LECTURE HANDOUTS

L1

EEE

II/III

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : I- APPLICATIONS OF SEMICONDUCTOR DEVICES

Date of Lecture:

Topic of Lecture: Introduction to semiconductor diode, PN junction diode structure, operation

Introduction :

- A semiconductor is a material which has electrical conductivity to a degree between that of a metal (such as copper) and that of an insulator (such as glass)..
- Di means two and ode means electrode. So physical contact of two electrodes is known as diode and its important function is alternative current to direct current.
- When the N and P-type semiconductor materials are first joined together a very large density gradient exists between both sides of the junction so some of the free electrons from the donor impurity atoms begin to migrate across this newly formed junction to fill up the holes in the P- type material producing negative ions.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Electronics
2. Engineering Physics

Detailed content of the Lecture:

SEMICONDUCTOR

A semiconductor is a material which has electrical conductivity to a degree between that of a metal (such as copper) and that of an insulator (such as glass). Semiconductors are the foundation of modern electronics, including transistors, solar cells, light-emitting diodes (LEDs), quantum dots and digital and analog integrated circuits.

DIODE

Diode – Di + ode

Di means two and ode means electrode. So physical contact of two electrodes is known as diode and its important function is alternative current to direct current.

INTRINSIC SEMICONDUCTOR

An intrinsic semiconductor is one, which is pure enough that impurities do not appreciably affect its electrical behaviour.

EXTRINSIC SEMICONDUCTOR

An extrinsic semiconductor is one that has been doped with impurities to modify the number and type of free charge carriers.

N-TYPE SEMICONDUCTORS

- Extrinsic semiconductors with a larger electron concentration than hole concentration are known as n-type semiconductors.
- N-type semiconductors are created by doping an intrinsic semiconductor with donor impurities.
- In an n-type semiconductor, the Fermi energy level is greater than that of the intrinsic semiconductor and lies closer to the conduction band than the valence band.
- Arsenic has 5 valence electrons, however, only 4 of them form part of covalent bonds. The 5th electron is then free to take part in conduction. The electrons are said to be the majority carriers and the holes are said to be the minority carriers.

P-TYPE SEMICONDUCTORS

- As opposed to n-type semiconductors, p-type semiconductors have a larger hole concentration than electron concentration.
- P-type semiconductors are created by doping an intrinsic semiconductor with acceptor impurities.
- P-type semiconductors have Fermi energy levels below the intrinsic Fermi energy level.
- The Fermi energy level lies closer to the valence band than the conduction band in a p- type semiconductor.
- Gallium has 3 valence electrons, however, there are 4 covalent bonds to fill. The 4^{th} bond therefore remains vacant producing a hole.
- The holes are said to be the majority carriers and the electrons are said to be the minority carriers.

PN JUNCTION DIODE

- When the N and P-type semiconductor materials are first joined together a very large density gradient exists between both sides of the junction so some of the free electrons from the donor impurity atoms begin to migrate across this newly formed junction to fill up the holes in the P- type material producing negative ions.

FORWARD BIAS CONDITION

- When positive terminal of the battery is connected to the P-type and negative terminal to
- N-type of the PN junction diode that is known as forward bias condition.

Operation

1. The applied potential in external battery acts in opposition to the internal potential barrier which disturbs the equilibrium.
2. As soon as equilibrium is disturbed by the application of an external voltage, the Fermi level is no longer continuous across the junction.

3. Under the forward bias condition the applied positive potential repels the holes in P type region so that the holes move towards the junction and the applied positive potential repels the electrons in N type region so that the electrons move towards the junction.
4. When the applied potential is more than the internal barrier potential the depletion region and internal potential barrier disappear.

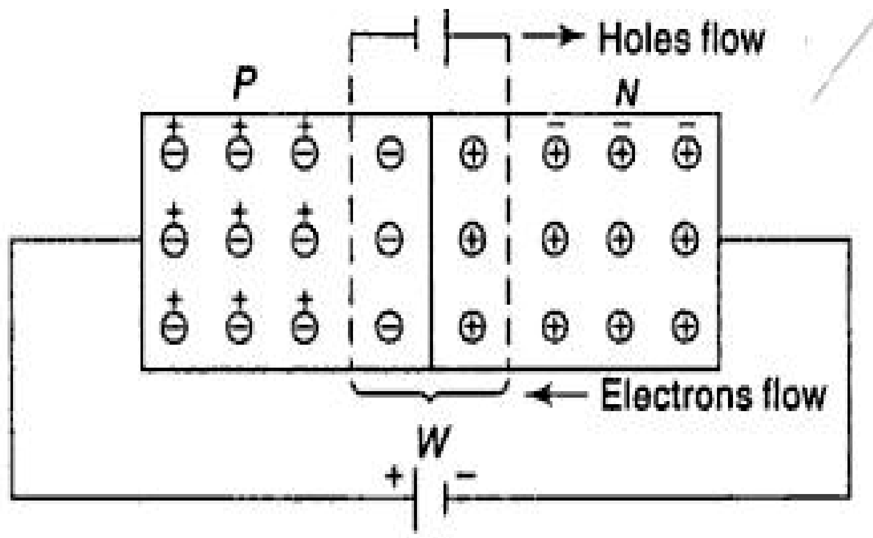

Figure: PN junctions under forward bias

UNDER REVERSE BIAS CONDITION

- When the negative terminal of the battery is connected to the P-type and positive terminal to N-type of the PN junction diode that is known as forward bias condition.

Operation

1. The holes from the majority carriers of the P side move towards the negative terminal of the battery and electrons which from the majority carrier of the N side are attracted towards the positive terminal of the battery.

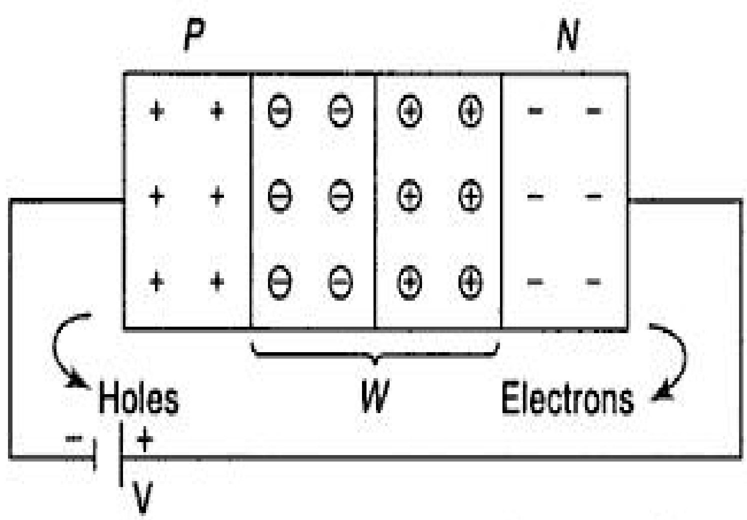

Figure PN junctions under reverse bias

2. Hence, the width of the depletion region which is depleted of mobile charge carriers increases. Thus, the electric field produced by applied reverse bias, is in the same direction as the electric field of the potential barrier.

3. Hence the resultant potential barrier is increased which prevents the flow of majority carriers in both directions. The depletion width W is proportional to under reverse bias.
Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=bczsfUFbHxk
Important Books/Journals for further learning including the page nos.: Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 115)

Course Faculty

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L2

LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : I- APPLICATIONS OF SEMICONDUCTOR DEVICES

Date of Lecture:

Topic of Lecture: VI characteristics

Introduction :

- The VI characteristics of PN junction diode in forwarding bias are nonlinear, that is, not a straight line.
- This nonlinear characteristic illustrates that during the operation of the N junction, the resistance is not constant.
- The slope of the PN junction diode in forwarding bias shows the resistance is very low.

Prerequisite knowledge for Complete understanding and learning of Topic:

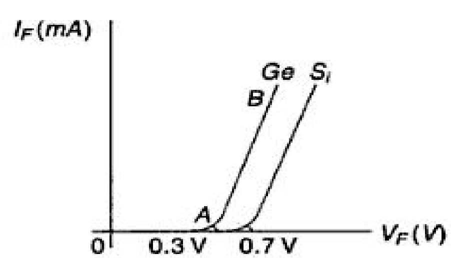
1. Electronics
2. Engineering Physics

Detailed content of the Lecture:

FORWARD BIAS CONDITION

V-I Characteristics

As the forward voltage increased for $V_F < V_o$, the forward current I_F almost zero because the potential barrier prevents the holes from P region and electrons from N region to flow across the depletion region in opposite direction.



V-I characteristics of a diode under forward bias

- For $V_F > V_o$, the potential barrier at the junction completely disappears and hence, the holes cross the junction from P to N type and electrons cross the junction to opposite direction, resulting large current flow in external circuit.

- A feature noted here is the cut in voltage or threshold voltage V_F below which the current is very small.
- At this voltage the potential barrier is overcome and the current through the junction starts to increase rapidly.
- Cut in voltage is 0.3V for germanium and 0.7 for silicon.

UNDER REVERSE BIAS CONDITION

V-I characteristics:

- Theoretically no current flow in the external circuit. But in practice a very small amount of current of the order of few microamperes flows under reverse bias.

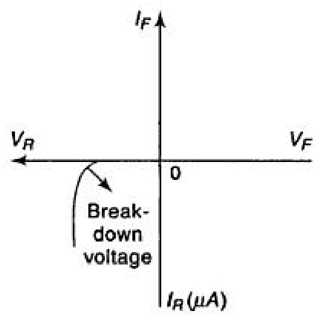


Figure V-I characteristics under reverse bias

- Electrons forming covalent bonds of semiconductor atoms in the P and N type regions may absorb sufficient energy from heat and light to cause breaking covalent bonds. So electron hole pairs continuously produced.
- Consequently the minority carriers electrons in the P region and holes in the N region, wander over to the junction and flow towards their majorityy carrier side giving rise a small reverse current. This current is known as reverse saturation current Io.
- The magnitude of this current is depends on the temperature because minority carrier is thermally broken covalent bonds.

Transition capacitances:

1. When P-N junction is reverse biased the depletion region act as an insulator or as a dielectric medium and the p-type an N-type region have low resistance and act as the plates.
2. Thus this P-N junction can be considered as a parallel plate capacitor.
3. This junction capacitance is called as space charge capacitance or transition capacitance and is denoted as CT .
4. Since reverse bias causes the majority charge carriers to move away from the junction , so the thickness of the depletion region denoted as W increases with the increase in reverse bias voltage.
5. This incremental capacitance CT may be defined as

$$CT = dQ/dV,$$

Where dQ is the increase in charge and dV is the change or increase in voltage.

6. The depletion region increases with the increase in reverse bias potential the resulting transition capacitance decreases.
7. The formula for transition capacitance is given as $CT = A\varepsilon/W$, where A is the cross sectional area of the region, and W is the width.

Diffusion capacitance:

1. When the junction is forward biased, a capacitance comes into play that is known as diffusion capacitance denoted as CD. It is much greater than the transition capacitance.
2. During forward biased the potential barrier is reduced. The charge carriers move away from the junction and recombine.
3. The density of the charge carriers is high near the junction and reduces or decays as the distance increases.
4. Thus in this case charge is stored on both side of the junction and varies with the applied potential. So as per definition change in charge with respect to applied voltage results in capacitance which here is called as diffusion capacitance.
5. The formula for diffusion capacitance is $CD = \tau ID / \eta VT$, where τ is the mean life time of the charge carrier, ID is the diode current and VT is the applied forward voltage, and η is generation recombination factor.
6. The diffusion capacitance is directly proportional to the diode current.
7. In forward biased CD >> CT . And thus CT can be neglected.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/channel/UCBkOVp1Cqz4MR0LYR8vKpZg

Important Books/Journals for further learning including the page nos.:
Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 117-120)

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L3

LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Mr.S.SARANRAJ

Unit : I- APPLICATIONS OF SEMICONDUCTOR DEVICES

Date of Lecture:

Topic of Lecture: Zener diode-Structure

Introduction :

- A Zener diode is a silicon semiconductor device that permits current to flow in either a forward or reverse direction.
- The diode consists of a special, heavily doped p-n junction, designed to conduct in the reverse direction when a certain specified voltage is reached.

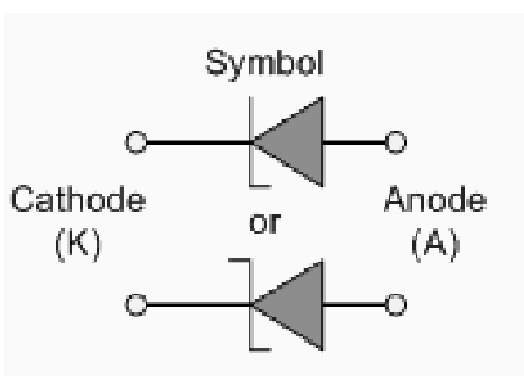
Prerequisite knowledge for Complete understanding and learning of Topic:

1. Electronics
2. Engineering Physics

Detailed content of the Lecture:

A ZENER DIODE:

- A Zener diode is a type of diode that permits current not only in the forward direction like a normal diode, but also in the reverse direction if the voltage is larger than the breakdown voltage known as "Zener knee voltage" or "Zener voltage".
- The device was named after Clarence Zener, who discovered this electrical property.



- However, the Zener Diode or "Breakdown Diode" as they are sometimes called, are basically the same as the standard PN junction diode but are specially designed to have a low pre- determined Reverse Breakdown Voltage that takes advantage of this high reverse voltage.

- The point at which a zener diode breaks down or conducts is called the "Zener Voltage" (Vz).The Zener diode is like a general-purpose signal diode consisting of a silicon PN junction.
- When biased in the forward direction it behaves just like a normal signal diode passing the rated current, but when a reverse voltage is applied to it the reverse saturation current remains fairly constant over a wide range of voltages.
- The reverse voltage increases until the diodes breakdown voltage VB is reached at which point a process called Avalanche Breakdown occurs in the depletion layer and the current flowing through the zener diode increasesdramatically to the maximum circuit value (which is usually limited by a series resistor).
- This breakdown voltage point is called the "zener voltage" for zener diodes.

Avalanche Breakdown*:*

- There is a limit for the reverse voltage. Reverse voltage can increase until the diode breakdown voltage reaches. This point is called Avalanche Break down region.
- At this stage maximum current will flow through the zener diode. This breakdown point is referred as -Zener voltage.
- The point at which current flows can be very accurately controlled (to less than 1%tolerance) in the doping stage of the diodes construction giving the diode a specific zener breakdown voltage, (Vz) ranging from a few volts up to a few hundred volts. This zener breakdown voltage on the I-V curve is almost a vertical straight line.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=Kj6Vpm6m9lU

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 127)

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L4

LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : I- APPLICATIONS OF SEMICONDUCTOR DEVICES

Date of Lecture:

Topic of Lecture: Zener diode –Operation

Introduction :

- Zener diode is made specifically to work in the zener voltage region.
- When any two resistances are connected in series, the the voltage gets divided across the resistances.
- The greater the resistance, greater is the voltage drop across a resistance.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Electronics
2. Engineering Physics

Detailed content of the Lecture:

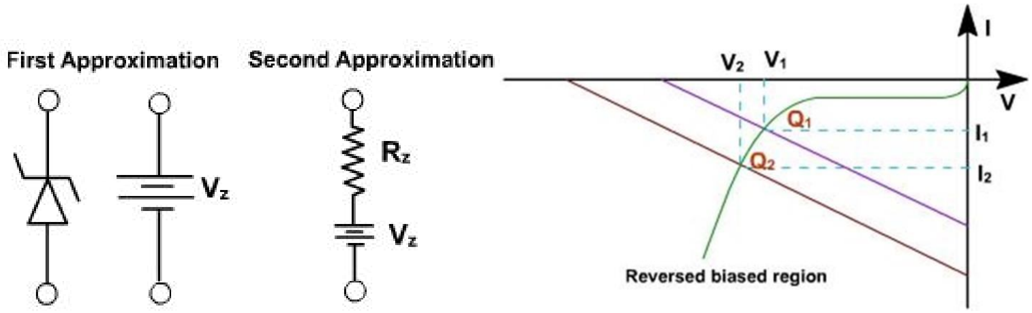
Zener Operation:

- When zener diode is forward biased it works as a diode and drop across it is 0.7 V. When it works in breakdown region the voltage across it is constant (V_Z) and the current through diode is decided by the external resistance.
- Thus, zener diode can be used as a voltage regulator in the configuration shown in figure 2 for regulating the dc voltage.
- It maintains the output voltage constant even through the current through it changes.

The load line of the circuit is given by $V_S = I_S R_S + V_Z$.

- The load line is plotted along with zener characteristic in figure The intersection point of the load line and the zener characteristic gives the output voltage and zener current.
- To operate the zener in breakdown region V_S should always be greater then V_Z. R_S is used to limit the current.
- If the V_S voltage changes, operating point also changes simultaneously but voltage across zener is almost constant.
- The first approximation of zener diode is a voltage source of V_Z magnitude and second approximation includes the resistance also. The two approximate equivalent

circuits are shown in below figure



- If second approximation of zener diode is considered, the output voltage varies slightly as shown in figure The zener ON state resistance produces more I * R drop as the current increases.
- As the voltage varies form V_1 to V_2 the operating point shifts from Q_1 to Q_2.

The voltage at Q_1 is,

$$V_1 = I_1 R_Z + V_Z$$

and at Q_2,

$$V_2 = I_2 R_Z + V_Z$$

Thus, change in voltage is

$$V_2 - V_1 = (I_2 - I_1) R_Z.$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=Kj6Vpm6m9lU

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 143)

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LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : I- APPLICATIONS OF SEMICONDUCTOR DEVICES

Date of Lecture:

Topic of Lecture: Zener diode - VI characteristics

Introduction :

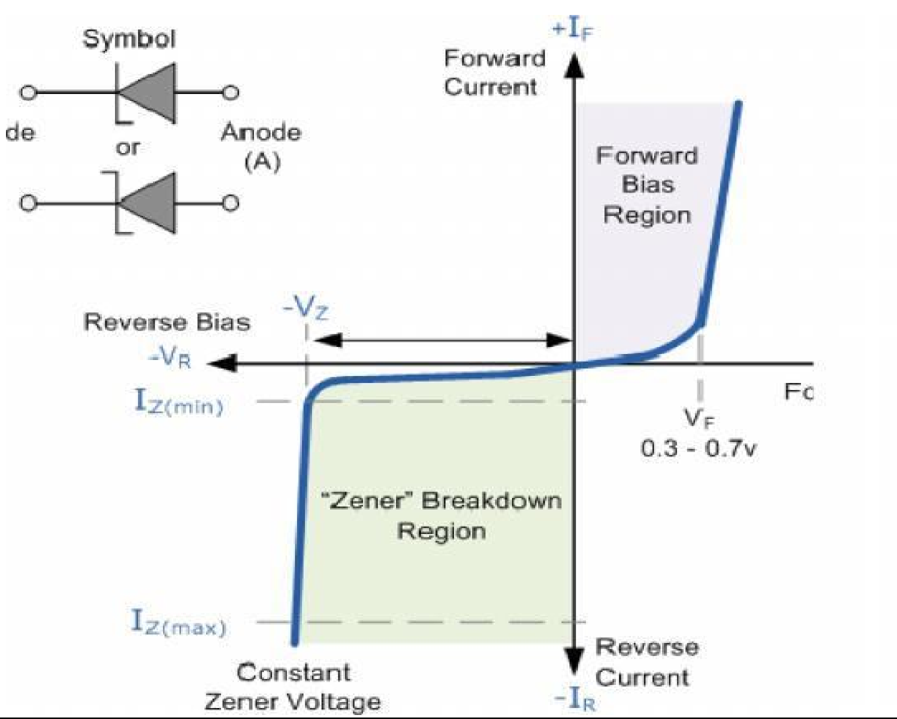
- When reverse biased voltage is applied to a zener diode, it allows only a small amount of leakage current until the voltage is less than zener voltage.
- When reverse biased voltage applied to the zener diode reaches zener voltage, it starts allowing large amount of electric current.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Electronics
2. Engineering Physics

Detailed content of the Lecture:

Zener diode characteristics



- The Zener Diode is used in its "reverse bias" or reverse breakdown mode, i.e. the diodes anode connects to the negative supply.
- From the I-V characteristics curve above, we can see that the zener diode has a region in its reverse bias
- The characteristics of almost a constant negative voltage regardless of the value of the current flowing through the diode and remains nearly constant
- A large changes in current as long as the zener diodes current remains between the breakdown current IZ(min) and the maximum current rating IZ(max).

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=lzUZSkrVBZM

Important Books/Journals for further learning including the page nos.:

Sedha.R.S, A Text Book of Applied Electronics, Sultan Chand Publishers, 2010. (Page Num -208)

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L6

LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : I- APPLICATIONS OF SEMICONDUCTOR DEVICES

Date of Lecture:

Topic of Lecture: Display devices- LED

Introduction :

- A LED display is a flat panel display that uses an array of light-emitting diodes as pixels for a video display.
- Their brightness allows them to be used outdoors where they are visible in the sun for store signs and billboards. In recent years, they have also become commonly used in destination signs on public transport vehicles, as well as variable-message signs on highways.
- LED displays are capable of providing general illumination in addition to visual display, as when used for stage lighting or other decorative (as opposed to informational) purposes.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Electronics
2. Engineering Physics

Detailed content of the Lecture:

LIGHT EMITTING DIODE (LED)

- A light emitting diode (LED) is known to be one of the best optoelectronic devices out of the lot. The device is capable of emitting a fairly narrow bandwidth of visible or invisible light when its internal diode junction attains a forward electric current or voltage.
- The visible lights that an LED emits are usually orange, red, yellow, or green. The invisible light includes the infrared light. The biggest advantage of this device is its high power to light conversion efficiency.
- That is, the efficiency is almost 50 times greater than a simple tungsten lamp. The response time of the LED is also known to be very fast in the range of 0.1 microseconds when compared with 100 milliseconds for a tungsten lamp.
- Due to these advantages, the device wide applications as visual indicators and as dancing light displays. We know that a P-N junction can connect the absorbed light energy into its proportional electric current.

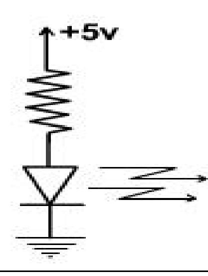
- The same process is reversed here. That is, the P-N junction emits light when energy is applied on it. This phenomenon is generally called electro luminance, which can be defined as the emission of light from a semi-conductor under the influence of an electric field.
- The charge carriers recombine in a forward P-N junction as the electrons cross from the N- region and recombine with the holes existing in the P-region. Free electrons are in the conduction band of energy levels, while holes are in the valence energy band.

