S J P N TRUST
HIRASUGAR INSTITUTE OF TECHNOLOGY

SUB: ANALOG AND DIGITAL ELECTRONICS

CODE:18CS33

Module 1

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OPTOELECTRONIC DEVICES

Optoelectronic Devices is the field that deals with study of devices that emit, detect and control light in the wavelength spectrum ranging from ultraviolet to far infrared. They include electrical-to-optical (convert electrical energy into light energy) and optical-to-electrical (convert light energy into electrical

PHOTODIODES:

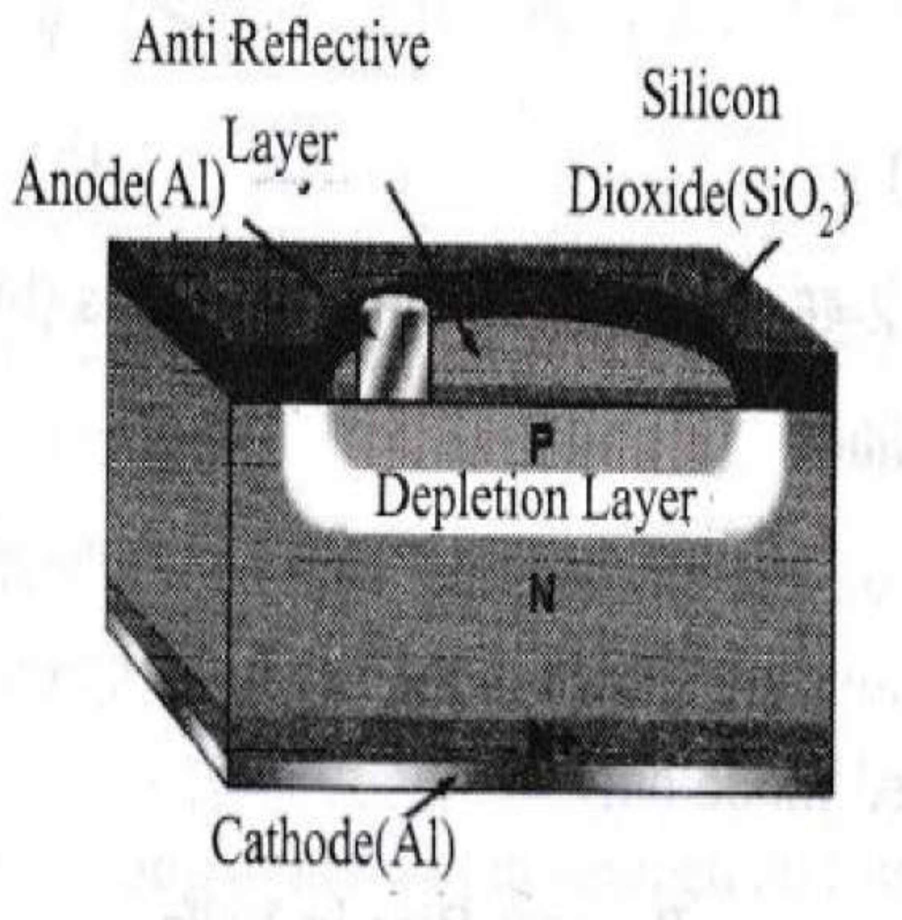
Photodiode is a light detector semiconductor device that converts light energy into electric current or voltage which depends upon the mode of operation.

The upper cut-off wavelength of a photodiode is given by; $$\lambda_c = \frac{1240}{E_g}$$

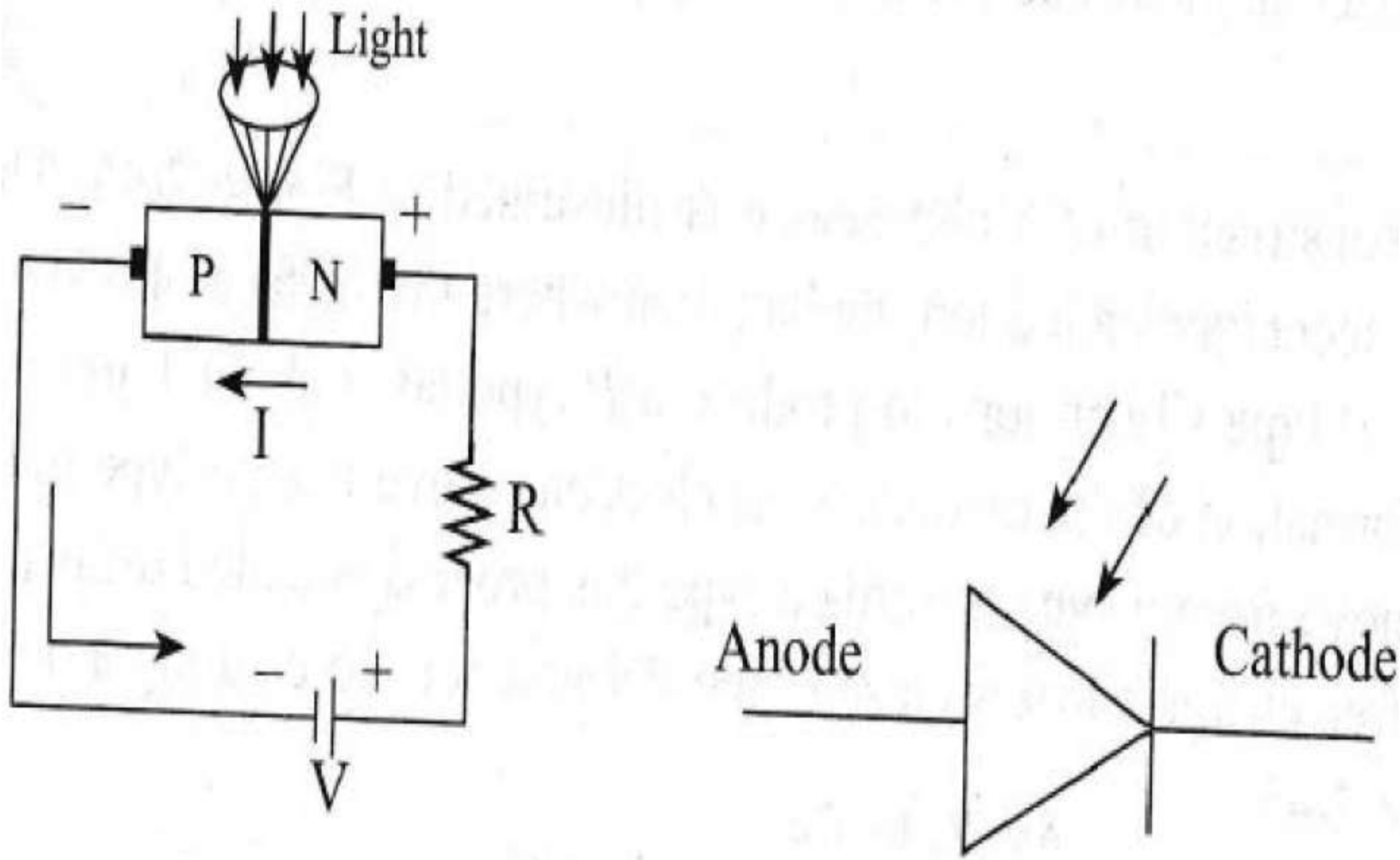
where, λ_c is the cut-off wavelength in nm and E_g is the bandgap energy in eV.

A normal p-n junction diode allows a small amount of electric current, under reverse bias, due to minority charge carriers. To increase the electric current under reverse bias condition, we need to generate more minority carriers. The external reverse voltage applied to the p-n junction diode will supply energy to the minority carriers, but it will not increase the population of minority charge carriers.

N-type; this process is called *diffusion*, resulting in the removal of free charge carriers close to the PN-junction, so creating a depletion layer as shown in the following Figure.



The (light facing) top of the diode is protected by a layer of Silicon Dioxide (SiO_2) in which there is a

