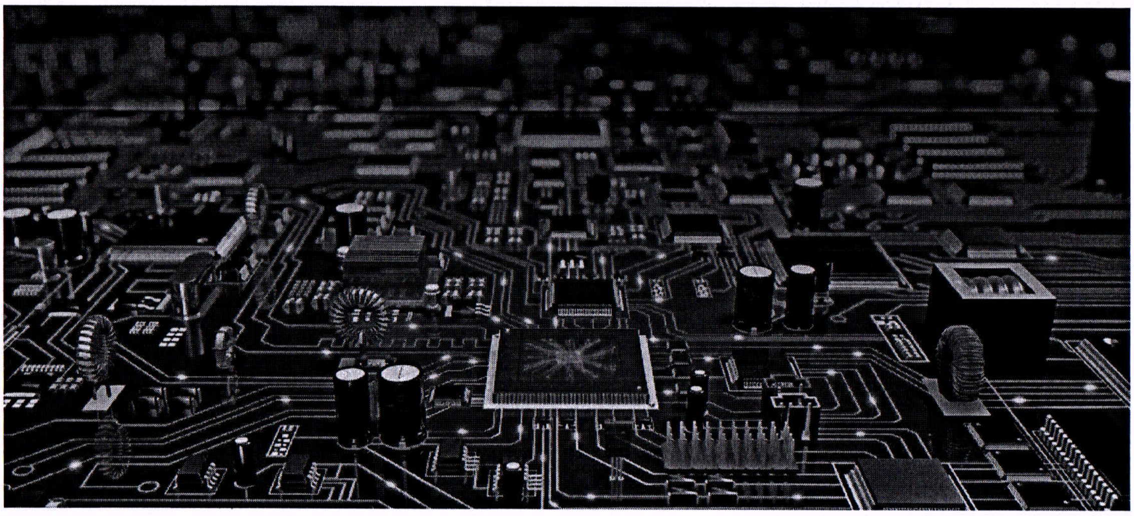
RAMAIAH INSTITUTE OF TECHNOLOGY

Introduction to Electronics Engineering (ESC133)



Manjunath C Lakkannavar

INTRODUCTION TO ELECTRONICS ENGINEERING

Course Code: ESC133
Pre-requisites: Physics of Semiconductors
Course Coordinator: Mr. Manjunath C Lakkannavar

Credits: 3:0:0
Contact Hours: 42

Unit – I

Semiconductor Devices: Introduction, Semiconductor diodes: PN junction diode and its characteristics, Diode types, Zener diodes, Light emitting diodes, Bipolar junction transistors: BJT operation, Characteristics, Current gain.

• Pedagogy/Course delivery tools:	➢ Chalk and talk
• Links:	➢ https://nptel.ac.in/courses/117103063
• Links:	➢ https://a.impartus.com/ilc/#/course/80947/295

Unit – II

Power Supplies: Block diagram, Half-wave rectifier, Full-wave rectifiers (Center Tapped/Bi-phase and Bridge) and Capacitor filter circuit, Zener diode voltage regulators, Output resistance and voltage regulation, Voltage multipliers

• Pedagogy/Course delivery tools:	➢ Chalk and talk
• Links:	➢ https://nptel.ac.in/courses/117103063
• Links:	➢ https://a.impartus.com/ilc/#/course/80947/295

Unit – III

Amplifiers: Types of amplifier, Gain, Common-emitter configuration as an Amplifier, Common-emitter configuration as Switch: Cut-off and saturation modes.
Oscillators: Positive feedback, Conditions for oscillation, BJT as an Oscillator (LC).

• Pedagogy/Course delivery tools:	➢ Chalk and talk
• Links:	➢ https://nptel.ac.in/courses/117103063
• Links:	➢ https://a.impartus.com/ilc/#/course/80947/295

Unit – IV

Logic Circuits: Logic functions, Logic gates: NOT, AND, OR, NAND, NOR, X-OR, X-NOR, Combinational Logic: Introduction, Adders: Half adder, Full adder, Sequential Logic: Introduction to Flip Flops, JK flip flop and its applications.

• Pedagogy/Course delivery tools:	➢ Chalk and talk
• Links:	➢ https://nptel.ac.in/courses/117103063
• Links:	➢ https://a.impartus.com/ilc/#/course/80947/295

Unit – V

Microprocessor: Introduction, Block diagram of a microprocessor system, Internal architecture of 8-bit microprocessor CPU, Microprocessor operation
Microcontroller: Introduction, Block diagram of a microcontroller system.

• Pedagogy/Course delivery tools:	➢ Chalk and talk
• Links:	➢ https://nptel.ac.in/courses/117103063
• Links:	➢ https://a.impartus.com/ilc/#/course/80947/295

Text Books:

1. Mike Tooley, 'Electronic Circuits: Fundamentals & Applications', 4th Edition, Elsevier, 2015. DOI https://doi.org/10.4324/9781315737980eBook, ISBN: 9781315737980

Reference Books:

1. Digital Logic and Computer Design, M. Morris Mano, PHI Learning, 2008 ISBN-978-81-203- 0417-84
2. D P Kothari, I J Nagrath, 'Basic Electronics', 2nd edition, McGraw Hill Education (India),Private Limited, 2018.

Course Outcomes (COs):

At the end of the course, students will be able to:

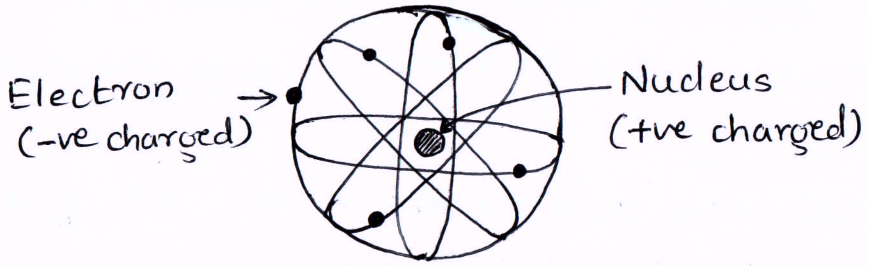
1. Describe semiconductor devices. (POs-1,2,8)
2. Understand semiconductor applications. (POs-1,2,8)
3. Analyze the various circuits of BJT. (POs-1,2,8)
4. Analyze logic circuits. (POs-1,2,8)
5. Understand the architecture and operation of microprocessor and microcontroller. (POs-1,8,10)

UNIT-1 : SEMICONDUCTOR DEVICES.

