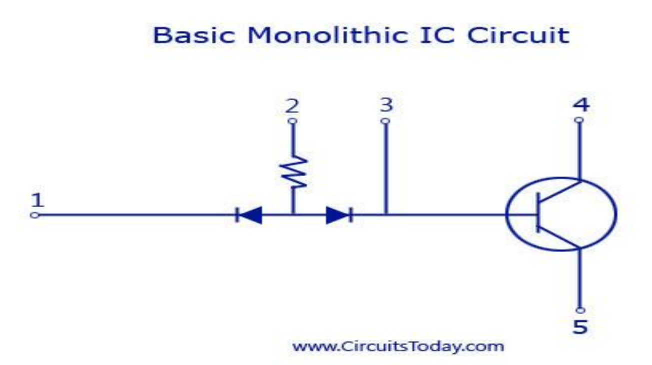
Digital IC's are the one's which work only on two defined levels 1's and 0's. They work on binary mathematics. They can contain millions of logic gates, flip-flops etc integrated on a single chip. Microprocessors and microcontrollers are examples of digital IC's

2. Analog Integrated Circuits:

Sensors, OP-AMP’s are analog IC’s. They work by processing continuous signals. They perform functions such as filtering, amplification, modulation, demodulation etc.

To know the basics a sample circuit must be considered to be converted to its monolithic form. With basic components like resistor, diode, and transistor a basic circuit is first made.

Basic Monolithic IC Circuit:

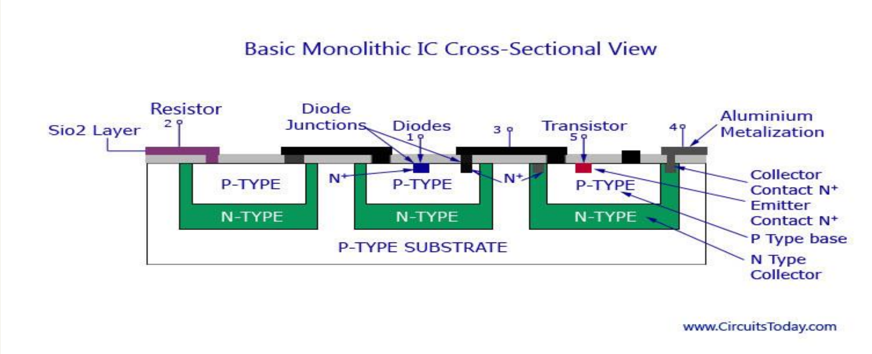


Basic Monolithic IC Circuit

www.CircuitsToday.com

With the basic circuit, the different layers for the monolithic IC are then considered. The basic structure of a monolithic IC will have 4 layers of different materials. The base layer will be a P-type silicon layer and is named as the substrate layer. This layer will have a typical thickness of 200 micrometer. Silicon is the preferred semiconductor for the P-type and N-type layer because of its favourable characteristics for the manufacturing of an IC.

The layer above the substrate P-type silicon layer is the N-type layer. All the active and passive components required for the circuit are fabricated onto this layer. This layer has a typical thickness of 25 micrometer. The N-type silicon material is grown as a single crystal extension of the P-layer and the components are required are fabricated using series of P-type and N-type impurity diffusions. The N-type layer becomes the collector for the transistor or an element for a diode or a capacitor.



Basic Monolithic IC Cross-Sectional View

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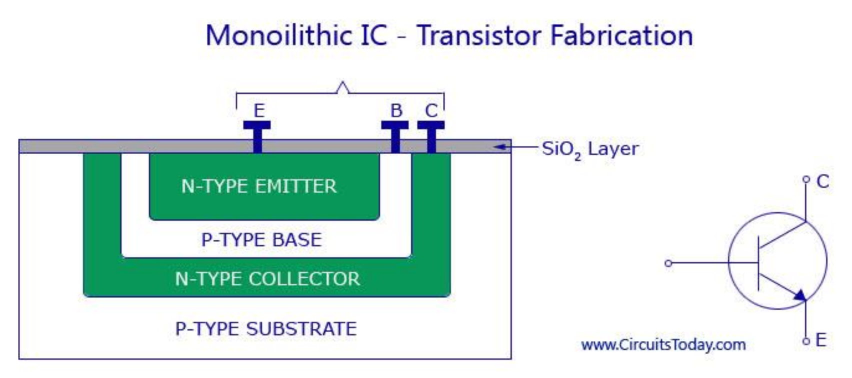
Basic Monolithic IC : The layer above N-type is made of silicon dioxide (SiO2) material. Since there is a selective P-type and N-type impurity diffusion going on in the second layer, this layer acts as a barrier in the process. This layer is etched away from the region where diffusion is desired to be permitted with [photolithographic process](). The rest of the wafer remains protected against diffusion. This layer also protects the silicon layer from contamination.

The up-most layer is that made of aluminium. This metallic layer is used to provide interconnections between the different components used in the IC. .2 Describe the fabrication of monolithic IC(Epitaxial Growth, Masking and Etching. Diffusion of Impurities etc)

2 .2 Describe the fabrication of monolithic IC – Component Fabrication and 2.3 Discuss, the fabrication of monolithic resistors, capacitors, diodes & bipolar junction transistors, Integrated field Effect Transistors.

Fabrication process of a transistor is shown in the figure below. A P-type substrate is first grown and then the collector, emitter, and base regions are diffused on top of it as shown in the figure. The surface terminals for these regions are also provided for connection.



<u>Monoilithic IC - Transistor Fabrication:</u>

Both transistors and diodes are fabricated by using the epitaxial planar diffusion process that is explained earlier. In case of discrete transistors, the P-type substrate is considered as the collector. `But this is not possible in monolithic IC’s, as all the transistors connected on one P-type substrate would have their collectors connected together. This is why separate collector regions are diffused into the substrate.

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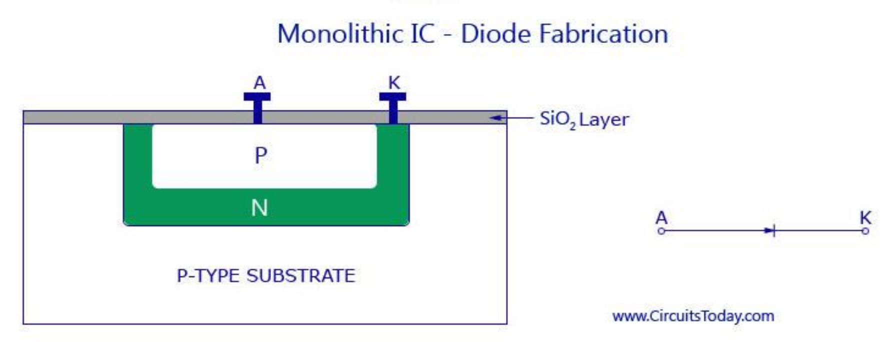
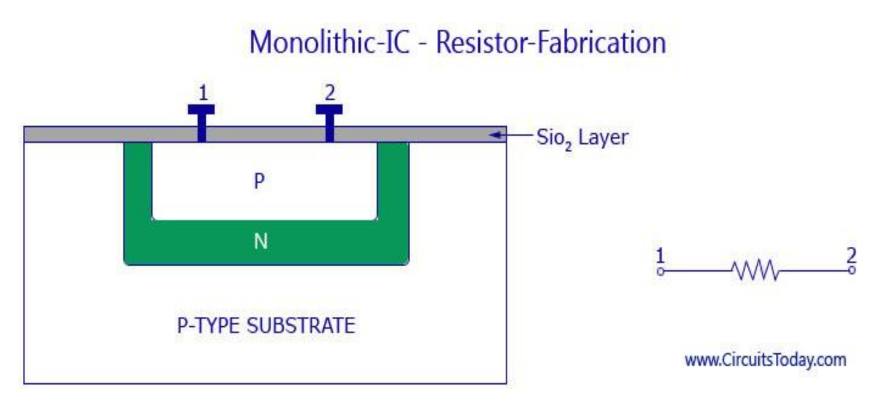
They are also fabricated by the same diffusion process as transistors are. The only difference is that only two of the regions are used to form one P-N junction. In figure, collector-base junction of the transistor is used as a diode. Anode of the diode is formed during the base diffusion of the transistor and the collector region of the transistor becomes the cathode of the diode. For high speed switching emitter base junction is used as a diode.



Resistors

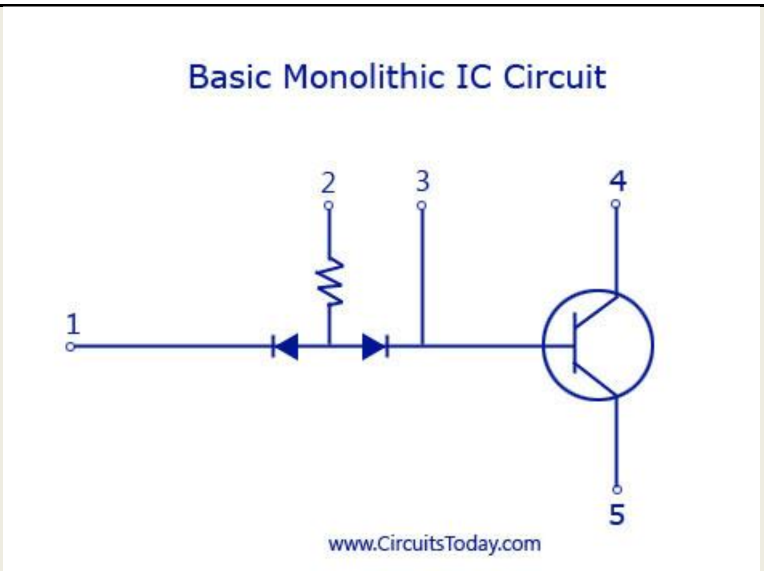
The resistors used in IC's are given their respective ohmic value by varying the concentration of doping impurity and depth of diffusion. The range of resistor values that may be produced by the diffusion process varies from ohms to hundreds of kilohms.



Monolithic IC's

We have already discussed the basics of **Integrated Circuits** in our previous post. The concepts of a basic monolithic IC will be discussed here.

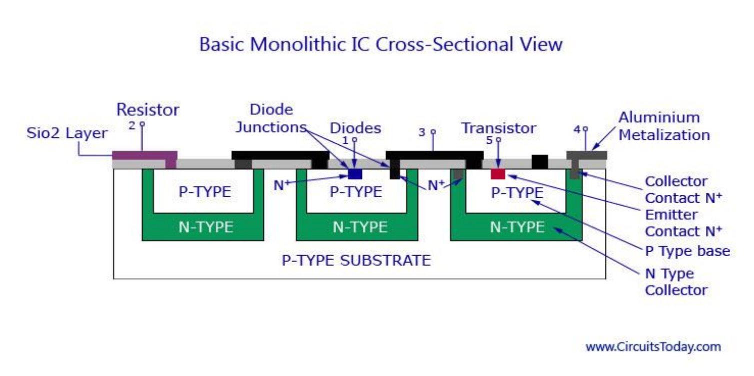
To know the basics a sample circuit must be considered to be converted to its monolithic form. With basic components like resistor, diode, and transistor a basic circuit is first made.



Basic Monolithic IC Circuit

Basic Monolithic IC Circuit: With the basic circuit, the different layers for the monolithic IC are then considered. The basic structure of a monolithic IC will have 4 layers of different materials. The base layer will be a P-type silicon layer and is named as the substrate layer. This layer will have a typical thickness of 200 micrometer. Silicon is the preferred semiconductor for the P-type and N-type layer because of its favourable characteristics for the manufacturing of an IC.

The layer above the substrate P-type silicon layer is the N-type layer. All the active and passive components required for the circuit are fabricated onto this layer. This layer has a typical thickness of 25 micrometer. The N-type silicon material is grown as a single crystal extension of the P-layer and the components are required are fabricated using series of P-type and N-type impurity diffusions. The N-type layer becomes the collector for the transistor or an element for a diode or a capacitor.



Basic Monolithic IC

The layer above N-type is made of silicon dioxide (SiO2) material. Since there is a selective P-type and N-type impurity diffusion going on in the second layer, this layer acts as a barrier in the process. This layer is etched away from the region where diffusion is desired to be permitted with photolithographic process. The rest of the wafer remains protected against diffusion. This layer also protects the silicon layer from contamination.

The up-most layer is that made of aluminium. This metallic layer is used to provide interconnections between the different components used in the IC.

Monolithic IC Manufacturing Process;

For the manufacture and production of the monolithic IC, all circuit components and their interconnections are to be formed in a single thin wafer. The different processes carried out for achieving this are explained below.

i. P-layer Substrate Manufacture

Being the base layer of the IC, the P-type is silicon is first built for the IC. A silicon crystal of P-type is grown in dimensions of 250mm length and 25mm diameter. The silicon is then cut into thin slices with high precision using a diamond saw. Each wafer will precisely have a thickness of 200 micrometer and a diameter of 25 mm. These thin slices are termed wafers. These wafers may be circular or rectangular in shape with respect to the shape of the IC. After cutting hundreds of them each wafer is polished and cleaned to form a P-type substrate layer.

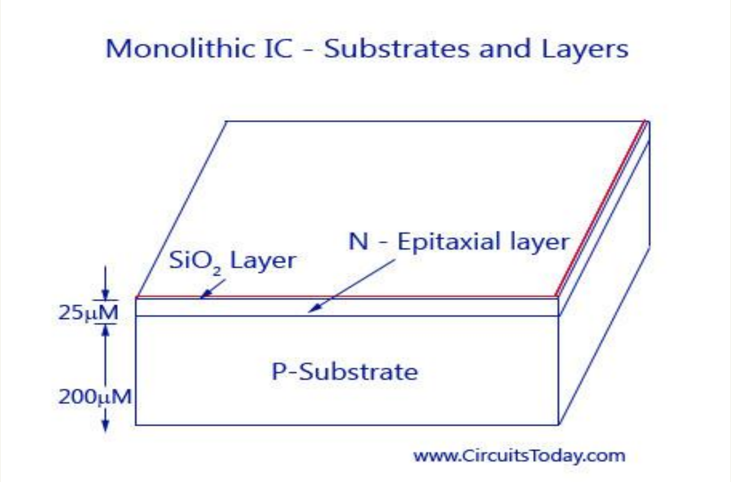
ii. N-type Epitaxial Growth

The epitaxial groth process of a low resistive N-type over a high resistive P-type is to be carried out. This is done by placing the n-type layer on top of the P-type and heating then inside a diffusion furnace at very high temperature (nearly 1200C). After heating, a gas mixture f Silicon atoms and pentavalent atoms are also passed over the layer.

This forms the epitaxial layer on the substrate. All the components required for the circuit are built on top of this layer. The layer is then cooled down, polished and cleaned.

iii. The Silicon Dioxide Insulation Layer

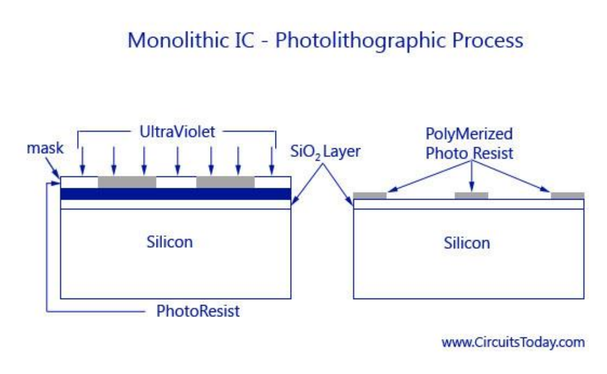
As explained above, this layer is required contamination of the N-layer epitaxy. This layer is only 1 micrometer thin and is grown by exposing the epitaxial layer to oxygen atmosphere at 1000C. A detailed image showing the P-type, N-type epitaxial layer and SiO2 layer is given below.



Monolithic IC-Substrates and Layers

iv. Photolithographic Process for SiO2:

To diffuse the impurities with the N-type epitaxial region, the silicon dioxide layer has to be etched in selected areas. Thus openings must be brought at these areas through photolithographic process. In this process, the SiO2 layer is coated with a thin layer of a photosensitive material called photoresist. A large black and white pattern is made in the desired patter, where the black pattern represents the area of opening and white represents the area that is left idle. This pattern is reduced in size and fit to the layer, above the photoresist. The whole layer is then exposed to ultraviolet light. Due to the exposure, the photoresist right below the white pattern becomes polymerized. The pattern is then removed and the wafer is developed using a chemical like trichloroethylene. The chemical dissolves the unpolymerized portion of the photoresist film and leaves the surface. The oxide not covered by polymerised photoresist is then removed by immersing the chip in an etching solution of HCl. Those portions of the Si02 which are protected by the photoresist remain unaffected by the acid. After the etching and diffusion process, with the help of chemical solvents like sulphuric acid, the resist mask is then removed by mechanical abrasion. The appropriate impurities are then diffused through oxide free windows.

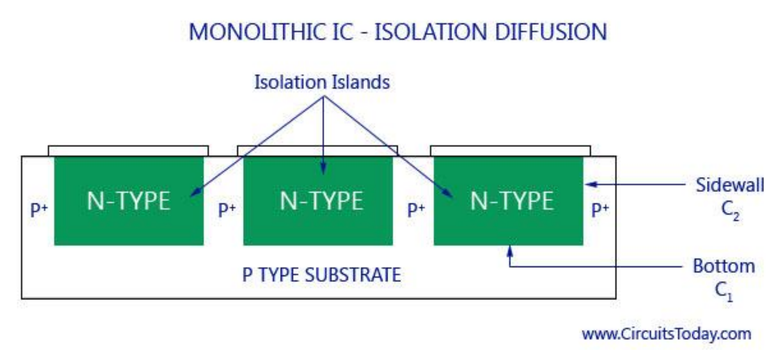


Monolithic IC - Photolithographic-Process

v. Isolation Diffusion

After photolithographic process the remaining SiO2 layer serves as a mask for the diffusion of acceptor impurities. To get a proper time period for allowing a P-type impurity to penetrate into the N-type epitaxial layer, isolation diffusion is to be carried out. By this process, the P-type impurity will travel through the openings in SiO2 layer, and the N-type layer and thus reach the P-type substrate, Isolation junctions are used to isolate between various components of the IC. The temperature and time period of isolation diffusion should be carefully monitored and controlled. As a result of isolation diffusion, the formation of N-type region called Isolation Island occurs. Each isolated island is then chosen to grow each electrical component. From the figure below you can see that the isolation islands look like back-to-back P-N junctions. The main use if this is to allow electrical isolation between the different components inside the IC. Each electrical element is later on formed in a separate isolation island. The bottom of the N-type isolation island ultimately forms the collector of an N-P-N transistor. The P-type substrate is always kept negative with respect to the isolation islands and provided with reverse bias at P-N junctions. The isolation will disappear if the P-N junctions are forward biased.

