Common Emitter Transistor Amplifier

Objectives

After going through this module, the learner will be able to :

- Understand the working of the Transistor as an amplifier
- Draw the relevant circuit diagram and understand the need for proper biassing for voltage gain
- Differentiate between input signal and output signal waveforms
- Learn about and explain the phase change of the output signal

Content Outline

- Unit syllabus
- Module Wise Distribution of Unit Syllabus
- Words You Must Know
- Introduction
- Transistor as an Amplifier (CE-configuration)
- Phase Relation Between Input and Output Voltages
- Explanation of Phase Reversal using Transfer Characteristics of the Transistor in Common Emitter Mode
- Summary

Unit Syllabus

Unit-09: Electronic Devices

Chapter-14: Semiconductor Electronic Material, Devices and Simple Circuits.

Energy bands in conductors, semiconductors and insulators (qualitative only) semiconductors intrinsic and extrinsic

Semiconductor diode -IV characteristics in forward and reverse bias, application of diode as a rectifier

Special purpose *p-n* diodes LED, photodiode, solar cell and Zener diode and their characteristics, Zener diode as a voltage regulator

Junction transistor, transistor action, characteristics of a transistor and transistor as amplifier common emitter configuration

Basic idea of Analog and Digital signal, logic gates OR, AND, NOR, NOT, NAND

Keeping the needs of state boards in mind we have not changed the content

Module Wise Distribution of Unit Syllabus 10 Modules

Module 1	● Energy bands in solids ● Forbidden gap ● Fermi level ● Energy bands in conductors, semiconductors and insulators
Module 2	● Uniqueness of semiconductors ● Charge carriers in semiconductors electrons and holes ● Intrinsic semiconductors ● Extrinsic semiconductors *p* and *n* type ● Why are *p* and *n* type semiconductors neutral?
Module 3	● p-n junction diode ● Potential barrier ● Depletion layer ● Characteristics of *p-n* junction diode ● Forward and reverse bias, knee voltage, magnitude of bias voltages ● To draw the IV characteristics curve for a *p-n* junction in forward bias and reverse bias
Module 4	● Application of diode ● Rectifier meaning and need of such a devise ● half wave and full wave rectifier ● rectifier in our homes ● Special purpose diode ○ LED ○ Photodiode ○ Solar cells ● Solar panels and future of energy
Module 5	● To identify a diode, an LED, a resistor and a capacitor ● Use a multimeter to

	○ See the unidirectional flow of current in case of a diode and an LED ○ Check whether a given diode is in working order
Module 6	● Zener diode ● Characteristics of Zener diode ● To draw the characteristic curve of a Zener diode and to determine its reverse breakdown voltage ● How is a Zener diode different from other diodes? ● Zener diode as a voltage regulator ● Working of a Zener diode ● Zener diodes in our homes
Module 7	● Junction transistor ● Design of the transistor ● *n-p-n* and *p-n-p* ● Use a multimeter to ○ identify base of transistor ○ distinguish between *n-p-n* and *p-n-p* type transistor ○ check whether a given electronic component (e.g. diode , transistor, or IC) is in working order ● Transistor action ● Characteristics of a transistor, *n-p-n* common emitter
Module 8	● Understanding transistor characteristics and its applications ● To study the characteristics of a common emitter *n-p-n*, *p-n-p* transistor and to find the values of current and voltage gains. ● Transistor as switch ● Transistor as amplifier
Module 9	● Transistor as an amplifier ● Circuit diagram and understanding bias

	- Input and output waveforms - phase change
Module 10	- Analog signals - logic gates - truth tables ○ OR ○ AND ○ NOT ○ NAND ○ NOR

Module 9

Words You Must Know

- **Conductors:** These are the materials which conduct electricity easily. They have a very large number of free electrons. conductors: material capable of carrying electric current, i.e. material which has "mobile charge carriers" and are therefore capable of electric current (e.g. electrons, ions.) e.g. metals, liquids with ions (water, molten ionic compounds), plasma.
- **Insulators:** These are the materials which do not conduct electricity because they do not have free electrons. Quartz, most covalent and ionic solids, plastics.
- **Semiconductors:** These are the materials for which electrical conductivity values less than conductors but more than that of insulators. The conductivities of semiconductors are highly temperature sensitive.
- **Semiconductors:** Materials germanium Ge, silicon Si, GaAs, GaP, InP have useful characteristic properties.
- **Superconductors:** certain materials have zero resistivity at very low temperature, but are quite like normal conductors at room temperature.
- **Energy Level:** As per Bohr's theory electrons revolve around the nucleus only in some specific orbits called stationary orbits. Energy of electrons in these orbits is constant; they are termed as energy levels.
- **Energy Bands Theory** in solid material, electron energy levels 'merge' to form bands of allowed energies. A band is a collection of a large number of close energies. The bands are separated by forbidden bands.

- **Valence Bands:** This band comprises energy of valence electrons.it is the outermost highest filled band with electrons of this band not contributing in conduction of electric current.
- **Conduction Band:** This is a higher band to valence band, it may be empty or partially filled in metals or in good conductors this band is filled
- **Forbidden Energy Gap (E_g):** It is the minimum energy required to take an electron from valence band to conduction band. Insulators have highest E_g and conductors have least Eg.
- **Intrinsic Semiconductors:** These are pure semiconductors without any impurity. They show very small electrical conductivity at room temperature.

  The gap between the valence band and conduction band is relatively small. These are covalent bonded materials such as Si and Ge the forbidden gap width in Si is 1.1 eV and for Ge it is 0.7 eV.

  Electrons moving to conduction band leave "hole" (covalent bond with missing electron) behind under influence of applied electric field, neighbouring electrons can jump into the hole, thus creating a new hole, etc.

  oles can move under the influence of an applied electric field, just like electrons; both contribute to conduction., in pure Si and Ge, there are equally many holes as there are conduction electrons.
- **Doping:** It is the deliberate and controlled addition of impurities in intrinsic semiconductors to enhance their electrical conductivity in a controlled manner.
- **Extrinsic Semiconductors**: Initially pure semiconductor to which an appropriate /designed impurities is added to increase its conductivity are known as extrinsic semiconductors or impurity semiconductors.
- **Dopant** two types of dopants used in doping the tetravalent Si or Ge element:

  (i) Pentavalent dopants (valency 5); like Arsenic (As), Antimony (Sb), Phosphorous (P), etc.