Introduction

The Atom

→ The atom can be thought of as consisting of a central nucleus surrounded by orbiting electrons as shown below.



→ The nucleus of an atom is largely a cluster of two types of particles, protons and neutrons.

→ Protons have a positive electrical charge, equal in magnitude to the negative charge on an electron.

→ A neutron has no charge at all.

→ Since atoms normally contain an equal number of electrons and protons, the net charge present will be ZERO.

→ If an atom loses an electron, it has lost some negative charge. Thus it becomes positively charged and is referred to as a positive ion.

→ Similarly, if an atom gains an additional electron, it becomes negatively charged and is termed as a negative ion.

→ Electrons are in constant motion as they orbit around the nucleus of an atom.

→ Electron orbits are organized into shells.

→ The maximum number of electrons present in the first shell is 2, in the second shell 8, and in third, fourth and fifth shells it is 18, 32 and 50 respectively.

→ It is important to note that, the movement of electrons only involves those present in the outer shell called Valence shell.

→ The semiconductors are mainly classified into two types they are Intrinsic and Extrinsic semiconductor.

→ An intrinsic semiconductor is a pure semiconductor without doping.

→ In an intrinsic semiconductor, the no. of electrons and holes (+ve) are equal. Therefore zero conductivity.

→ Doping is the phenomenon by which some impurity is added to a pure semiconductor to increase conductivity.

→ Depending on the doping there are two extrinsic semiconductor i.e., n-type and p-type.

→ In an n-type semiconductor, a pentavalent impurity is added, which has 5 valence electrons.

→ Pentavalent : Arsenic, Antimony, Phosphorous etc.

→ Each pentavalent impurity atom can donate one electron. Hence, it is called Donor atom.

→ In n-type, the electrons are majority and holes are minority carriers.

→ In p-type semiconductor, a trivalent impurity is added, which has 3 valence electrons.

→ Trivalent: Ga, In, B, etc.

→ The addition of each trivant impurity can make one hole. Hence, it is called Acceptor atom.

→ In p-type, holes are majority and electrons are minority carriers.

SEMICONDUCTOR DIODES

→ The two type of materials namely p-type and n-type are chemically combined with a special fabrication technique to form a PN junction.

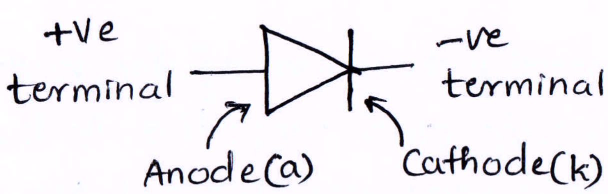
→ The resulting device is called a PN junction DIODE.

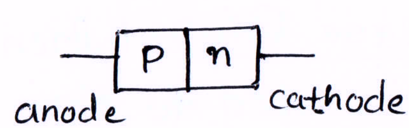
→ A diode is a one-way device, offering a low resistance when forward-biased, and behaving almost an open switch when reverse-biased.

→ PN Junction Diode

→ a pn-junction permits substantial current flow when forward biased, and blocks current when reverse-biased.

→ Thus, it can be used as switch: ON when forward-biased
OFF when reverse-biased.





→ If the p-type material is made positive relative to the n-type material by an amount greater than its forward threshold voltage/built in potential (0.6 V or 0.7 V in case of silicon and 0.2V or 0.3V in case of germanium), the diode will freely pass current.

→ If, on the other hand, the p-type material is made negative relative to the n-type material, virtually no current will flow in the device.

→ The connection to the p-type material is referred to as the anode(a) while that of the n-type material is called the cathode (k)

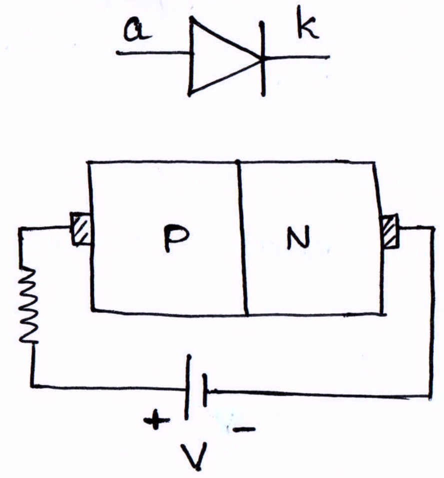
→ With no external applied potential, electrons from n-type will move into p-type materials and fill some vaccent holes.

→ This action is called as Diffusion. This result in the production of a region either side of the junction in which there are no free charge carriers. This zone is known as Depletion Region.

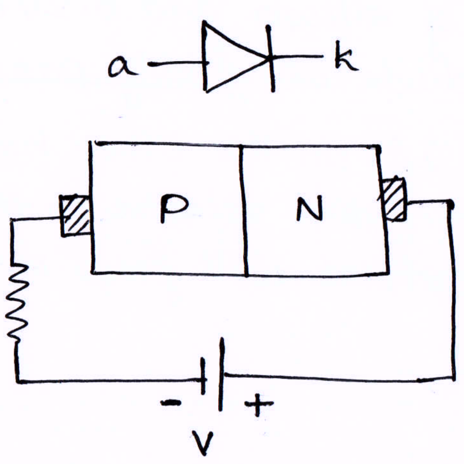
→ There are two ways of connecting voltage source to a PN junction.

1) Forward Bias: When the terminal of the battery is connected to the p-side and negative terminal to the n-type, it is said to be in forward biased. A large amount of current flows through the junction under this condition.

