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COURSE DURATION

Sub:- 18 GHz Communication System and Radio Block Interface (ST-57)

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Electronic Components
1. **Resistors** :- Resistor is an electrical element (or an electrical component or an electrical parameter) which is made of resistive material which oppose the flow of current, i.e. the component having the property of resistance is called ‘Resistor’.

1.1. Classification of different types of Resistors :-
Fundamentally, there are three types of resistors These are
(1) Fixed or Linear Resistors,
(2) Variable (Potentiometer type.) resistor and
(3) Special type resistor.

(1) Fixed Resistor:- Again fixed resistor can be divided into eight different types.

(2) Variable Resistor:- Again variable resistor can be divided into two (2) types.
These are :- i. Linear type variable resistors and ii. Non-linear type (Logarithmic variation ).
(2) i. The Linear type variable resistors again subdivided into two forms. Such
   as – a. Wire wound variable type linear type variable resistors.
       b. Carbon film linear type variable resistor.
(2) ii. The non-linear type variable resistor is made by carbon film non-linear variable resistor.
1.2 COLOUR CODE OF RESISTORS :-

Most of the manufacturers identify their resistance value by means of a colour code. There are two methods of applying this code. Such as –

1) A series of coloured band are painted on the resistor.

```
A B C Tol
```

C = Multiplier.
A&B= 1st. & 2nd. Significant resistance Codes.
TOL= Tolerance Band.

2) The entire body of the resistor is coloured. There are one or more colours on the ends of the resistor (called tip colours) and lastly there is a spot of point on the body.

The following colour code system was originally called RMA code (Radio manufacturers association code). Now, it is called EIA code (Electronic industries association code) or MIL code (Military code).

1.2.1 GENERAL COLOUR CODE AND ITS MODE OF REMEMBRANCE :-

In general, colour code is depicted on the body of the resistor. According to the colour code, the value of the resistance is calculated. The values of 1st. and 2nd. Significant colour codes are as in the following :-

---

*Electronic Components*
Now, easy way to remember the colour code is as in the following:-

```
B. B. R O Y OF Great Britain Has Very Good Wife
```

<table>
<thead>
<tr>
<th>B</th>
<th>B</th>
<th>R</th>
<th>O</th>
<th>Y</th>
<th>OF</th>
<th>Great</th>
<th>Britain</th>
<th>Has</th>
<th>Very</th>
<th>Good</th>
<th>Wife</th>
</tr>
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<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td></td>
<td></td>
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</table>

The third colour code indicates number of zeros to be arranged after putting first and second digits according to colour code (1st and 2nd digit).

A fourth colour code is also there which indicates percentage tolerance. If that colour be golden then that will indicate 5% tolerance.

Similarly, if the coating is of silvery lining then the tolerance is 10% and for general colour it is 20%.

1.2.2 A concrete example of colour code:

RESISTOR

Blue Grey Red Gold

In this case value of resistance will be calculated in the following way:-

1st digit indicates 6
2nd digit indicates 8
3rd digit indicates 2 i.e. two zeros.
4th digit indicates 5% tolerance.

These four items when arranged in a row that will be the calculated value.

Thus resistance value of the above mentioned resistor will be \( 6800 \text{ ohm} \pm 5\% \) of \( 6800 \text{ ohm} = 6800 \text{ ohm} \pm 340 \text{ ohm} \).
1.3 Statement :-
Capacitor is an electrical component composed of two conducting plates separated by an insulating medium called dielectric.

Formation :- Capacitance is the property of a capacitor and is expressed as C. Value of capacitor is expressed as capacitance. It is the ability of a capacitor to store charge. \( C = \frac{Q}{V} \), Q is charge stored on plates and potential difference established between the plates is V.

Properties of a capacitor :-
Capacitor possesses the following properties :-

a) It has the ability to store change.

b) It opposes any change of voltage in the circuit in which it is connected.

c) It blocks DC.

1.3.1 Factors on which capacitance depends :-
Capitance value of a capacitor depends upon the following factors :-

1) Plate area : \( C \) varies as \( A \). \( A \) is plate area.

2) Plate separation : \( C \) varies as \( \frac{1}{d} \). \( d \) is plate separation.

Here, i) Value of \( C \) (Capacitance) increases with the decrease of distance between the two plates.

ii) Similarly, value of \( C \) decreases with the increases of distance between plates.

3) Type of dielectric :- It depends upon relative permittivity of the material.

Here, \( C \) varies as relative permittivity .Types of Capacitors :- Capacitors are of two types :- (1) FIXED and (2) VARIABLE.

Fixed capacitors are also two types (i) Electrolytic and (ii)Non –Electrolytic . Non-Electrolytic capacitor are divided in to several parts .Those are (i)Mica capacitor,(ii)Ceramic capacitor and (iii)Paper capacitor etc.
In these cases no polarity indication is required. That is they may be connected to the circuits irrespective of polarity (+ve or –ve).

1.3.2 COMPARISON AMONG DIFFERENT TYPES OF FIXED CAPACITORS :-

<table>
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<tr>
<th>SL NO</th>
<th>TYPE</th>
<th>MATERIAL</th>
<th>DIELECTRIC MATERIAL</th>
<th>CONSTRUCTION</th>
<th>RATING</th>
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<tr>
<td>1.</td>
<td>Paper</td>
<td>Tin Foils</td>
<td>Tissue Paper</td>
<td>a) 0.001 to 2.0 µF. b) 2000 V.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Mica</td>
<td>Metal Plates</td>
<td>Mica Sheets</td>
<td>50-500 µF 500 V and above.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Ceramic</td>
<td>Thin coating of silver Compound</td>
<td>Dielectric Disc</td>
<td>0.01 µF (1 to 500 PF) 10 KV.</td>
<td></td>
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</table>

1.3.3 Advantages of ceramic over mica and paper capacitor :-

(1) Economical, (2) Very High working voltage rating, (3) Very small size but large capacitance, (4) It has very low power factor and value decreases with increase in frequency.

1.3.4 Electrolytic Capacitor- The entire sandwich with plates and dielectric is rolled up into a compact cylinder and placed inside a metal cylinder or can. Here, electrolyte is used as (-)ve plate. Thus these are polarised capacitors. These are connected in circuit according to (+)ve and (-)ve marking on the capacitor.

Construction:- Gauze saturated With electrolyte (Borax). A thin Film of A1203 (Alumina) made By electro chemical process). Its range is from 1µF to 10000µF.

USES:- 1) It is used to remove AC Ripple from power supply. 2) It is used as blocking capacitor to block DC and to pass AC

Electronic Components
1.3.5 VARIABLE CAPACITOR

Its capacitance value can be varied by rotating a shaft. It consists of metal plates separated from each other by air, one set of plate is stationary and called stator and the other set is known as rotor. One knob is fitted to the shaft a variable capacitor to rotate it. On rotation of the shaft the rotor goes in and out of the stator and value of capacitance varies from maximum to minium. When two or more capacitors are operated by a single shaft the same becomes “GANGED CAPACITOR”.

TRIMMERS/PADDERS are small capacitor used in connection with main variable capacitors. This is done for fine adjustment. Ranges :- 1) trimmers- 5 Pf to 30 Pf.
2) padders- 10 Pf to 500 Pf.

USES:- used in radio receivers.

VOLTAGE RATING OF CAPACITOR:-

1) paper & mica- 200-500 v DC
2) Ceramic – 1-12 KV DC.
3) Electrolytic capacitor :- (i) 25V, 150V, 450V DC, (ii) Miniature type – 6-10 V DC.

1.3.6 Combination of Capacitors :- It has mainly two types of combinations :-

(1) Series combination and (2) Parallel Combination.

Series Combination :- Here, (i) Charge of every capacitors is Q, (ii) Voltage of total no. of capacitors in series is V1+V2+V3, (iii) Value of combined capacitance is $C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$.

Parallel Combination :-

i) Here, each Q differs Q1 = Q1+Q2+Q3.
ii) Applied V to each is same.
iii) C = C1+C2+C3.

1.3.7 Ohmmeter indication of faults in capacitor:-

1. If the pointer goes to zero and stay there then the capacitor is shorted.
2. If the pointer goes to low resistance side and then comes up to a reading less than normal then it is leaky.
3. If Pointer does not go to low resistance value but proceeds to (Infinity) then it is open.
4. If the Pointer goes to low value (Charged) and then proceeds to (Infinity) then it is OK.

Electronic Components
1.4 **INDUCTOR**

Statement :- Inductor is an electrical component composed of a coil wound on a core. It has the property of generating opposing force (Counter e.m.f) when current passes through it.

Formation:- Inductor is formed by solid copper wire wrapping a core as shown in the figure. Air core Inductors are also available in which coils themselves support each other. Inductance is the property of an Inductor and is expressed as L.

Here, in an inductor V is \( \frac{\text{di}}{\text{dt}} \), that is rate of change of current through the coil. Now, \( V = L \frac{\text{di}}{\text{dt}} \) where, L is the constant of proportionality.

It may be expressed like this :- When current through an Inductor changes at the rate of \( \frac{\text{di}}{\text{dt}} \) then counter e.m.f. Induced in the inductor is

\[
V = L \frac{\text{di}}{\text{dt}}
\]

1.4.1 Types of Inductors:- Inductors are of two types : (1) Fixed Inductors and (2) Variable Inductors.

(1) Fixed Inductors:- Fixed inductors are those whose set values cannot be changed.

(2) Variable Inductors:- Variable inductors are those whose inductances can be varied over some range. Usually variable inductors are made, so that the core can be moved into and out of the winding. The position of the core determines the inductance value. Inductors are also known as chokes or coils.

Inductors may be arranged in series or parallel.

If two inductors be arranged in series then the total value of inductance \( L_{\text{Total}} = L_1 + L_2 \).

Similarly, two inductors when arranged in parallel then \( L_{\text{Total}} = \frac{1}{1/L1 + 1/L2} \).

Now, the reactance offered by an inductor is known as inductive reactance that is expressed as XL.

Here, \( X_L = 2 \pi f L \). Where \( f \) is the frequency and \( L \) is the inductive value.

Here, one thing important to note is that an inductor is a combination of inductor coil and a resistance in series as in the following:-

---

*Electronic Components*
Now, in case of series combination of two coils mutual inductance (between the two coils) is a criteria. In that case if the case be:-(1) Series aiding then $L_{\text{aiding}} = L_1 + L_2 + 2M$.

(2) Series opposing then $L_{\text{opposing}} = L_1 + L_2 - 2M$.

Subtracting: $L_a - L_o = 4M$ or $4M = L_a - L_o$ so, $M = \frac{L_a - L_o}{4}$.
CHAPTER-2

SEMI CONDUCTOR DIODES AND ITS USES

INTRODUCTION

Modern communication system is based on electrical and electronic devices. So to carry on the communication perfectly we should know their operation perfectly. To attain perfection in that sphere we should know operation of the components incorporated inside those devices. Thus we should observe the behaviours of the electrical and electronic components closely. Thus the knowledge so acquired will help us to operate the said devices perfectly.