  (ii)Trivalent dopants (valency 3); like Indium (In), Boron (B), Aluminium (Al), etc.
- ***p*-type Semiconductors**, these are formed by doping elements like Si and Ge with trivalent atoms. Like B, Al, Ga ,In ,such that only 3 of the 4 covalent bonds get filled . A hole or vacancy is created because of the unfilled fourth covalent bond. there are more holes as compared to electrons in p type extrinsic semiconductors.

- ***n*-type semiconductors**, these are formed by doping elements like Si and Ge with pentavalent atoms in this case impurity or dopant having 5 valence electrons like P,As Sb is added to a sample of initially pure semiconductor.. of these 4 electrons get used by the covalent bond of the surrounding Si or Ge atoms The fifth electron is unpaired or left loosely bound .Hence only a small amount of energy is needed to lift it into the conduction band (0.5 eV for Si) *n* type semiconductors have more conduction electrons and fewer holes. For example; doping fraction of 1 in 10^8 Sb in Si yields about 5×10^{16} conduction electrons per cm^3 at room temperature which is a gain of 5×10^5 conduction electrons over intrinsic Si.
- **Advantage of doped semiconductors is we can alter conductivity by choice of doping fraction and choose majority carriers.**
- ***p-n* Junction:** A *p-n* junction is a boundary, or interface, between the two types of semiconductors, (*p*-type and *n*-type), inside a single crystal.
- **Diffusion Current:** holes diffuse from *p*-side to *n*-side ($p \rightarrow n$) and electrons diffuse from *n*-side to p-side ($n \rightarrow p$). Diffusion means movement due to difference in concentration, from higher to lower concentration. In absence of electric field across the junction, holes "diffuse" towards and across the boundary into *n* type and capture electrons. Electrons diffuse across boundary, fall into holes ("recombination of majority carriers") which forms a depletion region, a **region without free charge carriers around the boundary,** charged ions are left behind (cannot move): the negative ions left on *p*-side give a net negative charge on *p*-side of the junction; the positive ions left on *n*-side give a collection of net positive charge on *n*-side of the junction. The potential barrier, created as an electric field across the junction, prevents further diffusion.
- **Potential Barrier:** Initially both the sides were electrically neutral. Now, because of diffusion of electrons and the holes, there are immobilised additional ions on both the sides.

  From the n side, electrons have diffused to the p side, so there are positive immobile ions on the *n* side, from the *p* side, holes have diffused to the *n* side, so there are negative immobile ions on the *p* side. These immobile ions near the junction create a potential difference across the junction.

- **Drift Current:** Due to the positive space-charge region on the n-side of the junction, and negative space-charge region on the *p*-side of the junction, an electric field, directed from positive charge towards negative charge develops.

  Due to this field, an electron on the *p*-side of the junction moves to the n-side and a hole on the *n*-side of the junction moves to *p*-side.

  The motion of charge carriers due to the electric field is called drift.
- **A drift current, which is opposite in direction to the diffusion current, is set up.**
- **Forward Bias** when an external voltage V is applied across a semiconductor diode such that p-side is connected to the positive terminal of the battery and *n*-side to the negative terminal it is said to be forward biased.
- **Reverse Bias:** The positive terminal of the battery is connected to the n-side of the semiconductor and negative terminal is connected to the *p*-side. This way of connecting a diode with a battery is called Reverse Biasing.
- **Characteristics of a *p-n* Junction Diode:** When a bias is placed across a conductor, its characteristic curves show the dependence of current on voltage placed across the conductor.
- **Knee Voltage** the special value of forward voltage beyond which the current increases with increase in the voltage is known as the knee Voltage.
- **Dynamic Resistance of a Junction Diode:** The I-V characteristics of a *p-n* junction diode during forward /reverse biasing) is not a straight line. We therefore cannot have a unique (constant) value for the resistance of the diode. We can, however use the basic definition of resistance

  $$resistance = \frac{change\ in\ potential\ difference}{corresponding\ change\ in\ current}$$

  We can use it to define

  Dynamic resistance of a junction diode (for a particular value of the applied /current flowing)is defined as the ratio of small change in the applied potential across the diode to the corresponding small change in the junction current.

  $dynamic\ resistance = \frac{\Delta V}{\Delta I}$
- **Rectifier** is a device which converts an alternating current (AC) into a direct current (DC).
- **Filter Circuit:** The ripples in the DC can be reduced by allowing the output to pass through a filter circuit.
- **Photodiodes** used for detecting optical signals (photodetectors).

- **Light Emitting Diodes (LED)** which convert electrical energy into light energy**.**
- **Photovoltaic Devices** which convert optical radiation into electricity (solar cells)
- **Transistors (bipolar) Transistor** combination of two diodes that share the middle portion, called "base" of transistor; other two sections: "emitter" and "collector"; usually, base is very thin and lightly doped. Two kinds of bipolar transistors: *p-n-p* and *n-p-n* transistors
- **Transistor Action *p-n-p* Transistor** if emitter-base junction is forward biased, "holes flow" from battery into emitter, move into base, some holes annihilated with electrons in *n*-type base, but because base thin and lightly doped, most holes make it through base into collector, holes move through collector into negative terminal of battery; i.e. "collector current" flows whose size depends on how many holes have been captured by electrons in the base. This depends on the number of *n* type carriers in the base which can be controlled by the size of the base current, which is allowed to flow from the base to the emitter. The base current is usually very small. Small changes in base current can cause big differences in collector current.

  Since due to chosen biasing the emitter base junction has lower resistance as compared to base collector hence resistance increases so it is called transistor or transfer of resistance.
- **Common Emitter *n-p-n* Input Characteristics of a Transistor:** The variation of the base current I_B with the base-emitter voltage V_{BE} is called the input characteristic
- **Input Resistance:** This is dynamic (ac resistance) and as can be seen from the input characteristic, its value varies with the operating current in the transistor

  $$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$$

  The value of r_i can be anything from a few hundreds to a few thousand ohms.
- **Output Characteristics of a Transistor:** The variation of the collector current I_C with the collector-emitter voltage V_{CE} is called the output characteristic
- **Output Resistance (r_o):** This is defined as the ratio of change in collector-emitter voltage (ΔV_{CE}) to the change in collector current (ΔI_C) at a constant base current I_B.

  $$r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$$

- **Current Amplification Factor (β):** This is defined as the ratio of the change in collector current to the change in base current at a constant collector-emitter voltage (V_{CE}) when the transistor is in active state.

  $$\beta_{ac} = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}$$

  This is also known as small signal current gain and its value is very large.