2) Reverse Bias: When positive terminal of the battery is connected to the n-side and negative to the p-side, it is said to be in reverse biased. No current or very small current flows through the junction.



Forward Biased PN Junction.



Reverse Biased PN Junction.

Forward Biased PN Junction.

→ When a PN junction is forward biased, the holes in p-type are repelled by the positive potential of the voltage and are forced to move towards the junction.

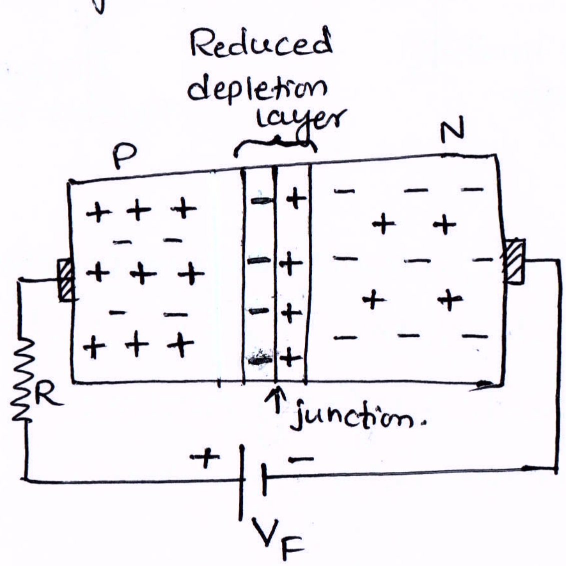
→ Similarly, the electrons in n-type are repelled by the negative potential of the voltage and are forced to move towards the junction.

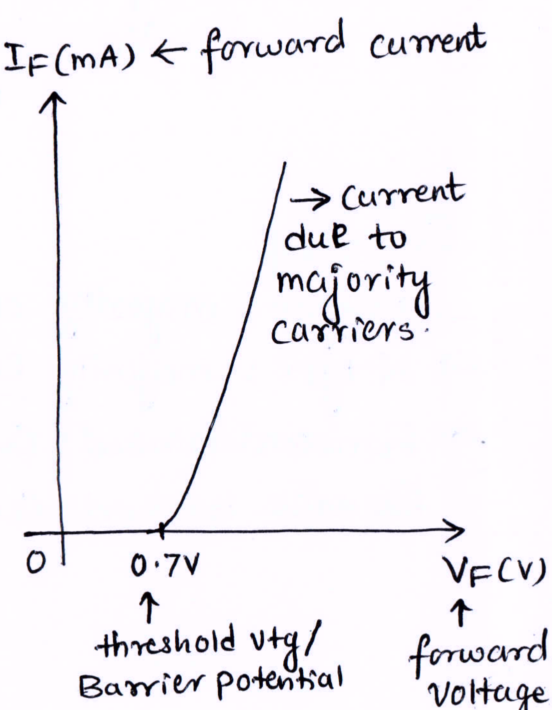
→ When the positive and negative charge carriers arrive at the junction, they will attract one another and combine.

→ As each negative and positive charge carrier combine at the junction, a new negative and positive charge carrier will be introduced at the either side of the junction from the voltage source.

→ As the applied voltage increases, the depletion region starts reducing. At a particular value of the applied voltage ($>0.7V$ Si) depletion region gets completely collapsed.

→ Due to this, a large no. of majority carriers can pass through the junction under the influence of applied forward biased voltage causing large current to flow through the junction.





R= Current limiting resistor.

Reverse Biased PN Junction.

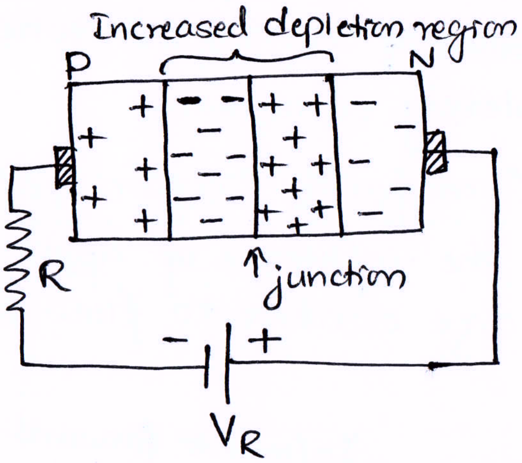
→ When a PN junction is reverse biased, the holes in the p-type are attracted by the negative potential of the applied voltage and are drawn away from the junction.

→ Similarly, the electrons in the n-type are attracted by the positive potential of the applied voltage and are drawn away from the junction. Which widens the depletion layer, increasing barrier potential.

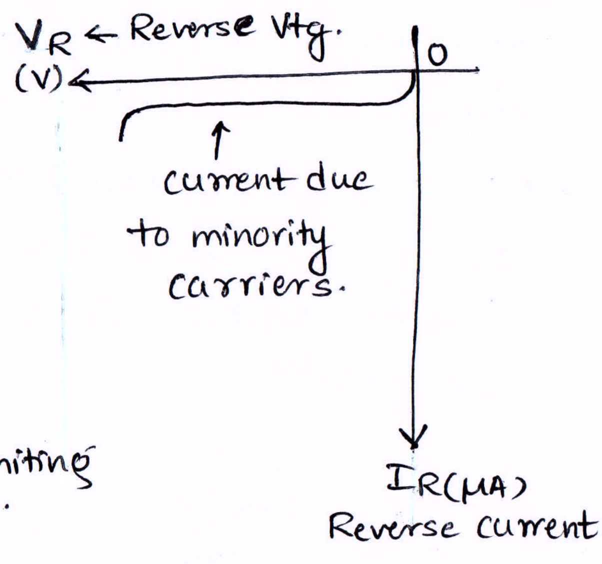
→ This leaves the junction area depleted; virtually no charge carriers exist. therefore, the junction area becomes an insulator, and current flow is inhibited.

→ Minority charge carriers however cross the junction, hence a small amount of current flows.