- Thus the energy level of the holes will be lesser than the energy levels of the electrons.
- Some part of the energy must be dissipated in order to recombine the electrons and the holes.
- This energy is emitted in the form of heat and light.
- The electrons dissipate energy in the form of heat for silicon and germanium diodes. But in Galium- Arsenide-phosphorous (GaAsP) and Galium-phosphorous (GaP) semiconductors, the electrons dissipate energy by emitting photons.
- If the semiconductor is translucent, the junction becomes the source of light as it is emitted, thus becoming a light emitting diode (LED).
- But when the junction is reverse biased no light will be produced by the LED, and, on the contrary the device may also get damaged.

- All the semiconductors listed above can be used. An N-type epitaxial layer is grown upon a substrate, and the P-region is produced by diffusion.
- The P-region that includes the recombination of charge carriers is shown is the top. Thus the P-region becomes the device surface.
- In order to allow more surface area for the light to be emitted the metal anode connections are made at the outer edges of the P-layer.
- For the light to be reflected as much as possible towards the surface of the device, a gold film is applied to the surface bottom.
- This setting also enables to provide a cathode connection. The re-absorption problem is fixed by including domed lenses for the device.
- All the wires in the electronic circuits of the device is protected by encasing the device.
- The light emitted by athe device depends on the type of semiconductor material used.
- Infrared light is produced by using Gallium Arsenide (GaAs) as semiconductor. Red or yellowlight is produced by using Gallium -Arsenide-Phosphorus (GaAsP) as semiconductor.

LED Circuit Symbol

The circuit symbol of LED consists of two arrow marks which indicate the radiation emitted by the diode.



LED Characteristics

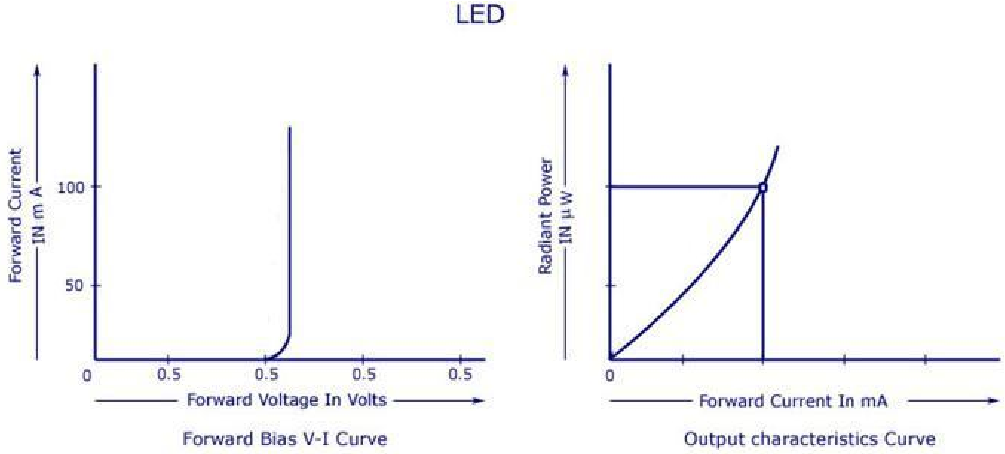


Figure: LED characteristics curve

- The forward bias Voltage-Current (V-I) curve and the output characteristics curve is shown in the figure above.
- The V-I curve is practically applicable in burglar alarms. Forward bias of approximately 1 volt is needed to give significant forward current.
- The second figure is used to represent a radiant power-forward current curve.
- The output power produced is very small and thus the efficiency in electrical-to-radiant energy conversion is very less.
- The commercially used LED‘s have a typical voltage drop between 1.5 Volt to 2.5 Volt or current between 10 to 50 milliamperes. The exact voltage drop depends on the LED current, colour, tolerance, and so on.

Advantages of LED's

- Very low voltage and current are enough to drive the LED.
- Voltage range – 1 to 2 volts.
- Current – 5 to 20 mill amperes.
- Total power output will be less than 150 mill watts.
- The response time is very less – only about 10 nanoseconds.
- The device does not need any heating and warm up time.
- Miniature in size and hence light weight.
- Have a rugged construction and hence can withstand shock and vibrations.
- An LED has a life span of more than 20 years.

Disadvantages of LED

- A slight excess in voltage or current can damage the device.
- The device is known to have a much wider bandwidth compared to the laser.
- The temperature depends on the radiant output power and wavelength.

Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=qE-4vmchq9c
Important Books/Journals for further learning including the page nos.: Sedha.R.S, A Text Book of Applied Electronics, Sultan Chand Publishers, 2010. (Page num - 213)

Course Faculty

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : I- APPLICATIONS OF SEMICONDUCTOR DEVICES

Date of Lecture:

Topic of Lecture: LCD

Introduction :

- LCD (Liquid Crystal Display) is a type of flat panel display which uses liquid crystals in its primary form of operation.
- LEDs have a large and varying set of use cases for consumers and businesses, as they can be commonly found in smartphones, televisions, computer monitors and instrument panels.

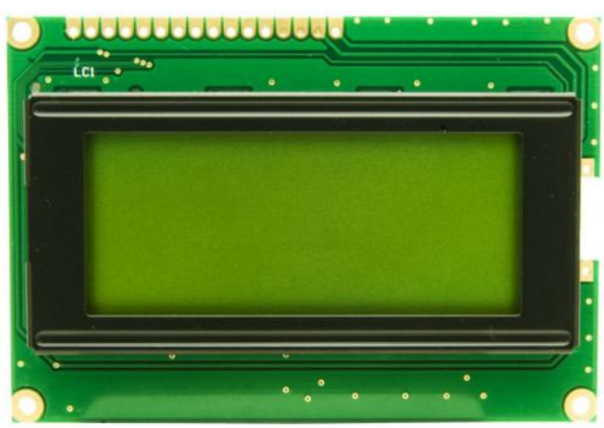
Prerequisite knowledge for Complete understanding and learning of Topic:

1. Electronics
2. Diode operation

Detailed content of the Lecture:

- A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals combined with polarizers.
- Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome.
- LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and seven-segment displays, as in a digital clock.
- They use the same basic technology, except that arbitrary images are made from a matrix of small pixels, while other displays have larger elements. LCDs can either be normally on (positive) or off (negative), depending on the polarizer arrangement.
- For example, a character positive LCD with a backlight will have black lettering on a background that is the color of the backlight, and a character negative LCD will have a black background with the letters being of the same color as the backlight.
- Optical filters are added to white on blue LCDs to give them their characteristic appearance.
- LCDs are used in a wide range of applications, including LCD televisions, computer monitors, instrument panels, aircraft cockpit displays, and indoor and outdoor signage.

- Small LCD screens are common in portable consumer devices such as digital cameras, watches, calculators, and mobile telephones, including smartphones. LCD screens are also used on consumer electronics products such as DVD players, video game devices and clocks.
- LCD screens have replaced heavy, bulky cathode ray tube (CRT) displays in nearly all applications.
- LCD screens are available in a wider range of screen sizes than CRT and plasma displays, with LCD screens available in sizes ranging from tiny digital watches to very large television receivers.
- LCDs are slowly being replaced by OLEDs, which can be easily made into different shapes, and have a lower response time, wider color gamut, virtually infinite color contrast and viewing angles, lower weight for a given display size and a slimmer profile (because OLEDs use a single glass or plastic panel whereas LCDs use two glass panels; the thickness of the panels increases with size but the increase is more noticeable on LCDs) and potentially lower power consumption (as the display is only "on" where needed and there is no backlight).
- OLEDs, however, are more expensive for a given display size due to the very expensive electroluminescent materials or phosphors that they use. Also due to the use of phosphors, OLEDs suffer from screen burn-in and there is currently no way to recycle OLED displays, whereas LCD panels can be recycled, although the technology required recycling LCDs is not yet widespread.
- Attempts to increase the lifespan of LCDs are quantum dot displays, which offer similar performance to an OLED display, but the Quantum dot sheet that gives these displays their characteristics cannot yet be recycled.
- Since LCD screens do not use phosphors, they rarely suffer image burn-in when a static image is displayed on a screen for a long time, e.g., the table frame for an airline flight schedule on an indoor sign.
- LCDs are, however, susceptible to image persistence. The LCD screen is more energy-efficient and can be disposed of more safely than a CRT can.
- Its low electrical power consumption enables it to be used in battery-powered electronic equipment more efficiently than CRTs can be.



Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=DoqorBJ1-38
Important Books/Journals for further learning including the page nos.: Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 192)

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LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : I- APPLICATIONS OF SEMICONDUCTOR DEVICES

Date of Lecture:

Topic of Lecture: Rectifiers: Half Wave Rectifiers

Introduction :

- A half wave rectifier is defined as a type of rectifier that only allows one half-cycle of an AC voltage waveform to pass, blocking the other half-cycle.
- Half-wave rectifiers are used to convert AC voltage to DC voltage, and only require a single diode to construct.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Electronics
2. Diode Operation

Detailed content of the Lecture:

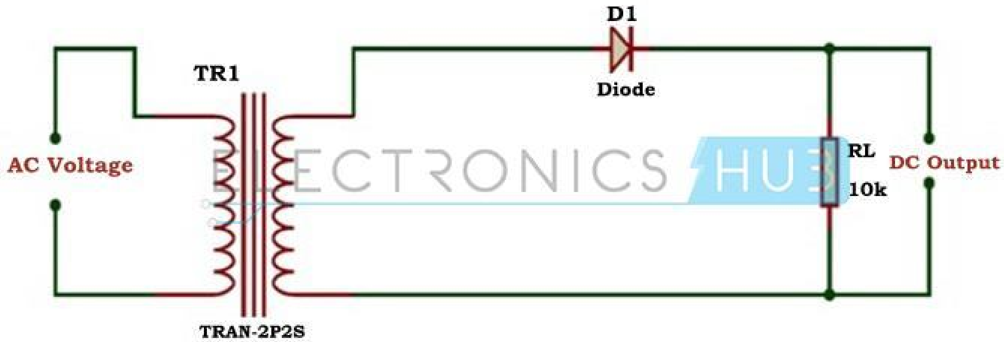
RECTIFIERS

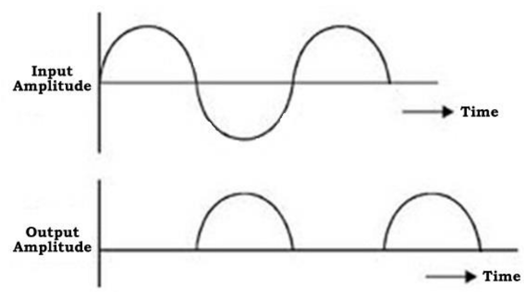
Rectifiers are classified according to the period of conduction. They are

- Half Wave Rectifier
- Full Wave Rectifier

Half Wave Rectifier:

- The half wave rectifier is a type of rectifier that rectifies only half cycle of the waveform.
- This describes the half wave rectifier circuit working.
- The half rectifier consist a step down transformer, a diode connected to the transformer and a load resistance connected to the cathode end of the diode.
- The circuit diagram of half wave transformer is shown below:

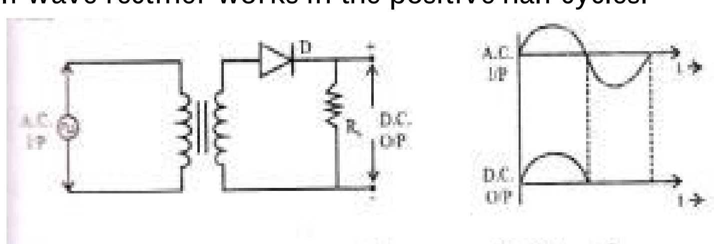




- The main supply voltage is given to the transformer which will increase or decrease the voltage and give to the diode.
- In most of the cases we will decrease the supply voltage by using the step down transformer here also the output of the step down transformer will be in AC.
- This decreased AC voltage is given to the diode which is connected serial to the secondary winding of the transformer, diode is electronic component which will allow only the forward bias current and will not allow the reverse bias current.
- From the diode we will get the pulsating DC and give to the load resistance RL.

Working of Half Wave Rectifier:

The input given to the rectifier will have both positive and negative cycles. The half rectifier will allow only the positive half cycles and omit the negative half cycles. So first we will see how half wave rectifier works in the positive half cycles.



a) Half wave Rectifier b) Wave forms

Positive Half Cycle:

- In the positive half cycles when the input AC power is given to the primary winding of the step down transformer, we will get the decreased voltage at the secondary winding which is given to the diode.
- The diode will allow current flowing in clock wise direction from anode to cathode in the forward bias (diode conduction will take place in forward bias) which will generate only the positive half cycle of the AC.
- The diode will eliminate the variations in the supply and give the pulsating DC voltage to the load resistance RL. We can get the pulsating DC at the Load resistance.

Negative Half Cycle:

- In the negative half cycle the current will flow in the anti-clockwise direction and the diode will go in to the reverse bias.
- In the reverse bias the diode will not conduct so, no current in flown from anode to cathode, and we cannot get any power at the load resistance.
- Only small amount of reverse current is flown from the diode but this current is almost negligible. And voltage across the load resistance is also zero.

Characteristics of Half Wave Rectifier:

There are some characteristics to the half wave rectifier they are

Efficiency: The efficiency is defined as the ratio of input AC to the output DC.

$$\text{Efficiency, } \eta = P_{dc} / P_{ac}$$

DC power delivered to the load,

$$P_{dc} = I^2_{dc} R_L = (I_{max} / pi)^2 R_L$$

AC power input to the transformer, P_{ac} = Power dissipated in junction of diode + Power dissipated in load resistance R_L

$$= I^2_{rms} R_F + I^2_{rms} R_L = \{I^2_{MAX}/4\}[R_F + R_L]$$

Rectification Efficiency,

$$\eta = P_{dc} / P_{ac} = \{4/ {}^2\}[R_L / (R_F + R_L)] = 0.406/\{1+ R_F/R_L\}$$

If R_F is neglected, the efficiency of half wave rectifier is 40.6%.

Ripple factor: It is defined as the amount of AC content in the output DC. It nothing but amount of AC noise in the output DC. Less the ripple factor, performance of the rectifier is more. The ripple factor of half wave rectifier is about 1.21 (full wave rectifier has about 0.48).

It can be calculated as follows:

The effective value of the load current I is given as sum of the rms values of harmonic currents I1, I2, I3, I4 and DC current Idc.

$$I^2 = I^2_{dc} + I^2_1 + I^2_2 + I^2_4 = I^2_{dc} + I^2_{ac}$$

Ripple factor, is given as

$$\gamma = I_{ac} / I_{dc} = (I^2 - I^2_{dc}) / I_{dc} = \{(I_{rms} / I_{dc}\ ^2)\text{-}1\} = K_f - 1$$

Where Kf is the form factor of the input voltage. Form factor is given as

$$K_f = I_{rms} / I_{avg} = (I_{max}/2) / (I_{max}/pi) = pi/2 = 1.57$$

So, ripple factor,

$$\gamma = (1.57^2 - 1) = 1.21$$

Peak Inverse Voltage: It is defined as the maximum voltage that a diode can with stand in reverse bias. During the reverse bias as the diode do not conduct total voltage drops across the diode. Thus peak inverse voltage is equal to the input voltage Vs.

Transformer Utilization Factor (TUF): The TUF is defined as the ratio of DC power is delivered to the load and the AC rating of the transformer secondary. Half wave rectifier has around 0.287 and full wave rectifier has around 0.693.Half wave rectifier is mainly used in the low power circuits. It has very low performance when it is compared with the other rectifiers.
Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=Ll0IOk_Ltfc
Important Books/Journals for further learning including the page nos.: Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 598)

Course Faculty

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

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L9

LECTURE HANDOUTS

EEE

II/III

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Mr.S.SARANRAJ

Unit : I- APPLICATIONS OF SEMICONDUCTOR DEVICES

Date of Lecture:

Topic of Lecture: Full Wave Rectifiers

Introduction :

- In a Full Wave Rectifier circuit two diodes are now used, one for each half of the cycle.
- A multiple winding transformer is used whose secondary winding is split equally into two halves with a common centre tapped connection, (C).
- This configuration results in each diode conducting in turn when its anode terminal is positive with respect to the transformer centre point C producing an output during both half-cycles, twice that for the half wave rectifier so it is 100% efficient

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Electronics
2. Diode Operation

Detailed content of the Lecture:

FULL WAVE RECTIFIER

- Full wave rectifier rectifies the full cycle in the waveform i.e. it rectifies both the positive and negative cycles in the waveform.
- We have already seen the characteristics and working of Half Wave Rectifier. This Full wave rectifier has an advantage over the half wave i.e. it has average output higher than that of half wave rectifier.
- The number of AC components in the output is less than that of the input.

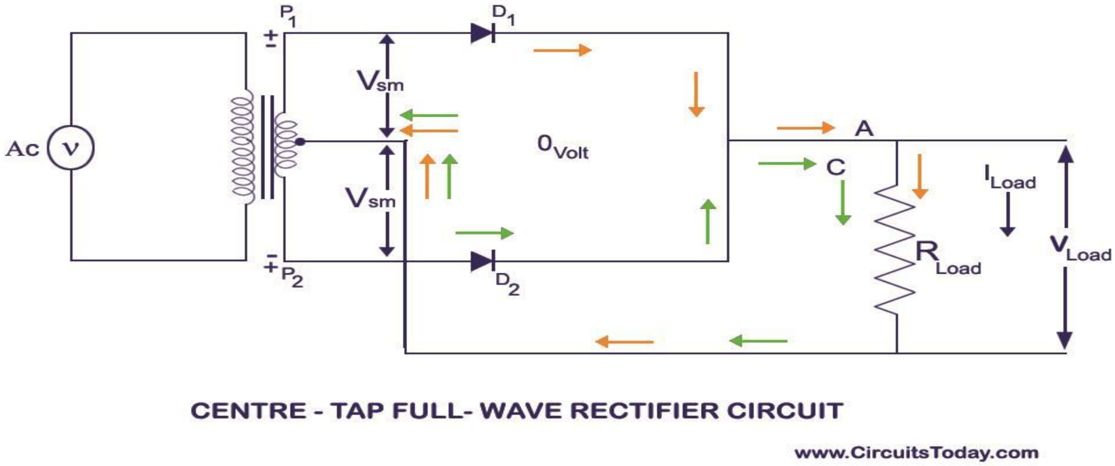
The full wave rectifier can be further divided mainly into following types.

1. Center Tapped Full Wave Rectifier
2. Full Wave Bridge Rectifier

Centre-Tap Full Wave Rectifier

- We have already discussed the Full Wave Bridge Rectifier, which uses four diodes, arranged as a bridge, to convert the input alternating current (AC) in both half cycles to direct current (DC).
- In the case of centre-tap full wave rectifier, only two diodes are used, and are connected to the opposite ends of a centre-tapped secondary transformer as shown in the figure below. The centre-tap is usually considered as the ground point or the zero voltage

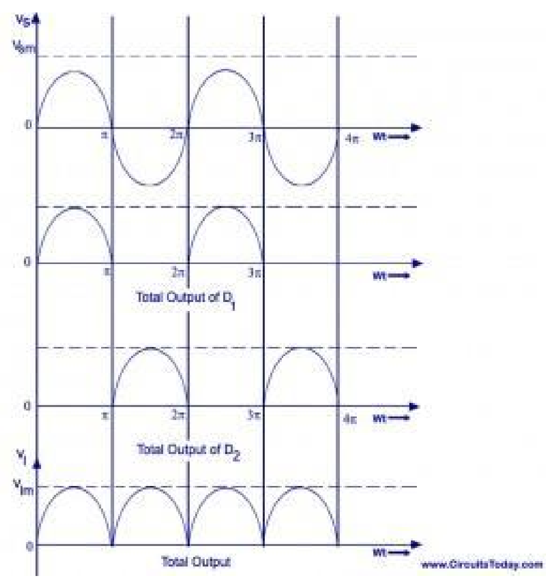
reference point.



Centre Tap Full Wave Rectifier Circuit

Working of Centre-Tap Full Wave Rectifier

- As shown in the figure, an ac input is applied to the primary coils of the transformer. This input makes the secondary ends P1 and P2 become positive and negative alternately.
- For the positive half of the ac signal, the secondary point D1 is positive, GND point will have zero volt and P2 will be negative. At this instant diode D1 will be forward biased and diode D2 will be reverse biased.
- As explained in the Theory Behind P-N Junction and Characteristics of P-N Junction Diode, the diode D1 will conduct and D2 will not conduct during during the positive half cycle.
- Thus the current flow will be in the direction P1-D1-C-A-B-GND. Thus, the positive half cycle appears across the load resistance RLOAD.
- During the negative half cycle, the secondary ends P1 becomes negative and P2 becomes positive. At this instant, the diode D1 will be negative and D2 will be positive with the zero reference point being the ground, GND. Thus, the diode D2 will be forward biased and D1 will be reverse biased. The diode D2 will conduct and D1 will not conduct during the negative half cycle. The current flow will be in the direction P2-D2-C-A-B-GND.



Centre-tap Full-wave Rectifier-Waveform

When comparing the current flow in the positive and negative half cycles, we can conclude that the direction of the current flow is the same (through load resistance RLOAD). When compared to the Half-Wave Rectifier, both the half cycles are used to produce the corresponding output. The frequency of the rectified output voltage is twice the input frequency. The output that is rectified, consists of a dc component and a lot of ac components of minute amplitudes.

Full wave bridge rectifier.

- A Full wave rectifier is a circuit arrangement which makes use of both half cycles of input alternating current (AC) and convert them to direct current (DC).
- Thus a full wave rectifier is much more efficient (double+) than a half wave rectifier. This process of converting both half cycles of the input supply (alternating current) to direct current (DC) is termed full wave rectification.
- Full wave rectifier can be constructed in 2 ways. The first method makes use of a center tapped transformer and 2 diodes. This arrangement is known as Center Tapped Full Wave

Full Wave Rectifier Theory

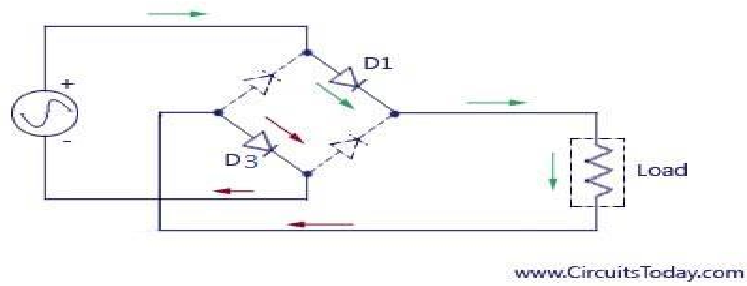
To understand full wave bridge rectifier theory perfectly, you need to learn half wave rectifier first. In the tutorial of half wave rectifier we have clearly explained the basic working of a rectifier. In addition we have also explained the theory behind a pn junction and the characteristics of a pn junction diode.

