Dated :

(Week-1)

Atomic Structure.

Atom

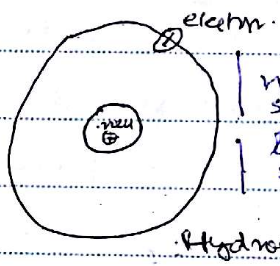
Proton = 2 up quarks, 1 down "
Charge: $\frac{2}{3}+\frac{2}{3}-\frac{1}{3}=1$

Atom is the basic particle of an element and all matters.

Neutron = 2 down $-\frac{1}{3}$
$= -\frac{1}{3}-\frac{1}{3}+\frac{2}{3}$
$=0$

Electron = 3 down $(-\frac{1}{3})$
$= -\frac{1}{3}-\frac{1}{3}-\frac{1}{3}=-1$

- Each element has different atomic structure.
- atom consists of proton, neutron, & electron,
- Atoms has shells & shell consists of orbits $2n^2$



n shells $=2n^2$
l subshell $= 2(2l+1)$

- Shell = K, L, M, N. (1, 2, 3, 4)

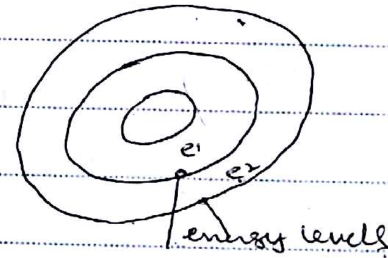
orbits = $K_s\ (s)_0 = 2$ elec $=2$

$L_s\ (s,p)_{0,1} = 2, 6 = 8$

$M_s\ (s,p,d) = 2,6,10 = 18$

$N_s\ (s,p,d,f) = 2,6,10,14 = 32$

$n = 2(n)^2$
$l = 0,1,2,3\ (n-1)$ — s p d f
$m_l = (-l \ldots +l)$
$m_s = +\frac{1}{2}, -\frac{1}{2}$



- orbits shows different energy levels.
- Outer most shell valence shell, electrons valence electron, escaped electrons free electrons.

Matter Classification.

1- Conductors. 2- Insulators. 3- Semi-Conductors.

1 Conductor.

- Conductor is a material that allow easily flow of electrical current,
- best conductors — single element materials copper, silver, gold, aluminum. 1 electron in valence shell. easily breaks.

Visit tShahab.com for more.

Insulators.

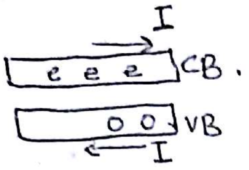
- Insulators are material that ~~[illegible]~~ do not allow flow of current under normal conditions.
  - good insulators are compound material, wood, glass, diamond.
  - Valence electrons tightly bond.

2 Semi-Conductors.

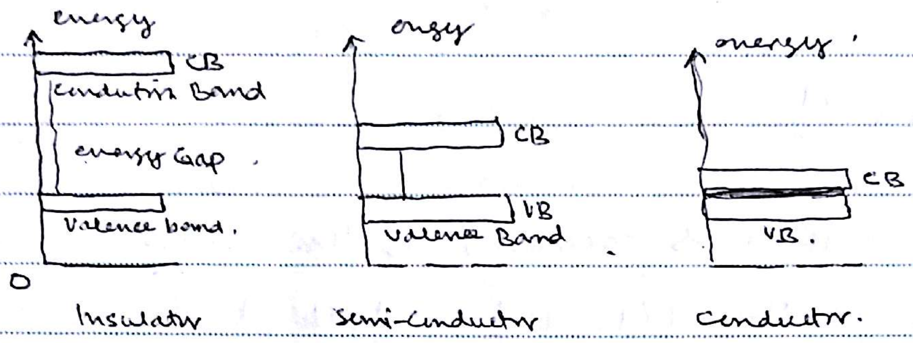
- semi-conductors are materials which conduct b/w Conductors & insulators.
  - pure semi-conductors are not good conductor nor good insulators, $Carbon_6$; $Silicon_{14}$, $Germanium_{32}$
    Valence electron = 4.
  - Pure semi-conductors = Intrinsic semi-conductors
  - Impure semi-conductors = Extrinsic semi-conductors.

· Energy-Band,

- Energy-band basicall shows energy levels of the electron.
  - Band formed by energy levels of valence electron is called Valence Band.
  - When atom is excited and valence electron escapse, becomes free electron, the region is known as Conduction Band.
  - Region b/w VB & CB is forbidden Band.



"electrons move faster than holes because electrons move in conduction band and holes move in valence band.



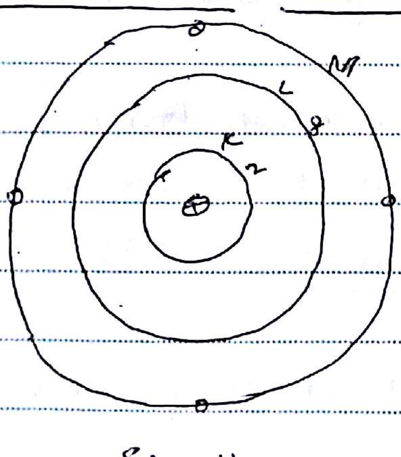
- For insulator difference / distance between VB & CB is Large and electron cross if breakdown condition reaches $\longrightarrow$ Large (extreme) Voltage.
- For semi-conductor

O super-conductor.

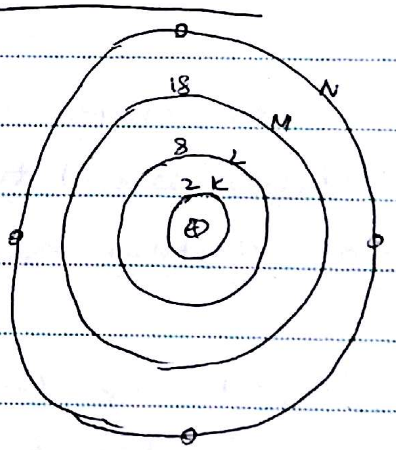
Germenium = 0.7ev (energy require).

Silicon = 1.1ev

Atomic Structure of Silicon & Germenium.



Si = 14



Ge = 32

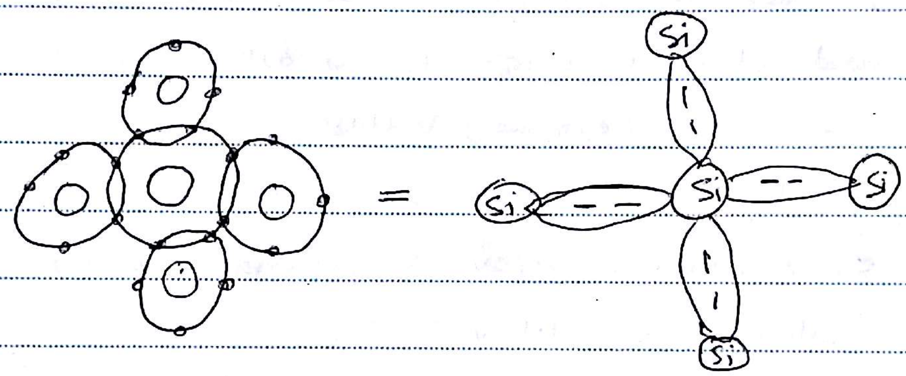
- Valence electrons in Germenium = 4^{th} shell.
- Valence electrons in silicon = 3^{rd} shell.

So Germenium electrons are at higher energy levels that why require less energy to get free.

- But silicon is mostly use becz, Ge_{32} get unstable at High tempreature.

3 Silicon Crystal.

- Silicon crystal is formed, by the sharing the valence electrons (4) with adjacent 4 silicons atoms.



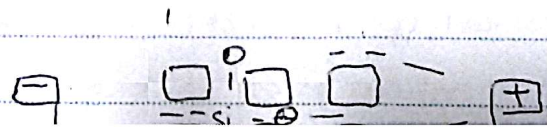
- Crystal is a material having solid & fixed structure

Si-crystal.

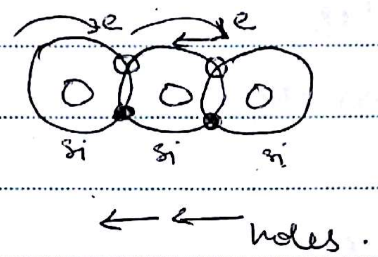
4. Types of Current flow.

- At room temp. no. of electrons moves from valence band to conduction band becomes free electron & leaves vaccancy. = hole.

- Deficiency cause hole, that is left due to electron escape.
- Electron & Hole current
  When voltage is applied to intrinsic semi-conductor. free electrons will move toward the +ve terminal. & this flow is called electron current.



- Hole current is caused, when electron escaps the Valence band/shell, so holes is replace and moves on.



5. Interensic Semi-conductor.

- Semi-conductor that is all pure is called Interensic Semi-conductor.
  Carbon, Silicon & Germanium.

6. Doping.

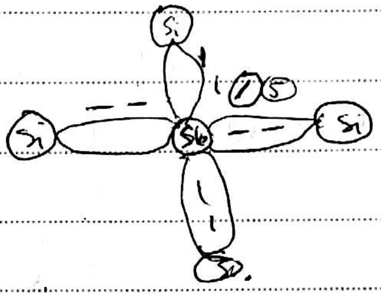
- Doping is the process of adding impurities to the pure semi-conductor for increasing the number of current carriers (electron/holes).

7. Exterensic Semi-conductor.

n-type & P-type Semi-conductors.

- n-type E. Semi conductor.

- n-type semi-conductor is formed by adding pentavalent atoms impurties to the pure silicon.
- These atoms have 5 valence electron. Arsenic (As), Phosporus, (P), Antimony (Sb).



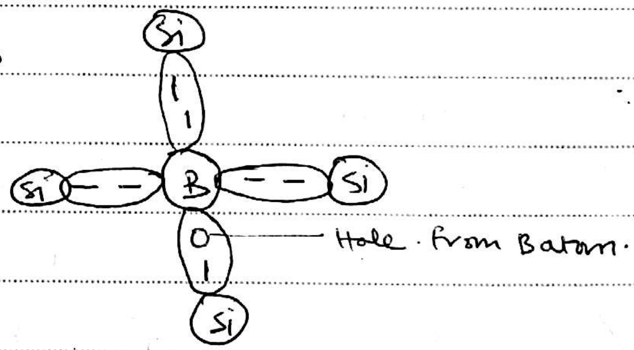
- majority carriers are electrons, holes in minority carrier.

P-type - Semi-Conductor.

- P-type Semi-Conductor is formed by adding trivalent atoms impurities to pure silicon.

- 3 valence electron, Boron(B), Indium, Gallium(Ga)

- majority carriers are holes & minority are electrons.



Extra

Electric current.

Electric current is the flow of electrons in the medium, $I = q/t$

Potential Difference

Energy dissipated in moving charge from one point to another. $P.D = \frac{\text{Work done / energy}}{\text{charge}}$.

Resistance.

The friction offered to the flow of current.

$R = (\text{const}) V/I$, $R \propto V$, $R \propto 1/I$

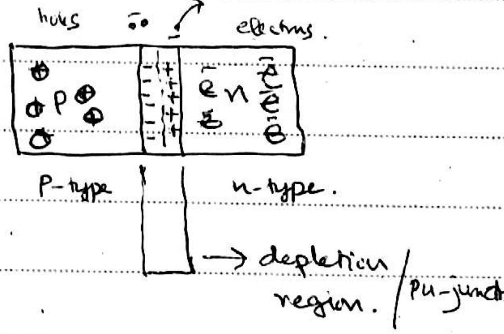
$\uparrow = 1$

Dated :

Lectures.
(week (2) + 3)

Unbiase Diode / Diode.

- Silicon block doped with pentavalent impurity & other part with trivalent impurity, forming pn junction and called as basic Diode. (Pn-junction allow E. Devices to work.) —|◀— one direction flow.
  - n-type material (pentavalent (5) atom + Siclicon atom, - majority carriers electrons.)
  - p-type material (trivalent (3) atom + silicon atom, majority carriers holes).
  - "Depletion region forms, free electrons moves in P-region, leaving pentavalent ions (+), Holes moves toward n-region Leaving trivalent ions (-)."