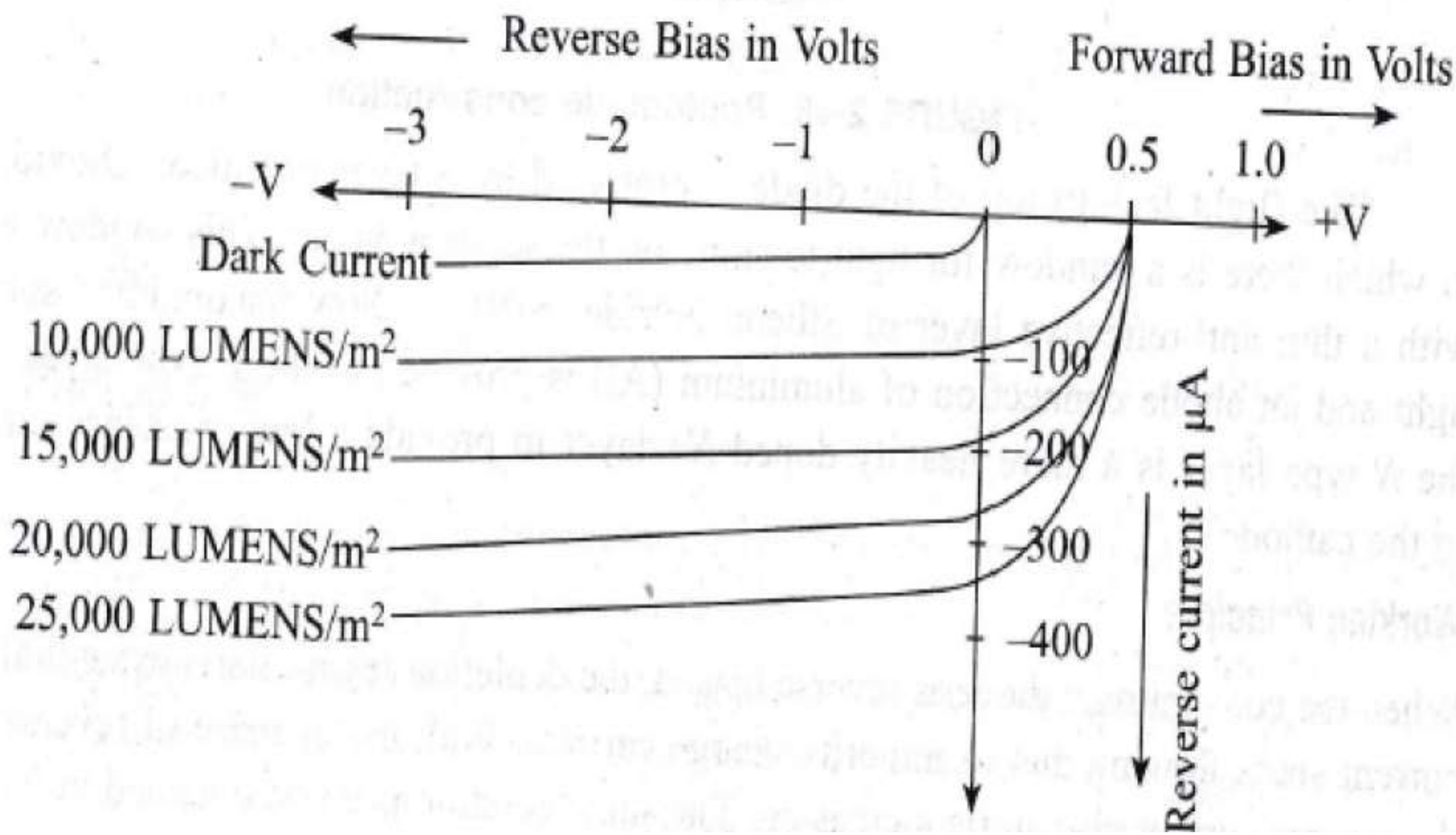


(a)

(b)

V-I Characteristics of Photodiode:

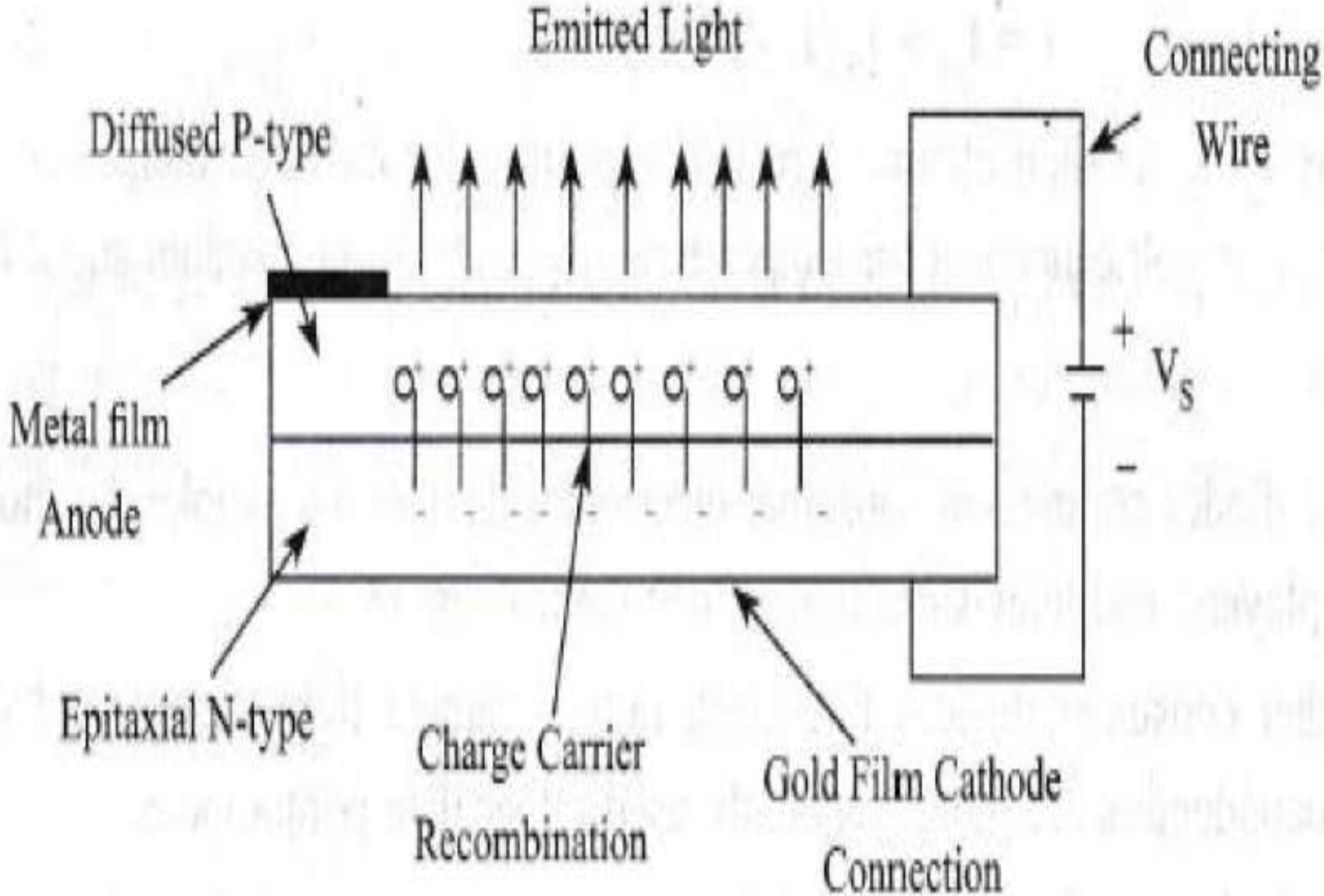
The characteristics curve of the photodiode can be understood with the help of the following Figure. The characteristics are shown in the negative region because the photodiode can be operated in reverse biased mode only.

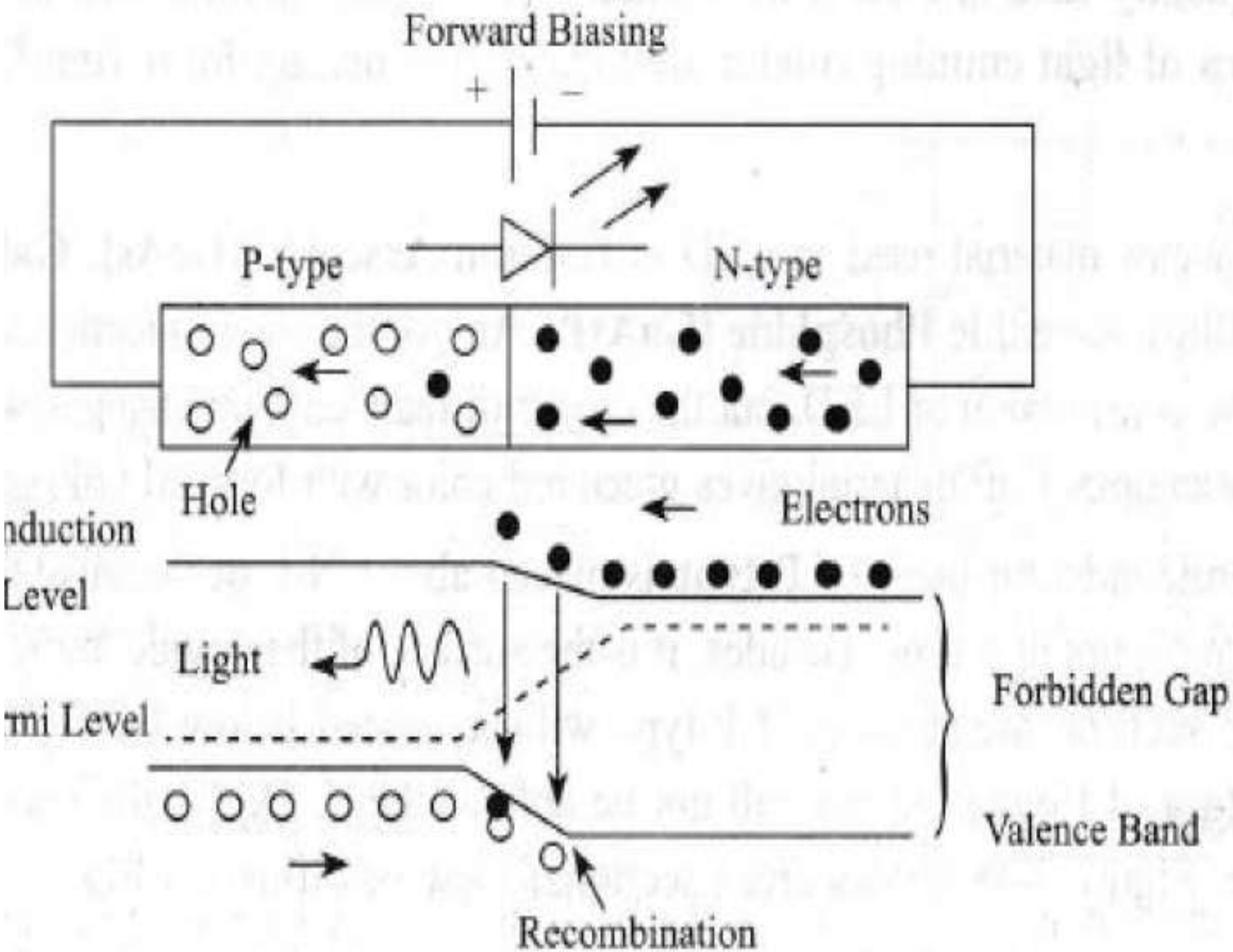


LIGHT EMITTING DIODE (LED):

The LED is a PN-junction diode which emits light when an electric current passes through it in the forward direction. A P-N junction can convert absorbed light energy into a proportional electric current. The same process is reversed here (i.e. the P-N junction emits light when electrical energy is applied to it). This phenomenon is generally called *Electroluminescence*.

Electroluminescence is the properly of the material to convert electrical energy into light energy and later it radiates this light energy. Different sizes of light emitting diodes are available in market form $1mm^2$ to onward.