Full Wave Rectifier Working & Operation

The working & operation of a full wave bridge rectifier is pretty simple. The circuit diagrams and wave forms we have given below will help you understand the operation of a bridge rectifier perfectly. In the circuit diagram, 4 diodes are arranged in the form of a bridge. The transformer secondary is connected to two diametrically opposite points of the bridge at points A & C. The load resistance R_L is connected to bridge through points B and D.

During the first half cycle

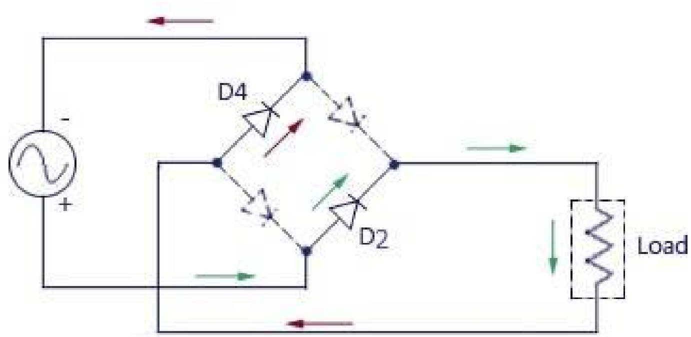
During first half cycle of the input voltage, the upper end of the transformer secondary winding is positive with respect to the lower end. Thus during the first half cycle diodes D1 and D_3 are forward biased and current flows through arm AB, enters the load resistance R_L, and returns back flowing through arm DC. During this half of each input cycle, the diodes D_2 and D_4 are reverse biased and current is not allowed to flow in arms AD and BC. The flow of current is indicated by solid arrows in the figure above. We have developed another diagram below to help you understand the current flow quickly. See the diagram below – the green arrows indicate beginning of current flow from source (transformer secondary) to the load resistance. The red arrows indicate return path of current from load resistance to the source, thus completing the circuit.



Flow of current in Bridge Rectifier

During the second half cycle

During second half cycle of the input voltage, the lower end of the transformer secondary winding is positive with respect to the upper end. Thus diodes D2 and D4 become forward biased and current flows through arm CB, enters the load resistance R_L, and returns back to the source flowing through arm DA. Flow of current has been shown by dotted arrows in the figure. Thus the direction of flow of current through the load resistance R_L remains the same during both half cycles of the input supply voltage. See the diagram below – the green arrows indicate beginning of current flow from source (transformer secondary) to the load resistance. The red arrows indicate return path of current from load resistance to the source, thus completing the circuit.



Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=LI0IOk_Ltfc

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 598)

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L10

LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : II- TRANSISTORS

Date of Lecture:

Topic of Lecture: UJT

Introduction :

The transistor is the main building block ―element‖ of electronics. It is a semiconductor device and it comes in two general types: the Bipolar Junction Transistor (BJT) and the Field Effect Transistor (FET).

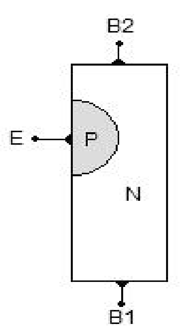
It is named as transistor which is an acronym of two terms: ―transfer-of-resistor.‖ It means that the internal resistance of transistor transfers from one value to another values depending on the biasing voltage applied to the transistor. Thus it is called Transfer resistor: i.e. TRANSISTOR.

Prerequisite knowledge for Complete understanding and learning of Topic:

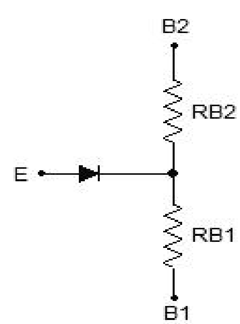
- Basics of PN Junction formation

Detailed content of the Lecture:

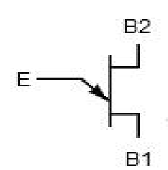
Unijunction transistor (abbreviated as UJT), also called the double-base diode is a 2-layer, 3-terminal solid-state (silicon) switching device. The device has-a unique characteristic that when it is triggered, its emitter current increases re generatively (due to negative resistance characteristic) until it is restricted by emitter power supply. Since the device has one pn junction and three leads it is commonly called UJT.



UJT Internal block diagram



UJT simplified internal circuit model



UJT circuit symbol

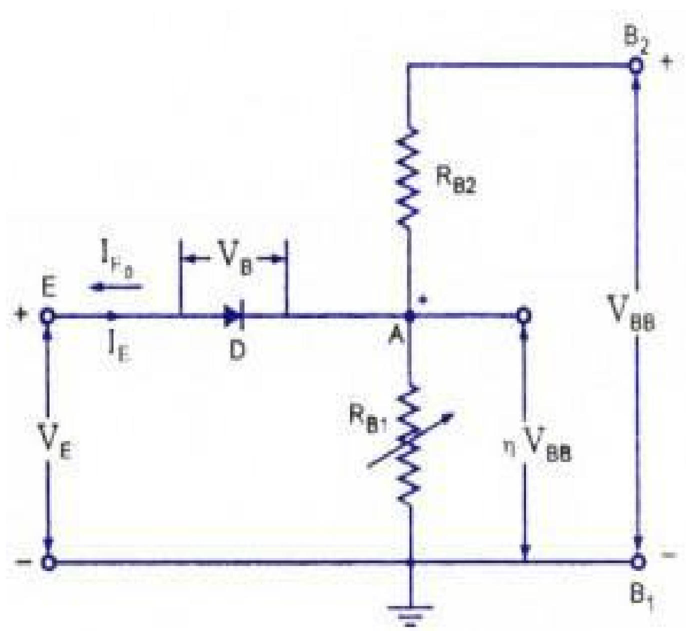
Construction of a UJT

The basic structure of a unijunction transistor is shown in figure. It essentially consists of a lightly-doped N-type silicon bar with a small piece of heavily doped P-type material alloyed to its one side to produce single P-N junction. The single P-N junction accounts for the terminology unijunction. The silicon bar, at its ends, has two ohmic contacts designated as base-1 (B_1) and base- 2 (B_2), as shown and the P-type region is termed the emitter (E). The emitter junction is usually located closer to base-2 (B_2) than base-1 (B_1) so that the device is not symmetrical, because symmetrical unit does not provide optimum electrical characteristics for most of the applications.

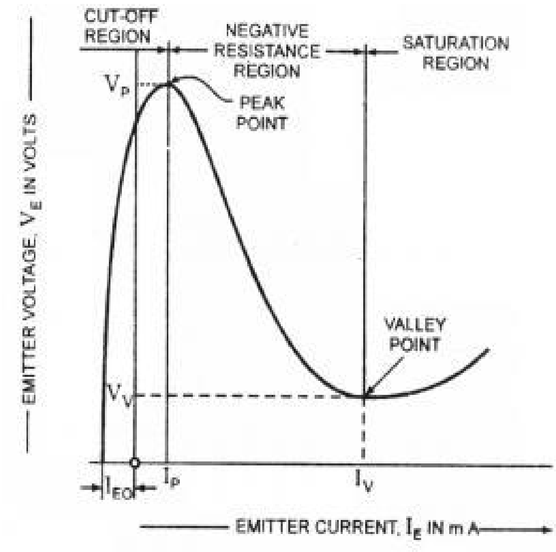
The symbol for unijunction transistor is shown in figure. The emitter leg is drawn at an angle to the vertical line representing the N-type material slab and the arrowhead points in the direction of conventional current when the device is forward-biased, active or in the conducting state. The basic arrangement for the UJT is shown in figure.

A complementary UJT is formed by diffusing an N-type emitter terminal on a P-type base. Except for the polarities of voltage and current, the characteristics of a complementary UJT are exactly the same as those of a conventional UJT.

- The device has only one junction, so it is called the unijunction device.
- The device, because of one P-N junction, is quite similar to a diode but it differs from an ordinary diode as it has three terminals.
- The structure of a UJT is quite similar to that of an N-channel JFET. The main difference is that P-type (gate) material surrounds the N-type (channel) material in case of JFET and the gate surface of the JFET is much larger than emitter junction of UJT.



Equivalent Circuit of a UJT



Static Emitter-Characteristic For a UJT

The static emitter characteristic (a curve showing the relation between emitter voltage V_E and emitter current I_E) of a UJT at a given inter base voltage V_{BB} is shown in figure. From figure it is noted that for emitter potentials to the left of peak point, emitter current I_E never exceeds I_{Eo} . The current I_{Eo} corresponds very closely to the reverse leakage current I_{Co} of the conventional BJT. This region, as shown in the figure, is called the cut-off region. Once conduction is established at $V_E = V_P$ the emitter potential V_E starts decreasing with the increase in emitter current I_E. This Corresponds exactly with the decrease in resistance R_B for increasing current I_E. This device, therefore, has a negative resistance region which is stable enough to be used with a great deal of reliability in the areas of applications listed earlier. Eventually, the valley point reaches, and any further increase in emitter current I_E places the device in the saturation region, as shown in the figure.

Three other important parameters for the UJT are I_P, V_V and I_V and are defined 3below:

Peak-Point Emitter Current I_p : It is the emitter current at the peak point. It represents the rnimrnum current that is required to trigger the device (UJT). It is inversely proportional to the interbase voltage V_{BB}.

Valley Point Voltage V_V: The valley point voltage is the emitter voltage at the valley point. The valley voltage increases with the increase in interbase voltage V_{BB}.

Valley Point Current I_V: The valley point current is the emitter current at the valley point. It increases with the increase in inter-base voltage V_{BB}.

- **Special Features of UJT.**

The special features of a UJT are :

1. A stable triggering voltage (V_P)— a fixed fraction of applied inter base voltage V_{BB}.

2. A very low value of triggering current.
3. A high pulse current capability.
4. A negative resistance characteristic.
5. Low cost.

Applications of UJT.

- Relaxation oscillators.
- Switching Thyristors like SCR, TRIAC etc.
- Magnetic flux sensors.
- Voltage or current limiting circuit.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=Ee34rPDqIws

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 115-116)

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L11

LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Mr.S.SARANRAJ

Unit : II- TRANSISTORS **Date of Lecture:**

Topic of Lecture: BJT

Introduction :

The transistor is the main building block ―element‖ of electronics. It is a semiconductor device and it comes in two general types: the Bipolar Junction Transistor (BJT) and the Field Effect Transistor (FET).

It is named as transistor which is an acronym of two terms: ―transfer-of-resistor.‖ It means that the internal resistance of transistor transfers from one value to another values depending on the biasing voltage applied to the transistor. Thus it is called Transfer resistor: i.e. TRANSISTOR.

Prerequisite knowledge for Complete understanding and learning of Topic:

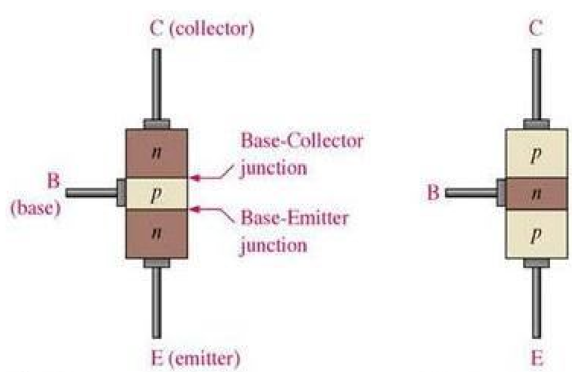
- Basics of PN Junction formation

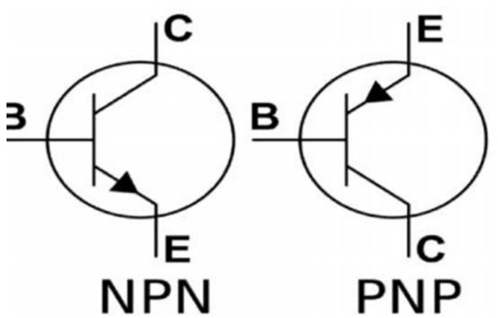
Detailed content of the Lecture:

TRANSISTOR CONSTRUCTION

PNP Transistor: In PNP transistor a thin layer of N-type silicon is sandwiched between two layers of P-type silicon.

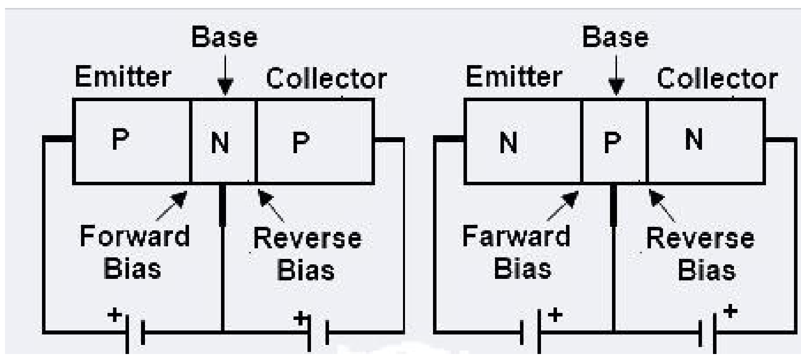
NPN Transistor: In NPN transistor a thin layer of P-type silicon is sandwiched between two layers of N-type silicon. The two types of BJT are represented in figure 2.1





The states of the two pn junctions can be altered by the external circuitry connected to the transistor. This is called biasing the transistor.

Usually the emitter- base junction is forward biased and collector –base junction is reverse biased. Due to forward bias on the emitter- base junction an emitter current flows through the base into the collector. Though, the collector –base junction is reverse biased, almost the entire emitter current flows through the collector circuit.



Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=-VwPSDQmdjM&list=PLwjK_iyK4LLDoFG8FeiKAr3IStRkPSxqq

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 210)

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L12

LECTURE HANDOUTS

EEE

II/III

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : II- TRANSISTORS

Date of Lecture:

Topic of Lecture: BJT - operation and V-I characteristics

Introduction :

The transistor is the main building block ―element‖ of electronics. It is a semiconductor device and it comes in two general types: the Bipolar Junction Transistor (BJT) and the Field Effect Transistor (FET).

It is named as transistor which is an acronym of two terms: ―transfer-of-resistor.‖ It means that the internal resistance of transistor transfers from one value to another values depending on the biasing voltage applied to the transistor. Thus it is called Transfer resistor: i.e. TRANSISTOR.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of PN Junction formation

Detailed content of the Lecture:

Modes	Emitter-Base junction	Collector-Base
Cutoff	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward
Reverse active	Reverse	Forward

A single pn junction has two different types of bias:

Forward bias
Reverse bias

There are two junctions in bipolar junction transistor. Each junction can be forward or reverse biased independently. Thus there are four modes of operations

Forward Active

In this mode of operation, emitter-base junction is forward biased and collector base junction is reverse biased. Transistor behaves as a source. With controlled source characteristics the BJT can be used as an amplifier and in analog circuits.

Cut off

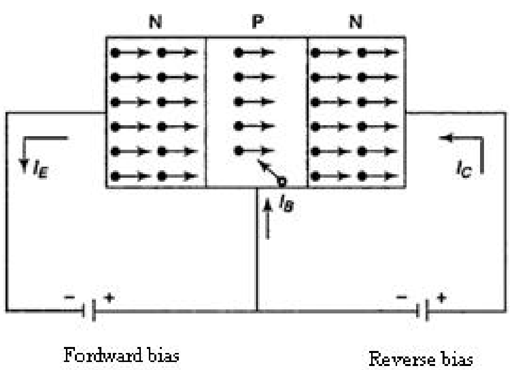
When both junctions are reverse biased it is called cut off mode. In this situation there is nearly zero current and transistor behaves as an open switch.

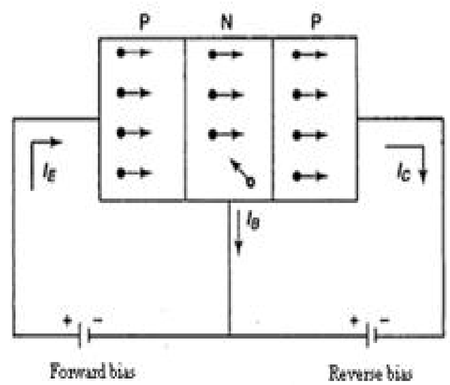
Saturation

In saturation mode both junctions are forward biased large collector current flows with a small voltage across collector base junction. Transistor behaves as an closed switch.

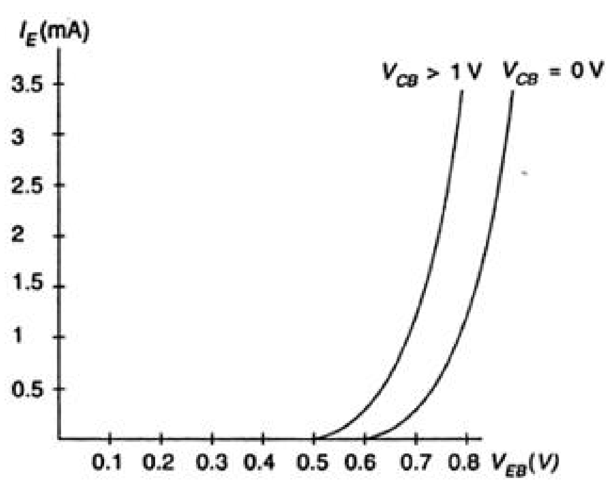
Reverse Active

It is opposite to forward active mode because in this emitter base junction is reverse biased and collector base junction is forward biased. It is called inverted mode. It is no suitable for amplification. However the reverse active mode has application in digital circuits and certain analog switching circuits.

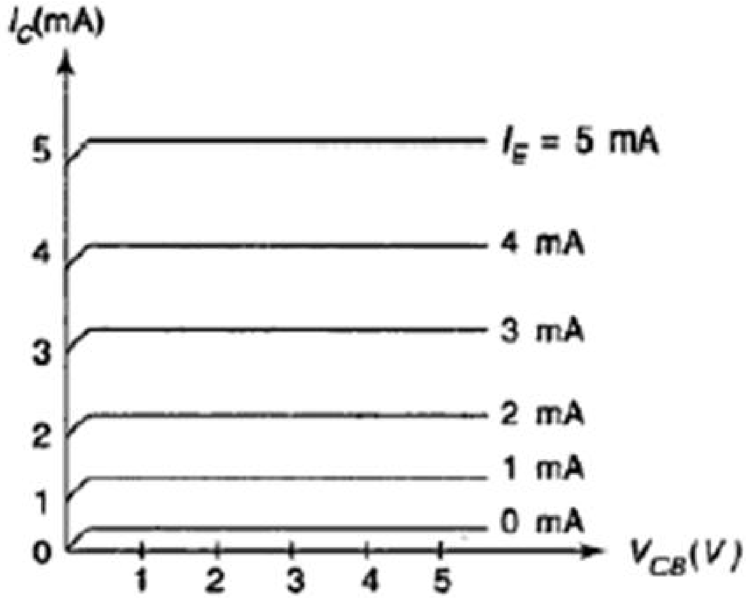




INPUT CHARACTERISTICS:



OUTPUT CHARACTERISTICS:



Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=-VwPSDQmdjM&list=PLwjK_iyK4LLDoFG8FeiKAr3IStRkPSxqq

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LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : II- TRANSISTORS

Date of Lecture:

Topic of Lecture: JFET - Construction, operation and V-I characteristics

Introduction :

The field effect transistor is a semiconductor device, which depends for its operation on the control of current by an electric field. There are two of field effect transistors:

1. JFET (Junction Field Effect Transistor)
2. MOSFET (Metal Oxide Semiconductor Field Effect Transistor) The FET has several advantages over conventional transistor.

It is less noisy than a bipolar transistor.
It exhibits no offset voltage at zero drain current.
It has thermal stability.
It is relatively immune to radiation.

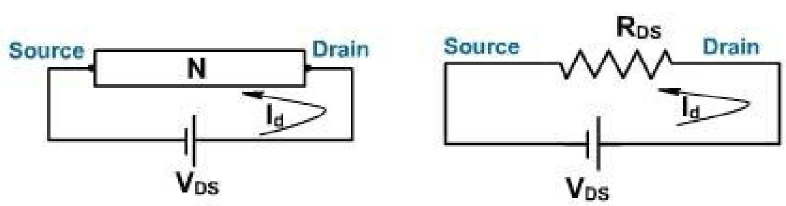
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of PN Junction formation

Detailed content of the Lecture:

Operation of FET:

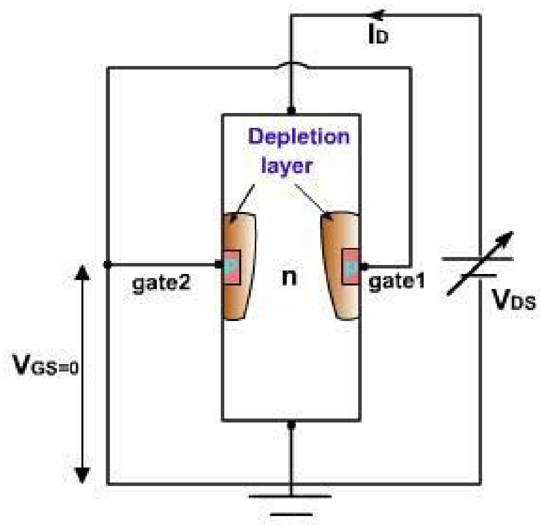
Consider a sample bar of N-type semiconductor. This is called N-channel and it is electrically equivalent to a resistance as shown.



Ohmic contacts are then added on each side of the channel to bring the external connection. Thus if a voltage is applied across the bar, the current flows through the channel.

The terminal from where the majority carriers (electrons) enter the channel is called source designated by S. The terminal through which majority carriers leaves the channel is called drain and designated by D. For an N-channel device, electrons are the majority carriers. Hence the circuit behaves like a dc voltage V_{DS} applied across a resistance R_{DS}. The resulting current is the drain current I_D. If V_{DS} increases, I_D increases proportionally.