2.1 Before studying semi conductor diodes we should know something regarding semiconductors. Semiconductors are those which behave half like conductors and half like insulators are called the semi conductors. Semi conductors are of two types, intrinsic and extrinsic according to their behaviours.

Now, we should observe these semiconductors more closely.

Intrinsic semi conductor behaves mostly as insulator. When temperature increases then due to thermal energy some covalent bonds break down and electrons come out as free electrons. Those free electrons become responsible for conduction of electricity inside intrinsic semiconductor.

Having seen this property of intrinsic semiconductor some special techniques have been applied to make the intrinsic semiconductor conductive.

That process is known as doping. Intrinsic semiconductors when doped with doping agents, extrinsic semiconductor evolves out. This type of semiconductor behaves like conductor. One funny thing is that doping level is one per $10^6$ or $10^8$ nos. of semiconductor atoms.

This extrinsic semiconductor is of two types:- (i) P type semiconductor and (ii) N type semiconductor depending upon the properties of doping agents.

Now, let us consider the types of doping agents, which are responsible for evolution of P type and N type semiconductor.
Two types of doping agents are:- (i) Trivalent and (ii) Pentavalent. These doping agents are known as impurity atoms.

Thus Trivalent/Pentavalent impurity atoms are utilised in formation of P type/N type semiconductor.

Now, (i) Trivalent impurity means the impurity which contains three valence electrons (i.e. 3 e in outermost orbit) examples are Boron, Galium, Indium etc.

Similarly (ii) Pentavalent impurity, means the impurity which contains five valence electrons. Examples are- As, Sb and P.

Now, these types of impurity atoms possess other names also. We can better remember the types of semiconductors according to these names.

These are as in the following :-

(i) Acce P tor type Impurity (P type impurity).
(ii) Do N or type Impurity (N type impurity).

Thus :- Intrinsic semiconductor + P type impurity = P type semiconductor and intrinsic semiconductor + N type impurity = N type semiconductor.

Now, we should search the clue regarding conductivity of P type and N type semiconductor.

These two types of semiconductors possess mainly two types of carriers. Those are named as majority holes and majority electrons.

In case of P type semiconductor majority carriers are holes. In N type semiconductor majority carriers are electrons.

Here, holes are positive type and electrons are negative type carriers.

Now, coming the case how holes are evolved in P type semiconductor. Here, P type semiconductor contains P type impurity i.e. acceptor type impurity i.e trivalent impurity. Let us consider a figure showing the composition of intrinsic semiconductor and trivalent impurity atoms.

Figure shows that ‘B’ contains three valence electrons. Naturally it has affinity to attract another one covalent bond to attain inertness.

Due to this affinity it causes bombardment of one covalent bond of one neighbouring semiconductor atom. This bombardment causes evolution of hole and electron pairs from which one electron is attracted towards the hole created in the impurity atom Boron (B).

Similarly, in case of N type semiconductor donor impurity atom P(Phosphorous) donates one free electron i.e gives out one free electron responsible for conductivity in N type semiconductor.

\[ \text{Electronic Components} \]
In this way generation and recombination of holes and electrons take place inside P and N type semiconductor.

Now, we can consider the case of Semiconductor diodes. Semiconductor diode is a device in which P type semiconductor and N type semiconductor remains side by side keeping a junction amid.

Here, one thing important to note is that as electrons flow from right to left so hole flow is recorded from left to right but this is not real flow but apparent flow. It resembles movement of train and apparent movement of trees buildings etc. (which actually does not move).

2.2 Formation of Semiconductor diode :- It is formed by doping a semiconductor with P-type impurity on one side and N type impurity on the other side.

Pictorial description of a semiconductor diode.

Electron flow(real flow)  
Hole flow(apparent flow)  

Electronic Components
The figure shows:

- Majority Carriers: (i) Holes for P-type SC.
  (iii) Electrons for N-type SC.

Different ions are:
- (i) (-)ve acceptor ions, immobile in nature.
- (ii) (+)ve donor ions, immobile in nature.

Immobile ions existing in depletion region are:
- (i) (-)ve acceptor ions (on left)
- (ii) (+)ve donor ions (on the right).

2.2.1 DEPLETION REGION:
- Depletion region means the region which is depleted from mobile carriers (i.e. holes and free electrons). This is also known as space charge region or transmission region.
  
N.B: Width of this depletion region is of the order of micrometer or \(10^{-6}\) m.

Now, we should study semiconductor diode closely.

Let us consider a block diagram of a semiconductor diode / PN junction diode.

In case of unbiased P.N junction, depletion region creates a potential hill which may be considered as a cell of mini EMF. P side of this mini cell is (-)ve and N side is (+)ve.

The depletion region remains wide to some extent in unbiased condition.

In case of biased P.N junction, depletion region remains narrower than that in unbiased condition.

Here, we see that P side is supplied with (+)ve potential and N side with (-)ve potential (connected from outside) and as a result the area of depletion region decreases as compared to the depletion region in UNBIASED condition.

Now biasing provided to PN junction diodes are of two types:
- (i) Forward biasing and (ii) Reverse biasing.

Now let us study the biasing cases more closely.

In figure ‘a’ holes flow from P side to N side and electrons flow from N side to P side and as a result unidirectional flow of current takes place i.e PN junction material acts as a rectifier. Thus in FB condition of PN junction the diode conducts current from P side to N side.

This type of biasing is observed in ordinary diodes.

In case of reverse biased diode the case becomes as in the following figure ‘b’.

Here minority current flows minority hole below N.
Symbol of ordinary diode :-

Used :- These are used as :- (a) Rectifier (AC to DC) 
(b) Switch (Unidirectional).

CHAPTER - 3

3.1 Zener Diodes and their applications :- We know ordinary diodes work in forward biased condition and majority carriers become responsible for carrying current. But zener diode works in reverse biased condition and minority carriers become responsible for carrying current.

Statement of Zener Diode :- These are diodes which have adequate power dissipations capabilities to operate in break down region. Here, one thing important to note is that in case of zener diode, zener break down action takes place.

Symbol of Zener diode:-

3.2 Break Down Phenomena :- In case of reverse biased diodes break down Occurs. Here in reverse biased condition after a particular applied voltage, Bombardment (rupture) of covalent bond takes place at a greater speed And electron hole pairs evolve and increase in current flow takes place. The critical voltage for which sharp rise of reverse current (IR) takes place is known as break down voltage. This break down voltage depends upon width of depletion region i.e. it depends upon doping level.

Two types of break downs are there:- (i) Zener break down and (ii) Avalanche break down.

3.2.1 Mechanism for Break Down :-
Zener break down:-- Here P and N parts are Heavily doped as a result JN becomes narrow. In such a situation when applied voltage is increased bit by bit then just below or at 6 V, the zener break down occurs while electric Field intensity becomes ZX’ 10^7 V/Meter.

This process does not involve collision of the carriers with crystal ions. Here, actually presence of high field exerts great force on covalent bonds and as a result bonds rupture. Here, one thing important to note is that beyond zener break down avalanche break down takes place.

Here, minority carriers collide with

Semiconductor atoms at depletion region.

As a result covalent bonds break down And formation of electron hole pairs take place. These again collide against the other covalent Bonds and another group of electron hole
Pairs take place. In this way, carriers (electrons and hole pairs) from avalanche break down (snow slide). This avalanche break down occurs at a voltage above 6 V.

Lightly doped P-N junction
Zener diode as Regulator:– Figure (1) shows a zener regulator circuit from figure (2) we can write
IS = IZ + IL, So IZ = IS – IL (Here, we see that it has been divided into parts I2 and IL).
Or, IZ = V_S – V_Z / R_S – V_Z / R_L,
Or, IZ = V_S – V_Z / R_S – V_Z / R_L.
The equation shows that IL depends
Upon R_L but IS is independent of R_L.
Thus IZ may be changed with the
Change of value of R_L but O/P remains
Constant V_Z

3.3 Different ratings of zener diode:–
   (i) Voltage rating :– 2.4 V to 200 V (Temperature dependent).
   (ii) Power Rating :– 150 MW to 50 Watts.

3.4 Application of Zener diode :-
   1) As voltage regulators.
   2) As peak clippers.
   3) For meter protection against excessive voltage.
   4) As fixed reference voltage for biasing and comparison purpose.
CHAPTER – 4

SPECIAL TYPES OF DIODES

4.1 Introduction: - Semiconductor diodes like ordinary diodes, zener diodes etc. work as rectifier, voltage regulators etc. There are some special types of diodes which perform different functions like Amplification, Oscillation, Frequency multiplication modulation and the like.

This is done by varying doping levels in extrinsic semiconductor (P type or N type) or using both intrinsic and extrinsic semiconductor simultaneously. In this way robustness of equipments has been avoided and sizes of equipments have been minimised to portable size.

4.1.1 Special Types of Diodes are :-

4.1.2 Description of Special Types of Diodes :-

Varactor Diode: - Varactor means variable capacitor. This is so named because in this case junction capacitance is easily varied electronically. This is done by changing reverse bias voltage of the diode. These are used as tuning component in microwave frequency multipliers.

Here, in varactor diode silicon (Si) is semiconductor material. These semiconductor materials are utilised in MW frequencies due to the follow reasons.

Case of Silicon :- Here, the advantages are :-
   a) High power handling capacity.
   b) Low noise property.
   c) Remains unaffected by ambient temperature.
   d) Large reverse break down voltage. For this property large voltage swing results.
   e) Maximum usable frequency is 25 GHz.

N.B: - Above \( \frac{f_c}{10} \) frequency \( R_b \) in (operating frequency \( \frac{f_c}{10} = \frac{250}{10} \) creases and diode quality drops down and noise increase in parametric amplifier and power description increase in frequency multiplier.

Case of \( Ge \) and \( As \) :- Here, the advantages are :-
   a) Higher maximum usable frequency (100 GHz).
   b) Function is better in lowest temperatures (-260°C).

These two are practicable due to higher mobility of charge carriers.
4.2 Construction of Varactor Diode:-

- Gold plated molibdenum stud (Cathode)
- Gold plated wire.
- Junction diode.
- Copper strip (Anode).
- Gold plated molibdenum stud. (Anode)

Symbol of Varactor Diode :-

4.2.1 Working principle of Varactor Diode:-

Here, band N regions are heavily doped as a result depletion region (at JN) is narrower and capacitance is high. When reverse bias is changed the capacitance value also changes.