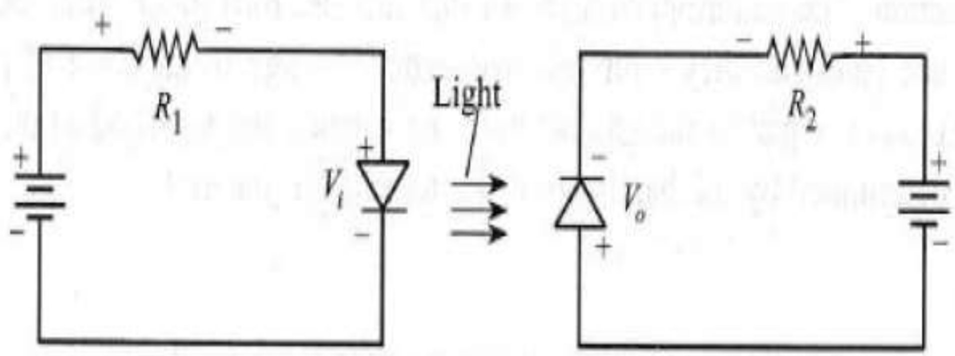

Emitted Light
Connecting Wire
Diffused P-type
Metal film
Anode
V_S
+
-
Epitaxial N-type
Charge Carrier Recombination
Gold Film Cathode Connection



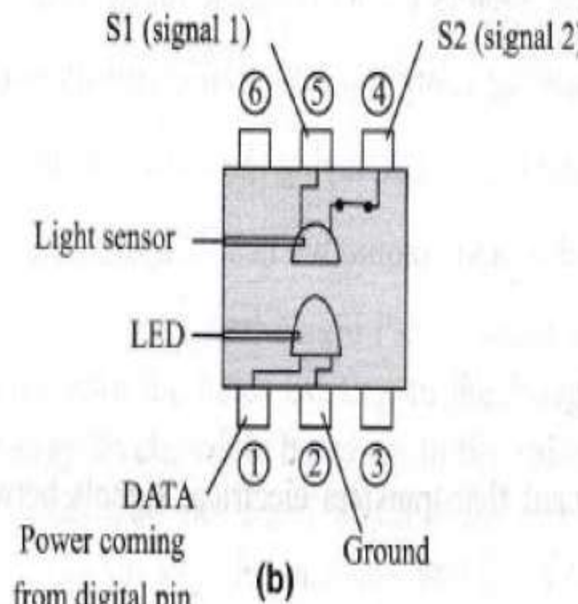
Forward Biasing
+
–
P-type
N-type
Hole
Electrons
nduction
Level
Light
mi Level
Forbidden Gap
Valence Band
Recombination

Working Principle:

When input current is applied to the LED, it switches ON and emits infrared light; the photosensor then detects this light and allows current to flow through the output side of the circuit; conversely, when the LED is off, no current will flow through the photosensor. By this method, the two flowing currents are electrically isolated. It consists of LED and photodiode; where the circuits are isolated electrically. In the following Figure, LED is forward biased, photodiode is reverse biased and output exists across R_2.



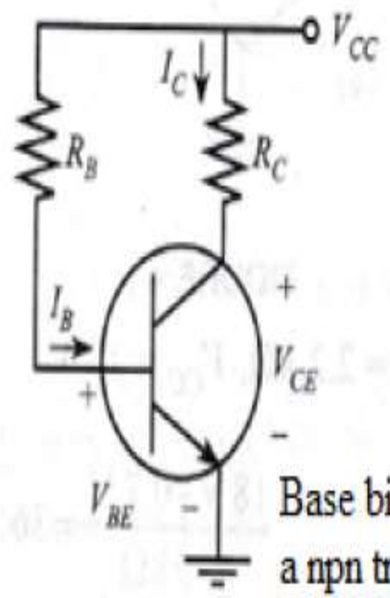
(a)



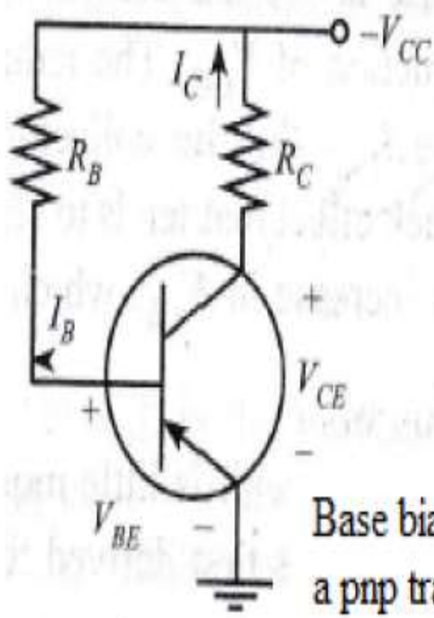
(b)

BASE BIAS or FIXED BIAS:

Base biasing configuration is given in the following Figure. A base resistance R_B is used between V_{CC} and base to establish the base current I_B. Since V_{CC} and R_B are fixed quantities, I_B remains fixed.



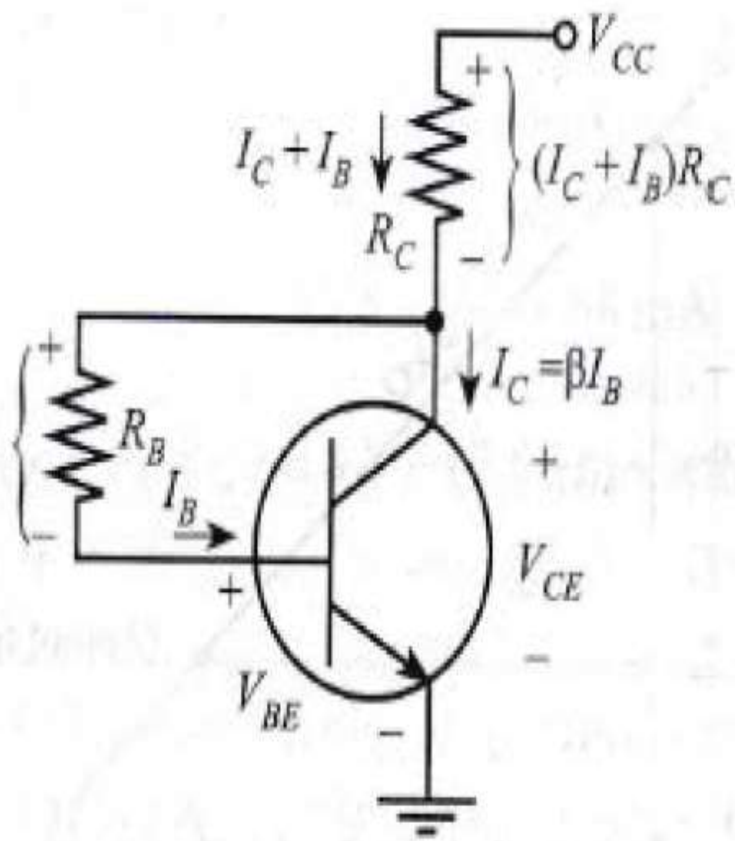
Base bias circuit using a npn transistor



Base bias circuit using a pnp transistor

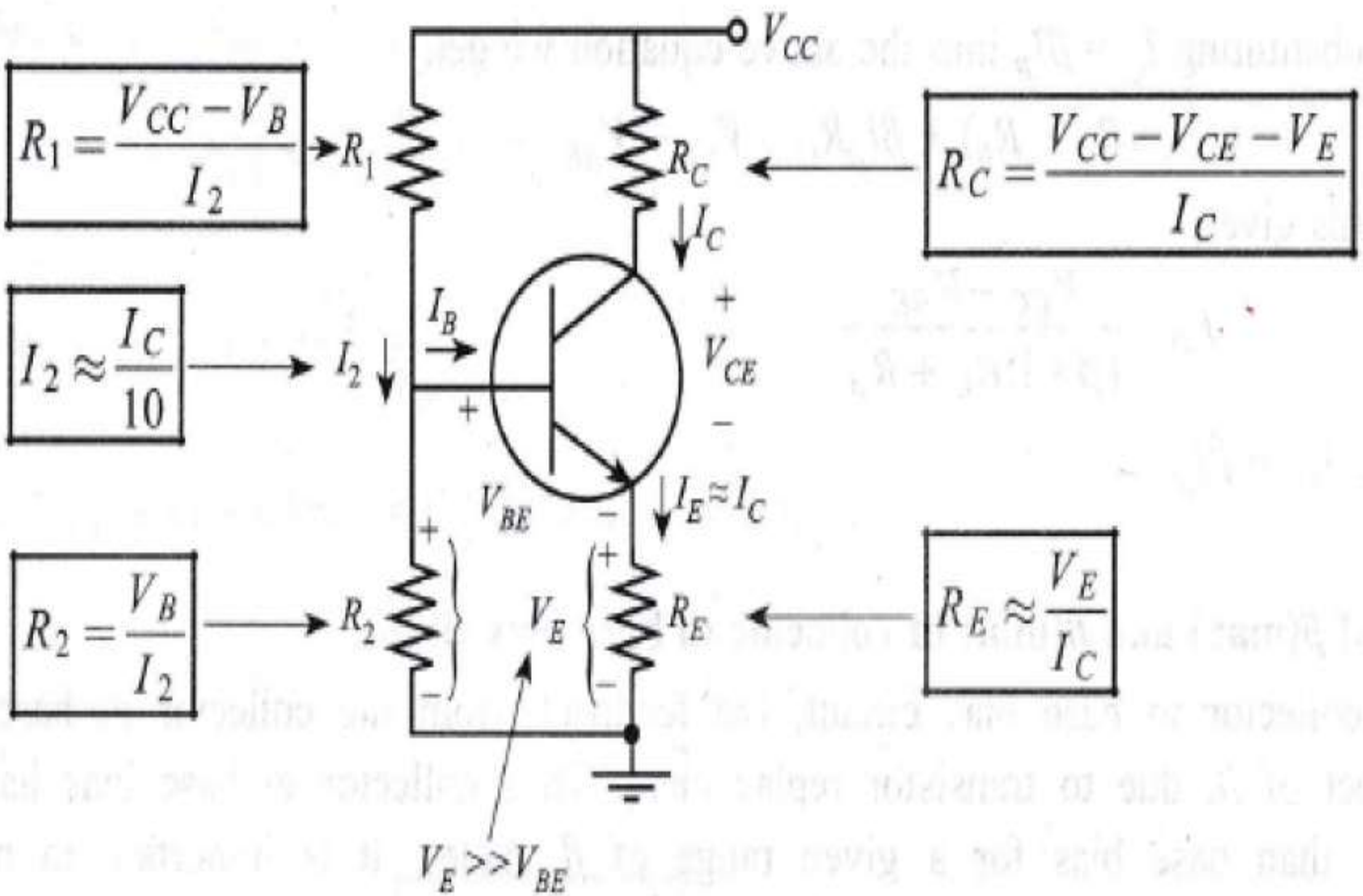
COLLECTOR-TO-BASE BIAS CIRCUIT:

The collector-to-base bias circuit shown in the following Figure, has the base resistor R_B connected between the transistor collector and base terminals. This circuit has significantly improved bias stability for h_{fe} changes compared to base bias.