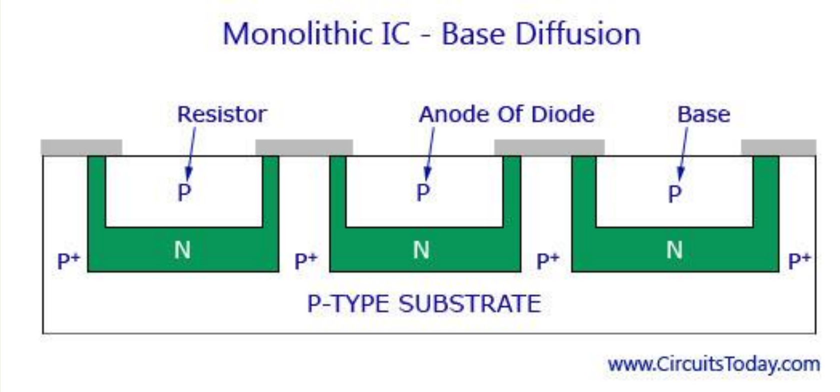
Monolithic IC - Isolation Diffusion:



Monolithic IC - Isolation Diffusion

An effect of capacitance is produced in the region where the two adjoining isolation islands are connected to the P-type substrate. This is basically a parasitic capacitance that will affect the performance of the IC. This kind of capacitance is divided into two. As shown in the figure C1 is one kind of capacitance that forms from the bottom of the N-type region to the substrate and capacitance C2 from the sidewalls of the isolation islands to the P-region. The bottom component C1 is essentially due to step junction formed by epitaxial growth and, therefore, varies as the square root of the voltage V between the isolation region and substrate. The sidewall capacitance C2 is associated with a diffused graded junction and so varies as (-1/2) exponential of V. The total capacitance is of the order of a few picoFarads.

vi. Base Diffusion: The working of base diffusion process is shown in the figure below. This process is done to create a new layer of SiO2 over the wafer. P-regions are formed under regulated environments by diffusing P-type impurities like boron. This forms the base region of an N-P-N transistor or as well as resistors, the anode of diode, and junction capacitor. In this case, the diffusion time is so controlled that the P-type impurities do not reach the substrate. The resistivity of the base layer is usually much higher than that of the isolation regions.

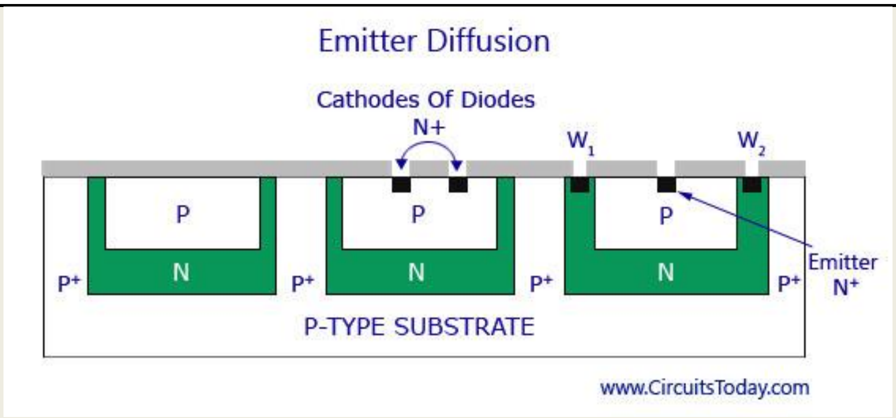


Monolithic IC - Base Diffusion

The isolation regions will have a lot lesser resistivity than that of the base layer.

vii. Emitter Diffusion

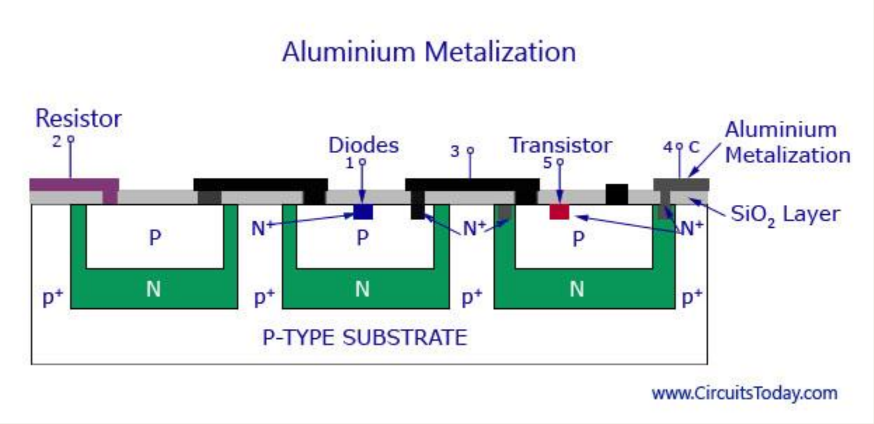
Masking and etching process is again carried out to form a layer of silicon dioxide over the entire surface and opening of the P-type region. The transistor emitters, the cathode regions for diodes, and junction capacitors are grown by diffusion using N-type impurities like phosphorus through the windows created through the process under controlled environmental process. As shown in the figure below there are two additional windows: W1 and W2. These windows are made in the N-region to carry an aluminium metallization process.



Emitter Diffusion

viii. Aluminium Metallization

The windows made in the N-region after creating a silicon dioxide layer are then deposited with aluminium on the top surface. The same photoresist technique that was used in photolithographic process is also used here to etch away the unwanted aluminium areas. The structure then provides the connected strips to which the leads are attached. The process can be better understood by going through the figure below.

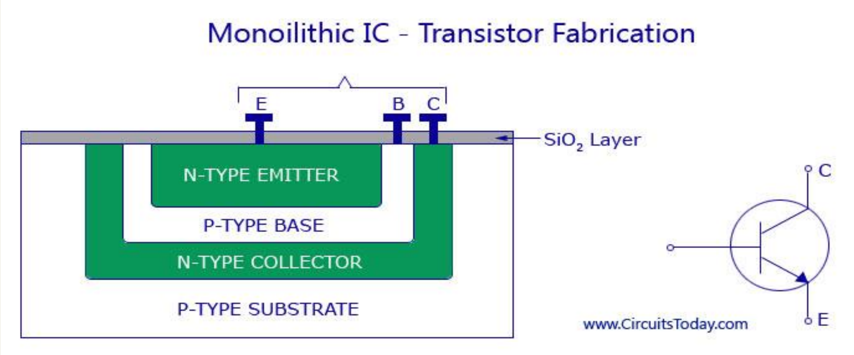


Aluminium Metalization

ix. Scribing and Mounting: This is the final stage of the IC manufacturing process. After the metallization process, the silicon wafer is then scribed with a diamond tipped tool and separated into individual chips. Each chip is then mounted on a ceramic wafer and is attached to a suitable header. Next the package leads are connected to the IC chip by bonding of aluminium or gold wire from the terminal pad on the IC chip to the package lead. Thus the manufacturing process is complete. Thu, hundreds of IC's is manufactured simultaneously on a single silicon wafer.

Monolithic IC – Component Fabrication: Now we shall discuss in detail how different circuit elements like capacitors, transistors, diodes, and resistors are fabricated into an IC. Please note that it is practically impossible to fabricate an inductor into an IC. It is thus added externally by connecting it to the corresponding IC pin as designed by the manufacturer.

Transistors: The fabrication process of a transistor is shown in the figure below. A P-type substrate is first grown and then the collector, emitter, and base regions are diffused on top of it as shown in the figure. The surface terminals for these regions are also provided for connection.



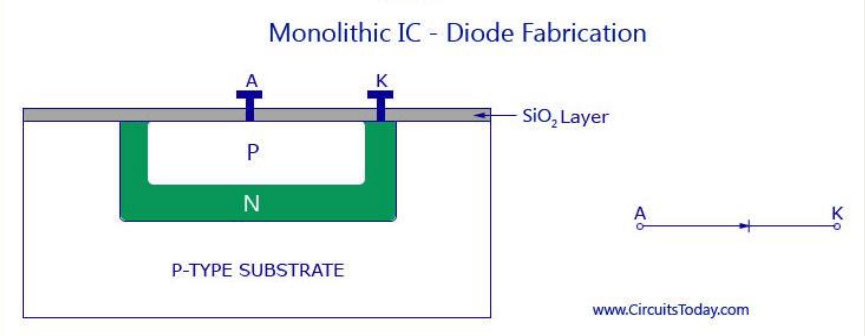
Monoilithic IC - Transistor Fabrication

Both transistors and diodes are fabricated by using the epitaxial planar diffusion process that is explained earlier. In case of discrete transistors, the P-type substrate is considered as the collector. `But this is not possible in monolithic IC's, as all the transistors connected on one P-type substrate would have their collectors connected together. This is why separate collector regions are diffused into the substrate.

Even though separate collector regions are formed, they are not completely isolated from the substrate. For proper functioning of the circuit it is necessary that the P-type substrate is always kept negative with respect to the transistor collector. This is achieved by connecting the substrate to the most negative terminal of the circuit supply. The unwanted or parasitic junctions, even when reverse-biased, can still affect the circuit performance adversely. The junction reverse leakage current can cause a serious problem in circuits operating at very low current levels. The capacitance of the reverse-biased junction may affect the circuit high-frequency performance, and the junction break down voltage imposes limits on the usable level of supply voltage. All these adverse effects can be reduced to the minimum if highly resistive material is employed for the substrate. If the substrate is very lightly doped, it will behave almost as an insulator.

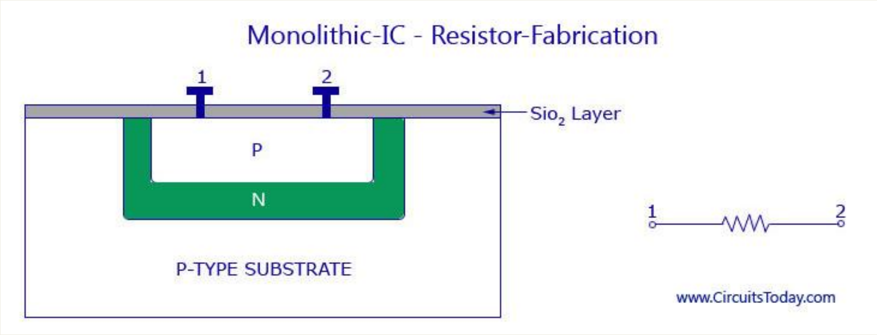
Diodes:

They are also fabricated by the same diffusion process as transistors are. The only difference is that only two of the regions are used to form one P-N junction. In figure, collector-base junction of the transistor is used as a diode. Anode of the diode is formed during the base diffusion of the transistor and the collector region of the transistor becomes the cathode of the diode. For high speed switching emitter base junction is used as a diode.



Monolithic IC - Diode Fabrication

Resistors: The resistors used in IC's are given their respective ohmic value by varying the concentration of doping impurity and depth of diffusion. The range of resistor values that may be produced by the diffusion process varies from ohms to hundreds of kilohms. The typical tolerance, however, may be no better than ± 5%, and may even be as high as ± 20%. On the other hand, if all the resistors are diffused at the same time, then the tolerance ratio may be good. Most resistors are formed during the base diffusion of the integrated transistor, as shown in figure below. This is because it is the highest resistivity region. For low resistance values, emitter region is used as it has much lower resistivity.

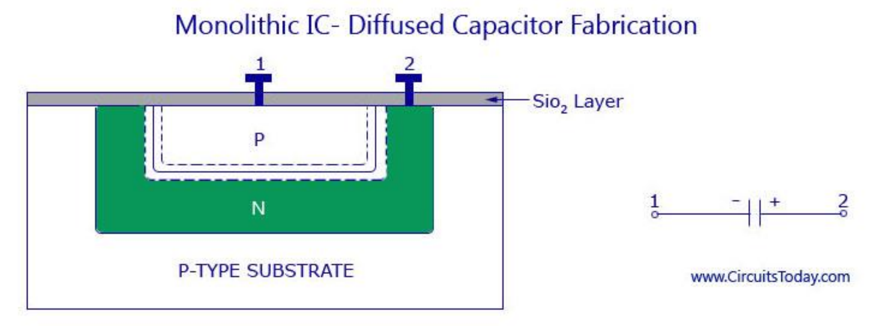


Monolithic IC - Resistor Fabrication

Another diffusion technique is also used for the growth of IC resistors. It is basically a thin-film technique. In this process a metal film is deposited on a glass or Si02 surface. The resistance value can be controlled by varying thickness, width and length of the film. Since diffused resistors can be processed while diffusing transistors. This technique is more economic and less time consuming and therefore, the most widely used.

Capacitors:

The figure below shows the P and N-regions forming the capacitor plates. The dielectric of the capacitor is the depletion region between them.



Monolithic IC - Diffused Capacitor Fabrication

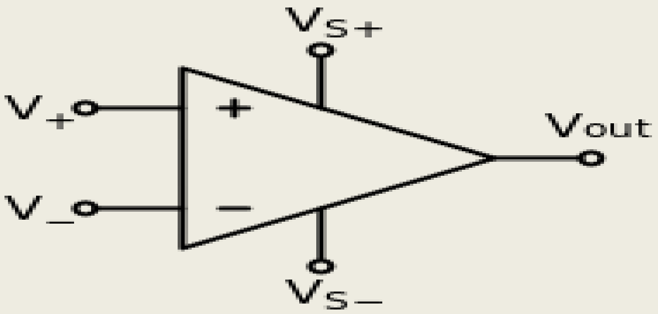
2.4 Explain briefly the difference between digital & linear ICs.

Sl. No	**Digital ICs.**	**Linear ICs.**
1.	Easy to design.	Discrete transistor networks like filters & amplifiers ,modulators that requires additional external components for operation.
2	Much more accurate & precise than analog ICs because this can be easily expanded to handle more digits by adding more switching circuits.	Linear ICs are quite complex & costly for accuracy & precision.
3	Fabrication is simpler & economical that of analog IC s because this does not requires high value of capacitors ,inductors &transformers.	Fabrication of analog ICs cannot be integrated economically.
4	Less affected by Noise.	Effect of Noise is more.
5.	Used in Computation & data processing, control system ,communications & measurements.	Used in Signal generators ,Radio frequency transmitters & receiver electric motors.

CHAPTER- 3 INTRODUCTION TO OP-AMP.

3.1 Define the term differential amplifier & explain its significance.

Differential amplifier:



Differential amplifier symbol

The inverting and non-inverting inputs are distinguished by "−" and "+" symbols (respectively) placed in the amplifier triangle. V_{s+} and V_{s-} are the power supply voltages; they are often omitted from the diagram for simplicity, but of course must be present in the actual circuit.

A differential amplifier **is a type of electronic amplifier that amplifies the difference between two voltages but does not amplify the particular voltages. Differential output**

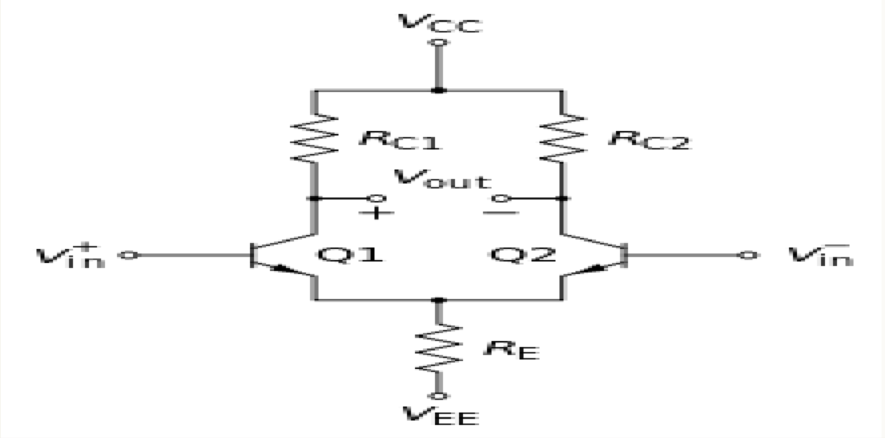


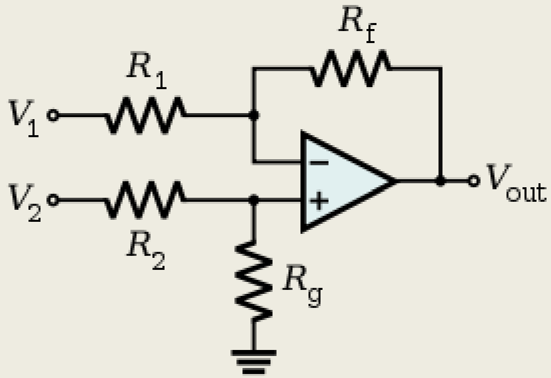
Figure 2: A classic long-tailed pair

With two inputs and two outputs, this forms a differential amplifier stage (Fig. 2). The two bases (or grids or gates) are inputs which are differentially amplified (subtracted and multiplied) by the pair; they can be fed with a differential (balanced) input signal, or one input could be grounded to form a phase splitter circuit. An amplifier with differential output can drive floating load or another stage with differential input.

Single-ended output:

If the differential output is not desired, then only one output can be used (taken from just one of the collectors (or anodes or drains), disregarding the other output without a collector inductor; this configuration is referred to as *single-ended output*. The gain is half that of the stage with differential output. To avoid sacrificing gain, a differential to single-ended converter can be utilized.