→ the amount of current depend upon the no. of minority carriers crossing or diffused the junction.



R = current limiting resistor.



Summary:

→ P-type: majority carriers (holes), minority carriers (electrons)

→ N-type: majority carriers (electrons), minority carriers (holes).

→ Forward biased: Current due to majority carriers.

→ Reverse biased: Current due to minority carriers.

DIODE TYPES.

→ Diode is a two-terminal electronic component that conducts electricity primarily in one direction.

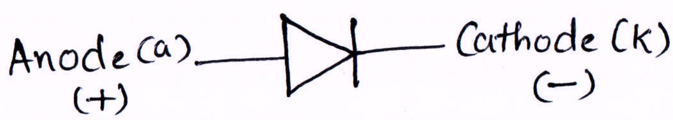
→ It has high resistance on one end and low resistance on the other end.

→ Diodes are used to protect circuits by limiting the voltage and to also transform AC into DC.

→ Semiconductors like Silicon and Germanium are used to make the most of the diodes.

→ There are different kinds of diodes and each type has its own applications.

Diode Symbol.



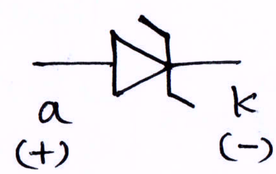
→ A standard diode symbol is represented as above.

→ In the above diagram, we can see that there are two terminals that are known as anode and cathode.

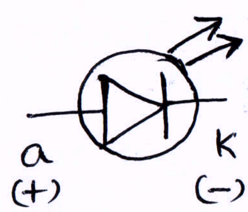
→ The arrowhead is the anode that represents the direction of the conventional current flow in the forward biased condition. The other end is cathode.

Types of Diodes

1) Zener Diode



2) Light Emitting Diode (LED)



1) Zener Diode:

→ A zener diode, also known as a breakdown diode, is a heavily doped semiconductor device that is designed to operate in the reverse direction.

→ When the voltage across the terminals of a Zener diode is reversed (typically less than 6V), and the potential reaches the Zener voltage (knee vtg.), the junction breaks down, and the current flows in the reverse direction. This effect is known as the Zener Effect.

→ If the reverse current is limited by means of a suitable series-connected resistor (Rs), the power dissipation in the diode can be kept to a level that will not destroy the device.

→ In this case, the diode may be operated continuously in reverse breakdown.

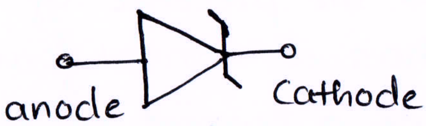
→ Diodes designed for operation in reverse breakdown are found to have a breakdown voltage that remains extremely stable over a wide range of current levels.

→ This property gives the breakdown diode many useful applications as a voltage reference source.

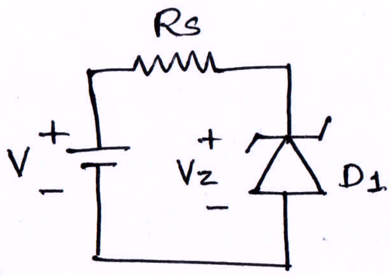
→ There are two mechanisms that cause breakdown in a reverse pn junction: Zener Breakdown & Avalanche Breakdown

Zener Breakdown	Avalanche Breakdown.
1) It occurs in diodes that are highly doped.	1) It occurs in diodes that are lightly doped.
2) Breakdown is due to intense electric field across junction. Ionization by electric field.	2) Breakdown is due to collision of accelerated carriers with the adjacent atoms. Ionization by collision (carrier multiplication).
3) It occurs with reverse bias voltage less than 5 V.	3) It occurs with reverse bias voltage above 5V
4) VI characteristics is very sharp	4) VI characteristics is not sharp. as zener breakdown.

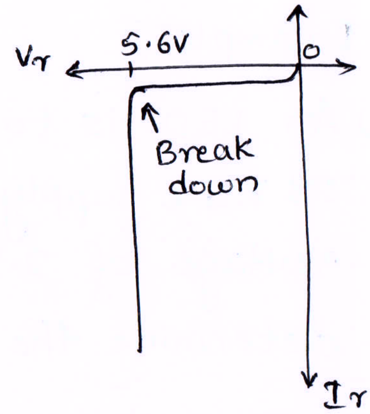
Zener Diode



Symbol



where,
Vz = Zener vtg.
Rs = Series Resistor
V = applied reverse vtg.
D1 = Zener Diode



VI characteristics

2) Light Emitting Diode (LED)

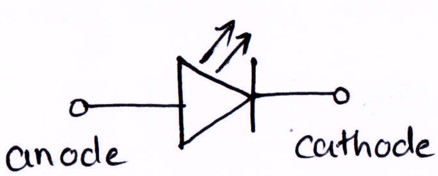
→ LED is a widely used standard source of light in electrical equipment. It has a wide range of applications ranging from mobile phone to large advertising billboards.

→ Light Emitting Diode is a semiconductor device that emits light when an electric current flows through it.

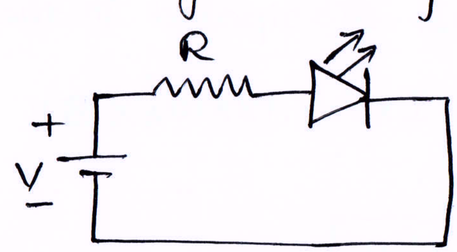
→ When current passes through an LED, the electrons recombine with holes emitting light in the process.

→ LEDs allow the current to flow in forward direction and blocks the current in the reverse direction.

→ LEDs are highly doped pn junctions. Based on the semiconductor material used and the amount of doping, an LED will emit coloured light when forward biased.



Symbol



LED circuit

→ In order to limit the forward current of an LED to an appropriate value, it is usually necessary to include a fixed resistor in series with an LED as shown above.