  If we simply find the ratio of I_C and I_B we get what is called βdc of the transistor.

  Hence

  $$\beta_{dc} = \frac{I_C}{I_B}$$

  Since I_C increases with I_B almost linearly and $I_C = 0$ when $I_B = 0$, the values of both β_{dc} and β_{ac} are nearly equal.

  So, for most calculations β_{dc} can be used. Both β_{ac} and βdc vary with V_{CE} and I_B (or I_C) slightly
- **Transfer Characteristics of a Transistor** plot transfer characteristics to show the variation of output voltage with input voltage called transfer as voltage is transferred from input to output.
- **Cut-off Region:** In the case of Si transistors, as long as input V_i is less than 0.6 V, the transistor will be in cut off state and current I_C will be zero.

  Hence $V_o = V_{CC}$
- **Saturation State:** With increase of V_i, I_C increases almost linearly and so V_o decreases linearly till its value becomes less than about 1.0 V.

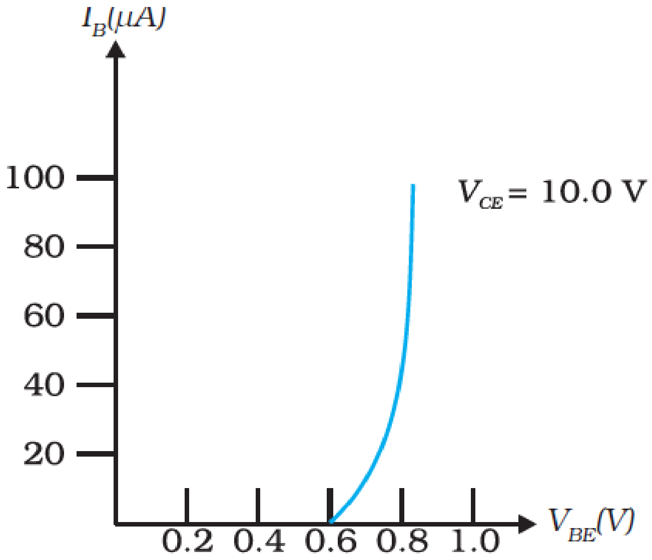
  Beyond this, the change becomes non-linear and the transistor goes into saturation state.

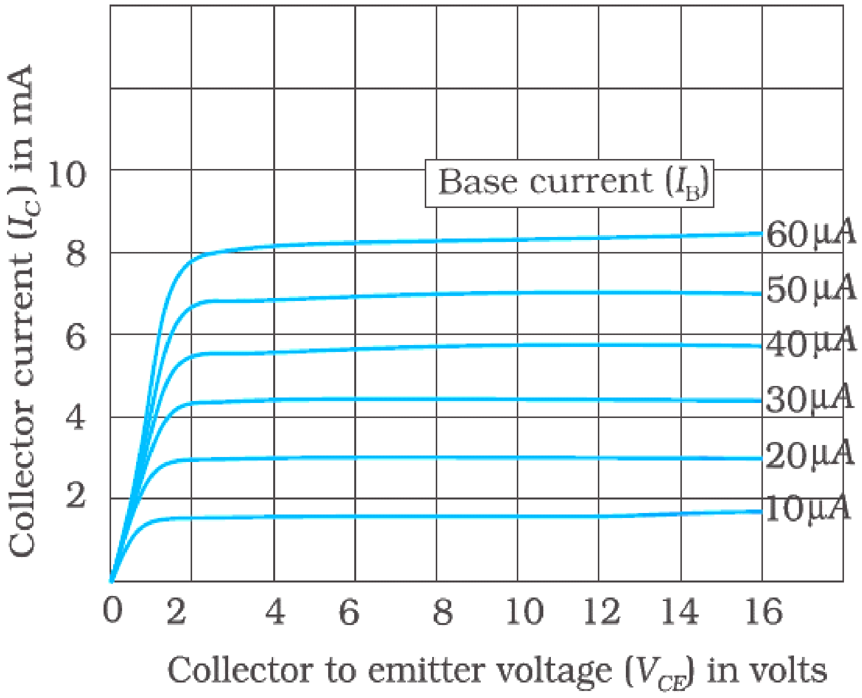
  With further increase in V_i the output voltage is found to decrease further towards zero though it may never become zero
- **Active Region:** When Vi becomes greater than 0.6 V the transistor is in active state with some current I_C in the output path and the output V_o decreases
- **Switch and Amplifier:** When the transistor is used in the cut off or saturation state it acts as a switch. On the other hand, to use the transistor as an amplifier, it has to operate in the active region.