Now on both sides of the n-type bar heavily doped regions of p-type impurity have been formed by any method for creating pn junction. These impurity regions are called gates (gate1 and gate2) as shown in fig.

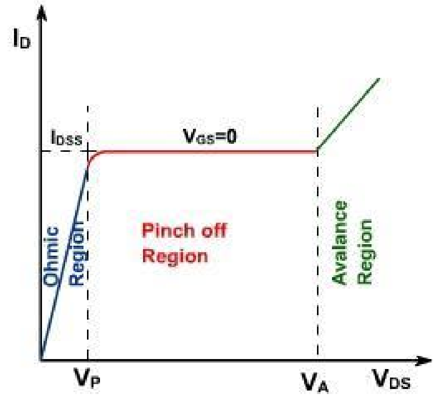


Both the gates are internally connected and they are grounded yielding zero gate source voltage (V_{GS} =0). The word gate is used because the potential applied between gate and source controls the channel width and hence the current.

As with all PN junctions, a depletion region is formed on the two sides of the reverse biased PN junction. The current carriers have diffused across the junction, leaving only uncovered positive ions on the n side and negative ions on the p side. The depletion region width increases with the magnitude of reverse bias. The conductivity of this channel is normally zero because of the unavailability of current carriers.

The potential at any point along the channel depends on the distance of that point from the drain, points close to the drain are at a higher positive potential, relative to ground, then points close to the source. Both depletion regions are therefore subject to greater reverse voltage near the drain. Therefore the depletion region width increases as we move towards drain. The flow of electrons from source to drain is now restricted to the narrow channel between the no conducting depletion regions. The width of this channel determines the resistance between drain and source.

Consider now the behavior of drain current I_D vs drain source voltage V_{DS}. The gate source voltage is zero therefore V_{GS}= 0. Suppose that V_{DS} is gradually linearly increased linearly from
0V. I_D also increases.



Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=_DZ7baOhNFQ

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 385)

Course Faculty

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L14

LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : II- TRANSISTORS

Date of Lecture:

Topic of Lecture: MOSFET - Construction, operation

Introduction :

MOSFET (Metal Oxide Semiconductor Field Effect Transistor)

Like JFET, it has a source, Drain and Gate.

It is also called IGFET (Insulated Gate FET) because gate terminal is insulated from channel. Therefore it has extremely high input resistance.

Prerequisite knowledge for Complete understanding and learning of Topic:

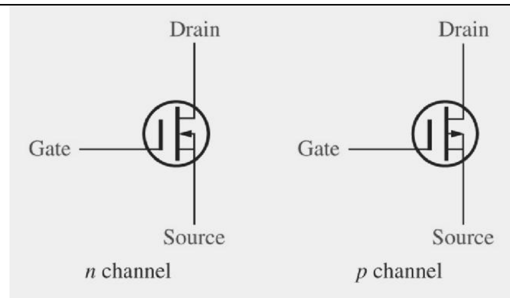
- Basics of Transistors

Detailed content of the Lecture:

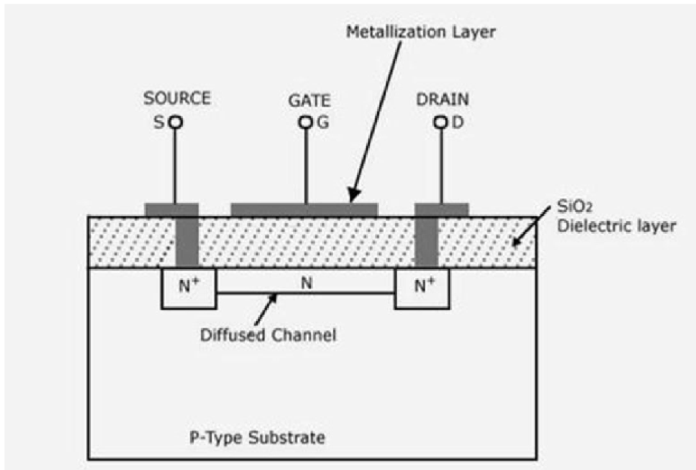
Types of MOSFET

It has two types

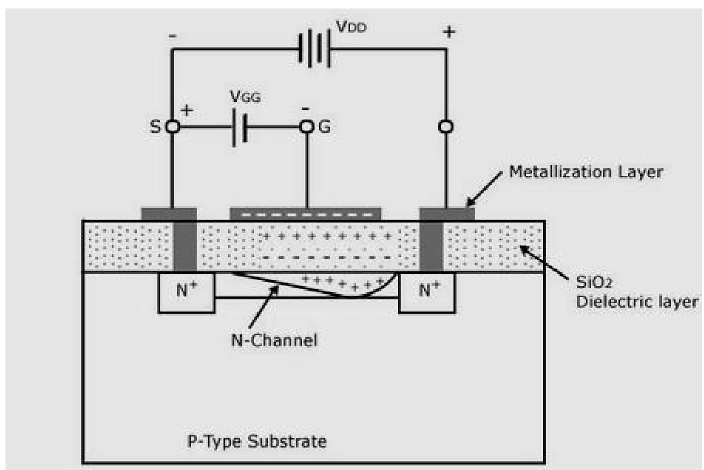
- Depletion mode MOSFET
  - N-channel
  - P-channel
- Enhancement mode MOSFET
  - N-channel
  - P-channel



Construction:



Operation:



Case (i) "when and is increased from zero"

Here N-base (Drain) is connected to positive supply. It acts as a reverse bias. Due to this, depletion region gets increases. Free electron from n-channel is attracted towards positive potential of drain terminal. This establishes current through channel flows from drain to source and denoted as I_{DSS}.

Pinch of voltage

The pinch off voltage is the voltage at which the junction is depleted of charge carriers.

Case (ii) "when and is increased from zero"

The negative charge on gate repels conduction electrons from the channel and attract holes from the p-type substrate.

Due to this electron-hole recombination occurs and reduce the number of free electrons in the channel available for conduction, reducing Drain current (I_D).

When negative voltage of is incresed the pinch of voltage decreased. When it is further increased the channel is fully depleted and no current flows through it.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=4_nGFY7zgDM

Important Books/Journals for further learning including the page nos.:

Sedha.R.S, A Text Book of Applied Electronics, Sultan Chand Publishers, 2010. (Page num - 259)

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L15

LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : II- TRANSISTORS

Date of Lecture:

Topic of Lecture: MOSFET - V-I characteristics

Introduction :

MOSFET (Metal Oxide Semiconductor Field Effect Transistor)

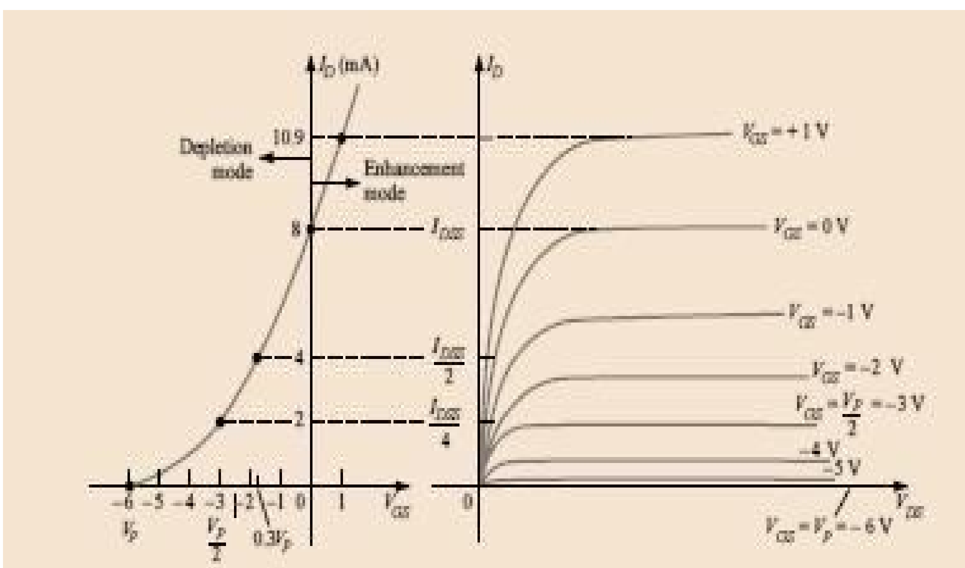
Like JFET, it has a source, Drain and Gate.

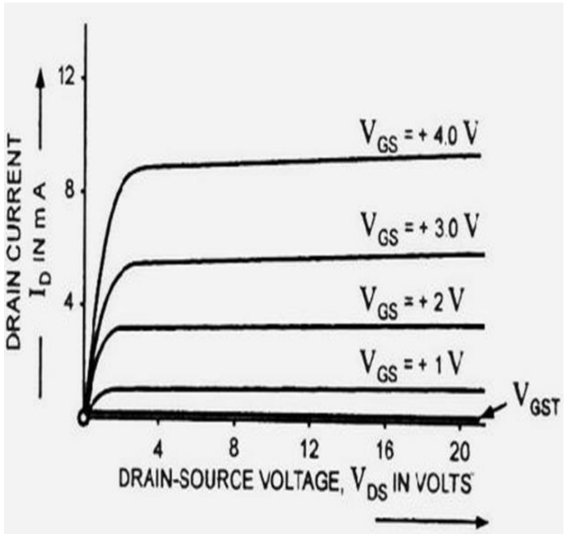
It is also called IGFET (Insulated Gate FET) because gate terminal is insulated from channel. Therefore it has extremely high input resistance.

Prerequisite knowledge for Complete understanding and learning of Topic:

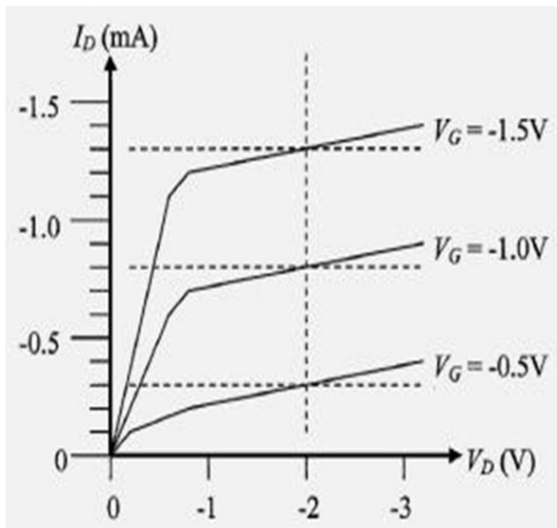
- Basics of Transistors

Detailed content of the Lecture:





Drain Characteristics



The point at which the load line intersects with I_B = 0 characteristic is known as cut off point. At this point base current is zero and collector current is almost negligibly small. At cut off the emitter diode comes out of forward bias and normal transistor action is lost. To a close approximation.

V_{CE} (cut off)V_{CC} (approximately).

The intersection of the load line and I_B = $I_{B(max)}$ characteristic is known as saturation point
. At this point I_B= $I_{B(max)}$, I_C= $I_{C(sat)}$. At this point collector diodes comes out of reverse bias and again transistor action is lost. To a close approximation,

$I_{C(sat)}$ V_{CC} / R_C(approximately).

The $I_{B(sat)}$ is the minimum current required to operate the transistor in saturation region. If the I_B is less than $I_{B(sat)}$, the transistor will operate in active region. If I_B > $I_{B(sat)}$ it always operates in saturation region.

Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=4_nGFY7zgDM
Important Books/Journals for further learning including the page nos.: Sedha.R.S, A Text Book of Applied Electronics, Sultan Chand Publishers, 2010. (Page num - 259)

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L16

LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : II- TRANSISTORS

Date of Lecture:

Topic of Lecture: IGBT Construction, operation and V-I characteristics

Introduction:

The Insulated Gate Bipolar Transistor also called an IGBT for short, is something of a cross between a conventional Bipolar Junction Transistor, (BJT) and a Field Effect Transistor, (MOSFET) making it ideal as a semiconductor switching device.

The IGBT transistor takes the best parts of these two types of transistors, the high input impedance and high switching speeds of a MOSFET with the low saturation voltage of a bipolar transistor, and combines them together to produce another type of transistor switching device that is capable of handling large collector-emitter currents with virtually zero gate current drive.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of Transistors

Detailed content of the Lecture:

The Insulated Gate Bipolar Transistor, (IGBT) uses the insulated gate (hence the first part of its name) technology of the MOSFET with the output performance characteristics of a conventional bipolar transistor, (hence the second part of its name). The result of this hybrid combination is that the ―IGBT Transistor‖ has the output switching and conduction characteristics of a bipolar transistor but is voltage-controlled like a MOSFET.

IGBTs are mainly used in power electronics applications, such as inverters, converters and power supplies, were the demands of the solid state switching device are not fully met by power bipolars and power MOSFETs. High-current and high-voltage bipolars are available, but their switching speeds are slow, while power MOSFETs may have high switching speeds, but high-voltage and high- current devices are expensive and hard to achieve.

The advantage gained by the insulated gate bipolar transistor device over a BJT or MOSFET is that it offers greater power gain than the bipolar type together with the higher voltage operation and lower input losses of the MOSFET. In effect it is an FET integrated with a bipolar transistor in a form of Darlington configuration as shown.

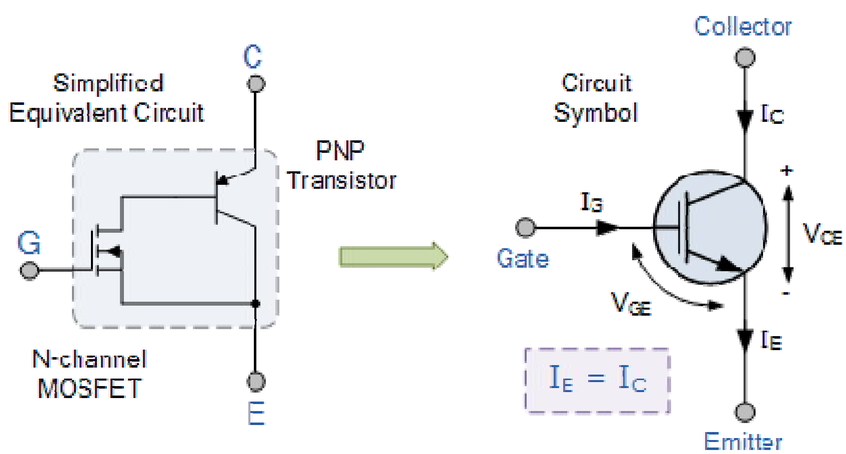
Insulated Gate Bipolar Transistor

The Insulated Gate Bipolar Transistor can be used in small signal amplifier circuits in much the same way as the BJT or MOSFET type transistors. But as the IGBT combines the low conduction loss of a BJT with the high switching speed of a power MOSFET an optimal solid state switch exists which is ideal for use in power electronics applications.

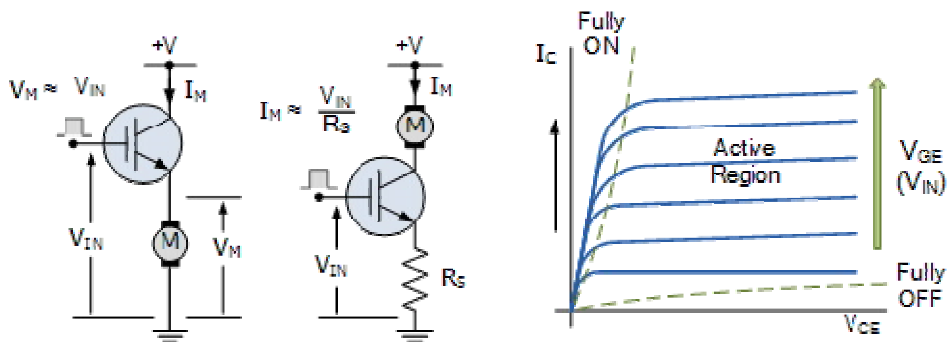
Also, the IGBT has a much lower -on-state‖ resistance, R_{ON} than an equivalent MOSFET. This means that the I^2R drop across the bipolar output structure for a given switching current is much lower. The forward blocking operation of the IGBT transistor is identical to a power MOSFET.

When used as static controlled switch, the insulated gate bipolar transistor has voltage and current ratings similar to that of the bipolar transistor. However, the presence of an isolated gate in an IGBT makes it a lot simpler to drive than the BJT as much less drive power is needed.

An insulated gate bipolar transistor is simply turned -ON‖ or -OFF‖ by activating and deactivating its Gate terminal. A constant positive voltage input signal across the Gate and the Emitter will keep the device in its -ON‖ state, while removal of the input signal will cause it to turn -OFF‖ in much the same way as a bipolar transistor or MOSFET.



IGBT CHARACTERISTICS:



Because the IGBT is a voltage-controlled device, it only requires a small voltage on the Gate to maintain conduction through the device unlike BJT's which require that the Base current is continuously supplied in a sufficient enough quantity to maintain saturation.

Also the IGBT is a unidirectional device, meaning it can only switch current in the ―forward direction‖, that is from Collector to Emitter unlike MOSFET's which have bi-directional current switching capabilities (controlled in the forward direction and uncontrolled in the reverse direction).

The principal of operation and Gate drive circuits for the insulated gate bipolar transistor are very similar to that of the N-channel power MOSFET. The basic difference is that the resistance offered by the main conducting channel when current flows through the device in its ―ON‖ state is very much smaller in the IGBT. Because of this, the current ratings are much higher when compared with an equivalent power MOSFET.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=ekSbhm4I0Go

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 396)

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L17

LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : II- TRANSISTORS

Date of Lecture:

Topic of Lecture: Thyristor construction, operation and V-I characteristics

Introduction:

 The SCR stand for Silicon Control Rectifier, it is used in industries because it can handle high values of current and voltage.

Three terminals

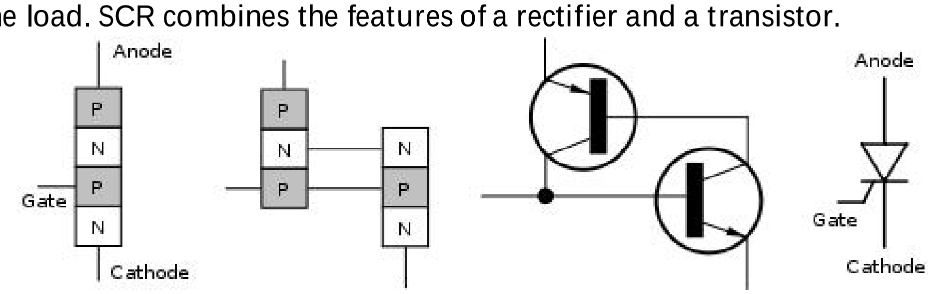
Anode - P-layer
Cathode - N-layer (opposite end) Gate - P-layer near the cathode

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of Transistors

Detailed content of the Lecture:

A silicon controlled rectifier is a semiconductor device that acts as a true electronic switch. It can change alternating current and at the same time can control the amount of power fed to the load. SCR combines the features of a rectifier and a transistor.



Construction

When a pn junction is added to a junction transistor the resulting three pn junction device is called a SCR. ordinary rectifier (pn) and a junction transistor (npn) combined in one unit to form pnpn device.

Three terminals are taken : one from the outer p- type material called anode a second from the outer n- type material called cathode K and the third from the base of transistor called Gate. GSCR is a solid state equivalent of thyratron. The gate anode and cathode of SCR correspond to the grid plate and cathode of thyratron SCR is called thyristor.

SCR Operation / Working

The Silicon Control Rectifier SCR start conduction when it is forward biased. For this purpose the cathode is kept at negative and anode at positive. When positive clock pulse is applied at the gate the SCR turns ON.

When forward bias voltage is applied to the Silicon Control Rectifier SCR, the junction J1 and J3 become forward bias while the junction J2 become reverse bias.

When we apply a clock pulse at the gate terminal, the junction J2 become forward bias and the Silicon Control Rectifier SCR start conduction. The Silicon Control Rectifier SCR turn ON and OFF very quickly, At the OFF state the Silicon Control Rectifier SCR provide infinity resistance and in ON state, it offers very low resistance, which is in the range of 0.01O to 1O.

SCR Firing & Triggering

The Silicon Control Rectifier SCR is normally operated below the forward break over voltage (VBO). To turn ON the Silicon Control Rectifier SCR we apply clock pulse at the gate terminal which called triggering of Silicon Control Rectifier, but when the Silicon Control Rectifier SCR turned ON, now if we remove the triggering voltage, the Silicon Control Rectifier SCR will remain in ON state. This voltage is called Firing voltage.

- **When Gate is Open**

No voltage applied to the gate, j2 is reverse biased while j1 and j3 are FB . J1 and J3 is just in npn transistor with base open .no current flows through the load RL and SCR is cut off. If the applied voltage is gradually increased a stage is reached when RB junction J2 breakdown .the SCR now conducts heavily and is said to be ON state. the applied voltage at which SCR conducts heavily without gate voltage is called Break over Voltage.

- **When Gate is Positive w.r.to Cathode:-**

The SCR can be made to conduct heavily at smaller applied voltage by applying small positive potential to the gate.J3 is FB and J2 is RB the electron from n type material start moving across J3 towards left holes from p type toward right. Electrons from j3 are attracted across junction J2 and gate current starts flowing. as soon as gate current flows anode current increases. the increased anode current in turn makes more electrons available at J2 breakdown and SCR starts conducting heavily. the gate loses all control if the gate voltage is removed anode current does not decrease at all. The only way to stop conduction is to reduce the applied voltage to zero.

- **Break over Voltage**

It is the minimum forward voltage gate being open at which SCR starts conducting heavily i.e turned on.

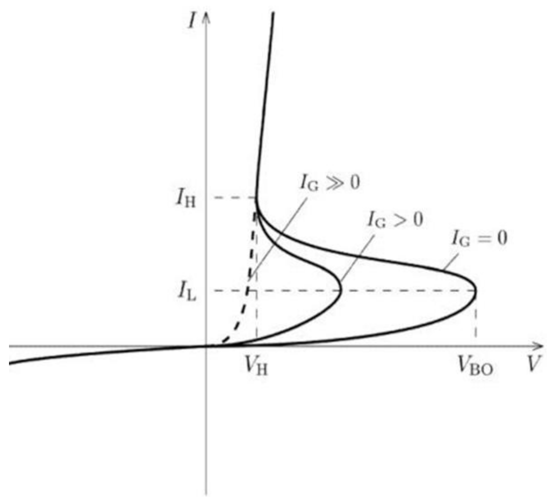
- **Peak Reverse Voltage (PRV)**

It is the maximum reverse voltage applied to an SCR without conducting in the reverse direction.