$\boxed{R = \frac{V - V_F}{I}}$, where V = applied vtg, V_F = forward vtg
I = forward current

Examples:

1) An LED is to be used to indicate the presence of a 21 V d.c supply rail. If the LED has a normal forward voltage of 2.2V, and is rated at a current of 15mA, determine the value of series resistor required.

Sol^n: Given: Applied Voltage, $V = 21V$
forward voltage, $V_F = 2.2V$
forward current, $I = 15mA$

$$\therefore \text{Required } R = \frac{V - V_F}{I} = \frac{21 - 2.2}{15 \times 10^{-3}} = \boxed{1.253 K\Omega}$$

The nearest preferred value is $\boxed{1.2K\Omega}$

2) An LED is to be used to indicate the presence of a 5V dc supply. If the LED has a normal forward voltage of 2V, and is rated at a current of 12mA, determine the value of series resistor required.

Sol^n: Given: $V = 5V$, $V_f = 2V$, $I = 12mA$

$$\therefore R = \frac{V - V_f}{I} = \frac{5 - 2}{12 \times 10^{-3}} = \boxed{250\Omega}$$

The power dissipated in the resistor will be given by $P = I \times V = 12 \times 10^{-3} A \times 3V = 0.036 = \boxed{36mW}$

OR

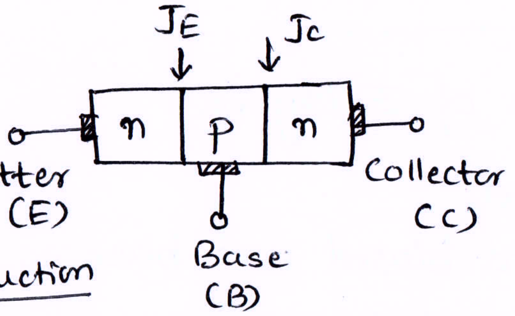
$\boxed{P = I^2 R}$

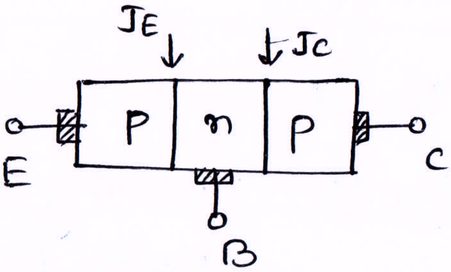
BIPOLAR JUNCTION TRANSISTORS (BJTs)

→ BJT has 3 layers of semiconductor material.

→ They are arranged either in npn (n type - p type - n type) sequence or in pnp sequence, and each of the three layers has a terminal.

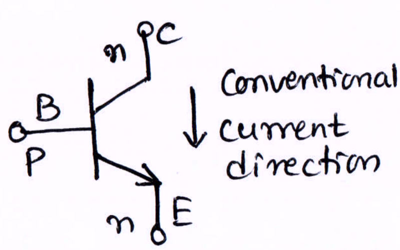
→

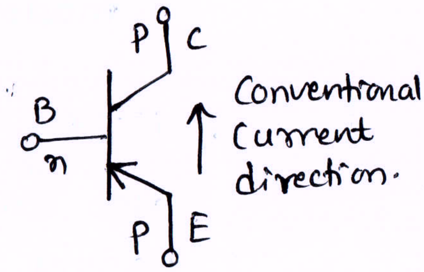




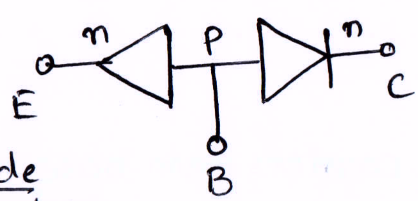
Construction

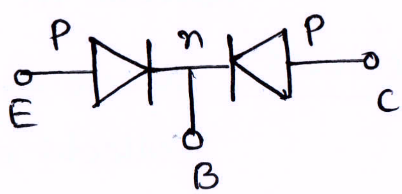
Symbol





Two Diode Analogy.





→ BJT is simply a sandwich of one type of semiconductor material (p type or n type) between two layers of the opposite type. as shown above.

→ The center layer is called the BASE, one of the outer layers is termed the EMITTER, and the other outer layer is referred as COLLECTOR.

→ Two pn-junctions exist in each transistor: the emitter-base (JE) junction and collector-base junction. (Jc) as shown above.

→ Circuit symbols for npn and pnp transistors are shown above.

→ The arrowhead on each symbol identifies the transistor emitter terminal and it indicates the conventional direction of current flow.

Construction Details of Transistor.

→ The transistor consists of 3 layers:

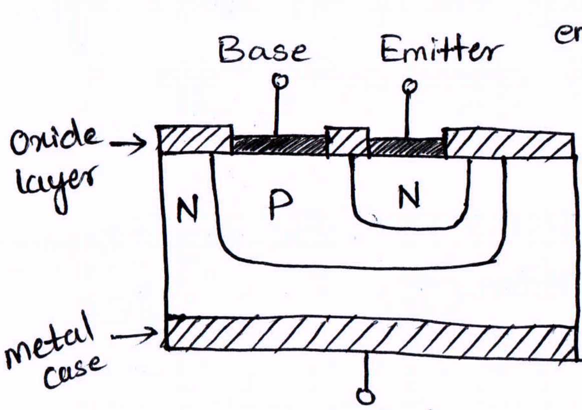
i) Emitter : heavily doped,
always forward biased wrt base,
moderate in size (width).