3.2 Draw the four differential amplifier configuration and show the no of Input signal used and the way the Output is measured voltage of each amplifier (no mathematical derivations)



3.3 Block diagram representation of a typical Op- Amp :

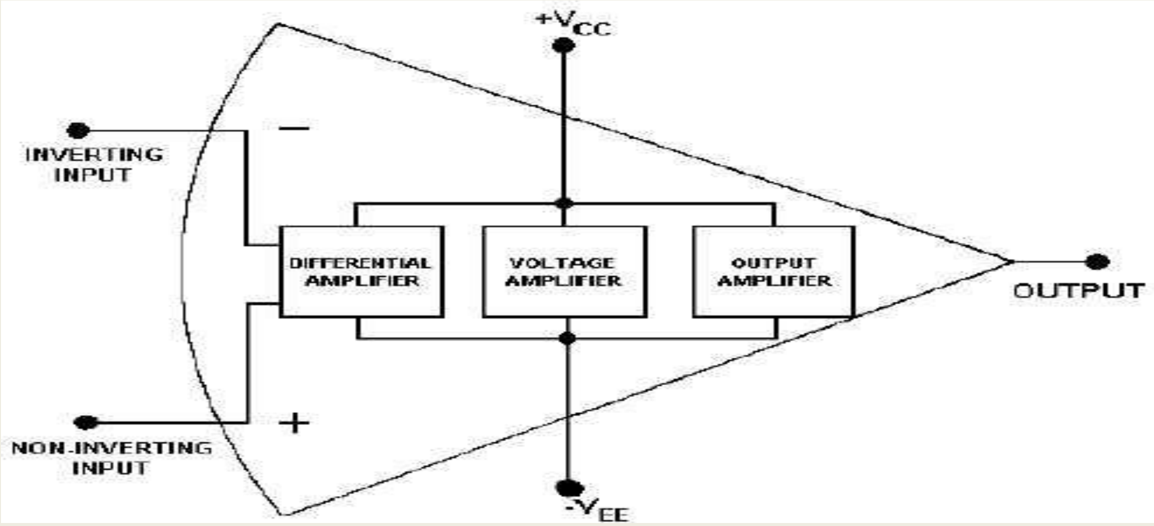
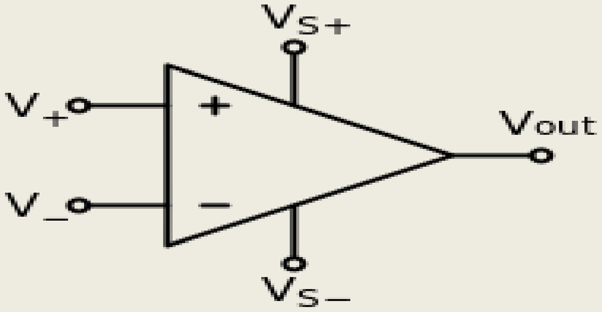


Figure .—Block diagram of an operational amplifier.

The input stage is a differential amplifier. The differential amplifier used as an input stage provides differential inputs and a frequency response down to d.c. Special techniques are used to provide the high input impedance necessary for the operational amplifier. The second stage is a high-gain voltage amplifier. This stage may be made from several transistors to provide high gain. A typical operational amplifier could have a voltage gain of 200,000. Most of this gain comes from the voltage amplifier stage. The final stage of the OP AMP is an output amplifier. The output amplifier provides low output impedance. The actual circuit used could be an emitter follower. The output stage should allow the operational amplifier to deliver several mill amperes to a load. Notice that the operational amplifier has a positive power supply (+V $_{CC}$) and a negative power supply (-V $_{EE}$). This arrangement enables the operational amplifier to produce either a positive or a negative output. The two input terminals are labeled "inverting input" (-) and "non inverting input" (+). The operational amplifier can be used with three different input conditions (modes). With differential inputs (first mode), both input terminals are used and two input signals which are 180 degrees out of phase with each other are used. This produces an output signal that is in phase with the signal on the non inverting input. If the non inverting input is grounded and a signal is applied to the inverting input (second mode), the output signal will be 180 degrees out of phase with the input signal (and one-half the amplitude of the first mode output). If the inverting input is grounded and a signal is applied to the non inverting input (third mode), the output signal will be in phase with the input signal (and one-half the amplitude of the first mode output

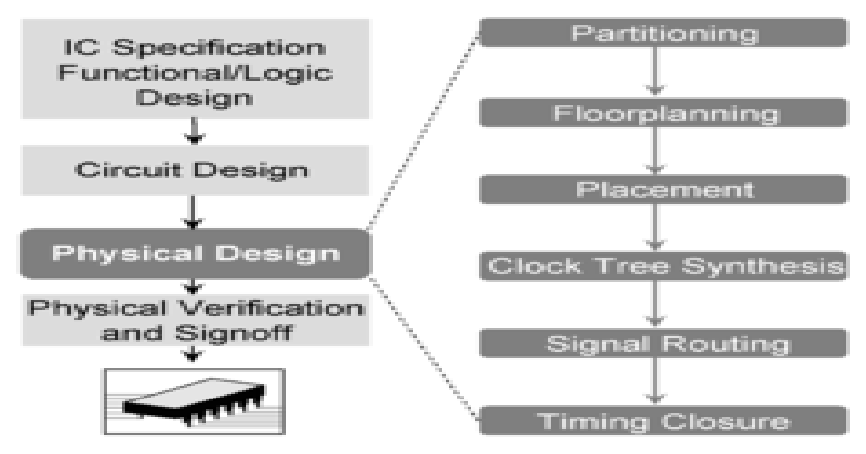
3.4 Analyse a typical Op-Amp equivalent circuits and draw the schematic symbol. An **operational amplifier** (op-amp) is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In this configuration, an op-amp produces an output potential (relative to circuit ground) that is typically hundreds of thousands of times larger than the potential difference between its input terminals.



Circuit diagram symbol for an op-amp. Pins are labeled as listed above.

3.5 Discuss the types of integrated circuits manufacturer’s designations of ICs, Package types, pin identification and temperature and ordering information. IC design can be divided into the broad categories of digital and analog IC design. Digital IC design is to produce components such as microprocessors, FPGAs, memories (RAM, ROM, and flash) and digital ASICs. Digital design focuses on logical correctness, maximizing circuit density, and placing circuits so that clock and timing signals are routed efficiently. Analog IC design also has specializations in power IC design and RF IC design. Analog IC design is used in the design of op-amps, linear regulators, phase locked loops, oscillators and active filters. Analog design is more concerned with the physics of the semiconductor devices such as gain, matching, power dissipation, and resistance. Fidelity of analog signal amplification and filtering is usually critical and as a result, analog ICs use larger area active devices than digital designs and are usually less dense in circuitry.

Physical design



Physical design steps within the digital design flow

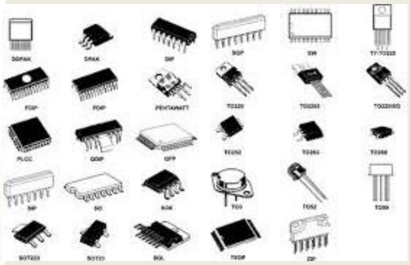
During the physical design stage, all design components are instantiated with their geometric representations. The main steps of physical design are listed below. In practice there is not a straightforward progression - considerable iteration is required to ensure all objectives are met simultaneously. This is a difficult problem in its own right, called design closure.

- Floorplanning: The RTL of the chip is assigned to gross regions of the chip, input/output (I/O) pins are assigned and large objects (arrays, cores, etc.) are placed.
- Logic synthesis: The RTL is mapped into a gate-level netlist in the target technology of the chip.
- Placement: The gates in the netlist are assigned to nonoverlapping locations on the die area.
- Logic/placement refinement: Iterative logical and placement transformations to close performance and power constraints.
- Clock insertion: Clock signal wiring is (commonly, clock trees) introduced into the design.
- Routing: The wires that connect the gates in the netlist are added.
- Postwiring optimization: Performance (timing closure), noise (signal integrity), and yield (Design for manufacturability) violations are removed.
- Design for manufacturability: The design is modified, where possible, to make it as easy and efficient as possible to produce. This is achieved by adding extra vias or adding dummy metal/diffusion/poly layers wherever possible while complying to the design rules set by the foundry.
- Final checking: Since errors are expensive, time consuming and hard to spot, extensive error checking is the rule, making sure the mapping to logic was done correctly, and checking that the manufacturing rules were followed faithfully.
- Tapeout and mask generation: the design data is turned into photomasks in mask data preparation.

Analog design

Before the advent of the microprocessor and software based design tools, analog ICs were designed using hand calculations and process kit parts. These ICs were low complexity circuits, for example, op-amps, usually involving no more than ten transistors and few connections. An iterative trial-and-error process and "overengineering" of device size was often necessary to achieve a manufacturable IC. Reuse of proven designs allowed progressively more complicated ICs to be built upon prior knowledge. When inexpensive computer processing became available in the 1970s, computer programs were written to simulate circuit designs with greater accuracy than practical by hand calculation. The first circuit simulator for analog ICs was called SPICE (Simulation Program with Integrated Circuits Emphasis). Computerized circuit simulation tools enable greater IC design complexity than hand calculations can achieve, making the design of analog ASICs practical. The computerized circuit simulators also enable mistakes to be found early in the design cycle before a physical device is fabricated. Additionally, a computerized circuit simulator can implement more sophisticated device models and circuit analysis too tedious for hand calculations, permitting Monte Carlo analysis and process sensitivity analysis to be practical. The effects of parameters such as temperature variation, doping concentration variation and statistical process variations can be simulated easily to determine if an IC design is manufacturable. Overall, computerized circuit simulation enables a higher degree of confidence that the circuit will work as expected upon manufacture.

Integrated circuits are put into protective packages to allow easy handling and assembly onto printed circuit boards and to protect the devices from damage. A very large number of different types of package exist. Some package types have standardized dimensions and tolerances, and are registered with trade industry associations such as JEDEC and Pro Electron. Other types are proprietary designations that may be made by only one or two manufacturers. Integrated circuit packaging is the last assembly process before testing and shipping devices to customers.



3.6 Device identification and the need of two power supply for ICs : The IC is identified by marking the device type number on the face of the IC. The number is usually accompanied by the data code, indicating the year and week the device was manufactured.

Power supplies for ICs: Most linear ICs use one or more differential amplifier stages, and differential amplifier requires both positive and negative power supply for proper operation of the circuit. This means that most linear ICs need both a positive and a negative power supply. A few linear ICs use unequal power supplies, and some ICs require only a positive supply. Some dual supply op amp ICs can be operated from a single supply voltage,provided that a special external circuit is used with it but digital ICs generally require only one positive supply voltage.

View of IC Designer

Design parameters by which Design success is measured:

- Performance Specifications
- Size of Wafer, Die and overall manufacturing cost
- Design time including engineering and time to tape out
- Ease of Test pattern generation , verification and testability.

Proposed Architecture

Algorithm

Process Technology

+

VLSI CAD Tools

=

Chip for fabrication

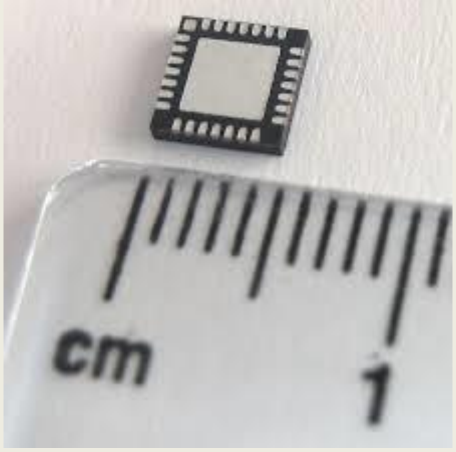
Figure 1: Generalized View of a IC Designer

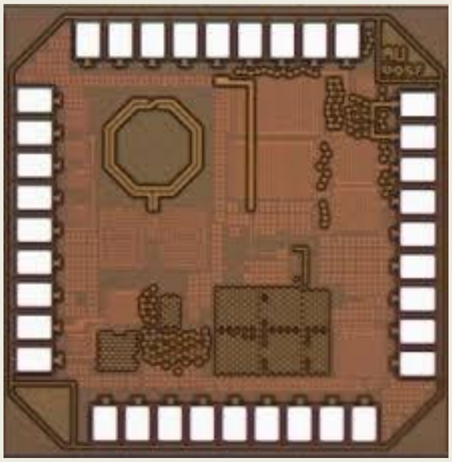
- Design is a continuous tradeoff between namely 3 parameters namely Price, Power and performance.

3.6 Device identification and the need of two power supply for ICs .

IC Packaging

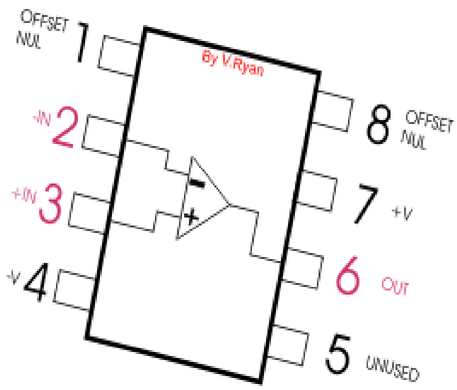
By,
SANTOSH NIMBAL





CHAPTER-4 OPERATIONAL AMPLIFIER CIRCUITS & FEEDBACK CONFIGURATIONS.

4.1 Explain general information of data sheet of 741.



The 741 integrated circuit looks like any other 'chip'. However, it is a general purpose OP-AMP. You need only to know basic information about its operation and use. The diagram opposite shows the pins of the 741 OP-AMP. The important pins are 2, 3 and 6 because these represent inverting, non-inverting and voltage out. Notice the triangular diagram that represents an Op-Amp integrated circuit.

4.2 Define the following electrical characteristics input offset voltage, input offset current, CMMR, Large signal voltage gain, Slew rate .

The **input offset voltage** (V_{os}) is a parameter defining the differential DC voltage required between the inputs of an amplifier, especially an operational amplifier (op-amp), to make the output zero (for voltage amplifiers, 0 volts with respect to ground or between differential outputs, depending on the output type)

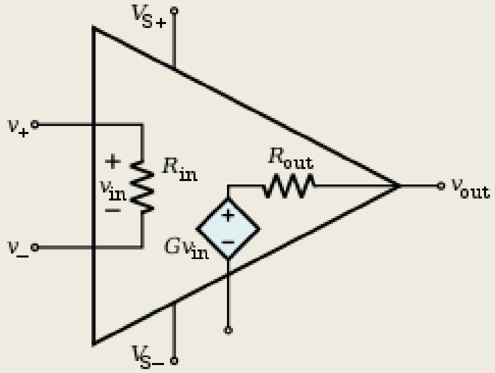
The **common-mode rejection ratio** (CMRR) of a differential amplifier (or other device) is the rejection by the device of unwanted input signals common to both input leads, relative to the wanted difference signal.

Slew rate : **Slew rate** is defined as the maximum rate of change of output voltage per unit of time and is expressed as volt per second. Limitations in slew rate capability can give rise to non linear effects in electronic amplifiers.

4.3 Define Ideal operational amplifier and its equivalent circuits.

An ideal op-amp is usually considered to have the following properties:

Ideal op-amps



An equivalent circuit of an operational amplifier that models some resistive non-ideal parameters.

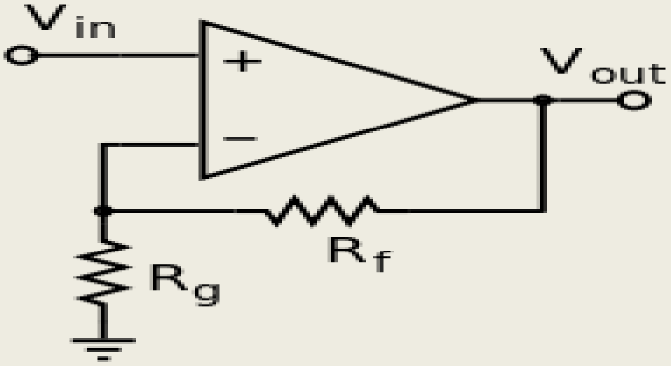
An ideal op-amp is usually considered to have the following properties:

- Infinite open-loop gain G = v_{out} / 'v_{in}
- Infinite input impedance R_{in}, and so zero input current
- Zero input offset voltage
- Infinite voltage range available at the output
- Infinite bandwidth with zero phase shift and infinite slew rate
- Zero output impedance R_{out}
- Zero noise

Infinite Common-mode rejection ratio (CMRR)

4.4 Draw and explain the Open Loop configuration (inverting, non-inverting Amplifier) Open loop amplifier

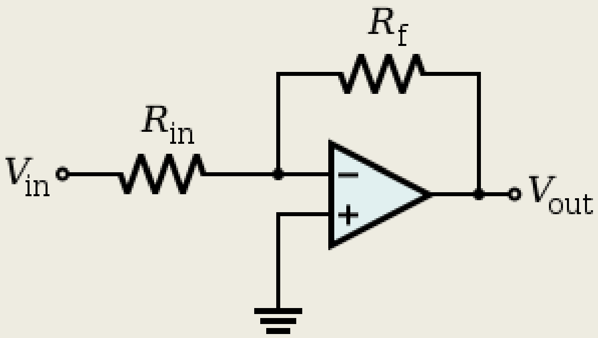
The magnitude of A_{OL} is typically very large—100,000 or more for integrated circuit op-amps—and therefore even a quite small difference between V_+ and V_- drives the amplifier output nearly to the supply voltage. Closed loop



An op-amp with negative feedback (a non-inverting amplifier)

If predictable operation is desired, negative feedback is used, by applying a portion of the output voltage to the inverting input. The *closed loop* feedback greatly reduces the gain of the circuit. When negative feedback is used, the circuit's overall gain and response becomes determined mostly by the feedback network, rather than by the op-amp characteristics. If the feedback network is made of components with values small relative to the op amp's input impedance, the value of the op-amp's open loop response A_{OL} does not seriously affect the circuit's performance. The response of the op-amp circuit with its input, output, and feedback circuits to an input is characterized mathematically by a transfer function; designing an op-amp circuit to have a desired transfer function.

Inverting amplifier



An op-amp connected in the inverting amplifier configuration

In an inverting amplifier, the output voltage changes in an opposite direction to the input voltage.