Here, as band N parts are heavily doped, so the depletion region is narrower here. As reverse bias voltage increases, width in depletion region increases and capacitance value decrease.
Thus capacitance value changes with the change of reverse bias voltage. Thus \( J_n \) capacitance value is inversely proportional to width of the depletion region. It is made clear by the figure. Here, \( C_0 = C_j \) for zero bias voltage of the varactor diode. Avalanche occurs at very high reverse voltage.

### 4.2.2 Equivalent Circuit of Varactor Diode

**Particular Values**

- \( C_c = 1.4 \) PF.
- \( C_0 = 25 \) PF (Capacitance at zero bias)
- \( C_{min} = 5 \) PF.
- \( L_s = 0.013 \mu \text{H} \).
- \( R_b = 1.3 \) Ohms.

**Particular Values**

- \( C_0 = 25 \) PF, \( C_c = 1.4 \) PF.
- \( C_{min} = .5 \) PF, \( L_s = 0.013 \mu \text{H} \).
- \( R_b = 1.3 \) Ohms.

### 4.2.3 Applications of Varactor Diode:

1. Suitable for parametric amplifiers and harmonic generators. Varactor diode is suitable due to the following reasons:
   - \( i \) Large variation of capacitance value.
   - \( ii \) Small value of \( C_j \) (Junction capacitance).
   - \( iii \) Lowest possible value of series resistance (\( R_b \)).
2. Suitable for super high frequent applications (MW). This is because it has the property of minimum high frequency loss.
3. Used as frequency multiplier in case of MW working.
4. Used in frequency and phase modulator circuit.

   a) **Practical Modulator Circuit:**

   b) **Step Recovery Diode:** It is also known as ‘Snap off varactor’ It is PN JN diode made up of Si or Ga As.
4.3 Symbol of step recovery diode :- Construction :- Same as that of Varactor diode. But doping of PN JN is different here.

Doping Profile :- Here, P and N parts are lightly doped near to JN as compared to away from JN.

4.3.1 Working Principle :- SRD is designed to store charges in forward biased condition and discharges briefly the stored energy in the form of sharp pulse in reverse bias condition and goes off after a particular period and repeats the cycle in the next and so on. The sharp pulses formed are very rich in harmonies. The duration of pulses is 100 to 1000 pulses/second depending upon the diode design.

It has been found that when the diode goes from forward to reverse bias, the free electrons and holes temporarily goes away from the junction resulting in reverse current but due to unusual doping the reverse current stops immediately at some point in the reverse half cycle.

Wave form study reveals the conditions of charging and discharging more clearly :-

Here, we see that during discharge the reverse current stops suddenly at a point of the curve i.e snaps off at a point (as if diode has been kept open at that particular point).

Equivalent Circuit :-

4.3.2 Applications :- 1) SRD can be used in frequency multiplier circuits in UHF and lower range of microwave frequencies.

2) SRD amplifier are used as power sources in :- (i) UHF, (ii) Transmitter of lower range of MW frequencies, (iii) Receiver of lower range of MW frequencies, (iv) Signal generators of lower range of MW frequencies.

3) Used in ‘Combiner Generator’. It is possible to use SRD without a tuned O/P circuit to produce multiple harmonies in so called com B GEN.

4) Staking of several SRDS is possible in a single package to increase power handling capacity.
**IMPATT DIODE** :-

4.4 IMPATT = IMP act Avalanche and Transit Time.
Construction:- The construction is as in the following :-

![Diagram of IMPATT diode components]

- Copper cathode
- Gold wire
- Gold alloy contact
- Ceramic tube
- Copper anode

**Indications :-**

- \( P' \) = Heavily doped P region.
- \( N' \) = N region.
- \( N \) = Normally doped n- region.
- \((-\)\) = Minority electrons.
- \((+\)\) = Minority holes.

The device consists of two copper electrodes between which P+ type, N type and N+ type semi conducting materials are arranged and gold wire and gold alloy contacts are kept in between for fool proof contact.

**4.4.1 PRINCIPLE OF WORKING :-**

IMPATT diode works on the principle of impact avalanche and transit time (IMPATT). This also exhibits negative resistance characteristics. This may be better explained if it be shown that applied voltage and resulting current are 180° out of phase. That means when voltage is minimum current will be maximum and vice versa.
WAVE FORM STUDY :-

Applied DC RF Voltage.

Current pulse

RF Voltage = 0
RF voltage = Max.
Time
I/P pulse at cathode.
Time.

From the figure it is clear that:-

i) When RF voltage is zero current attains peak i.e. here V and J are 90° out of phase.
ii) When RF voltage is max. (-) ive, current attains another peak V & I is again 90° out of phase.

When we unite these (i) and (ii) it reveals that V & I are in 180° phase opposition. Thus the diode possesses (-)  ive resistance characteristic is proved.

The current pulse forms at junction and then flows towards cathode (due to presence of reverse bias) at a drift velocity depending upon the value of the high DC field.

Time taken by the pulse to reach the cathode depends upon this drift velocity and also on the thickness of the heavily doped (N+) layer. The thickness of the drift space is so selected that the time taken for the current pulse to arrive at the cathode corresponds to the time of (-) ive peak of the RF voltage.

Thus 180° phase difference attains between RF voltage and the current pulse at the cathode. This proves the existence of dynamic RF (-) ive resistance applied DC voltage (due to externally applied signal or due to existence of RF oscillations in the circuit) then the following cases happen:-

During (+) ve swing of the RF signal, the reverse voltage across the diode is greater than its avalanche threshold voltage and then free electron hole pairs cross the junction with a higher velocity. In such a situation additional hole and electron pairs are formed due to bombardment of co-valent bonds by the electron hole pairs moving with a super high speed. Thus the great IMP act of the carriers (electrons& holes) Avalanche current multiplication results in IMPATT diode.
4.4.2 Application:-

1. IMPATT diode is used as microwave oscillator due to the presence of (-)ve resistance.
2. It is used in MW amplifiers due to existence of avalanche multiplication of current.

N.B:- It is used mainly in 7D17 TOSHIBA radio as an amplifier.

4.5 TUNNEL DIODE OR ESAKI DIODE:-
It is a heavily doped P-N junction diode, which exhibits (-) ve resistance in forward biased condition. Here P and N parts are heavily doped so depletion region is very thin of the order of 0.01 micrometer.

CONSTRUCTION :- Germanium (Ge) or Ga As is preferred for formation of tunnel diode.
Symbol of tunnel diode

4.5.1 PRINCIPLE OF WORKING:-

TUNNEL DIODE V-I CURVE FOR Ge
Here, semiconductor materials are doped as one thousand times more than an ordinarily doped semiconductors. Here, due to heavily doped semiconductor materials, the depletion layer is very very thin in order of 0.01 micro meter. As a result tunnelling occurs very easily.

Moreover, time taken by the carrier to cross the junction is considerably short and as a result MW operation is practicable by this device.

4.5.2 STUDY OF V-I CHARACTERISTIC CURVE :-

The curve reveals the following points:-

1. Forward current increases with the increase of forward voltage up to peak value as seen in OA part. The corresponding current is known as peak current.
2. As forward voltage (i.e. forward bias) increases till further the forward current gradually drops down and attains ‘VALLEY VALUE’ (of voltage). It is depicted at point B. The corresponding current is called valley current. Thus AB part shows (-)ve resistance. This makes the diode useful for oscillator and amplifier.
3. As forward bias value is increases till further, the forward current increases very rapidly. This part behaves as ordinary diode. It is depicted by BC part of the characteristic curve.
4. Peak current here is 2mA and valley current is 0.2 mA. Thus peak to valley ratio is 2/0.2= 10

4.5.3 APPLICATION:-

1. used as Mw oscillator.
2. used as (-)ve resistance amplifier.

4.5.4 A concrete example how tunnel diode is attached to the circuit :-
4.6 PIN DIODE :- Pin diode means the diode which contains ‘P’ type semiconductor and N type semiconductor separated by a intrinsic semiconductor.

Formation :-

![PIN Diode Diagram]

**CONSTRUCTION:-**

**SYMBOL OF PIN DIODE :-**

4.6.1 Principle of action of Pin Diode :-

PIN diode acts as ordinary diode up to a frequency of . It ceases to work as ordinary diode rectifier above this frequency as carrier is stored up in intrinsic semiconductor. At microwave range diode acts as variable resistance.

When bias is varied in a pin diode the following actions take place :-

i) When forward biased, the resistance varies between 1 to 10 ohms.

ii) When reverse biased, the resistance varies between 5 K ohms to 10 K ohms.

Thus pin diode resistance may be varied to a large range of value (Unit is ohms). In that case PIN diode acts as microwave switch.

Applications:- 1. Used for MW switching, frequency range up to 15 GHz and power handling capacity up to 200 watts range from 40 Ns (for high power) to 1 ns at low powers.

2. PIN diode may be used as amplitude modulator.

3. It can be used as a limiter.
4.7 GUNN DIODE: Gunn diode has been named after GUNN (a scientist). Its operation does not depend upon the junction properties but bulk properties of a semiconductor material.

CONSTRUCTION OF GUNN DIODE:

Symbol of Gunn Diode:

4.7.1 Principle of Working: When a high DC voltage gradient in excess of 3300 V/cm is applied across a thin slice of GaAs, a (-)ve resistance is developed in the crystal. If this slice be connected to a suitably tuned circuit, oscillations will occur.

Now, as voltage gradient applied is very high so carrier (electron) velocity is also very high and so oscillations will occur in MW frequency.

Here, oscillations occur in the GUNN diode due to ‘Transferred Electron Effect or GUNN Effect’.

This GUNN effect is independent from total voltage/current and remains unaffected by magnetic field or different types of contacts GUNN effect occurs only in N type material and so majority carriers are electrons.

Frequency of oscillations matches here with the time of transfer of electrons according to intensity of applied voltage. Thus a domain of electrons (a bunch of electrons) evolves once per cycle and arrives at (+)ve end of the slice to excite oscillations in the associated tuned circuit.

4.7.2 STUDY OF V-I CHARACTERISTIC CURVE:.

Electronic Components
4.7.3 Explanation of V-I Characteristic Curve: When voltage is applied across the slice of Ga as the excess electrons formed in doped N type semiconductor flow to the (+)ve end (anode) of the slice.

As voltage is increased till further, electrons move towards (+)ve end with greater velocity and as a result current also increases.

Here, (i) in OA region (+)ve resistance is developed, (ii) In AB region (-)ve resistance grows and (iii) BC region is again (+)ve resistance.

4.7.4 Applications: 1. Used as MW oscillator, (2) Used as local oscillator.

Availability Ranges: 4 GHz (1.5 Watt CW MAX) to 75 GHz (50 MW CW MAX).