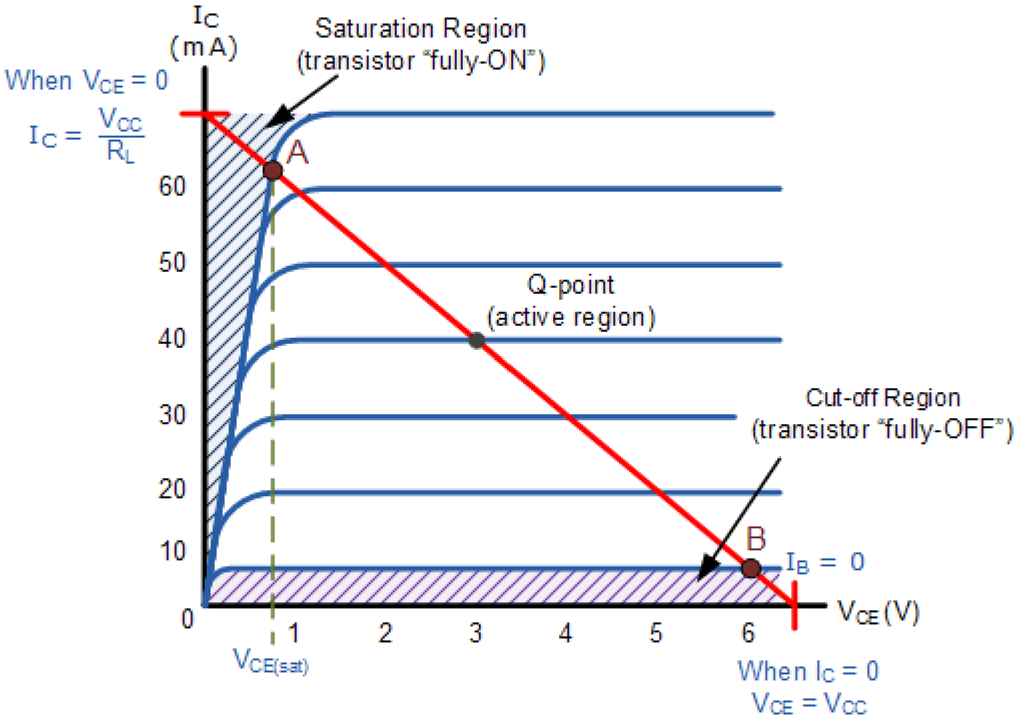
Introduction

In the previous modules in this unit we have understood solid state devices. In our study we have focused on semiconductors, a class of solid materials that have conductivities between conductors and insulators.

Input and Output Characteristic Curves and Transfer Characteristics







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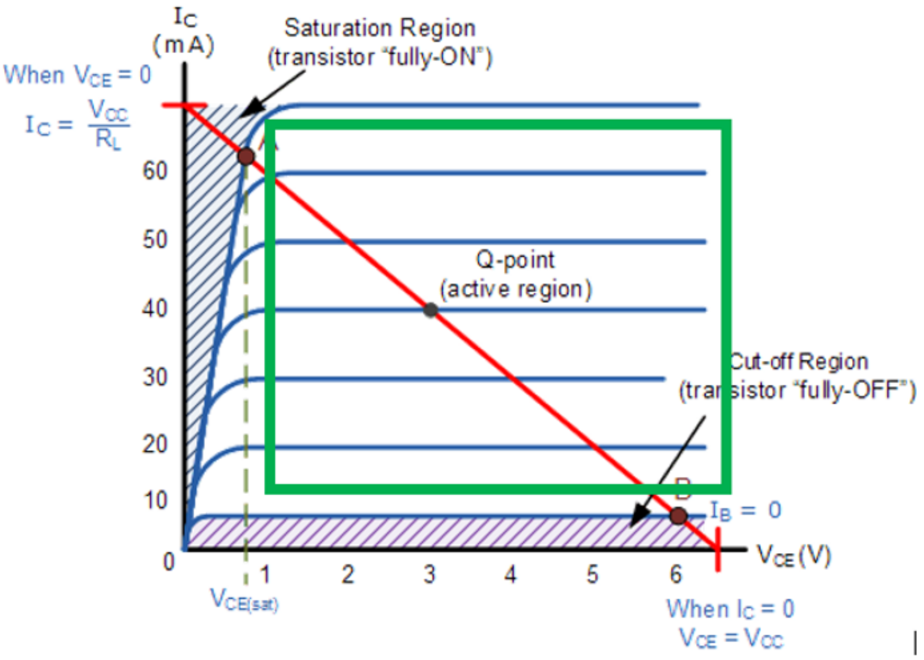
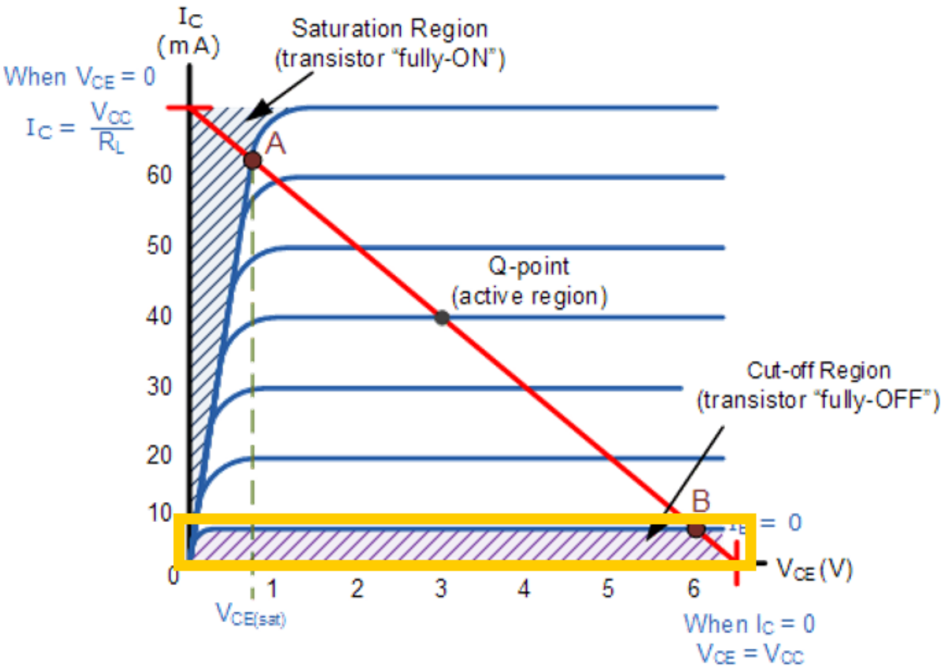
From the Graph

- **Region 1**-In linear portion of the graph for different I_B the transistor is **active**, region, the response is: I_c = const.