As with the non-inverting amplifier, we start with the gain equation of the op-amp:

$$V_{\text{out}} = A_{OL}\left(V_{+} - V_{-}\right)$$

This time, V_{-} is a function of both V_{out} and V_{in} due to the voltage divider formed by R_{f} and R_{in}. Again, the op-amp input does not apply an appreciable load, so:

$$V_{-} \ = \frac{1}{R_{\text{f}} + R_{\text{in}}}\left(R_{\text{f}} V_{\text{in}} + R_{\text{in}} V_{\text{out}}\right)$$

Substituting this into the gain equation and solving for V_{out}:

$$V_{\text{out}} = -V_{\text{in}} \cdot \frac{A_{OL} R_{\text{f}}}{R_{\text{f}} + R_{\text{in}} + A_{OL} R_{\text{in}}}$$

If $A_{OL}$is very large, this simplifies to

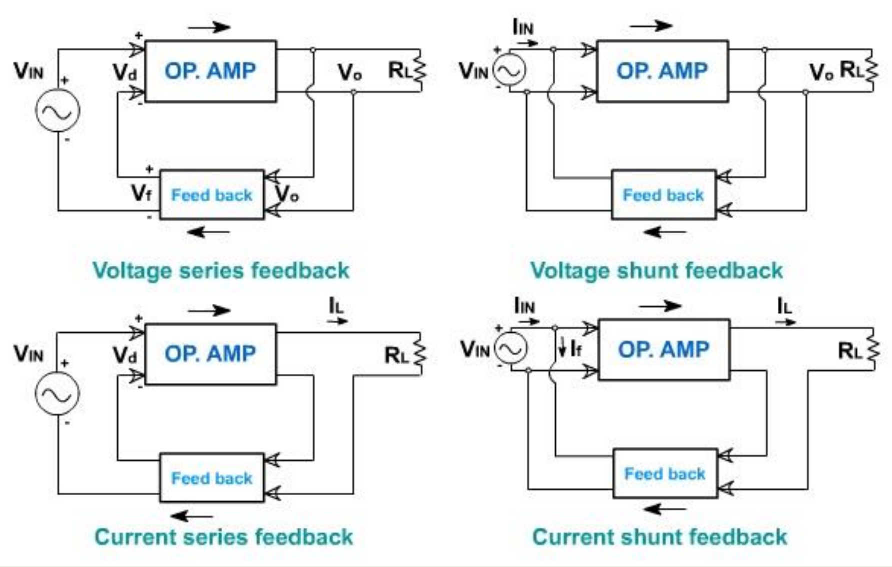
$$V_{\text{out}} \approx -V_{\text{in}} \frac{R_{\text{f}}}{R_{\text{in}}}$$

A resistor is often inserted between the non-inverting input and ground (so both inputs "see" similar resistances), reducing the input offset voltage due to different voltage drops due to bias current, and may reduce distortion in some op-amps.

A DC-blocking capacitor may be inserted in series with the input resistor when a frequency response down to DC is not needed and any DC voltage on the input is unwanted. That is, the capacitive component of the input impedance inserts a DC zero and a low-frequency pole that gives the circuit a bandpass or high-pass characteristic.

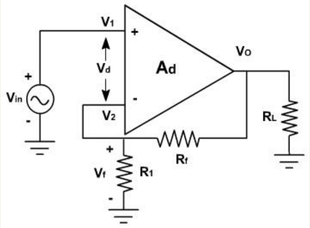
The potentials at the operational amplifier inputs remain virtually constant (near ground) in the inverting configuration. The constant operating potential typically results in distortion levels that are lower than those attainable with the non-inverting topology.

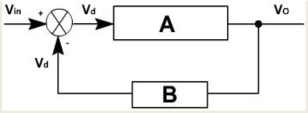
- 4.5 Draw the block representation of four feedback configurations. Voltage – series feedback
    - Voltage – shunt feedback
    - Current – series feedback
    - Current – shunt feedback



Voltage series feedback:

It is also called non-inverting voltage feedback circuit. With this type of feedback, the input signal drives the non-inverting input of an amplifier; a fraction of the output voltage is then fed back to the inverting input. The op-amp is represented by its symbol including its large signal voltage gain A_d or A, and the feedback circuit is composed of two resistors R_1 and R_f. **as shown in fig. 5**





$$\text{Open loop voltage gain } A_d = \frac{v_o}{v_d}$$

$$\text{Closed loop voltage gain } A_{CL} = \frac{v_o}{v_{in}}$$

$$\text{Feedback circuit gain } B = \frac{v_f}{v_o}$$

$$\text{The differential voltage input } v_d = v_{in} - v_f$$

The feedback voltage always opposes the input voltage, (or is out of phase by 180° with respect to input voltage), hence the feedback is said to be negative.

The closed loop voltage gain is given by

$$\begin{aligned}
A_{CL} &= \frac{v_o}{v_{in}} \\
v_o &= A\,(v_1 - v_2) = A\,(v_{in} - v_f) \\
&= A\,(v_{in} - Bv_o) \\
v_o\,(1 + AB) &= A\,v_{in} \\
\frac{v_o}{v_{in}} &= \frac{A}{1 + AB}
\end{aligned}$$

The product A and B is called loop gain. The gain loop gain is very large such that AB >> 1

$$\begin{aligned}
\therefore \frac{v_o}{v_{in}} &= \frac{A}{AB} = \frac{1}{B} \\
&= \frac{R_1 + R_f}{R_1} \\
&= 1 + \frac{R_f}{R_1}
\end{aligned}$$

This shows that overall voltage gain of the circuit equals the reciprocal of B, the feedback gain. It means that closed loop gain is no longer dependent on the gain of the op-amp, but depends on the feedback of the voltage divider. The feedback gain B can be precisely controlled and it is independent of the amplifier.

Physically, what is happening in the circuit? The gain is approximately constant, even though differential voltage gain may change. Suppose A increases for some reasons (temperature change). Then the output voltage will try to increase. This means that more voltage is fedback to the inverting input, causing v_d voltage to decrease. This almost completely offset the attempted increases in output voltage.

Similarly, if A decreases, The output voltage decreases. It reduces the feedback voltage v_f and hence, v_d voltage increases. Thus the output voltage increases almost to same level.

Different Input voltage is ideally zero.

Again considering the voltage equation,

$v_O = A_d v_d$

or $v_d = v_O / A_d$

Since A_d is very large (ideally infinite)

\ v_d » 0.

and $v_1 = v_2$ (ideal).

This says, that the voltage at non-inverting input terminal of an op-amp is approximately equal to that at the inverting input terminal provided that A_d is very large. This concept is useful in the analysis of closed loop OPAMP circuits. For example, ideal closed loop voltage again can be obtained using the results

$$
\begin{aligned}
&v_1 = v_{in} \\
&v_2 = v_f = \frac{R_1}{R_1 + R_f} v_o \\
&\therefore\ v_1 = v_2 \\
&\therefore\ v_{in} = \frac{R_1}{R_1 + R_f} v_o \\
&v_o = \left(1 + \frac{R_1}{R_f}\right) v_{in}
\end{aligned}
$$

4.6 Draw the circuit diagram of the voltage series feedback amplifier and derive the close loop Voltage gain, gain of feedback circuits input resistance, and output resistance, bandwidth and total output offset voltage wit

4.7 Draw the circuit diagram of the voltage shunt feedback amplifier and derive the close loop

Voltage shunt Feedback:

Fig. 1, shows the voltage shunt feedback amplifier using OPAMP.

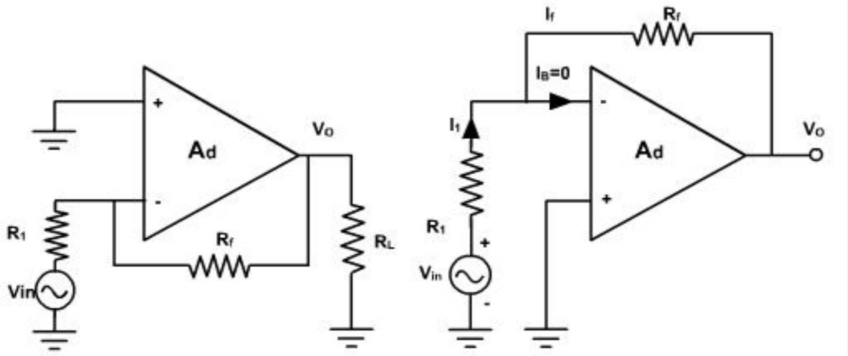


Fig. 1

The input voltage drives the inverting terminal, and the amplified as well as inverted output signal is also applied to the inverting input via the feedback resistor R_f. This arrangement forms a negative feedback because any increase in the output signal results in a feedback signal into the inverting input signal causing a decrease in the output signal. The non-inverting terminal is grounded. Resistor R_1 is connected in series with the source.

The closed loop voltage gain can be obtained by, writing Kirchoff's current equation at the input node V_2.

$$i_1 = i_f + i_B$$

The closed loop volt since R_1 is very large, the input current i_B is negligibly small.

$$\therefore\ i_1 = i_f$$

$$\frac{v_{in} - v_2}{R_1} = \frac{v_2 - v_0}{R_f}$$

and $$(v_1 - v_2) = \frac{v_0}{A}$$

$$v_2 = -\frac{v_0}{A} \text{ (because } v_1 = 0\text{)}$$

$$\therefore \frac{v_{in} + {}^{v_0}\!/\!_{A}}{R_1} = \frac{\left(-{}^{v_0}\!/\!_{A}\right) - v_0}{R_f}$$

$$A_f = \frac{v_0}{V_{in}} = \frac{R_f A}{R_1 + R_f + AR_1}$$

Since A is very very high therefore, $AR_1 >> (R_1 + R_f)$

$$\therefore A_f = -\frac{R_f}{R}$$

$$= -\frac{1}{B}$$

Since, $B = \left({}^{R_1}\!/\!_{R_f}\right)$

Voltage gain, gain of feedback circuits, and input resistance, and output resistance, bandwidth **Input Resistance with Feedback:**

To find the input resistance Miller equivalent of the feedback resistor R_f, is obtained, i.e. R_f is splitted into its two Miller components as shown in fig. 2. Therefore, input resistance with feedback R_{if} is then

$$R_{if} = R_1 + \left(\frac{R_{if}}{1 + A}\right)$$

Since R_i and A are very large, Therefore,

$$\left(\frac{R_f}{1 + A}\right) \Big\| R_i \approx 0 \text{ ohm}$$

Hence $R_{if} = R_i$

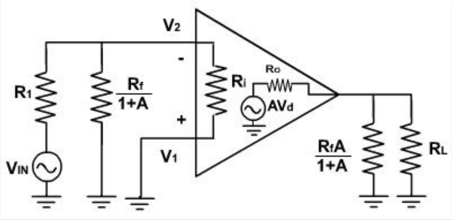


Fig. 2

Output Resistance with Feedback:

The output resistance with feedback R_{of} is the resistance measured at the output terminal of the feedback amplifier. The output resistance can be obtained using Thevenin's equivalent circuit,shown in **fig. 3**.

$i_O = i_a + i_b$

Since R_O is very small as compared to $R_f + (R_1 || R_2)$

Therefore,i.e. $i_O = i_a$

$v_O = R_O i_O + A v_d$.

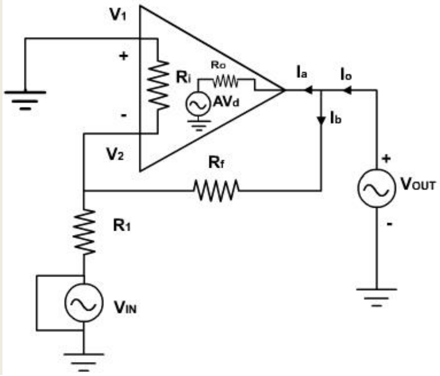
$v_d = v_i - v_2 = 0 - B v_O$

$$i_0 = \frac{v_0 - Av_d}{R_0}$$

$$= \frac{v_0 - ABv_0}{R_0}$$

$$R_{0f} = \frac{v_0}{i_0} = \frac{R_0}{1+AB}$$

$$\text{where, } B = {}^{R_1}\!/_{R_f}$$



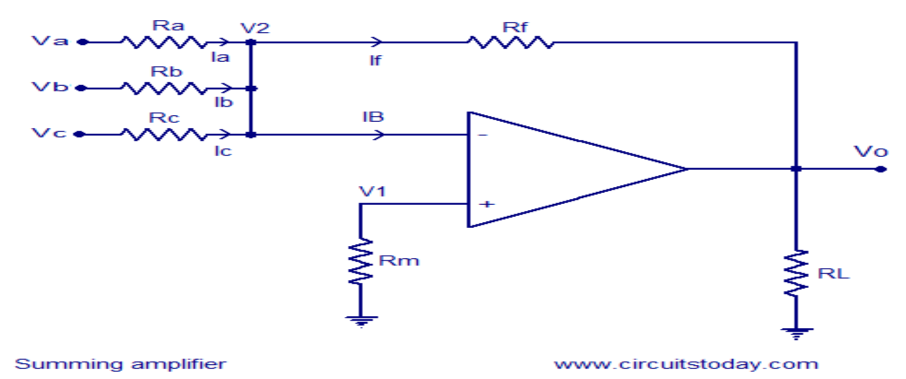
Similarly, the bandwidth increases by (1+ AB) and total output offset voltage reduces by (1+AB).

and total output offset voltage with feedback

CHAPTER-5. APPLICATION OF OPERATIONAL AMPLIFIER & TIMER CIRCUITS .,

5.1 Discuss the summing scaling and averaging of inverting and non-inverting amplifiers Summing amplifier using opamp.

Summing amplifier is a type operational amplifier circuit which can be used to sum signals. The sum of the input signal is amplified by a certain factor and made available at the output .Any number of input signal can be summed using an opamp. The circuit shown below is a three input summing amplifier in the inverting mode.



Summing amplifier circuit

In the circuit, the input signals Va,Vb,Vc are applied to the inverting input of the opamp through input resistors Ra,Rb,Rc. Any number of input signals can be applied to the inverting input in the above manner. Rf is the feedback resistor.Non inverting input of the opamp is grounded using resistor Rm. RL is the load resistor. By applying kirchhoff's current law at not V2 we get,

Ia+Ib+Ic = If+Ib

Since the input resistance of an ideal opamp is close to infinity and has infinite gain. We can neglect Ib & V2 There for Ia+Ib+Ic = If ……….(1)

Equation (1) can be rewritten as

(Va/Ra) + (Vb/Rb)+ (Vc/Rc) = (V2-Vo)/Rf

Neglecting Vo,

we get Va/Ra + Vb/Rb + Vc/Rc = -Vo/Rf

Vo = -Rf ((Va/Ra)+(Vb/Rb)+(Vc/Rc))

Vo = -((Rf/Ra)Va + (Rf/Rb) Vb + (Rf/Rc) Vc)……..(2)

If resistor Ra, Rb, Rc has same value ie; Ra=Rb=Rc=R, then equation (2) can be written as

Vo = -(Rf/R) x (Va + Vb +Vc)…………….(3)

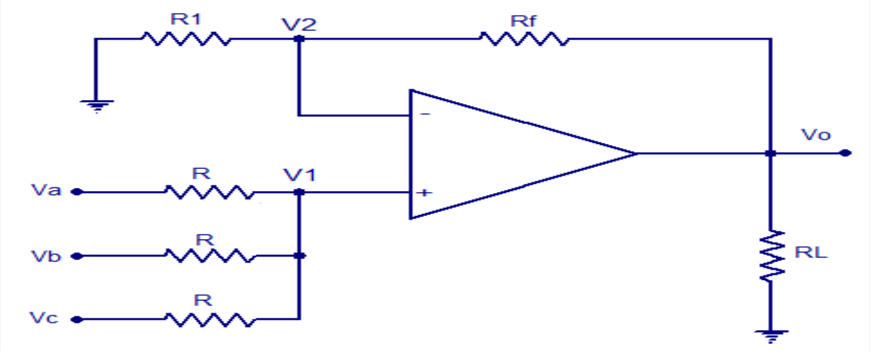
If the values of Rf and R are made equal , then the equation becomes,

Vo = -(Va + Vb +Vc)

Averaging Circuit : An averaging circuit can be made from the above circuit by making the all input resistor equal in value ie; Ra = Rb = Rc =R and the gain must be selected such that if there are m inputs, then Rf/R must be equal to 1/m.

Scaling amplifier : In a scaling amplifier each input will be multiplied by a different factor and then summed together. Scaling amplifier is also called a weighted amplifier. Here different values are chosen for Ra, Rb and Rc. The governing equation is Vo = -((Rf/Ra)Va + (Rf/Rb) Vb + (Rf/Rc) Vc).

Summing amplifier in non inverting configuration.



Summing amplifier non inverting configuration

Summing amplifier in non inverting configuration

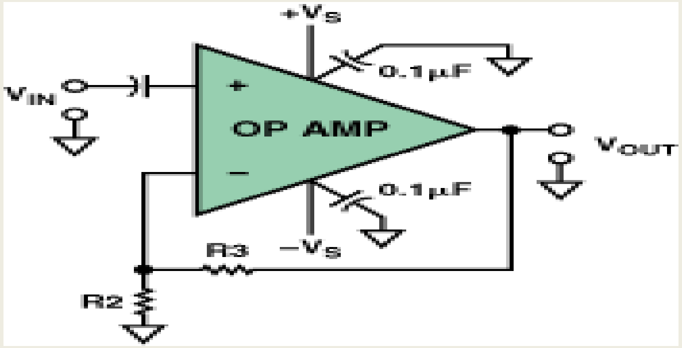
A non inverting summing amplifier circuit with three inputs are shown above. The voltage inputs Va, Vb and Vc are applied to non inverting input of the opamp. Rf is the feedback resistor. The output voltage of the circuit is governed by the equation;

Vo = (1+ (Rf/R1)) ((Va+Vb+Vc)/3)

Configuration.

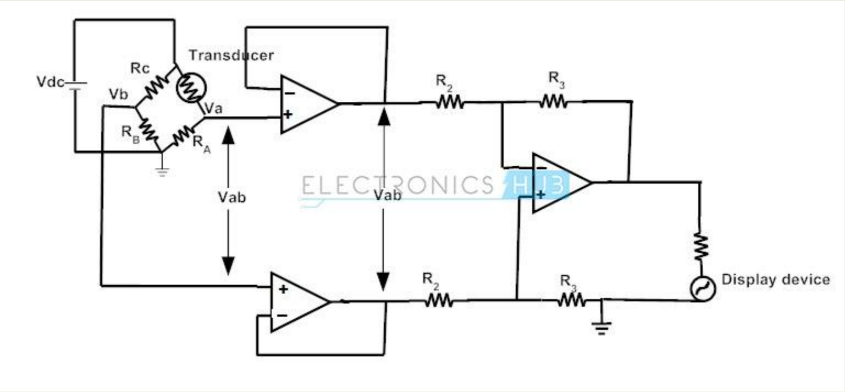
5.2 Explain DC & AC Amplifies using OP-AMP.

