STATE BOARD OF TECHNICAL EDUCATION &TRAINING, TAMILNADU

DIPLOMA IN ENGINEERING/TECHNOLOGY SYLLABUS

N SCHEME

(To be Implemented for the students admitted from the year 2020 - 2021 onwards)

Course Name : 1040:Electronics and Communication Engineering

Subject Code : 4040310

Semester :IIISemester

Subject title : ELECTRONIC DEVICES AND CIRCUITS

TEACHINGAND SCHEME OF EXAMINATION

No ofweeks/ semester: 16weeks

Subject	Instruction		Examination			
	Hours /Week	Hours /Semester	Marks			Duration
			Internal Assessment	Board Examination	Total	
Electronic Devices and Circuits	5	80	25	100*	100	3 Hrs

* Examination will be conducted for 100 marks and it will be reduced to 75 marks.

Topics and allocation of hours

UNIT	TOPIC	Hrs
I	Filters, Zener diode and Opto-electronic devices	14
II	Bipolar Junction Transistor, Field Effect Transistor and UJT	16
III	Feedback, Amplifiers and Oscillators	16
IV	Special Semiconducting Devices(SCR, DIAC AND TRIAC)	14
V	Wave shaping Circuits	13
	Tests and Model Exam	7
	Total	80

RATIONALE:

EveryElectronicsEngineershouldhavesoundknowledgeaboutthecomponentsuse Electronics Industry.This is vitalin R&DDepartment for chip level troubleshooting. To r theindustrialneeds,diplomaholders mustbetaughtaboutthemostfundamentalsub ElectronicdevicesandCircuits.Bystudyingthissubject,theywillbeskilledinhandlingall t ofelectronic devices and ableto applytheskill in electronics system.

OBJECTIVES:

On completion ofthefollowing units of syllabus contents, the students must be able to:

- Know the importance of Filters
- Know the construction,working principle and applications ofZener diode
- Know the construction,working principle and applications ofOptoelectronic devices
- Know the biasing methods of Transistors and their applications
- Study the performance of special devices like UJT,FET
- Studythe Concept of Feedback, different types of Negative feedback connections
- Know the Types of Transistor amplifiers ,Transistor oscillators and their applicatior
- Study the performance of Special semiconducting devices like SCR, DIAC, andTF
- Explain the concept ofwave shaping circuits, Bistable Multivibrator and Schmitt trig
- Studytheworking principle ofclippers , clampers , Voltage Multipliers and their applications

4040310 ELECTRONIC DEVICES AND CIRCUITS

DETAILED SYLLABUS

Contents: Theory

Unit	Name of the topics	Hours
I	**FILTERS, ZENER DIODES AND OPTO-ELECTRONIC DEVICES**	
	1.1: FILTERS Definition - Types - Capacitor filter - Inductor filter - L section filter - Pi section and RC filter - Comparison and Applications of Filters	5
	1.2: ZENER DIODE Construction, Working principle and Characteristics of Zener Diodes-Zenerbreakdown-Avalanchebreakdown- Zenerdiode asa Voltageregulator.	5
	1.3: OPTO-ELECTRONIC DEVICES Definition - Types - Symbol, Working , Characteristics and Applications of LED, 7 Segment LED - Photo diode, Photo transistor and Opto- coupler	4
II	**BIPOLAR JUNCTION TRANSISTOR (BJT), FIELD EFFECT TRANSISTOR (FET) AND UNI JUNCTION TRANSISTOR (UJT)**	
	2.1: BIPOLAR JUNCTION TRANSISTOR Transistorbiasing: Need for biasing - Types- Fixedbias,Collector tobase bias andSelfbias (Operation only ,No derivation of circuit elements and parameters)–Define: Stability factor - Operation of Common Emitter TransistorasanA mplifier andasa switch.	7
	2.2: FIELD EFFECT TRANSISTOR (FET) Construction– Workingprinciple–Classification - Drain and Transfer Characteristics -Applications–Comparison betweenFETandBJT- FET amplifier (common source amplifier).	5
	2.3: UNIJUNCTION TRANSISTOR (UJT) Construction- Equivalentcircuit-Operation-Characteristics- UJTasa relaxation oscillator	4

III	**FEEDBACK , AMPLIFIERS AND OSCILLATORS** **3.1: FEEDBACK** Concept - effects of negativefeedback-Types of negativefeedback connections - Applications **3.2: AMPLIFIERS** Transistor amplifiers - Types - RC coupled amplifier - Working and Frequency responsecharacteristics –Working of Common Collector Amplifier(Emitter follower) **3.3 : OSCILLATORS** **Transistoroscillators**–Conditionsforoscillation(Barkhausencriterion)- Classifications– HartleyOscillator– Colpitts Oscillator – RC Phaseshift oscillator
IV	**SPECIAL SEMICONDUCTING DEVICES (SCR, DIAC AND TRIAC)** **4.1:SCR (SILICON CONTROLLED RECTIFIER)** Symbol – Layered Structure – Transistor analogy - Working–VIcharacteristics–Applications - ComparisonbetweenSCRand Transistor **4.2: DIAC (Diode for Alternating Current)** Symbol – Layered structure - Working – VIcharacteristics- Applications **4.3: TRIAC (Triode for Alternating Current)** Symbol – Layered structure - Working – VIcharacteristics- Applications
V	**WAVE SHAPING CIRCUITS** **5.1: CLIPPERSAND CLAMPERS** Construction and working of Positive, Negative and biased Clippers - Construction and working of Positive and Negative Clamper **5.2: Voltage Multipliers** Construction and working of Voltage Doubler and Tripler. **5.3 :Multivibrator and SchmittTrigger** Construction – Working – Waveform of Astable and Monostable Multivibratorusing Transistorsand SchmittTrigger usingTransistors

UNIT - I

FILTERS, ZENER DIODES AND OPTO - ELECTRONIC DEVICES

FILTER:

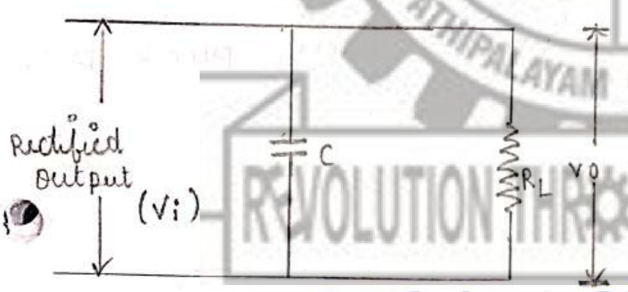
It is used to convert pulsating DC signal into a pure DC signal.

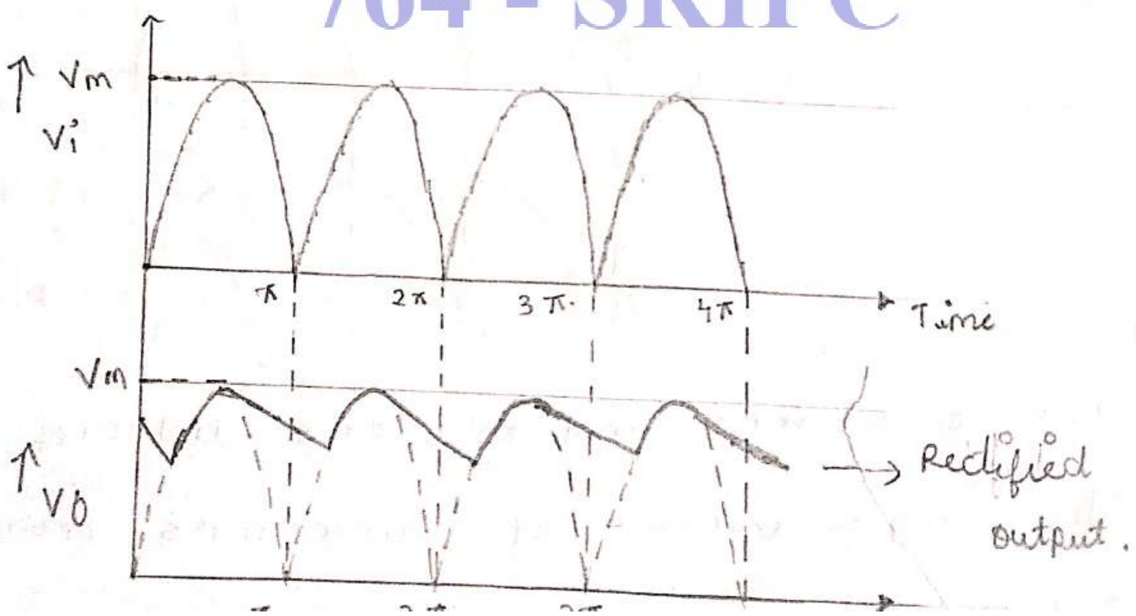
Types

⇒ Capacitor, inductor, LC, π, RC

Capacitor:

The pulsating DC voltage at the rectifier O/P is applied across the capacitor

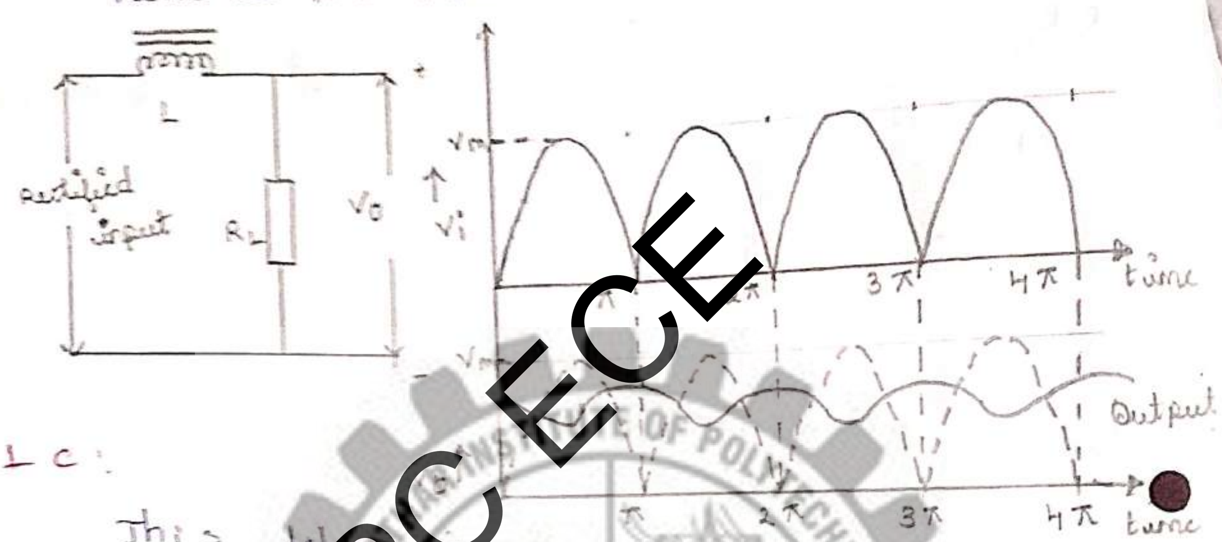




Inductor:

Inductor can change and discharge the current depends on the amount of I.

hence ac ripple will be reduced.

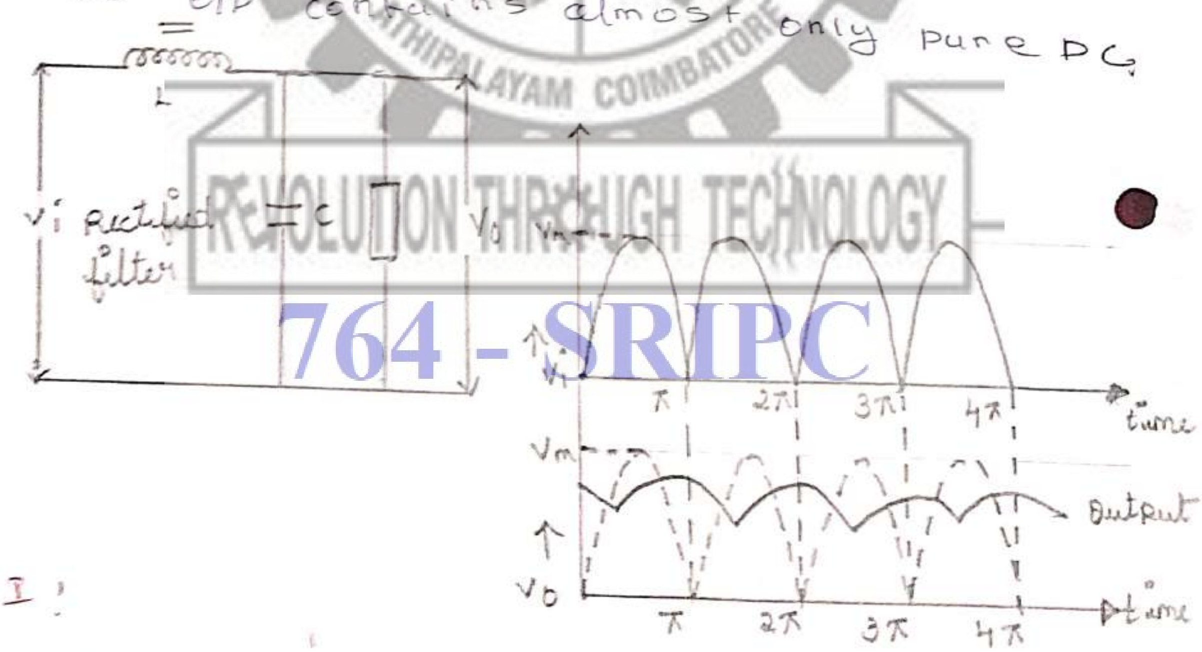


LC:

This filter is a combination of C and Inductor.

It passes the DC components to the load. The AC component is also once again filtered by capacitor C.

so O/P contains almost only pure DC.



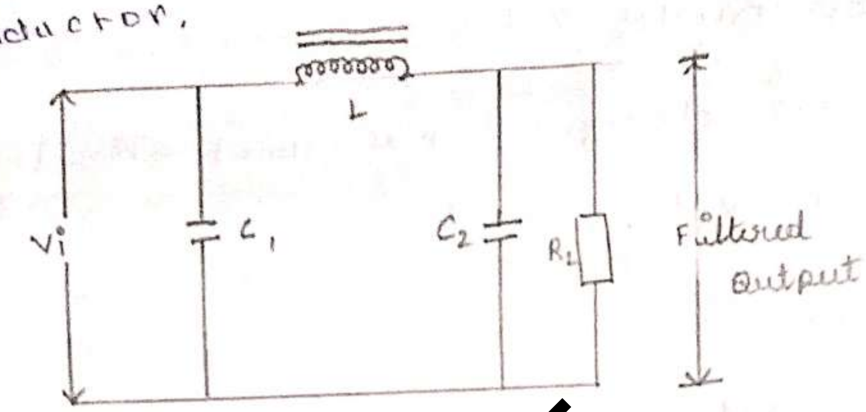
PI:

Two capacitors and only one Inductor.

The large values of capacitors produce high DC O/P.

AC components ...

e inductor,



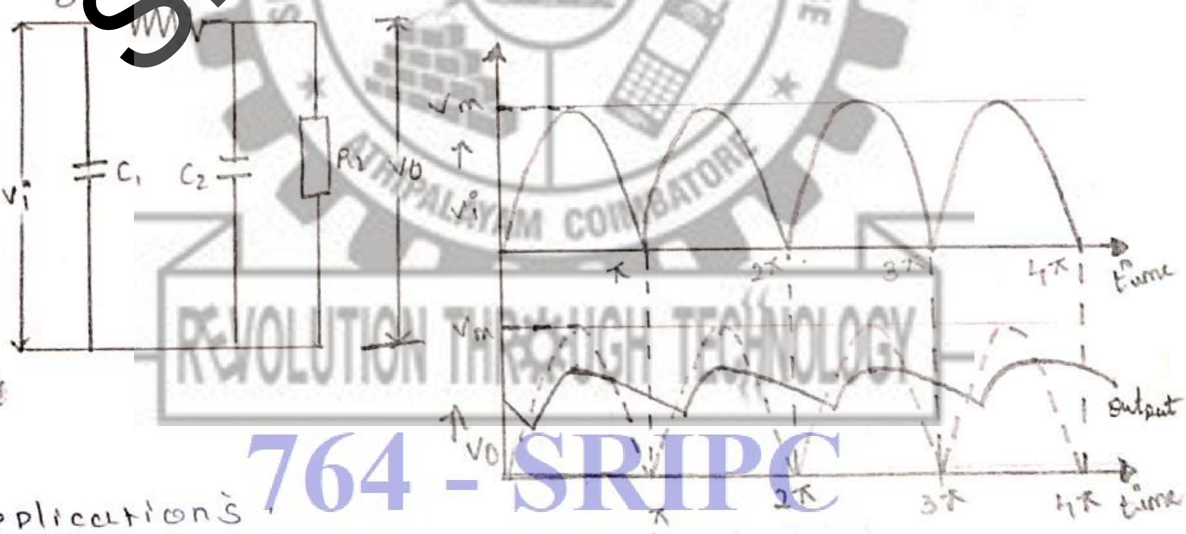
RC:

Resistor and Capacitor filter

The ripples are dropped across R instead of RL.

R -> high impedence

C2 -> removes the AC and present in the DC signal.