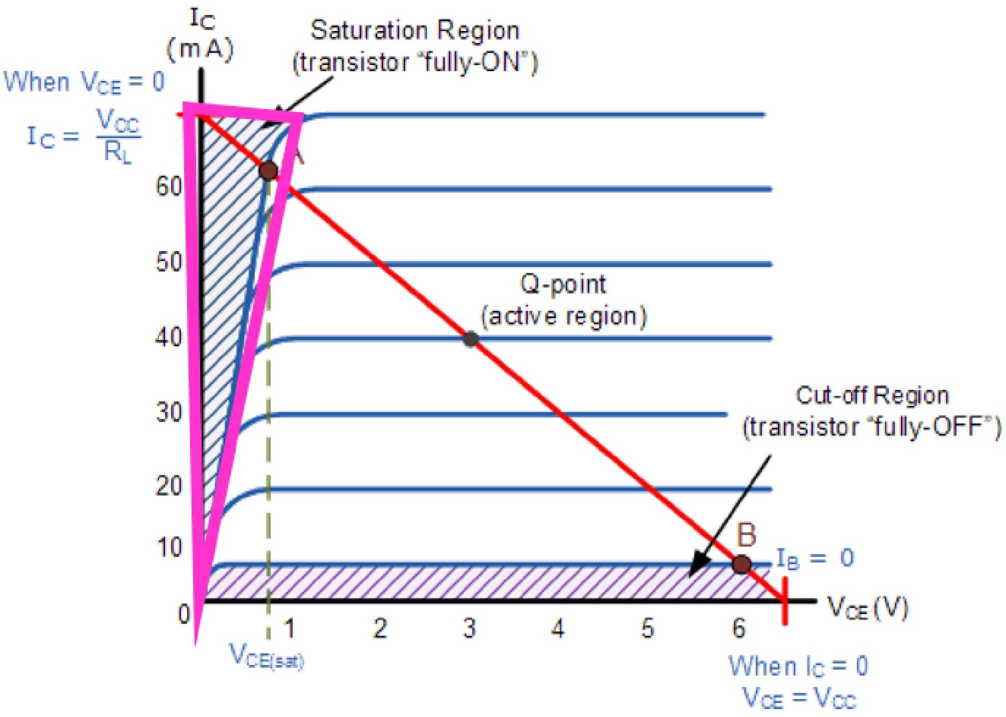


- **Region 2-** In **Cut off region**, Response is: $I_c = 0$.

  - No matter how large the increase in V_{CE}, Ic is still zero. It is Similar to Air gap in the plug type key in the laboratory.

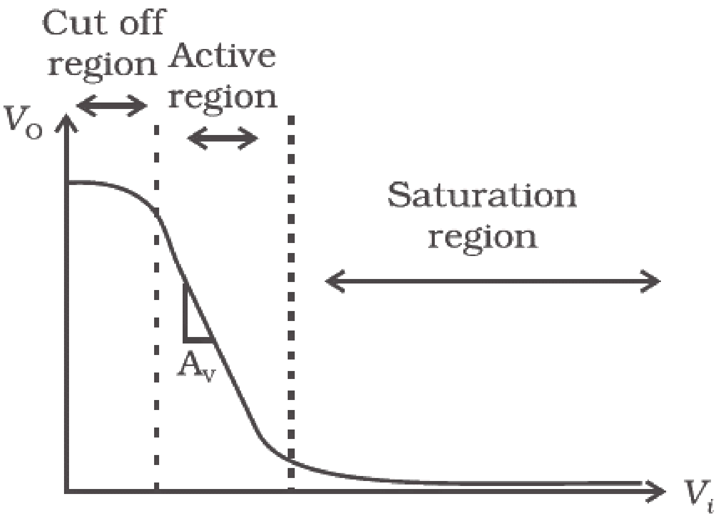


- **Region 3-**In **Saturation region**, Response is: I_c = const. V_{CE} is constant, being the slope of the curve.



We can plot a **Transfer Characteristic Curve**

The above graphs when plotted to show the variation of output voltage with input voltage give transfer characteristics, which means how the voltage is ‘transferred’ from input to output.



This is called transfer characteristics .

The cut off region corresponds to input voltages lower than knee voltage for the emitter base forward bias.

Transistor as an Amplifier (CE-Configuration)

To operate the transistor as an amplifier it is necessary to fix its operating point somewhere in the middle of its active region.

If we fix the value of V_{BB} corresponding to a point in the middle of the linear part of the transfer curve then the dc base current I_B would be constant and corresponding collector current I_C will also be constant.

The dc voltage $V_{CE} = V_{CC} - I_C R_C$ would also remain constant.

The operating values of V_{CE} and I_B determine the operating point of the amplifier.

If a small sinusoidal voltage with amplitude V_s is superposed on the dc base bias by connecting the source of that signal in series with the V_{BB} supply, then the base current will have sinusoidal variations superimposed on the value of I_B.

As a consequence the collector current also will have sinusoidal variations superimposed on the value of I_C, producing in turn corresponding change in the value of V_O.

We can measure the ac variations across the input and output terminals by blocking the dc voltages by large capacitors.

In the description of the amplifier given above we have not considered any ac signal.

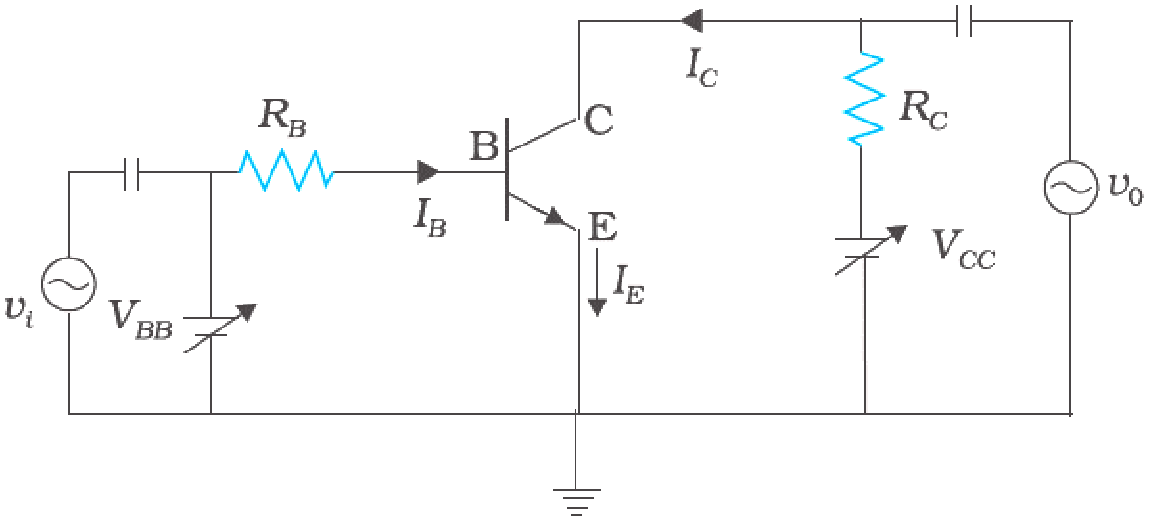
In general, amplifiers are used to amplify alternating signals.