One of the most common application problems encountered is the failure to provide a dc return path for bias current in ac-coupled operational- or instrumentation-amplifier circuits. In Figure 1, a capacitor is connected in series with the noninverting (+) input of an op amp to ac couple it, an easy way to block dc voltages that are associated with the input voltage (V_{IN}). This should be especially useful in high-gain applications, where even a small dc voltage at an amplifier's input can limit the dynamic range, or even result in output saturation. However, capacitively coupling into a high-impedance input, without providing a dc path for current flowing in the + input, will lead to trouble!



5.3 Explain the operation of instrumentation amplifier using Transducer Bridge .

The resistive transducer bridge is a network of resistors whose resistance varies due to changes in some physical condition. For example, Thermistors change their resistance with temperature and Light Dependent Resistors change their resistance to change in light intensity. By making such a bridge as a part of the circuit, it is possible to produce an electrical signal proportional to the change in the physical quantity being measured. Such an electrical signal can be amplified and used to monitor and control the physical process. An instrumentation amplifier can be constructed with a transducer bridge connected to one of its input terminals, as shown in the figure below.



Let the resistance of the transducer device in the resistive bridge be R_T and the change in its resistance be ΔR. The effective resistance of the transducer device is $R_T \pm \Delta R$. The resistive bridge is supplied with a DC voltage, V_{dc}.

When the bridge is balanced, i.e. at some reference condition of the physical quantity being measured, we get,

$V_a = V_b$ and $R_A(Vdc)/(R_A+R_T) = R_B(Vdc)/(R_B+R_C)$

Under this condition, the differential input to the instrumentation amplifier is $V_{Diff} = V_b - V_a = 0$

Thus, the output of the amplifier is zero. Consequently, the display device connected at the output displays the reference value of the physical quantity being measured. The reference condition is generally chosen by the designer and it depends on the device characteristics of the transducer, the type of physical quantity being measured and the type of the application.

When there is a change in the physical quantity being measured, the voltage V_a will no longer be equal to V_b. This is because the resistance of the transducer device changes from R_T to $(R_T \pm \Delta R)$. This produces a differential input for the instrumentation amplifier and the output of the amplifier will no longer be zero.

The resistances R_B and R_C are constant and hence the voltage V_B remains same as before, i.e. $V_b = R_B(Vdc)/(R_B+R_C)$

But the voltage V_a changes due to the change in resistance of the transducer device and is now given as,

$Va = R_A(Vdc)/(R_A+R_T+ \Delta R)$

The differential voltage V_{Diff} is, $V_{Diff} = V_b - V_a$

$$V_{Diff} = \{R_B(Vdc)/(R_B+R_C)\} - \{R_A(Vdc)/(R_A+R_T+ \Delta R)\}$$

If all the resistances in the circuit are chosen to be of same value, i.e. $R_A = R_B = R_C = R_T = R$

$V_{Diff} = \{R(Vdc)/(2R)\} - \{R(Vdc)/(2R+ \Delta R)\}$

$V_{Diff} = \{RVdc[2R+\Delta R] - R.Vdc.2R\}/ 2R(2R+\Delta R)$

$V_{Diff} = .Vdc[+\Delta R-]/\{2(2R+\Delta R)\}$

$V_{Diff} = \Delta R(Vdc)/\{2(2R+\Delta R)\}$

If the value of V_{Diff} is positive, it indicates that V_b is greater than V_a.

The output of the instrumentation amplifier is given as, $V_O = (R_3/R_2)V_d$

$V_o = (R_3/R_2)\ [\Delta R(Vdc)/\{2(2R+\Delta R)\}]$

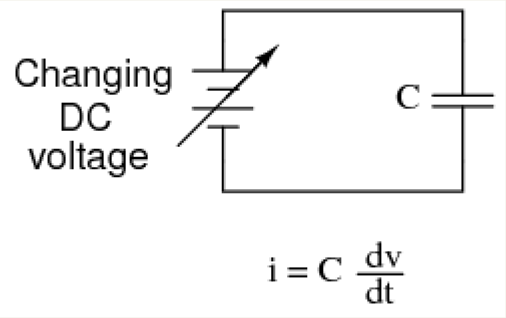
As the change in resistance ΔR << 2R, V_o can be written as, $V_o = (R_3/R_2)[\Delta R/4R](Vdc)$

From the above equation, it can be noted that the output depends on the change in the resistance ΔR. The display can be calibrated in terms of the units of the physical quantity being measured.

5.4 Discuss the integrator and differentiator using op-amp.

By introducing electrical reactance into the feedback loops of op-amp amplifier circuits, we can cause the output to respond to changes in the input voltage over *time*. Drawing their names from their respective calculus functions, the *integrator* produces a voltage output proportional to the product (multiplication) of the input voltage and time; and the *differentiator* (not to be confused with *differential*) produces a voltage output proportional to the input voltage's rate of change.

Capacitance can be defined as the measure of a capacitor's opposition to changes in voltage. The greater the capacitance, the more the opposition. Capacitors oppose voltage change by creating current in the circuit: that is, they either charge or discharge in response to a change in applied voltage. So, the more capacitance a capacitor has, the greater its charge or discharge current will be for any given rate of voltage change across it. The equation for this is quite simple:

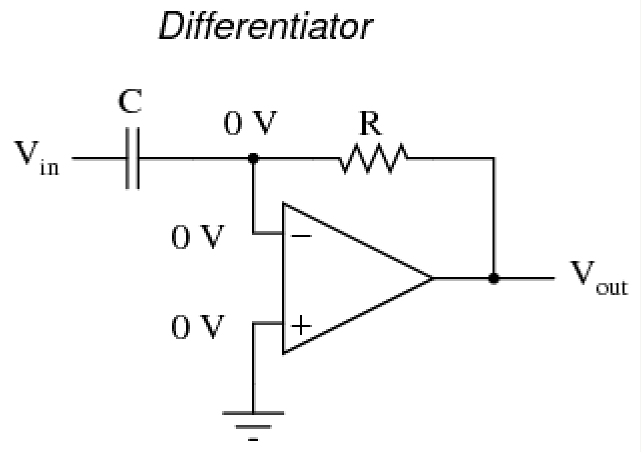


$$i = C\frac{dv}{dt}$$

The *dv/dt* fraction is a calculus expression representing the rate of voltage change over time. If the DC supply in the above circuit were steadily increased from a voltage of 15 volts to a voltage of 16 volts over a time span of 1 hour, the current through the capacitor would most likely be *very* small, because of the very low rate of voltage change (dv/dt = 1 volt / 3600 seconds). However, if we steadily increased the DC supply from 15 volts to 16 volts over a shorter time span of 1 second, the rate of voltage change would be much higher, and thus the charging current would be much higher (3600 times higher, to be exact). Same amount of change in voltage, but vastly different *rates* of change, resulting in vastly different amounts of current in the circuit.

To put some definite numbers to this formula, if the voltage across a 47 µF capacitor was changing at a linear rate of 3 volts per second, the current "through" the capacitor would be (47 µF)(3 V/s) = 141 µA.

We can build an op-amp circuit which measures change in voltage by measuring current through a capacitor, and outputs a voltage proportional to that current:



The right-hand side of the capacitor is held to a voltage of 0 volts, due to the "virtual ground" effect. Therefore, current "through" the capacitor is solely due to *change* in the input voltage. A steady input voltage won't cause a current through C, but a *changing* input voltage will.

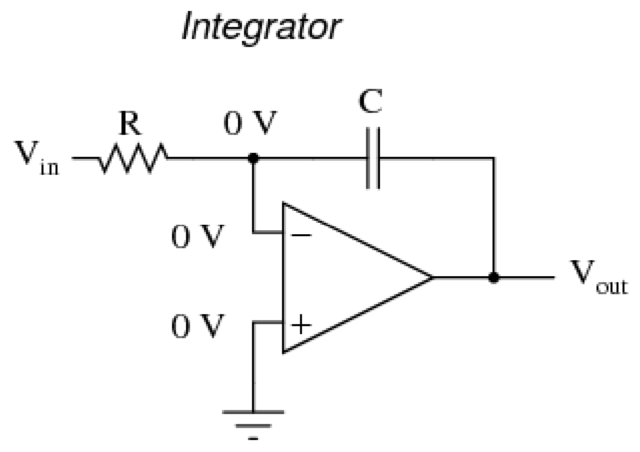
Capacitor current moves through the feedback resistor, producing a drop across it, which is the same as the output voltage. A linear, positive rate of input voltage change will result in a steady negative voltage at the output of the op-amp. Conversely, a linear, negative rate of input voltage change will result in a steady positive voltage at the output of the op-amp. This polarity inversion from input to output is due to the fact that the input signal is being sent (essentially) to the inverting input of the op-amp, so it acts like the inverting amplifier mentioned previously. The faster the rate of voltage change at the input (either positive or negative), the greater the voltage at the output.

The formula for determining voltage output for the differentiator is as follows:

$$V_{out} = -RC \ \frac{dv_{in}}{dt}$$

Applications for this, besides representing the derivative calculus function inside of an analog computer, include rate-of-change indicators for process instrumentation. One such rate-of-change signal application might be for monitoring (or controlling) the rate of temperature change in a furnace, where too high or too low of a temperature rise rate could be detrimental. The DC voltage produced by the differentiator circuit could be used to drive a comparator, which would signal an alarm or activate a control if the rate of change exceeded a pre-set level.

In process control, the derivative function is used to make control decisions for maintaining a process at setpoint, by monitoring the rate of process change over time and taking action to prevent excessive rates of change, which can lead to an unstable condition. Analog electronic controllers use variations of this circuitry to perform the derivative function. On the other hand, there are applications where we need precisely the opposite function, called *integration* in calculus. Here, the op-amp circuit would generate an output voltage proportional to the magnitude and duration that an input voltage signal has deviated from 0 volts. Stated differently, a constant input signal would generate a certain *rate of change* in the output voltage: differentiation in reverse. To do this, all we have to do is swap the capacitor and resistor in the previous circuit:



Integrator

As before, the negative feedback of the op-amp ensures that the inverting input will be held at 0 volts (the virtual ground). If the input voltage is exactly 0 volts, there will be no current through the resistor, therefore no charging of the capacitor, and therefore the output voltage will not change. We cannot guarantee what voltage will be at the output with respect to ground in this condition, but we can say that the output voltage *will be constant*.

However, if we apply a constant, positive voltage to the input, the op-amp output will fall negative at a linear rate, in an attempt to produce the changing voltage across the capacitor necessary to maintain the current established by the voltage difference across the resistor. Conversely, a constant, negative voltage at the input results in a linear, rising (positive) voltage at the output. The output voltage rate-of-change will be proportional to the value of the input voltage.

The formula for determining voltage output for the integrator is as follows:

$$\frac{dv_{out}}{dt} = -\ \frac{V_{in}}{RC}$$

or

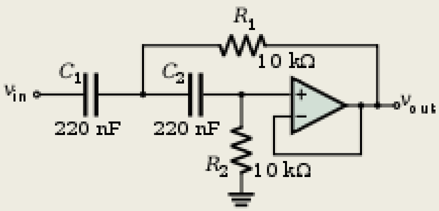
$$V_{out} = \int_{0}^{t} -\ \frac{V_{in}}{RC}\ dt + c$$

Where,

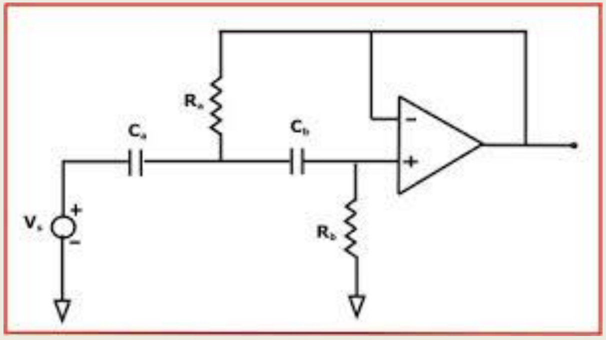
c = Output voltage at start time $(t=0)$

5.5 Define active filter and describe the filter design of fast order low Pass Butterworth filter. An **active filter** is a type of analog electronic filter that uses active components such as an amplifier. Amplifiers included in a filter design can be used to improve the performance and predictability of a filter,[1] while avoiding the need for inductors (which are typically expensive compared to other components). An amplifier prevents the load impedance of the following stage from affecting the characteristics of the filter. An active filter can have complex poles and zeros without using a bulky or expensive inductor. The shape of the response, the Q (quality factor), and the tuned frequency can often be set with inexpensive variable resistors. In some active filter circuits, one parameter can be adjusted without affecting the others. [1]

Using active elements has some limitations. Basic filter design equations neglect the finite bandwidth of amplifiers. Available active devices have limited bandwidth, so they are often impractical at high frequencies. Amplifiers consume power and inject noise into a system. Certain circuit topologies may be impractical if no DC path is provided for bias current to the amplifier elements. An **active filter** is a type of analog electronic filter that uses active components



5.6 Describe the filter design of fast order High Pass Butterworth filter. The **Butterworth filter** is a type of signal processing filter designed to have as flat a frequency response as possible in the passband. It is also referred to as a **maximally flat magnitude filter**. Butterworth stated that:



"An ideal electrical filter should not only completely reject the unwanted frequencies but should also have uniform sensitivity for the wanted frequencies".

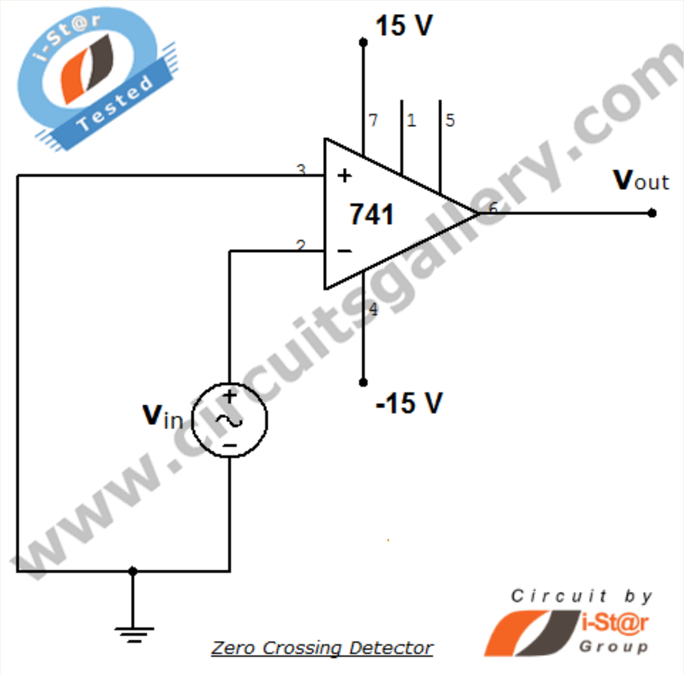
Such an ideal filter cannot be achieved but Butterworth showed that successively closer approximations were obtained with increasing numbers of filter elements of the right values. At the time, filters generated substantial ripple in the passband, and the choice of component values was highly interactive. Butterworth showed that a low pass filter could be designed whose cutoff frequency was normalized to 1 radian per second and whose frequency response (gain) was

$$G(\omega) = \sqrt{\frac{1}{1+\omega^{2n}}},$$

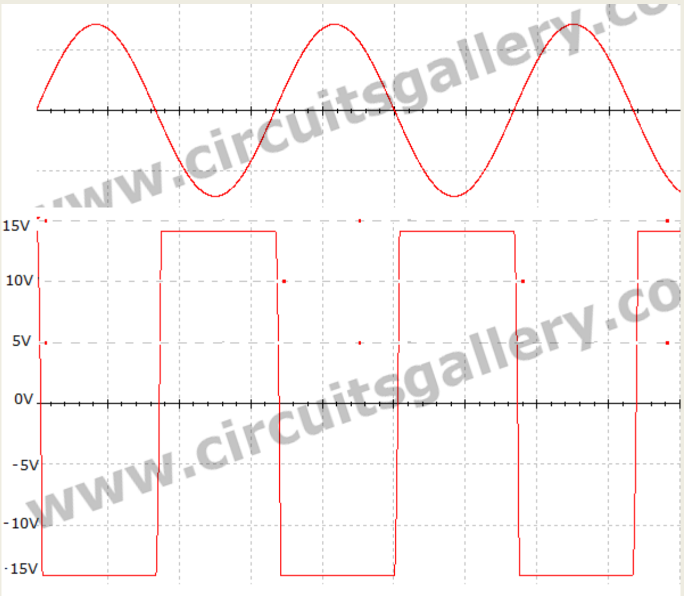
where ω is the angular frequency in radians per second and *n* is the number of poles in the filter—equal to the number of reactive elements in a passive filter. If ω = 1, the amplitude response of this type of filter in the passband is 1/√2 ≈ 0.707, which is half power or −3 dB. Butterworth only dealt with filters with an even number of poles in his paper. He may have been unaware that such filters could be designed with an odd number of poles. He built his higher order filters from 2-pole filters separated by vacuum tube amplifiers. His plot of the frequency response of 2, 4, 6, 8, and 10 pole filters is shown as A, B, C, D, and E in his original graph.

5.7 Explain the concept of Zero-Crossing Detector using Op-Amp Zero crossing detector(ZCD) is a **voltage comparator** that switches the output between +Vsat and –Vsat (Vsat: Saturation voltage almost equal to 14V) when the input crosses zero reference voltage. Then **what is a comparator?** In simple words comparators are basic operational amplifier circuits that compare two voltages simultaneously and switches the output according to the comparison. We can say zero crossing detection circuit is a comparator example. We will discuss in detail about comparator in our upcoming articles. Inverting zero cross detector circuit schematic using op amp 741 IC is shown below along with working, input output wave forms.