  - Depletion refers to the region its neither have free electrons / holes.

  - Potential Barrier is created and no further electrons can move. into P-region. which then needs external voltage Source, to cross the barrier, Si = 0.7V. P.D Ge = 0.3V P.D. 25°C.

  - "Depletion Region is thin layer of +ve & -ve ions. / called as Pn-junction as well." The region is depleted. of charges (electrons / holes). It contains the pentavalent and trivalent ions.

Dated :

Biasing Diode.

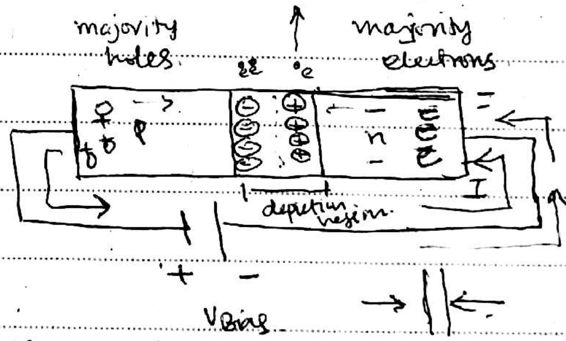
• As no more electrons could flow accross the depletion - region, so external source is required for which Biasing is require. we use generally a dc voltage source for electronic device to work.

- bias refers to establish dc source/ operating conditions accross the electronic device.

- Forward Bias.
- Reverse Bias.

2- Forward Bias.

- Bias to apply DC source.
- Forward Bias is condition to allows current through Pn-junction.

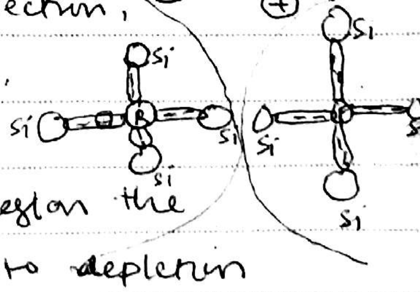


- -ve negative side to n-type
- +ve side to P-type.

- The VBias is more than Barrier potential so cross the barrier & flow of electrons starts

∴ current P ← n

- +ve side of terminal arracts the electron, where path is provided by holes.



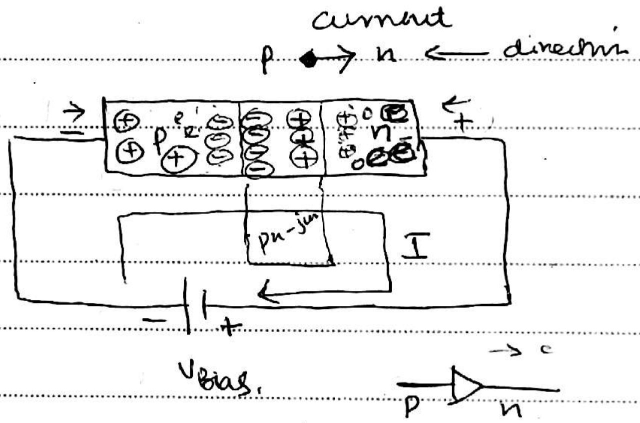
Effect on Depletion Region.

As more electrons flow into depletion region the positive ions reduced, as more holes flow into depletion region from other side -ve ions reduces, so depletion region gets narrower. /shrinks

Dated :

3. Reverse Bias.

- Reverse Bias is the condition, which ~~allows~~ prevents current through Diode



- ⊖ve side of Vbias to P-type
- ⊕ve Side of Vbias to n-type.

Effect on depletion region.

When current start to flow,

- +ve side Bias attracts ⊖free electrons / pentavalent electron. So more +ve pentavalent ions creat.
- −ve side Bias attracts ⊕holes, so electrons get transfered and trivalent ⊖ve ions are formed, which makes depletion region more WIDER.

- Current is due to flow of minority carriers in Reverse-Bias.

- Reverse current flows due to minority carrier in n ~~type and~~ & P type material. ~~/ n / P-type material~~.
- free minority electrons in P-region is pushed by −ve Bias voltage, it cross the barrier, combines with minority holes in n-region & flows down to +ve terminal of ~~b~~battery causing very small reverse current.

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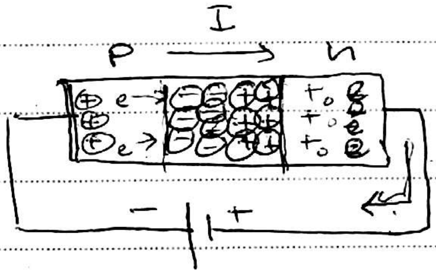
4. Reverse BreakDown.



- When reverse Bias voltage is increased gradually current will also increase & change drastically. (breakDown voltage).
- So free electron (minority) in P-region; as its with high ~~sppeen~~ speed so collide with other valence electrons, and this number increases.
- it then cross the barriers, where on other side there is already majority electrons, (n-region) so current will increase with very high intensity. so high reverse current is generated that can damage the diode/device.
- This rapid increase in current carriers in reverse break down is called Avalanche.

• When the reverse bias voltage is increased to breakdown voltage, the ⊖ve terminal of the battery pushes $\bar{e}_s$ (minority carriers of P-type) into the n-type, where these electrons on their way knows out large number of electrons, resulting in Large current. Known as Breakdown.

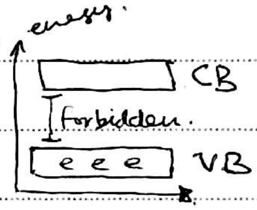
✓ "The external reverse bias voltage when increases to a value called breakdown voltage, reverse current will increase drastically" and could damage the diode".

Visit tShahab.com for more.

Lectures.
(Week-3)

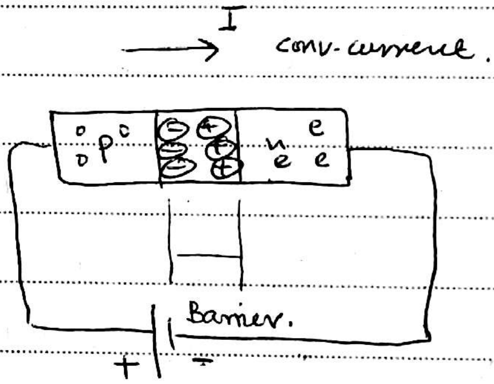
1- Energy Levels. (already Discussed)....

- Electrons revolve around the neucleus in permitted energy levels, contributing to the energy of that shell.



- Valence Band. - Forbidden Region.
- Conduction Band.

2- Barrier Potential.

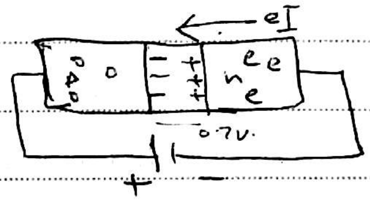


- After formation of Pn-junction electrons diffuse into the P-region & holes diffuse into n-region near by junction, Leaving ⊕ and ⊖ ions.
- A point is reached when total charge of electrons / holes opposes the further diffusion, & equiblirum is reached.
- Barrier is created as because of ⊕ and ⊖ charges in the depletion region and electric field is created.
- "The energy require to move an electron through depletion region into p-region is called Barrier-Potential."

• The barrier potential depends upon the several factors.
  • semiconductive material
  • amount of Doping
  • and temperature

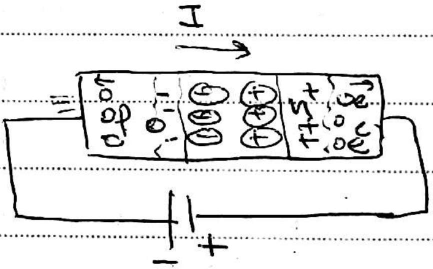
3. Energy Hill

Energy Hill is the barrier / energy gradiant accross the depletion region n-type electron must climb to get into P-region.



4. Reverse Bias Diode.

- Reverse Bias is the condition where current is experiencing huge resistance.



- ⊕ve terminal is connected to n-type & ⊖ve terminal to the P-type part of the diode.

- As the ⊕ve terminal attracts the electrons from n-type region more ⊕ve ions will produce & increases. On other side ⊖ve terminal electrons flows through holes and increases ⊖ve ions near junction which causes widening of depletion region.

o electrons in p-region are forced by ⊖ve voltage source to cross depletion region and combine with minority holes in in n-region produces v. low reverse current

- ~~At a stage.~~ Reverse current is produce as electrons of ⊖ termnal forces minority carrier in P-region to cross depletion and enter in N-region.

Dated :

Lectures.
(week-4)

1- Basic Ideas (Diode)

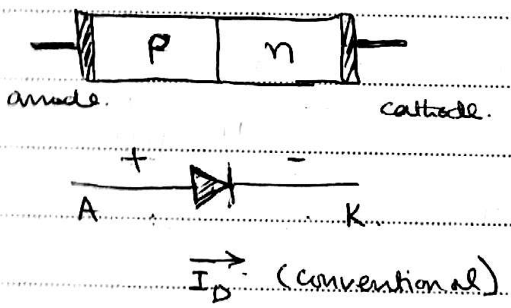
- A diode is a single Pn-junction device, part of the diode is n-type semi-conductor and part of it is P-type semi-conductor.

- Diode is a non-linear device, because of its potential barrier due to which it behaves non-linearly.

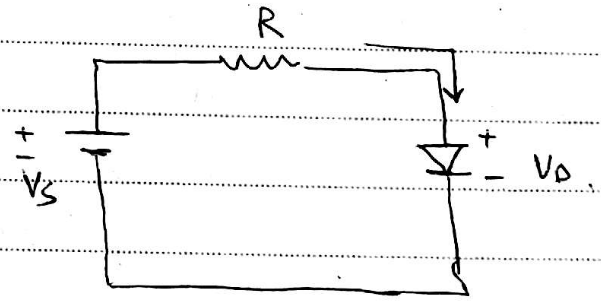
→ below knee.
V – small.
I – small.
→ above knee
V – exceeds
I – huge change.

Symbols for Diode:

- P-side of diode is called anode & n side is called cathode. Diode symbol looks like an arrow that points from P to n side of the diode.

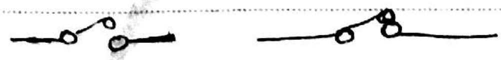


(a)



(b).

- Diode is like a switch. Its closed (ON) when its in forward bias mode and open (OFF) when its in reverse bias mode.

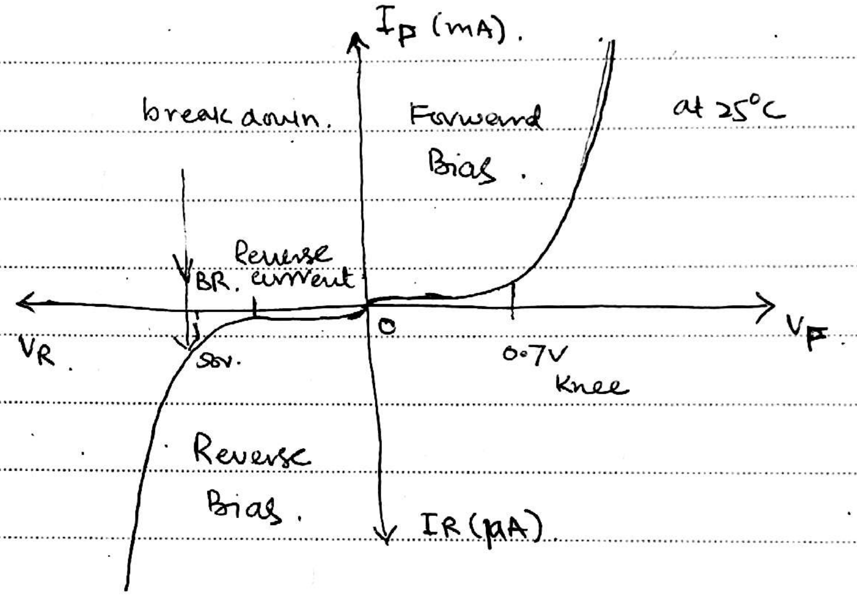


Reverse Bias

Forward Bias.