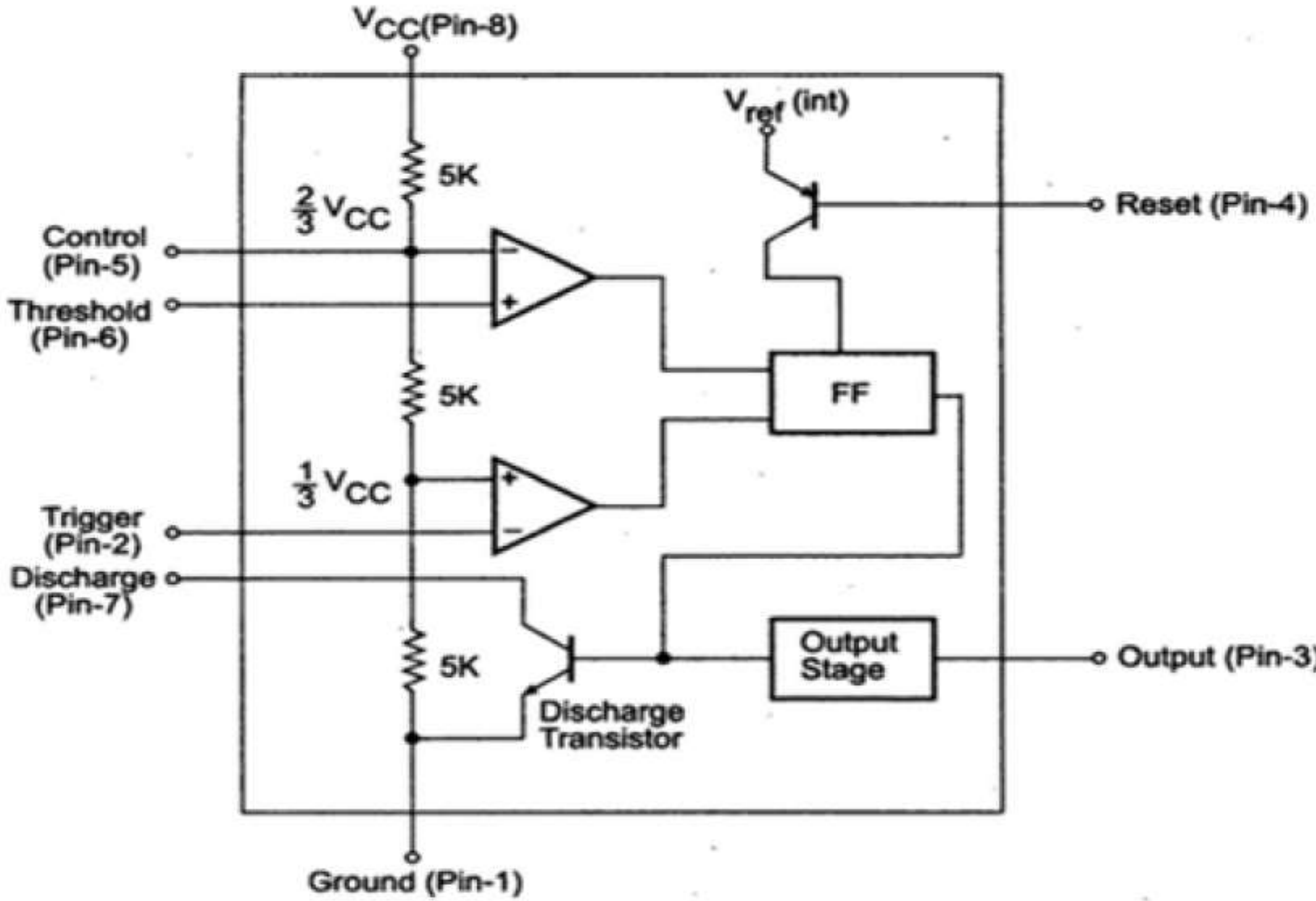
VOLTAGE DIVIDER (EMITTER CURRENT) BIAS CIRCUIT:

Voltage divider bias is the most stable of the three basic transistor biasing circuits. A voltage divider circuit is shown in the following Figure.



Timer IC-555:

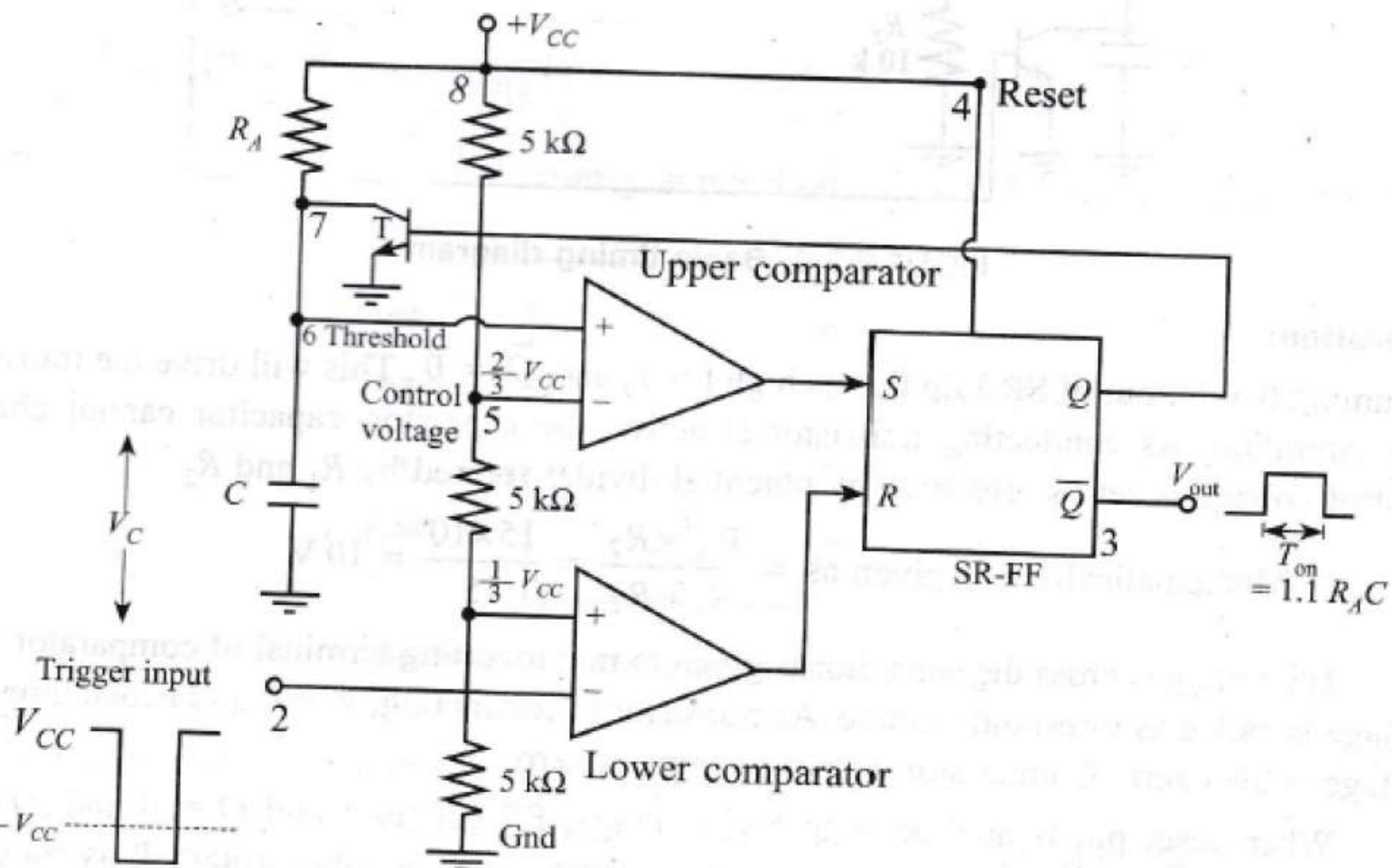
Timer IC-555 is the one of the most commonly used general-purpose linear integrated circuits.