Zero crossing circuit diagram



ZCD Input and Output Waveform



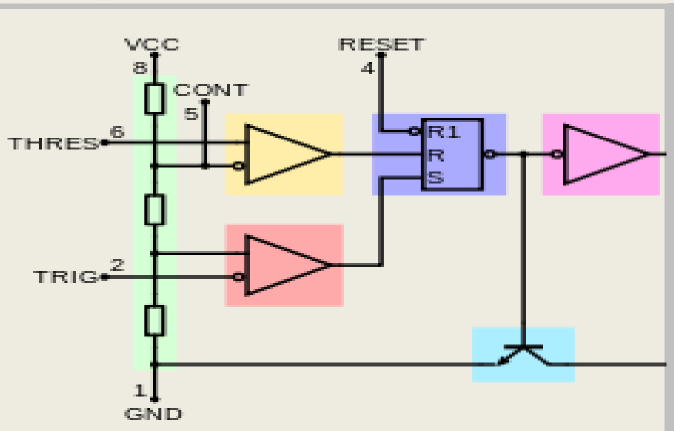
Working of zero crossing detector circuit

- Working of ZCD can be easily understood if you know the working of a basic opamp comparator.
- In ZCD, we are setting one of the inputs as zero i.e. zero reference voltage.
- The output is driven into –Vsat when the input signal passes through zero to positive direction.
- Conversely, when input signal passes through zero to negative direction, the output switches to +Vsat.

Zero crossing detector applications

ZCD circuit can be used to **check** whether the op-amp is in **good condition**. Zero crossing detectors can be used as frequency counters and for switching purposes in power electronics circuits.ZCD is a basic op amp circuit.

5.8 Draw the block diagram and operation of IC 555 timer &IC 565 PLL& its applications. The **555 timer IC** is an integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications. The 555 can be used to provide time delays, as an oscillator, and as a flip-flop element. Derivatives provide up to four timing circuits in one package.



Internal block diagram

The **555 timer IC** is an integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications. The 555 can be used to provide time delays, as an oscillator, and as a flip-flop element. Derivatives provide up to four timing circuits in one package.

Introduced in 1971 by Signetics, the 555 is still in widespread use due to its ease of use, low price, and stability. It is now made by many companies in the original bipolar and also in low-power CMOS types. As of 2003, it was estimated that 1 billion units are manufactured every year.[1]

Modes

The 555 has three operating modes:

- **Monostable** mode: In this mode, the 555 functions as a "one-shot" pulse generator. Applications include timers, missing pulse detection, bouncefree switches, touch switches, frequency divider, capacitance measurement, pulse-width modulation (PWM) and so on.
- **Astable** (free-running) mode: The 555 can operate as an oscillator. Uses include LED and lamp flashers, pulse generation, logic clocks, tone generation, security alarms, pulse position modulation and so on. The 555 can be used as a simple ADC, converting an analog value to a pulse length. E.g. selecting a thermistor as timing resistor allows the use of the 555 in a temperature sensor: the period of the output pulse is determined by the temperature. The use of a microprocessor based circuit can then convert the pulse period to temperature, linearize it and even provide calibration means.
- **Bistable** mode or Schmitt trigger: The 555 can operate as a flip-flop, if the DIS pin is not connected and no capacitor is used. Uses include bounce-free latched switches.

IC 565 PLL

A PLL is also available as an integrated circuit IC. IC 565 PLL can be used for FM detection.

Figure (a) shows the circuit diagram of an FM detector using 565 PLL.

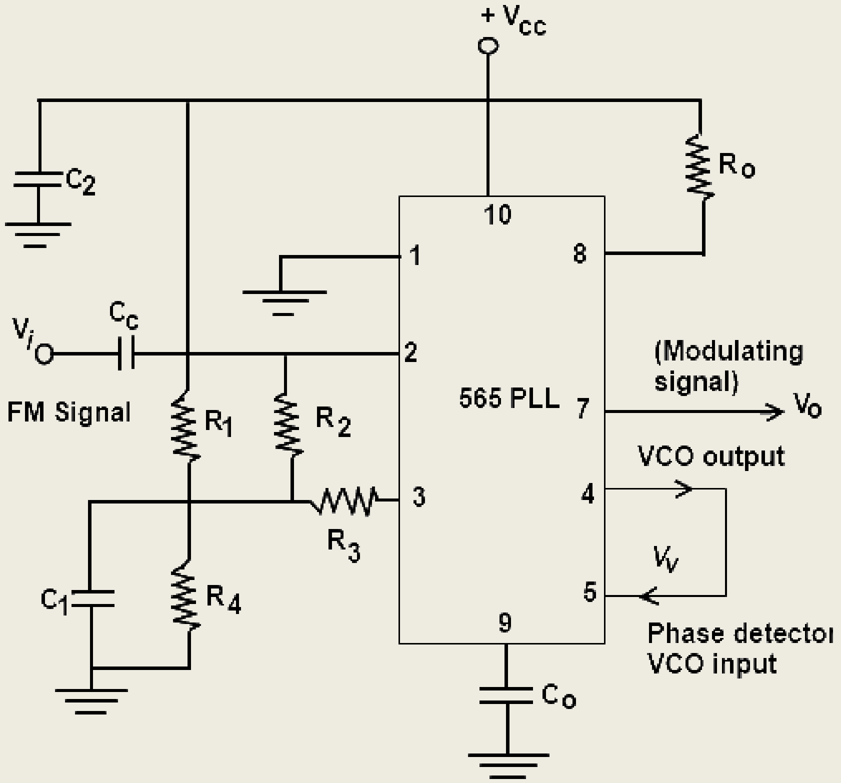


Figure (a): Circuit Diagram for an FM Detector Using IC 565 PLL

Internal Block Diagram of IC 565

The internal block diagram shows that IC 565 PLL consists of phase detector, VCO, and amplifier. The amplifier also functions as the low pass filter. This is a 14 pin dual in line package.

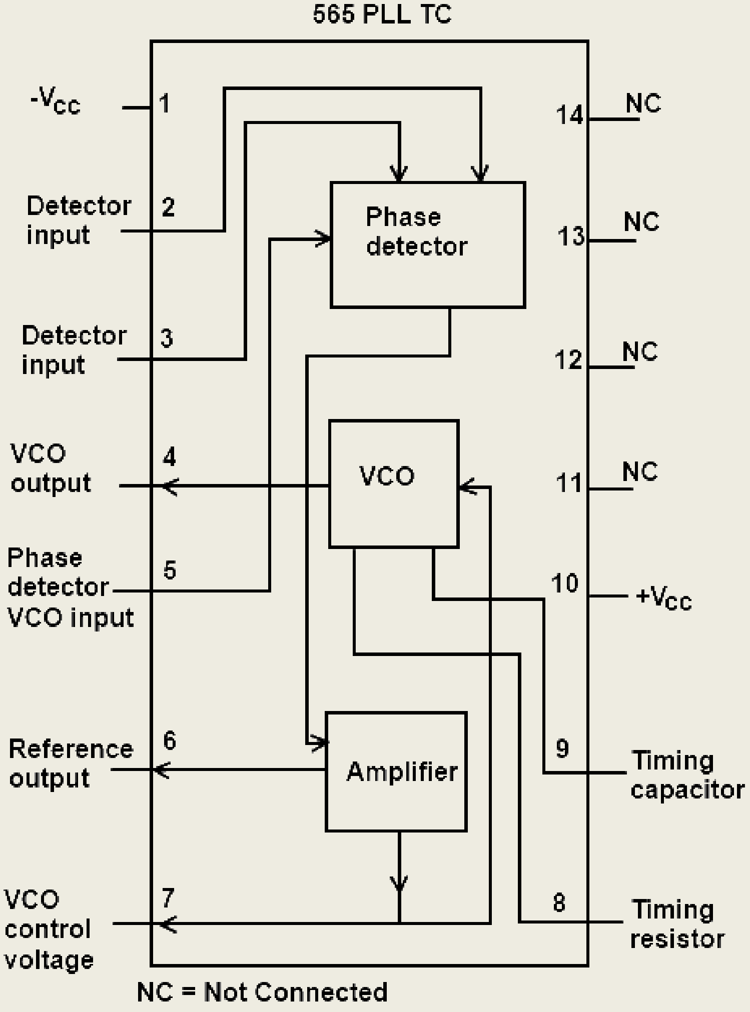


Figure (b): Internal Block Diagram of IC 565 PLL

In figure (b), notice that PLL IC consists of two power supply pins marked ±Vcc. The positive terminal of the Vcc is connected to pin number 10, and the negative (ground) terminal of Vcc is connected to pin number 1. The output signal to the phase detector is applied to pin numbers 2 and 3. The VCO output is applied to the phase detector through pin number 5. The output of the phase detector is internally connected to the amplifier (low-pass filter).

The output or the phase detector is low-pass filtered and amplified by the amplifier stage. The Output or the amplifier is the control voltage that is applied to VCO to force it to track the incoming frequency. The control voltage is also available at pin number 7. This is the output signal. In the ease of FM demodulator, the signal at pin number 7 is the modulating signal. The amplifier also generates an output at pin number 6for reference purposes.

The VCO gets its control voltage internally from the amplifier and its output at pin number 4. The VCO output should be given to the phase detector through pin number 5. It is customary to short pin numbers 4 and 5 so that the VCO output is applied directly to the phase detector. The external resistor and capacitor can set the free-running frequency of the VCO. The resistor and capacitor are called the timing resistor and the timing capacitor. The timing resistor is connected at pin number 8, and the timing capacitor is connected at pin number 9.

Pin numbers 11, 12, 13, and 14 are not connected because they do not have any internal circuitry with them. These are marked as NC in Figure (b). These pins are there because they are connected to IC.

Circuit Description

Figure (a) shows the circuit external to the IC 565 PLL for FM detection. The circuit shown in this figure is a general circuit. The choice of the timing components, resistor R_0 and capacitor C_0 decides the various parameters and the free-running frequency of PLL. Accordingly, the values of other components are also chosen.

In Figure (a), only a few components are externally connected to IC. The power supply, V_{cc}, is connected between pin numbers 1 and 10, with $+V_{cc}$ applied at pin number 10. The timing resistor R_o is connected to pin number 8, and the timing capacitor, C_o is connected to pin number 9. The VCO output, which is available at pin number 4 is applied to phase-detector input at pin number 5. Pin number 4 is shorted with pin number 5 as no external component is required in this case.

The input FM signal, V_i, is applied to pin number 2 through the coupling capacitor C_c. A part of this signal is also applied to pin number 3 through the potential divider network, consisting of R_2, R_3, and R_4. The dc power supply is also provided to the input pins 2 and 3 through R_1 from $+V_{cc}$ supply. The capacitor C_2 is used to filter out an AC ripple, if present in the DC supply.

The demodulated FM signal is nothing but the control signal, which is available at pin number 7. Therefore, the signal available at pin number 7 is the required modulating signal.

Parameters of Interest

The manufacturers of IC chips provide information related to the design of the circuit using their IC chips. They provide the design equations for important and key parameters of the circuit in terms of the circuit components and known circuit Conditions.

Some typical design equations for various parameters related to PLL operation are:

- Free-running frequency (f_o). The free-running frequency of VCO may he calculated as:

  $$f_0 = 0.3/R_0C_0$$

  For C_0 = 1.5 nF and R_0 = 20 KΩ, the free-running frequency is calculated as:

  $$f_0 = 0.3/(20 \text{ X } 10^3)(1.5 \text{ X } 10^{-9})$$
  $$f_0 = 10 \text{ KHz}$$

  Thus, for the central frequency of an FM signal to be 10 kHz, a resistor 420 KΩ and a capacitor of 1.5 nF can be used as timing components.

- Loop gain
  The loop gain of PLL decides the amount of phase change among the input signals of the phase detector for a change in the input signal frequency. The loop may be defined as:

$$A_L = K_D K_O \text{ per second}$$

where
K_D = Phase detector sensitivity in volt/radians
K_O = Oscillator sensitivity in radians/see-volt
A typical formula given by a manufacturer nay be given is:

$$K_D K_O = 33.6\ f_0/V_c$$

Where
f_0 = free-running frequency of V_{co} in Hz
V_c = Supply voltage
if V_c = 12 V and f = 10 KHz

$$K_D K_O = 33.6 \text{ X } 10 \text{ X } 10^3\ f_0/12$$
$$K_D K_O = 28 \text{ X } 10^3$$

Therefore, the loop given for the given values of V_c and f_0 is 28,000.

- Hold-in range
  The hold-in range may be calculated as:

$$f_h = \pm 8 f_0/V_c$$

Where
f_0 = free running of VCO
V_c = supply voltage
For f_0 = 10 KHz and V_c = 12 V, the hold-in range is calculated from above Equation as:

$$f_h = \pm 8 \text{ X } 10 \text{ X } 10^3/12$$
$$f_h = \pm 6.67 \text{ KHz}$$

Therefore, for the given values, the loop will remain locked over a frequency range of ±6.67 KHz after it is locked initially.

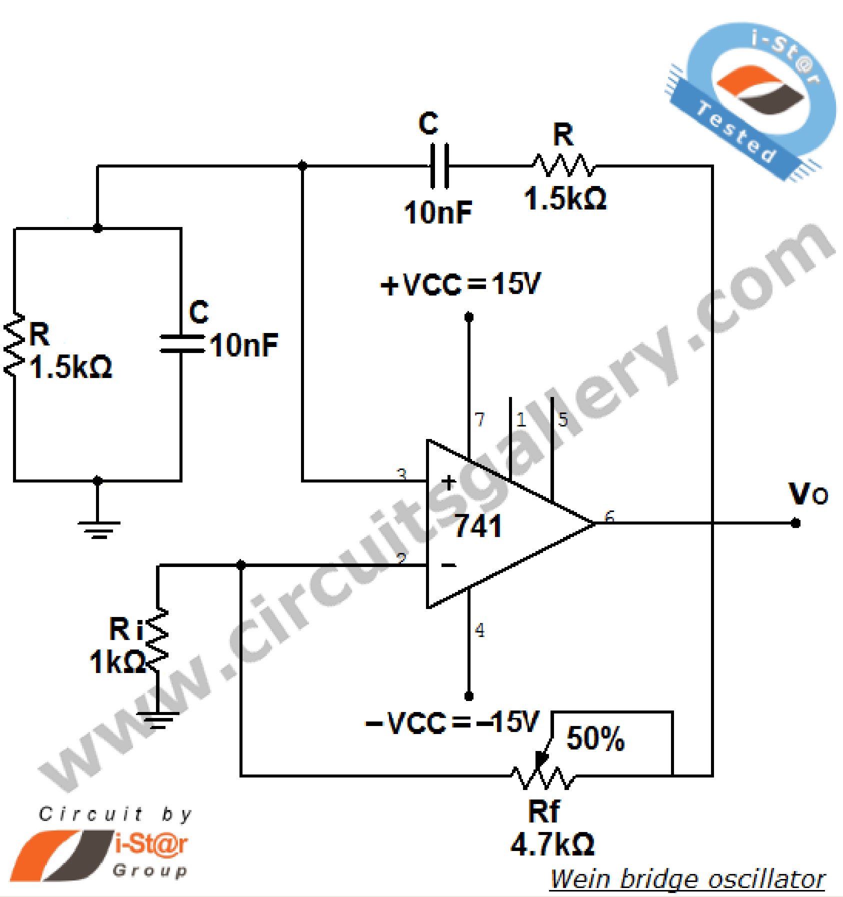
5.9 Explain the working of Wein Bridge Oscillator using operational Amplifier. Wien bridge oscillator is an **audio frequency sine wave oscillator** of high stability and simplicity. Before that let us see **what is oscillator?** An oscillator is a circuit that produces periodic electric signals such as sine wave or square wave. The application of oscillator includes **sine wave generator**, local oscillator for synchronous receivers etc.

Here we are discussing **wein bridge oscillator using 741 op amp IC**. It is a low frequency oscillator. The op-amp used in this oscillator circuit is working as non-inverting amplifier mode. Here the feedback network need not provide any phase shift. The circuit can be viewed as a wien bridge with a series RC network in one arm and parallel RC network in the adjoining arm. Resistors Ri and Rf are connected in the remaining two arms.

Also see:

- RC phase shift oscillator using 741 op amp
- RC phase shift oscillator using transistor

Wien bridge oscillator Circuit Diagram



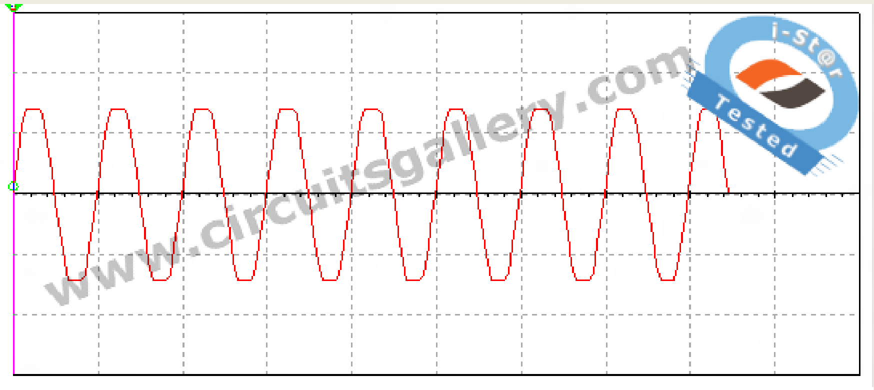
Wein bridge oscillator

Components Required

1. Resistors (1KΩ, 1.5KΩ x2)

2. Potentiometer(4.7KΩ)
3. Capacitor(0.1µF x2)
4. 741 Op amp

Output Waveform



Working of Wein bridge Oscillator

- The feedback signal in this oscillator circuit is connected to the non-inverting input terminal so that the op-amp works as a non-inverting amplifier.

- The condition of zero phase shift around the circuit is achieved by balancing the bridge, zero phase shift is essential for sustained oscillations.

- The frequency of oscillation is the resonant frequency of the balanced bridge and is given by the expression **fo = 1/2πRC**

- At resonant frequency (ƒo), the inverting and non-inverting input voltages will be equal and “in-phase” so that the negative feedback signal will be cancelled out by the positive feedback causing the circuit to oscillate.

- From the analysis of the circuit, it can be seen that the feedback factor β= 1/3 at the frequency of oscillation. Therefore for sustained oscillation, the amplifier must have a gain of 3 so that the loop gain becomes unity.