V-I Characteristic curve of Diode

- above the knee in forward bias current increases rapidly.



- In reverse bias there is a small reverse current, due to minority carriers until the breakdown stage reaches.

Power Dissipation.

- power dissipation is calculated in same way as that of resistor

dissipation = release / emitts

$$P_D = V_D I_D \text{ (watts)}$$

- **Power rating** is the maximum power that the diode can safely dissipate with-out degrading its properties.

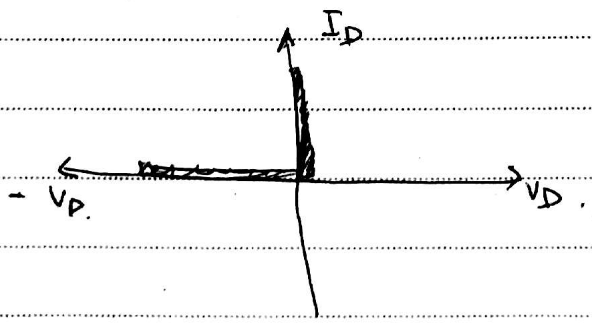
$$P_{max} = V_{max} I_{max} \text{ (watts)}$$

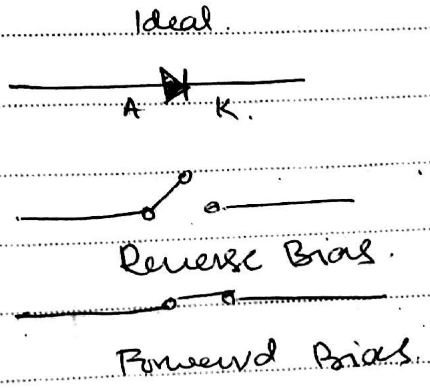
Visit tShahab.com for more.

2- Ideal Diode / First Approximation.

- ideal diode acts like a switch, its closed (on) in forward bias mode and open (OFF) in reverse bias mode.

- The equivalent circuit for ideal diode is



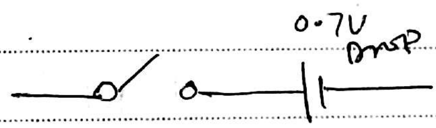


3- The Second Approximation

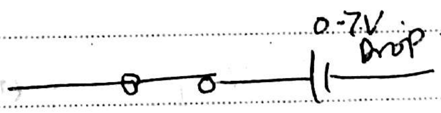
In. Second approximation, diode as switch and 2nd factor, barrier potential is added to it.

- The 2nd approximation give more accurate results for load current and voltage.

Circuit (equivalent)



Reverse Bias



Forward Bias

7. Load Lines

Load line is used to calculate the exact current and voltage of Diode.

Equation for Load line

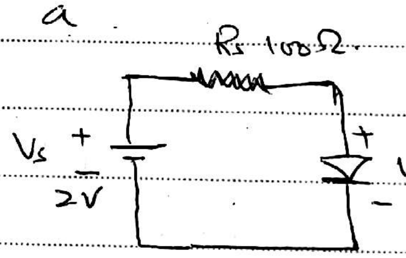
The current through diode is

$$I_D' = \frac{V_s - V_D}{R_s} \quad \text{—— (7.1)}$$

Current remains same, as it series circuit.

Equation 7.1, is a linear so give us a straight Line, on the graph for V & I

- Example to explain Load line



For $V_s = 2V$, $R_s = 100\,\Omega$.

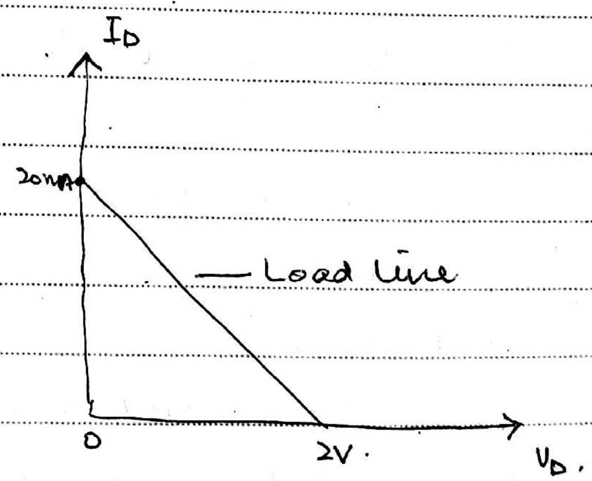
Load current will be

$$I_D = \frac{2 - V_D}{100}.$$

(i)- Let $V_D = 0$.

$$I_D = \frac{2V - 0}{100\,\Omega} = 20mA. \quad \text{(saturation point)}$$

maximum current



(ii)- it gives one point. now assume $V_D = 2V$.

$$I_D = \frac{2V - 2V}{100} = 0\cdot A. \quad \text{(cuttoff point)}$$

minimum current.

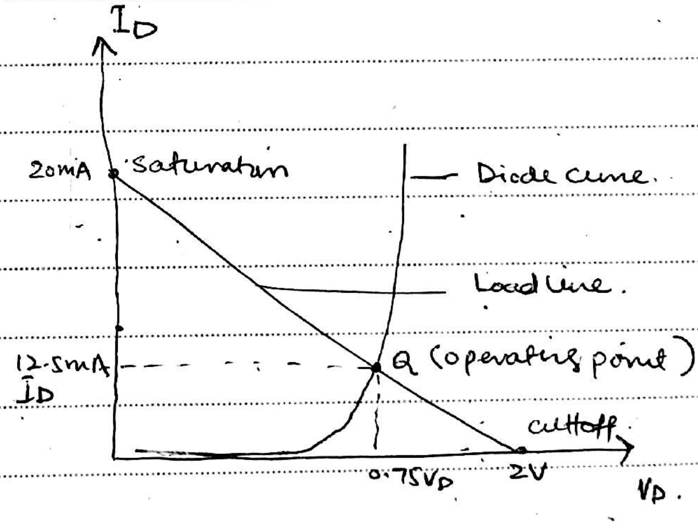
it gives another point, to be drawn at graph.

The Q-Point:

- The point of intersection of diode curve and Load line is known as Q-point. abbreviated for quiescent which means "at rest".

Q-point is operating point of the diode in this example q-point has values of $I_D = 12.5mA$ and $V_D = 0.75V$.

- So the current & voltage of diode satisfy both Ohm's Law & diode curve.



[Diode - Applications]

(Lectures.)

Rectifiers

Week-5

Most electronic devices use dc-voltage to work, since power-line voltage is ac-voltage, so the first theing is to convert ac-voltage to dc-voltage, that is provided by the power supply of the device, and the circuit that produce dc-voltage is called Rectifier.

- The circuit that convert ac-voltage to dc-voltage is called Rectifier.

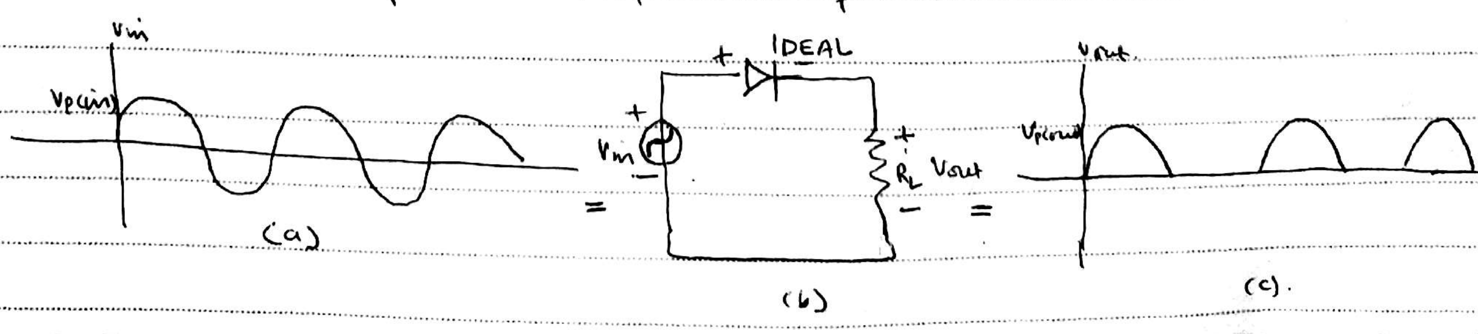
1- Half-Wave Rectifier

In the Half-wave rectifier, the diode is conducting during positive half the cycle, as the diode is "on" and in forward bias, where as in negative half cycle diode is 'OFF" as its in reverse bias, so its in non-conduction state.

- This half-wave voltage produces a unidirectional load current.
- For ideal diode, the peak output voltage equals the peak input voltage.

$V_{rms} = \frac{V_P}{\sqrt{2}}$.

Ideal half wave : $V_p(out) = V_p(in)$.

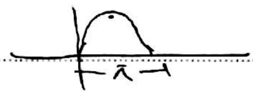


- DC - Value of Half - Wave Signal:

The dc value is the average value of the signal.
The dc value for half wave signal is;

$$V_{avg} = V_{dc} = \frac{V_p}{\pi}$$

∵ area under the curve.



$$V_{dc} = 0.318\,V_p.$$

So V_{avg} is the 31.8 percent of the peak value of the voltage.

- Output Frequency:

Each ⊕ve half. Cycle of input voltage, produces one ⊕half-cycle of output voltage so;

Half wave: $f_{(out)} = f_{(in)}$

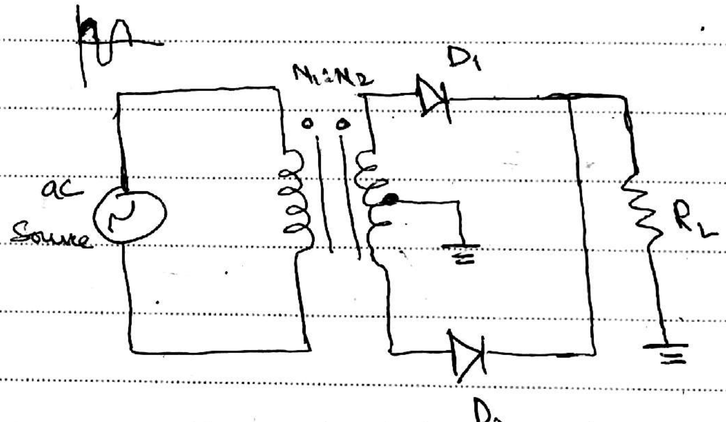
- For Second Approximation;

In 2nd Approximation, the input voltage source must use voltage to cross the barrier-potential of 0.7V, so the Vout will be;

2d half wave: $V_{p(out)} = V_{p(in)} - 0.7V.$

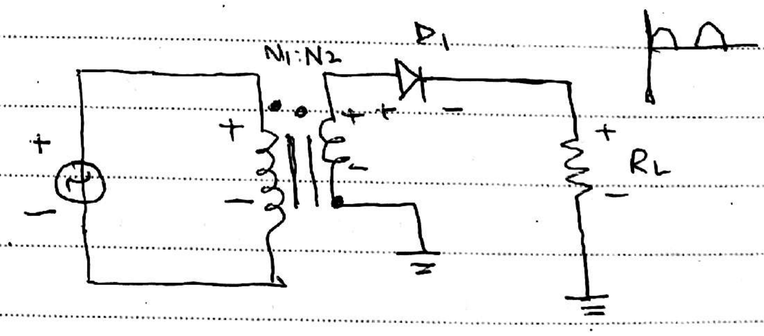
3- Full-Wave Rectifier.

- A full wave rectifier allows unidirectional current through the Load during the entire input cycle, thus changing ac-voltage to dc-voltage.



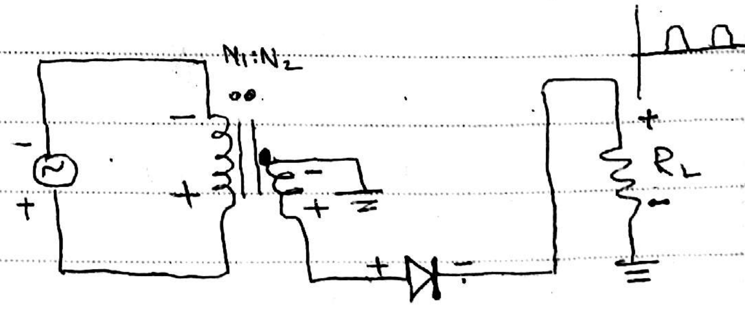
Full-wave-Rectifier (a)

- The full wave rectifier is equivalent to two half wave rectifiers Each of these rectifier has an input voltage equal to half of the Secondary Voltage.