Internal Schematic of Timer IC-555

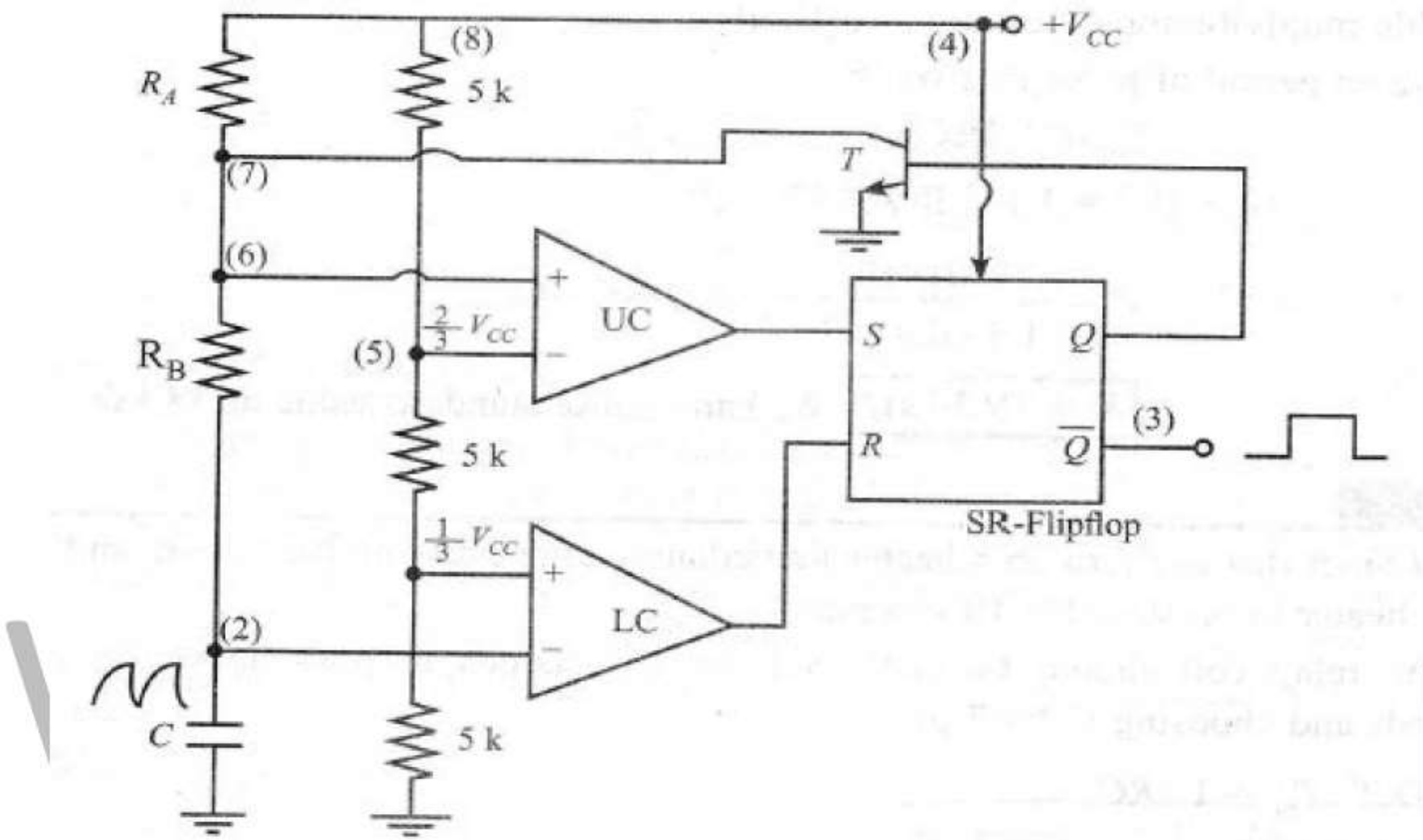
MONOSTABLE MULTIVIBRATOR:

Monostable multivibrator using 555 timer IC is as shown in the following Figure. This 555 timer is called monostable multivibrator because it has only one stable state. Resistor R_A and capacitor C are components connected externally to the IC-555. Threshold voltage (6) and discharge (7) pins are connected to each other.



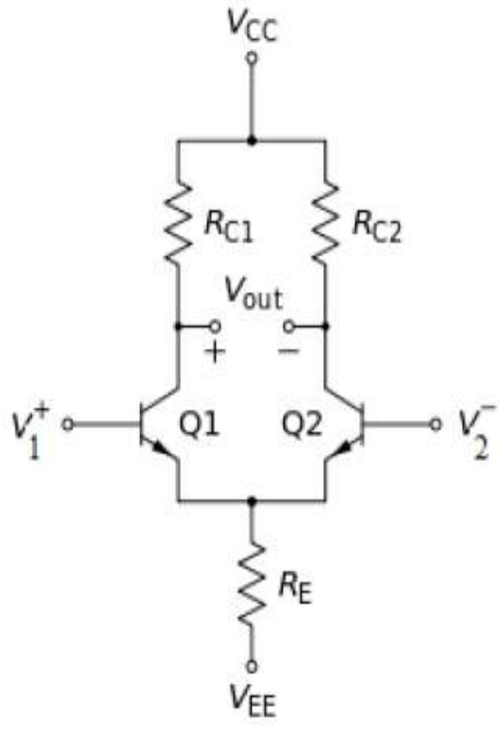
ASTABLE MULTIVIBRATOR:

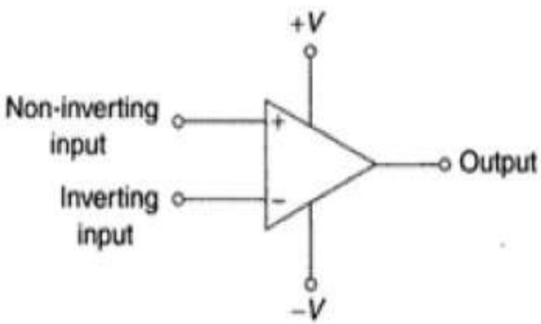
An *astable multivibrator* does not have any stable state; it keeps changing its state from low to high and high to low. This multivibrator is also called *free running multivibrator* or *rectangular wave generator* circuit. *Astable multivibrator* does not require an external trigger pulse to change the state of the output. The circuit configuration of an astable rnultivibrator is as shown in the following Figure.



OPERATIONAL AMPLIFIER (OP-AMP) APPLIATION CIRCUITS

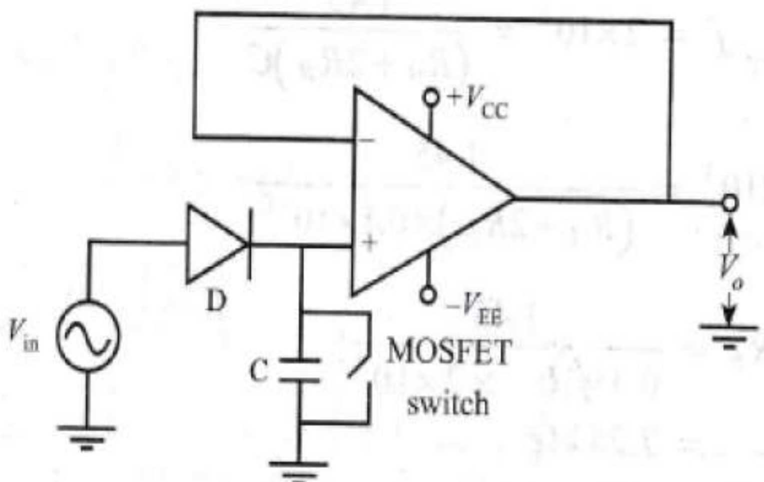
An **Op-Amp** is a direct-coupled high gain, high bandwidth differential amplifier with very high value of input impedance and very low value of output impedance.

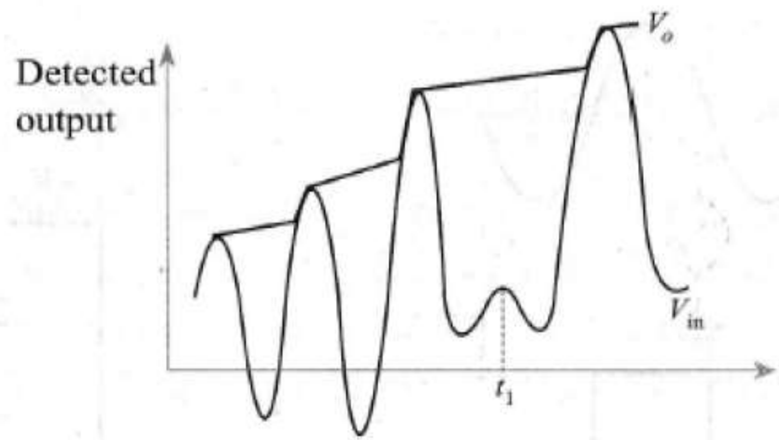




PEAK DETECTORS:

Peak detector detects holds the most positive value attained by the input signal. The following Figure shows peak detector circuit.





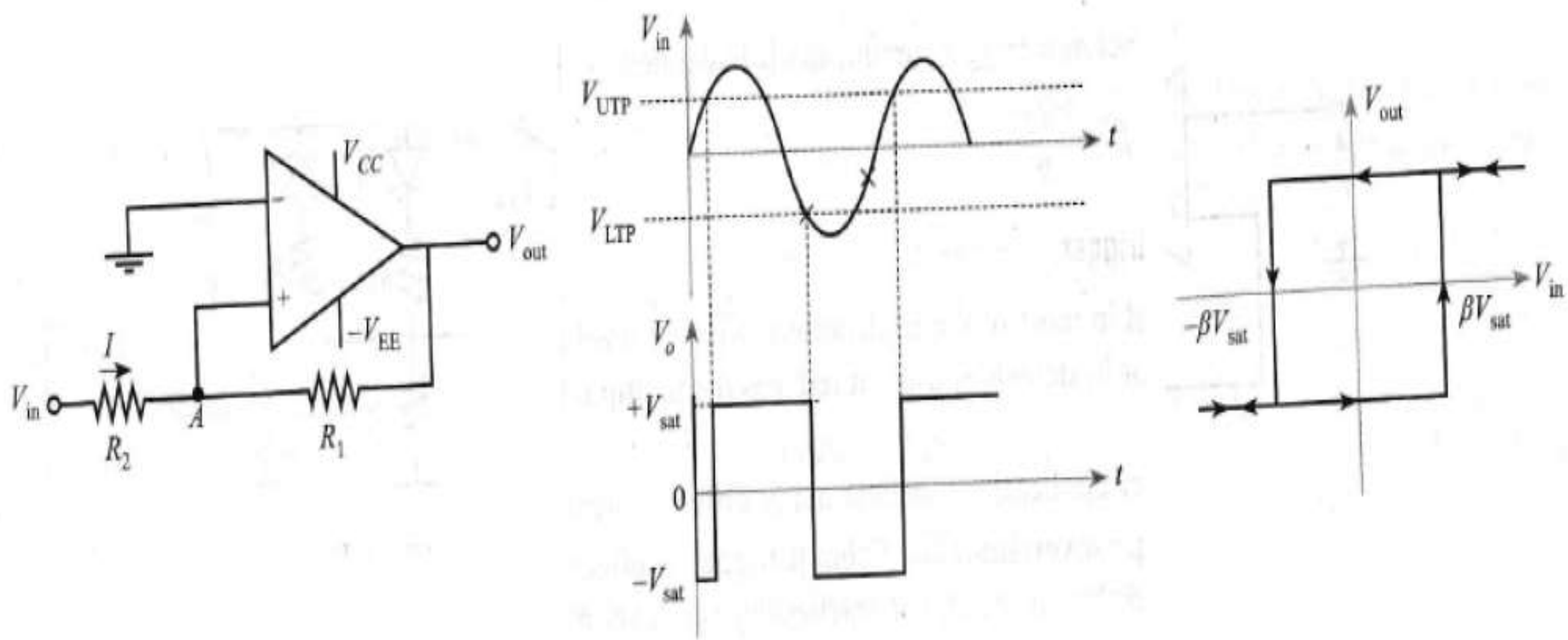
During positive half cycle of the input, D-conducts and capacitor charges to peak (highest) value of the input. Capacitor retains its charged value unless and until it discharges with a help of switch.