A practical circuit:

```
               Conducting mounting
               Bias voltage via OV prot.
               Loading
               RF
               λg/2
               Conducting tuning plug
               end screws
               choke
```

4.8 Scott key Barrier Diode:

4.8.1 Construction: It has a metallic part (Titanium surrounded by gold for low ohmic resistance) and a N type semiconductor part. Gold plated titanium N-type Ga As

As majority carriers are electrons here so scottkey barrier diode is a unipolar device.

Symbol:

```
FB (Forward Bias)
```

Circuit containing scottkey barrier diode:
4.8.2 Principle of operation of Scottkey barrier diode :-
1. When the diode is unbiased, free electrons on N part are at a lower energy level than free electrons on the metal side. That is orbits of free electrons on N side are smaller than those on the metal side. This difference in orbit size or energy level is called ‘Scottkey Barrier’.

2. When diode is forward biased, free electrons on N side gain enough energy to travel in larger orbits. Due to this free electrons can cross the junction and enter the metal side. Now, as the free electrons plunge into the metal with energy so they are also called Hot Carriers and the scottkey barrier diode is called ‘Hot Carrier’.

One thing important to note is that as the metal has no holes (one type of carrier), there is no depletion layer or stored charges in the junction so this diode can off and on faster than a bipolar diode.

4.8.3 Applications :- Used as Mixers and Detectors. Availability :- Up to 100 GHz MW.
CHAPTER : 5

5.0 Transistors- Bipolar, Testing and Applications :-

5.1 Introduction:- Among two principal semiconductor devices, Transistor, rather bipolar junction transistor is one. This device is mainly used for amplification and switching. Now the device should be studied to know about its specialities in construction and principle of operation.

Basically, Bipolar Junction transistor is a transistor having two junctions and two carriers, holes and electrons are involves in operation. As it has two polarities of carriers slot is known as bipolar junction transistor. When it is observed closely it shows as it is constructed by joining two semiconductor diodes back to back.

5.2 Meaning of Transistor :- Transistor = TRANSfer + ResISTOR.

5.2.1 Principle of Operation :-

First part of the transistor is known as emitter, second part is base and the last part is collector. When transistor comes into action then its emitter part emits carrier, this carrier diffuses to the next part i.e base and then goes direct to the third part known as collector part and gets collected there. This is why the three parts of the transistor are named as emitter part base part and collector part. The figure shows that 1st part is medium (size).

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Moreover, holes generated into the base region (Minority holes due to B-C reverse bias) cross into the collector section and electrons (Minority electrons) thermally generated in the collector region cross the junction into the base layer. These two types of carriers constitute the reverse saturation current.

Thus collector current is composed of :-
(i) Injected holes at E-B diode and
(ii) Thermally generated carriers crossing the collector base junction.

5.2.2 Type of Transistors :- Transistors here are of two types :-
(i) PNP Transistor and (ii) NPN Transistor.

Symbols of Transistors :

Symbolically represented transistor in operation – (Showing transistor currents and voltage drops inside transistor).

5.2.3 Explanation of Terms :-

a) $I_E$ = Emitter current (+ ve when indicated into the transistor).
b) $I_B$ = Base Current.
c) $I_C$ = Collector Current.
d) $V_{BE}$ = Voltage drop between base and emitter.
e) $V_{CB}$ = Voltage drop between collector and base.
f) Common Base = Base is common to both voltages (Voltage drops).

Here, $I_C = I_E + I_B$

5.3 Types of Transistors according to configuration:-
Transistors are of three types as per configuration those are:-

i) Common Base configuration.
ii) Common emitter configuration.
iii )Common collector configuration.

Electronic Components
Description of these types of transistors :-

5.3.1 Common Base Configuration:- Here, base is common to both input and output circuit.

Common Base PNP Transistor :-

Here, \( V_{EE} \) = Emitter supply voltage.
\( V_{CC} \) = Collector supply voltage.

Other voltages have already been stated as per signal

Figure :- (i) Emitter base junction is forward biased.
(ii) Base collector junction is reverse biased.

\( I_E \), \( I_B \) and \( I_C \) are currents flowing into the transistor and considered as (+)ve in nature. Here, \( \alpha_{dc} \) is the ratio of dc values of \( I_C \) and \( I_E \). This signifies the measure of the quality of the transistor.

Thus \( \alpha_{dc} = I_C/I_E \) forward current transfer ratio.

\( I_C = \alpha_{dc} \times I_E \)

Now, \( I_E = I_B + I_C \) or, \( I_B = I_E - I_C = I_E - (1 - \alpha) I_E \)

So, \( I_B = (1 - \alpha) I_E \).

5.3.2 Common Emitter configuration :-

Here, \( \beta_{dc} \) is the ratio between dc values of \( I_C \) and \( I_B \).

\( \beta_{dc} = I_C/I_B \) or \( I_C = \beta_{dc} I_B \).

Now \( I_E = I_B + I_C = I_B + \beta_{dc} I_B = (1 + \beta_{dc}) I_B \)

Relation between \( \alpha \) and \( \beta \):-

Current amplification factor :- \( \alpha = I_C/I_E \) for common Base and \( \beta = I_C/I_B \) for common emitter.

So, \( \beta/\alpha = I_E/I_B \)

Now, \( I_B = I_E - I_C \)
So \( \beta = \frac{I_C}{I_E - I_C} \)

Or \( \beta = \frac{\alpha}{1 - \alpha} \)  

Thus \( \alpha = \frac{\beta}{1 + \beta} \)  

From equation 1\& 2 \( 1 - \alpha = \frac{1}{1 + \beta} \)  

Electronic Components
\[ 1 + \beta = \frac{1}{1 - \alpha} \quad 4 \]

From equation 3 & 4 \[ \alpha = \frac{\beta}{1+\beta} \quad \text{and} \quad \beta = \frac{\alpha}{1 - \alpha} \]

Thus it may be written as:

\[ I_E = \frac{I_B}{1 - \alpha}; \quad I_B = I_E \left( 1 - \alpha \right) \quad \text{and} \quad I_C = \alpha \cdot I_E \]

So, \[ I_E : I_B : I_C = 1 : \left( 1 - \alpha \right) : \alpha \]

5.3.3 Common collector configuration :-

This configuration may be named as emitter follower as output flows from emitter here. Here, collector is common to both input and output circuit.

Here, also, \( I_E = I_B + I_C = \frac{I_C}{I_B} \)

Or, \( I_C = I_B \)

Thus, \( I_E = I_B + I_C = I_B + I_B = (1 + \alpha) I_B \).

That is output current is equal to \((1 + \alpha) \times \) input current.

5.4 Leakage currents in Transistors :-

Let us consider the conditions of different currents like \( I_E, I_B, I_C \) etc. flowing in a transistor.

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Let us consider the conditions of different currents like \( I_E, I_B, I_C \) etc. flowing in a transistor.
ii) Base current is \( IB = (1 - \alpha) \) IE – ICBO.

iii) Collector current is \( IC = \alpha IE \) where \( \alpha \) is the current amplification factor (Current gain).

iii) Leakage current between collector and base when emitter is open circuited is ICBO.

From these four items it may be written as IC = \( \alpha \) IE + ICBO —-(1) here, \( \alpha \) is current amplification factor or current gain and is equal to IC/IE.

\[
IB = (1 - \alpha) \) IE – ICBO ---- (2)
\]

Adding (1) and (2) \( IC + IB = \alpha IE + \) ICBO + IE - \( \alpha \) IE – ICBO = IE.

Thus, IE = IB + IC or, IC = IE – IB.

5.4.1 Leakage current in common emitter configuration :-

\[ \beta IB \]

Transistor

\( I_{CEO} = \) Leakage current from collector to emitter when base is open circuited.

In figure (2):- \( IC = IB + I_{CEO} = IE + I_{CEO} \), Again, IB = IE – IC.

Thus, IB = IE – IC = IE – ( \( \alpha \) IE + I_{CEO}) = IE – \( \alpha \) IE – I_{CEO} or, IB = (1 - \( \alpha \) ) IE – I_{CEO}.

5.5 Biasing of Transistor :-

If transistor be made to operate, biasing circuit is a must. It is well known that Bipolar Junction Transistor is a bi junction device. It (Transistor) contains emitter, base and collector parts.

Emitter and base parts constitute E-B junction and base, collector parts constitute B- C Junction.

Until and unless EB Junction is forward biased and BC junction is reverse biased no. transistor current will flow.

Electronic Components
It may be said that EB Junction is responsible for pushing majority carriers toward collector and B-C JN is responsible for pulling those carrier towards the large size collector part.

Thus it is clear that biasing voltages should be adjusted in such a way that these push and pull conditions may be satisfied for easy flow of transistor current.

5.5.1 Function of Biasing Circuit: Biasing circuit has two functions: (1) To achieve the desired Q point, (2) To maintain the Q point at desired value and stabilise it against variation of temperature power supply etc.

(1) Location of Q-Point:

\[ \begin{align*}
&I_C \\
&I_B \\
&V_{BB} \\
&V_{CE} \\
&E \\
&B \\
&C \\
&V_{CC} \\
\end{align*} \]

PNP

5.5.2 Conditions to be considered for locating Q Point:

1) Maximum allowable collector current = IC max.
2) Maximum permissible CE voltage = VCE max.
3) Maximum permissible collector dissipation (PD i.e power dissipation) = VCC x IC.
4) Saturation line near VCE = O.
5) Cut off line at IB = O.

If all the five conditions are satisfied then quiescent point will exist at the middle position of the curves which are almost linear in nature.

This Q-Point determines:

i) IB, (ii) IC and (iii) VCE.

5.6 Biasing Rules:

For P N P

For N P N

Electronic Components
VEB = E is more (+) ive than B (Second subscript)

VBC = B is more (+) ive than C (i.e B is less (-)ive than C).

Different types of Biasing Circuits :-

5.6.1  1.Fixed Bias Circuit :-

Here, in NPN transistor circuit :-

\[ Vcc = IB \times RB + VBE \text{ or, } IB \times RB = VCC - VBE \text{ or } IB = VCC - VBE/RB \quad (1) \]

Now, as \( Vcc > VBE \) So, \( IB > Vcc/RB \).

Thus, IB is almost fixed.

Again, \( Vcc = ICRL + VCE \) So, \( VCE = Vcc - IC \cdot RL \).

5.6.2  2.Collector to Base Bias :-

From the figure it is clear that

\[ VCE - VBE = IB \times RB, \]

Or, \( IB = VCE - VBE/RB \).

\( VCE/RB \text{ as } VBE \ll VCE \)

So, \( IB = VCE/RB \text{ or, } VCE = IB \times RB \).

Again, \( VCE = Vcc - (IB + IC) \times RL \).
Thus, $IB_{RB} = VCC - IB_{RL} - IC_{RL}$

Or, $IB_{RB} + IB_{RL} = VCC - IC_{RL}$

Or, $IB_{RB} = VCC - IC_{RL}/RB + RL = VCC/RB + RL - IC_{RL}/RB + RL$.