Applications:

Rectifier's

Radio

Audio systems

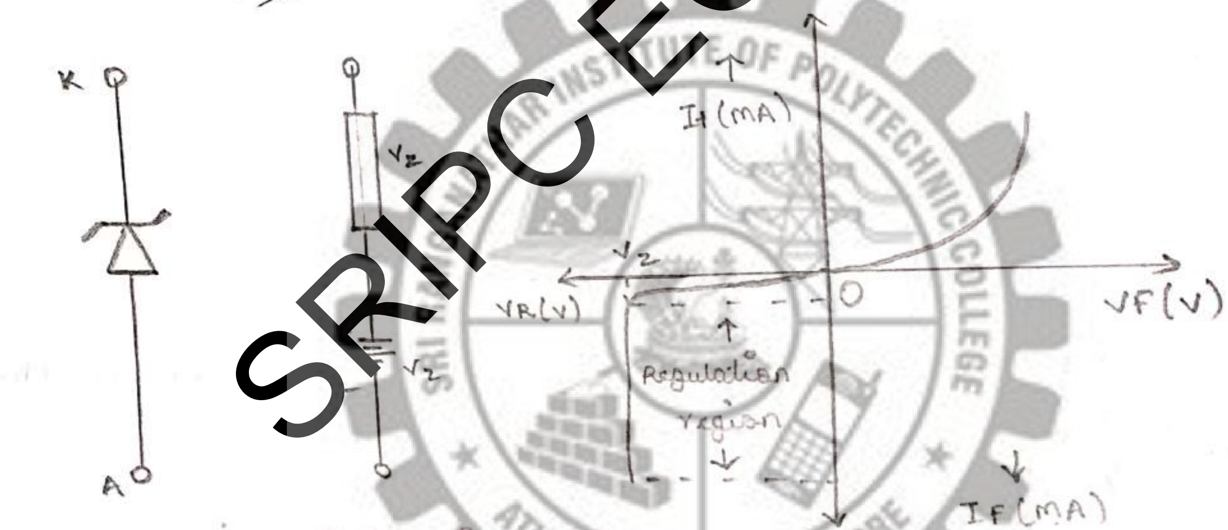
Signal Processing unit

Zener Diode.

It's designed P N Junction diode heavily doped.

Terminals :

⇒ Anode , cathode



(a) Symbol (b) equivalent circuit (c) V-I characteristics

The Operation of the zener diode is same as that of an ordinary P N junction diode.

⇒ Forward bias

⇒ Reverse bias

Forward bias :

Anode connected to the "+"

Kathode connected to the "–"

The Reverse breakdown at the zener diode may be occure due to the following mechanism.

=> Avalanche breakdown

=> Zener breakdown.

Avalanche:

lightly doped zener diode's the width of the depletion layer is large.

This breakdown occurs at higher reverse voltage levels.

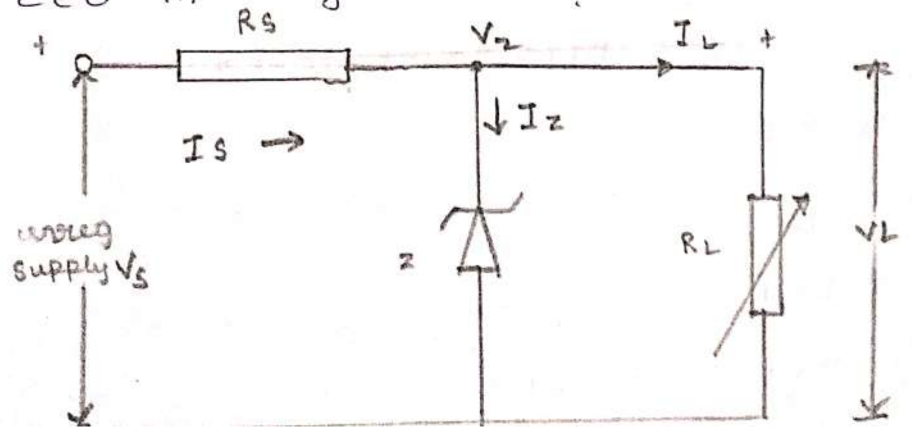
Zener breakdown:

=> heavily doped.

Voltage Regulator:

Z-D is operated in the breakdown region. it maintains a constant voltage across it.

This property of the zener diode is utilized in regulators.



$$I_s = \frac{V_s - V_z}{R_s}$$

I_z = zener current

$$I_L = \frac{V_L}{R_L}$$

$$I_z = I_s - I_L$$

OPTO ELECTRONICS DEVICES

Opto ⇒ light signal or energy

It is the study and application of electronic devices that source, detect and control light.

Types:

⇒ Photo diodes, photo Transistors, photo voltaic cells.

⇒
- LED
- Tungston filament lamp
- CRT

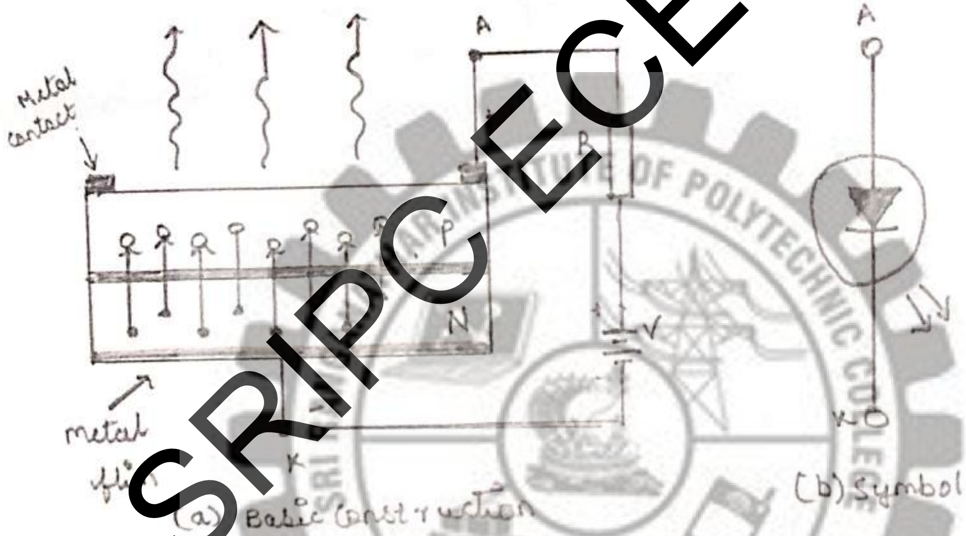
⇒
- LDR
- LCD
- Opto Isolators

LED:

=> Light Emitting Diode

=> it's Emits light when current flows Through it.

=> LED is a specially made forward biased pn junction diode



The colour of the light is emits from the diode depending upon the type of material used

GaAs -> Infrared
GaAsP -> Red or green
GaAsP -> Red or yellow

Forward bias:

=> Electrons and holes recombination

The energy difference b/w valance band and conduction band is radiated in the form of light.

Characteristics:

Light emitted from the diode is directly proportional to the forward current's flows through the diode.

Applications:

- ⇒ Indicators
- ⇒ 7-seg led's
- ⇒ Switching applications

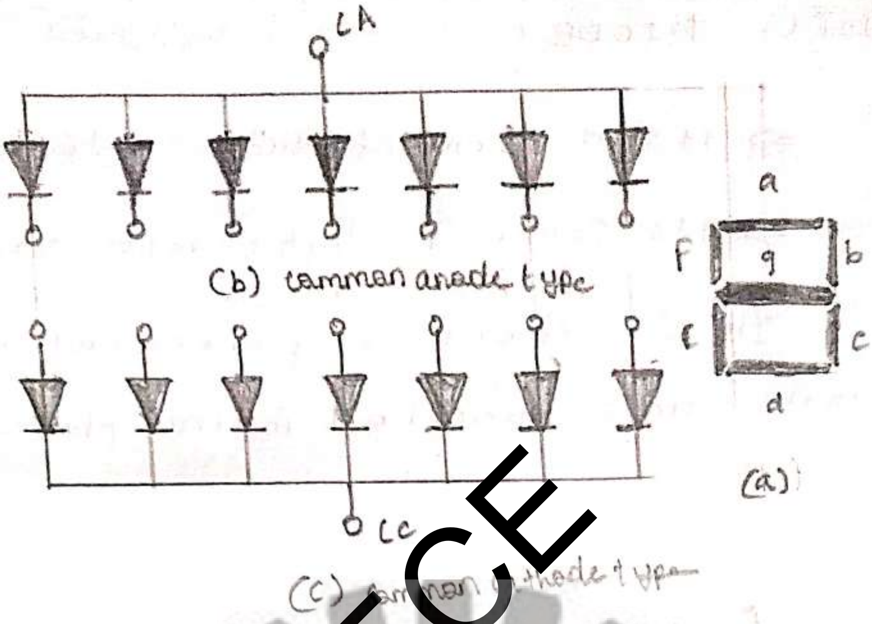
SEVEN SEGMENT LED

⇒ It contains seven rectangular LED's.

⇒ Each LED's called segment.

There are two possible Connections:

⇒ Common anode



generally the seven segment LED is driven by decoder's or code converter's

⇒ common anode,

active low configuration for the code converter.

⇒ common cathode.

active high o/p circuit.

⇒ Terminals.

⇒ a, b, c, d, e, f and g

The o/p is generally a TTL type.

The value of the current flowing through the chosen LED is set by a proper choice of series resistor R.

Applications:

⇒ Timers
⇒ calculators
⇒ clock radio's

PHOTO DIODE:

⇒ it's a semi conductor device

⇒ it's convert light into current

The current is generated when photons are absorbed in the photo diode

The P+ diffusion layer is formed over heavily doped n type epitaxial layer.

Terminals:

⇒ Anode

⇒ Cathode

light energy cannot lose so large amount of light can be changed into current.

MECHANISM:

Inner photo electric effect.

⇒ if absorption occurs in the junction

- characteristic's

A photo diode is always operated reverse bias mode.

Photo current is almost independent of applied reverse bias voltage.

The maximum photo current is limited by the power dissipation of the photo diode.

Applications:

Photo detectors

electrical isolation

opto coupler's

camera's

sensor's

Photo Transistor:

⇒ It is type of NPN Transistor.

⇒ common emitter configuration.

Bias:

collector → emitter Region.

⇒ The function of Transistor is controlled by light energy

(a) Construction (b) symbol

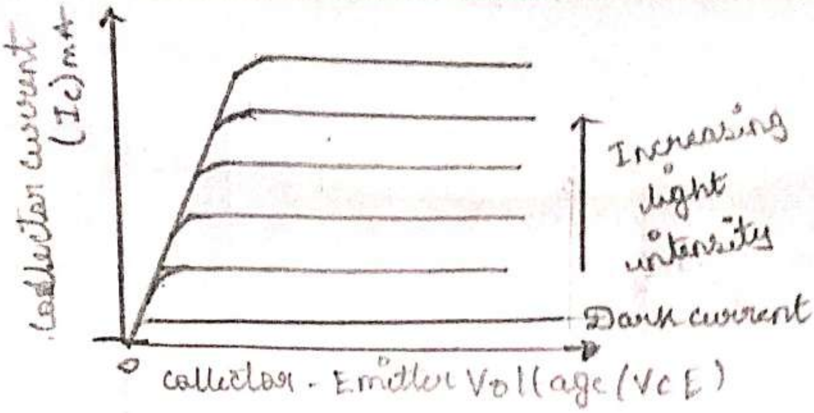
⇒ The small lens is fixed on this hole for allowing a focussed light beam to concentrate the collector-base junction.

Operation:

voltage applied

emitter-base junction → F.B

collector-base junction → R.B



The amount of current flow depends upon the intensity of focussed light.

Applications :

- punch card reader's
- security systems.
- IR detectors.
- Electric controls
- Relay.

Opto coupler :

- ⇒ it's a solid state component.

  ⇒ it can cause unwanted voltage spikes and noise due to coil windings and closing and opening of contact poits

  ⇒ it is an useful alternative for electromechanical Relays

  ⇒ it is very much used in digital circuits

UNIT-II

BJT FET UJT

TOPICS

- BIPOLAT JUNCTION TRANSISTOR
  - TRANSISTOR BIASING
  - COMMON EMITTER TRANSISTOR
- FIELD EFFECT TRANSISTOR
  - FET-CONSTRUCTION AND WORKING PRINCIPLE
  - COMMON SOURCE AMPLIFIER
- UNIJUNCTION TRANSISTOR
  - UJT-CONSTRUCTION AND OPERATION
  - UJT-RELAXATION OSCILLATOR

BIPOLAR JUNCTION TRANSISTOR

- INTRODUCTION
  - Semiconductor devices
  - Containing 3layers and 2 junctions
    - Layers-NPN
    - Junctions-j1 j2
- TERMINALS
  - Emitter Base Collector
- TYPES
  - NPN transistor
  - PNP transistor

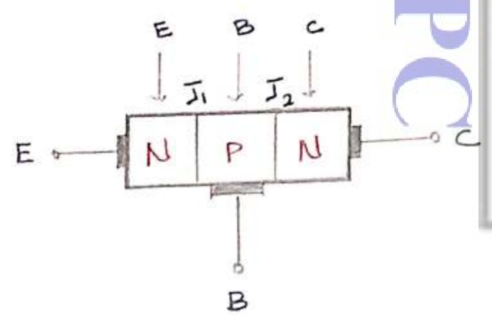
TRANSISTOR BIASING

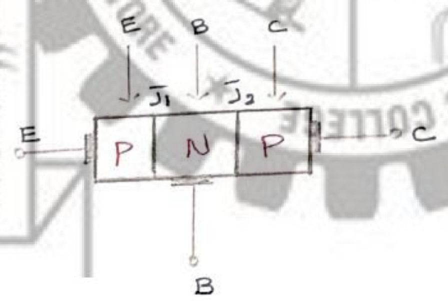
- Biasing is the process of providing DC voltage to the transistor which helps in the functioning of the circuit
- Types

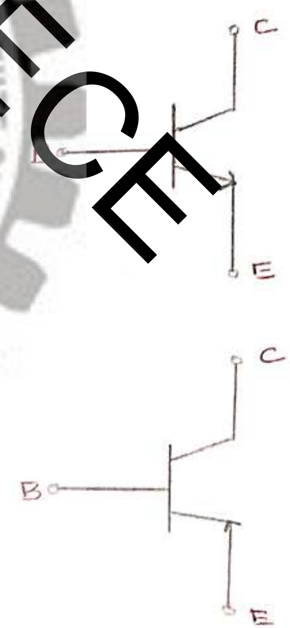
  Fixed bias

  Collector to base bias

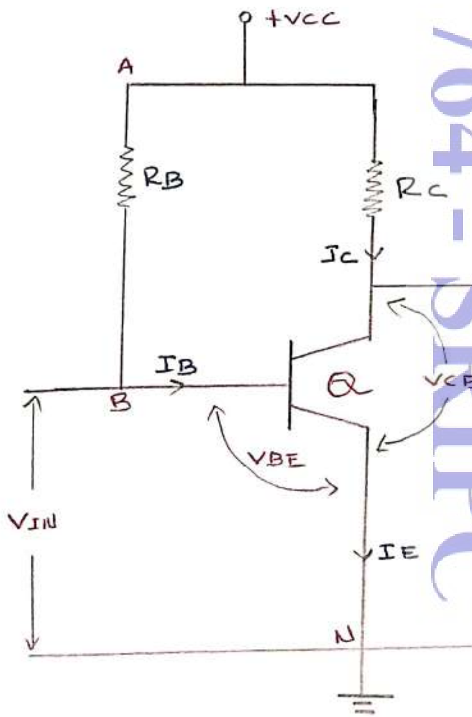
  Self bias





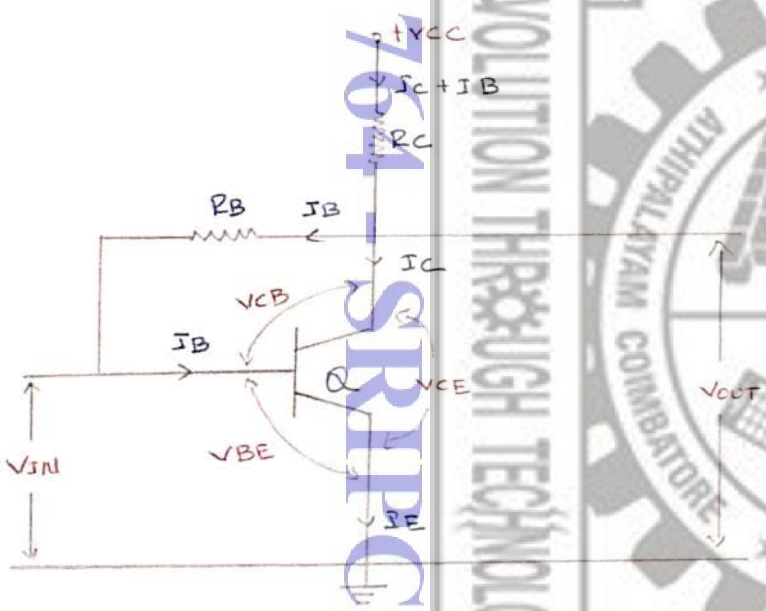


FIXED BIAS



- Vcc-fixed value,on selection of RB the base current IB is fixed therefore this types is called fixed bias.
  in this circuit the operating the
  transistor may be changed anywhere
  in the active region by merely changing the bias resistor(Rb)
  Collector current does not constant
- Advantage
  simple circuit
- Disadvantage
  poor stabilization

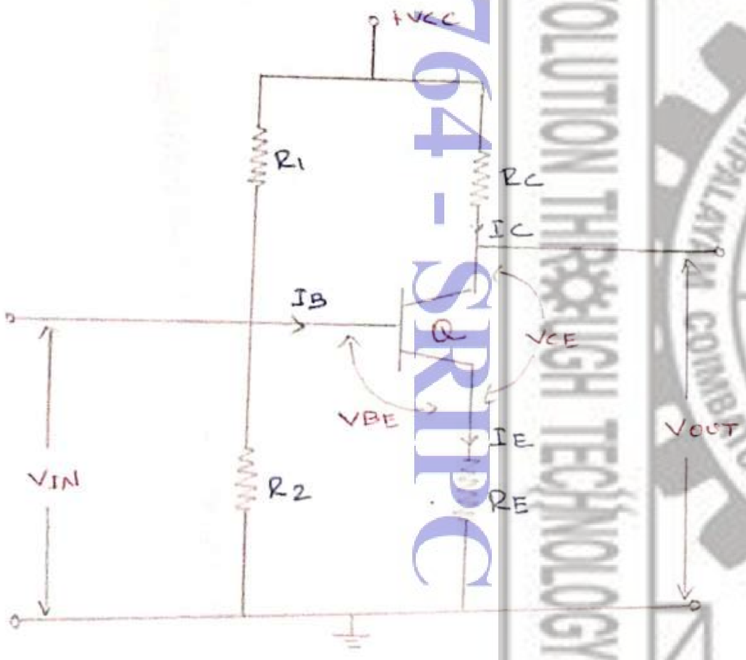
COLLECTOR TO BASE BIAS



It is also called as collector to base bias circuit. It is an improvement over fixed bias method. In this, biasing resistor is connected between collector and base of the transistor to provide feedback path.