- For an inverting amplifier the gain is set by the feedback resistor network Rf and Ri and is given as the ratio -Rf/Ri.

Design

The required frequency of oscillation **fo=1kHz**

we have,

$$f_O = \frac{1}{2\pi RC}$$

Take **C=0.01µF**, then **R=**1.6kΩ (Use **1.5kΩ** standard)

Gain of the amplifier section is given by,

$$G = 1 + \frac{R_f}{R_i} = 3$$

Take **Ri=1kΩ**, then **Rf**=2.2kΩ (Use **4.7kΩ Potentio meter** for fine corrections)

Wien bridge oscillator Frequency calculator

R1 and C1 in the series arm and R2 C2 in parallel arm of feedback circuit

Enter the Value of Resistor, R1 :in Ω
Enter the Value of Capacitor, C1 :in Farads
Enter the Value of Resistor, R2 :in Ω
Enter the Value of Capacitor, C2 :in Farads

Frequency of oscillation, F :in Hz

5.10 **Explain Current to voltage Convertor using Operational Amplifier :** The current to voltage converter was presented as a special case of the inverting amplifier in which an input current is converted into a proportional output voltage. One of the most common uses of the current to voltage converter is in digital to analog circuits and in sensing current through photo detectors such as photocells, photodiodes and photovoltaic cells. Photosensitive devices produce a current that is proportional to an incident radiant energy or light and therefore can be used to detect the light.

Voltage to frequency and frequency to voltage converters: This investigates the Teledyne 9400 series, which can be used as voltage to frequency (V/F) or frequency to voltage (F/V) converters. These converters have the same internal circuitry and connection diagrams, but they differ slightly in electrical characteristics. A complete V/F or F/V system can be formed simply by using two external capacitors, three resistors and a reference voltage. The 9400 series consists of CMOS and bipolar devices that can operate on dual or single supply voltages.

5.11 Explain the Voltage to Frequency Convertor using Operational Amplifier: The 9400 is designed for pulse and square wave outputs having a frequency range of 1Hz to 100kHz.The input can be either current or voltage and the output can interface with most forms of logic. The equivalent circuit consists of an integrator, comparators, a delay network, a divide-by-2 network, an open – collector output transistors. The input current is converted to a charge by the integrating capacitor and shows up as a linearly decreasing voltage at the output of the op amp integrator. The output of the integrator is sensed by the comparator. The output of the comparator is then applied via the delay network to the output transistor Q1,the divide-by-2 network, and the charge/discharge control unit. The output of the divide-by-2 network drives the output transistor Q2.

The V/F converter is used in instrumentation and control, digital and communication systems, temperature sensing and control, transducer encoding, analog to digital converters, digital panel meters, phase-locked loops and analog data transmission and recording.

5.12 Explain the Frequency to Voltage Conversion using Operational Amplifier: When used as an F/V converter the 9400 generates an output voltage that is linearly proportional to the input frequency waveform. The features of the 9400 F/V converter include dc to 100-kHz operation, op-amp output, programmable scale factor, high input impedance (>10Mohm), and above all its capability to accept any voltage wave shape.

The 9400 F/V converter can be used in applications such as frequency meters and tachometers, speedometers, rpm indicators,FM demodulation frequency multipliers and dividers and motor control.

CHAPTER- 6. IC VOLTAGE REGULATORS .

6.1 Explain the operation of power supply using 78XX and 79XX Series

(Fixed Voltage Regulator) Regulator IC 78xx and 79xx

20/05/2014 Kang Pree

As we know that almost all electronic equipment requires a stable DC voltage source in order to operate properly and optimally. Battery and Accumulator is a stable DC voltage source for this purpose. However, the voltage source will continue to decline and eventually run out so that it can no longer be used as an energy source. In this condition a particular brand battery must be replaced with a new battery, but for the other battery and accumulator rechargeable energy can be done.

To charge the battery voltage can disconnect the battery to be recharged, but many electronic devices that provide special charging port so no need to disconnect the battery, the device can even still be able to operate while charging.

Some electronic devices such as laptops, notebooks, and tablets already have automatic re-charging feature while operate the equipment. In other words, the user can use the laptop while charging. The advantages of this system can protect users lose files or disrupted work because when the main AC power off, then the battery will automatically supplying a voltage to the equipment, otherwise when the main power is restored, the battery that had been used can be recharged while continuing to work.

To stabilize the DC voltage can be done in many ways using a variety of electronic components in accordance with a requirement specification of electronic equipment. Electronic components are combined to form a DC regulator circuit, one of the main components for this purpose is a **regulator IC 78xx and 79xx**.

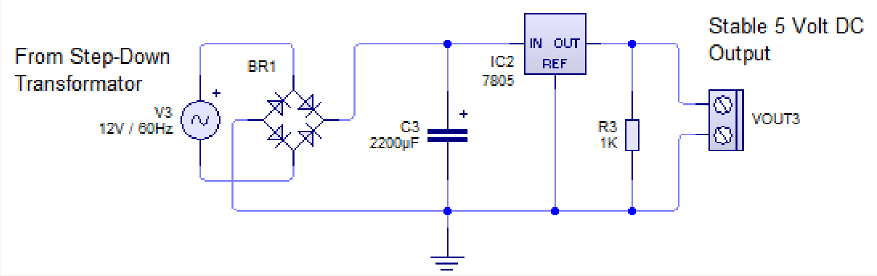
IC 78xx regulator serves to stabilize the positive DC voltage (positive and ground) while the regulator IC 79xx serves to stabilize the negative DC voltage (ground and negative). “xx” is the two numbers listed on the label IC which is a stable DC voltage that can be generated. Example, IC 7805 produce stable positive DC voltage of +5 volts, the IC 7912 generates a negative DC voltage of -12 volts stable, and so on.

The physical form of the *regulator IC 78xx and 79xx* are the same, it’s just three feet ICs have different functions. For positive voltage regulator IC 78xx, the first leg is the input, the second leg (middle) is ground, and the third leg is the output. For negative voltage regulator IC 79xx, the first leg is grounded, the second leg is the input, and the third leg is the output.

Regulator IC 78xx

regulator IC 78xx and 79xx has characteristics specified by the manufacturer in order to work correctly and optimally, for the purposes of this can be seen through the data-sheet book.

Below is one example of a DC voltage regulator circuit using IC 7805 to produce a stable DC voltage +5 Volt.

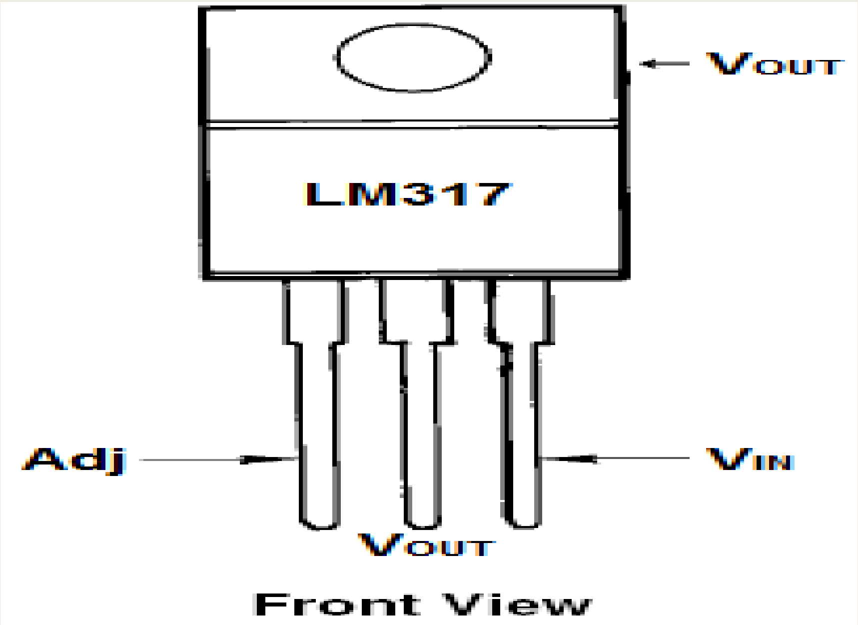


Full Wave Regulator

6.2 Draw the functional block diagram of IC regulator LM 723 &LM 317.

LM317 Pinout

The LM317 Voltage Regulator has 3 pins. Below is the pinout:



Looking from the front of the voltage regulator, the first pin (on the left) is the Adjustable Pin, the middle is Vout, and the last pin(on the right) is VIN.

VIN- VIN is the pin which receives the incoming voltage which is to be regulated down to a specified voltage. For example, the input voltage pin can be fed 12V, which the regulator will regulate down to 10V. The input pin receives the incoming, unregulated voltage.
Adjustable- The Adjustable pin (Adj) is the pin which allows for adjustable voltage output. To adjust output, we swap out resistor R2 value for a different resistance. This creates adjustable voltages.
VOUT- VOUT is the pin which outputs the regulated voltage. For example, the LM317 may receive 12V as the input and output a constant 10V as output.

LM317 Schematic Diagram

Now that you know the pins, how do we modify the voltage to that which we want output?

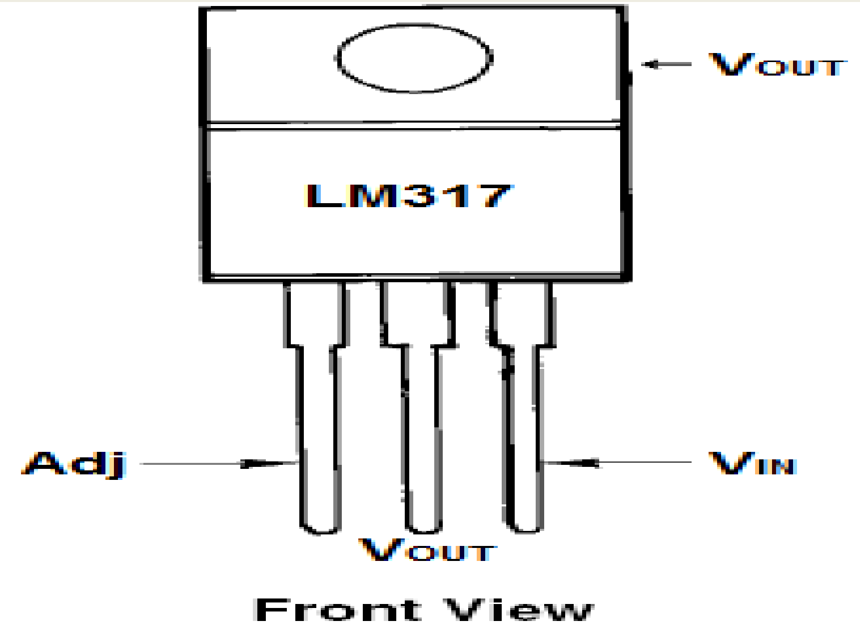
We do this by changing the value of the resistor connected to the Adj pin of the voltage regulator.

Let's see how the schematic is set up:

6.3 Explain the voltage power supply using LM 317 and LM 337.

LM317 Pinout

The LM317 Voltage Regulator has 3 pins. Below is the pinout:



Looking from the front of the voltage regulator, the first pin (on the left) is the Adjustable Pin, the middle is Vout, and the last pin(on the right) is VIN.

VIN- VIN is the pin which receives the incoming voltage which is to be regulated down to a specified voltage. For example, the input voltage pin can be fed 12V, which the regulator will regulate down to 10V. The input pin receives the incoming, unregulated voltage.
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VOUT- VOUT is the pin which outputs the regulated voltage. For example, the LM317 may receive 12V as the input and output a constant 10V as output.

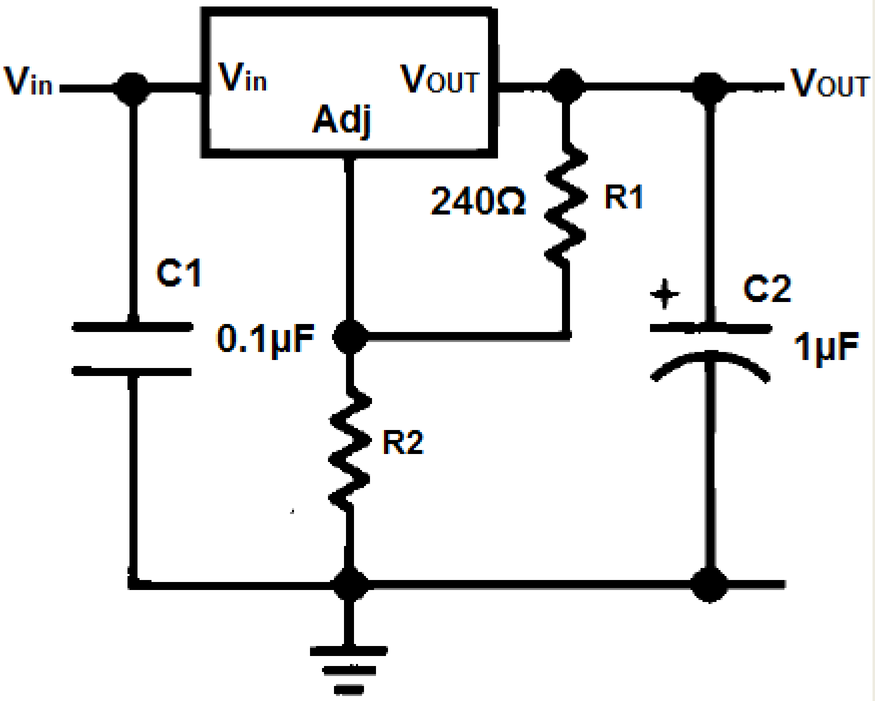
LM317 Schematic Diagram

Now that you know the pins, how do we modify the voltage to that which we want output?

We do this by changing the value of the resistor connected to the Adj pin of the voltage regulator.

Let's see how the schematic is set up:

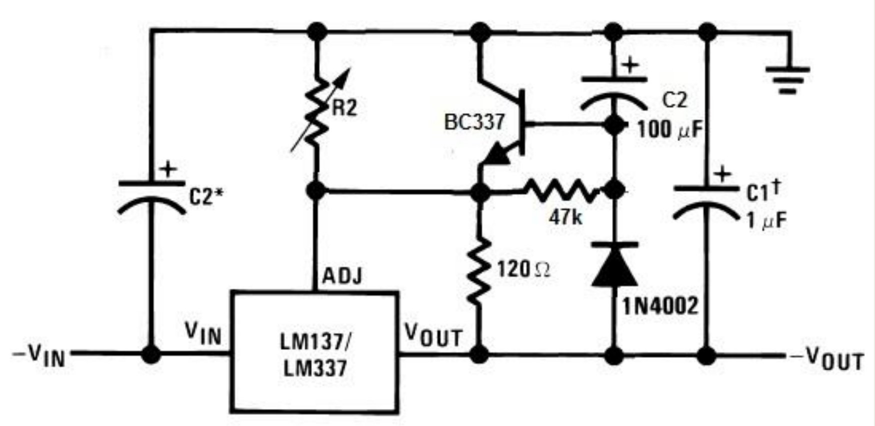
LM317 Voltage Regulator Circuit



Here you see we connect two resistors to the voltage regulator. These resistors determine the voltage that the voltage regulator adjusts to and outputs.

The voltage that the adjustable regulator outputs is determined by the equation below:

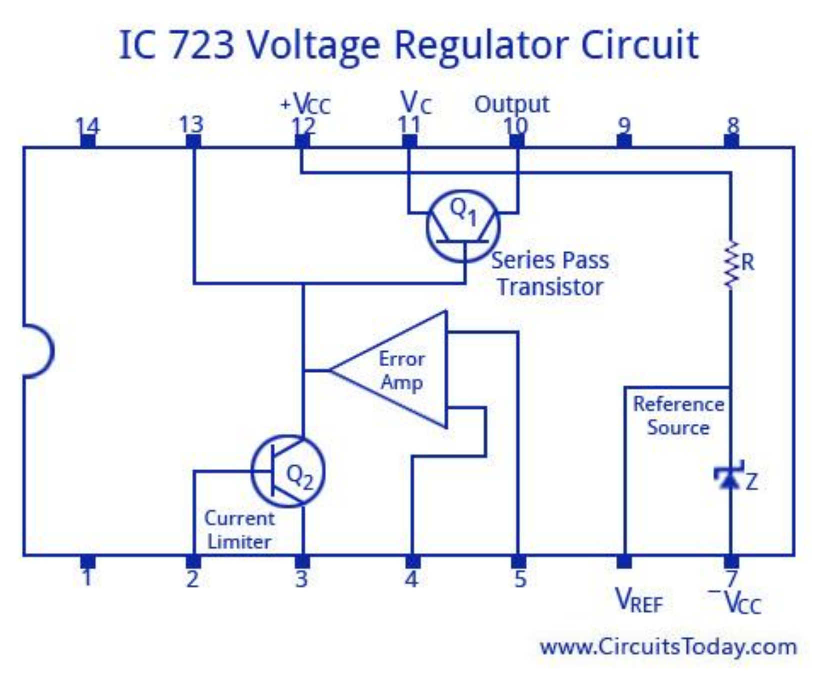
$$V_{OUT} = 1.25V\left(1+\frac{R2}{R1}\right)$$



6.4 Explain the voltage power supply using LM 723.

IC 723 Voltage Regulators

We have already explained in detail about the basics of **regulated power supply**, **voltage regulators** and **IC voltage regulators**. Let us take a look at one of the most popular IC voltage regulators, the 723 Voltage Regulator IC. The functional diagram of the voltage regulator is shown below. It consists of a voltage reference source (Pin 6), an error amplifier with its inverting input on pin 4 and non-inverting input on pin 5, a series pass transistor (pins 10 and 11), and a current limiting transistor on pins 2 and 3. The device can be set to work as both posistive and negaive voltage regulators with an output voltage ranging from 2 V to 37 V, and output current levels upto 150 m A. The maximum supply voltage is 40 V, and the line and load regulations are each specified as 0.01%.