5.7 Applications :-

5.7.1 Common Base :- As an interface between low impedance and high impedance device as it contains low I/P impedance and high output impedance. As an interface between moderately high I/P impedance and high O/P impedance.

5.7.2 Common Collector :- As an interface between high impedance device as it contains high input impedance and low O/P impedance.

5.7.3 COMPARISON AMONG CB, CE AND CC AMPLIFIER AS PER PERFORMANCE

<table>
<thead>
<tr>
<th>PERFORMANCE</th>
<th>CB</th>
<th>CE</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Ai$ (Current gain)</td>
<td>0.98</td>
<td>50</td>
<td>51</td>
</tr>
<tr>
<td>$Av$ (Voltage gain)</td>
<td>70</td>
<td>70</td>
<td>0.00</td>
</tr>
<tr>
<td>$Ri$ (Input resistance)</td>
<td>20 Ohms</td>
<td>1000 Ohms</td>
<td>100 K Ohms</td>
</tr>
<tr>
<td>$Ro$ (Output resistance)</td>
<td>1 M Ohms</td>
<td>50 K Ohms</td>
<td>30 Ohms</td>
</tr>
</tbody>
</table>

5.7.4 Applications of Transistors as per performance :-

<table>
<thead>
<tr>
<th>Transistor Configuration</th>
<th>Matches Between</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB</td>
<td>Low impedance source to High impedance load (As CB has low I/P Impedance and high O/P Impedance.)</td>
<td>As pre amplifier stage.</td>
</tr>
<tr>
<td>CE</td>
<td>Moderately high I/P Impedance to High O/P impedance</td>
<td>In different types of amplifier.</td>
</tr>
<tr>
<td>CC</td>
<td>High impedance source Low impedance Buffer amplifier to isolate the load (As CC has high I/P Impedance and low O/P Impedance.)</td>
<td>previous stage.</td>
</tr>
</tbody>
</table>
5.8 Cascade Amplifier Stages :- If we want to form cascade amplifier then the different stages of the cascade amplifier may be depicted as in the following :-

5.8.1 Case I :- When external source is a low impedance source :-

![Diagram showing cascade amplifier stages with Case I](image)

5.8.2 Case II :- When external source has high I/P Impedance :-

![Diagram showing cascade amplifier stages with Case II](image)

CHAPTER – 6

6.1 Introduction :- After thyristor family, field effect transistors come into picture where the transistor operates by the effect of Electric Field. Here, the current is controlled by Electric Field.

In case of a conventional transistor it has been found that operation depends upon both types of carriers (Holes and electrons i.e. two polarities) and thus it is named as BJT (Bipolar Junction Transistor). But carrier (Single Polarity) i.e. majority carriers only. This is why it is known as UNIPOLAR DEVICE.

Another major difference between BJT and FET is that BJT has low input impedance whereas FET has high input impedance (like unipolar valves) valve is of the order of mega ohms.

Some other remarkable advantages of FET as compared to BJT are :-

a) It produces lesser noise than BJT.

b) Effect of radiation is less as compared to that of BJT.

c) It has better thermal stability.

d) In fabrication of IC (Integrated circuit) FET is simpler to develop.

e) It is an excellent signal chopper due to absence of off set voltage at zero drain current.

Electronic Components
But major drawback in FET is that it has very small gain band with product as compared to BJT. FET may be subdivided into the following categories as given in tabular form.

<table>
<thead>
<tr>
<th>FET</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>JFET (In field effect Transistor)</td>
<td>MOSFET (Metal oxide semiconductor field effect transistor. It may also be called as IGFET / Insulated Gate FET).</td>
</tr>
<tr>
<td>Single Gate</td>
<td>Dual Gate</td>
</tr>
<tr>
<td>Enhancement mode</td>
<td>MOS FET</td>
</tr>
<tr>
<td>Depletion Mode</td>
<td>MOS FET</td>
</tr>
</tbody>
</table>

### Construction:

![Diagram of FET](image)

- **P-type strip (on both sides)**
- **N-type channel**
- **Symbol of FET**
- **Source - S**
- **Drain - D**
- **Gate - G**
- **VGG/VGS**
- **VDD/VDS**

In FET, there is a bar of N-type known as channel and a strip of heavily doped P-type semiconductor. Here, P-type semiconductor is formed on channel by alloying or diffusion. If P-type semiconductor is sandwiched between heavily doped N-type region then it is known as P-channel FET. Ohmic contacts are formed (Made) at the two ends of the channel (N-type here in figure). Voltage is applied between source and drain. Here, current flows from one end of channel to the other (When voltage is applied between S and D).

#### 6.1.1 The Source:
- This is the terminal through which the majority carriers enter the bar. The conventional current is IS.

#### 6.1.2 The Drain:
- This is the terminal through which majority carriers go out of the bar or leave the bar. The conventional current here is ID. VDS = VDD is the drain to source voltage.

#### 6.1.3 The Gate:
- This is present on both sides of N-channel and forms controlled electrodes (Known as gate). Here, voltage $V_{GS} = V_{GG}$ is applied between gate to source so as to reverse bias the PN junction. Current at gate is IG.

#### 6.1.4 The Channel:
- This is the bar sandwiched between the two gates through which majority carrier flows from source to drain.

*Electronic Components*
6.2 Operation of N-Channel FET :- Before operation of N-channel FET is discussed the fact should be recapped about reverse biased PN JN. The figure shows the conditions of mobile and immobile ions present in RB PN JN.

As in the figure, due to the fact of reverse biased gate and heavily doped P region the depletion region penetrates into the N-type bar and reduces the conducting area of N-channel. The decrease in conducting area causes decrease in the channel conductivity and thus causes decrease in current flowing from source to drain.

From the figure it is clear that as VGG (Gate to source voltage) is increased, the reverse bias at gate JN increases and thickness of depletion region further increases and effective conducting area of N-channel decreases and thus source to drain current decreases.

Thus for a fixed drain to source voltage it is possible to control the ID (Drain Current) by varying reverse bias voltage across the gate junction.

Any time varying signal voltage \( V_{GS} \) is applied in series with \( V_{GG} \) i.e. bias voltage Gate then varying component of drain current and time results and as a result varying Voltage across load results in drain circuit. This \( V_{DS} \) is amplified version of signal Voltage \( V_{GS} \).

6.2.1 Clarification of the name field effect Transistor :-

Here, current control is the effect of the extension of the field associated with the depletion region as caused by the increasing reverse bias.

6.2.2 The characteristic curves show :-

When \( V_{GS} = 0 \), the gate junction is fully open. Then with \( V_{DS} = 0 \) no attraction potential exist at the drain as a result no \( I_D \) flows through the drain terminal.

Now, for small increase of \( V_{DS} \) N-type bar acts as semiconductor and \( I_D \) increases with increase of \( V_{DS} \). Now with increase of \( I_D \), ohmic voltage drop between the source and the channel region, the gate junction resulting in the corresponding constriction of the ducting portion of the channel.

Electronic Components
As $V_{DS}$ is increased stage by stage a particular voltage reaches at which the channel is pinched off i.e. FET behaves more or less as blocked i.e. most of the free charges are removed from the channel.

The voltage, for which the channel is pinched off, is known as pinch off voltage when $V_{DS}$ increases still further, $I_D$ increases and attains almost constancy value.

As $V_{GS}$ goes more and; more (-)ve, the reverse bias also increases accordingly. Here the curves gets shapes like the curve for $V_{GS} = 0$ only difference is in $V_p$ (Pinch off voltage) which attains lesser values in each stage of negative values of $V_{GS}$.

When $V_{DS}$ is increased still further avalanche break down occurs at the gate junction and $I_D$ shoots to a high value. Here, it is observed that avalanche break down occurs at successive lower values of $V_{DS}$ as gate reverse bias magnitude is increased.

6.3 MOSFET :- MOSFET means, metal oxide semiconductor. Field Effect Transistor or insulated gate FET.

6.3.1 Construction :-

Here, in MOSFET parallel plate condenser is formed with the metal area, siozlayer (as didertric) and semiconductor channel N. Thus the gate is insulated by means of siozlayer. This is why MOSFET is called insulated FET. This sioz layer is responsible for very high input impedance of MOSFET (Range of impedance is $10^{10} - 10^{15}$ Ohms).

The gate is (-)ive and N type substrate is grounded and an electric field results normal to sioz layer. This electric field originates from induced (+)ive charges on N substrate and terminates on (-)ive charges to reseutag as the lower surface of sioz layer.

These induced (+)ive charges from minority carriers of N- type substrate and an INVERSION LAYER FORMS.

Magnitude of these (+)ive charges increase with the increase of (-)ive voltage applied on gate.
The region just below the SiO₂ layer, P type carriers (Holes) are existing (Due to induced P channel). In such a position the conductivity of this region increases there by current flow from source to drain increase (through this channel).

Thus the drain current (I_D) is enhanced on application of (-)ive gate voltage. This is why this type of MOSFET is called enhancement MOSFET.

6.3.2 Characteristic Curve :

The figure shows drain characteristics ( a graph when I_D V_DS versus I_D is drawn). The graph reveals :- (i) I_D is very small (NA) when as V_GS is more (-)ive, a slower increase in I_D results. (ii) When V_GS is made still more (-)ive the current I_D increases more as compared to case (ii).

Here, one thing important to note is V_GS (Gate source threshold voltage) or VT, a voltage at which a typically small value of I_D (of the order of 10^-A) results. This V_GST is indicated by manufacturer in the DATE other things which manufacturers indicate in their DATA sheet are:- I_D (Drain current), (ii) V_GS. For a typical P channel MOSFET V_GST or V_T = -4 volts. V_DS = -12 volts.

Now, it is known that the commercial 5 volt supply needed for operation of bipolar IC which becomes insufficient for the operation of MOSFET.

Techniques are applied to keep VT small (Smaller than – 4 volts ) to avail the following advantages:-

a) Lower supply voltages are needed i.e. less expensive power supply arrangement is utilised there.

b) Operation is easier with bipolar IC devices.

c) Lower I/P voltage swing results for turning the MOSFET ON AND OFF. This results in smaller switching time and faster operation.

To lower the magnitude of VT the essential changes to be done in construction of P- channel enhancement MOSFET is :

i) Changing of orientation from 111 to 100.

ii) Replacement of siO₂ layer by a mixture of si₂ N₄ (Silicon nitride ) and SiO₂ layer. This change take the V_T down to –2 volts due to higher dielectric contents (twice that of siO₂ alone).

iii) Replacement of Al (Gate electrode) polycrystalline. Silicon doped with boron.