If there is a change in β due to piece to piece variation between transistors or if there is a change in β and I_{CO} due to the change in temperature. So collector current tends to increase. As a result, voltage drop across R_C increases. Due to reduction in V_{CE}, I_B reduces. The result is that the circuit tends to maintain a stable value of collector current, keeping the Q point fixed.

SELF BIAS

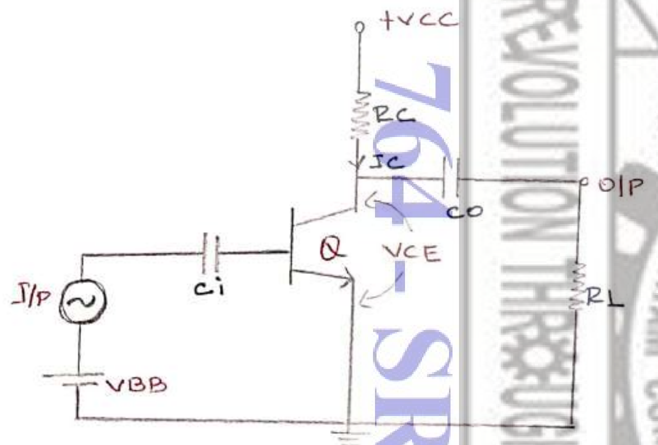


If the temperature of the transistor rises for any reason (due to a rise in ambient temperature or due to current flow through it), the collector current will increase. This increase in current also causes the DC quiescent point to move away from its desired position (level). This reaction to temperature is undesirable because it affects amplifier gain (the number of times of amplification) and could result in distortion, as we will see later in this chapter. A better method of biasing, known as *self-bias* is obtained by inserting the bias resistor directly between the base and collector

AMPLIFIER

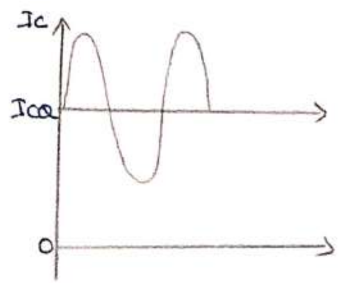
- An amplifier is an electronic device that **increases the voltage, current, or power of a signal**. Amplifers are used in wireless communications and broadcasting, and in audio equipment of all kinds. They can be categorized as either weak-signal amplifiers or power amplifiers.

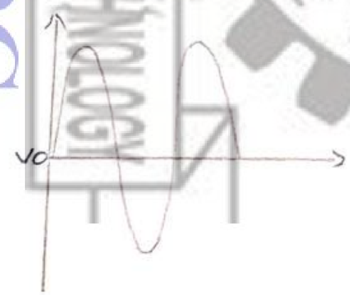
COMMON EMITTER TRANSISTOR



- A common-emitter amplifier is one of three basic single-stage bipolar-junction-transistor (BJT) amplifier topologies, typically used as a voltage amplifier. It offers high current gain (typically 200), medium input resistance and a high output resistance. The output of a common emitter amplifier is 180 degrees out of phase to the input signal

- The common emitter amplifier is a three basic single-stage bipolar junction transistor and is used as a voltage amplifier. The input of this amplifier is taken from the base terminal, the output is collected from the collector terminal and the emitter terminal is common for both the terminals.





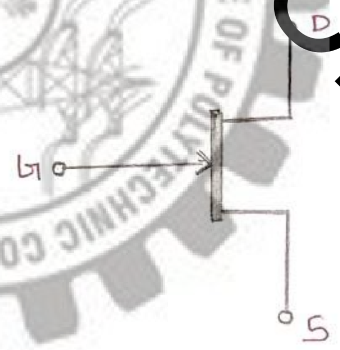
FIELD EFFECT TRANSISTOR

- FET-unipolar semiconductor devices

  Flow of current through it is controlled by an electric field

  Flow of current only depends upon the majority carriers(ELECTRONS or HOLES)

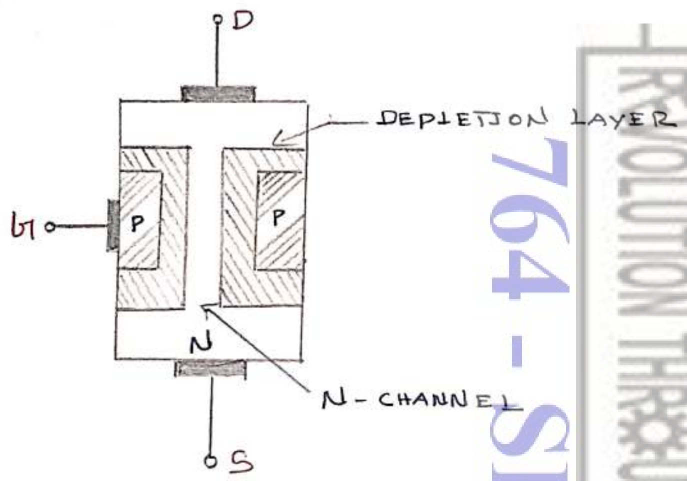
- TERMINALS
  - Gate
  - Drain
  - Source

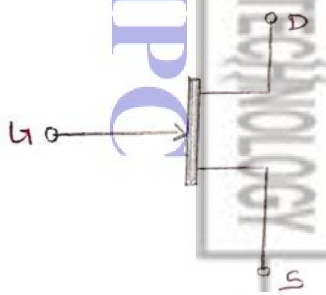


CLASSIFICATIONS

- FET
  - JFET
    - N CHANNEL
    - P-CHANNEL
  - MOSFET
    - DEMOSFET
      - N-CHANNEL
      - P-CHANNEL
    - E-MOSFET
      - N-CHANNEL
      - P-CHANNEL

CONSTRUCTION





- **Gate**

  This terminals controls the flow of charge carriers from source to drain

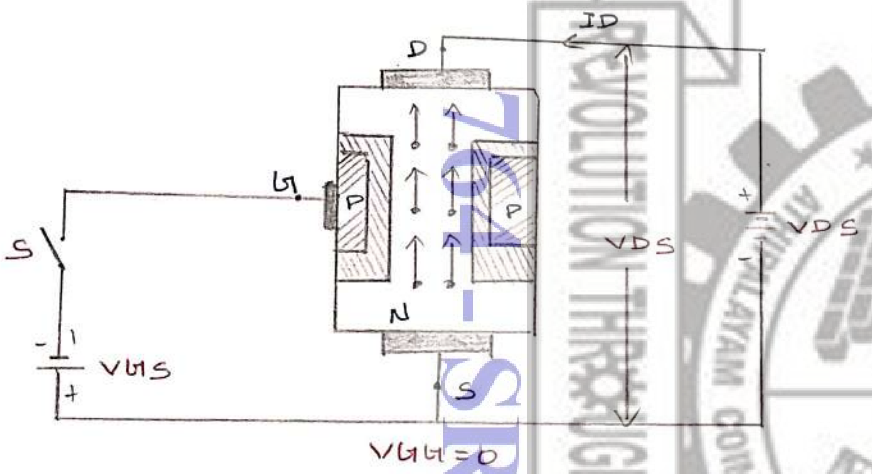
- **Source**

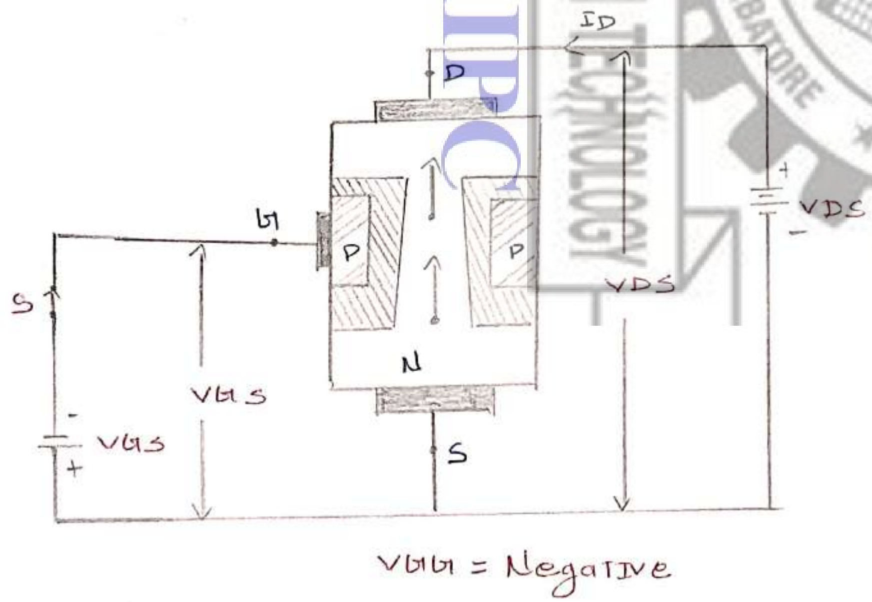
  Source is the terminal through which the majority charge carriers are entered in the FET

- **Drain**

  Drain is the terminal through which the majority charge carriers exit from the FET.

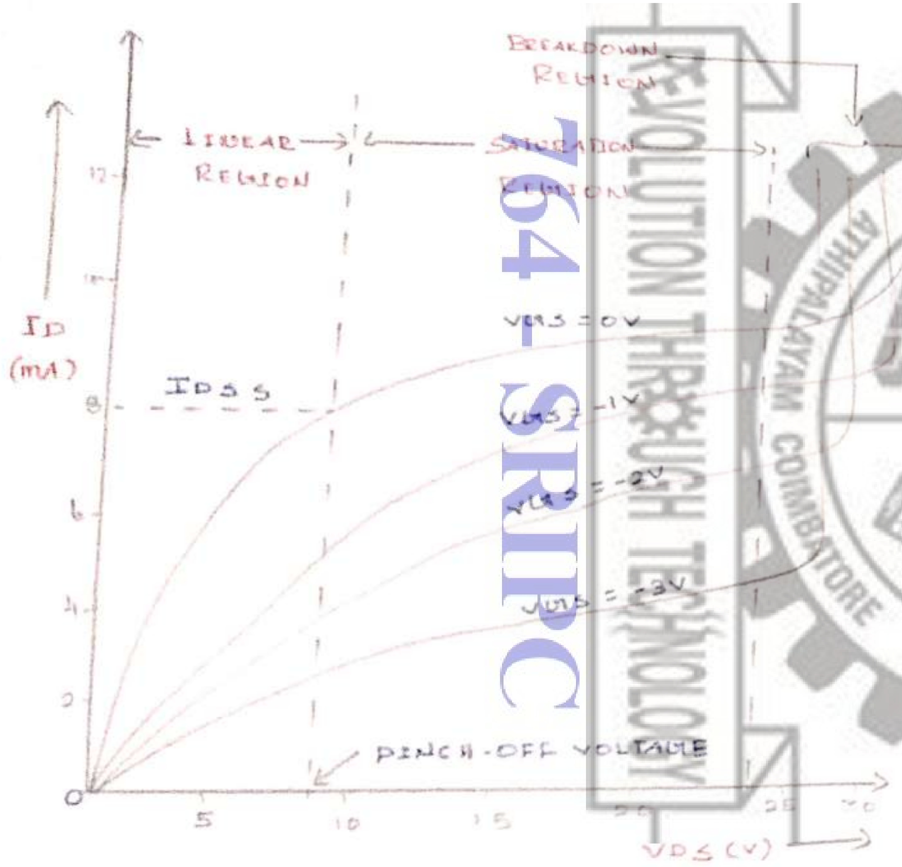
WORKING PRINCIPLE





- ➢ VGS=0
  - ✓ Large amount of electrons will flow from drain to source through a wide channel in between the depletion region
- ➢ VGS=reverse voltage increased
  - ✓ it increases the width of the depletion region reduce the width of the channel so current flow is always reduced.

CHARACTERISTICS



➢ LINEAR REGION

drain to source voltage increased,

drain current increased

Id is directionaly proportional to VGS

➢ SATURATION REGION

drain to source voltage

drain current becomes almost constant

Id increasing

➢ BREAKDOWN REGION

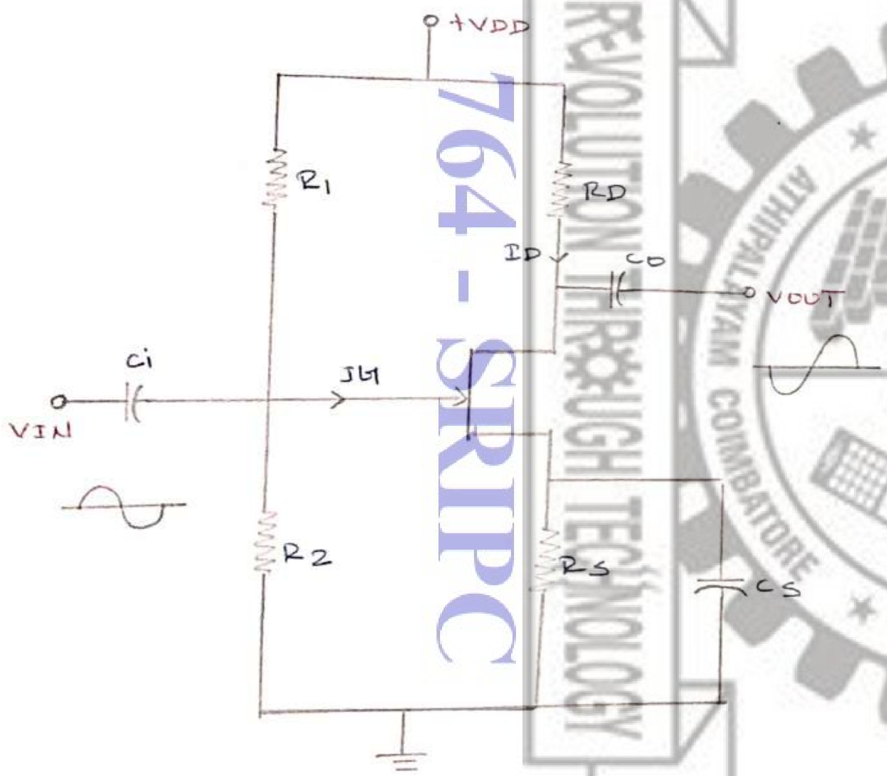
drain to source voltage,

drain current

increases to very high value

with a slight increase of VDS

COMMON SOURCE AMPLIFIER

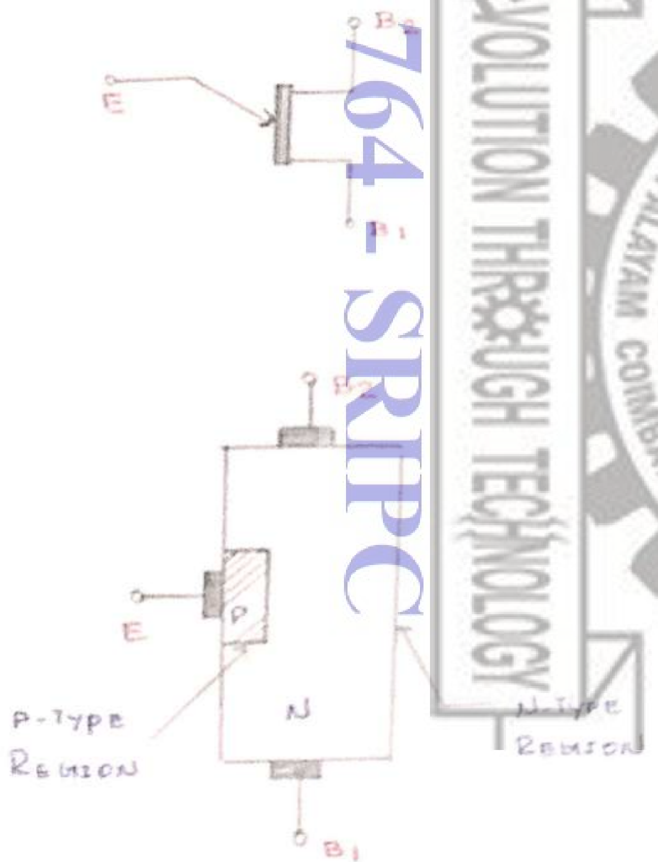


- An increases in gate source voltage produce more drain current, drain voltage decreasing
- ✓ positive half cycle of the i/p signal produces negative half cycle of the o/p signal similarly.
- ✓ i/p-negative half cycle and o/p-positive half cycle
- ✓ Thus the output is 180* out of phase with the input signal
- ✓ The magnitude of the o/p signal is greater than applied i/p signal
- ✓ So it can operates as an amplifier

UNIJUNCTION TRANSISTOR

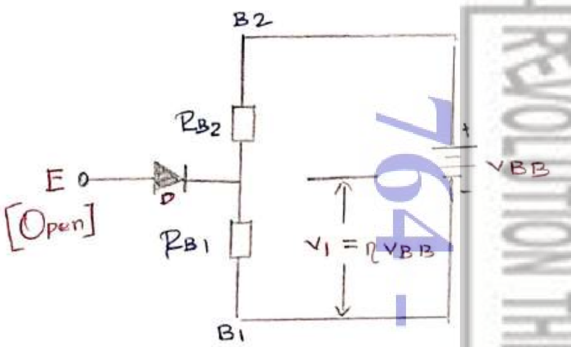
- UJT
  - ✓ It is a three terminal semiconductor switching devices
  - ✓ It has only PN junction
- ➢ TERMINALS
  - ✓ Emitter –p type region
  - ✓ Base 1 –n type silicon bar
  - ✓ Base 2

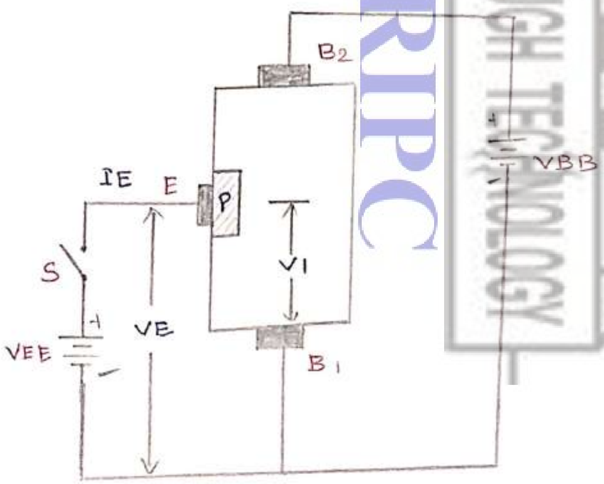
CONSTRUCTION



- Terminals-
  - emitter base 1 base 2
  - ✓ Lightly doped N-type silicon bar heavily doped P-type material is diffused into the bar
  - ✓ P-type region is called Emitter(E)
  - ✓ N-type region is called Base 1 base 2
  - ✓ The emitter junction is placed such that it is more closed tob1 than b2