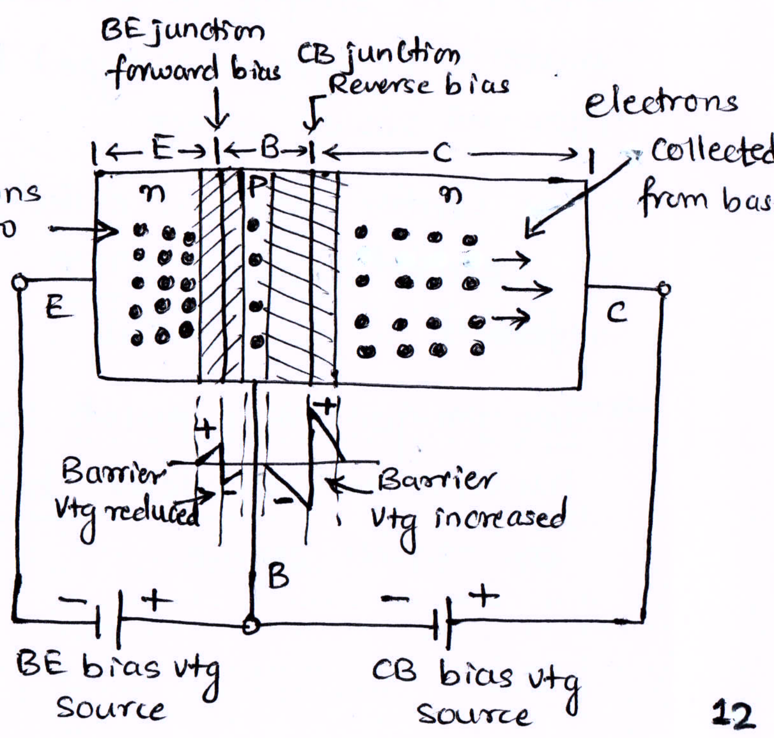
ii) Base : lightly doped,
also called control terminal,
passes emitter charge carriers into collector,
narrow in size.

iii) Collector : Moderately doped,
Collects all majority carriers from base,
Large in size.

BJT Operation:

1) NPN Transistor Construction





→ Consider the above fig. which shows an npn transistor with external bias voltages.

→ For normal operation, the base-emitter (BE) junction is forward biase'd and the collector-base (CB) junction is reverse biased.

→ The forward bias at the BE junction reduces the barrier voltage and causes electrons to flow from the n-type emitter to the p-type base.

→ The electrons are emitted into the base region: hence the name emitter. This constitute emitter current.

→ The reverse bias at the CB junction causes the CB depletion region to penetrate deeper into the base than collector because of lightly doped.

→ The electrons crossing from the emitter to the base arrive quite close to the large negative-positive electric field at the CB depletion region.

→ Because electrons have a negative charge, they are drawn across the CB junction by the bias voltage. They are said to be collected.

→ Some of charge carriers entering the base from the emitter do not reach the collector, because they recombine with few holes in the base (2%, due to lightly doped) and flow out of the base terminal.

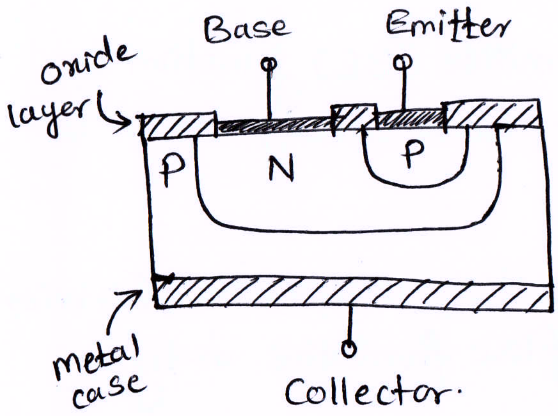
→ This constitutes the base current, it flows due to recombination of electrons and holes.

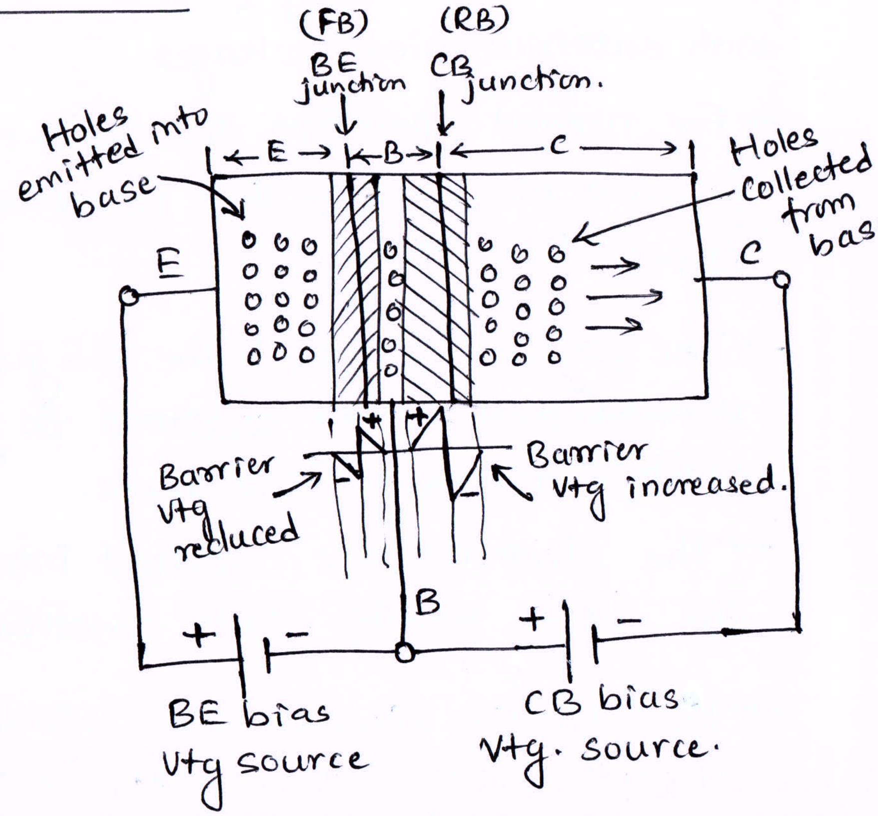
→ The remaining large no. of electrons (98%) will cross the reverse-biased collector junction to constitute the collector current. Thus by KCL,

$$\boxed{I_E = I_B + I_C}$$

where I_E = emitter current, I_B = Base Current & I_C = Collector current.

2) PNP Transistor Construction.





→ A pnp transistor behave exactly like an npn device, with the exception that the majority charge carriers are holes.