The op-amp is connected as a voltage follower and its output voltage will be equal the drop across capacitor which is positive peak value of the applied voltage and will remain that for long periods until next more higher peak occurs at the input. For negative cycle of input, the diode is reverse biased and capacitor retains its value.

Non-Inverting Schmitt Trigger:

The input voltage V_{in} is applied to the non-inverting input terminal and the feedback voltage also goes to the non-inverting terminal. The inverting terminal is grounded..

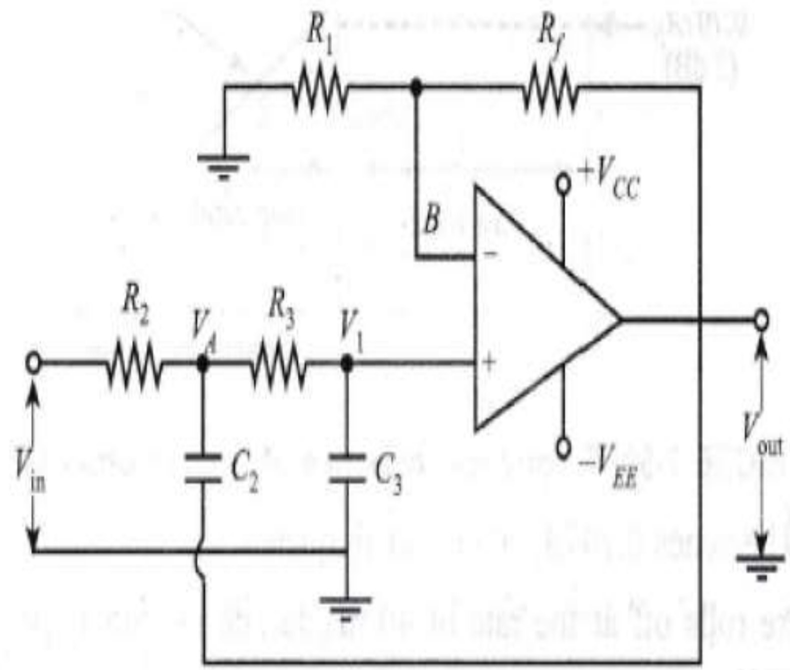
Initially, assume that the output is in the negative saturation ($-V_{sat}$). Then the feedback voltage is also negative. This feedback voltage will hold the output in negative saturation, until the input voltage becomes positive enough to make voltage positive.

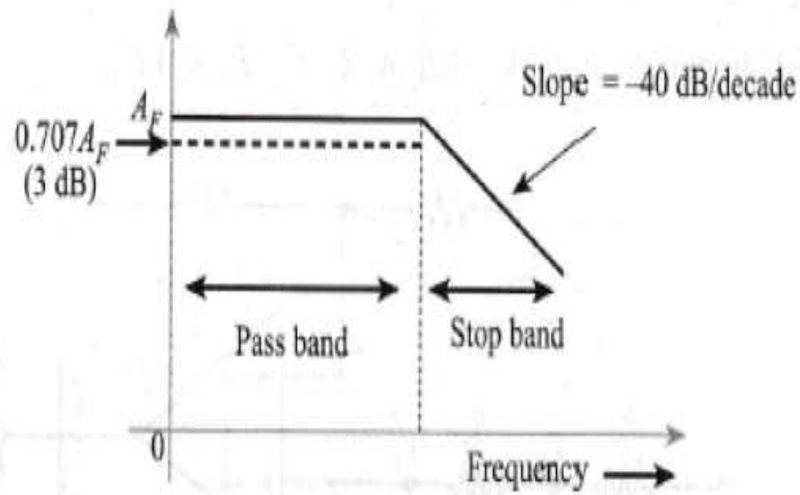


Let V_A is the voltage at point A. Hence, $V_A = IR_2$.

Second Order Low-Pass Filter:

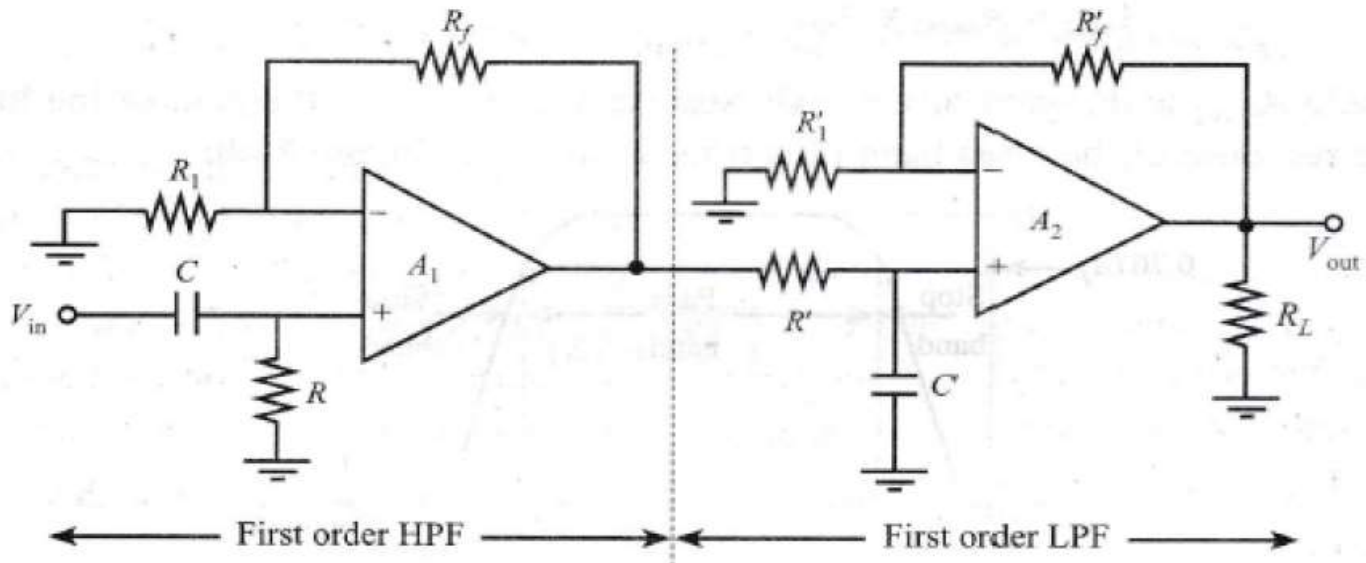
First order filter can be converted to second order filter by adding an extra RC-network, as shown in the following Figure. The frequency response of second order low-pass filter is same as the first order low-pass filter except that the gain at the stop band rolls off at the rate of 40 dB/decade.

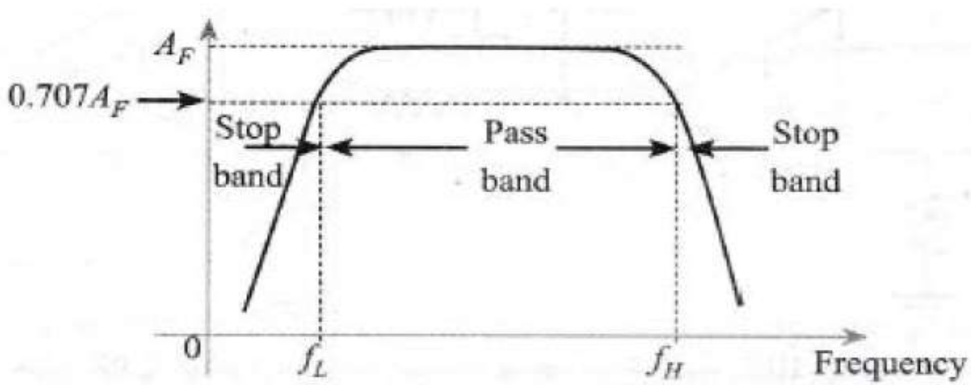




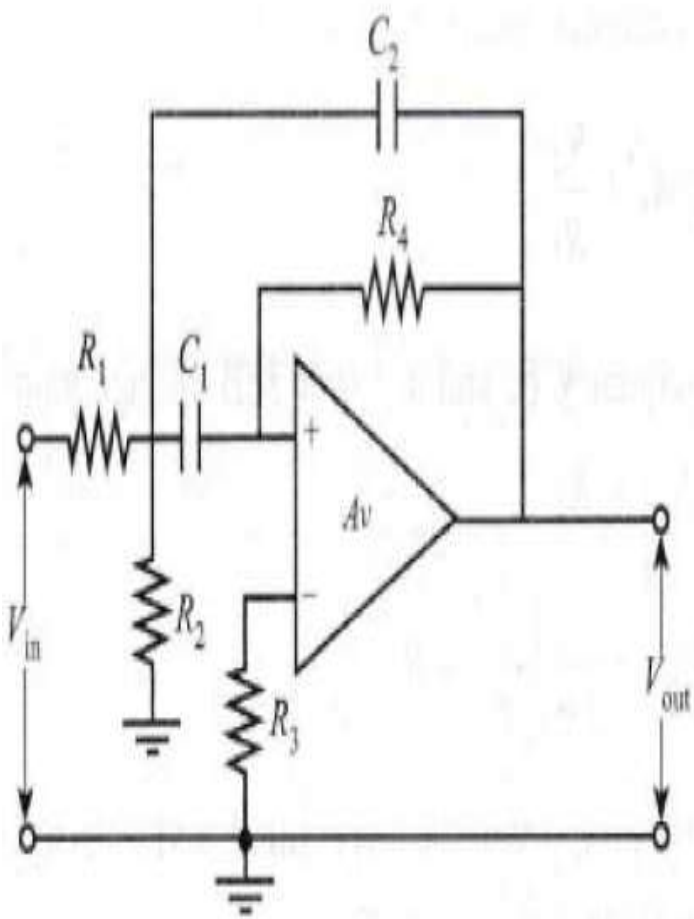
Wide Band-Pass Filter:

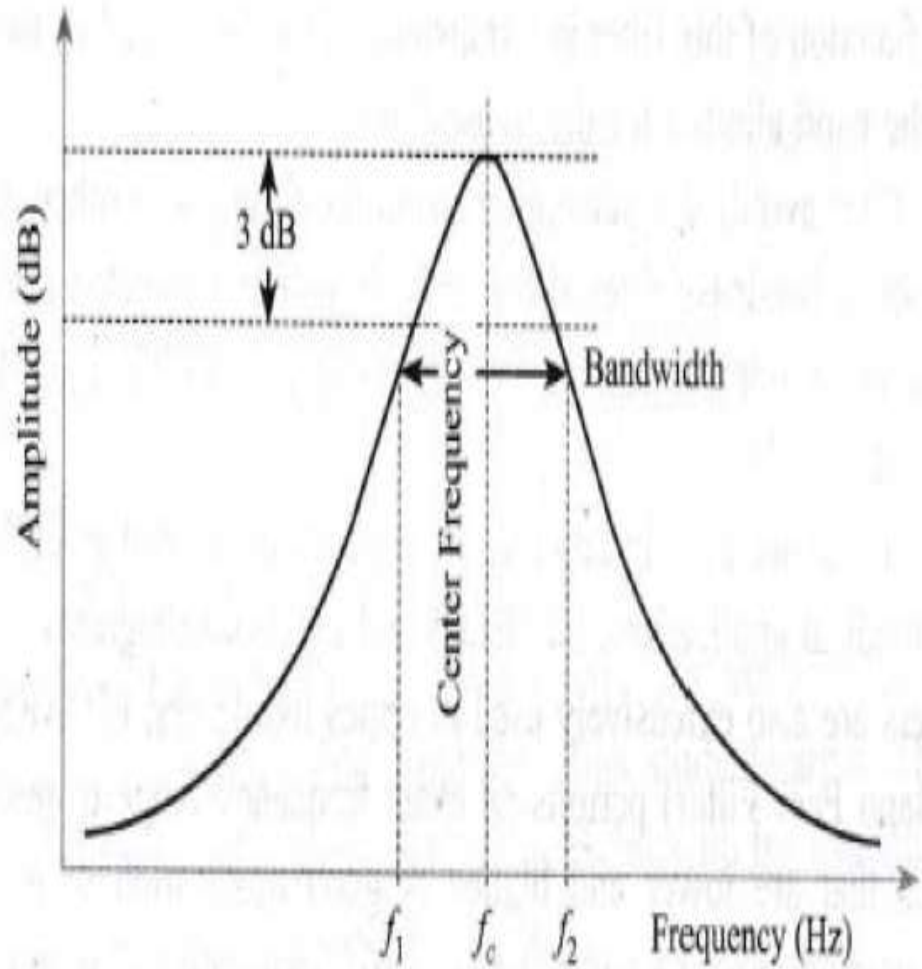
A low Q-filter will have a wide-pass-band; i.e., with $Q < 10$. It has wide flat response over the range of frequencies and bandwidth is large.





- Maximum Gain, $A_v = -\frac{R_2}{2R_1} = -2Q^2$

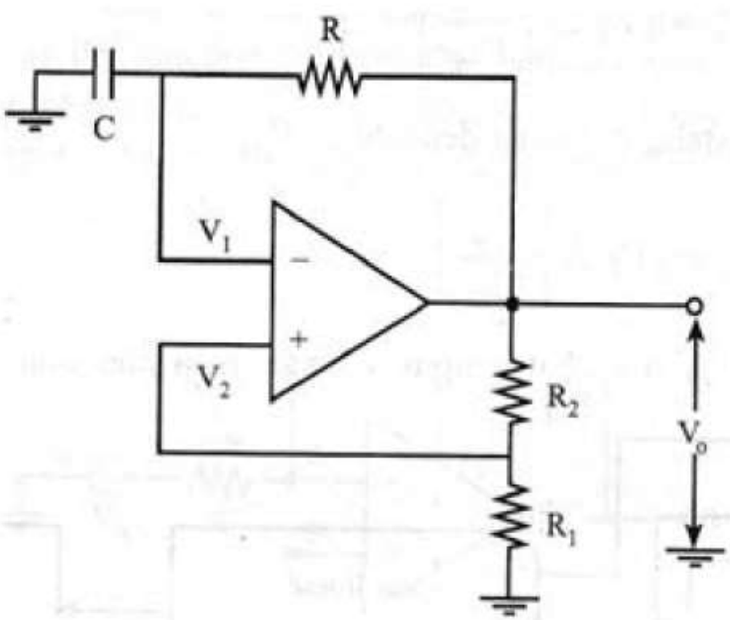


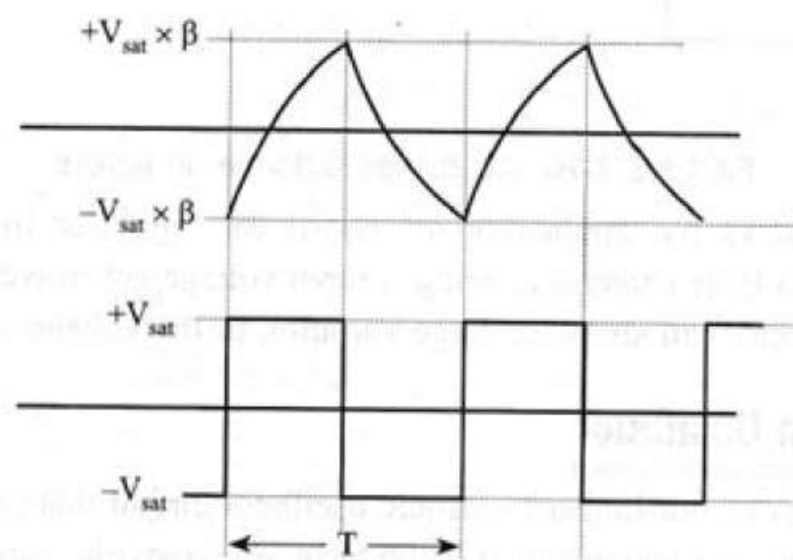


RELAXATION OSCILLATOR:

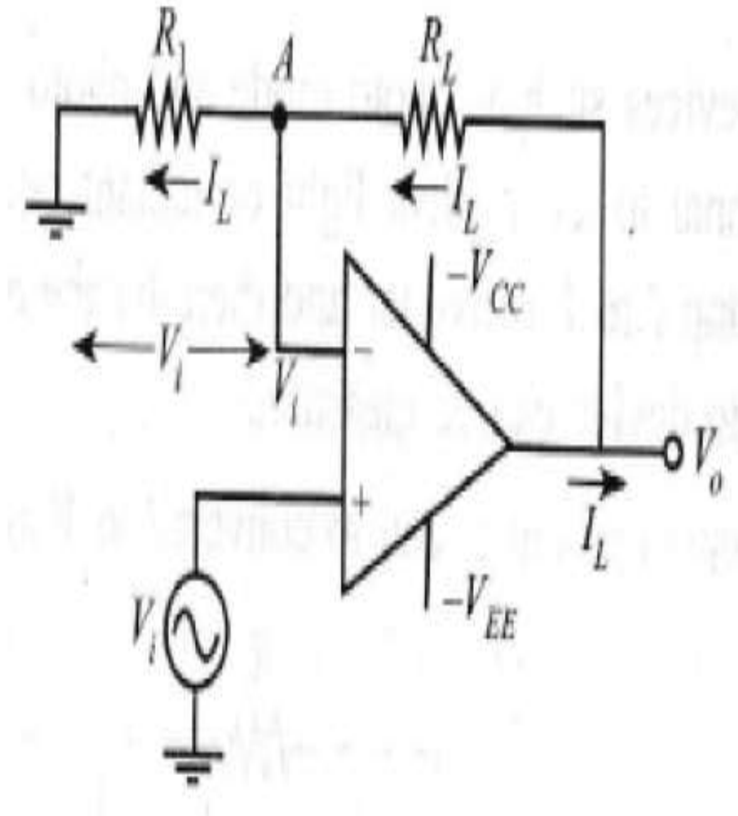
Relaxation oscillator is a non-linear electronic oscillator circuit that generates a continuous non-sinusoidal output signal in the form of rectangular wave, triangular wave or a saw-tooth wave. The time period of non-sinusoidal output depends on the charging time of the capacitor connected in the oscillator circuit.

The relaxation oscillator basically contains a feedback loop that has a switching device in the form of transistor, relays, operational amplifiers, comparators, or a tunnel diode that charges a capacitor through a resistance till it reaches a threshold level then discharges it again. The following Figure shows the basic circuit of an Op-Amp based relaxation oscillator.