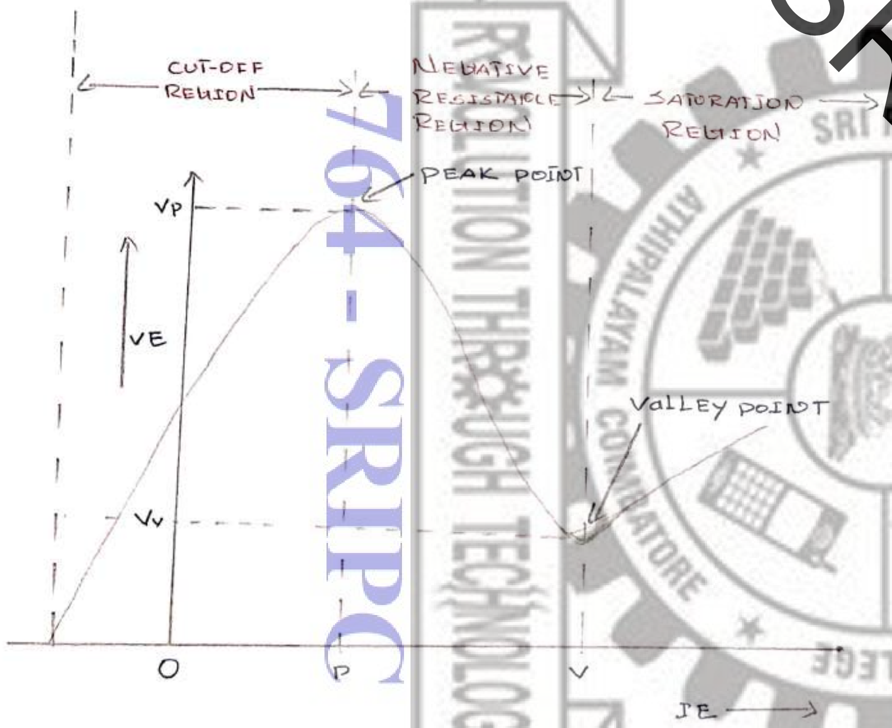
OPERATION





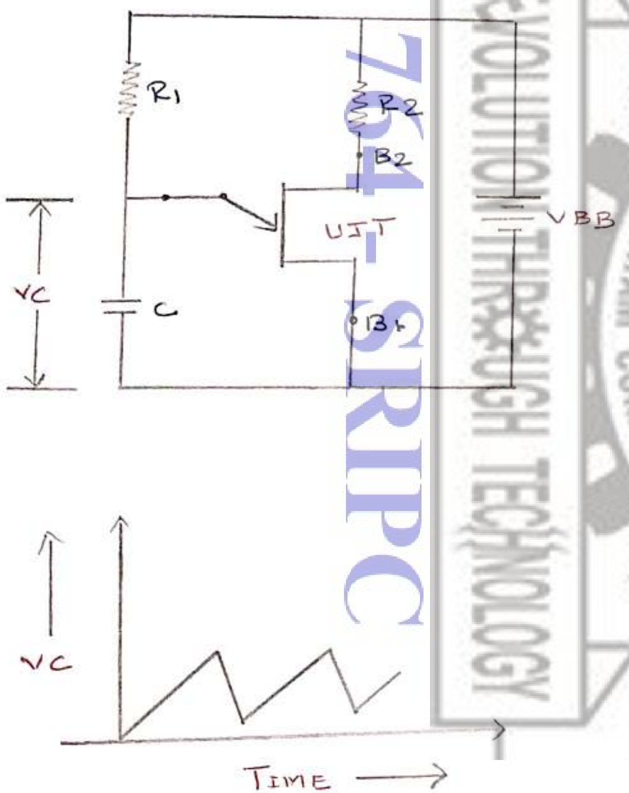
- Emitter-positive voltage
- PN junction reverse bias
- Emitter voltage increase
- PN junction linearly changed forward bias.
- Emitter current high
- Now the device is ON state.
- Emitter- negative voltage
- PN junction reverse bias
- Emitter current low
- Now the devices is OFF state.

CHARACTERISTICS



- The diode is reverse bias hence the region to the left of the peak point is called cut off region.
- After firing voltage the diode starts conduction it produce the negative resistance region. this region between peak point and valley point.
- After valley point current becomes saturation.the region beyond the valley point is called saturation region.

UJT- RELAXATION OSCILLATOR



- The charges of the capacitor depend upon the conduction level of UJT.
- Capacitor voltage is low junction is reverse bias UJT will not conduct.
- Capacitor voltage is high UJT starts conducting.
- The capacitor charge and discharge continuously a continuous sawtooth signal is produced at its output.

UNIT - III
FEEDBACK, AMPLIFIERS AND OSCILLATORS

3.1. FEEDBACK

The process of injecting a fraction of output signal of a circuit back to the input is called feedback.

There are two types of feedback, namely

(i) Positive feedback, and
(ii) Negative feedback

i) Positive feedback

When the feedback signal (voltage or current) is in phase with the input signal, it is called positive feedback. In this feedback, the feedback signal aids the input signal, increases the amount of input signal, and the gain also increases. Hence it can be called regenerative or direct feedback. It is generally used in oscillator circuits.

ii) Negative feedback

When the feedback signal (voltage or current) is out of phase with the input signal, it is called negative feedback. In this feedback, the feedback signal opposes the input signal, decreases the amount of input signal, and the gain also decreases. Hence it can be also called degenerative or inverse feedback. It is generally used in amplifiers.

3.1.1. General Theory of Feedback

The block diagram of an amplifier with feedback is shown in the fig.3.1. When switch 'S' is open, the amplifier operates without any feedback network.

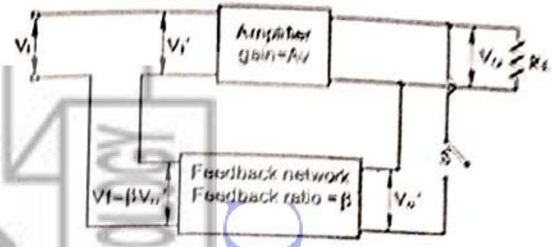


Fig-3.1 Block diagram of an amplifier with a feedback network

Now the gain of an amplifier without feedback, $A_v = \frac{V_o}{V_i}$

where

V_o = voltage of output signal without feedback

V_i = voltage of input signal without feedback

When switch 'S' is closed, the amplifier operates with feedback network. Now the output voltage is varied from V_o to V_o'.

The output voltage of feedback network, $V_f = \beta V_o'$

The actual voltage developed at the input of the amplifier with feedback = $V_i' = V_i + \beta V_o'$

The output voltage with feedback = V_o'

$$V_o' = A_v V_i'$$

$$V_o' = A_v(V_i + \beta V_o')$$

$$V_o' = A_v V_i + A_v \beta V_o'$$

$$V_o' - A_v\beta V_o' = A_v V_i$$

$$V_o'(1 - A_v\beta) = A_v V_i$$

From this equation, the gain of feedback amplifier,

$$A_{vf} = \frac{V_o'}{V_i} = \frac{A_v}{1 - \beta A_v}$$

The term 'βA_v' is called feedback factor. The expression $(1 - \beta A_v)$ is called loop gain. The sign of β is positive for positive feedback and negative for negative feedback.

Hence the gain of positive feedback amplifier,

$$A_{vf} = \frac{A_v}{1 - \beta A_v}$$

The gain of negative feedback amplifier,

$$A_{vf} = \frac{A_v}{1-(-\beta)A_v} = \frac{A_v}{1 + \beta A_v}$$

Thus in positive feedback, $A_{vf} > A_v$, gain increases. In negative feedback, $A_v > A_{vf}$, gain decreases.

3.1.2. Advantages of Negative Feedback

(i) Increases the input impedance by the factor of $(1+A_v\beta)$

(ii) Decreases the output impedance by the factor of $(1+A_v\beta)$

(iii) Increases the stability

(iv) Reduces the distortions like harmonic distortion, frequency distortion and phase distortion.

(v) Reduces the noise

(vi) Increases the bandwidth

The lower cut-off frequency of the amplifier is decreased by the factor of $(1 + A_v\beta)$ and the upper cutoff frequency is increased by the factor of $(1+A_v\beta)$

3.1.3. Effects of Negative Feedback

i) Increase the stabilisation of Gain

In general, the gain of an amplifier depends upon the active device used, the operating voltage and the load impedance. The negative feedback can be used to improve the stability of the amplifier.

The gain of negative feedback amplifier,

$$A_{vf} = \frac{A_v}{1 + \beta A_v}$$

Choosing the feedback ratio (β) very high, the feedback factor βA_v is made very greater than 1

$$\text{So, } A_{vf} = \frac{A_v}{\beta A_v} = \frac{1}{\beta}$$

If we choose the feedback network as resistance network, its function is independent of the frequency of the voltage applied. So stability will be increased.

ii) Reduction of Distortion

Non linear harmonic distortion is introduced in an amplifier because of their operation in the non linear region of device characteristics.

If negative feedback is applied to the amplifier, the gain is reduced. So the distortion is also reduced. The reduction in the non-linear distortion is same as the reduction of gain by the negative feedback.

$$\therefore Df = \frac{D}{1 + \beta Av}$$

where, Df = Distortion factor with negative feedback

D = Distortion factor without feedback

So the distortion in negative feedback amplifier is reduced with the factor of $(1 + \beta\ Av)$

(iii) Reduction in Noise

Noise interference is introduced in an amplifier, and amplified in the same ratio as the input signal. The reduction in the noise interference is same as the reduction of gain by negative feedback.

$$\therefore Nf = \frac{N}{1 + \beta\ Av}$$

where, Nf = Noise interference with the negative feedback

N = Noise interference without feedback

So noise interference in negative feedback amplifier is reduced with the factor of $(1 + \beta Av)$.

iv) Increase the Bandwidth

In any amplifier system the product of Gain and Bandwidth is constant. In negative feedback amplifiers, the gain is reduced with the factor of $(1 + \beta Av)$. By this effect the lower cut of frequency is reduced and the upper cut of frequency is increased. Therefore the band width of negative feedback amplifier is increased.

Reduction in gain can be overcome by providing one or two more stages in cascade.

v) Input resistance

The effect of negative feedback on input resistance depends upon the way in which the output is fedback to the input. The input resistance is illustrated in the fig.3.2.

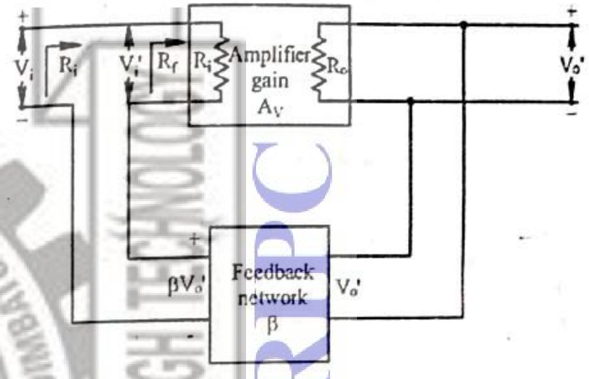


Fig-3.2

Here, Ri = input resistance without feedback

Rif = input resistance with feedback

$$Ri = \frac{Vi'}{Ii}$$

$$Rif = \frac{Vi}{Ii}$$

$$Vi' = Vi + (-\beta)\ Vo'$$

$$Vi' = Vi + (-\beta)\ Av\ Vi' \quad [\ Vo' = Av\ Vi']$$

$$Vi = Vi'\ (1 + \beta\ Av)$$

$$\text{Now, } Rif = \frac{Vi}{Ii} = \frac{Vi'}{Ii}\ (1 + \beta\ Av)$$

$$\therefore Rif = Ri\ (1 + \beta Av)$$

So the input resistance in negative feedback amplifier will be increased with an amount of (1 + βAv).

(vi) Output resistance

The effect of negative feedback on output resistance depends upon whether the feedback signal is proportional to either output voltage or output current. If the feedback signal is proportional to output voltage, the output resistance decreases for both shunt and series feedbacks.

$$Rof = \frac{Ro}{1 + \beta Av}$$

So the output resistance in negative feedback amplifier will be decreased with an amount of (1 + βAv)

3.1.4. Types of Negative Feedback

The basic amplifier in a network may be a voltage, current, transconductance or transresistance amplifier. There are four different ways are used to feedback the output signal with the input. They are discussed below.

i) Voltage series feedback

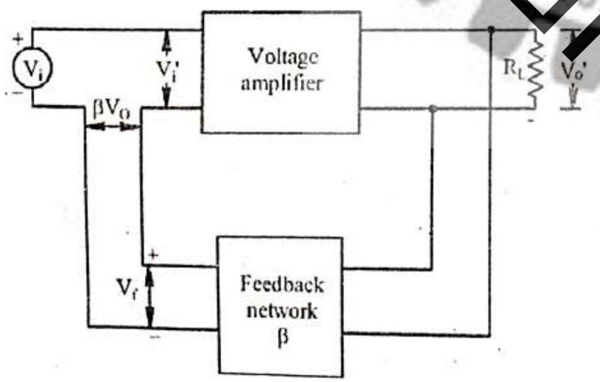


Fig-3.3

In voltage series feedback, a portion of output voltage is fed in series with the input, as shown in the fig.3.3. In this scheme, the amplifier worked as voltage amplifier.

Here the Input resistance increases, and the Output resistance decreases

ii) Voltage shunt feedback

In voltage shunt feedback, a portion of output voltage is fedback to the input in parallel, as shown in the fig.3.4. Here the amplifier used is called transresistance amplifier.

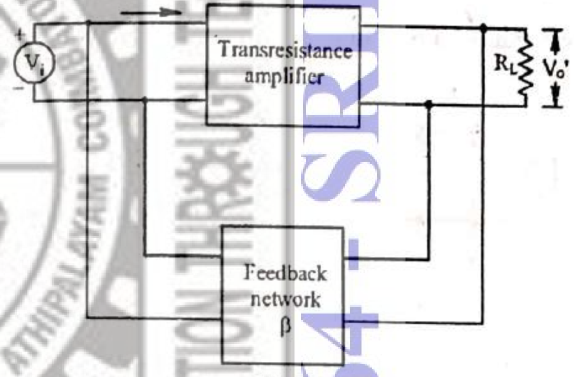


Fig-3.4

Here both the input resistance and output resistance decreases.

iii) Current series feedback

In current series feedback, a portion of output current is fedback to the input in series as shown in the fig.3.5. Here the amplifier used is called Transconductance amplifier.

Here both the input resistance and output resistance increases.

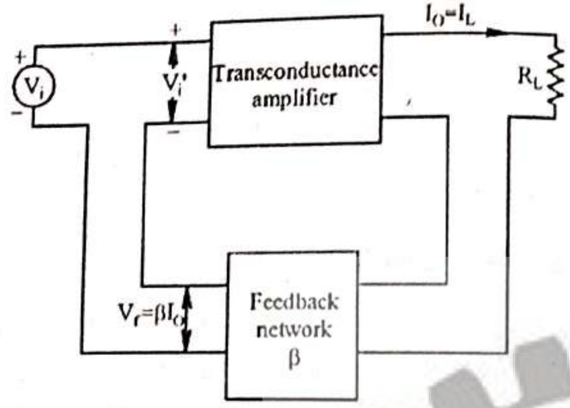


Fig-3.5

iv) Current shunt feedback

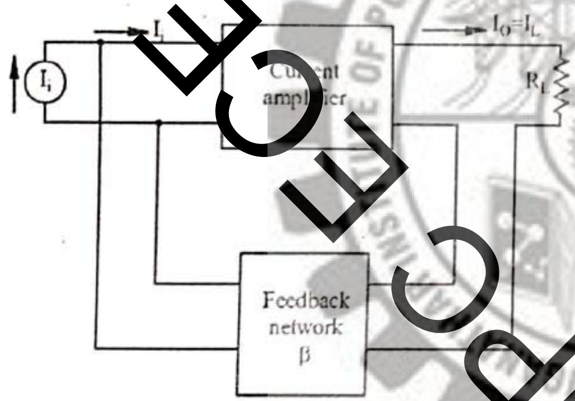


Fig-3.6

In current shunt feedback, a portion of output current is fedback to the input in parallel form, as shown in the fig 3.6. Here the amplifier used is called current amplifier.

Here the input resistance decreases and output resistance increases.

3.1.5. Applications

(i) Stabilize Amplifier gain.

(ii) Reduce nonlinear distortion.

(iii) Increases circuit stability.

(iv) Increases input impedance.

(v) Decreases output impedance.

(vi) Reduces noise level.

(vii) Improve frequency response and bandwidth.

(viii) More linear operations.

3.1.6. Applications of Positive Feedback

(i) Used in Oscillators.

3.1.7. Applications of Negative Feedback

(i) Used in large bandwidth amplifiers.

(ii) Used in regulated power supply.

(iii) Used in various amplifiers design of the electronic field.

3.1.8. Comparison of Positive feedback and Negative feedback

S.No.	Parameter	Positive feedback	Negative feedback
1.	Relation between input and output signal.	Input and output signals are in same phase.	Input and output signals are in opposite phases.
2.	Effects on the signal.	Makes the input signal stronger.	Makes the input signal weaker.

3.	Final output signal	Greater final output	Smaller final output.
4.	Stability	Decreases	Increases.
5.	Uses	In Oscillators	In amplifiers.
6.	Distortions	Not reduced	All distortors are reduced.
7.	Gain	Increases	Decreases.

3.2. AMPLIFIERS

3.2.1. Transistor Amplifier

A transistor acts as an amplifier by raising the strength of a weak signal. The DC bias voltage applied to the emitter base junction, makes it remain in forward biased condition. Thus a small input voltage results in large output voltage, which shows that the transistor works as an amplifier.