- **Holding Current**

It is the maximum anode current gate being open at which SCR is turned off from on conditions.

V-I Characteristics of SCR



- **Forward Characteristics**

When anode is +vew.r.t cathode the curve between V &I is called Forward characteristics. OABC is the forward characteristics of the SCR at Ig =0. if the suppliedvoltage is increased from zero point A is reached .SCR starts conducting voltage across SCR suddenly drops (dotted curve AB) most of supply voltage appears across RL

- **Reverse Characteristics**

When anode is –ve w.r.t cathode the curve b/w V&I is known as reverse characteristics reverse voltage come across SCR when it is operated with ac supply reverse voltage is increased anode current remains small avalanche breakdown occurs and SCR starts conducting heavily is known as reverse breakdown voltage.

Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=7ukDKVHnac4
Important Books/Journals for further learning including the page nos.: Sedha.R.S, A Text Book of Applied Electronics, Sultan Chand Publishers, 2010. (Page num - 267)

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L18

LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : II- TRANSISTORS

Date of Lecture:

Topic of Lecture: Two Transistor Analogy

Introduction:

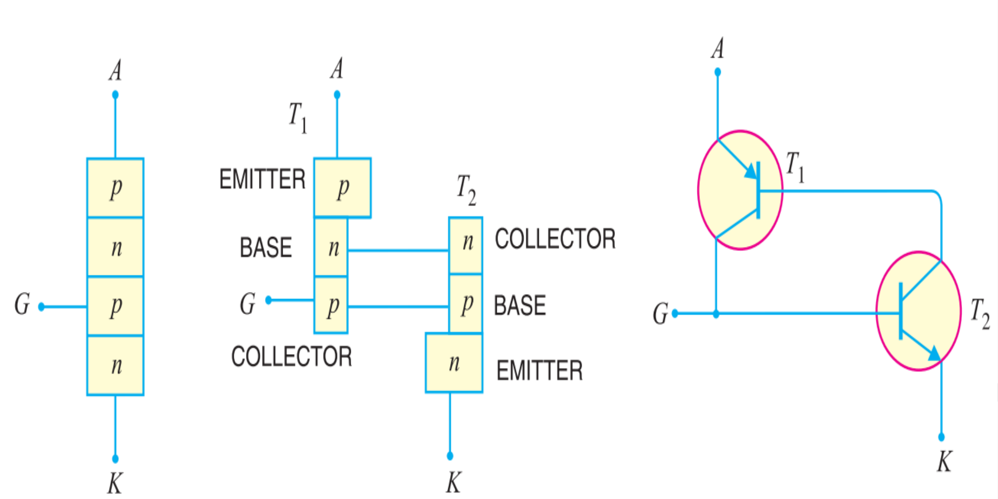
Two transistor analogy of SCR is a method of representing SCR in the form of two transistor model. This represents SCR is the combination of PNP and NPN transistor.

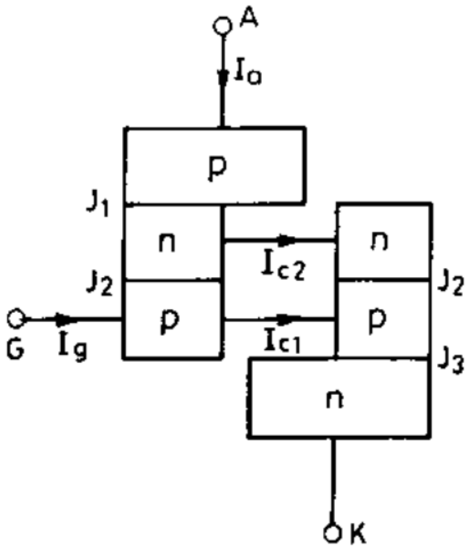
SCR or thyristor is a three terminal semiconductor device which having P-N-P-N structure. The basic operating principle of SCR can understand by two transistor method of SCR.

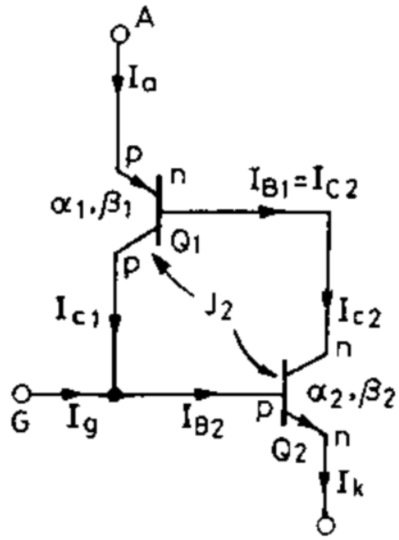
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of Transistors

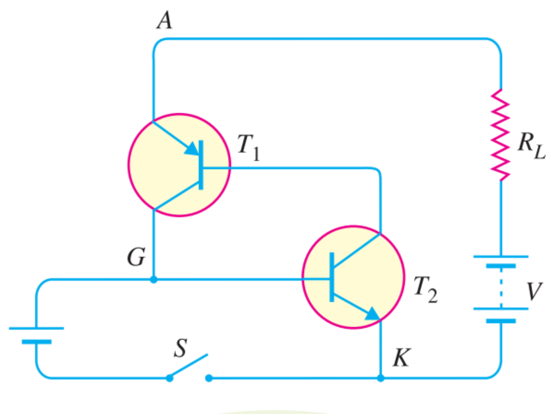
Detailed content of the Lecture:







SCR working with two transistor model



Woking of the SCR can be easily explained by two transistor model of SCR. As per figure you can see with supply voltage V and load resistance R is applied to SCR. Here first Assume the supply voltage V is less than break over voltage as is usually the case. When the gate is open (i.e. switch S open), there is base current Ib=0. For the base of the T2 is connected with the collector of The T1. Therefore, no current flows in the collector of T2 and hence that of T1. So for this condition, SCR is in OFF condition.

Whenever switch S is closed, a small gate current will flow through the base of T2 which means its collector current will increase. The collector of the transistor T2 is connected with transistor T1. So, the collector current of T2 is the base current of T1. Therefore, the collector current of T1 increases. But collector current of T1 is the base current of T2. This action is accumulative since an increase of current in one transistor causes an increase of current in the other transistor. As a result of this action, both transistors are driven to saturation, and heavy current flows through the load RL. Under such conditions, the SCR closes.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=7ukDKVHnac4
Important Books/Journals for further learning including the page nos.:
Sedha.R.S, A Text Book of Applied Electronics, Sultan Chand Publishers, 2010. (Page num - 387)

Course Faculty

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L19

LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : III - AMPLIFIERS

Date of Lecture:

Topic of Lecture: BJT small signal model

Introduction:

An amplifier is used to increase the signal level. It is used to get a larger signal output from a small signal input. Assume a sinusoidal signal at the input of the amplifier. At the output, signal must remain sinusoidal in waveform with frequency same as that of input. To make the transistor work as an amplifier, it is to be biased to operate in active region. It means base-emitter junction is forward biased and base-collector junction is reverse biased

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of BJT.

Detailed content of the Lecture:

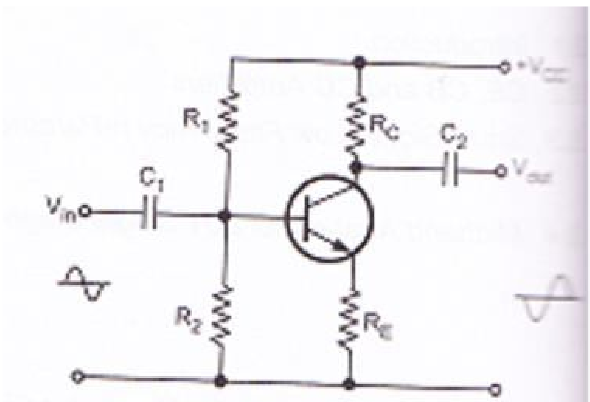
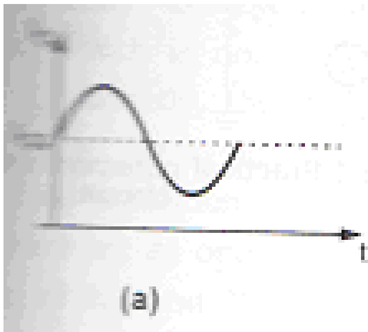
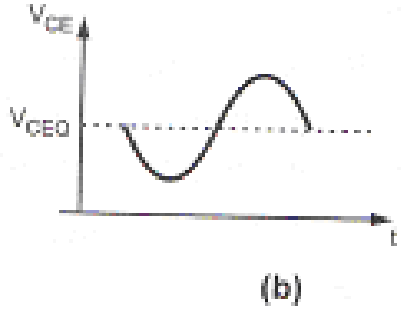


Fig. Common emitter amplifier

In the absence of input signal, only D.C. voltage is present in the circuit. It is known as zero signal or no signal condition or quiescent condition. D.C. collector-emitter voltage V_{CE}, D.C. collector current I_C and base current I_B is the quiescent operating point for the amplifier. Due to this base current varies sinusoidaly as shown in the below figure





Video Content / Details of website for further learning (if any):

www.learnabout-electronics.org

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill, 2012 (Page Num – 296)

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LECTURE HANDOUTS

EEE

II/III

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : III - AMPLIFIERS

Date of Lecture:

Topic of Lecture: Analysis of CE amplifiers

Introduction:

An amplifier is used to increase the signal level. It is used to get a larger signal output from a small signal input. Assume a sinusoidal signal at the input of the amplifier. At the output, signal must remain sinusoidal in waveform with frequency same as that of input. To make the transistor work as an amplifier, it is to be biased to operate in active region. It means base-emitter junction is forward biased and base-collector junction is reverse biased

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of BJT.

Detailed content of the Lecture:

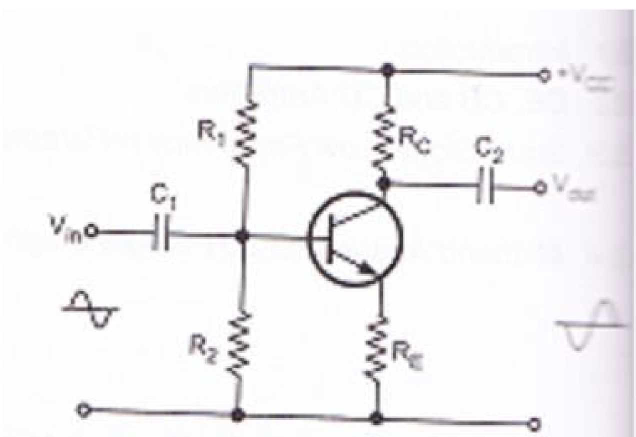
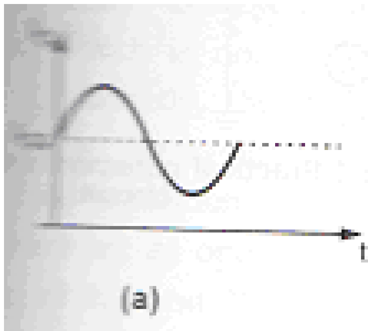
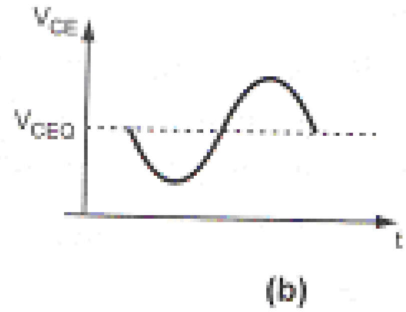


Fig. Common emitter amplifier

In the absence of input signal, only D.C. voltage is present in the circuit. It is known as zero signal or no signal condition or quiescent condition. D.C. collector-emitter voltage V_{CE}, D.C. collector current I_C and base current I_B is the quiescent operating point for the amplifier. Due to this base current varies sinusoidaly as shown in the below figure





1. **Biasing Circuit:**
Resistors R_1, R_2 and R_E forms the voltage divider biasing circuit for CE amplifier and it sets
the proper operating point for CE amplifier.

2. **Input Capacitor C_1:**
C_1 couples the signal to base of the transistor. It blocks any D.C. component present in the signal and passes only A.C. signal for amplification.

3. **Emitter Bypass Capacitor C_E:**
C_E is connected in parallel with emitter resistance R_E to provide a low reactance path to the
amplified A.C. This will reduce the output voltage and reducing the gain value.

4. **Output Coupling Capacitor C_2:**
C_2 couples the output of the amplifier to the load or to the next stage of the
amplifier. It blocks D.C. and passes only A.C. part of the amplified signal.

Need for C_1, C_2, and C_E:

The impedance of the capacitor is given

by, $X_C = 1 / (2\prod fc)$

Phase reversal:

The phase relationship between the input and output voltages can be determined by considering the effect of positive and negative half cycle separately. The collector current is β times the base current, so the collector current will also increases. This increases the voltage drop across R_C.

$V_C = V_{CC} - I_C R_C$

Increase in I_C results in a drop in collector voltage V_C, as V_{CC} is constant. V_i increases in a positive direction, V_o goes in negative direction and negative half cycle of output voltage can be obtained for positive half cycle at the input.

In negative half cycle of input, A.C. and D.C. voltage will oppose each other. This will reduce the base current. Accordingly collector current and drop across R_C both will reduce and it increases the output voltage. So positive half cycle at the output for negative half cycle at the input can be obtained. So there is a phase shift of 180^o between input and output voltages for a common emitter amplifier.

Video Content / Details of website for further learning (if any):

www.learnabout-electronics.org

Important Books/Journals for further learning including the page nos.:

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L21

LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : III - AMPLIFIERS

Date of Lecture:

Topic of Lecture: Analysis of CB amplifiers

Introduction:

An amplifier is used to increase the signal level. It is used to get a larger signal output from a small signal input. Assume a sinusoidal signal at the input of the amplifier.

At the output, signal must remain sinusoidal in waveform with frequency same as that of input. To make the transistor work as an amplifier, it is to be biased to operate in active region. It means base-emitter junction is forward biased and base-collector junction is reverse biased

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of BJT.

Detailed content of the Lecture:

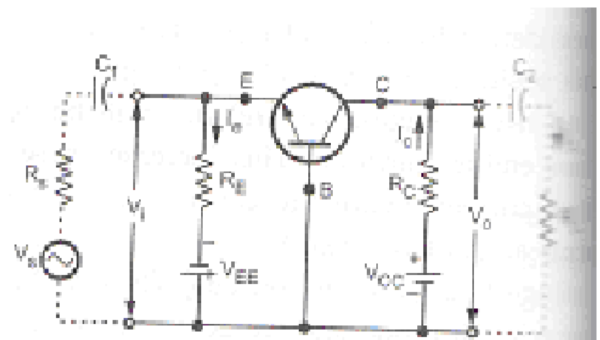

Fig. Common base circuit

From above circuit, the signal source is coupled to the emitter of the transistor through C_1. The load resistance R_L is coupled to the collector of the transistor through C_2. The positive going pulse of input source increases the emitter voltage. As base voltage is constant, forward bias of emitter- base junction reduces. This reduces I_b, I_c and drop across R_c.

$V_o = V_{CC} – I_C R_C$

Reduction in I_C results in an increase in V_o. Positive going input produces positive going output and vice versa. So there is no phase shift between input and output in common base amplifier.

1. **Biasing Circuit:**
Resistors R_1, R_2 and R_E forms the voltage divider biasing circuit for CE amplifier and it sets
the proper operating point for CE amplifier.

2. **Input Capacitor C_1:**
C_1 couples the signal to base of the transistor. It blocks any D.C. component present in the signal and passes only A.C. signal for amplification.

3. **Emitter Bypass Capacitor C_E:**
C_E is connected in parallel with emitter resistance R_E to provide a low reactance path to the
amplified A.C. This will reduce the output voltage and reducing the gain value.

4. **Output Coupling Capacitor C_2:**
C_2 couples the output of the amplifier to the load or to the next stage of the
amplifier. It blocks D.C. and passes only A.C. part of the amplified signal.

Need for C_1, C_2, and C_E:

The impedance of the capacitor is given

by, $X_C = 1 / (2\prod f_C)$

Phase reversal:

The phase relationship between the input and output voltages can be determined by considering the effect of positive and negative half cycle separately. The collector current is β times the base current, so the collector current will also increases. This increases the voltage drop across R_C.

$V_C = V_{CC} - I_C R_C$

Increase in I_C results in a drop in collector voltage V_C, as V_{CC} is constant. V_i increases in a positive direction, V_o goes in negative direction and negative half cycle of output voltage can be obtained for positive half cycle at the input.

In negative half cycle of input, A.C. and D.C. voltage will oppose each other. This will reduce the base current. Accordingly collector current and drop across R_C both will reduce and it increases the output voltage. So positive half cycle at the output for negative half cycle at the input can be obtained. So there is a phase shift of 180^o between input and output voltages for a common emitter amplifier.

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L22

LECTURE HANDOUTS

EEE

II/III

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : III - AMPLIFIERS

Date of Lecture:

Topic of Lecture: Analysis of CC amplifiers

Introduction:

An amplifier is used to increase the signal level. It is used to get a larger signal output from a small signal input. Assume a sinusoidal signal at the input of the amplifier. At the output, signal must remain sinusoidal in waveform with frequency same as that of input. To make the transistor work as an amplifier, it is to be biased to operate in active region. It means base-emitter junction is forward biased and base-collector junction is reverse biased

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of BJT.

Detailed content of the Lecture:

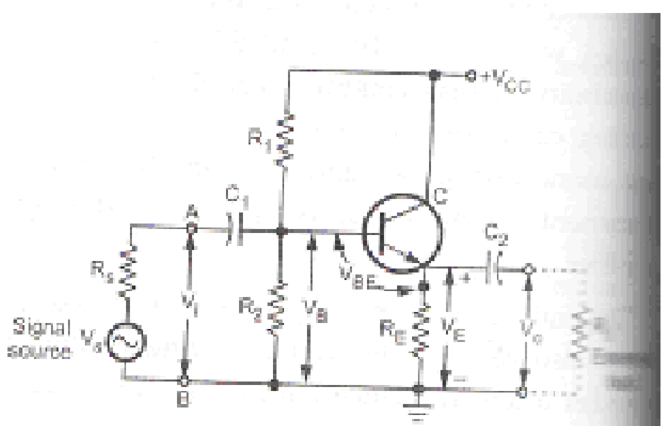

Fig. Common collector circuit

From above circuit, D.C. biasing is provided by R_1, R_2 and R_E. The load resistance is capacitor coupled to the emitter terminal of the transistor. When a signal is applied to base of the transistor, V_B is increased and decreased as the signal goes positive and negative respectively.

From figure, $VE = VB - V_{BE}$

Consider V_{BE} is constant, so the variation in V_B appears at emitter and emitter voltage V_E will vary same as base voltage V_B. In common collector circuit, emitter terminal follows the signal voltage applied to the base. It is also known as emitter follower.

Reduction in I_C results in an increase in V_o. Positive going input produces positive going output and vice versa. So there is no phase shift between input and output in common base amplifier.

1. **Biasing Circuit:**
Resistors R_1, R_2 and R_E forms the voltage divider biasing circuit for CE amplifier and it sets
the proper operating point for CE amplifier.

2. **Input Capacitor C_1:**
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amplified A.C. This will reduce the output voltage and reducing the gain value.

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amplifier. It blocks D.C. and passes only A.C. part of the amplified signal.

Need for C_1, C_2, and C_E:

The impedance of the capacitor is given by,

$$X_C = 1 / (2\prod fc)$$

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The phase relationship between the input and output voltages can be determined by considering the effect of positive and negative half cycle separately. The collector current is β times the base current, so the collector current will also increases. This increases the voltage drop across R_C.

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Increase in I_C results in a drop in collector voltage V_C, as V_{CC} is constant. V_i increases in a positive direction, V_o goes in negative direction and negative half cycle of output voltage can be obtained for positive half cycle at the input.

In negative half cycle of input, A.C. and D.C. voltage will oppose each other. This will reduce the base current. Accordingly collector current and drop across R_C both will reduce and it increases the output voltage. So positive half cycle at the output for negative half cycle at the input can be obtained. So there is a phase shift of 180º between input and output voltages for a common emitter amplifier.

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Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill, 2012 (Page Num – 307)

Course Faculty

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : III - AMPLIFIERS

Date of Lecture:

Topic of Lecture: Gain and frequency response

Introduction:

An audio frequency amplifier which operates over audio frequency range extending from 20 Hz to 20 kHz. Audio frequency amplifiers are used in radio receivers, large public meeting and various announcements to be made for the passengers on railway platforms.

Over the range of frequencies at which it is to be used an amplifier should ideally provide the same amplification for all frequencies. The degree to which this is done is usually indicated by the curve known as frequency response curve of the amplifier

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of BJT.

Detailed content of the Lecture:

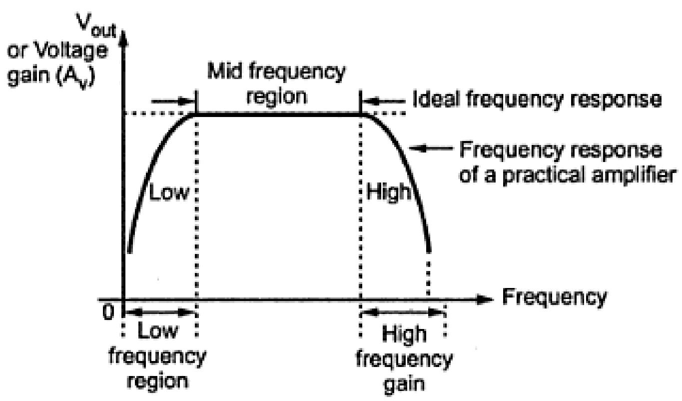

Fig. A typical frequency response of an amplifier

To plot this curve, input voltage to the amplifier is kept constant and frequency of input signal is continuously varied. The output voltage at each frequency of input signal is noted and the gain of the amplifier is calculated. For an audio frequency amplifier, the frequency range is quite large from 20 Hz to 20 kHz. In this frequency response, the gain of the amplifier remains constant in mid-frequency while the gain varies with frequency in low and high frequency regions of the curve. Only at low and high frequency ends, gain deviates from ideal characteristics. The decrease in voltage gain with frequency is called roll-off.