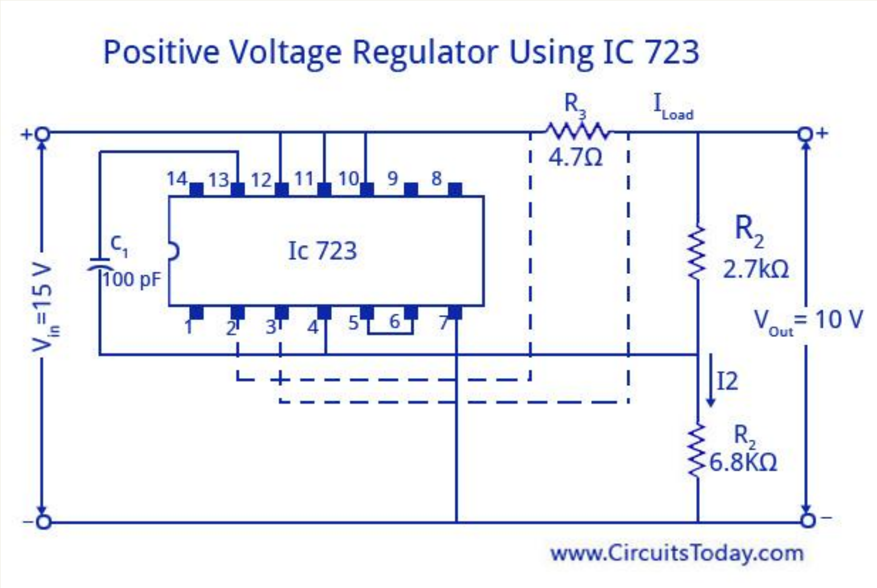


IC 723 Voltage Regulator Circuit

We have already explained in detail about the basics of voltage regulators and IC voltage regulators. Let us take a look at one of the most popular IC

voltage regulators, the 723 Voltage Regulator IC. The functional diagram of the voltage regulator is shown below. It consists of a voltage reference source (Pin 6), an error amplifier with its inverting input on pin 4 and non-inverting input on pin 5, a series pass transistor (pins 10 and 11), and a current limiting transistor on pins 2 and 3. The device can be set to work as both posistive and negaive voltage regulators with an output voltage ranging from 2 V to 37 V, and output current levels upto 150 m A. The maximum supply voltage is 40 V, and the line and load regulations are each specified as 0.01%.

The figure shown below is a positive voltage regulator with an IC 723. The output voltage can be set to any desired positive voltage between (7-37) volts. 7 volts is the reference starting voltage. All these variations are brought with the change of values in resistors R1 and R2 with the help of a potentiometer. A darlington connection is made by the transistor to Q1 to handle large load current. The broken lines in the image indicate the internal connections for current limiting. Even foldback current limiting is possible in this IC. A regulator output voltage less than the 7 V reference level can be obtained by using a voltage divider across the reference source. The potentially divided reference voltage is then connected to terminal 5.



Positive Voltage Regulator Using IC 723

Another importat point to note about this IC is that the supply voltage at the lowest point on the ripple waveform, should be at least 3 V greater than the output of the regulator and greater than Vref. If it is not so a high-amplitude output ripple is possible to occur.

CHAPTER -7. PRINTED CIRCUIT BOARD (PCB).

7.1 Discuss the different types of PCB : single sided double sided multi layer **Different types of PCB:**

1)Breadboard

This is a way of making a temporary circuit, for testing purposes or to try out an idea. No soldering is required and all the components can be re-used afterwards. It is easy to change connections and replace components.

Fig 2. Breadboard

2)Stripboard

Permanent, soldered

Stripboard has parallel strips of copper track on one side. The strips are 0.1" (2.54mm) apart and there are holes every 0.1" (2.54mm). It can be cut with a junior hacksaw, or simply snap it along the lines of holes by putting it over the edge of a bench or table and pushing hard.

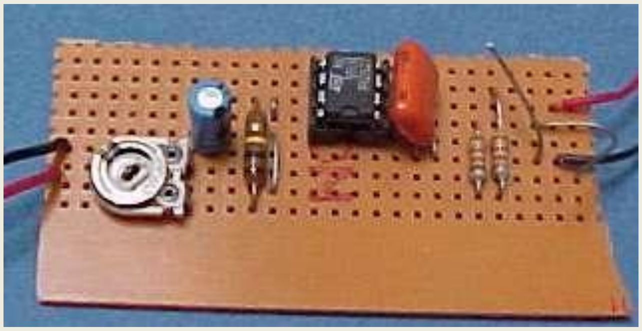


Fig 3 . Stripboard

3)Printed Circuit Board

Permanent, soldered

Printed circuit boards have copper tracks connecting the holes where the components are placed. They are designed specially for each circuit and make construction very easy.

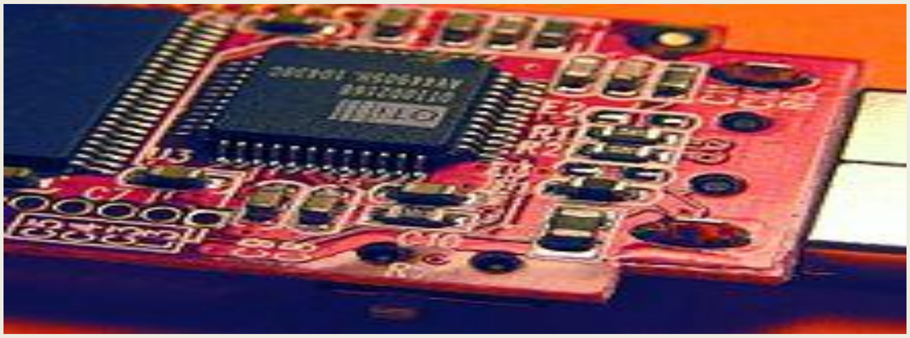
PCB

Fig 4

SMD : (Surface mount Components):

Surface mount technology (**SMT**) is a method for constructing electronic circuits in which the components (SMC, or Surface Mounted Components) are mounted directly onto the surface of printed circuit board (PCBs). Electronic devices so made are called surface mount devices or **SMD**s. In the industry it has largely replaced the throgh hole technology construction method of fitting components with wire leads into holes in the circuit board.

Surface Mount Capacitor.



Surface-mount components on a USB flash drive's circuit board. The small rectangular chips with numbers are resistors, while the unmarked small rectangular chips are capacitors. The capacitors and resistors pictured are 0603 (1608 metric) package sizes, along with a very slightly larger 0805 (2012 metric) ferrite bead. Not shown here, even smaller chip capacitors are 0402 (1005 metric) and 0201 (0603 metric) sizes

7.2 Explain the PCB design principle (Brief description): The schematic Diagram, Layout design,

A **printed circuit board** (**PCB**) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. PCBs can be *single sided* (one copper layer), *double sided* (two copper layers) or *multi-layer*. Conductors on different layers are connected with plated-through holes called vias. Advanced PCBs may contain components - capacitors, resistors or active devices - embedded in the substrate.

Printed circuit boards are used in all but the simplest electronic products. Alternatives to PCBs include wire wrap and point-to-point construction. PCBs require the additional design effort to lay out the circuit but manufacturing and assembly can be automated. Manufacturing circuits with PCBs is cheaper and faster than with other wiring methods as components are mounted and wired with one single part. Furthermore, operator wiring errors are eliminated.

When the board has only copper connections and no embedded components, it is more correctly called a *printed wiring board* (*PWB*) or *etched wiring board*. Although more accurate, the term printed wiring board has fallen into disuse. A PCB populated with electronic components is called a *printed circuit assembly* (*PCA*), *printed circuit board assembly* or *PCB assembly* (*PCBA*).

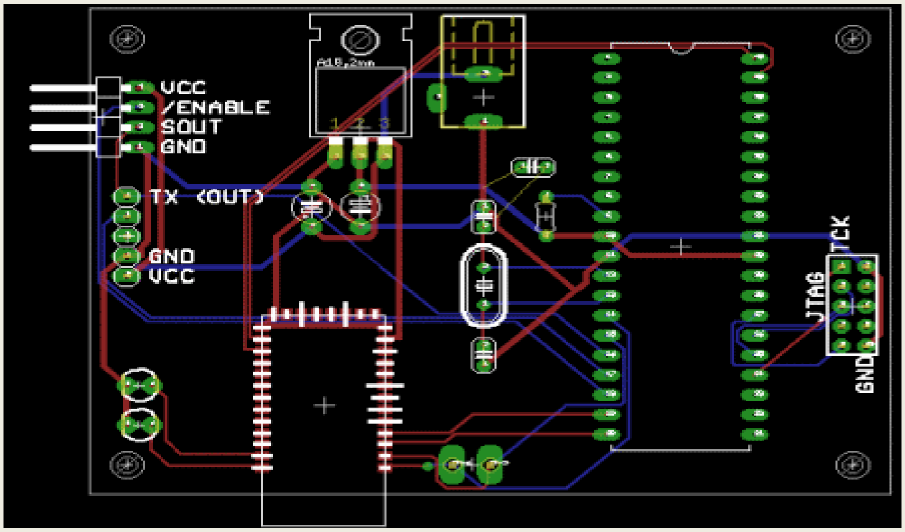
PCB design process

Preparing the board layout

Now it's time to draw the board. You need to transfer your schematic diagram into a drawing of your printed circuit board.

Drawing PCB's is artwork. Take your time, and make sure it looks good. Follow the design guidelines for drawing circuit boards.

Most PCB software will have tools that will help you draw your board from the schematic. I can't cover them all, but I've written a PCB design tutorial for Eagle to help you learn.



Artwork, Manufacturing of film master.

7.3 Explain PCB fabrication procedure (Brief description): Cutting of PCB, Cleaning, Lamination,

Exposing, Developing, Etching, Drilling, Solder Max, Tinning, Legend Printing and Finishin**Patterning (etching)**

The vast majority of printed circuit boards are made by bonding a layer of copper over the entire substrate, sometimes on both sides, (creating a "blank PCB") then removing unwanted copper after applying a temporary mask (e.g. by etching), leaving only the desired copper traces. A few PCBs are made by adding traces to the bare substrate (or a substrate with a very thin layer of copper) usually by a complex process of multiple electroplating steps. The PCB manufacturing method primarily depends on whether it is for production volume or sample/prototype quantities. PCB milling uses a two or three- axis mechanical milling system to mill away the copper foil from the substrate. A PCB milling machine (referred to as a 'PCB Prototyper') operates in a similar way to a plotter, receiving commands from the host software that control the position of the milling head in the x, y, and (if relevant) z axis. Data to drive the Prototyper is extracted from files generated in PCB design software and stored in HPGL or Gerber file format.

Etching

Chemical etching is done with ferric chloride, ammonium persulfate, or sometimes hydrochloric acid.For PTH (plated-through holes), additional steps of electroless deposition are done after the holes are drilled, then copper is electroplated to build up the thickness, the boards are screened, and plated with tin/lead. The tin/lead becomes the resist leaving the bare copper to be etched away.

Lamination

Some PCBs have trace layers inside the PCB and are called multi-layer PCBs. These are formed by bonding together separately etched thin boards.

Drilling

Holes through a PCB are typically drilled with tiny drill bits made of solid tungsten carbide. The drilling is performed by automated drilling machines with placement controlled by a drill tape or drill file. These computer-generated files are also called numerically controlled drill (NCD) files or "Excellon files". The drill file describes the location and size of each drilled hole. These holes are often filled with annular rings (hollow rivets) to create vias. Vias allow the electrical and thermal connection of conductors on opposite sides of the PCB.Most common laminate is epoxy filled fiberglass. Drill bit wear is partly due to embedded glass, which is harder than steel. High drill speed necessary for cost effective drilling of hundreds of holes per board causes very high temperatures at the drill bit tip, and high temperatures (400-700 degrees) soften steel and decompose (oxidize) laminate filler. Copper is softer than epoxy and interior conductors may suffer.

Damage during drilling : When very small vias are required, drilling with mechanical bits is costly because of high rates of wear and breakage. In this case, the vias may be evaporated by lasers. Laser-drilled vias typically have an inferior surface finish inside the hole. These holes are called micro vias.It is also possible with controlled-depth drilling, laser drilling, or by pre-drilling the individual sheets of the PCB before lamination, to produce holes that connect only some of the copper layers, rather than passing through the entire board. These holes are called blind vias when they connect an internal copper layer to an outer layer, or buried vias when they connect two or more internal copper layers and no outer layers.The walls of the holes, for boards with 2 or more layers, are made conductive then plated with copper to form plated-through holes that electrically connect the conducting layers of the PCB. For multilayer boards, those with 4 layers or more, drilling typically produces a smear of the high temperature decomposition products of bonding agent in the laminate system. Before the holes can be plated through, this smear must be removed by a chemical de-smear process, or by plasma-etch. Removing(etching back) the smear also reveals the interior conductors as well.

Exposed conductor plating and coating : PCBs are plated with solder, tin, or gold over nickel as a resist for etching away the unneeded underlying copper.After PCBs are etched and then rinsed with water, the soldermask is applied, and then any exposed copper is coated with solder, nickel/gold, or some other anti-corrosion coating.Matte solder is usually fused to provide a better bonding surface or stripped to bare copper. Treatments, such as benzimidazolethiol, prevent surface oxidation of bare copper. The places to which components will be mounted are typically plated, because untreated bare copper oxidizes quickly, and therefore is not readily solderable. Traditionally, any exposed copper was coated with solder by Hot air solder levelling (HASL). This solder was a tin-lead alloy, however new solder compounds are now used to achieve compliance with the RoHS directive in the EU and US, which restricts the use of lead. One of these lead-free compounds is SN100CL, made up of 99.3% tin, 0.7% copper, 0.05% nickel, and a nominal of 60ppm germanium.It is important to use solder compatible with both the PCB and the parts used. An example is Ball Grid Array (BGA) using tin-lead solder balls for connections losing their balls on bare copper traces or using lead-free solder paste. Other platings used are OSP (organic surface protectant), immersion silver (IAg), immersion tin, electroless nickel with immersion gold coating (ENIG), and direct gold plating (over nickel). Edge connectors, placed along one edge of some boards, are often nickel plated then gold plated. Another coating consideration is rapid diffusion of coating metal into Tin solder. Tin forms intermetallics such as Cu5Sn6 and Ag3Cu that dissolve into the Tin liquidus or solidus(@50C), stripping surface coating and/or leaving voids. Electrochemical migration (ECM) is the growth of conductive metal filaments on or in a printed circuit board (PCB) under the influence of a DC voltage bias. Silver, zinc, and aluminum are known to grow whiskers under the influence of an electric field. Silver also grows conducting surface paths in the presence of halide and other ions, making it a poor choice for electronics use. Tin will grow "whiskers" due to tension in the plated surface. Tin-Lead or Solder plating also grows whiskers, only reduced by the percentage Tin replaced. Reflow to melt solder or tin plate to relieve surface stress lowers whisker incidence. Another coating issue is tin pest, the transformation of tin to a powdery allotrope at low temperature.

Solder resist : Areas that should not be soldered may be covered with a polymer solder resist (solder mask) coating. The solder resist prevents solder from bridging between conductors and creating short circuits. Solder resist also provides some protection from the environment. Solder resist is typically 20-30 micrometres thick

Printed circuit assembly : After the printed circuit board (PCB) is completed, electronic components must be attached to form a functional printed circuit assembly, or PCA (sometimes called a "printed circuit board assembly" PCBA). In through-hole construction, component leads are inserted in holes. In surface-mount construction, the components are placed on pads or lands on the outer surfaces of the PCB. In both kinds of construction, component leads are electrically and mechanically fixed to the board with a molten metal solder. There are a variety of soldering techniques used to attach components to a PCB. High volume production is usually done with machine placement and bulk wave soldering or reflow ovens, but skilled technicians are able to solder very tiny parts (for instance 0201 packages which are 0.02 in. by 0.01 in.) by hand under a microscope, using tweezers and a fine tip soldering iron for small volume prototypes. Some parts are impossible to solder by hand, such as ball grid array (BGA) packages. Often, through-hole and surface-mount construction must be combined in a single assembly because some required components are available only in surface-mount packages, while others are available only in through-hole packages. Another reason to use both methods is that through-hole mounting can provide needed strength for components likely to endure physical stress, while components that are expected to go untouched will take up less space using surface-mount techniques. After the board has been populated it may be tested in a variety of ways: While the power is off, visual inspection, automated optical inspection. JEDEC guidelines for PCB component placement, soldering, and inspection are commonly used to maintain quality control in this stage of PCB manufacturing. While the power is off, analog signature analysis, power-off testing.While the power is on, in-circuit test, where physical measurements (i.e. voltage, frequency) can be done.While the power is on, functional test, just checking if the PCB does what it had been designed for.To facilitate these tests, PCBs may be designed with extra pads to make temporary connections.Sometimes these pads must be isolated with resistors. The in-circuit test may also exercise boundary scan test features of some components. In-circuit test systems may also be used to program nonvolatile memory components on the board.In boundary scan testing, test circuits integrated into various ICs on the board form temporary connections between the PCB traces to test that the ICs are mounted correctly. Boundary scan testing requires that all the ICs to be tested use a standard test configuration procedure, the most common one being the Joint Test Action Group (JTAG) standard.When boards fail the test, technicians may desolder and replace failed components, a task known as rework.

Surface Mount Technology

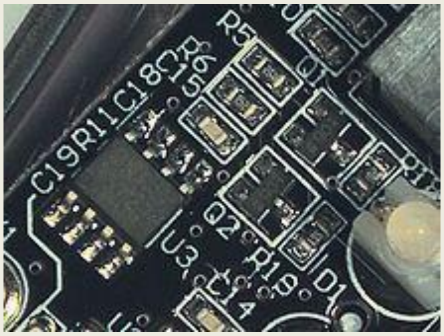


Fig-1

Surface mount components, including resistors_ ,an integrated circuit & Transistor

Surface-mount technology emerged in the 1960s, gained momentum in the early 1980s and became widely used by the mid 1990s.Components were mechanically redesigned to have small metal tabs or end caps that could be soldered directly on to the PCB surface. Components became much smaller and component placement on both sides of the board became more common than with through-hole mounting, allowing much higher circuit densities. Surface mounting lends itself well to a high degree of automation, reducing labour costs and greatly increasing production and quality rates. Carrier Tapes provide a stable and protective environment for Surface mount devices (SMDs) which can be one-quarter to one-tenth of the size and weight, and passive components can be one-half to one-quarter of the cost of corresponding through-hole parts. However, integrated circuits are often priced the same regardless of the package type, because the chip itself is the most expensive part. As of 2006, some wire-ended components, such as small-signal switch diodes are actually significantly cheaper than corresponding SMD versions.