Now let us superimpose an ac input signal v_i (to be amplified) on the bias V_{BB} (dc) as shown in the circuit diagram.

The output is taken between the collector and the ground.

The working of an amplifier can be easily understood,

if **we first assume that $v_i = 0$**. Then applying Kirchhoff's law to the output loop,



$$V_{CC} = V_{CE} + I_C R_L$$

Likewise, the input loop gives

$$V_{BB} = V_{BE} + I_B R_B$$

When v_i is not zero, we get

$$V_{BE} + v_i = V_{BE} + I_B R_B + \Delta I_B \left(R_B + r_i\right)$$

The change in V_{BE} can be related to the input resistance *ri* and the change in I_B.

Hence

$$v_i = \Delta I_B \left(R_B + r_i\right)$$

$$= r \Delta I_B$$

The change in I_B causes a change in Ic. We define a parameter β_{ac}, which is similar to the β_{dc} as

$$\beta_{ac} = \frac{\Delta i_c}{\Delta i_b} = \frac{i_c}{i_b}$$

which is also known as the **ac current gain Ai.**

Usually β_{ac} is close to β_{dc} in the linear region of the output characteristics.

The change in Ic due to a change in I_B causes a change in V_{CE} and the voltage drop across the resistor R_L because V_{CC} is fixed.

These changes are

$$\Delta V_{CC} = \Delta V_{CE} + R_L \Delta I_C = 0$$

Or $\Delta V_{CE} =- R_L \Delta I_C$

The change in V_{CE} is the output voltage v_0. We get

$$v_o = \Delta V_{CE} =- \beta_{ac} R_L \Delta I_B$$

The **voltage gain of the amplifier is**

$$A_o = \frac{v_o}{v_i} = \frac{\Delta V_{CE}}{r \Delta I_B}$$

$$=- \frac{\beta_{ac} R_L}{r}$$

The negative sign represents that output voltage is opposite with phase with the input voltage.

From the discussion of the transistor characteristics you have seen that there is a current gain βac in the CE configuration.

Here we have also seen the voltage gain A_v.

Therefore the power gain A_p can be expressed as the product of the current gain and voltage gain.

Mathematically,

$$A_p = \beta_{ac} \times A_v$$

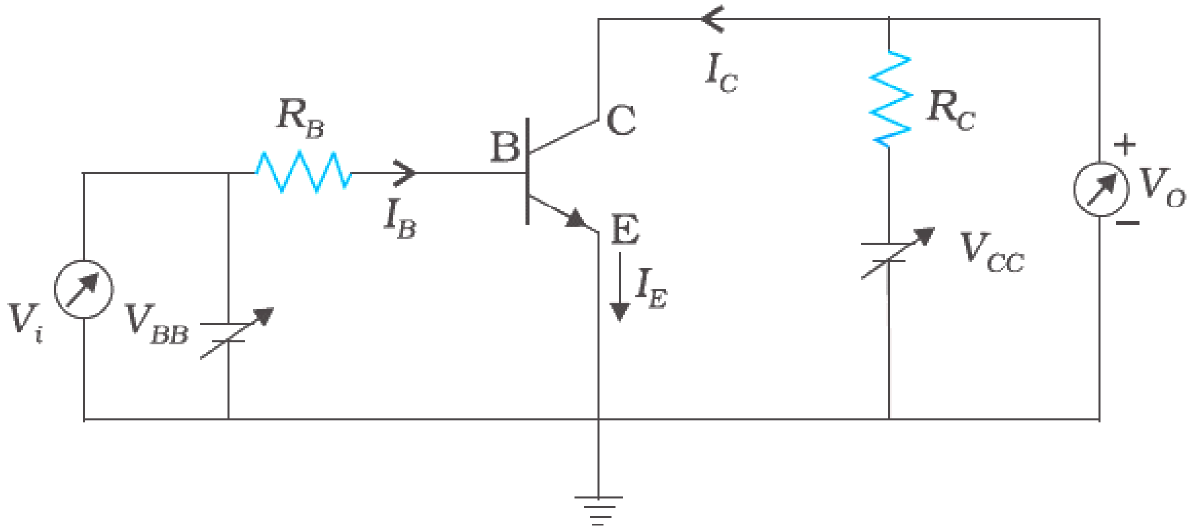
Since β_{ac} and A_v are greater than 1, we get ac power gain.

However, it should be realised that a transistor is not a power generating device.

The energy for the higher ac power at the output is supplied by the battery.

Example:

In given circuit



The V_{BB} supply can be varied from 0V to 5.0 V. The Si transistor has β_{dc} = 250 and R_B = 100 kW, R_C = 1 KW, V_{CC} = 5.0V. Assume that when the transistor is saturated, V_{CE} = 0V and V_{BE} = 0.8V. Calculate

- The minimum base current, for which the transistor will reach saturation. Hence,
- Determine V_i when the transistor is 'switched on'.
- Find the ranges of V_i for which the transistor is 'switched off' and 'switched on'.

Solution:

Given at saturation

V_{CE} = 0Vand V_{BE} = 0.8V

$$V_{CE} = V_{CC} - I_C R_C$$

$$I_C = \frac{V_{CC}}{R_C} = \frac{5.0V}{1.0kohm} = 5.0mA$$

Therefore

$$I_B = \frac{I_C}{\beta} = \frac{5.0mA}{250} = 20\mu A$$

The input voltage at which the transistor will go into saturation is given by

$$v_i = V_{BB} = I_B R_B + V_{BE}$$

$$= 20\ \mu A \times 100\ k\ ohm\ +\ 0.8\ V\ =\ 2.8\ V$$

The value of input voltage below which the transistor remains cut off is given by