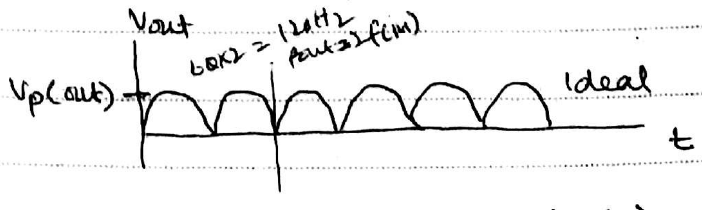


⊕ve half cycle circuit (b)

Diode D_1 conducts on the positive half cycle, producing positive Load Voltage, and Doide D_2 Conducts on the negative half cycle, producing ⊕ve Load Voltage, So as a result rectified load current flows during both half cycles.



⊖ ve half cycle circuit (c)



Full-wave output (d)

Dated :

- Dc or Average value for Full wave rectifier.
Since the full wave rectifier has twice as many positive cycles as that of half wave, So V_{avg} is ;

$V_{rms} = \frac{1}{\sqrt{2}} V_P$.

$$V_{avg} = V_{dc} = 2V_P / \pi$$

$2/\pi = 0.636$ or 63.6%

So the average value is 63.6% of the peak value.

- Output Frequency.
Same as it has twice as many positive cycles compare to half wave so it frequency is

$T_{in} = \frac{1}{60 Hz}$ 16.7ms. (HW)

$$\text{Full wave} \quad f_{(out)} = 2 f_{(in)}.$$

$T_{out} = 0.5(16.7)$ (FW)
$= 8.33$ msec.

- Second Approximation.
As full wave rectifier is equivalent to two half wave rectifiers. So peak output voltage is

∵ For ideal.

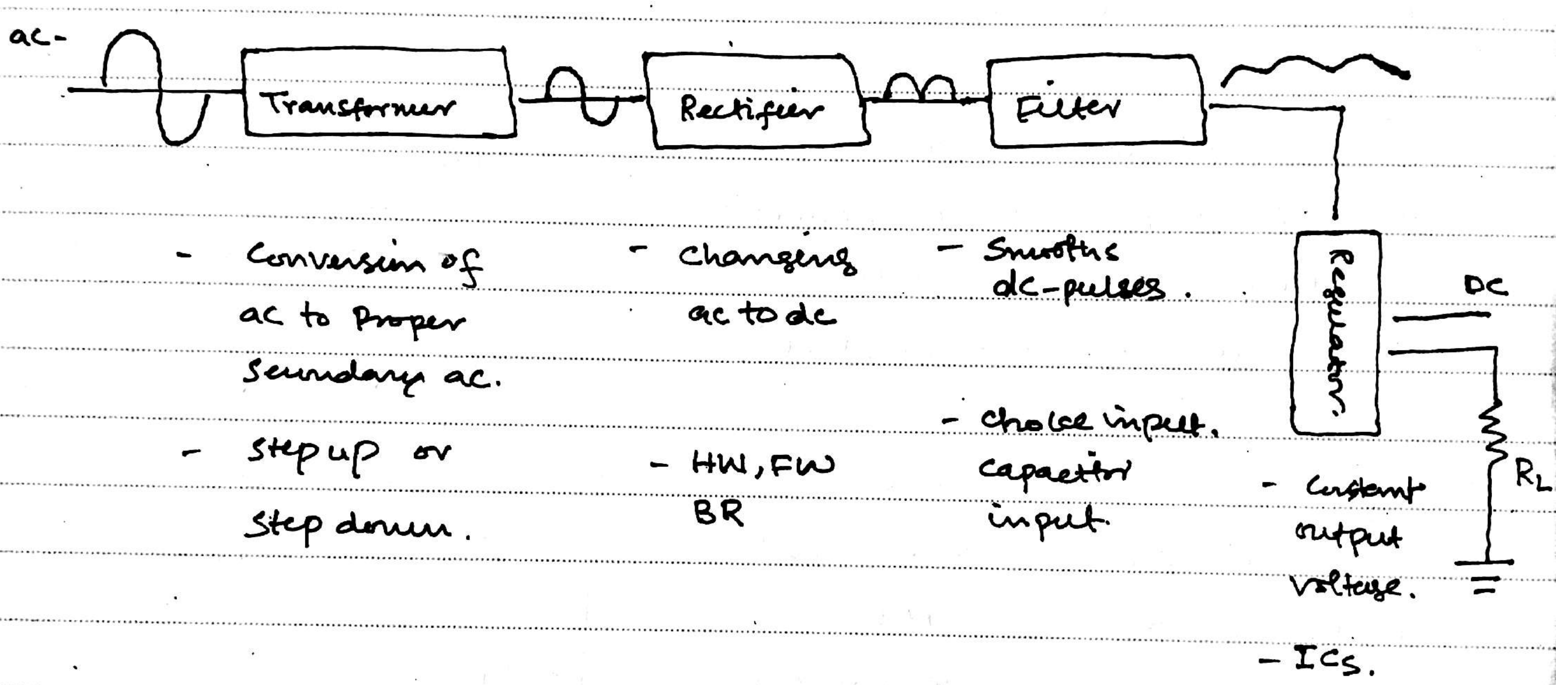
$$V_{p(out)} = V_{p(in)_{half}} - 0.7V$$

$V_{p(sec)}(out) = \frac{1}{2} V_{p(in)_{sec}}$

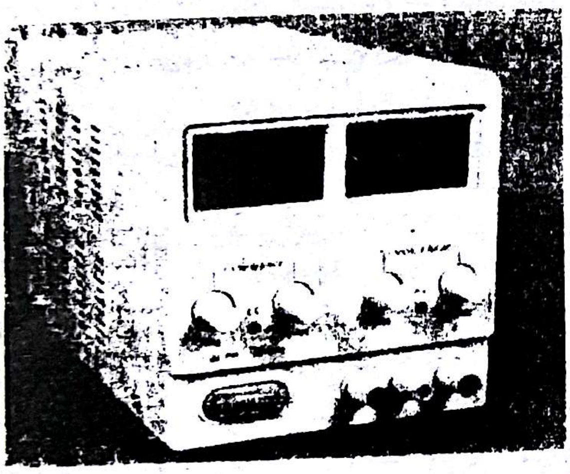
$$V_{p(out)} = \frac{1}{2} V_{p(sec)} - 0.7V.$$

Dated : ____________

Power Supply Block Diagram



DC Power Supplies



17.1. Introduction

Most of the electronic devices and circuits require a dc source for their operation. Dry cells and batteries are one form of dc source. They have the advantage of being portable and ripple-free. However, their voltages are low, they need frequent replacement and are expensive as compared to conventional dc power supplies. Since the most convenient and economical source of power is the domestics ac supply, it is advantageous to convert this alternating voltage (usually, 220 V rms) to dc voltage (usually smaller in value). This process of converting ac voltage into dc voltage is called *rectification* and is accomplished with the help of

(*i*) rectifier,

(*ii*) filter; and

(*iii*) voltage regulator circuits.

These elements put together constitute dc power supply.

17.2. Unregulated Power Supply

An unregulated power supply is one whose dc terminal voltage is affected significantly by the amount of load. As the load draws more current, the dc terminal voltage becomes less.

17.3. Regulated Power Supply

It is that dc power supply whose terminal voltage remains almost constant regardless of the amount of current wn from it. An unregulated supply can be converted into a regulated power supply by adding a ge regulating circuit to it (Art. 17.17).

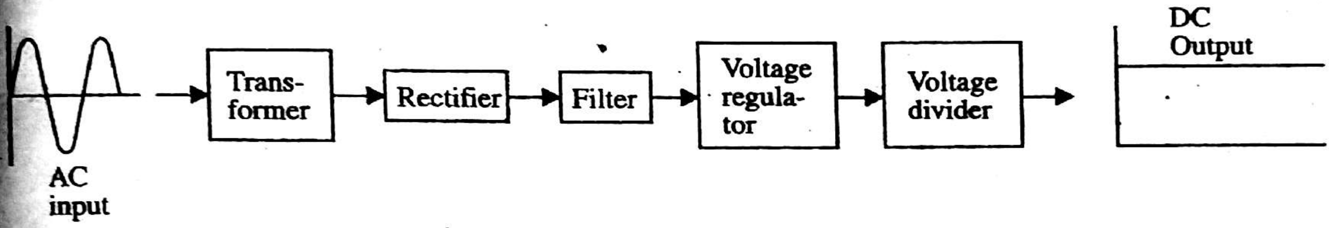


Fig. 17.1

A typical dc power supply consists of five stages as shown in Fig. 17.1.

1. Transformer

Its job is either to step up or (mostly) step down the ac supply voltage to suit the requirement he solid-state electronic devices and circuits fed by the dc power supply. It also provides isolation m the supply line–an important safety consideration.

2. Rectifier

It is a circuit which employs one or more diodes to convert ac voltage into pulsating dc voltage.

3. Filter

The function of this circuit element is to remove the fluctuations or pulsations (called ripples) sent in the output voltage supplied by the rectifier. Of course, no filter can, in practice, give an put voltage as ripple-free as that of a dc battery, but it approaches it so closely that the power pply performs as well.

4. Voltage Regulator

Its main function is to keep the terminal voltage of the dc supply constant even when

(*i*) ac input to the transformer varies (deviations from 220 V are common) or

(*ii*) the load varies.

Usually, Zener diodes and transistors are used for voltage regulation purposes. Again, it is npossible to get 100% constant voltage but minor variations are acceptable for most of the jobs.

5. Voltage Divider

Its function is to provide different dc voltages needed by different electronic circuits. It consists of a number of resistors connected in series across the output terminals of the voltage regulator. Obviously, it eliminates the necessity of providing separate dc power supplies to different electronic circuits working on different dc levels.

Comments

Strictly speaking, all that is really required for conversion from ac to dc is a transformer and rectifier (in fact, even the transformer could be eliminated if no voltage transformation is required). The filter, voltage regulator and voltage divider are mere refinements of a dc power supply though they are essential for most applications except for battery charging and running small dc motors etc.

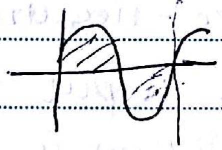
Dated : ____________

2- Clippers and Limiters.

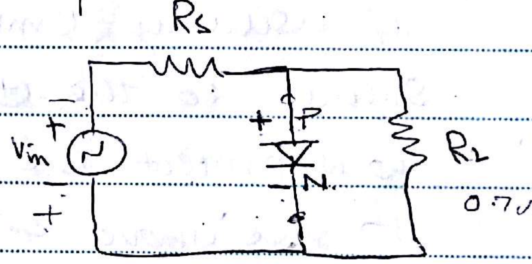
Clipper:

A clipper is a circuit that either remove positive or negative part of the signal. It basically shapes the signal to the required conditions.

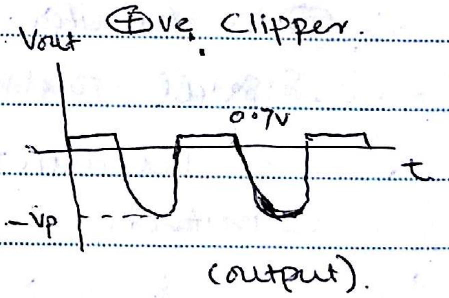
Positive Clipper:



During the ⊕ve half cycle the diode is turned on. and the Looks Like a short across the output terminal, only 0.7v, will appear in the ⊕ve half cycle. and during the negative half cycle diode acts Like open and all the negative voltage appear across the Load resistor.