3.2.2. Types of Amplifiers

Amplifiers are classified according to the following categories.

a) According to the primary function

- i) Voltage amplifiers
- ii) Current amplifiers
- iii) Power amplifiers

b) According to the frequency range

- i) Audio frequency amplifiers
- ii) Radio frequency amplifiers
- iii) Video frequency amplifiers

c) According to the coupling method

- i) Direct coupled amplifiers
- ii) RC coupled amplifiers
- iii) LC coupled amplifiers
- iv) Transformer coupled amplifier

d) According to the configuration

- i) Common Emitter (CE) amplifier
- ii) Common Base (CB) amplifier
- iii) Common Collector (CC) amplifier

e) According to the load

- i) Tuned amplifiers
- ii) Untuned amplifiers

f) According to the period of conduction

- i) Class A amplifier
- ii) Class B amplifier
- iii) Class AB amplifier
- iv) Class C amplifier

3.2.3. RC Coupled Amplifier

A two stage RC coupled CE amplifier using NPN transistor is shown in the fig.3.7. It is a most popular type of coupling because it is cheap and provides excellent operation. R_C (R_{C1} and R_{C2}) is the collector load resistor. R_1, R_2 and R_E provide biasing and stabilization. C_E prevents the loss of amplification due to negative feedback. The capacitors C_i and C_0 are used to block the DC signal and transmit only AC signal. The capacitor C_C is used to connect the output (collector) of first stage to the input (base) of second stage.

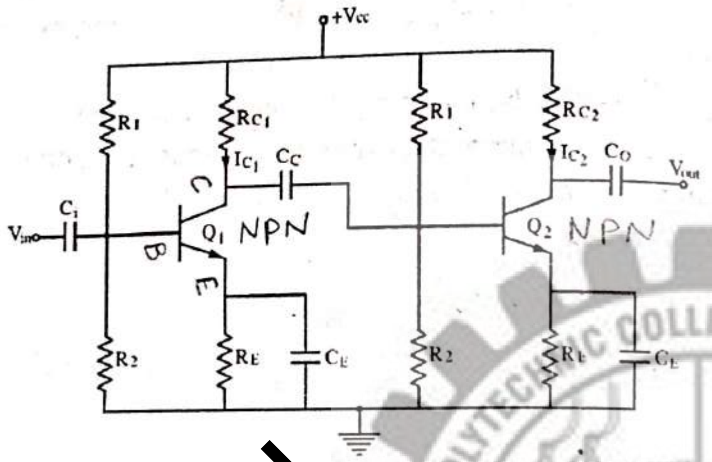


Fig: 3.5 Two stage RC coupled amplifier

When an AC signal is applied to the base of the first transistor (Q_1) it appears in the amplified form across its collector load register R_{C1}. This amplified signal is given to the base of next stage through coupling capacitor C_C. The second stage does further amplification of the signal. The first stage produces 180^0 phase shift and the second stage produces another 180^0 phase shift. So the total phase shift is 360^0. Hence the output signal is in phase with the applied input signal.

The overall gain of this amplifier is equal to the product of the gain of two stages. The influence of the capacitors used in this circuit, reduces the overall gain of the amplifier at low and high frequency ranges. The gain is high and constant, only at mid frequency ranges.

3.2.3.1. Frequency response

An amplifier should operate irrespective of the frequency of the input signal. But practically an amplifier does not magnify all frequency range of input signal with an equal amount. Practically, by using the reactive components, the gain will be decreased at low and high frequency ranges and constant only at mid frequency ranges. This behaviour of the amplifier is briefly explained below.

(i) Low frequency range :

At low frequencies, the reactance of coupling capacitor C_C is quit high and hence very low amount of signal will pass from first stage to the second stage. So gain will be reduced. Similarly the reactance of the bypassing capacitor C_E is very high, hence it cannot shunt the emitter resistor R_E effectively.

These two factors reduce the voltage gain of the amplifier at low frequency range.

(ii) High frequency range : At high frequencies the reactance of the coupling capacitor is very low. Hence it behaves as a short circuit. This increases the loading effect of next stage.

Similarly at high frequencies the reactance of bypassing capacitor C_E is very low which increases the base current. This reduces the current amplification factor β. These two factors reduce the voltage gain of the amplifier at high frequency range.

(iii) Mid frequency range : At mid frequencies the voltage gain of the amplifier is constant. At this range the effect of coupling capacitor is to maintain a uniform voltage gain.

In this range as the frequency increases, the reactance of C_C decreases which tends to increase the voltage gain. However at the same time, lower reactance means higher loading of the first stage tends to decrease the voltage gain. These two factors almost cancel each other, resulting in a uniform gain at mid frequency range.

3.2.3.2. Frequency response characteristics

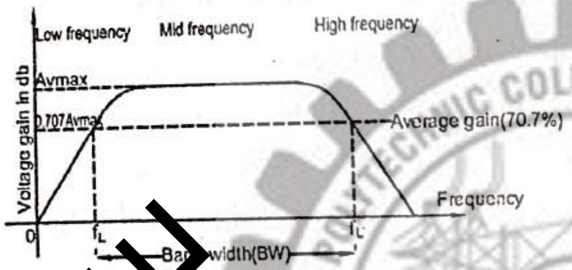


Fig: 3.8 Frequency response characteristics

The frequency response characteristics of a two stage RC coupled amplifier is shown in the fig.3.8. The gain is reduced at low and high requency ranges, and constant only at mid frequency range. From the response curve we will calculate lower cut off frequency (f_L), upper cut off frequency (f_U) and Bandwidth (BW).

Lower cut off frequency (f_L):

The frequency at which the voltage gain of the amplifier is 70.7% of maximum gain (average gain) on lower side of the frequency range is called lower cut off frequency (f_L)

Upper cut-off frequency (f_U):

The frequency at which the voltage gain of the amplifier is 70.7% of maximum gain (average gain) on the

higher side of the frequency range is called upper cut off frequency (f_U).

Bandwidth (BW)

The range of frequency over which the gain is equal to or greater than 70.7% of maximum gain is known as Bandwidth.

It is also defined as the frequency difference between the upper cutoff frequency and lower cutoff frequency.

Advantages

(i) Frequency response is excellent
(ii) Cost is low
(iii) Non-linear distortion is low
(iv) It is compact, light and small

Disadvantages

(i) Low voltage gain and power gain
(ii) Noise is produced with age, particularly in moist climates.
(iii) Impedance matching is poor.

3.2.4. Common Collector amplifier (Emitter Follower)

Common collector amplifier is called emitter follower. The emitter follower is a current amplifier that has no voltage gain. Its most important characteristic is that it has high input impedance and low output impedance. Hence it is an ideal circuit for impedance matching. The circuit of an emitter follower is shown in the fig. 3.9.

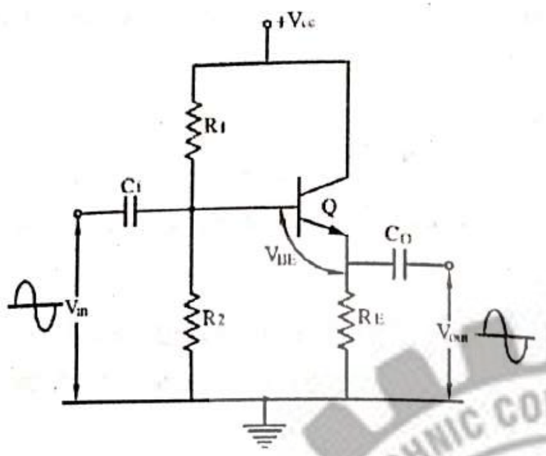


Fig: 3.9 Emitter follower

The emitter resistor R_E itself acts as a load and the AC output voltage is taken across R_E. The resistors R_1 and R_2 provide for proper biasing. The input and output capacitors (Ci and Co) block DC signals, and allow only AC signals.

The input signal is applied between base and emitter terminals. The output voltage is taken across R_E. The voltage drop across R_E opposes the input voltage, thus providing negative feedback. It is a negative current feedback circuit, since the voltage feedback is proportional to the emitter current (output current).

During conduction, the voltage drop across base-emitter (V_{BE}) is very low, hence $V_{in} \cong V_{out}$. The output (emitter) signal follows the input signal in phase, amplitude and frequency. So it is called emitter follower.

Characteristics

(i) Voltage gain is nearly equal to unity
(ii) High current gain and power gain

(iii) High input impedance and low output impedance
(iv) Input and output AC voltages are in phase.

3.3. OSCILLATORS

3.3.1. Transistor Oscillators -Introduction

Many electronic devices require a source of energy at a specific frequency, which may range from few Hz to several MHz. This is achieved by an electronic device called oscillator.

Oscillator is an electronic device which generates an AC signal with required frequency, required amplitude and required waveshape. In radio and television receivers, oscillators are used to generate high frequency carrier signals. Oscillators are widely used in radars, electronic equipments and other electronic devices.

Oscillators are broadly classified into two types . They are

i) Sinusoidal oscillators
ii) Non-sinusoidal oscillators (Relaxation oscillators)

The sinusoidal oscillators are used for generating only sinusoidal signals with required frequency and required amplitude.

The non-sinusoidal oscillators are used for producing non-sinusoidal signals like square, rectangular, triangular or sawtooth signals with required amplitude and required frequency.

3.3.2. Classification of Oscillators

Oscillators are classified into the following different types

(A) According to the waveform generated

(i) Sinusoidal oscillators

a) LC oscillators, and

b) RC oscillators

(ii) Non - sinusoidal oscillators (Relaxation oscillators)

a) Squarewave generator

b) Rectangular wave generator

c) Sawtooth wave generator

d) Triangular wave generator

(B) According to the fundamental mechanism used

(i) Negative resistance oscillators

(ii) Feedback oscillators

(C) According to the frequency generated

(i) Audio Frequency (AF) oscillators

(ii) Radio Frequency (RF) oscillators

(iii) Very High Frequency (VHF) oscillators

(iv) Ultra High Frequency (UHF) oscillators

(v) Microwave oscillators

3.3.3. Condition for Oscillation (Barkhausen criteria)

Barkhausen criteria is the statement which gives the essential condition for maintaining self sustained oscillation. The block diagram of a feedback amplifier is shown in the fig. 3.10.

The oscillators do not have any input signal (except supply) and hence Vi = 0 in this circuit.

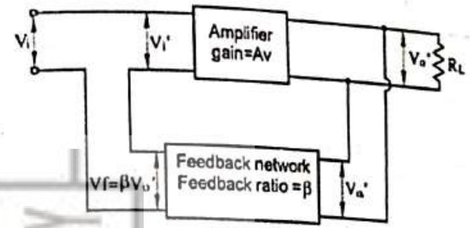


Fig-3.10
Condition for oscillation

Let

Input signal without feedback = Vi

Output signal without feedback = Vo

Gain of the amplifier without feedback,

$$Av = \frac{V_o}{V_i}$$

The actual input signal applied to the amplifier with feedback = Vi'

The output signal of the amplifier with feedback = Vo'

The output signal of feedback network, Vf = β Vo'

Actually, the signal voltage developed at the input of the amplifier is, Vi' = Vi + Vf

$$Vi' = Vi + \beta\ Vo' \qquad (\because Vf = \beta\ Vo')$$

For self maintaining oscillation, there is no separate input signal, hence Vi' = β Vo' (∵ Vi = 0)

Hence Vo' = Av Vi'

$$Vo' = Av\,\beta\,Vo' ;$$

Therefore $Av\,\beta = 1$ (Loop gain = 1)

$Av\,\beta = 1$ is the expression for self maintaining oscillation, which is called condition for oscillation or barkhausen criterian.

$$Av\,\angle\theta_1 + \beta\,\angle\theta_2 = 1\angle 0$$

$$Av\beta = 1$$

$$\therefore \quad \theta_1 + \theta_2 = 0^0 = n2\pi$$

ie., the sum of the phase shift of amplifier and feedback network is equal to zero.

3.3.4. Hartley Oscillator

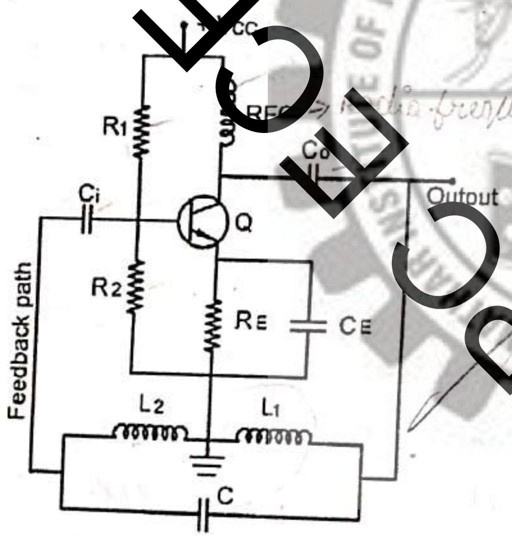


Fig-3.11 Hartley oscillator

The circuit diagram of a Hartley oscillator is shown in the fig-3.11. It is a LC oscillator. This oscillator contains a CE amplifier, feedback network, and a tank circuit made up of L_1, L_2 and C. The resistors R_1 and R_2 provide necessary bias to the amplifier. The capacitors Ci and Co are used to

block the DC components. The capacitor CE is a bypass capacitor. It bypasses the amplified AC signal. The resistor R_E provides negative feedback to the amplifier to improve its stability. The RF choke (RFC) provides a path for collector bias current but offers high impedance for oscillating signal.

Principle of operation

When the supply is turned ON, the capacitor 'C' is charged. When this capacitor is fully charged, it discharges through the coils L_1 and L_2, setting up an oscillation. The output voltage of the amplifier appears across L_1 and the feedback voltage appears across L_2. The voltage across L_2 is 180^0 out of phase with the output voltage. It is the feedback signal. A phase shift of another 180^0 is produced by CE amplifier. Hence the total phase shift between input and output is $180^0 + 180^0 = 360^0$. This results in positive feedback which makes the oscillation as continuous undamped.

The frequency of the oscillation is given by, $F = \frac{1}{2\pi\sqrt{LC}}$

where $L = L_1 + L_2$

It is used in local oscillators of radio receiver and audio oscillator circuits.

3.3.5. Colpitts Oscillator

The Colpitts oscillator is same as Hartley oscillator. The major difference between the two is that the Colpitts oscillator uses a tapped capacitor whereas the Hartley oscillator uses a tapped inductor. The circuit diagram of colpitts oscillator is shown in the fig-3.12.

The tank circuit is made up of C_1, C_2 and L. The resistors R_1 and R_2 provide proper bias and, R_E with C_E provides stabilization. The RF choke (RFC) gives high impedance for high frequency oscillating signal. The frequency of the oscillation is given by

$$F = \frac{1}{2\pi\sqrt{LC}}; \quad \text{where} \quad C = \frac{C_1 C_2}{C_1 + C_2}$$

(Since C_1 and C_2 are in parallel)

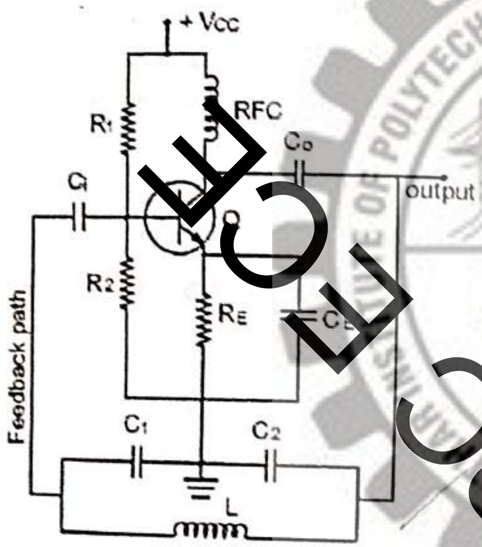


Fig-3.12 Colpitts oscillator

Principle of operation

When the supply is switched 'ON', the capacitor C_1 and C_2 are charged. Then these capacitors discharge through the coil 'L'. So oscillations are produced. The oscillations across C_1 are applied to the input of the CE amplifier. The amplified output is available at the collector terminal of the transistor.

The amount of feedback depends upon the capacitance values of C_1 and C_2. The capacitor feedback circuit provides 180^0 phase shift. The transistor amplifier (CE) provides another 180^0 phase shift. Hence the total phase shift is 360^0, which provides positive feedback. Therefore continuous undamped oscillation is produced.

Colpitts oscillators are widely used in signal generators and local oscillator of superhetrodyne radio receiver.

3.3.6. RC Phase Shift Oscillator

The LC oscillators have two general drawbacks

(i) It cannot be used for very low frequencies, because the coil becomes too much bulky, expensive and noisy.

(ii) The frequency stability and waveform are very low.

The RC oscillators produce good frequency stability signal and also operate at very low frequencies.

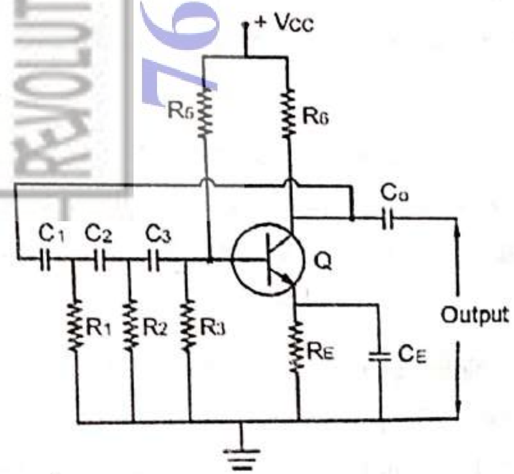


Fig-3.13 RC phase shift oscillator

The circuit diagram of RC phase shift oscillator is shown in the fig-3.13. The oscillator consists of three stages of RC networks (R_1C_1, R_2C_2 and R_3C_3). The resistor R_5 provides bias, and R_E with C_E provides stabilization. The frequency of the oscillation is given by

$$F = \frac{1}{2\pi\sqrt{6}\,RC}\ ; \quad \text{where } R = R_1 = R_2 = R_3,\quad C = C_1 = C_2 = C_3$$

Principle of operation

When the supply is switched ON, the random variations of base current caused by noise variations in the transistor and voltage variations in the power source produce oscillation. This variation is amplified by the CE amplifier.

The feedback network consists of three stages of RC networks. The three stages are identical. The feedback section provides 180^0 phase shift because each RC network provides 60^0 phase shift ($3 \times 60^0 = 180^0$). The CE amplifier provides another 180^0 phase shift. Hence the total phase shift is 360^0, which provides positive feedback. Therefore, continuous undamped oscillation is produced.