These to operations reduce the value of VT = 4-6 V to VT = 1.5 – 2.5
6.3.3 Power Supply for P-Channel Enhancement MOSFET :-

<table>
<thead>
<tr>
<th>Supply Voltages</th>
<th>Source Grounded</th>
<th>Drain Grounded</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With high $V_T$</td>
<td>With low $V_T$</td>
</tr>
<tr>
<td>$V_{SS}$ (Source supply)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$V_{DD}$ (Drain Supply)</td>
<td>-12</td>
<td>0</td>
</tr>
<tr>
<td>$V_{GG}$ (Gate Supply)</td>
<td>-24</td>
<td>-12</td>
</tr>
</tbody>
</table>

6.3.4 Depletion MOSFET :-

The figure is self explanatory.

Speciality :- ID (drain) current flows appreciably for $V_{GS}$ is 4Volts

When gate voltage is made (-) ve, (+) ve charge gates induced in N- type channel through Al metallisation and SiO$_2$ layer comprising capacitor (Plates are (i) Al metallisation and (ii) N- channel and SiO$_2$ acts as dielectric).

Here, in N- channel MOSFET, majority carriers are electrons and induced carriers are (+) changes these (+) ve charges cause the N- channel less conductive.

Here, as N- type channel is depleted of majority carriers so it is named as depletion N- channel MOSFET.
Here, N-channel depletion MOSFET may be converted to enhancement MOSFET by applying (+)ve voltage to gate. In that case (-)ve charges will be induced in N-type channel thereby increasing (-)ve carrier (induced + majority). Thus $S_D$ increases.

CHAPTER – 7

SCR, UJT, DIAC, TRIAC Etc.

7.1 Introduction :- After study of special types of diodes, a particular type of semiconductor device to be studied presently. This type of device is known as Thyristor. Thyristor literally means Thermal Resistor (Thyriatric Resistor or Thermal resistor). Although it is known as resistor yet it is a three junction device. More clearly, Thyristor is a combination of two transistors PNP and NPN.

Two Transistor Analogy :-

```
\begin{center}
\begin{tikzpicture}
\node[draw, circle, fill=white, minimum size=1cm] (a) at (0,0) {A};
\node[draw, circle, fill=white, minimum size=1cm] (b) at (1,0) {K};
\node[draw, circle, fill=white, minimum size=1cm] (c) at (2,0) {K};
\node[draw, circle, fill=white, minimum size=1cm] (d) at (0,-1) {P};
\node[draw, circle, fill=white, minimum size=1cm] (e) at (1,-1) {N};
\node[draw, circle, fill=white, minimum size=1cm] (f) at (2,-1) {P};
\node[draw, circle, fill=white, minimum size=1cm] (g) at (0,-2) {N};
\node[draw, circle, fill=white, minimum size=1cm] (h) at (1,-2) {P};
\node[draw, circle, fill=white, minimum size=1cm] (i) at (2,-2) {N};
\draw[->] (a) -- (b);
\draw[->] (b) -- (c);
\draw[->] (c) -- (d);
\draw[->] (d) -- (e);
\draw[->] (e) -- (f);
\draw[->] (f) -- (g);
\draw[->] (g) -- (h);
\draw[->] (h) -- (i);
\end{tikzpicture}
\end{center}
```

This was invented by a general electric company (in the year 1960). Now a days, thyristor have largely replaced the devices like : (i) Thyatron, (ii) Mercury Arc Rectifiers, (iii) Excitrons and (iv) Ignitrons etc.

7.1.1 Family of Thyristor :- The family of thyristor may be described in tabular form like this.

```
<table>
<thead>
<tr>
<th>SL</th>
<th>NAME OF THE DEVICE</th>
<th>CONSTRUCTION</th>
<th>SYMBOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SCR (Silicon controlled rectifier).</td>
<td>A P N P K</td>
<td>A K</td>
</tr>
</tbody>
</table>

Electronic Components
2. **SCS (Silicon controlled switch)**
   (4 terminal reverse blocking tetrode thyristor).

3. **DIAC (Two terminal by directional PNP switch).**

4. **TRIAC (3- terminal by directional PNP Switch).**

Let us now go through the cases one by one.

7.1.2 **SCR :-**

**Basic Structure**

7.1.3 **Circuit Representation :-**
7.1.4 Operation :- At first the gate terminal G is not connected to any external circuit. In that case \( I_G = 0 \).

When supply voltage is connected between A&K of SCR increase with resistance R, the case happens like this:-

i) \( J_1 \) & \( J_3 \) are forward biased.

ii) \( J_2 \) is reverse biased.

Thus the three junctions are properly biased for proper operation of the transistors T1 and T2. The collector currents are given by:-

\[
IC_1 = -\alpha_1I + IC_{O1} \quad \text{(1)}
\]

\[
IC_2 = \alpha_2I + IC_{O2} \quad \text{(2)}
\]

For PNP transistor ICO1 (-)ve while for NPN transistor ICO2 (+)ve.

Hence, ICO2 = - ICO1 = Ic/2.

For PNP = ICO1 is (-)ve.

For NPN = ICO2 is (+)ve.

For transistor sum of all the currents is zero. Thus for transistor T1 : \( I + IC_1 - IC_2 = 0 \) (As current entering into transistor is (+)ve.).

Putting the values of IC1 & IC2 on (3) we get :

\[
I + (-\alpha_1I + IC_{O1} - (\alpha_2I + ICO_2)) = 0.
\]

Or, \( I - \alpha_1I - \alpha_2I + IC_{O1} - ICO_2 = 0 \).

Or, \( I \{1 - (\alpha_1 + \alpha_2)\} + IC_{O1} - ICO_2 = 0 \).

Or, \( I \{1 - (\alpha_1 + \alpha_2)\} = ICO_2 - ICO_1 \).

Thus, we can write \( I = \frac{ICO_2 - ICO_1}{1 - (\alpha_1 + \alpha_2)} \).

Here, when IG (Gate current) appears at gate terminal SCR is fired and acts as short circuit between A and K. A limiting R1 (Load resistance) is connected to prevent high current through A and K.

---

Electronic Components
When gate is (+)ive with respect to cathode, IG flows first through gate G, then through base to emitter and in the mean time current from collector to base of T2 flows and base current flows from T1 to T2 as a result collector current flows from T1 to base of T2 and as a result larger gate current (IG) results. In this time saturation state of conduction reaches between T1 and T2. In this state a condition of feed back results and due to that after triggering when gate is switched off i.e. IG = 0 then also conduction continues.

After that when the anode potential is taken down below holding level, SCR goes off. During triggering, a pulse of a few a value (I6 = a few mA) is applied momentarily (4 ) at gate terminal. The output of the SCR becomes many amp. Value.

This pulse when used in AC circuit then the SCR is fired by IG at particular instant within each (+)ve half cycle.

7.1.5 ON AND OFF TIMES OF GATE :- Initially, the SCR remains in OFF state. When triggering pulse is applied then the SCR goes from OFF state to ON state. The time taken to turn on the SCR is known as Turn-On-Time. (of SCR).

For taking a SCR from “OFF State to ON State” we should take care of the following :-

i) The pulse amplitude should be kept sufficiently large.

ii) Pulse duration should be so adjusted that “Gate time to Hold” condition may be reached. If this condition is not reached, the SCR will turn from ON state to OFF state again (after immediate with drawl of triggering pulse).

Similarly, at the time of taking the SCR from “ON State to OFF” state the anode voltage should be dropped down below the holding voltage VH.

Now, time taken to make the SCR OFF (from ON State) is known as turn off time. This time is defined as the time interval starting from the dropping of anode voltage needed to complete the switching off process.

One thing important to note it that the anode voltage must be kept below holding voltage for a particular period of time known as ‘Gate Recovery Time’. Otherwise, the SCR will return back to ON State.

7.1.6 VOLT-AMPERE CHARACTERISTICS OF S C R :-

Let us observe the characteristics stage by stage.
i) Here, when IG = 0, no conduction takes place.

ii) When large forward voltage is applied between anode and cathode then a break over voltage VBO fires the SCR. Here, if base bias is such that applied voltage is less than VBO then (+)ive triggering voltage/current may be applied to the cathode gate so as to lower Vbo than applied voltage. In such condition SCR is turned ‘ON’.

In this way, IG comes in, fires the SCR and SCR goes to ‘ON’ state and a forward curve results which resembles curve of ordinary diode (as indicated in the figure).

After triggering, SCR remains at ‘ON’ state even after reverse biasing of gate.

Now, to turn the SCR ‘OFF’ we should reduce the anode voltage below the holding voltage VH i.e. by reducing anode current below the holding current.
7.1.7 SYMBOL OF SCR :-

In V-I characteristic curve it is seen that the firing voltage (i) decrease with increasing (+)ive gate current and (ii) increase with increasing (-)ive gate current. The current after break over is larger than that before break over by a factor 1000 or more.

The V-I characteristics curve reveals the following particular :-
(a) With VF (Forward voltage) applied to SCR, a small forward current flows until the applied voltage equals to Vbo. At this Vbo, forward current is Ibo.
(b) With VF applied there off a series resistor R and exceeding Vbo the diode switches over from OFF state (Block state) to ON state (Saturation state) and thereby operates in saturation region. The design is known then said to latch (i.e changes from OFF state to ON state). This ON state is continue till the current reduces to a value IH called holding current or latching current. The corresponding voltage VH is called holding voltage or latching voltage.

For different PN PN diodes the ranges of Vbo and Ibo are :-
(i) Vbo varies from tens of volts to several hundreds of volts, (ii) Ibo varies up to a few hundreds of amps.

Moreover, in the OFF range i.e. for currents from 0 to Ibo the dynamic resistance varies from a few M ohms to several hundred

7.1.8 SCR Ratings :-

- a) Current ratings (IA) – Exceeding 100 Amps.
- b) Voltage ratings (VA) – Exceeding 1000 volts.
- c) Holding voltage (VH) – 1 volt.
- d) Gate current (IG) ratings- 1/1000 x IA.

Here, IG of about 40 mA is enough to turn on an anode current of 100 Amps.

7.1.9 SCS – Silicon Controlled Switch:-

SCS may be operated in the following ways :-

- i) Two transistor equivalent of SCS and
- ii) Diode transistor equivalent of SCS.

Electronic Components
7.1.10 Application of SCR:-

SCR is used as (i) Motor speed control in both DC and AC motors. (ii) Power control (iii) Power Transmission (v) Switch. SCS- Silicon controlled switch: -

This may be operated in the following ways:

i) Two transistor equivalent:-

Here, the figure shows to transistor Complementary pair with regenerative Feedback.

Here, base current of transistor T\(_2\) (NPN) is IB and this IB being amplified by the gain B\(_2\) of the transistor T\(_2\) becomes collector current of transistor T\(_2\) and this is the base current to transistor T\(_1\). This B\(_2\) IB being multiplied by B\(_1\) i.e gain of transistor T\(_1\), becomes B\(_1\)B\(_2\)IB which constitutes the IC of T\(_1\) and this B\(_1\)B\(_2\)IB becomes the base current to transistor T\(_2\).

Now, if B\(_1\)B\(_2\)IB exceeds IB (Initial base current) then both the transistors go into conducting and thus SCS is in the ON state.

Now, if IA (Anode current) reduces, B\(_1\) and B\(_2\) reduces and the product B\(_1\)B\(_2\) reduces and B\(_1\)B\(_2\) 1. In such a situation regeneration ceases and SCS gets switched off.
7.2 Volt Ampere Characteristics of S C S :-

Here, as applied forward voltage (VF) region  
Anode is increased, the current at first  
Slowly increases up to point A and  
Rapidly in the region AB as in SCR.

At point B, the product B₁B₂ and  
Suddenly the ON condition results. region

![Diagram showing Volt-Ampere Characteristics of SCS](image-url)
CHAPTER - 8
INTEGRATED CIRCUIT

8.1 Introduction :- Semiconductor devices had been invented to overcome the problems faced in valves like diode, triode, tetrode etc of early days. Now, in the early days of semiconductors we have got semiconductor diodes and transistors which had been utilised along with other circuits elements like resistor, inductor, capacitor and the like.

In recent days to overcome the complexities in connecting semiconductor devices with other circuit elements as stated above the integrated circuits have been invented. This invention has inserted another feather to the crown of electronics.

Here, in IC, the semiconductor circuit elements i.e active elements other elements like R.L.C etc. i.e passive elements have been made along with their interconnection in a single chip and complexities have been minimised.

With the advent of IC, Micro Electronics have been pioneered.

Micro Electronics (Flow Chart) :-