$$V_{i(lowest)} = 0.6V,\ V_{i\,(highest)} = 2.8V$$

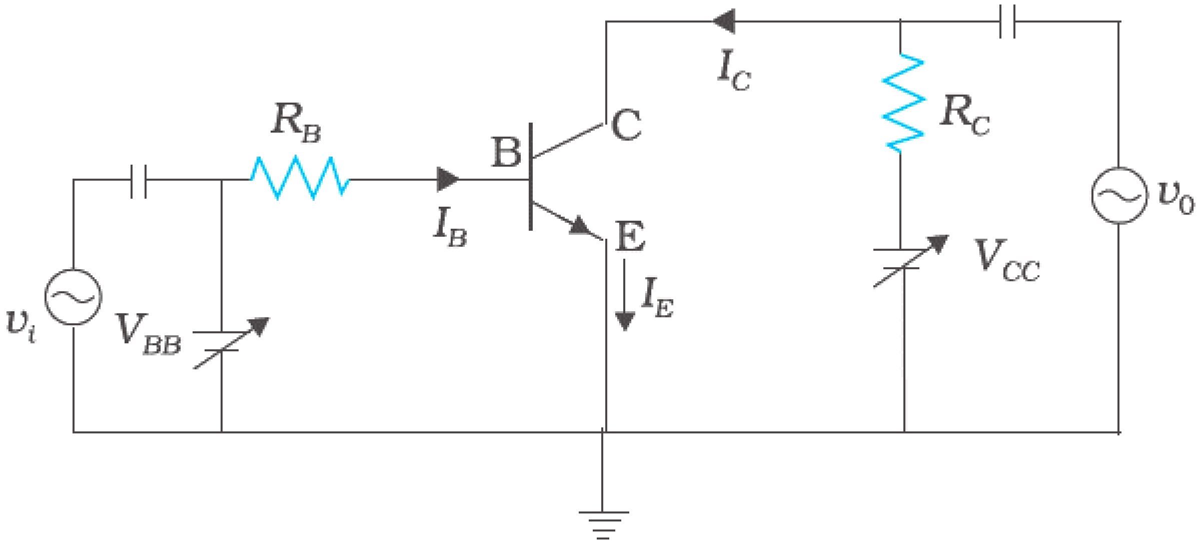
Between 0.0V and 0.6V, the transistor will be in the 'switched off' state.

Between 2.8V and 5.0V, it will be in 'switched on' state.

Note that the transistor is in active state when I_B varies from 0.0mA to 20mA. In this range, $I_C = \beta I_B$ is valid. In the saturation range, $I_C \leq \beta I_B$

Example:

For a CE transistor amplifier, the audio signal voltage across the collector resistance of 2.0 kW is 2.0 V. Suppose the current amplification factor of the transistor is 100, What should be the value of R_B in series with V_{BB} supply of 2.0 V if the dc base current has to be 10 times the signal current. Also calculate the dc drop across the collector resistance.



Solution:

The output ac voltage is 2.0 V.

So, the ac collector current $I_C = 2.0/2000 = 1.0$ mA.

The signal current through the base is, therefore given by

$I_B = I_C / \beta = 1.0 \text{ mA}/100 = 0.010$ mA.

The dc base current has to be 10× 0.010 = 0.10 mA.

$R_B = (V_{BB} - V_{BE}) / I_B$.

Assuming $V_{BE} = 0.6$ V,

$R_B = (2.0 - 0.6)/0.10 = 14$ k ohm.

The dc collector current $I_C = 100 \times 0.10 = 10$ mA.

Example:

For transistor action, which of the following statements are correct?

- Base, emitter and collector regions should have similar size and doping concentrations.
- The base region must be very thin and lightly doped.
- The emitter junction is forward biased and collector junction is reverse biased.
- Both the emitter junction as well as the collector junction are forward biased.

Solution:

Both (b) and (c)

Example:

For a transistor amplifier, the voltage gain

- Remains constant for all frequencies.
- Is high at high and low frequencies and constant in the middle frequency range.
- Is low at high and low frequencies and constant at mid frequencies.
- None of the above.

Solution:

- Because of the presence of junction and external capacitances the voltage gain of a transistor depends upon frequency. The gain decreases both at low as well as high frequencies

Example:

For a CE-transistor amplifier, the audio signal voltage across the collector resistance of 2 kW is 2 V. Suppose the current amplification factor of the transistor is 100, find the input signal voltage and base current, if the base resistance is 1 kW.

Solution:

$V_i = 0.01$ V $I_B = 10$ mA

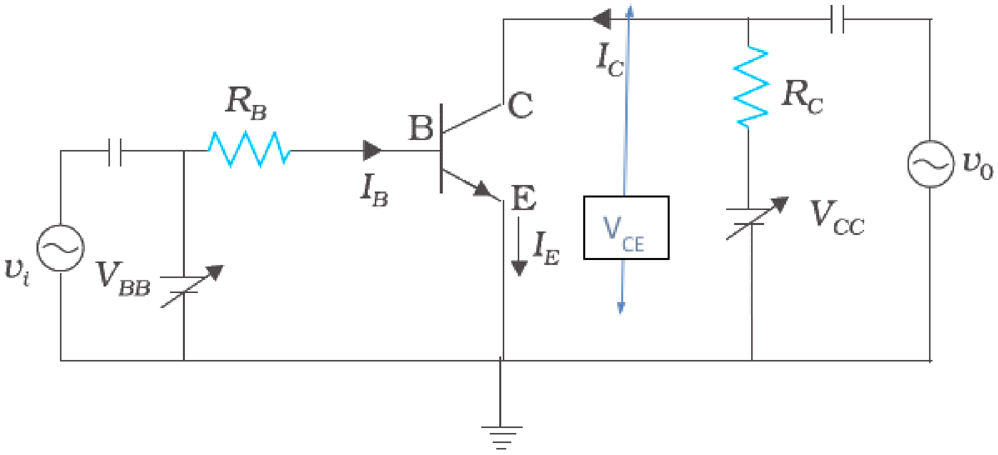
Example:

- Two amplifiers are connected one after the other in series (cascaded).
- The first amplifier has a voltage gain of 10 and the second has a voltage gain of 20. If the input signal is 0.01 volt, calculate the output ac signal.
- Solution: 2 V

Phase Relation Between Input and Output Voltages

In a common emitter amplifier, the output voltage signal obtained across the collector and the emitter is 180° out of phase with the input voltage signal applied across the base and the emitter.