Advantages

(i) Does not require transformers and inductors
(ii) It can produce very low frequency signals
(iii) The circuit provides good frequency stability

Disadvantages

(i) It is difficult to start oscillation
(ii) It gives low power output
(iii) This RC oscillator is not suitable for tuned oscillator because the variation of capacitor and resistor values also changes the phase shift of the RC networks.

UNIT - IV
SPECIAL SEMICONDUCTOR DEVICES
(SCR, DIAC, AND TRIAC)

4. Introduction

Thyristor is a semiconductor device, having two or more junctions. The device may act as an 'ON'- 'OFF' switch. It can be fabricated to have voltage ratings of several hundreds volts and current ratings from few amperes to thousand amperes. The family of thyristor consists of PNPN diode (Shockley diode), SCR, LASCR, TRIAC, DIAC, QUADRAC, etc. These are called special semiconductor devices.

4.1. SCR (Silicon Controlled Rectifier)

SCR is a three terminal (anode, cathode and gate), three junction and four layer semiconductor switching device. The basic structure and symbol of SCR is shown in the fig-4.1.

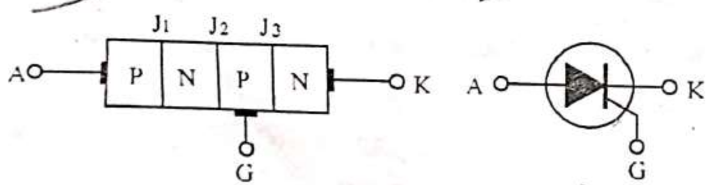


Fig. 4.1 Silicon Controlled Rectifier.

4.1.1. Layered structure of SCR

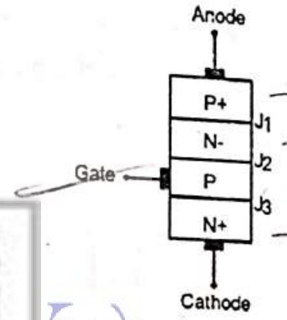


Fig 4.2 Layered structure of SCR

The layered structure of SCR is shown in the fig 4.2. It has three terminals of Anode, Cathode and Gate. It has also four layers of P-N-P-N and three junctions of J_1, J_2, and J_3.

The first layer is the P^+ layer and it is a heavily doped layer. The second layer is N^- layer and it is a lightly doped layer. The third layer is P layer and it is a moderately doped layer. The fourth layer is the N^+ layer and it is a heavily doped layer. The anode termenal is taken from the first P^+ layer and the Cathode terminal is taken from the last N^+ layer. The Gate terminal is taken from the middle of the P layer. Leakage current of silicon is small compared to the germainium. Hence SCR is made up of the silicon.

When the anode is positive with respect to the cathode, the SCR is in forward bias. When the anode is negative with respect to cathode, the SCR is in reverse bias. The VI characteristrics of SCR is divided into three parts. This is also known as the mode of operation of SCR.

The three modes are

i) Forward blocking mode
ii) Forward conducting mode
iii) Reverse blocking mode.

4.1.2. Principle of operation

In the normal operating conditions, a positive voltage is applied to the anode (A) and a small positive voltage is applied to the gate (G) with respect to the cathode (K), as shown in the fig-4.3.

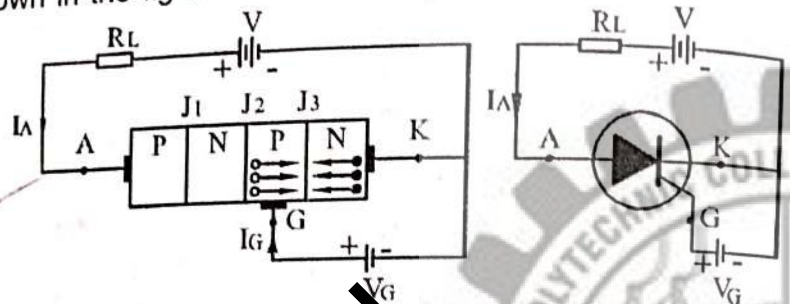


Fig. 4.3 Operation of SCR when gate is +ve w.r.t. cathode.

When the gate is kept open ($V_G = 0$), the SCR is similar to a PNPN diode. The junctions J_1 and J_3 operate in forward bias and the junction J_2 operates in reverse bias. So no current flows through the SCR. Therefore the SCR is in OFF state. The SCR now offers high resistance.

When the anode voltage is gradually increased, the junction J_2 attains breakdown at a particular voltage. Now the SCR conducts heavily going to 'ON' state. The anode voltage, at which the SCR conducts heavily (ON state) without gate voltage is called 'Breakover voltage.'

When a small positive voltage is applied to the gate, the junction J_3 is in forward biased and the junction J_2 is in reverse biased by this voltage. Now the electrons move from N type layer (cathode) to P type layer, through the junction J_3. The electrons in junction J_3 are also attracted by junction J_2, and gate current starts flowing. The holes also move from P layer (G) to N-layer (K) which in turn increases the anode current, and makes more electrons available at junction J_2. This cumulative process make to breakdown the junction J_2 in a short time. Now the SCR conducts heavily.

Once an SCR is turned 'ON', the gate loses its control. Even if the gate voltage is removed, the SCR does not go to 'OFF' state. To turn the device OFF is only done by lowering the anode voltage, and makes the current less than holding current (I_H).

4.1.3. Two Transistor analogy of SCR

The operation of SCR can be explained in simple by using two transistor method. The SCR can be split into two parts, which consist of T_1 (PNP) and T_2 (NPN) transistors connected in "back to back", shown in the fig-4.4.

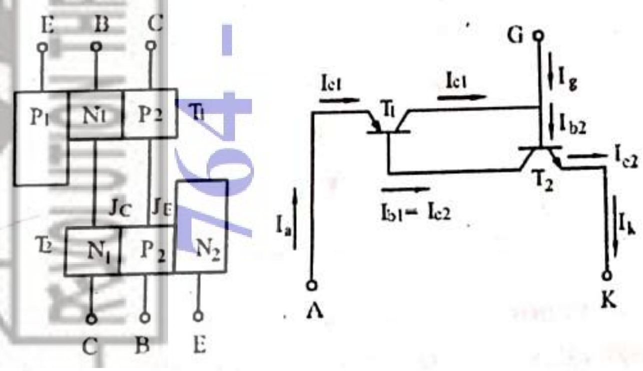


Fig. 4.4 Equivalant circuit of SCR

α_1 and α_2 are the current gains of transistors T_1 and T_2 respectively. When the sum of α_1 and α_2 is equal to unity, the SCR goes to ON state. The current gain of T_2 increases as the gate current is increased (proportional to gate voltage).

4.1.4. VI Characteristics

The high value of gate current can easily ON the device with low anode to cathode voltages. The VI characteristics of SCR are shown in the fig-4.5.

In forward biasing, as the anode-cathode voltage exceeds the forward breakover voltage (V_{BO}), the SCR turns ON, and the anode-cathode voltage decreases quickly to a voltage marked as B.

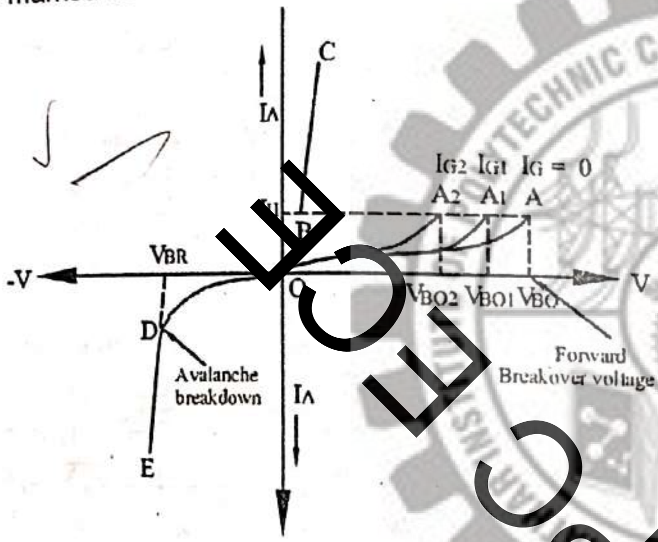


Fig. 4.5 V- I charactristics of SCR

The current at B is called holding current (I_H). It is the minimum value of anode current to keep the SCR in ON state. The region between the point B and C is called forward conduction region.

When the anode voltage is negative with respect to cathode, the junctions J_1 and J_3 operates in reverse biasing and the junction J_2 operates in forward biasing. When the reverse voltage is linearly increased, avalanche breakdown occurs in a particular reverse voltage. Now the current increases rapidly.

Latching current

It is the maximum anode current must attain to continue to remain in forward conduction mode even when gate current is removed.

Holding current

It is the minimum value of current below which anode current must fall to come in OFF state.

4.1.5. Applications

(i) Used in speed control of AC and DC motors
(ii) Used in Inverters and Converters
(iii) Used in AC and DC circuit breakers
(iv) Used for phase control, and heater control
(v) Used in battery chargers.

4.1.6. Comparison between SCR and Transistor

S.No	Transistor	SCR
i)	Three layer device	Four layer device
ii)	Terminals are Collector, Base and Emitter.	Terminals are Anode, Gate and Cathode
iii)	Available only in low power ratings	Available in lower and higher power ratings
iv)	Need continuous current for keeping it in a conduction state.	Need only one pulse for keeping it in a conduction state

v)	High internal power loss.	Lower internal power loss
vi)	Always controlled by base terminal.	After conduction the gate terminal losses its control
vii)	Applications: Amplification, switching etc.	Applications: Rectification. Power control etc.

4.2. DIAC (Diode for Alternating Current)

Diac is a two terminal semiconductor switching device. It has two terminals, namely MT_1 and MT_2, and both are inter-changeable. The Diac is equivalent to two number of four layer diodes connected in parallel, but in opposite direction. The basic structure, equivalent circuit and symbol are shown in the fig.4.6. The Diac conducts in both directions equally.

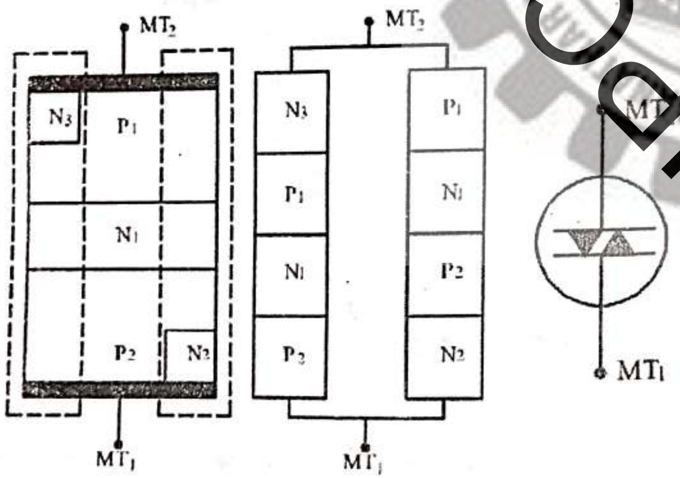


Fig. 4.6 Diac

4.2.1. Principle Of Operation

The Diac can operate in both directions, depending upon the voltage applied in between MT_2 and MT_1. In both sides the Diac can be switched 'ON' only when the applied voltage reaches the breakover voltages.

i) MT_2 is positive with respect to MT_1

When MT_2 is positive with respect to MT_1, the junctions J_1 and J_3 are working in forward bias and the junctions J_2 and J_4 are working in reverse bias. Now a small leakage current flows through $P_1N_1P_2N_2$ and no current flows through $P_2N_1P_1N_3$. When the applied voltage exceeds the breakover voltage, the reverse biased junction J_2 break due to avalanche effect. So current flows from MT_2 to MT_1 through $P_1N_1P_2N_2$, which current 'ON' the Diac, shown in the fig-4.7.

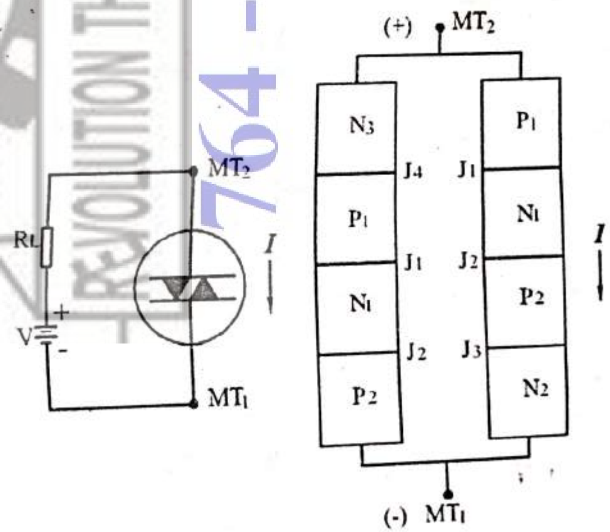


Fig. 4.7 Working of Diac (MT_2 is +ve w.r.t. MT_1)

ii) MT_2 is negative with respect to MT_1

When MT_2 is negative with respect to MT_1, the junctions J_1 and J_3 are reverse biased and the junctions J_2 and J_4 are forward biased. Therefore no current flows through $P_1N_1P_2N_2$. Now a small leakage current flows through $P_2N_1P_1N_3$. When the applied voltage exceeds the breakover voltage, the reverse biased junction J_1 break due to avalanche effect. Now the current passes from MT_1 to MT_2 through $P_2N_1P_1N_3$, shown in the fig.4.8.

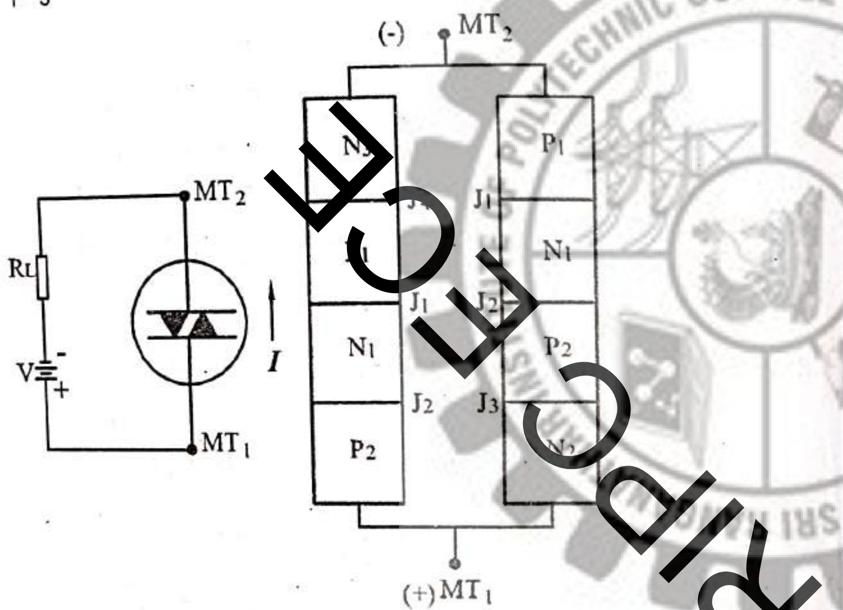


Fig. 4.8 Working of Diac (MT_2 is -ve w.r.t. MT_1)

4.2.2. VI Characteristics

The VI characteristics of Diac is shown in the fig.4.9.

The I quadrant and III quadrant curves are identical, because the Diac operates in both sides as identical. The Diac conducts (ON) only, when the applied voltage exceeds the breakover voltage. After breakdown, the current increases

linearly with respect to time, due to the effect of avalanche breakdown.

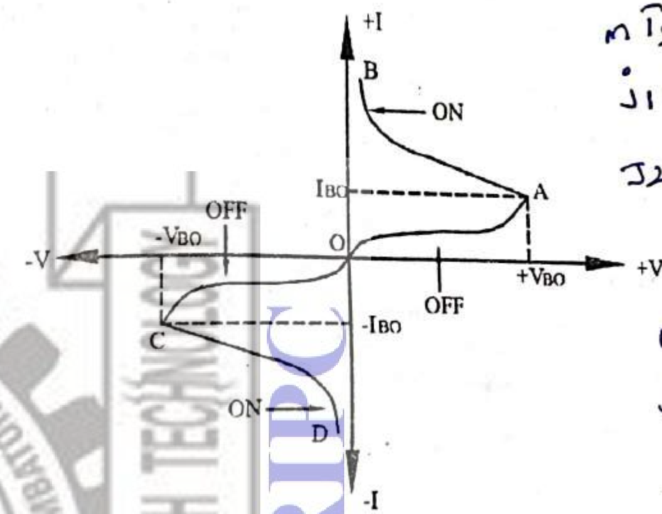


Fig. 4.9 V-I characteristics of Diac

4.2.3 Applications

i) Used in motor speed control
ii) Used in heater control
iii) Used in light dimmer circuit.
iv) Used in Triac phase control circuits.

4.3. TRIAC (Triode for Alternating Current)

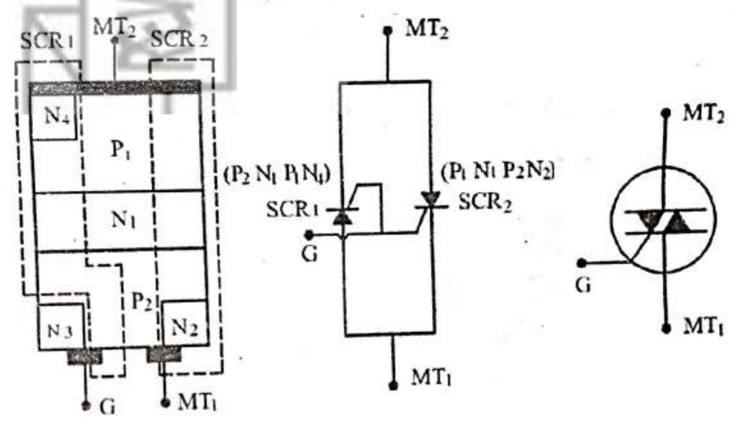


Fig. 4.10 Triac

Triac consists of four layers like PNPN in the positive direction and the negative direction consists of NPNP. Triac is a three terminal, bidirectional semiconductor switching device. It can control alternating current in a load. It's three terminals are MT_1, MT_2 and Gate. The basic structure and symbol of a Triac is shown in the fig.4.10.