→ As illustrated in above fig. the BE junction is forward biased (FB) and CB junction is reverse biased (RB).

→ The forward bias of emitter base junction causes the flow of holes in the p-type emitter region towards the n-type base region. and constitute the emitter current (I_E).

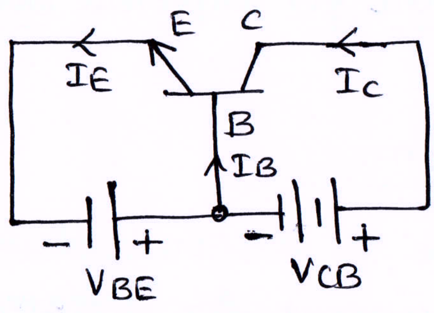
→ As these holes cross into the base region, they tend to combine with the electrons. Since the base is lightly doped and very thin, hence only a small no. of holes (2%) combine with electrons and constitute base current (I_B).

→ The remaining (98%) cross the base and reach into the collector region to constitute the collector current (I_C)

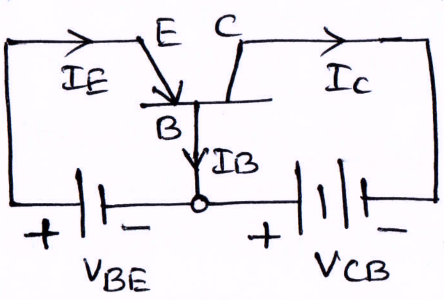
→ Again, the emitter current is the sum of collector current and base current.

$$\boxed{I_E = I_B + I_C}$$

Simple Biasing diagrams of transistors for operations.



npn transistor



pnp transistor

BJT Characteristics.

→ To study the input and output characteristics of BJT, we need to understand the different configurations of BJT.

→ BJT can be connected in 3 different configurations by keeping one terminal common and using the other two terminals for the input and output.

→ The three different configurations of BJT are:

i) Common Base (CB) Configuration.

ii) Common Emitter (CE) Configuration.

iii) Common Collector (CC) Configuration.

→ Among these, CB configuration will have voltage gain, but no current gain.

→ CC configuration will have current gain, but no voltage gain.

→ Where as, CE configuration will have both voltage gain as well as current gain.

→ Therefore, will study the characteristics of BJT with respect to CE Configuration.

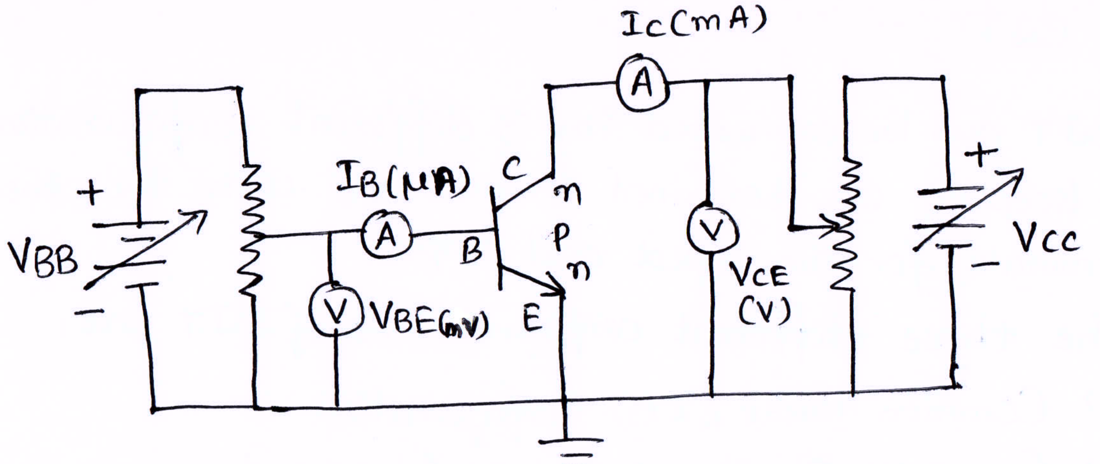
→ Input characteristics Definition

The input characteristic curve is drawn between input voltage and input current for different constant output voltage.

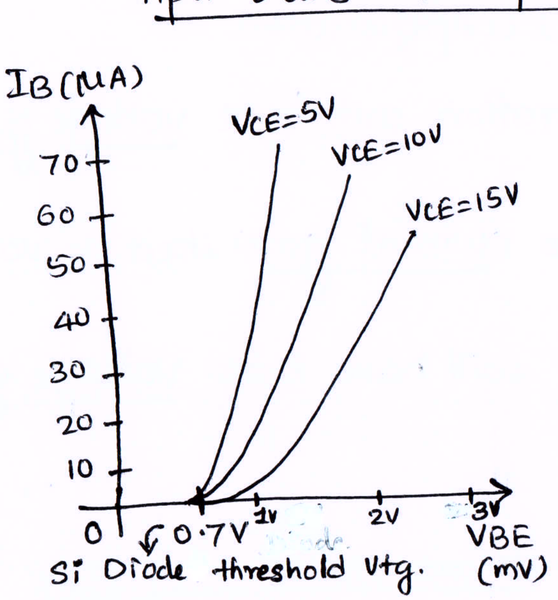
→ Output Characteristics Definition.

The output characteristic curve is drawn between output voltage and output current for different constant input current.

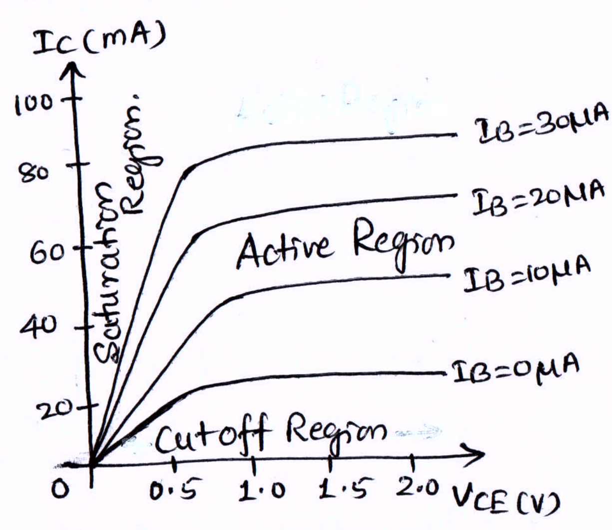
Input and Output characteristics of BJT



npn transistor experimental setup



Input Characteristics



Output Characteristics.