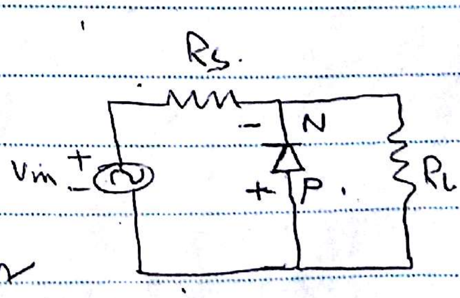
⊕ve Clipper.

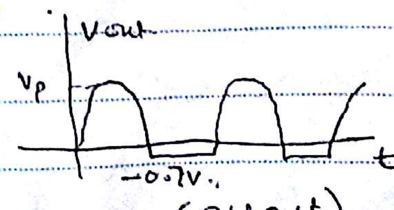


(output).

Negative Clipper:

By reversing the polarity of the diode, we get a negative clipper, For the ⊕ve half cycle, the diode would be off and voltage will appear across the Load, where as for the ⊖ve half cycle the diode will conduct and 0.7V will appear through the ⊖ve half cycle.



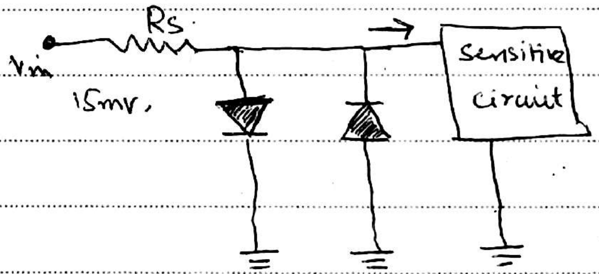


(output)

Limiter

- A Limiter is circuit that prevents input voltage from undesirable increase for sensitive circuits.

- The positive-negative Limiter protects the input signal, if usually 15mv is an input signal so the ⊕ve Limiter will protect the input signal to rise above 0.7V. and the ⊖ve Limiter will protect the signal to drop below -0.7V. So the variation to input is Limited.



- For a normal operation both diodes would be OFF.

Dated : ____________

3. Clampers:

The Clamper is a circuit that shifts a signal positively or negatively by adding the dc-component voltage to the signal.

⊕ve DC is added.

⊖ve H.cycle : $-V_{p(in)} + V_{p(in)} - 0.7V$

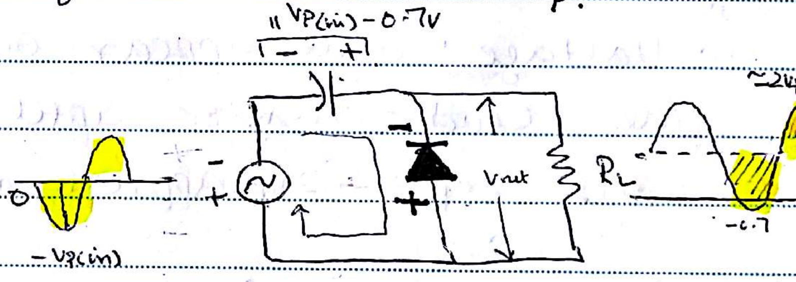
⊕ve H.cycle : $V_{p(in)} + V_{p(in)} - 0.7V$

$= 2V_{p(in)} - 0.7V.$

$\cong 2V_p.$

- Positive Clamper

Positive Clamper basically shifts the signal ⊕vely upwards, by adding the dc-voltage.



positive clamper Operation

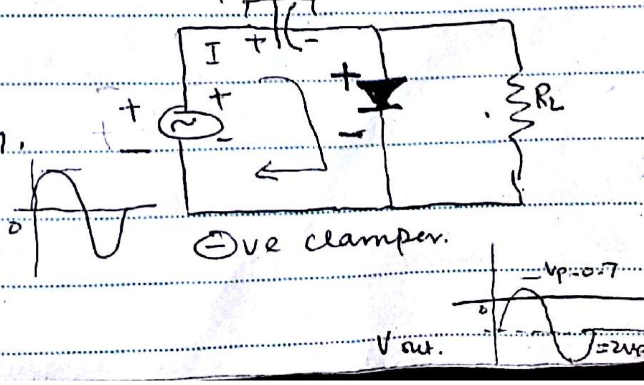
⊕ve dc value is added.

For the first ⊖ve half cycle, the diode is forward bias, and capacitor starts charging upto the level of $V_p - 0.7V$ approx. after the quarter ⊖ve half cycle, the diode starts to reverse bias, as because of the polarities, so the voltage will appear across the Load-resistor upto the value of $2V_p$ approx.

$V_{P(in)} - 0.7$, $2V_p = ac + dc$

- Negative Clamper.

Negative Clamper shifts the signal ⊖vely downwards, by changing the diode direction, which changes capacitor polarities as well.



⊖ve clamper.

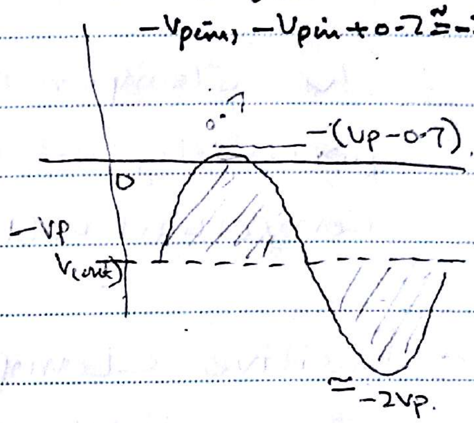
⊖ve DC-added.

⊕ve H.cycle =

$V_{pin} - V_{p(in)} + 0.7 = 0.7v$

⊖ve H.cycle =

$-V_{p(in)} - V_{pin} + 0.7 \cong -2V$



⊖ve clamper output.

− ⊖ve dc-value is added.

For the positive half cycle the diode is forward bias and the capacitor is charging upto the level of $-(V_{p(in)} - 0.7)$. After the quarter ⊕ve half-cycle the diode starts to reverse bias as because polarities, so the voltage will appear across the Load-resistor uptil the level of: $-2V_p$ approximately.

Clampers are use in television receiver, radars and communication systems as well.

Dated :

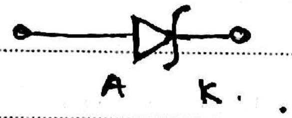
(Lectures)

1. Zener Diodes

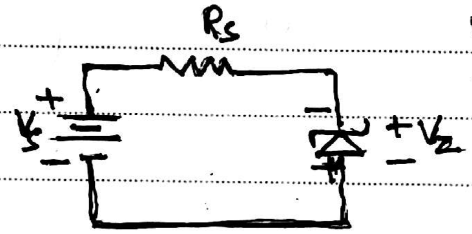
Week-(7+8)

- A zener diode is a silicon pn-junction device that is designed to operate in the reverse breakdown-region. The zener diode is a backbone for voltage regulator circuits which provides the constant voltage despite large changes in line voltage.

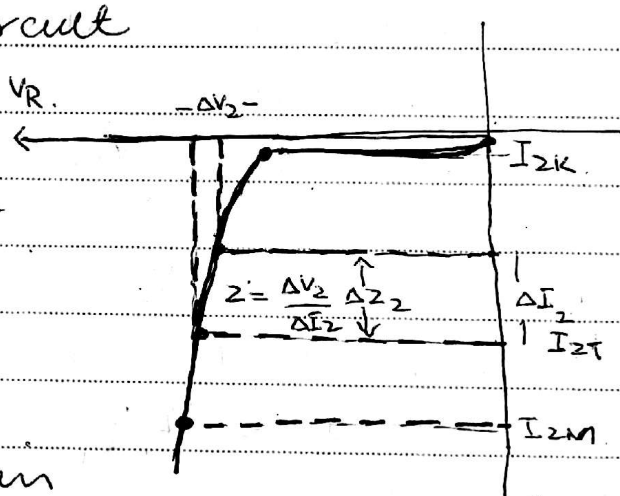
- Zener diodes equivalent circuit



(a). Schematic Symbol.



(b) Zener Diode



(c) [V-I-characteristic curve]

- The zener diodes can operate in three regions. Forward, Leakage and breakdown.

In forward region it starts conducting from 0.7V, just like silicon diode.

In leakage region (between 0 — breakdown) it has only small reverse current.

In breakdown region, the current has increased sharply, where as the voltage remains constant approximately equal to V_z.

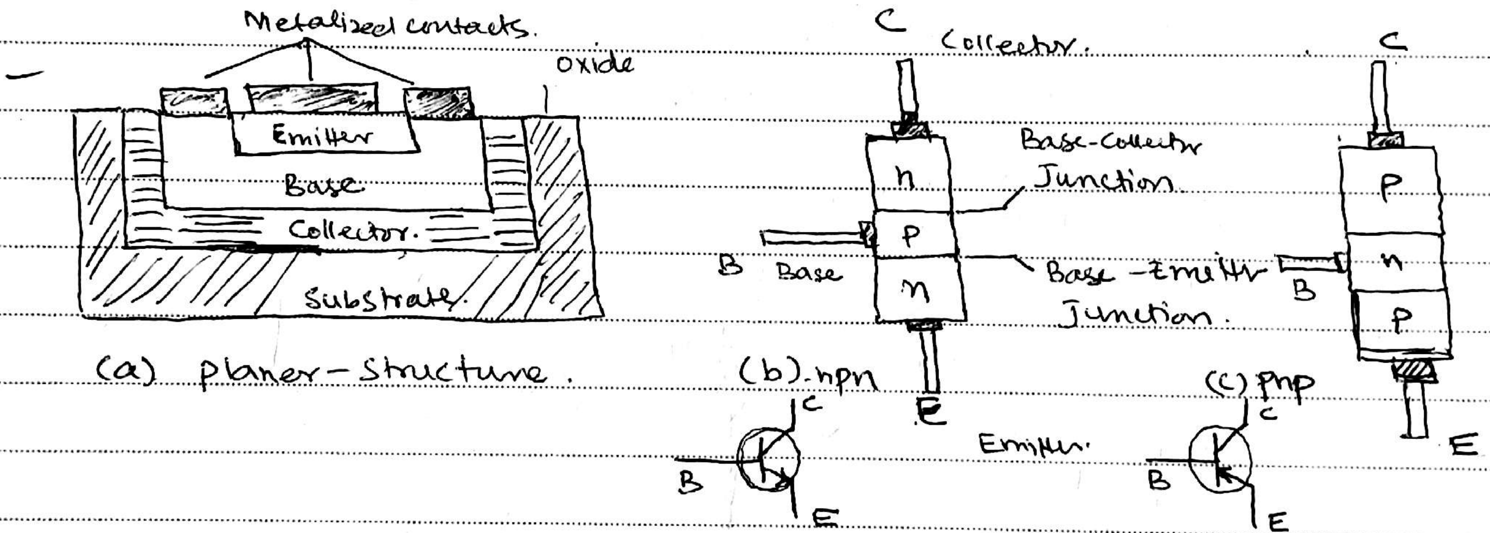
When breakdown voltage is greater than 5V, Avalanch effect is produced, (large reverse current because of minority carries, and when $V_{BR} < 5V$, zener effect is produced.

Date:

Bipolar Junction Transistors (BJTs) (Lectures)

1- The unbiased Transistor / BJTs. Week - 9.

- BJTs stands for Bipolar Junction transistor. bipolar means using both polarities (electrons & holes). Transistors are formed by the formation of three regions emitter, base & collector separated by two pn-junctions.