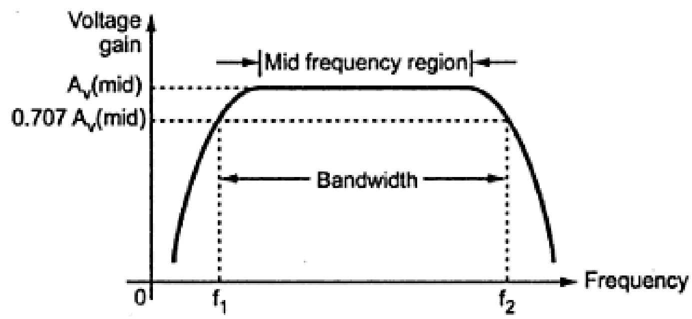

Fig. Frequency response, half power frequencies and bandwidth of an RC coupled amplifier

From above figure, the frequencies f_1 & f_2 are called lower cut-off and upper cut-off frequencies. Bandwidth of the amplifier is defined as the difference between f_2 & f_1.

Bandwidth of the amplifier = $f_2 - f_1$

The frequency f_2 lies in high frequency region while frequency f_1 lies in low frequency region. These two frequencies are also called as half-power frequencies since gain or output voltage drops to 70.7% of maximum value and this represents a power level of one half the power at the reference frequency in mid-frequency region.

Video Content / Details of website for further learning (if any):

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Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill, 2012 (Page Num – 316)

Course Faculty

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : III - AMPLIFIERS

Date of Lecture:

Topic of Lecture: MOSFET small signal model

Introduction:

It provides an excellent voltage gain with high input impedance. Due to these characteristics, it is often preferred over BJT.

Three basic FET configurations

Common source, common drain and common gate

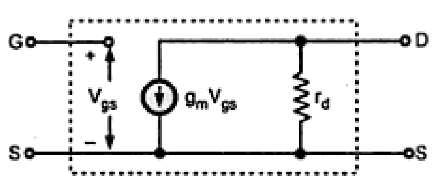
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of MOSFET

Detailed content of the Lecture:

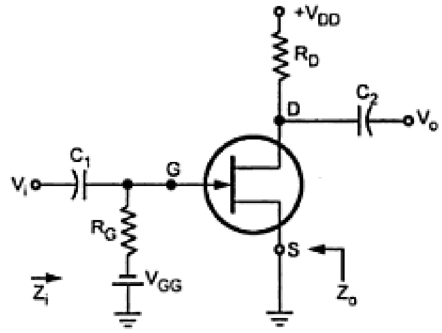
MOSFET low frequency a.c Equivalent circuit

Figure shows the small signal low frequency a.c Equivalent circuit for n-channel JFET.



Common Source Amplifier With Fixed Bias

Figure shows Common Source Amplifier With Fixed Bias. The coupling capacitor C1 and C2
which are used to isolate the d.c biasing from the applied ac signal act as short circuits for ac analysis.



The following figure shows the low frequency equivalent model for Common Source Amplifier
With Fixed Bias. It is drawn by replacing

- All capacitors and d.c supply voltages with short circuit
- JFET with its low frequency a.c Equivalent circuit

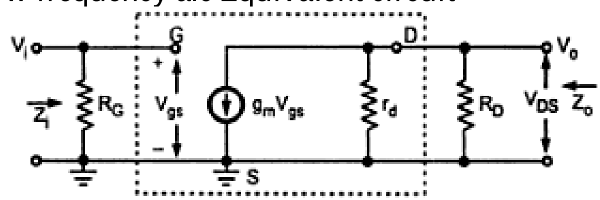


Fig3.3 small signal model of CS **MOSFET** amplifier

- **Input Impedance Zi**
  - Zi = R_G
- **Output Impedance Zo**

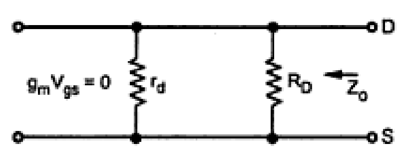


Fig: Equivalent circuit model of **MOSFET** for output

It is the impedance measured looking from the output side with input voltage Vi equal to Zero.

As Vi=0,Vgs =0 and hence g_mVgs =0 . And it allows current source to be replaced by an open circuit.

So,

$$Z_o = R_D \| r_d$$

If the resistance rd is sufficiently large compared to R_D,
then

$Z_o \approx R_D \quad \because r_d >> R_D$

Voltage Gain A_v :

The voltage gain $A_v = \frac{V_{ds}}{V_{gs}} = \frac{V_o}{V_i}$

Looking at Fig. we can write

$$V_o = -g_m V_{gs} (r_d || R_D)$$

As we know $V_i = V_{gs}$ w

$$V_o = -g_m V_i (r_d || R_D)$$

$$\therefore \quad A_v = \frac{V_o}{V_i} = -g_m (r_d || R_D)$$

and if $r_d >> R_D$,

$$A_v \approx -g_m R_D$$

Table summarizes performance of common source amplifier with fixed bias.

Parameter	Exact	With $r_d >> R_D$
Z_i	R_G	R_G
Z_o	$R_D \|\| r_d$	R_D
A_v	$-g_m (R_D \|\| r_d)$	$-g_m R_D$

Video Content / Details of website for further learning (if any):

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Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill, 2012 (Page Num – 392 - 396)

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L25

LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : III - AMPLIFIERS

Date of Lecture:

Topic of Lecture: Analysis of CS and Source follower

Introduction:

It provides an excellent voltage gain with high input impedance. Due to these characteristics, it is often preferred over BJT.

Three basic FET configurations

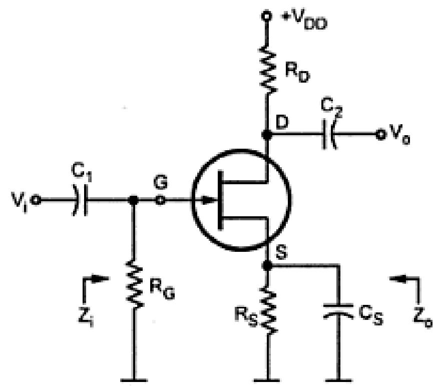
Common source, common drain and common gate

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of MOSFET

Detailed content of the Lecture:

Figure shows Common Source Amplifier With self Bias. The coupling capacitor C1 and C2 which are used to isolate the d.c biasing from the applied ac signal act as short circuits for ac analysis. Bypass capacitor Cs also acts as a short circuits for low frequency analysis.



Common source amplifier model of **MOSFET**

The following figure shows the low frequency equivalent model for Common Source Amplifier With self Bias.

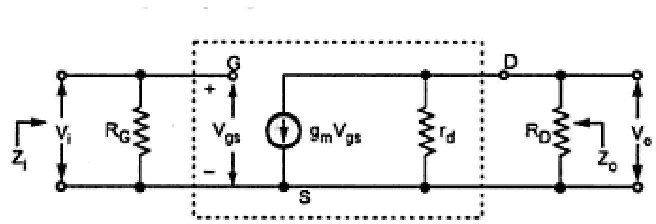


Fig : **Small signal model for Common source amplifier** model of **MOSFET**

Common source amplifier with self bias (unbypassed Rs)

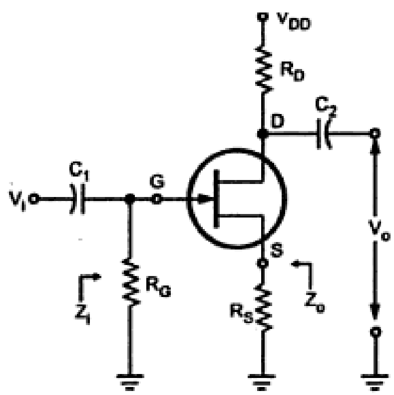


Fig: **Common source amplifier** model of **MOSFET**

Now Rs will be the part of low frequency equivalent model as shown in figure.

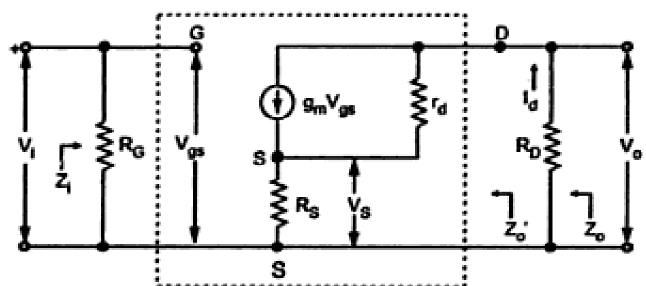


Fig: **Small signal model for Common source amplifier** model of **MOSFET**

- **Input Impedance Zi**

  - $Zi = R_G$

- **Output Impedance Zo**

It is given by

$$Z_o = [\, r_d + R_s (\mu + 1) \,] \,||\, R_D$$

$$Z_o = Z_o' \,||\, R_D$$

re

$$Z_o' = \left. \frac{V_o}{I_d} \right|_{V_i = 0}$$

$$Z_o = [\, r_d + R_s (g_m r_d + 1) \,] \,||\, R_D$$

$$Z_o = [\, r_d + R_s (\mu + 1) \,] \,||\, R_D$$

$$Z_o = [\, r_d + R_s (g_m r_d + 1) \,] \,||\, R_D$$

The negative sign in the voltage gain indicates there is a 180^o phase shift between input and output voltages.

Video Content / Details of website for further learning (if any):

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Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill, 2012 (Page Num – 316)

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LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Faculty : Dr. R. PRAKASH

Unit : III - AMPLIFIERS

Date of Lecture:

Topic of Lecture: High frequency Analysis

Introduction:

High frequency analysis will be carried out in both BJT and MOSFET amplifiers. It has various characteristics based upon its frequency ranges.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics of frequency response

Detailed content of the Lecture:

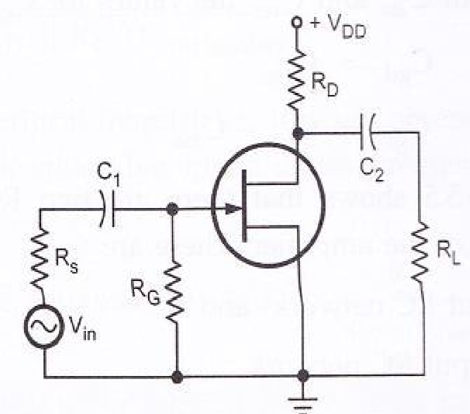

Fig. Typical RC coupled common source amplifier

Let us consider a typical common source amplifier as shown in the above figure.

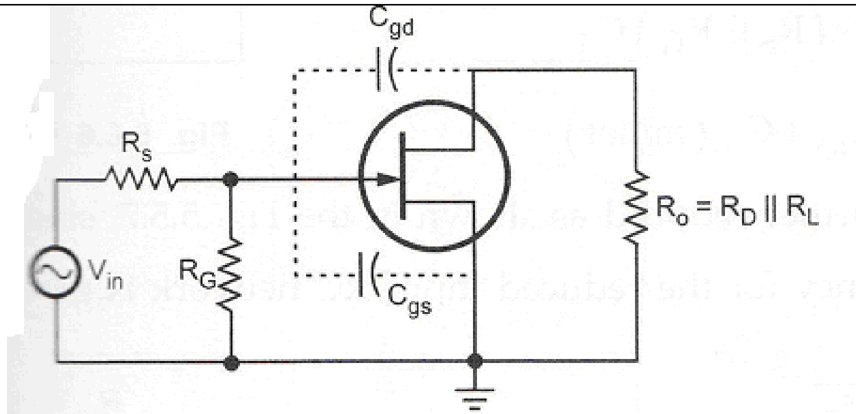

Fig. High frequency equivalent circuit

From above figure, it shows the high frequency equivalent circuit for the given amplifier circuit. It shows that at high frequencies coupling and bypass capacitors act as short circuits and do not affect the amplifier high frequency response. The equivalent circuit shows internal capacitances which affect the high frequency response.

Video Content / Details of website for further learning (if any):

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LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: ELECTRONIC DEVICES AND CIRCUITS / 19GES33

Course Teacher : Dr. R. PRAKASH

Unit : III - AMPLIFIERS

Date of Lecture:

Topic of Lecture: High frequency Analysis

Introduction:

High frequency analysis will be carried out in both BJT and MOSFET amplifiers. It has various characteristics based upon its frequency ranges.

Prerequisite knowledge for Complete understanding and learning of Topic:

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Detailed content of the Lecture:

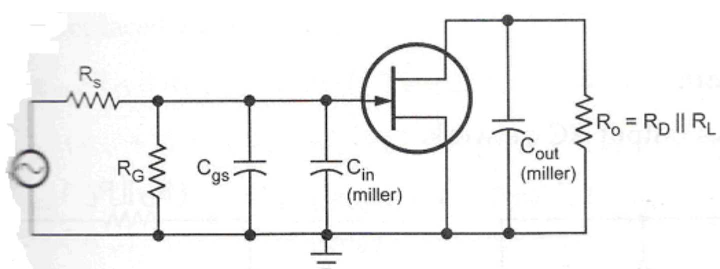

Fig. Simplified high frequency equivalent circuit

$$C_{in\,(miller)} = C_{gd}\,(A_v + 1)$$

$$C_{out\,(miller)} = C_{gd}\,\frac{(A_v + 1)}{(A_v)}$$

Where

$$C_{gd} = C_{rss}$$

$$C_{gs} = C_{iss} - C_{rss}$$

From simplified high frequency equivalent circuit, it has two RC networks which affect the high frequency response of the amplifier. These are,

1. Input RC network
2. Output RC network

Input RC network:

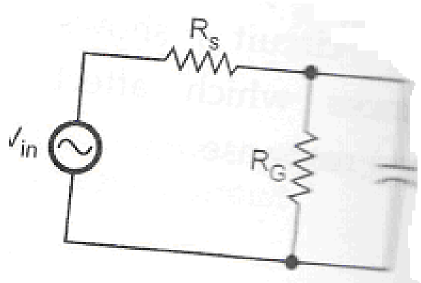

Fig. Input RC network

From above figure,

$$f_{c(input)} = \frac{1}{2\pi\left(R_S \,||\, R_G\right) C_T}$$

where $\quad C_T = C_{gs} + C_{in}(miller)$

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LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: 19GES33 / ELECTRONIC DEVICES AND CIRCUITS

Course Faculty : Dr. R. PRAKASH

Unit : IV- Multistage Amplifiers & Differential Amplifier

Date of Lecture:

Topic of Lecture: BIMOS cascade amplifier

Introduction :

- A device which accepts an input signal and produces an output signal proportional to the input, is called an amplifier.
- An amplifier which amplifies the difference between The two input signals is called differential amplifier. The differential amplifier configuration is used in variety of analog circuits.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Amplifier
2. MOSFET

Detailed content of the Lecture:

✓ A high-gain high-speed fully differential folded-cascade operational amplifier with improved slew rate (SR) is implemented in a BiCMOS process.

✓ The amplifier can source / sink much larger current than the quiescent current when output voltage is slewing, even with a current reduction in the common-base path.

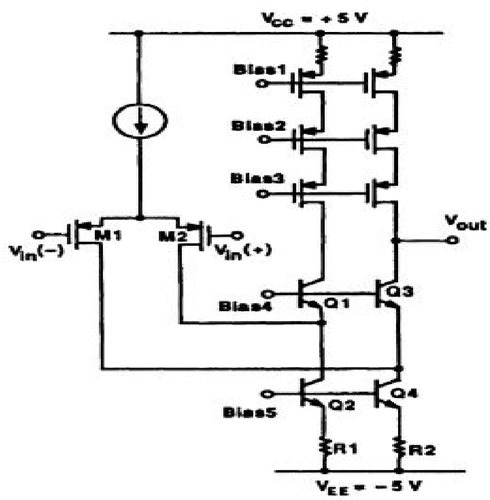
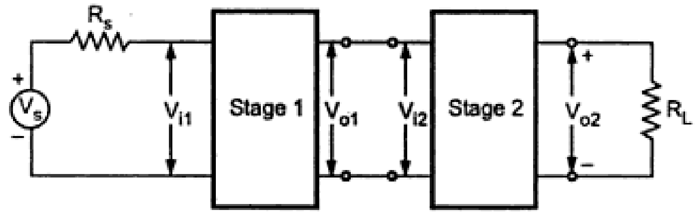


Fig. BiCMOS folded-cascode operational amplifier.

Two Stage Cascaded Amplifier:



Vi1 is the input of the first stage and Vo2 is the output of second stage. So, Vo2 / Vi1 is the overall voltage gain of two stage amplifier.

$$A_V = \frac{V_{o2}}{V_{i1}}$$

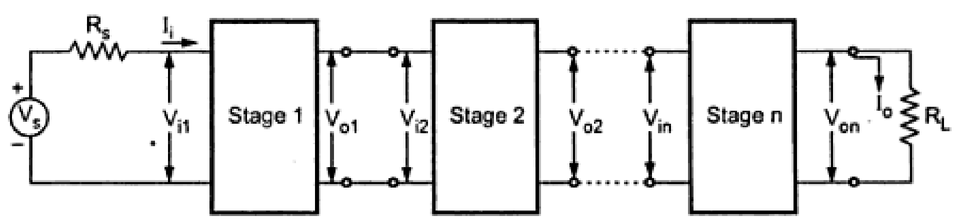
$$= \frac{V_{o2}}{V_{i2}} \frac{V_{i2}}{V_{i1}}$$

$$V_{o1} = V_{i2}$$

$$\therefore A_V = \frac{V_{o2}}{V_{i2}} \frac{V_{o1}}{V_{i1}}$$

$$= A_{V2} A_{V1}$$

n-Stage Cascaded Amplifier:



Voltage gain :

The resultant voltage gain of the multistage amplifier is the product of voltage gains of the various stages.

Av = Avl Av2 ... Avn

Gain in Decibels

- ✓ In many situations it is found very convenient to compare two powers on logarithmic scale rather than on a linear scale. The unit of this logarithmic scale is called decibel (abbreviated dB). The number N decibels by which a power P2 exceeds the power P1 is defined by

$$N = 10 \log \frac{P_2}{P_1}$$

- ✓ Decibel, dB denotes power ratio. Negative values of number of dB means that the power P2 is less than the reference power P1 and positive value of number of dB means the power P2 is greater than the reference power P1.
- ✓ For an amplifier, P1 may represent input power, and P2 may represent output power. Both can be given as

$$P_1 = \frac{V_i^2}{R_i} \text{ and } P_2 = \frac{V_o^2}{R_o}$$

- ✓ Where Ri and Ro are the input and output impedances of the amplifier respectively.Then,

$$N = 10 \log_{10} \frac{V_o^2 / R_o}{V_i^2 / R_i}$$

- ✓ If the input and output impedances of the amplifier are equal i.e. Ri = Ro= R, then

$$N = 10 \log_{10} \frac{V_o^2}{V_i^2} = 10 \log_{10} \left(\frac{V_o^2}{V_i^2} \right) = 10 \times 2 \log_{10} \frac{V_o}{V_i} = 20 \log_{10} \frac{V_o}{V_i}$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=NNf2o_TNwLk

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 323)

Course Faculty

L 29

LECTURE HANDOUTS

EEE

II/III

Course Name with Code: 19GES33 / ELECTRONIC DEVICES AND CIRCUITS

Course Faculty : Dr. R. PRAKASH

Unit : IV- Multistage Amplifiers & Differential Amplifier

Date of Lecture:

Topic of Lecture: Differential amplifier

Introduction :

- A device which accepts an input signal and produces an output signal proportional to the input, is called an amplifier.
- An amplifier which amplifies the difference between The two input signals is called differential amplifier. The differential amplifier configuration is used in variety of analog circuits.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Amplifier Basics

Detailed content of the Lecture:

Introduction of Differential Amplifier

- ✓ The differential amplifier is an essential and basic building block in modern IC amplifier.
- ✓ The Integrated Circuit (IC) technology is well known now a days, due to which the design of complex circuits become very simple.
- ✓ The IC version of operational amplifier is inexpensive, takes up less space and consumes less power. The. differential amplifier is the basic building block of such IC operational amplifier.

Basics of Differential Amplifier

- ✓ The Differential Amplifier amplifies the difference between two input voltage signal. Hence it is also called as difference amplifier.

Consider an ideal differential amplifier shown in the Fig. A

Differential Gain A_d

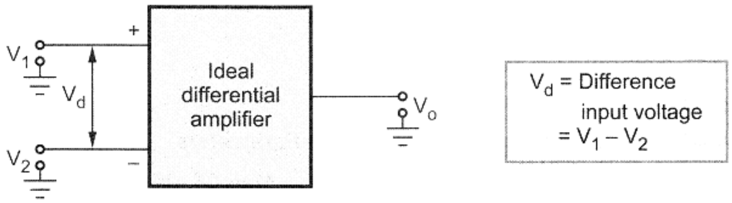


Fig. Ideal differential amplifier

- ✓ V_1 and V_2 are the two input signals while Vo is the output. Each signal is measured with respect to the ground.

In an ideal differential amplifier, the output voltage Vo is proportional to the difference between the two input signals. Hence we can write,

$$V_o \propto (V_1 - V_2) \quad \ldots(1)$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=yXJADXuWtII

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 357-362)

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L 30

LECTURE HANDOUTS

EEE

II/III

Course Name with Code: 19GES33 / ELECTRONIC DEVICES AND CIRCUITS

Course Faculty : Dr. R. PRAKASH

Unit : IV- Multistage Amplifiers & Differential Amplifier

Date of Lecture:

Topic of Lecture: Common mode and Differential analysis

Introduction :

- A device which accepts an input signal and produces an output signal proportional to the input, is called an amplifier.
- An amplifier which amplifies the difference between The two input signals is called differential amplifier. The differential amplifier configuration is used in variety of analog circuits.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic operation of amplifier

Detailed content of the Lecture:

Differential Gain A_d

✓ From Equation 1 we can write,

$$\therefore \quad V_o = A_d (V_1 - V_2) \quad \ldots(2)$$

where AD is the constant of proportionality. The AD is the gain with which differential amplifier amplifies the difference between two input signals. Thus it is called differential gain of the differential amplifier.

Thus, Ad = Differential gain

The difference between the two inputs (V_1 - V_2) is generally called difference voltage and denoted as Vd.

$$V_o = A_d V_d \quad \ldots(3)$$

Hence the differential gain can be expressed as,

$$A_d = \frac{V_o}{V_d}$$ ...(4)

Generally the differential gain is expressed in its decibel (dB) value as,

$$A_d = 20 \text{ Log}_{10} (A_d) \text{ in dB}$$ **...(5)**

V_0= A_C V_C

$$V_o = A_c V_c$$

Common Mode Gain Ac:

If we apply two input voltages which are equal in all the respects to the differential amplifier i.e. V1 = Vz then ideally the output voltage Vo = (V_1 - V_2) A_d, must be zero.But the output voltage of the practical differential amplifier not only depends on thedifference voltage but also depends on the average common level of the two inputs. Such an average level of the two input signals is called common mode signal denoted as V_C

$$V_c = \frac{V_1 + V_2}{2}$$ ...(6)

Practically, the differential amplifier produces the output voltage proportional to such common mode signal, also.