Input characteristics of CE Configuration:

→ Its a curve drawn between input voltage (V_{BE}) at x-axis and input current (I_B) at y-axis for different constant values of output voltage (V_{CE}) as seen above.

→ It is seen that, the CE input characteristics are those of a forward biased pn junction.

→ The characteristic shows that very little base current (I_B) flows until the base-emitter voltage (V_{BE}) exceeds 0.7V (Si diode threshold vtg).

→ Thereafter the base current increases rapidly as seen above. with small increase in input voltage (V_{BE}).

→ The above i/p characteristics also shows that, for a given value of V_{BE}, I_B is reduced when higher V_{CE} levels are employed.

→ This is because, the higher V_{CE} produces greater depletion region penetration into the base, reducing the width of base and also the recombination of charge carriers in base.

Output Characteristics of CE Configuration:

→ Its a curve drawn between output voltage (V_{CE}) at x-axis and output current (I_C) at y-axis for different constant values of input current (I_B) as seen above.

→ As we increase V_{CE} (Output voltage), depletion region penetrates deeper into the base region causing reduction in the width of base region and also recombination of charge carriers in the base.

→ This draws more charge carriers from the emitter to the collector region.

→ So, although I_B is constant, I_C increases to some extent with increasing V_{CE}. as shown above.

→ It is also observed from the o/p characteristics that I_C reduces to zero when V_{CE} becomes zero.

→ This is because, when V_{CE} reduces, the common-base junction becomes forward-biased, and this repels minority charge carriers, thus reducing I_C to zero.

→ The o/p characteristics consists of 3 regions to operate.

i) Active Region:

BE junction is forward biased & CB junction is reverse biased.

ii) Saturation Region:

Both BE and CB junctions are forward biased.

iii) Cut off Region:

Both BE and CB junctions are reverse biased.

Current Gain

→ The current gain offered by a transistor is a measure of its effectiveness as an amplifying device.

→ The most commonly used configuration for amplification and high gain is Common-Emitter (CE) Configuration.

→ In this configuration, the input current is applied to the base and the output current appears in the collector.

→ The common-emitter current gain is given by:

$$\boxed{h_{FE} = \frac{I_C}{I_B}}$$

where h_{FE} is the hybrid parameter which represents large signal (d.c) forward current gain.

I_C represents Collector Current and

I_B is Base Current.

→ When small signal operation is considered, the values of I_C and I_B are incremental. The current gain is then given by

$$\boxed{h_{fe} = \frac{\Delta I_C}{\Delta I_B}}$$

where ΔI_C is the change in collector current which results from a corresponding change in base current ΔI_B.

& h_{fe} is the hybrid parameter which represents small signal (ac) forward current.

Note : In h_{FE} & h_{fe}, 'f' indicates forward transfer characteristics and 'e' indicates common emitter configuration.

Examples :

1) A transistor operates with $I_C = 30mA$ & $I_B = 600\mu A$. Determine the value of I_E and h_{FE}.

Sol^n :

$$I_E = I_C + I_B = 30\,mA + 600\,\mu A = \boxed{30.6\,mA}$$

$$\& \; h_{FE} = \frac{I_C}{I_B} = \frac{30mA}{600\mu A} = \boxed{50}.$$

2) A transistor operates with $I_C = 97mA$ and $I_E = 98mA$. Determine the value of I_B and common emitter current gain.

Sol^n :

$$I_B = I_E - I_C = 98mA - 97mA = \boxed{1mA}$$

$$\& \; h_{FE} = \frac{I_C}{I_B} = \frac{97mA}{1mA} = \boxed{97}.$$

3) A transistor is used in a linear amplifier arrangement. The transistor has large and small signal current gains of 200 and 175 respectively and bias is arranged so that the static value of $I_C = 10mA$. Determine I_B and the change of output collector current (ΔI_C) that would result from a $10\mu A$ change in input current (ΔI_B).

Sol^n (next page) →

Sol^n : Given: $h_{FE} = 200$, $h_{fe} = 175$, $I_C = 10mA$, $\Delta I_B = 10\mu A$

i) $I_B = \frac{I_C}{h_{FE}} = \frac{10mA}{200} = \boxed{50\mu A}$

ii) wkt
$$h_{fe} = \frac{\Delta I_C}{\Delta I_B}$$

$\therefore \Delta I_C = h_{fe} \times \Delta I_B = 175 \times 10\mu A = \boxed{1.75mA}$

4) A transistor operates with a collector current of 2.5A and $I_B = 125mA$. Determine I_E & h_{FE}.

Sol^n; $I_E = I_C + I_B = 2.5A + 125mA$
$$= 2.5 + 0.125 = \boxed{2.625A}$$

$$h_{FE} = \frac{I_C}{I_B} = \frac{2.5}{0.125} = \boxed{20}$$

5) A transistor operates with a $I_C = 98mA$ and an $I_E = 103mA$. Determine I_B and h_{FE}.

Sol^n; $I_B = I_E - I_C = 103mA - 98mA = \boxed{5mA}$

$$h_{FE} = \frac{I_C}{I_B} = \frac{98mA}{5mA} = \boxed{19.6} \simeq \boxed{20}$$

6) A bipolar transistor is to be used in a driver circuit in which $I_B = 12mA$ is available. If the load requires a current of 200mA, determine the minimum value of CE current gain required.

Sol^n :
$$h_{FE} = \frac{I_C}{I_B} = \frac{200mA}{12mA} = \boxed{16.67}$$