(a) planer-structure. (b) npn (c) pnp

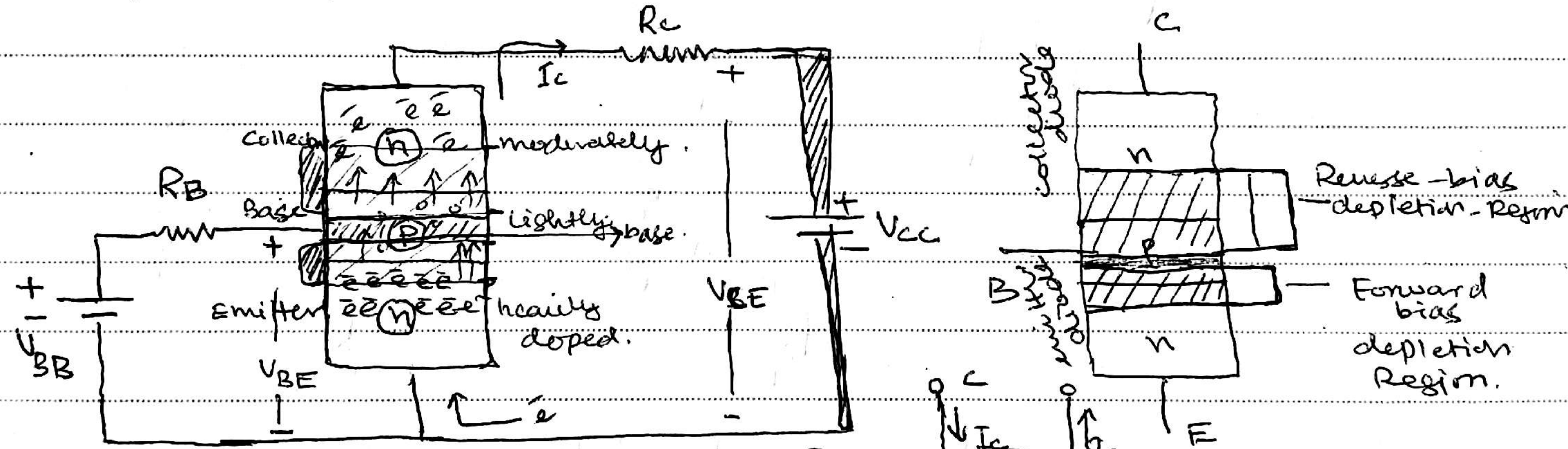
- BJTs have two types, npn & pnp transistors. npn has two n-regions and one p-region where as pnp has two p-regions and one n-region seperated by two pn-junctions. pn-junction joining Base and emitter region is called as Base-Emitter junction and pn-junction joining Base and collector is called as Base-Collector Junction. The emitter is the bottom region doped heavily. Base is the central region doped lightly and collector is the top-region doped moderately.

Transistors are use for amplification purposes. and could be used as a switch as well.

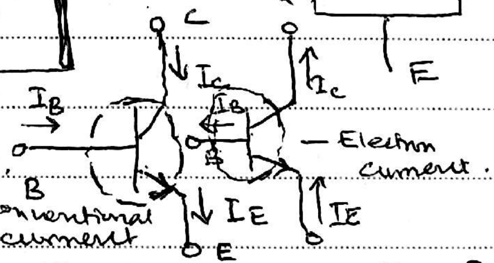
2- Biased-Transistor/Transistor Operation:

For the transistor to run properly both the pn-junction should be biased properly/correctly with external dc-voltage sources.

For both transistor npn or pnp base-emitter (BE) junction should be forward-bias and base-collector (BC)-junction should be reverse bias. The operation of both npn & pnp are same.



npn-Transistor.

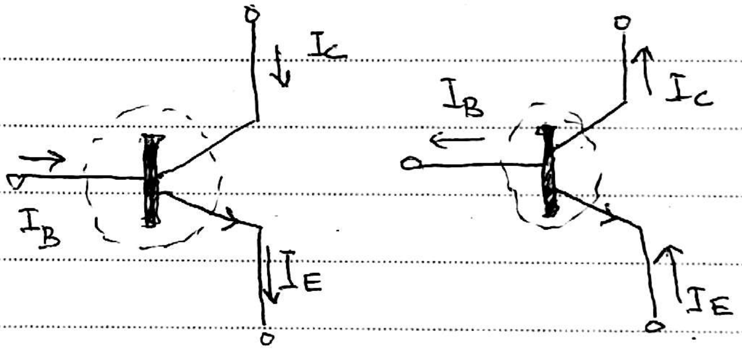


The Forward-bias Base-Emitter narrows the BE-depletion region, where as reverse-bias base-Collector widens BC ~~the~~ depletion region. As the V_{BB} forward bias the emitter-region, it forces the free electrons to cross the depletion region and enter into the Base. The thin base gives almost all the electrons ($\bar{e}$s) enough time to diffuse into the Collector, where these electrons are pulled by the +ve terminal of the Vcc voltage producing Collector-current. (I_C)

3- Transistor Currents

- Transistor Contains three currents, emitter current (I_E), base current (I_B) and Collector current (I_C).

As the emitter is the source of electrons so I_E is the Largest current. the base current is much small, where as all the electrons pass to collector from base (approximately) so Collector current is almost as Large as emitter.



(a). npn- Conventional current.

(b). npn- electron current.

For current relation-ship apply Kirchhoff's current Law: so

$$I_E = I_C + I_B$$

emitter current is sum of base-current & collector current.

and $I_C \simeq I_E$ $\because$ I_B is much smaller. 1% of I_C.

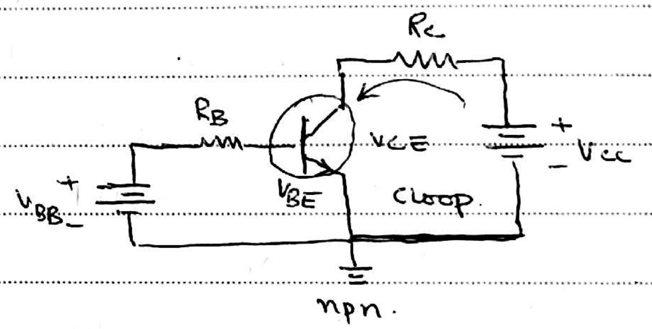
Alpha : The dc-alpha (α_{dc}) is the ratio of collector current to the emitter current. the ratio is always less than 1, as I_C is approximately equal to I_E.

$$\alpha_{dc} = I_C / I_E.$$

Beta : The dc-beta (β_{dc}) is the ratio of collector current to the base current. Its called as Current gain, because smaller base-current controls, larger collector current. Its values lies between 100 & 300. (power transistor) & 20 to 100 (For H. power transistor). so; $\beta_{dc} = \dfrac{I_C}{I_B}$

3- Collector Curves.

The collector curve is between V_{CE} (Collector-Emitter voltage) and collector current (I_C) for the fixed value of base current (I_B).



Collector voltages and power:

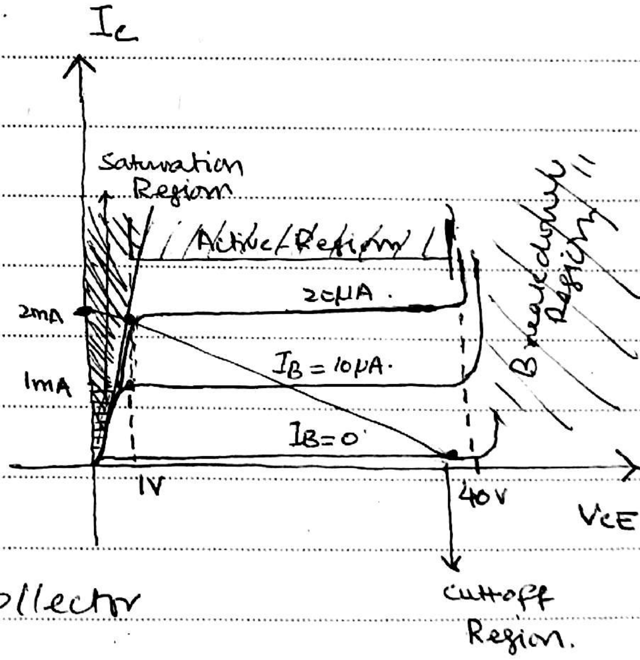
Using Kirchhoff's Voltage Law in the collector loop we gets;

$V_{CC} = V_{CE} + I_C R_C$.

$V_{CE} = V_{CC} - I_C R_C$. & $P_D = V_{CE} I_C$.

$I_C = \frac{V_{CC} - V_{CE}}{R_C}$.

Region of Operation:



Transistor operates in different region depends upon its usage.

As an amplifier transistor is operated in Active-region.

In active/Linear Region emitter diode is Forward-bias and Collector diode is reverse bias, where as the collector current remains constant, because it gather almost all electrons that emitter injects in the base so its not effected by voltage of collector.

Second one region is breakdown-region. transistor is not optimized for breakdown region. so it would be damage if its operated in break-down Region.

Dated :

Saturation - Region and cuttoff - region are the operated region when transistor is use as a switch:

In saturation - region both emitter and collector diodes are forward bias, as collector is yet not get reverse-bias, so here is a sharp rise in the collector current I_c. Saturation-region resembles switch ON.

$I_{c(sat)}$ — max.

V_{CE} — min (0)

In cuttoff region. both emitter and collector are reverse bias, so there is a small reverse collector current that flow in reverse direction, where as base - current is zero. Cuttoff region resembles switch OFF.

I_c — min (0).

V_{CE} — max (V_{cc}).

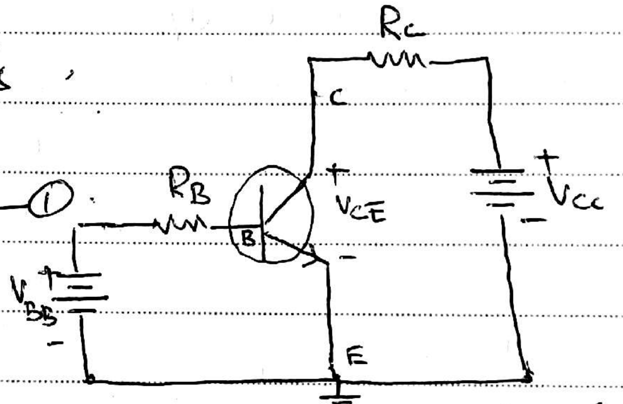
2- The Load Line

The Load line is effect of load on I_c and V_{CE}.
The straight line between the I_c and V_{CE} gives the load line.

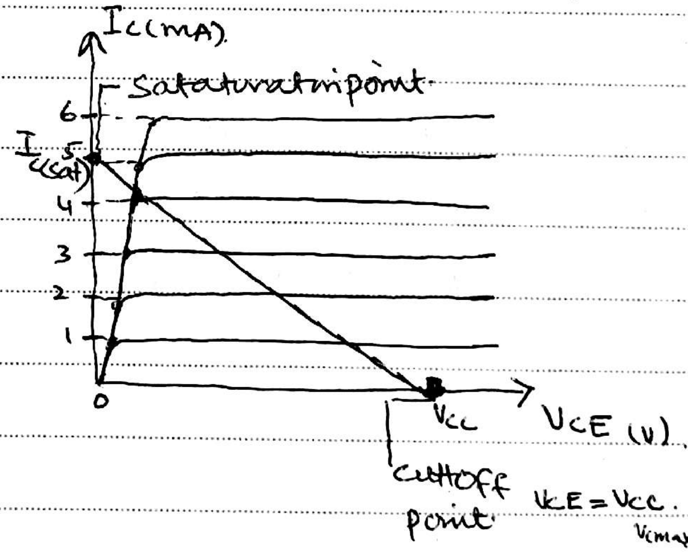
Load line equation is, given by;

$$\boxed{V_{CE} = V_{cc} - I_c R_c} \text{ — (1)}$$

$$I_c = \frac{V_{cc} - V_{CE}}{R_c}$$



(a)- Common Emitter (npn).