```
MICRO ELECTRONICS

Functional Devices (BPF)                                         Integrated Circuits                              Minidiscrète Devices

Hybrid Circuits                                                   Active & Passive Circuits                          Passive film circuits
                                                          (Monolithic (Lithos Stone) Single)                

Si thin Flim circuit                                             Discrete active devices & Thin film Circuits.     

Multichip Interconnec-                                          Thin film circuit                                  Thick film circuit.
```
8.1.1 Formation of monolithic integrated circuits :-

Monolithic literally means single chip, Monolithic is a Greek word. When divided in syllable it means :- (i) Mono mean single and (ii) Litho means stone.

Thus single stone. Here, stone is replaced by chip. In this way monolithic integrated circuit has become IC CHIP (Made up of silicon- Si). Let us now consider a concrete example to show the information of IC CHIP.

The circuit to be made on single IC CHIP :-

![Circuit Diagram]

D1= Diode (s.c)  R=Resistor and T1= Transistor (NPN)

Fabrication ;-) Fabrication of IC chip (FOC the given circuit) involves the following steps :-
  i) Epitaxial Growth.
  ii) Isolation Diffusion.
  iii) Base Diffusion
  iv) Emitter Diffusion.
  v) Aluminium Metallisation.
  vi) Securing and mounting.

Before describing all these we should know the following techniques first :-

8.1.2 1) Grown Junction :- In this case at first the semiconductor like Si/Ga/As is taken then; first doped with P-type impurity then that P-type material is doped with N-type material. In large quantity thus a continuous crystal is made which is party P-type and partly N-type in nature with a JN a mid i.e. JN DIODE is formed. Similarly in case of JN transistor alternate layers of P,N and P are formed by this technique.

8.1.3 2) Diffused Junction :- Before going through diffused junction we should know about the process or diffusion. Diffusion means spreading like kerosene layer on the floor. Thus the JN produced by spreading process is known as diffused junction. Here, the JN is produced by gaseous diffusion of P and N type material on semiconductor wefer.

8.1.4 3) Epitaxial grown Junction :- Epistasis literally means like this (i) Epis in Greek means layered and taxis ordered. Now, the fabrication of IC chip may be discussed thoroughly in the following way :-This means growing of a material on a substrate material in such a way that the grown material forms a continuation of the substrate material.

8.1.5 Epitaxial Growth :- In this process, on a highly resistive P-type substrate, N-type layer is grown epitaxially in such a way that the N type material forms a continuation with P type material. This operation is performed inside a special furnace called reactor ( temp. is 900 to 1000 ).

---

**Electronic Components**

<table>
<thead>
<tr>
<th>SiO2 layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-type epitaxial layer</td>
</tr>
<tr>
<td>P-type substrate</td>
</tr>
</tbody>
</table>
Here, P type substrate is highly resistive (10 ohms cm approx.) and N type material is off lower resistivity (0.1 to 0.6 ohms cm). In the next, the epitaxial grown layer so formed is cleaned and polished. After cleaning and polishing, a layer of $\text{SiO}_2$ is formed on N type material by heating the layer to a temperature of 1000$^\circ$ C in an oxygen atmosphere. This $\text{SiO}_2$ layer prevents diffusion of impurities through it.

**8.2 Isolation Diffusion :-**

Here, we see that silicon dioxide layer is removed at different places. This is done through photolithographic etching process.

**8.3 PHOTO LITHOGRAPHIC ETCHING :-** This is the process which helps removing of silicon dioxide layer selectively to form openings through which impurities may be diffused. At first the wafer is coated with a uniform film of photosensitive emulsion. After that a mask is prepared keeping an eye on desired circuit elements to be grown on the wafer (thin slice). In the next, the mask is placed on the wafer and exposed to ultraviolet rays. The rays enter the wafer through transparent parts of the mask and attacks the $\text{SiO}_2$ layer and removes the desired parts.

Now, P type impurities penetrate through N type epitaxial grown layer and reach the P type substrate. As a result N type ISOLATION ISLANDS or isolation regions are formed. Thus the figure shows different isolation island which reveals that several PN junction are evolved. This helps electrical isolation between different circuit components. Here, concentration of acceptor atoms in the region between isolation is land is much greater which is depicted by Pt. Region.

Here, a parasitic capacitance grows as a by product of isolation process. Those are (capacitances)

i) $C_b$ means capacitance between bottom of N type region and substrate.

ii) $C_W$ means capacitance between side walls of isolation is lands and Pt. Region.

$C_b + C_W = C_T = \text{a few PF (Pico Farad)}$.

**8.4 BASE DIFFUSION :-** In this process consists of :-

a) Forming a new layer of $\text{SiO}_2$.

b) Creating of openings by photolithographic process.

c) Diffusing P type impurities (Boron) through these openings.

The depth of diffusion should be carefully regulated so that N type material does not penetrate to the substrate. The resistivity of region is higher than the isolation (n type) region. Thus this P region may constitute :- (i) A resistor ®, (ii) Base of an NPN transistor (B), (iii) Anode of a diode (A) or (iv) A junction capacitor (CJ).
8.5 EMITTER DIFFUSION :-

In this process a layer of SiO$_2$ is formed and openings are formed by photolithographic process in the P region. N type impurities (Phosphorous) are then diffused through these openings to form:

(i) Emitter of a transistor, (ii) Cathode of a diode or (iii) Emitter JN capacitor.

In addition to windows in P region windows are also formed in N region to the insert leads (when required) leads are ohmic contacts made of Aluminium.

Diffusion of phosphorous into N region results in formation of heavy concentration (denoted as N+) at the points of contact with the aluminium.

8.5.1 ALUMINIUM METALIZATION :-

In this process:

(i) A new layer of SiO$_2$ is formed.
(ii) Forming a new set of windows on the new layer of SiO$_2$ at the points where aluminium contacts are to be made.
(iii) Making interconnections using vacuum deposition of this even layer of aluminium on the entire region of the wafer.
(iv) Etching away all undesired aluminium areas using photo resist technique, leaving only the desired pattern of interconnection as shown on the figure above.

Let us now consider the circuit to be formed on the wafer:

The circuit is: (to be formed):

8.5.2 The monolithic IC :-

Thus it can be concluded that the steps to be followed for fabrication of IC CHIP are:

i) Crystal growth of a substrate.
ii) Epitaxial growth.
iii) Growth of SiO$_2$ layer.
iv) Photo etching.
v) Diffusion.
vi) Vacuum evaporation of aluminium.

Electronic Components
### 8.6 Types of ICS in Tabular Form:

<table>
<thead>
<tr>
<th>ICS</th>
<th>Analogue IC</th>
<th>Logic Gates</th>
<th>Multivibrator</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Power amplifier.</td>
<td>(+ive logic)</td>
<td>(-ive logic).</td>
<td></td>
</tr>
<tr>
<td>b) High frequency amplifiers.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Differential operational amplifier.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) Voltage regulator.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Memotable</td>
<td>Monostable</td>
<td>Bistable</td>
<td>Astable</td>
</tr>
<tr>
<td>COMBINATIONAL MEMORIES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AND</td>
<td>NOT</td>
<td>OR</td>
<td></td>
</tr>
<tr>
<td>NAND</td>
<td></td>
<td>NO R</td>
<td></td>
</tr>
<tr>
<td>REGISTERS</td>
<td>Counters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLIP FLOPS</td>
<td>(RS, JK &amp; D type)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>REGISTERS</td>
<td>Counters</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It is clear that the IC in which different analogue components like resistors, capacitors, inductors, transistors etc are formed, is called analogue IC.

Let us now go through the analogue IC first:

#### 8.6.1 RESISTORS:

- Resistors may be of three types:
  - (a) Diffused resistors
  - (b) thin film resistors and
  - (c) thick film resistors.

![Diffused Resistor Diagram](image1)

![Thin Film Resistor Diagram](image2)
8.6.2. CAPACITORS:- Capacitors may be of three types:-
   a) Diffused junction capacitor,
   b) Thin film capacitor and
   c) MOS capacitor.

Here, N+ emitter and P type base forms the desired capacitor (JN capacitor):
The capacitance between reverse biased P- region and N type isolation island is some how reduced
due to large capacitance of the forward biased junction in diffused junction series (with P type based
capacitor isolation).

8.6.3 MOS- Capacitors:- It is like a parallel plate capacitor of the following layers. Al- metallisation
forms the top plate SiO₂ layer form the dielectric and N+ layer forms the bottom plate of the MOS-
capacitor.

8.6.4 Equivalent circuit:- Here, C is the MOS capacitor R is the series resistor or N+ region. C1 is
the parasitic capacitance between P-type. Substrate and N- type isolation layer. P type substrate and
N- type isolation forms diode D1.
8.6.5 Parameters of Junction Capacitors and Thin Film MOS capacitors:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Junction Capacitor</th>
<th>Thin Film Mos Capacitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Capacitance,PP/Hil2</td>
<td>0.2</td>
<td>0.25 to 0.5</td>
</tr>
<tr>
<td>2. Maximum Capacity, PF</td>
<td>400</td>
<td>800</td>
</tr>
<tr>
<td>3. Break Down Voltage, Volts</td>
<td>5-20</td>
<td>50-200</td>
</tr>
<tr>
<td>4. Tolerance</td>
<td>±20%</td>
<td>± 20%</td>
</tr>
</tbody>
</table>

8.7 Integrated Inductors:- To form an inductor in a single IC chip is difficult so it is connected externally with different ICs in a circuit.

One process is there where integrated inductors are simulated using other devices like :- i) Transistor, (ii) A transistor in conjunction with RC circuit and (iii) An operational amplifier.

8.7.1 Monolithic Bipolar Junction Transistor:- In this case NPN type of transistor is formed in general. Here, the following steps are followed one after another. (i) A P-type silicon wefer of thickness 25 mm is used to form the substrate (Resistivity 0.1 ohms-m).
CHAPTER-9

9.1 Regulated Power Supply:-

Power supply is a must to run any type of electrical or electronic device. Modern communication is based on micro electronic composed of sophisticated electronic components link diodes, transistors, ICs, Microprocessor chips and the like.

Now, for smooth running of those units/components properly introduced from which (device) more or less constant output DC voltage come out as output. Those types of outputs cause smooth and secured running of modern sophisticated micro electronic oriented circuits.