The gain with wich it amplifies the common mode signal to produce the output is called common mode gain of the differential amplifier A_C.

$$V_o = A_c V_c$$ ..(7)

Thus there exists some finite output for V1 = V2 due to such common mode gain A_C, in case of practical differential amplifiers.

So the total output of any differential amplifier can be expressed as,

$$V_o = A_d V_d + A_c V_c$$ ..(8)

For an ideal differential amplifier, the differential gain A_d, must be infinite while the common mode gain must be zero.

But due to mismatch in the internal circuitry, there is some output available for V_1 = V2 and gain A_C is not practically zero. The value of such common mode gain A_C very small while the value of the differential gain A_d is always very large.

Common Mode Rejection Ratio (CMRR):

- ✓ When the same voltage is applied to both the inputs, the differential amplifier is said to be operated in a common mode configuration. Many disturbance signals, noise

- ✓ CMRR in dB $= 20 \log \left|\frac{A_d}{A_c}\right|$ dB
- ✓ signal appear as a common input signal to both the input terminals of the differential amplifier. Such a common signal should be rejected by the differential amplifier.
- ✓ It is defined as the ratio of the differential voltage gain A_d to common mode

  voltage gain A_C

$$CMRR = \rho = \left|\frac{A_d}{A_c}\right| \quad ....(9)$$

$$\text{CMRR in dB} = 20 \log \left|\frac{A_d}{A_c}\right| \text{ dB} \quad .....(10)$$

common Mode operation:

- ✓ In this mode, the signals applied to the base of Q1 and Q2 are derived from the same
- ✓ source. So the two signals are equal in magnitude as well as in phase. The circuit diagram is shown in the Fig.
- ✓ In phase signal voltages at the bases of Q1 and Q2 causes in phase signal voltages to appear across R_E, which add together. Hence R_E carries a signal current and provides a negative feedback. This feedback reduces the common mode gain of differential amplifier.

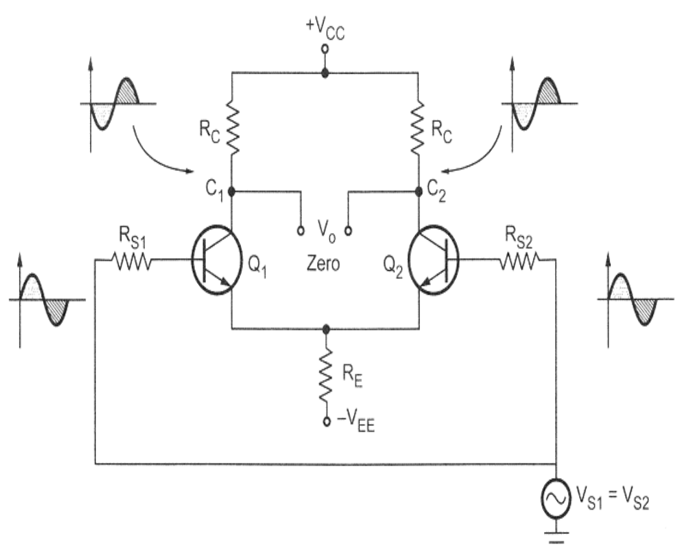
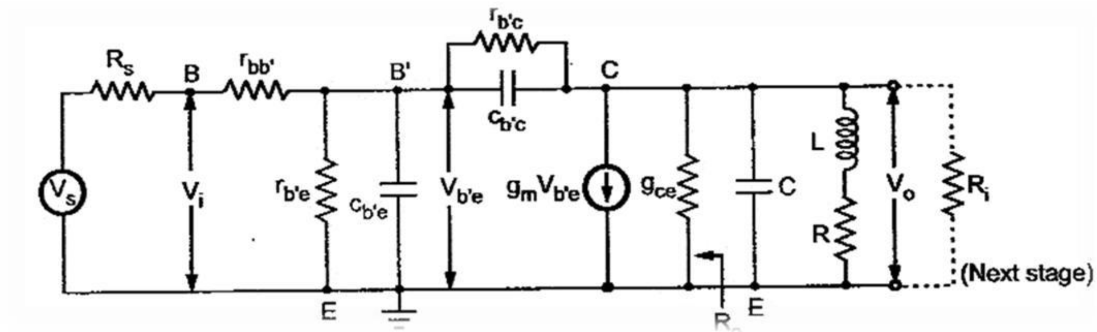


Fig. Common mode operation

- ✓ While the two signals causes in phase signal voltages of equal magnitude to appear across the two collectors of Q_1 and Q2. Now the output voltage is the difference between the two collector voltages, which are equal and also same in phase,

- ✓ Eg. (20) - (20) = 0. Thus the difference output Vo is almost zero, negligibly small. ideally it should be zero.

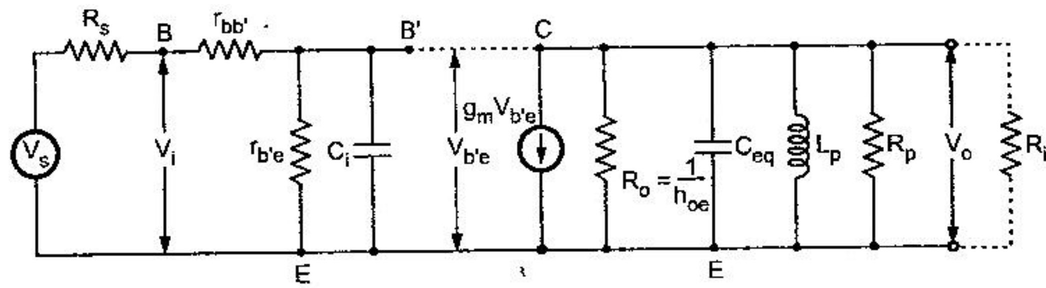


Ri- input resistance of the next stage

R**0-**output resistance of the generator gmVb‘e

Cc & CE are negligible small

The equivalent circuit is simplified by



$$C_i = C_{b'e} + C_{b'c}(1 - A)$$

$$C_{eq} = C_{b'c}\left(\frac{A-1}{A}\right) + C$$

Where,
A-Voltage gain of the amplifier
C-tuned circuit capacitance

$$g_{ce} = \frac{1}{r_{ce}} = h_{oe} - g_m h_{re} \simeq h_{oe} = \frac{1}{R_o}$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=yXJADXuWtII

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 357-362)

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L 31

LECTURE HANDOUTS

EEE

II/III

Course Name with Code: 19GES33 / ELECTRONIC DEVICES AND CIRCUITS

Course Faculty : Mr.S.SARANRAJ

Unit : IV- Multistage Amplifiers & Differential Amplifier

Date of Lecture:

Topic of Lecture: Differential mode operation

Introduction :

- A device which accepts an input signal and produces an output signal proportional to the input, is called an amplifier.
- An amplifier which amplifies the difference between The two input signals is called differential amplifier. The differential amplifier configuration is used in variety of analog circuits.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basics of amplifier

Detailed content of the Lecture:

Differential Gain A_d

✓ From Equation 1 we can write,

$$\therefore \quad V_o = A_d (V_1 - V_2) \quad \ldots(2)$$

where AD is the constant of proportionality. The AD is the gain with which differential amplifier amplifies the difference between two input signals. Thus it is called differential gain of the differential amplifier.

Thus, Ad = Differential gain

The difference between the two inputs (V_1 - V_2) is generally called difference voltage and denoted as Vd.

$$V_o = A_d V_d \quad \ldots(3)$$

Hence the differential gain can be expressed as,

$$A_d = \frac{V_o}{V_d} \quad ...(4)$$

Generally the differential gain is expressed in its decibel (dB) value as,

Differential Mode Operation:

- ✓ In the differential mode, the two input signals are different from each other. Consider the two input signals which are same in magnitude but 180" out of phase. These signals, with opposite phase can be obtained from the center tap transformer. The circuit used in differential mode operation is shown in the Fig..

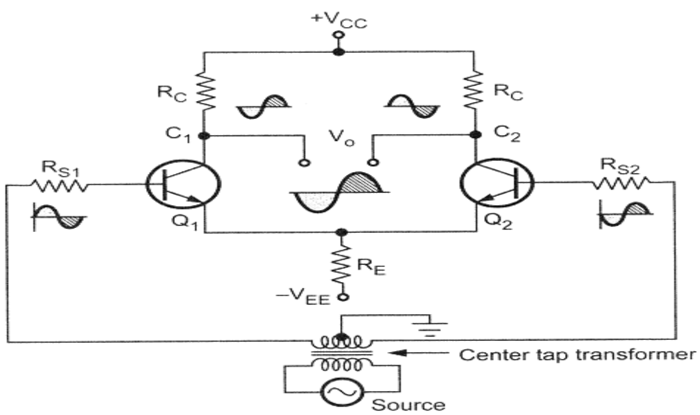


Fig Differential mode operation

- ✓ Assume that the sine wave on the base of Q_1 is positive going while on the base of Q_2 is negative going. With a positive going signal on the base of Q_1, m amplified negative going signal develops on the collector of Q1. Due to positive going signal, current through R_E also increases and hence a positive going wave is developed across R_E.
- ✓ Due to negative going signal on the base of Q2, an amplified positive going signal develops on the collector of Q_2.
- ✓ And a negative going signal develops across R_E, because of emitter follower action of Q_2. So signal voltages across R_E, due to the effect of Q1 and Q2 are equal in magnitude and 180o out of phase, due to matched pair of transistors. Hence these two signals cancel each other and there is no signal across the emitter resistance.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=yXJADXuWtlI

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 357-362)

Course Faculty

L 32

LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: 19GES33 / ELECTRONIC DEVICES AND CIRCUITS

Course Faculty : Dr. R. PRAKASH

Unit : IV- Multistage Amplifiers & Differential Amplifier

Date of Lecture:

Topic of Lecture: FET input stages, Single tuned amplifiers

Introduction :

- ✓ FETs are also known as unipolar transistors since they involve single-carrier-type operation.
- ✓ That is, FETs use electrons or holes as charge carriers in their operation, but not both. Many different types of field effect transistors exist. Field effect transistors generally display very high input impedance at low frequencies.
- ✓ The most widely used field-effect transistor is the MOSFET
- ✓ The field effect transistor is a semiconductor device, which depends for its operation on the control of current by an electric field

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Amplifiers
2. FET

Detailed content of the Lecture:

Field Effect Transistor:

The field effect transistor is a semiconductor device, which depends for its operation on the control of current by an electric field. There are two of field effect transistors:

1. **JFET** (Junction Field Effect Transistor)
2. MOSFET (Metal Oxide Semiconductor Field Effect Transistor)

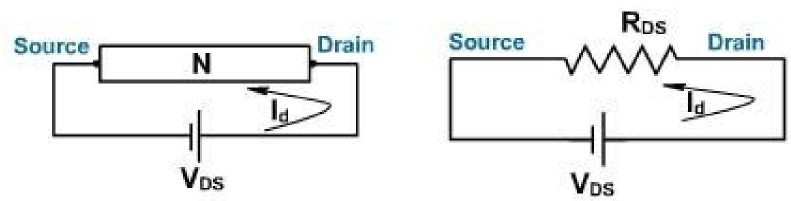
The FET has several advantages over conventional transistor.

1. In a conventional transistor, the operation depends upon the flow of majority and minority carriers. That is why it is called bipolar transistor. In FET the operation depends upon the flow of majority carriers only. It is called unipolar device.

2. The input to conventional transistor amplifier involves a forward biased PN junction with its inherently low dynamic impedance. The input to FET involves a reverse biased PN junction hence the high input impedance of the order of M-ohm.
3. It is less noisy than a bipolar transistor.
4. It exhibits no offset voltage at zero drain current.
5. It has thermal stability.
6. It is relatively immune to radiation.

Operation of FET:

consider a sample bar of N-type semiconductor. This is called N-channel and it is electrically equivalent to a resistance as shown in **fig. 1**.



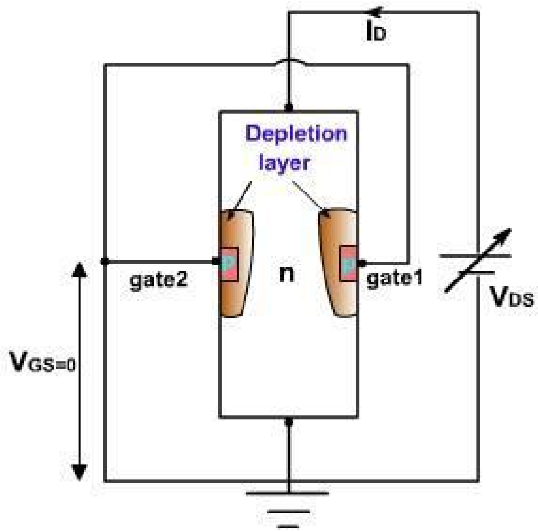
Ohmic contacts are then added on each side of the channel to bring the external connection. Thus if a voltage is applied across the bar, the current flows through the channel.

The terminal from where the majority carriers (electrons) enter the channel is called source designated by S. The terminal through which majority carriers leaves the channel is called drain and designated by D. For an N-channel device, electrons are the majority carriers. Hence the circuit behaves like a dc voltage V_{DS} applied across a resistance R_{DS}. The resulting current is the drain current I_D. If V_{DS} increases, I_D increases proportionally.

Now on both sides of the n-type bar heavily doped regions of p-type impurity have been formed by any method for creating pn junction. These impurity regions are called gates (gate1 and gate2) as shown in **fig. 2**.

Both the gates are internally connected and they are grounded yielding zero gate source voltage (V_{GS} =0). The word gate is used because the potential applied between gate and source controls the channel width and hence the current.

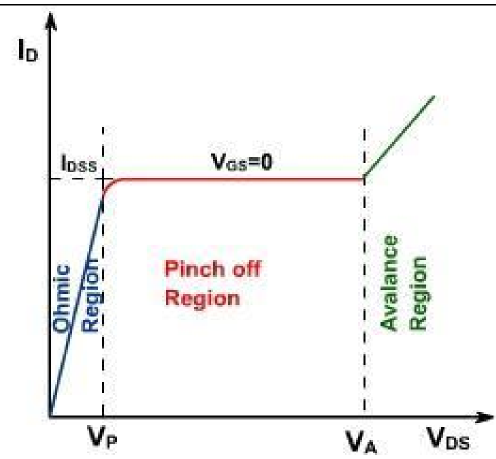
Both the gates are internally connected and they are grounded yielding zero gate source voltage (V_{GS} =0). The word gate is used because the potential applied between gate and source controls the channel width and hence the current.

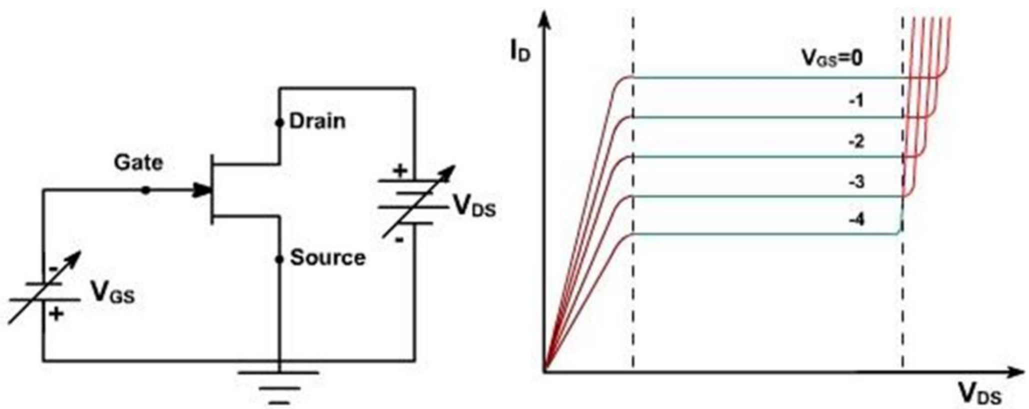


Consider now the behavior of drain current I_D vs drain source voltage V_{DS}. The gate source voltage is zero therefore $V_{GS}= 0$. Suppose that V_{DS} is gradually linearly increased linearly from
0V. I_D also increases.

Since the channel behaves as a semiconductor resistance, therefore it follows ohm's law. The region is called ohmic region, with increasing current, the ohmic voltage drop between the source and the channel region reverse biased the junction, the conducting portion of the channel begins to constrict and I_D begins to level off until a specific value of V_{DS} is reached, called the **pinch of voltage V_P**.

At this point further increase in V_{DS} do not produce corresponding increase in I_D. Instead, as V_{DS} increases, both depletion regions extend further into the channel, resulting in a no more cross section, and hence a higher channel resistance. Thus even though, there is more voltage, the resistance is also greater and the current remains relatively constant. This is called pinch off or saturation region. The current in this region is maximum current that FET can produce and designated by I_{DSS}. (Drain to source current with gate shorted).





As with all pn junctions, when the reverse voltage exceeds a certain level, avalanche breakdown of pn junction occurs and I_D rises very rapidly as shown.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=cOICDYuY-gA

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 405)

Course Faculty

L 33

LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: 19GES33 / ELECTRONIC DEVICES AND CIRCUITS

Course Faculty : Mr.S.SARANRAJ

Unit : IV- Multistage Amplifiers & Differential Amplifier

Date of Lecture:

Topic of Lecture: FET input stages, Single tuned amplifiers

Introduction :

- ✓ Single Tuned Amplifiers consist of only one Tank Circuit and the amplifying frequency range is determined by it.

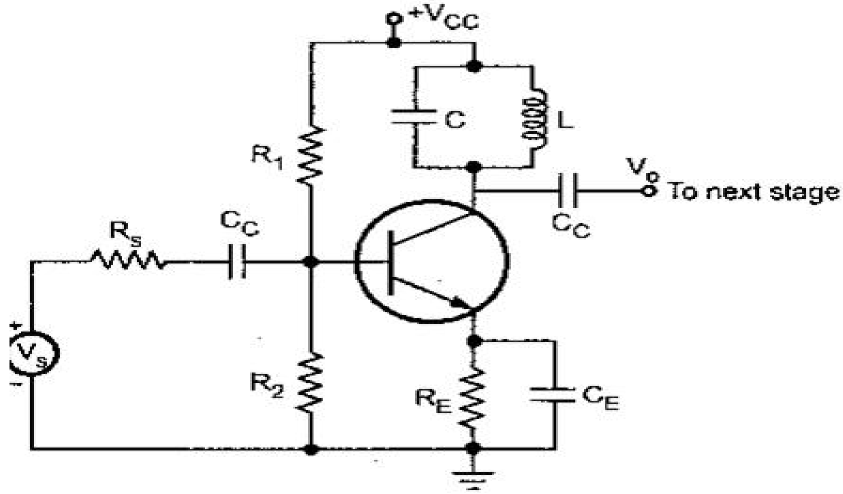
Prerequisite knowledge for Complete understanding and learning of Topic:

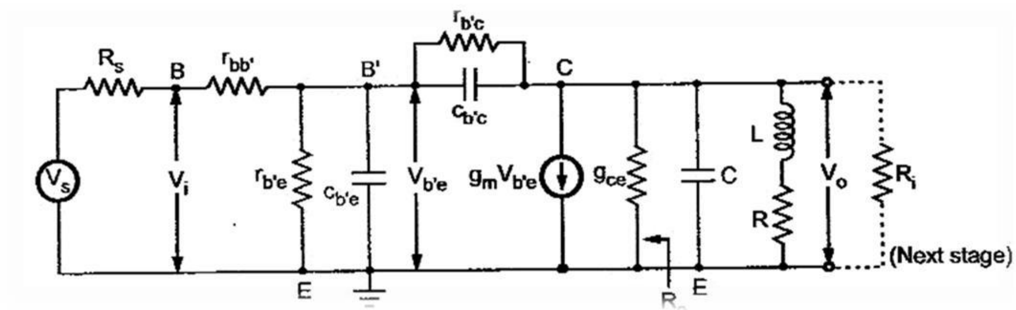
1. Amplifiers
2. FET

Detailed content of the Lecture:

Single tuned amplifier:

- ✓ Single Tuned Amplifiers consist of only one Tank Circuit and the amplifying frequency range isdetermined by it.
- ✓ By giving signal to its input terminal of various Frequency Ranges.
- ✓ The Tank Circuit onits collector delivers High Impedance on resonant Frequency, Thus the amplified signal is CompletelyAvailable on the output Terminal.
- ✓ And for input signals other than Resonant Frequency, the tank circuit provides lower impedance, hence most of the signals get attenuated at collector Terminal.



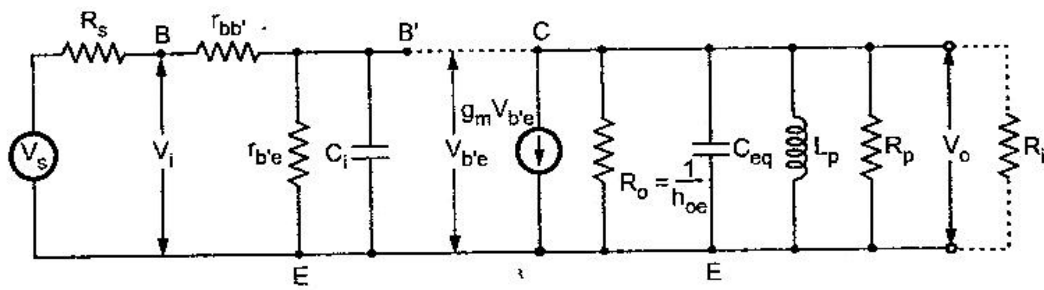


Ri- input resistance of the next stage

R**0-**output resistance of the generator gmVb'e

Cc & CE are negligible small

The equivalent circuit is simplified by



$$C_i = C_{b'e} + C_{b'c}(1 - A)$$

$$C_{eq} = C_{b'c}\left(\frac{A-1}{A}\right) + C$$

Where,

A-Voltage gain of the amplifier C-tuned circuit capacitance

$$g_{ce} = \frac{1}{r_{ce}} = h_{oe} - g_m h_{re} \approx h_{oe} = \frac{1}{R_o}$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=cOICDYuY-gA

Important Books/Journals for further learning including the page nos.:

Sedha.R.S, A Text Book of Applied Electronics, Sultan Chand Publishers, 2010. (Page Num – 514)

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L 34

LECTURE HANDOUTS

EEE

II/III

Course Name with Code: 19GES33 / ELECTRONIC DEVICES AND CIRCUITS

Course Faculty : Dr. R. PRAKASH

Unit : IV- Multistage Amplifiers & Differential Amplifier

Date of Lecture:

Topic of Lecture: Gain and frequency response

Introduction :

- An audio frequency amplifier which operates over audio frequency range extending from 20 Hz to 20 kHz. Audio frequency amplifiers are used in radio receivers, large public meeting and various announcements to be made for the passengers on railway platforms. Over the range of frequencies at which it is to be used an amplifier should ideally provide the same amplification for all frequencies.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Gain
2. Frequency

Detailed content of the Lecture:

Frequency response of amplifiers:

The degree to which this is done is usually indicated by the curve known as frequency response curve of the amplifier.