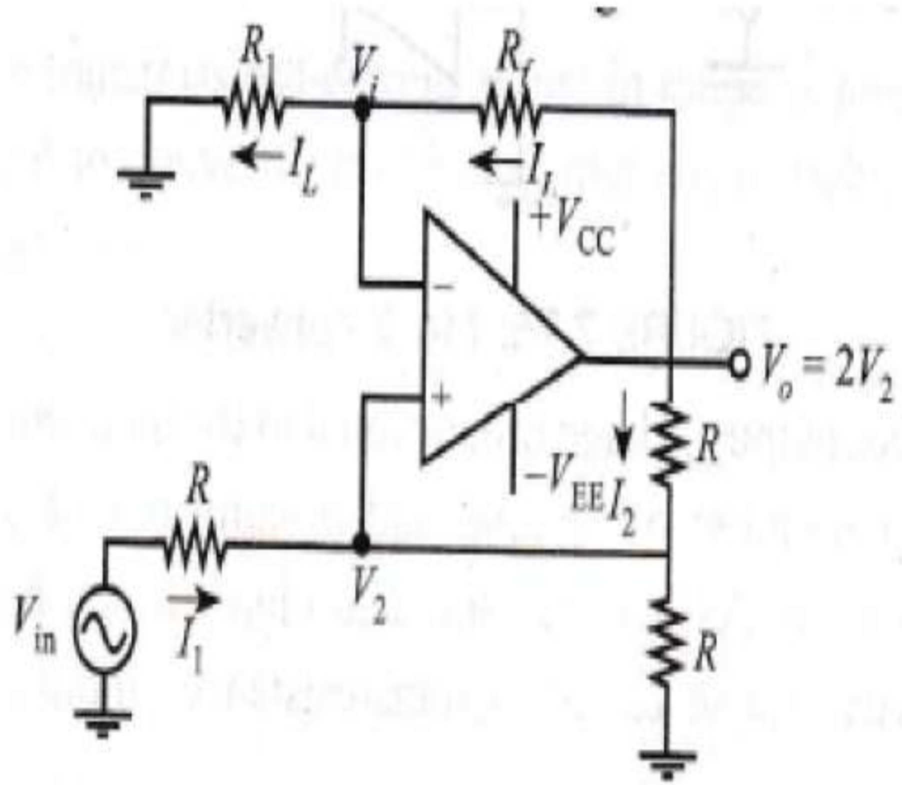




a) **Voltage to Current Converter with Floating Load:** The circuit is shown in the following Figure, where R_L is the floating load.



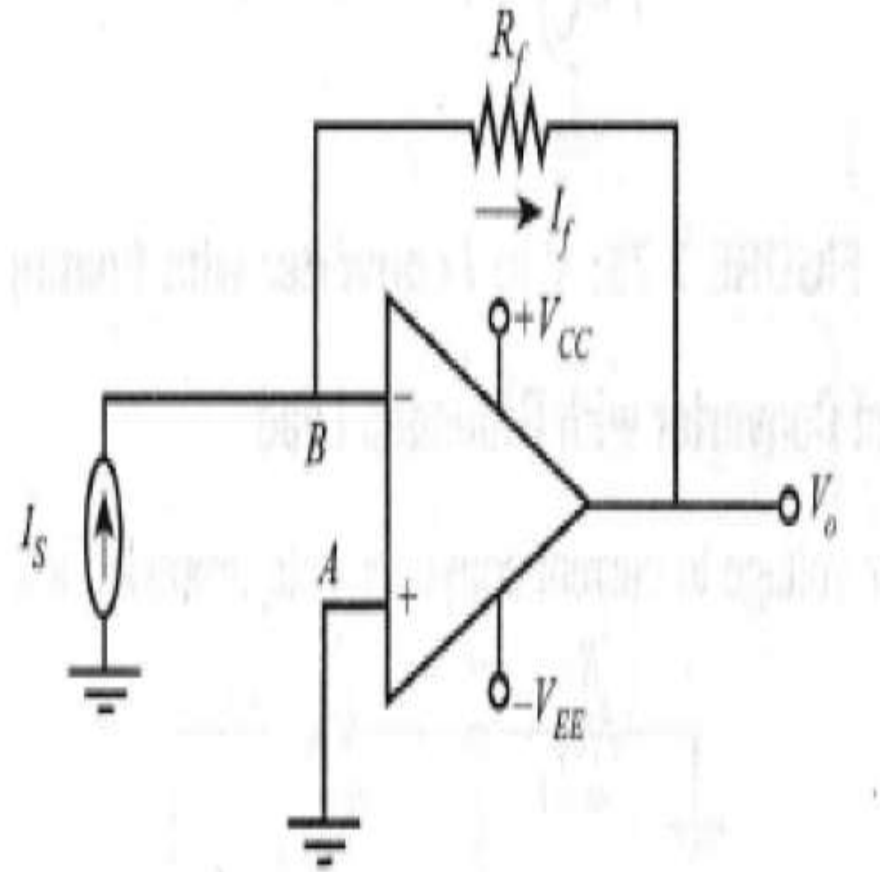
Voltage to Current Converter with Grounded Load: The circuit is shown in the following Figure.



$$I_1 = \frac{V_{in} - V_2}{R} \qquad I_2 = \frac{V_0 - V_2}{R}$$

CURRENT TO VOLTAGE (C TO V) CONVERTER:

Consider the simple Op-Amp circuit to convert I to V, as shown in the following Figure.



VOLTAGE REGULATORS

All electronic systems that we use daily, requires a stable power supply voltage source; and voltage regulators accomplish that. *Voltage regulator* is a circuit that keeps the output voltage constant under all operating conditions. *Voltage regulation* is the process of keeping a voltage steady under conditions of changing applied voltage, changing load and temperature.

There are *two types* of voltage regulators: *shunt* and *series*.

Need for Regulators:

In ordinary power supplies, the voltage regulation is very poor. The DC output voltage changes appreciably with change in load current. The output voltage also changes due to fluctuations in the input AC supply. This is due the following reasons:

Performance Parameters of a Power Supply:

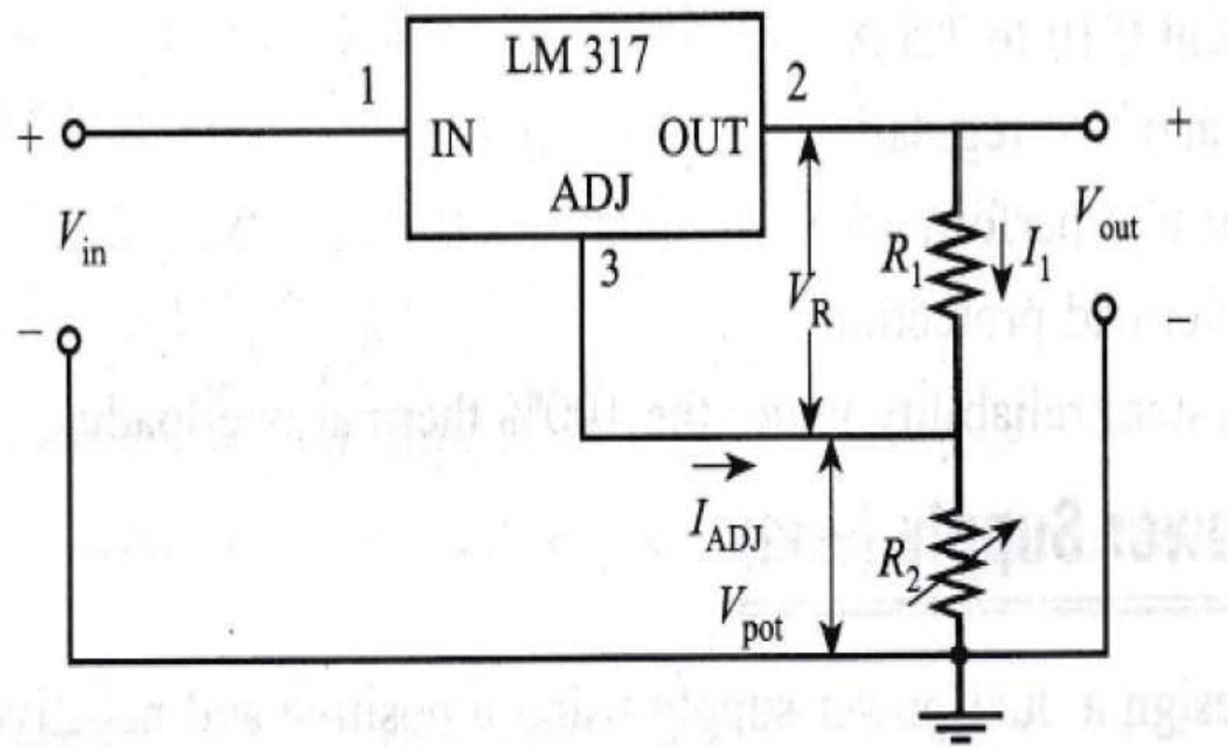
The power supply is judged by some parameters, called as *performance parameters*. These performance parameters are explained below:

1. ***Line Regulation:*** If the input to the rectifier unit i.e. 230 V changes, the output DC of rectifier will also change and since the output of rectifier is applied to the regulator, the output of regulator will also vary. Thus the source causes the change in output. This is as *source regulation* or *line regulation*. It is defined as the change in regulated DC output for a given change in input (line) voltage. Ideally the source regulation should be zero and practically it should be as low as possible.

2. ***Load Regulation:*** *Load regulation* is defined as the change in the regulated output voltage when load current is changed from zero (no load) to maximum value (full load). The load regulation ideally should be zero, but practically it should be as small as possible. The following Figure shows the load regulation characteristics.

Percentage load regulation = $\left[\frac{V_{NL} - V_{FL}}{V_{FL}}\right] * 100$

LM317 is a classic example of positive adjustable voltage regulator, whose output voltage can be varied over a range of 1.2 V to 57 V. LM337 is an example of negative adjustable voltage regulator. LM337 is actually a compliment of LM317 which are similar in operation and design with the only difference being polarity of regulated output voltage.



Connection of LM317 Adjustable Voltage Regulator