Thus regulated power supplies are those which give out constant outputs inspite of fluctuation of voltage in the inputs.

A voltage regulator is basically a voltage stabilizer with additional provision of varying stabilized voltage output as and when required.

A voltage regulator performs two functions:-

i) Regulating or varying the output voltage of a circuit.

ii) Keeping the voltage constant at the desired value inspite of variations in the supply voltage in the load.

The category (ii) is most common in use. This may be classified into three categories:- Type A- Here, output voltage remains constant inspite of the changes in input voltage.

Type B- Here, output voltage remains constant in spite of variations in the load.

Type C- Here, output voltage remains constant inspite of variation of both the input voltage and the load.

9.1.1 Principle of Automatic Voltage Regulator :-

It consists of two unites: (i) The measuring unit and (ii) The regulating unit.

The measuring unit performs the following functions:-

a) It detects and measures the change in the input or output voltage of the regulator and

b) It produces a signal to operate the regulating unit.

The regulating unit receives signals from the measuring unit and acts to correct the output voltage of the regulator to a constant value with least possible variation.

In a perfect automatic voltage regulator measuring and regulating units can be separately identified. These two units are generally called stabilizers (those which stabilizes the output voltage).

9.1.2 Ordinary Voltage Stabilizer using zener diode:-

Unregulated DC voltage \( V_i \) and a current \( I_L \) flows through a zener diode \( Z_L \) which stabilizes the output voltage \( V_0 \).

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Here, from the circuit it is clear that zener diode is connected direct across the load impedance. Here the output voltage $V_0$ appears across load impedance $Z_L$. Thus output voltage remains almost constant inspite of input voltage ($V_1$) or load impedance.

### 9.1.3 VI characteristics of Zener Diode:

We know, zener diode is a reverse biased Diode. So, in this diode the current is equal to reverse saturation current $I_0$ depicted in the annexed figure.

Forward

- $I_0 = 1$ A for Germanium diode.
- $= 1$ nA for silicon diode.

Now, as magnitude of reverse bias increases and attains a critical voltage known as zener voltage $V_z$, the zener break down takes place and IR reverse current increases suddenly as shown in the figure. This $V_z$ depends upon the material used.

### 9.1.4 DC Voltage regulators:

This device gives out a stabilized output dc voltage inspite variations of dc input voltage. This stabilized voltage may be carried at all types of dc voltage regulates:

1) Series voltage regulator, (ii) Shunt voltage regulator.

**Series voltage regulator:** Block diagram of series voltage regulator

### 9.1.5 Short description of Block Diagram:

At first the sampling unit picks up a sample of the output voltage and feeds it to the comparison unit. The comparison unit compares the fraction of $V_0$ (Output voltage) with the reference voltage supplied by reference unit and produces at its output a signal which is proportional to the difference. This signal is fed to the amplifier unit. The amplifier

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unit should be so chosen that it can amplify the difference signal to a suitably high level to drive the control unit.
In most of the cases a single transistor amplifier serves both the purpose as comparison unit and the dc amplifier.

The control unit utilises the amplified difference signal to maintain a constant output voltage.

9.2 Short description of different units :-

9.2.1 1) Sampling Unit :- It is a simple voltage divider network across the output voltage as shown in the figure:-

\[ V_0 \]

\[ R_1 \]

\[ R_2 \]

To comparison Unit

9.2.2 (2) Reference Unit:- This unit provides a reference voltage which remains constant throughout a wide range of current. Silicon break down diode is generally used as voltage reference as its break down voltage is almost constant over a wide range of reverse current.

Diagram of a reference voltage unit is as in the following:-

Equivalent circuit of reference unit
9.3 Comparison Unit: - This unit compares fraction of $V_0$ (output voltage) with the reference voltage. The circuit of this unit may be drawn as in the following:

![Comparison Unit Circuit Diagram]

9.3.1 DC amplifier Element: - It has high gain and low gain.
1) High gain helps to amplify differential signal to a suitably high level to drive the control unit.
2) Low gain helps in retaining circuit stability.

9.3.2 Necessary circuit of DC amplifier element:

![DC Amplifier Circuit Diagram]

9.3.3 Control Unit: - This helps to maintain a constant output voltage. Necessary circuit is as in the following:

![Control Unit Circuit Diagram]

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9.4 Some more information regarding regulated power supply:-

Let us first consider some power supply, which is unregulated in character. This type of power supply unit consists of:

a) Transformer, b) Rectifier and c) Filter.

The circuit containing this elements is as in the following:

9.4.1 Half wave rectifier with capacitor filter:-

9.4.2 Full wave rectifier circuit:-

9.5 Short coming of unregulated power Supply:-

There are certain reasons due to which unregulated power supply in is not sufficient for many applications.

The reasons behind that are:

1) First one is its poor regulation. The output voltage is not constant as load varies.
2) Second thing is that the dc output voltage varies with the AC input.
3) Third reason is that the DC output voltage varies with temperature as semiconductor devices are used here.

All these three short comings should be over come in the following circuit and thus regulated power supply is regulated by this circuit.
Unregulated DC power supply

Ro

Vin

I_L

R1

Feedback network

R2

RL

Reference voltage

Vi

Differential amplifier

Vo'
CHAPTER- 10

10.1 DC – DC Converter and Filter Circuit :- Different electronic devices/components like, transistors, flip flops, logic gates, different memory devices counters, ICs etc. require standard and stable voltages for their accurate and fool proof operation.

Moreover, various dc voltages like ±5 V, ±12V, ±18V etc. are required to operate various electronic devices and components.

To do so it is required to arrange different DC supplies from; individual DC sources. To arrange this is a non economic and some job. To solve this type of problem DC-DC converts have been harnessed.

10.1.1 A concrete example of DC-DC converter with labelled block diagram:-

- 48VDC

DC-DC Converter

+ 5VDC

- 5VDC

+ 12V DC

These voltages energise different electronic devices and components.

DC-DC converters are devices to convert either:- 1) Low DC to high DC or 2) High DC to low DC.

Now for this type of conversions two basic operations are required those are:-

1) DC to AC then again 2) AC to DC.

A simplified block diagram may be drawn as below:-

The diagram is self explanatory. Here at first (i) DC is converted to AC and in the next (ii) AC is reconverted to DC and smoothen by filter circuit.

10.1.2 Filter Circuits:-

In case of DC-DC converter it has been found that at first DC is converted to AC then AC is reconverted to DC. After reconversion, it is required to smoothen that DC i.e. to keep the output free from ripple. Filter circuits are arranged to do so i.e. to smoothen the DC.

10.1.3 Statement of Filter Circuits:-

It is a device, which removes the AC components of rectifier output but allows the DC components to reach the load.

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**10.1.4 Description of Filter Circuits:**
Filter circuits are arranged between the rectifiers and load. This circuit is a combination of inductors and capacitors to pass DC and by-pass AC respectively. Similarly, inductors offer high attenuation to AC and capacitors block DC.

A simplified block diagram of filter circuit is as in the following:

\[ \text{Output from rectifier} \quad \text{Filter circuit} \quad \text{Pure DC output} \]

**10.2 Types of Filter Circuits:** There are three types of Filter Circuits commonly used:

1. Capacitor filter, 2. Choke input filter and 3. Capacitor input filter or $\Pi$ filter.

**10.2.1 Capacitor Filter:** It is a fact that capacitor bypasses AC and blocks DC. Rectifier output when fed to load keeping capacitor across the rectified output. Block diagram of capacitor filter is as in the following:

Here, pulsating DC voltage of the rectifier is applied across the capacitor. As rectifier voltage increases, it charges the capacitor as well as supplies current to load.

At the end of the quarter cycle at point A the capacitors charged to the peak value $V_m$ of the rectifier voltage. Now, rectifier voltage starts decreasing and in this time the capacitor discharged through the load and voltage across it decreases from A to B. The voltage across load decrease only slightly because in the next moment the next voltage leak comes and recharges the capacitor. This process is repeated again and again and the output voltage wave form becomes ABCDEFH (as shown in figure).

USES:- It is commonly used in transistor radio battery eliminators.

**10.2.2 Choke Input Filter:** Here, rectified DC enters the circuit (filter circuit) through choke which offers high resistance to AC and low resistance to DC. In this circuit the capacitor is connected across the load.
10.2.2 (a) Circuit Diagram of Choke Input Filter:

![Circuit Diagram of Choke Input Filter]

10.2.2 (b) Working of Filter Circuit:- The output of the rectifier enters into the choke input filter and passes through choke which offers high resistance to AC component of the rectified DC and low resistance to the rectified DC.

Thus it is clear that almost the whole of AC appears across choke and the DC component goes through to the load and gets rid of AC component.

When the rectifier output passes through the point 3 the capacitor by passes the AC and offers high resistance of DC component.

10.2.3 Capacitor Input Filter or Π Filter:- In this type of filter rectifier output centres the circuit through capacitor. This is the reason for the nomenclature (capacitor input filter).

10.2.3 Circuit Diagram of Capacitor Input Filter:

![Circuit Diagram of Capacitor Input Filter]

The figure is self-explanatory. Here, two capacitor in parallel and one choke in series makes a network.
10.2.3 (a) Working of Capacitor input Filter:-

The pulsating output from the rectifier is applied across input terminals 1.2 of the filter.

Action of the filters are in the following:-

a) The capacitor C1 offers low reactance to AC component of rectifier output and offers maximum reactance to the DC component. Thus C1 bypasses maximum AC ripple and DC goes into the choke without any obstruction.

b) The choke offers high reactance to the AC component. Thus this allows DC component to flow through it and blocks the AC.

c) The other capacitor C2 bypasses the AC component which the choke failed to block. Thus pure DC component appears across the load.