Saturation point is the point where V_{CE} is approximately zero and Collector current is maximum, so its given by.

$$I_{c(sat)} = \frac{V_{cc}}{R_c}, \quad V_{CE} = 0.$$

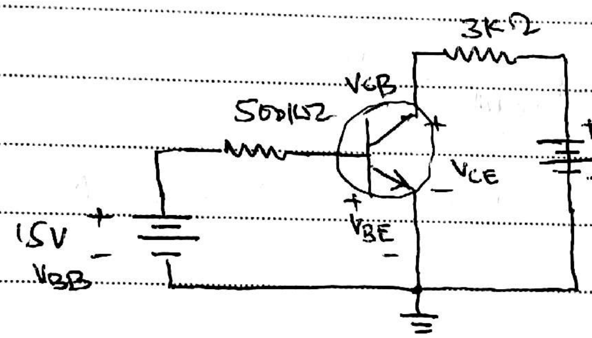
CuttoFF point is the point, where I_c is very small approximately zero and V_{CE} is maximum of V_{cc} so its given by;

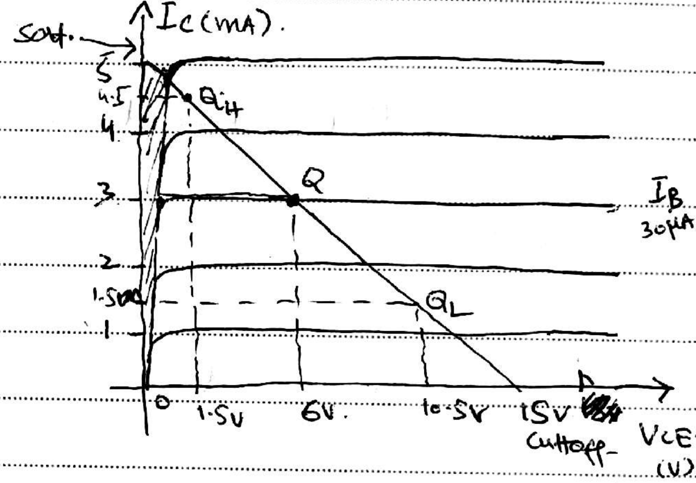
$$V_{CE(cuttoff)} = V_{cc}, \quad I_c = 0.$$

cuttoFF = open
saturatin = close

3 - The Operating Point.

The operating point or Q-point gives the Operating co-ordinates of I_c (collector current) and V_{CE} (Collector Emitter voltage) on the Load-Line.





The operating point is plotted as:
using Formulas we get the Transistor curve, Load Line and then the Q-point.

$$I_B = \frac{V_{BB} - V_{BE}}{R_B}.$$

$$I_c = \beta_{dc} I_B.$$

$$V_{CE} = V_{cc} - I_c R_c.$$

For Transistor curve.

For ideal Transistor : $V_{BE} = 0$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = V_{BB}/R_B = \frac{15}{500K\Omega} = 30\,\mu A.$$

suppose.
$\beta dc = 100$.

$$I_c = \beta I_B = (100)(30\,\mu A) = 3\,mA.$$

For Load Line

saturation point : $I_{c(sat)} = V_{cc}/R_c = 15/3k\Omega = 5mA.$

$I_{c(sat)} = 5mA, \; V_{CE} = 0$

Cuttoff point : $V_{CE(\text{cut off})} = V_{cc}$

$V_{CE} = 15V \quad \& \quad I_c = 0mA.$

For Q-point.

Here $I_c = 3mA.$

whereas ; $V_{CE} = V_{cc} - I_cR_c.$

$= 15 - (3mA)(3k\Omega)$

$= 15 - 9$

$V_{CE} = 6\text{volts}.$ $\quad I_c = 3mA.$

$V_{CE} = 6\text{volts}.$

Drawing these points of I_c and V_{CE} gives the Q-point.

$150 - 50 = 100$, $100 - 50 = 50$

For variations in Beta value (50 — 150).

For Low Q-point : $I_c = \beta_{dc}(I_B)$

$= 50(30\mu A) = 1.5mA.$

$V_{CE} = 15V - (1.5mA)(3k\Omega) = 10.5V.$

For High Q-point : $I_c = \beta_{dc}(I_B)$

$= 150(30\mu A) = 4.5mA.$

$V_{CE} = 15 - (4.5mA)(3k\Omega) = 1.5V.$

JFETs (Basics) : FETs >

FET stands for field Effect Transistor, which is a unipolar device, because it operates on the single type of charge carrier.

FET has two types

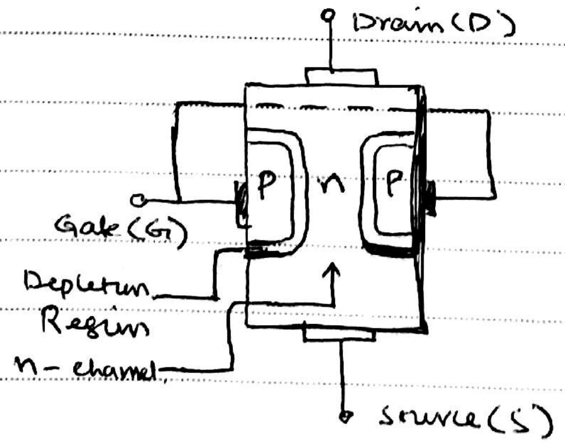
(i) JFETs (Junction field Effect Transistor)

(ii) MOSFETs (Metal oxide semiconductor Field Effect Transistors).

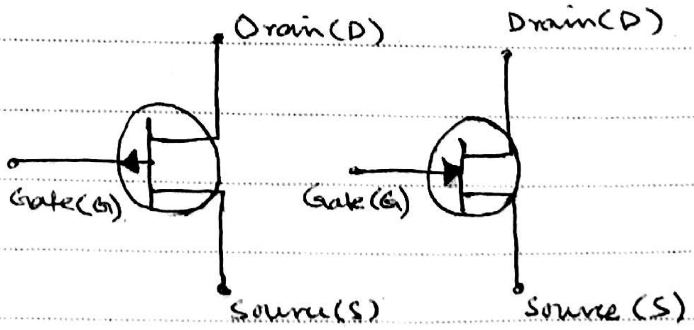
1- JFETs

JFETs (Junction Field Effect Transistor) is a type of FET that operates in a reverse bias condition of the pn-junction. JFETs has two main types n-channel JFETs & p-channel JFETs.

n-channel JFETs is formed by diffusing two p-type regions in the n-type material. The upper end is the Drain, lower end is the Source and the two p-regions are connected to the Gate.



(a). n-Channel JFET

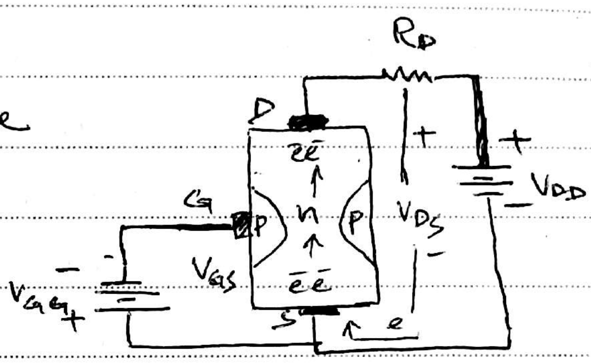


(b). P-channel. n-channel.

(b)- (symbols.)

Dated :

JFET is operated with the Gate-source pn-junction reverse bias. So V_{GG} set the reverse bias-voltage. where as V_{DD} is the drain voltage.



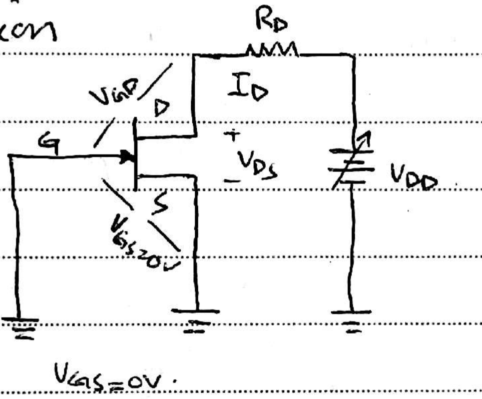
The electrons enter the source cross the pn-junction and enter into drain, terminateing at the V_{DD} (+ve terminal).

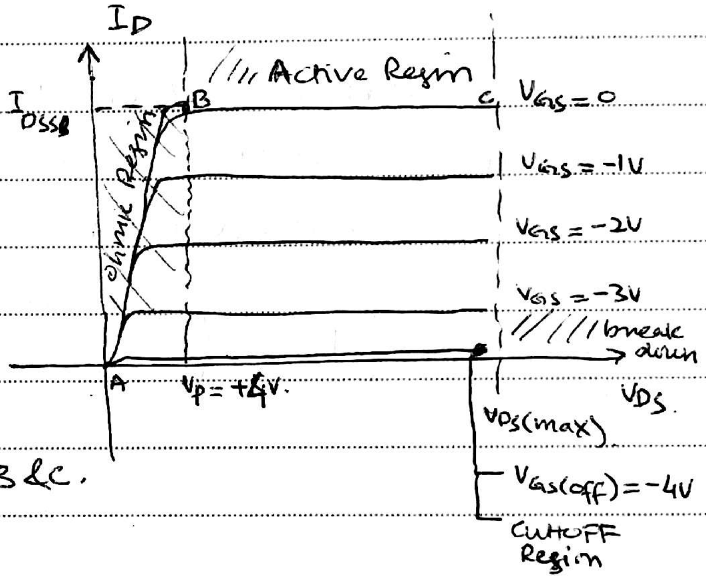
Through gate to source voltage (V_{GS}) the width of the channel could be controlled thus controlling the Drain current (I_D).

2- Drain Curves (JFET):

- The Drain curve is between the Drain source voltage (V_{DS}) and drain-current (I_D) for the shorted Gate source voltage ($V_{GS}=0V$).

- For ohmic Region JFETs behaves as ohmic-resistance, For Active-region drain current remains constant between B&C.





- Pinch-OFF Voltage: (V_P)>

For $V_{GS}=0V$, the value of V_{DS} for which there is a constant value of drain current (I_D) is called pinch-OFF voltage (V_P). Its called as drain to source current with shorted Gate (I_{DSS}).

For pinch OFF voltage condition is;

$V_{GS}=0$, $I_D=I_{DSS}$ and $V_{DS}=V_P$. (minimum value of V_{DS})

CutOFF voltage: ($V_{GS(OFF)}$)>

For $V_{GS}=-V_P$, the value of V_{DS} at which the drain current reaches its minimum value is called CutOFF Voltage ($V_{GS(OFF)}$).

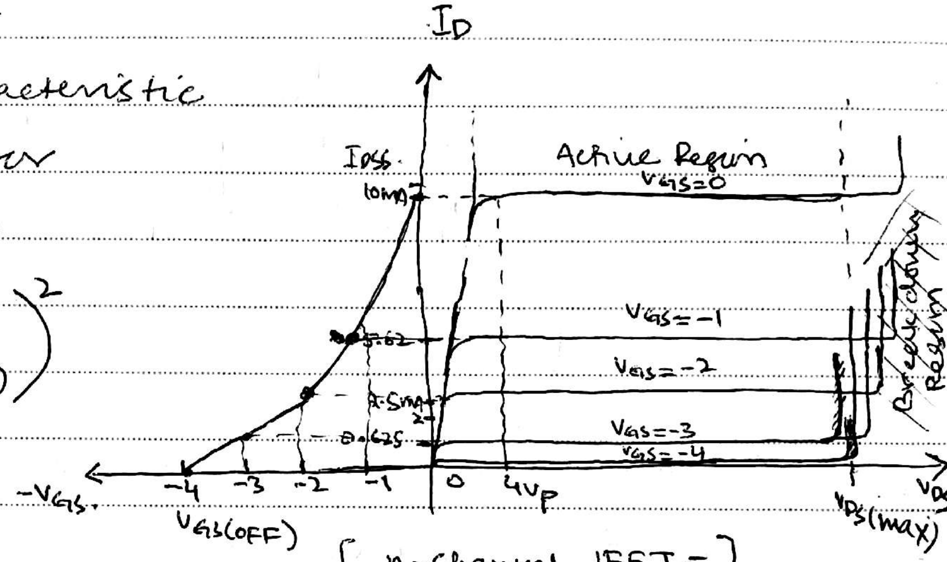
$V_{GS}=-V_P$, $I_D=\min(0)$ and $V_{DS}=\max$.

3 - JFET - Transfer Characteristic Curve

The transfer characteristic curve is between the drain-current (I_D) and Gate-Source Voltage (V_{GS}) by using the values of Drain-curve.

The transfer characteristic curve equation for JFET is given by:

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(OFF)}}\right)^2$$



n-channel JFET: TC-curve.

The JFET-Transfer characteristic curve shows the operating limits of a JFET.

$I_D = 0$ when $V_{GS} = V_{GS(OFF)}$

& $I_D = I_{DSS}$ when $V_{GS} = 0$.

example: The JFET has a $I_{DSS} = 9mA$ and $V_{GS(OFF)} = -8V$. using these values find out I_D, for $V_{GS} = 0V, -1V$ and $-4V$.