Triac is equivalent to two SCRs connected in parallel but in opposite direction, as shown in the fig- 4.10.(b). So it will act as a switch in both directions.

4.3.1. Principle Of Operation

The Triac is operated in four modes, which depend upon the polarity of voltage applied across to its main terminals and also gate terminal. The circuit connection for four modes of operation is shown in the fig.4.11.

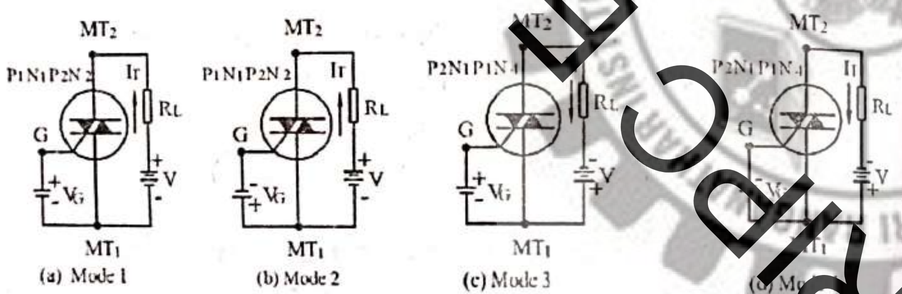


Fig. 4.11 Various modes of Triac operation

(i) MT_2 and G are positive with respect to MT_1 (Mode 1)

The current I flows from MT_2 to MT_1 through $P_1N_1P_2N_2$ (SCR_2). The junctions P_1N_1 and P_2N_2 are now in forward bias and the junction N_1P_2 is in reverse bias.

A positive gate voltage forward biases the P_2N_2 junction, and also breakdowns the reverse biased junction N_1P_2.

(ii) MT_2 is positive and Gate is negative with respect to MT_1 (Mode 2)

The current I flows from MT_2 to MT_1 through $P_1N_1P_2N_2$ (SCR_2). The junctions P_1N_1 and P_2N_2 are working in forward bias and the junction N_1P_2 is working in reverse bias.

A negative gate voltage forward biases the P_2N_3 junction. The current carriers are injected into P_2 layer and it breaks the N_1P_2 junction. So it turns the Triac in 'ON' state.

In the above two modes, Triac operates in the first quadrant.

iii) MT_2 is negative and Gate is positive with respect to MT_1 (Mode 3)

The current flows from MT_1 to MT_2 through $P_2N_1P_1N_4$ (SCR_1). Now the junctions P_2N_1 and P_1N_4 are working in forward bias and the junction N_1P_1 is working in reverse bias. A positive gate voltage forward biases the P_2N_2 junction. The current carriers are injected into the N_1 layer and it breaks the N_1P_1 junction. So it turns the Triac in 'ON' state.

iv) MT_2 and Gate are negative with respect to MT_1 (Mode4)

The current flows from MT_1 to MT_2 through $P_2N_1P_1N_4$ (SCR_1). The junctions P_2N_1 and P_1N_4 are working in forward bias and the junction N_1P_1 is working in reverse bias. A negative gate voltage forward biases the P_2N_3 junction. Now the current carriers are injected into N_1 layer and it breaks the N_1P_1 junction. So it turns the Triac in 'ON' state.

In mode 3 and mode 4, the SCR operates in the third quadrant.

4.3.2. VI Characteristics

The characteristics of Triac is shown in the fig.4.12. The VI characteristics of SCR in the first and third quadrants are identical. The Triac is 'OFF', until the applied voltage of either polarity exceeds breakover voltage (V_{BO}). When the applied voltage exceeds V_{BO}, the Triac turns 'ON'. Now the current increases to a higher value and the voltage across the Triac decreases to a lower value. The increasing gate voltages will turn 'ON' the Triac at lower gate voltages.

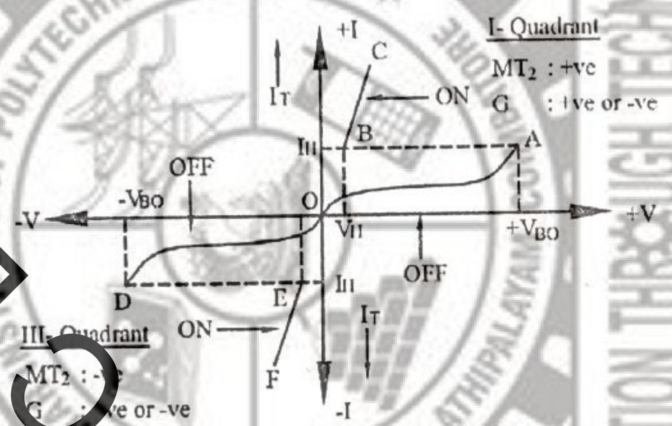


Fig. 4.12 V- I characteristics of Triac

4.3.3. Applications

(i) Used for illumination control

(ii) Used for temperature control

(iii) Used for liquid level control

(iv) Used for motor speed control

(v) Used to turn AC power 'ON' and 'OFF'.

UNIT - V

WAVE SHAPING CIRCUITS

5.1. CLIPPERS AND CLAMPERS

5.1.1. CLIPPERS

Clipper is a non-linear waveshaping circuit. It limits (reduces) the amplitude of an input signal, by removing (clipping) the portion(s) of the input signal. The clipping function will take place on positive side, negative side or on both sides. This circuit would not affect the phase and frequency of the input signal. This circuit is also called as limiters, slicers or amplitude selectors.

Classification

The diode clippers are classified into the following types.

(i) Positive clipper
(ii) Negative clipper
(iii) Biased diode clipper
(iv) Combination diode clipper

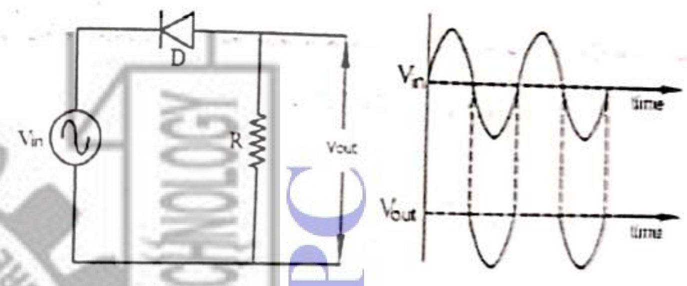
5.1.1.1. Positive Clipper

The positive clipper removes the full positive half cycles of the input signal. It is divided into two types.

(a) Series diode positive clipper
(b) Shunt diode positive clipper

(a) Series Diode Positive Clipper

In series diode positive clipper, the diode is connected in reverse direction, in series with the output as shown in the fig.5.1(a).



(a) Circuit diagram (b) Input and output waveforms

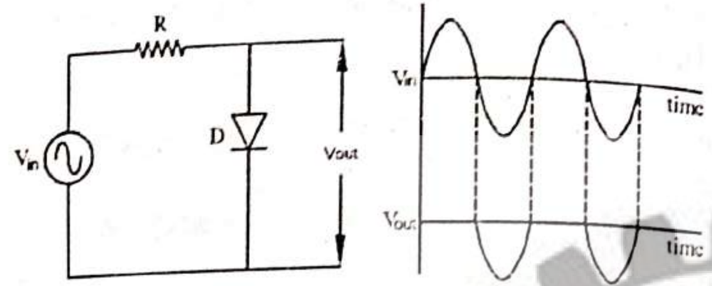
Fig.5.1 Series diode positive clipper

During the positive half cycles of the input signal, the diode conducts in reverse bias. Hence, no voltage dropped across R. So the output voltage (V_{out}) is equal to zero. During the negative half cycles, the diode conducts in forward bias. No voltage drops across the diode. So the output signal contains full negative half cycles of the input signal, as shown in the fig.5.1(b). This circuit clips the full positive half cycles, so it is called positive clipper.

(b) Shunt Diode Positive Clipper

In shunt diode positive clipper, the diode is connected in parallel with the output, as shown in the fig.5.2(a). The diode is connected in forward direction. During the positive half cycles of the input signal, the diode conducts in forward bias. No voltage dropped across the diode. So the output voltage, V_{out} is equal to zero. During the negative half cycles of the input signal the diode conducts in reverse bias. Now the reverse resistance of the diode is very much greater than

R. So the applied input negative half cycle is fully dropped across the diode.



(a) Circuit diagram (b) Input and output waveforms

Fig.5.2 Shunt diode positive clipper

Hence the output contains only the negative half cycles of the input signal, as shown in the fig.5.2(b). So it is also called positive clipper.

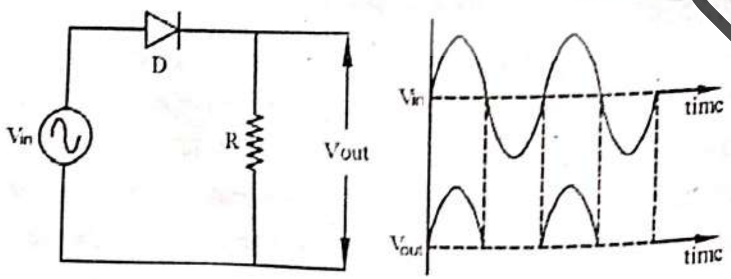
5.1.1.2. Negative Clipper

The negative clipper removes the negative half cycles of the input signal. It is divided into two types.

(i) Series diode negative clipper

(ii) Shunt diode negative clipper.

(i) Series Diode Negative Clipper

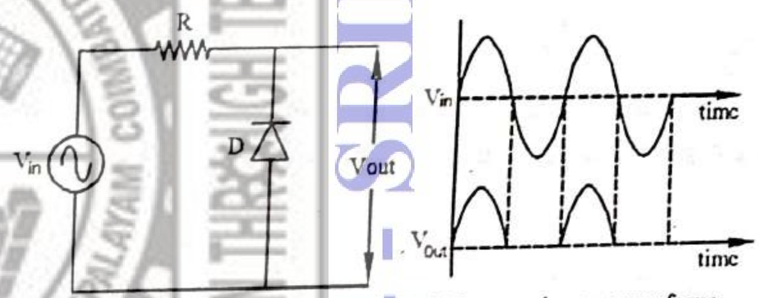


(a) Circuit diagram (b) Input and output waveforms

Fig.5.3 Series diode negative clipper

In series diode negative clipper the diode is connected in series (forward direction) with the output resistor R, shown in the fig.5.3(a). During the positive half cycles of the input signal, the diode conducts in forward bias. So the input signal is dropped across R. Similarly during the negative half cycles of the input signal, the diode conducts in reverse bias. So no voltage drops across R. Hence the output signal contains only positive half cycles of the input, as shown in the fig.5.3(b).

(ii) Shunt Diode Negative Clipper



(a) Circuit diagram (b) Input and output waveforms

Fig5.4 Shunt diode negative clipper

In shunt diode negative clipper the diode is connected in parallel with the output, as shown in the fig-5.4(a). During the positive half cycles of the input signal, the diode conducts in reverse bias. So the input signal is fully dropped across the diode. Similarly during the negative half cycles of the input signal, the diode conducts in forward bias. So no voltage dropped across the diode. Hence, the output signal contains only positive half cycles of the input signal, as shown in the fig.5.4(b)

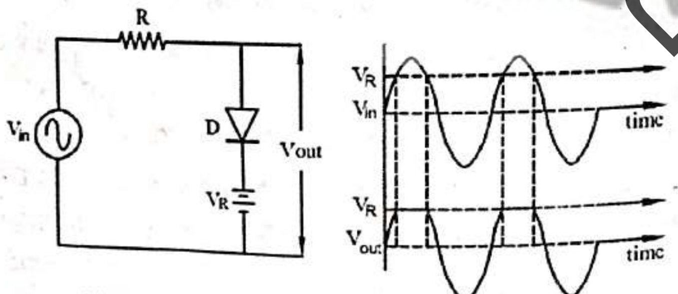
5.1.1.3. Biased Diode Clipper

The positive and negative clippers removes the input signal at zero level. So the ouput contains only either positive or negative half cycles of the input signal. But the biased diode clipper removes the input signal from a desired DC level, either in positive side or in negative side. In this circuit, a battery source is connected in series with the diode. The voltage of the battery, must be less than the signal maximum input voltage V_m. It contains two types.

(i) Positive biased clipper
(ii) Negative biased clipper.

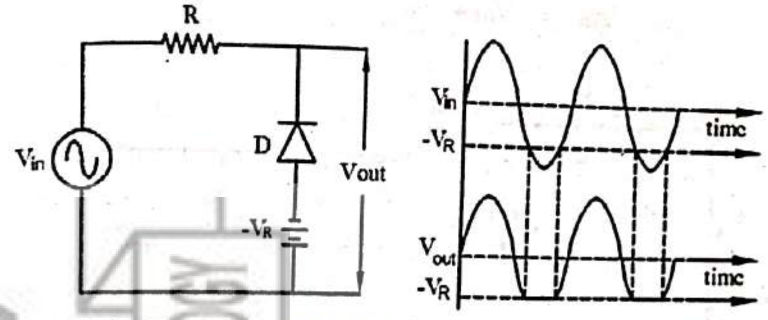
(i) Positive biased clipper

In this circuit, the positive terminal of the battery is connected in series with the cathode of the diode as shown in the fig.5.5(a). Both are connected in parallel with the output. When the applied input signal magnitude is greater than $+V_R$, the diode conducts in forward bias, otherwise the diode conducts in reverse bias. So the output contains only the input signal, which magnitude is less than V_R. Hence it is called positive biased clipper. The input and output signal waveforms are shown in the fig.5.5(b)



(a) Circuit diagram (b) Input and output waveforms
Fig5.5 Positive biased clipper

(ii) Negative biased clipper



(a) Circuit diagram (b) Input and output waveforms
Fig5.6 Negative biased clipper

In this circuit, the negative terminal of the battery is connected in series with the anode of the diode, as shown in the fig.5.6(a). When the applied input signal magnitude is less than $-V_R$, the diode conducts in forward bias, otherwise the diode conducts in reverse bias. So the output signal contains only the input signal, which magnitude is greater than $-V_R$. Hence, it is called negative biased clipper. The input and output signal waveforms are shown in the fig.5.6(b).

5.1.2. CLAMPERS

Clamper is a circuit, that shifts the input AC signal into a desired DC level, without affecting its waveshape and frequency . The clamper contains two types

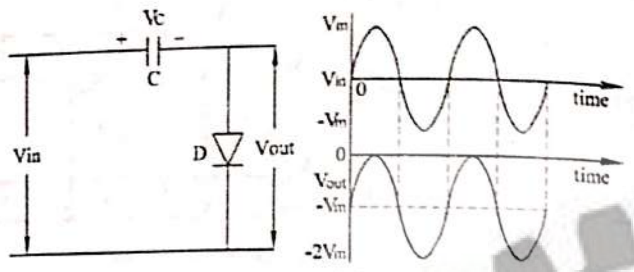
(i) Positive clamper (ii) Negative clamper

5.1.2.1. Negative Clamper

The circuit of a diode negative clamper and its input and output waveforms are shown in the fig.5.7. During the first positive quarter cycle of the input, the diode conducts in forward bias. So the capacitor is charged through the diode, with the mentioned polarity. Now the full input signal voltage is occupied by the capacitor ($V_C=V_m$)

$V_{out} = -V_c + V_{in}$ $\quad (V_{in} = V_m)$

$\therefore \quad V_{out} = -V_m + V_{in}$



(a) Circuit diagram (b) Input and output waveform

Fig5.7 Diode negative clamper

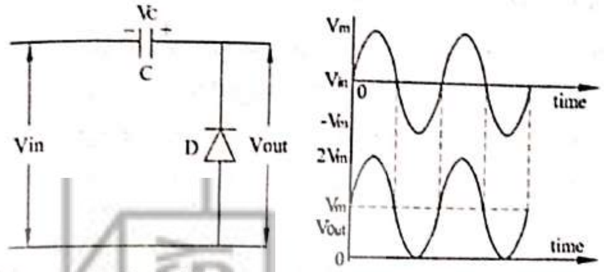
The negative voltage of the capacitor ($-V_m$) is added with the input signal and developed at the output (across the diode). Due to the capacitor voltage, the diode is always conducting in reverse biasing. Hence the already stored voltage in the capacitor does not discharged. So each part of the input signal is shifted to the negative side with an amount of voltage V_m (negative side). Hence the positive peak of the input signal is shifted to the zero voltage level, called negative clamper.

5.1.2.2. Positive Clamper

The diode has been reversed in positive clamper. The circuit diagram, input and output signal waveforms are shown in the fig.5.8. The capacitor is charged with a negative voltage, during the first half of the negative half cycle. This voltage adds with the input, to make the diode always conduct in reverse bias.

$V_{out} = V_c + V_{in}$ [Since $V_c = V_m$]

$V_{out} = V_m + V_{in}$



(a) Circuit diagram (b) Input and output waveform

Fig.5.8 Diode positive clamper

Hence each part of the input signal is shifted to the positive side with an amount of $+V_m$. The negative peak of the input signal is shifted to zero level. Hence it is called positive clamper.

5.2. VOLTAGE MULTIPLIERS

Voltage multiplier is a specialized rectifier circuit. It converts AC electrical power from a lower voltage to a higher DC voltage. It typically using a network of capacitors and diodes. The output of multiplier is theoretically an integer times of AC peak input; for example 2, 3 or 4 times the AC peak input. Thus it is possible to get 200VDC from a 100V peak AC source using a doubler, 300VDC from a tripler and 400VDC from a quadrupler. Voltage multipliers can be generate a few volts for electronic appliances to millions of volts for purposess such as high energy physics experiments and lightning safety testing.

Voltage multipliers are classified in to four types. They are

i) Halfwave voltage doupler

ii) Fullwave voltage doupler

iii) Voltage tripler

iv) Voltage quadrupler

5.2.1. Half wave Voltage Doubler

The circuit diagram of half wave voltage doubler is shown in the fig 5.9. During the negative half cycle of the input, diode . D_1 is forward biased and charging up the capacitor C_1 to the peak value of the input voltage(V_m). Because there is no return path for capacitor C_1 to discharge into, it remains fully charged and acting as a storage device in series with the supply voltage V_{in}.