Let us try and understand why this happens



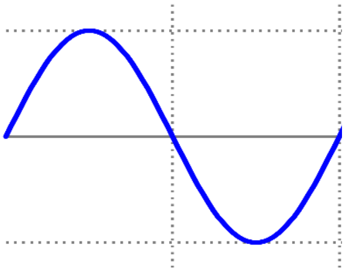
Positive half input cycle

- The first half cycle of the input signal is positive.it reduces the forward biasing of the base emitter circuit.
- The emitter current decreases and so does the collector current. The decrease in collector current results in an increase in collector voltage $V_{CE.}$
- Since the collector is connected to the negative terminal of battery V_{CC} ,an increase in collector voltage means that the collector becomes more negative ,
- Thus during the positive half-cycle of the ac input voltage signal, the output voltage signal at the collector undergoes a negative half cycle.

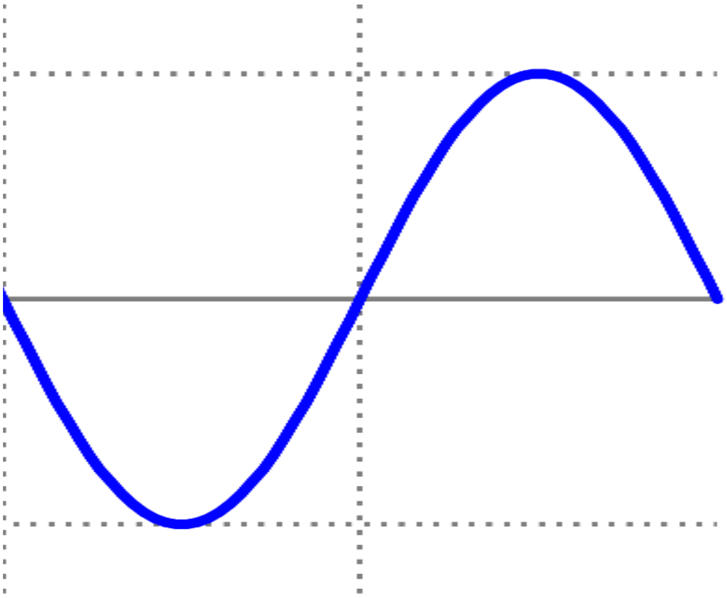
Negative half input cycle

- The negative half cycle of the input voltage signal supports and hence increases the forward biasing of the base emitter circuit.
- Therefore the emitter current I_E and corresponding collector current I_C increases. As a result, the collector voltage V_{CE} decreases, that is, the collector becomes less negative.
- Thus, during the negative half cycle of the ac input voltage signal, the output voltage signal at the collector undergoes a positive half cycle.

So if the input signal is as shown



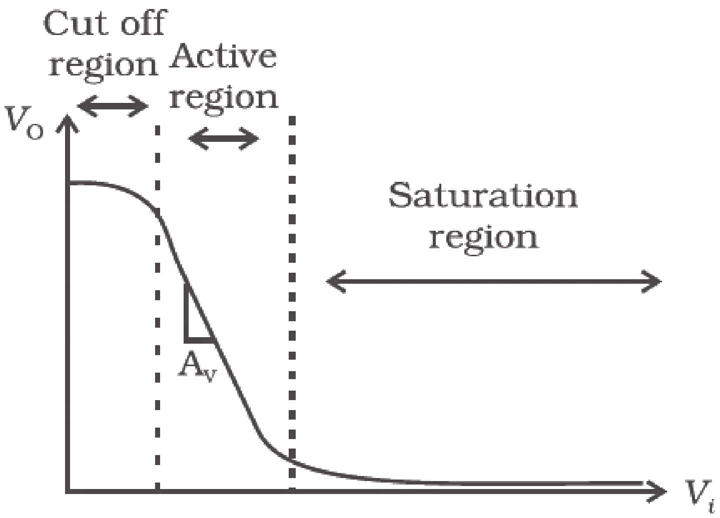
Output signal will be



- The frequency of the signal does not change.
- Amplitude increases.
- Phase is reversed.
- Output is extracted across emitter collector terminals of the transistor .
- The input is fed into the base emitter circuit.

Explanation Of Phase Reversal Using Transfer Characteristics Of The Transistor In Common Emitter Mode

Observe the transfer characteristics,The transistor operates as an amplifier in the active region of the graph



Draw an input ac waveform along the x axis. Note the signal should vary the emitter base forward bias but never make it within the cut off or saturation regions.The variation in v_i result in variation in v_o.Observe the output voltage curve to understand phase reversal of V_o with V_i

The frequency remains unaffected. The amplitude and phase change

Summary

We have learnt in this module

- *p-n* junction is the 'key' to all semiconductor devices.
- When such a junction is made, a 'depletion layer' is formed consisting of immobile ion-cores devoid of their electrons or holes. This is responsible for a junction potential barrier.
- By changing the external applied voltage, junction barriers can be changed. In forward bias (*n*-side is connected to the negative terminal of the battery and *p*-side is connected to the positive), the barrier is decreased while the barrier increases in reverse bias. Hence, forward bias current is more (mA) while it is very small (μA) in a *p-n* junction diode.
- Transistor is an *n-p-n or p-n-p* junction device.
- The central block (thin and lightly doped) is called 'Base' while the other electrodes are 'Emitter' and 'Collectors'.
- The emitter-base junction is forward biased while the collector-base junction is reverse biased.

- The transistors can be connected in such a manner that either C or E or B is common to both the input and output. This gives the three configurations in which a transistor is used: Common Emitter (CE), Common Collector (CC) and Common Base (CB).
- The plot between I_C and V_{CE} for fixed I_B is called output characteristics
- The plot between I_B and V_{BE} with fixed V_{CE} is called input characteristics.
- The important transistor parameters for CE-configuration are:
- Input resistance $r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)$ $keeping\ V_{CE}\ constant$
- Output resistance $r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)$ $keeping\ I_B\ constant$
- Current amplification factor $\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right)$ $keeping\ V_{CE}\ constant$
- Transistor can be used as an amplifier and oscillator. In fact, an oscillator can also be considered as a self-sustained amplifier in which a part of output is feed-back to the input in the same phase (positive feedback). The voltage gain of a transistor amplifier in common emitter configuration is:
- $A_v = \left(\frac{v_0}{v_i}\right) = \beta \frac{R_C}{R_B}$

  Where R_c and R_B are the resistances in collector and base sides of the circuit

- When the transistor is used in the cut off or saturation state, it acts as a switch.