Solution: For $V_{GS} = 0V$.

$$I_D = I_{DSS} = 9mA.$$

For $V_{GS} = -1V$.

$$I_D = I_{DSS}\left(1 - V_{GS}/V_{GS(OFF)}\right)^2 = 6.89\,mA.$$

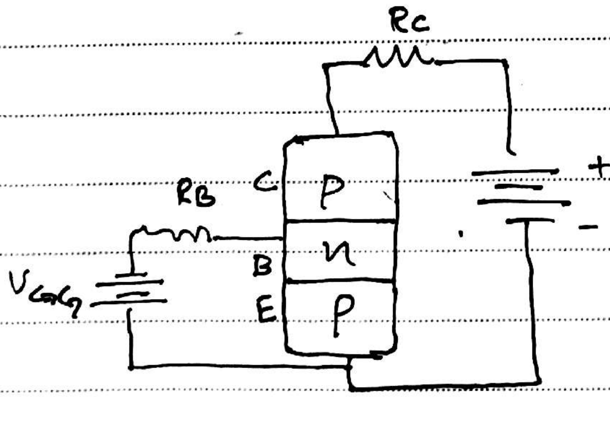
For $V_{GS} = -4V$

$$I_D = I_{DSS}\left(1 - V_{GS}/V_{GS(OFF)}\right)^2 = 2.25\,mA.$$

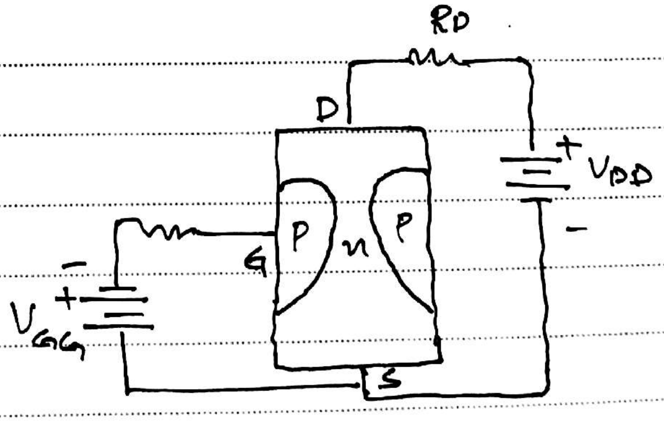
6- Comparision between BJT and FET

Bipolar Junction Transistor / Field Effect Transistor

BJT	FET
1- BJT is a bipolar junction device i.e electrons, holes	1- Field Effect Transistor is a unipolar device i.e n-channel or P-channel JFET.
2- BJT is a current controlled device (I_B)	2. FET is a voltage controlled device, (V_{GS})
3- BJT operates on the forward bias mode (V_{BE} - Emitter diode).	3- FET Operates on the reverse bias voltage (V_{GG} ⊖)
4- BJT are temperature sensitive devices	4- FET are temperature stable devices
5- BJT are Large in size	5- FET are Smaller in size.



npn - BJT.



n-channel JFET.

▶ MOSFETS

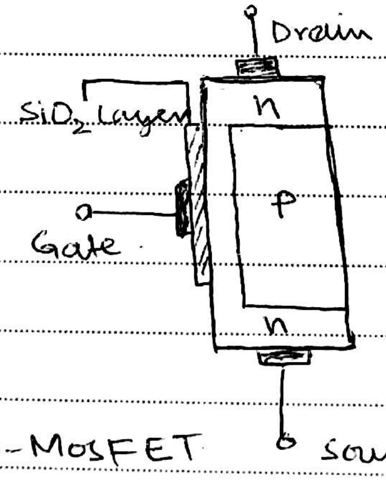
MOSFETs is another type of FET, it stands for Metal-Oxide Semiconductor Field Effect Transistor. It differ from JFET in the structure that its Gate is isolated from the channel. Its also Known as Insulated-Gate FET (IGFET).

Types of MOSFET

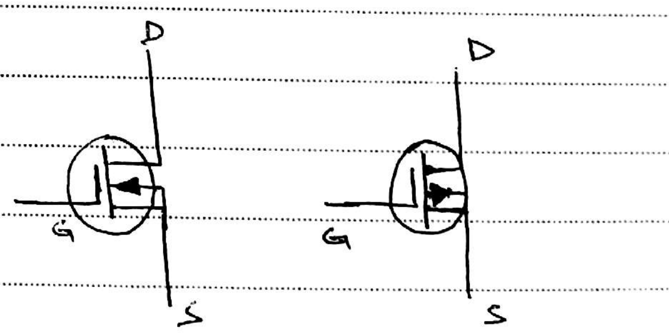
(i) - D-MOSFET. (Depletion) (ii) E-MOSFET (Enhancement)

1- D-MOSFET: (Depletion-Mode) >

D-MOSFET contains the n-region (narrow-channel) diffused into the substrate of P-region. Drain and source are connected with n-region where as Gate is insulated from the channel with SiO_2 Layer.



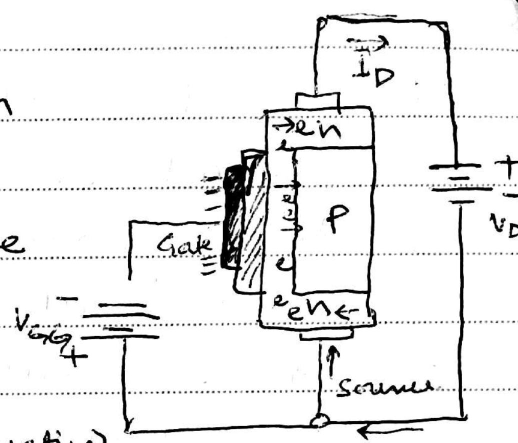
(a)- D-MOSFET



(b)- n-channel P-channel

In the D-MOSFET, the Gate-Voltage is ⊖ve, where as when the supply voltage VDD froces free electrons, it flows from the source and then through the narrow channel towards the drain. Here gate just act as one plate of capacitor, channel as other plate of capacitor where as SiO_2-Layer is di-electric.

With the ⊖ve voltage on the Gate repels the conduction electrons from the channel, depleting n-channel from electrons, hence increasing ⊖ve voltage decreasing the conductivity of the channel, where as ⊕ve voltage increases the channel conductivity

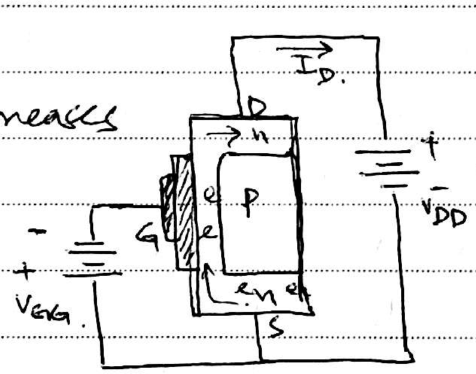


Dated :

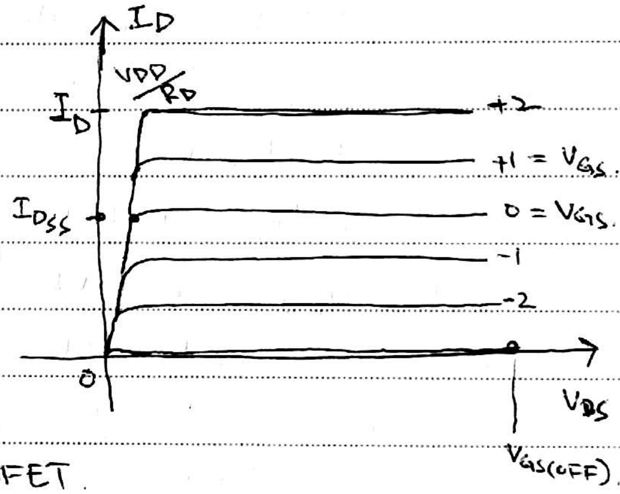
2. Drain Curve: (D-MOSFET) >

The Drain curve of n-channel D-MOSFET is similar to the JFET, and in between the Drain current (I_D) and Drain source voltage (V_{DS}). The only difference is that D-MOSFET is also operated in the ⊕ V_{GS} voltage.

The Drain-current (I_D) decreases as the V_{GS} gets ⊖ve and I_D increases with the ⊕V_{GS}.



n-channel D-MOSFET.



I_{DSS} is the Drain current with shorted Gate. and is achieved when $V_{GS} = 0$. Here I_{DSS} is no longer a maximum drain current.

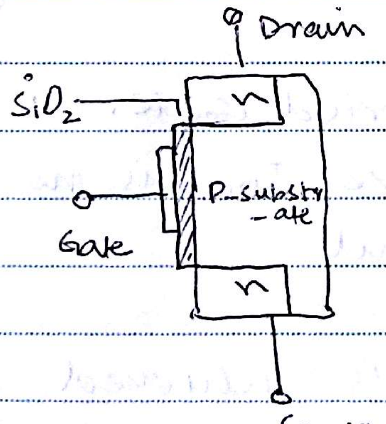
$V_{GS(OFF)}$ is the cutoff point and is achieved when drain current is zero.

- Negative V_{GS} = Depletion-mode
- Positive V_{GS} = Enhancement-mode.

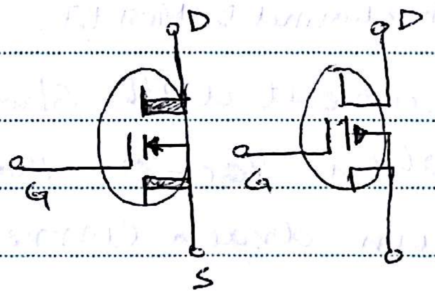
3- Enhancement Mode MOSFET: (E-MOSFET)

Enhancement Mode MOSFET is formed, such that the p-substrate extends towards the SiO_2 Layer. and there is no n-channel.

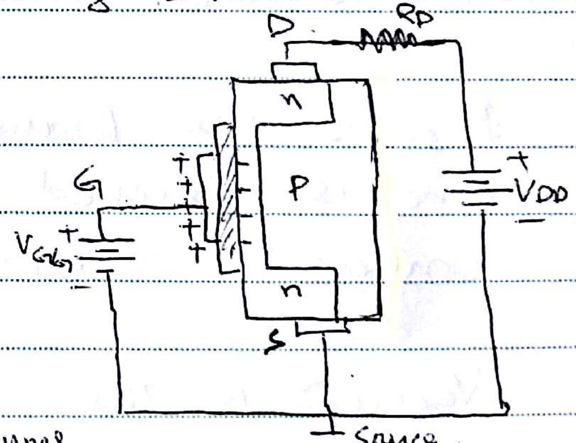
E-MOSFET Operates with the ⊕ve gate Source Voltage (V_{GS}). The positive gate (G) attracts the free-electrons into P-region, that ($\bar{e}$), combines with holes, until the holes with the SiO_2 Layer fills up, resulting in a thin Layer same as n-type material so the electrons flow from Source (S) to Drain (D) producing Drain-current.



(a). E-MOSFET

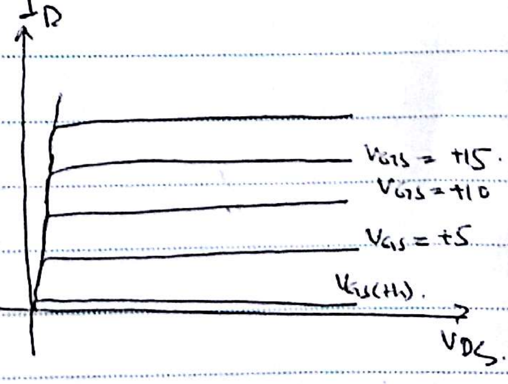


(b)- n channel P-channel



(c). E-MOSFET ($V_{GS} > V_{GS(th)}$)

The Drain curve for E-MOSFET is for positive V_{GS} values.
The minimum V_{GS} that is required for the thin n-type Layer is called threshold voltage ($V_{GS(th)}$).



Reference Material:

1. Principles of Electronics by VK Mehta.
2. Electronic Principles by Albert Malvino (seventh Edition)