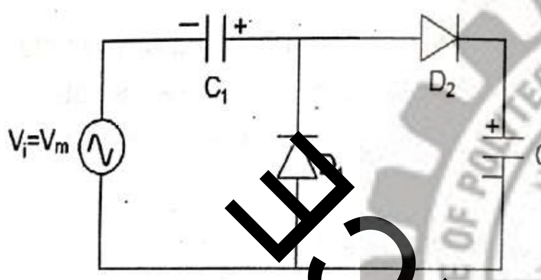


Fig. 5.9 Voltage doubler

During the possitive half cycle, diode D_1 is reverse biased blocking the discharging of C_1 while diode D_2 is forward biased and charging up capacitor C_2. Now the capacitor C_2 charges to twice the peak value voltage of the input signal ($2V_m$).

So on the negative half cycle D_1 charges C_1 to V_m and on the possitive half cycle D_2 adds the AC peak voltage to V_m on C_1 and transfers it all to C_2. The voltage across capacitor C_2 discharges through the load and ready for the next half cycle. As the capacitor C_2 only charges up during one half cycle of the input, it is called half wave voltage doubler. The resulting output voltage discharged in to the load has a ripple frequency equal to the supply frequency.

Advantages

i) It can replace the expensive and heavy transformers.

ii) Negative voltage can be created by reversing the polarity of diodes and capacitors.

iii) It can increase the voltage multiplication factor by cascading the similar voltage multipliers.

Applications

i) Ion pumps
ii) Television CRT
iii) X-ray systems
iv) Copy machine
v) Radar equipment
vi) Travelling wave tube.

5.2.2. Full wave Voltage Doubler

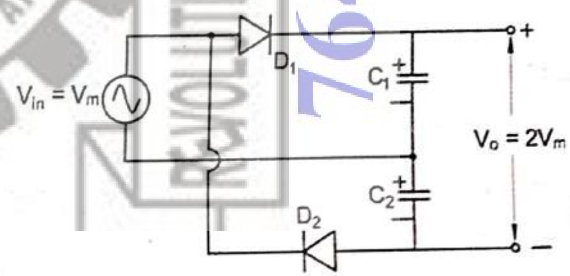


Fig.5.10 Full wave voltage doubler

A fullwave voltage doubler is shown in the fig 5.10. During the positive cycle of the AC input, the current flows through D_1 charges the capacitor C_1 to the voltage level of V_m.

Similarly during the negative half cycle of the AC input, the current flow through D_2 charges the capacitor C_2 to the value of V_m. The capacitor C_1 and C_2 are connected in series so the net output voltage across the load is $2V_m$.

Advantages

i) Ripple frequency is twice the supply frequency, so easy to filter high frequency ripples.

ii) Better voltage regulation.

Disadvantages

i) Common ground between input and output is not available.

5.2.3. Voltage Tripler

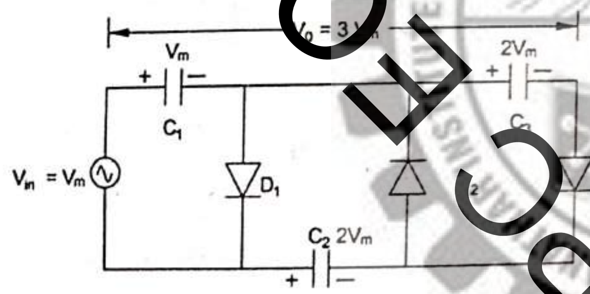


Fig. 5.11 Voltage Tripler

Voltage Tripler circuit is formed by adding an additional single diode-capacitor stage to the half wave voltage doubler circuit. The circuit increases its input voltage by a factor of three. A voltage tripler circuit concepts of one and a half voltage doubler stages. This voltage multiplier circuit gives a DC ouput equal to three times the peak value (V_m) of the sinusoidal input signal. The circuit diagram of voltage tripler is shown in the fig.5.10.

During the positive half cycle of the input the diode D_1 conducts in forward bias so the capacitor C_1 charges to the input peak voltage of V_m. During the next negative half cycle, the input voltage combined with the capacitor C_1 voltage and charges the capacitor C_2 through the diode D_2.

Now the capacitor C_2 charges with the combined voltages of input signal and voltage drop areas C_1. So the voltage of $2V_m$ is stored in the capacitor C_2.

During the next half cycle the capacitor C_1 voltage, input signal voltage and the capacitor C_2 voltage combined to charge the capacitor C_3 through diode D_3. So $2V_m$ is developed across C_3, becuase C_1 opposes the input voltage. Now $1V_m$ is dropped across C_1 and $2V_m$ across C_3. The two capacitors are connected in series. As result the load has a voltage equal to $3V_m$. So the real ouput voltage will be three times the peak input voltage.

5.3. MULTIVIBRATORS AND SCHMITT TRIGGER

5.3.1. MULTIVIBRATORS

Multivibrator is a type of relaxation oscillator. It produces square or rectangular waveforms, or stable time delays with required frequencies. The output of multivibrator is only in two states (or levels). State is in low level or in high level. According to the operating conditions, the states are classified into two types. They are stable state and quasi stable (unstable) state. A state which is converted only by applying external trigger pulse is called stable state.Similarly, a state which is converted automatically, without applying any trigger pulse is called quasi stable state.

Multivibrators are classified into the following types.

(i) Astable Multivibrator
(ii) Monostable Multivibrator
(iii) Bistable Multivibrator

In all these multivibrators two transistors are used. They are connected in back to back. That means the output (collector) of one transistor is connected to the input (base) of next transistor. This connection provides regenerative feedback to both transistors. By this effect the transistors operates either in saturation region or in cut-off region. So its output is either in low level or high level. The output of both transistors are complement to each other. If the output of one transistor is in low level, the output of other goes to high level and vice-versa.

5.3.1.1. Astable Multivibrator

Astable multivibrator contains no stable states, both states are quasi stable states. It produces continuous square wave (or rectangular wave) signal without applying any external trigger pulses. So it is also called as free running multivibrator.

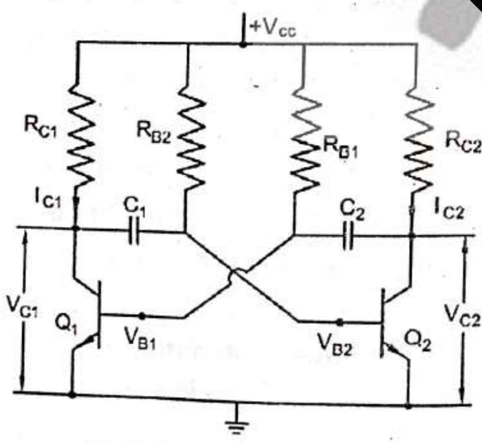


Fig.5.12 Astable Multivibrator

The circuit diagram of collector coupled Astable multivibrator is shown in the fig.5.12. The collector terminals of Q_1 and Q_2 are connected to the supply voltage through Rc_1 and Rc_2 respectively. The collector of Q_1 is connected to the base of Q_2 through C_1. Similarly the collector of Q_2 is connected to the base of Q_1 through C_2. The resistors R_{B_1} and R_{B_2} provide proper bias to both the transistors.

In a symmetrical astable multivibrator, $Q_1 = Q_2$, $Rc_1 = Rc_2$, $R_{B_1} = R_{B_2}$ and $C_1 = C_2$. When supply is switch ON, one transistor conducts more than other, because of the slight mismatch between the two transistors. (No other transistors are 100% identical)

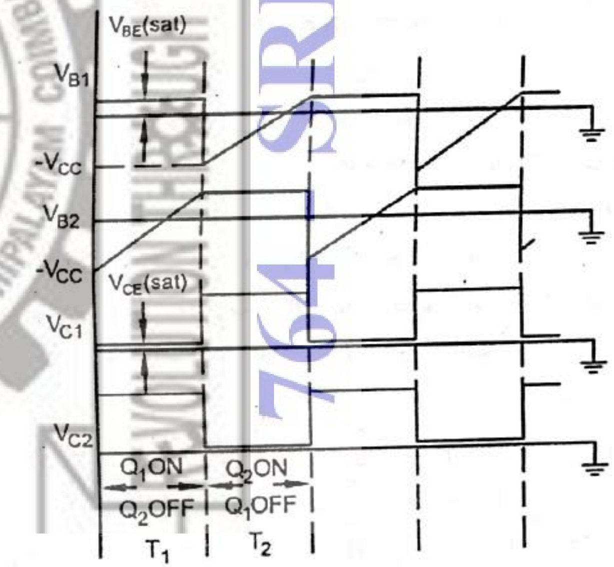


Fig.5.13 Astable multivibrator signal waveforms

We assume that the conduction of Q_1 is faster than Q_2. The current Ic_1 is slightly greater than I_{C2}. The regenerative feedback action, makes to increase the conduction of Q_1 and to decrease the conduction of Q_2. By this effect Vc_1 decreases and Vc_2 increases. Finally the transistor Q_1 goes to saturation and Q_2 goes to cut-off. So the output of Q_1 (Vc_1) is low and the output of Q_2 (Vc_2) is high. When Q_1 is at saturation, the full supply voltage is also dropped across Rc_1. Since Q_2 is at cut-off, the voltage across Rc_2 is zero. During this condition the voltages at the base of Q_1 (V_{B_1}) is less positive and the base of Q_2 (V_{B_2}) is -Vcc, because the initial voltage occurs at the collector of Q_1 is dropped across C_1.

Now the capacitor C_1 is going to charge from -Vcc to positive supply voltage through R_{B_2}. When the capacitor C_1 attains a sufficient voltage (more than V_{B_1}) to drive Q_2, the conduction of Q_2 increases. Now the Ic_2 flows through the collector of Q_2. By the regenerative feedback action, the conduction of Q_2 again increases, and the conduction of Q_1 decreases. Finally the transistor Q_1 goes to cut-off and Q_2 goes to saturation. Now Vc_1 goes to high level and Vc_2 goes to low level. The voltage already placed at the collector of Q_2 is fully dropped across the capacitor C_2. The base of Q_1 goes to -Vcc, and base of Q_1 goes to less positive.

Now the capacitor C_2 is going to charge from -Vcc to supply voltage through R_{B_1}, is applied to the base of Q_1. When the capacitor C_2 attains a sufficient voltage to drive Q_1, again Q_1 goes to conduction and attain saturation. Immdiately Q_2 goes to cut-off. By this cumulative actions, continuous square wave signals are produced at its collectors. The output of Q_1 (Vc_1) is always 180^0 out of phase with respect to the output of Q_2 (Vc_2). Both outputs are complement to each other. The signal waveforms are shown in the figure.5.13.

The ON period of Q_1 is equal to the OFF period of Q_2. This period (T_1) depends upon the charging effect of the capacitor C_1 through R_{B_2}.

$$T_1 = 0.69\, R_{B_2} C_1 \text{ sec}$$

The ON period of Q_2 is equal to the OFF period of Q_1. This period (T_2) depends upon the charging effect of the capacitor C_2 through R_{B_1}.

$$T_2 = 0.69\, R_{B_1} C_2 \text{ sec}$$

If $R = R_{B_1} = R_{B_2}$ and $C = C_1 = C_2$

Total period, $T = T_1 + T_2 = 1.38$ RC sec

5.3.1.2. Monostable multivibrator

Monostable multivibrator contains only one stable state. The other state is quasi stable state. Hence it is also called as one shot multivibrator. It is used to generate precise time delays. The circuit diagram of Monostable multivibrator is shown in the fig.5.14.

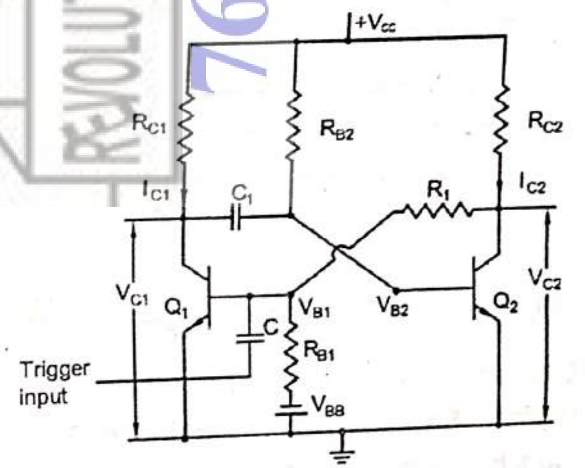


Fig.5.14 Monostable Multivibrator

When a sufficient magnitude of positive pulse is applied to its trigger input, the base of Q_1 is forward biased and it starts conduction. The current Ic_1 starts flowing through the collector of Q_1. The voltage of Vc_1 decreases. The regenerative feedback also increases the conduction of Q_1 and also decreases the conduction of Q_2. Finally Q_1 goes to saturation and Q_2 goes to cutoff. The voltages Vc_1 is low and Vc_2 is high. The voltage already placed at the collector of Q_1 is fully dropped across the capacitor C_1. Hence the voltage now occurred at the base of Q_1 is less positive, and the voltage occured at the base of Q_2 is - Vcc. This state is a quasi-stable state, because it is automatically changed by the charging effect of capacitor C_1.

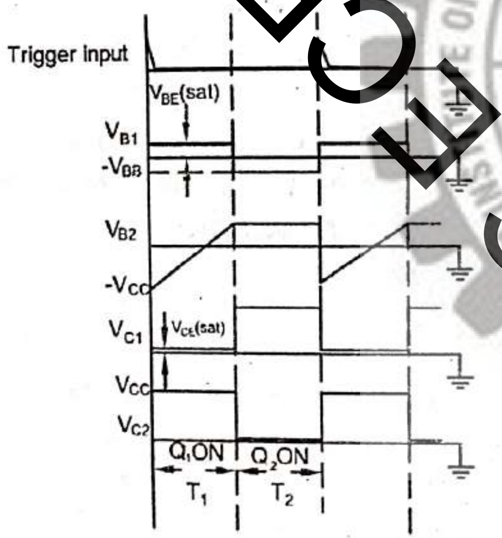


Fig.5.15 Monostable multivibrator signal waveforms

Now the capacitor C_1 is going to charge towards Vcc through the resistor R_{B_2}. When the capacitor C_1 attains a sufficient voltage to switch ON the transistor Q_2 (i.e., V_{B_2} is greater than V_{B_1}) it starts conduction. By the regenerative

feedback actions, the conduction of Q_2 increases and the conduction of Q_1 decreases. Finally Q_2 goes to saturation and Q_1 goes to cut-off. Now the base voltage of Q_1 (V_{B_1}) goes to - V_{BB} and the base voltage of Q_2 goes to less positive. This state is a stable state. This state is converted only by applying external trigger pulse to the Trigger input. The signal waveforms are shown in the fig.5.15. The ON period of Q_1 or the OFF period of Q_2 depends upon the value of C_1 and R_{B_2}.

$$T = 0.69\, R_{B_2}\, C_1 \text{ sec}$$

5.3.2. Schmitt trigger

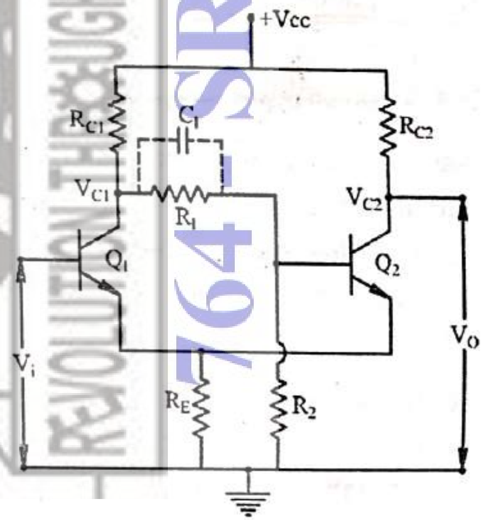


Fig.5.16 Schmitt trigger

The schmitt trigger is an important switching circuit, that is widely used in digital system. It's stable state is determined by the amplitude of the input voltage. The circuit diagram of schmitt trigger is shown in the fig.5.16. It differ from the bistable multivibrator in two aspects. They are

i) There is no coupling is used in between the collector of Q_2 and the base of Q_1.

ii) It's feedback is obtained through resistor R_E.

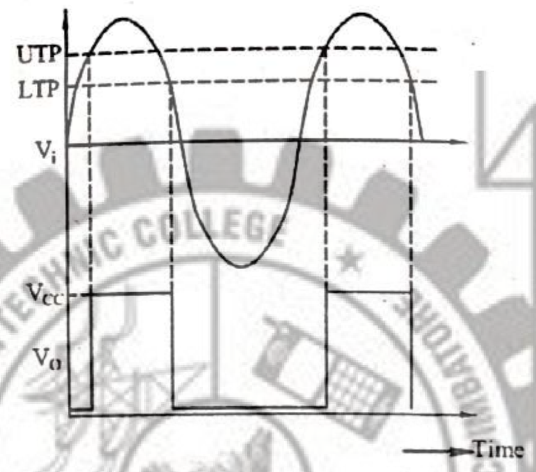


Fig.5.17 Schmitt trigger waveform

In the absence of an input signal (Vi) Q_1 is OFF and Q_2 is ON. The output voltage is zero. This is true because the current through either transistors when it is ON, develops a bias across R_E that causes Q_1 to be reverse biased. Thus Q_2 is definitely in conduction.

When Vi is increasing and to make Q_1 ON, ic_1 starts flowing. Due to the drop across R_{C1}, the base voltage of Q_2 reduces. By this cumulative action, the conduction of Q_1 increases and the conduction of Q_2 decreases. Finally Q_1 goes to saturation and Q_2 goes to cut-off. The point at which Q_1 goes to saturation (ON) is called upper trip point (UTP). At this point the output is approximately equal to V_{CC}.

In the second quarter cycle of the input signal, the input voltage decreases. So the conduction of Q_1 decreases. Now I_{C1} reduces and V_{C1} increases. This directly controls the base voltage of Q_2 which also increases. Thus when Vi starts decreasing and become equal to the cut-off level of Q_1, Q_1 again goes to cut off and Q_2 goes to ON. The level of Vi at which Q_2 again becomes ON is called lower trip point (LTP) of the schmitt trigger. Now the output voltage again goes to zero level. The schmitt trigger waveform is shown in the fig.5.17.

In schmitt trigger, the UTP is differ from LTP because some hysteresis formed by different circuit components.

The width of hysteresis = UTP – LTP

The amount of hysteresis can be changed by changing the values of RC_1 and RC_2.