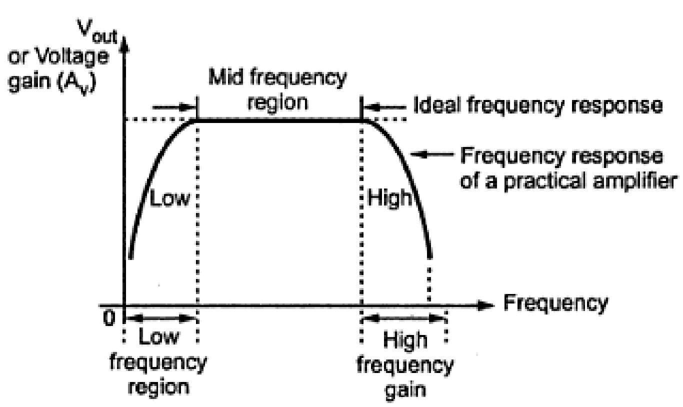

Fig. A typical frequency response of an amplifier

✓ To plot this curve, input voltage to the amplifier is kept constant and frequency of input signal is continuously varied. The output voltage at each frequency of input signal is noted and the gain of the amplifier is calculated. For an audio frequency amplifier, the frequency range is quite large from 20 Hz to 20 kHz.

- ✓ In this frequency response, the gain of the amplifier remains constant in mid-frequency while the gain varies with frequency in low and high frequency regions of the curve. Only at low and high frequency ends, gain deviates from ideal characteristics. The decrease in voltage gain with frequency is called roll-off.

Definition of cut-off frequencies and bandwidth:

- ✓ The range of frequencies can be specified over which the gain does not deviate more than 70.7% of the maximum gain at some reference mid-frequency.

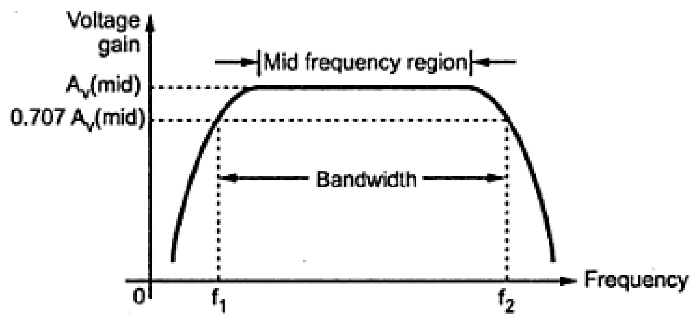

Fig. Frequency response, half power frequencies and bandwidth of an RC coupled amplifier

- ✓ From above figure, the frequencies f_1 & f_2 are called lower cut-off and upper cut-off frequencies. Bandwidth of the amplifier is defined as the difference between f_2 & f_1.

Bandwidth of the amplifier = $f_2 - f_1$

- ✓ The frequency f_2 lies in high frequency region while frequency f_1 lies in low frequency region. These two frequencies are also called as half-power frequencies since gain or output voltage drops to 70.7% of maximum value and this represents a power level of one half the power at the reference frequency in mid-frequency region.

Frequency gain of a certain amplifier is 100. Then, Voltage gain = 20 log 100 = 40 db

At f_1 and f_2 $A_V = 100/\sqrt{2} = 70.7$

Voltage gain at f_1 = Voltage gain at f_2 = 20 log 70.7 = 37 db

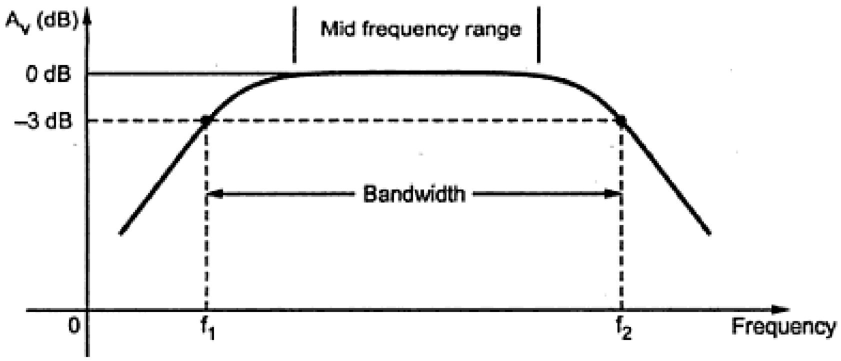

Fig. Normalized voltage gain vs frequency

- ✓ From above figure, it shows that the voltage gain at f_1 and f_2 is less than 3db of the maximum voltage gain. Due to this the frequencies f_1 and f_2 are also called as 3 db frequencies. At f_1 & f_2 power gain drops by 3 db. For all frequencies within the bandwidth, amplifier power gain is at least half of the maximum power gain. This bandwidth is also referred to as 3 db bandwidth.

Significance of octaves and decades:

The octaves and decades are the measures of change in frequency. A ten times change in frequency is called a decade. Otherwise, an octave corresponds to a doubling or halving of the frequency.

Example: An increase in frequency from 100 Hz to 200 Hz is an octave.

A decrease in frequency from 100 kHz to 50 kHz is also an octave.

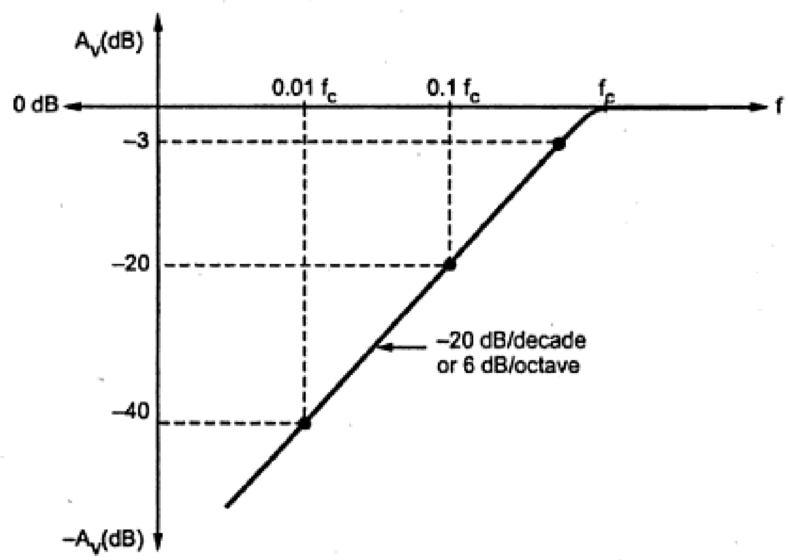

Fig. Frequency response showing significance of decade and octave

At lower and higher frequencies the decrease in the gain of amplifiers is often indicated in terms of db / decades or db / octaves.

$$A = \frac{A_{mid}}{\sqrt{1+(f/f_2)^2}}$$

If the attenuation in gain is 20 db for each decade, then it is indicated by line having slope of 20 db/decade. A rate of -20 db/decade is approximately equivalent to -6db/octave. A rate of -40 db/decade is approximately equivalent to -12db/octave.

Midband gain:

It is defined as the band of frequencies between 10 f_1 and 0.1 f_2. It is denoted as midband gain or A_{mid}.

The voltage gain of the amplifier outside the midband is approximately given as,

$$A = \frac{A_{mid}}{\sqrt{1+(f_1/f)^2}\sqrt{1+(f/f_2)^2}}$$

In midband,

$$f_1/f \approx 0 \text{ and } f/f_2 \approx 0.$$

Midband:

$$A = A_{mid}$$

Below the midband,

$$f/f_2 \approx 0$$

As a result, the equation becomes,

Below midband:

$$A = \frac{A_{mid}}{\sqrt{1+(f_1/f)^2}}$$

Above midband,

$$f_1/f \approx 0.$$

As a result, the equation becomes,

Above midband:

$$A = \frac{A_{mid}}{\sqrt{1+(f/f_2)^2}}$$

Problem:

For an amplifier, midband gain = 100 and lower cutoff frequency is 1 kHz. Find the gain of an amplifier at frequency 20 Hz.

Solution:

Below midband:

$$A = \frac{A_{mid}}{\sqrt{1+(f_1/f)^2}}$$

$$A = \frac{100}{\sqrt{1+\left(\frac{1000}{20}\right)^2}} = 2$$

Effect of various capacitors on frequency response:

Effect of coupling capacitors:

The reactance of the capacitor is X_C =

$1/2\prod f_C$

At medium and high frequencies, the factor f makes X_C very small, so that all coupling capacitors behave as short circuits. At low frequencies, X_C increases. This

Effect of Bypass capacitors:

At lower frequencies, bypass capacitor C_E is not a short. So emitter is not at ac ground.X_C in parallel with R_E creates an impedance. The signal voltage drops across this impedance reducing the circuit gain.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=wfkzz1rg-xk

Important Books/Journals for further learning including the page nos.:

Sedha.R.S, A Text Book of Applied Electronics, Sultan Chand Publishers, 2010. (Page num - 515)

Course Faculty

MUTHAYAMMAL ENGINEERING COLLEGE

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

LECTURE HANDOUTS

L 35

EEE **II/III**

Course Name with Code: 19GES33 / ELECTRONIC DEVICES AND CIRCUITS

Course Faculty : Mr.S.SARANRAJ

Unit : IV- Multistage Amplifiers & Differential Amplifier

Date of Lecture:

Topic of Lecture: Neutralization methods

Introduction :

- ✓ Two methods of neutralization are commonly used with grounded grid amplifiers.
- ✓ In the first method, the grids of a push-pull amplifier are connected to a point having zero impedance to ground, and a bridge of neutralizing capacitances is used which is equal to the anode-filament capacitances of the tubes.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Amplifier
2. RF Amplifier

Detailed content of the Lecture:

NEUTRALIZATION METHODS:

- ✓ In tuned RF amplifiers, transistors are used at the frequencies nearer to their unity gain bandwidths, to amplify a narrow band of high frequencies centred around a ratio frequency.
- ✓ At this frequency, the inter junction capacitance between base and collector, Cbc of the transistor becomes dominant,
- ✓ i.e., its reactance between low enough to be considered, which is otherwise infinite to be neglected as open circuit.
- ✓ Being CE configuration capacitance Cbe, shown in the fig. come across input and output circuits of an amplifier.

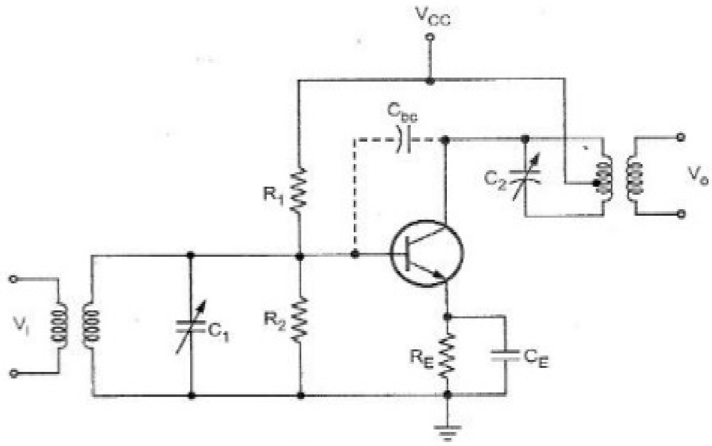


Fig. Neutralization using CE configuration capacitance

Hazeltine Neutralization:

- ✓ The fig shows one variation of the Hazeline circuit. In this circuit a small value of variable capacitance CN is connected from the bottom of coil, point B, to the base.
- ✓ Therefore, the internal capacitance Cbc, shown dotted, feeds a signal from the top end of the coil, point A, to the transistor base and the CN feeds a signal o equal magnitude but opposite polarity rom the bottom o coil, point B, to the base.
- ✓ The neutralizing capacitor, CN can be adjusted correctly to completely nulliy the signal ed through the Cbc.

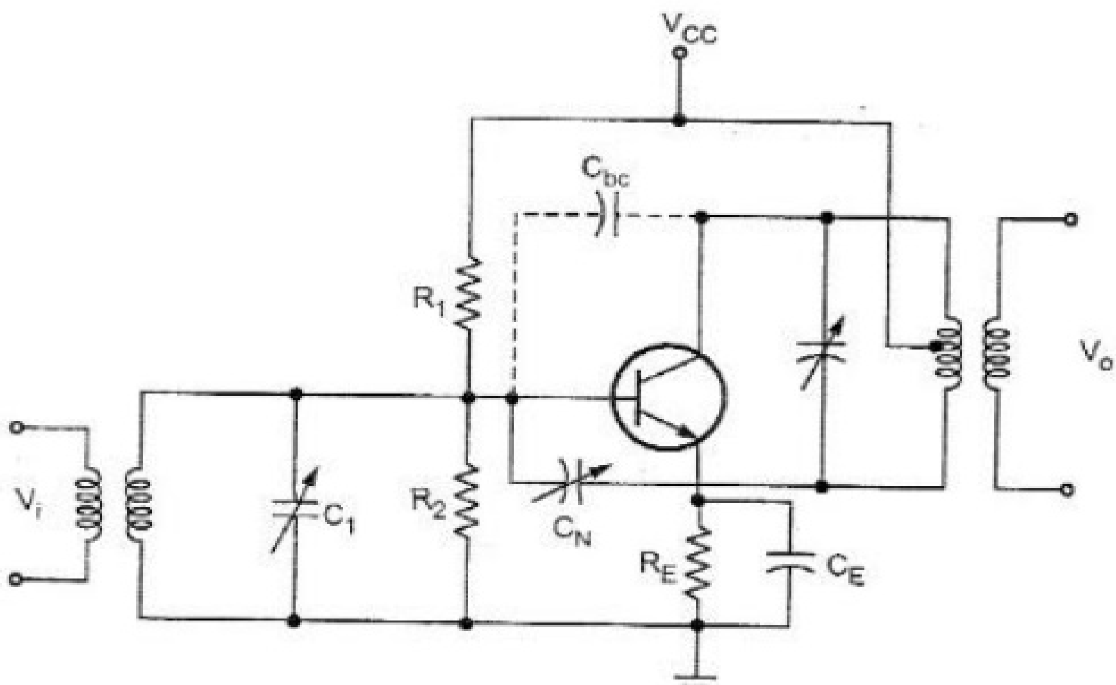
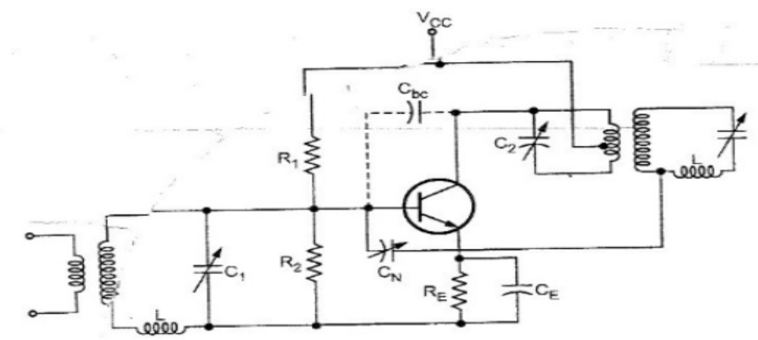


Fig.Tuned RF Amplifier

Neutralization using coil:

- ✓ The Fig shows the neutralization o RF amplifier using coil. In this circuit, L part of the tuned circuit at the base o next stage is oriented or minimum coupling to the other winding.

- ✓ It is wound on a separate from and is mounted at right angle to the coupled windings.
- ✓ If the windings are properly polarized, the voltage across L due to the circulating current in the base circuit will have the proper phase to cancel the signal coupled through the base to collector, Cbc capacitance.



Tuned RF amplifier using coil

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=wXl15Zrm51w

Important Books/Journals for further learning including the page nos.:

Sedha.R.S, A Text Book of Applied Electronics, Sultan Chand Publishers, 2010. (Page num - 487)

Course Faculty

LECTURE HANDOUTS

L 36

EEE

II/III

Course Name with Code: 19GES33 / ELECTRONIC DEVICES AND CIRCUITS

Course Faculty : Dr. R. PRAKASH

Unit : IV- Multistage Amplifiers & Differential Amplifier

Date of Lecture:

Topic of Lecture: power amplifiers –Types (Qualitative analysis).

Introduction :

- ✓ The ideal amplifier would deliver 100 percent of the power it draws from the dc power supply to its load. In practice, 100 percent efficiency cannot be achieved (at this time) because every amplifier uses some percentage of the power it draws from the dc power supply.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Amplifier
2. Power

Detailed content of the Lecture:

POWER AMPLIFIERS

- ✓ The efficiency of an amplifier is the ratio of ac output power to dc input power, written as a percentage. By formula:

$$\eta = \frac{\text{ac output power}}{\text{dc input power}} \times 100$$

- ✓ The lower the position of the Q-point on the dc load line, the higher the maximum theoretical efficiency of a given amplifier. Typical Q-point locations for class A, B, AB, and C amplifiers are shown in Figure 11.1 of the text.

AC Load Lines

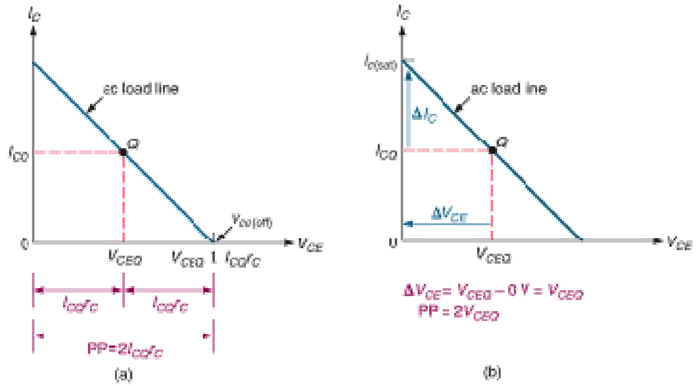
The ac load line is a graph of all possible combinations of i_C and v_{CE} for a given amplifier. Under normal circumstances, the ac and dc load lines for a given amplifier are not identical .

Amplifier Compliance

The compliance (PP) of an amplifier is the limit that the output circuit places on its peak-to-peak output voltage. The compliance for a given amplifier is found using the following equations

$$PP = 2I_{CQ}r_C \text{ and } PP = 2V_{CEQ}$$

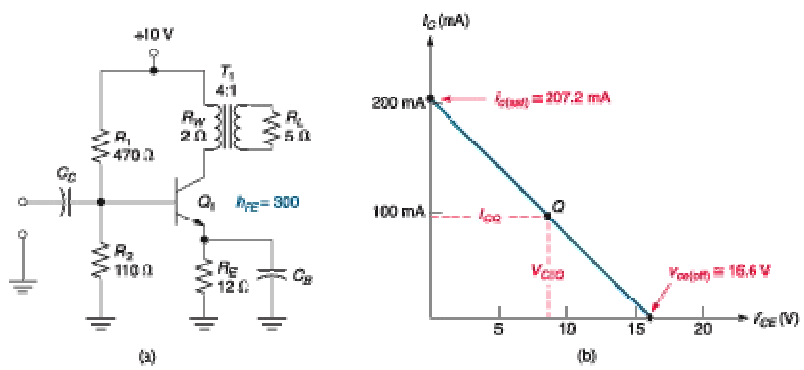
These equations are developed as illustrated in Figure 11.1.



- ✓ The compliance of an amplifier is determined by solving both PP equations and using the lower of the two results, as demonstrated in Example 11.1 of the text. Note the following:
- ✓ When an amplifier has a value of PP = $2V_{CEQ}$, exceeding the value of PP results in saturation clipping.
- ✓ When an amplifier has a value of PP = $2I_{CQ}r_C$, exceeding the value of PP results in cutoff clipping. However, the circuit will experience nonlinear distortion before the amplifier peak-to-peak output reaches the value of PP.

1 Transformer-Coupled Class A Amplifiers

A transformer-coupled class A amplifier is shown in Figure 11.2. The transformer is used to couple the amplifier output signal to its load.



A transformer-coupled class A amplifier

- ✓ The dc biasing of the transformer-coupled class A amplifier is similar to that of other amplifiers, outside of the fact that the value of V_{CEQ} is designed to be as close as possible to the value of V_{CC}.
- ✓ Plotting the ac load line of a transformer-coupled class A amplifier is demonstrated in Section 11.3.3 of the text. The following are typical characteristics for the transformer-coupled circuit:
- ✓ V_{CEQ} is very close to the value of V_{CC}.

- ✓ The maximum output voltage is very close to $2V_{CEQ}$ and therefore, can approach the
- ✓ value of $2V_{CC}$.
- ✓ The maximum theoretical efficiency of a transformer-coupled class A amplifier is 50%. In practice, the transformer-coupled amplifier has a value of $\eta < 25\%$. The high theoretical value is a result of assu
- ✓ The efficiency of a transformer-coupled circuit is calculated as shown in Example 11.7 of the text.
- ✓ The transformer-coupled class A amplifier has the following advantages over the

RC- coupled circuit:

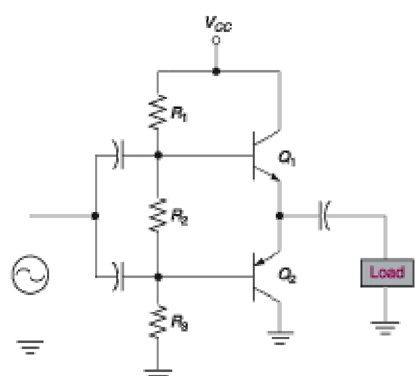
- ✓ Higher efficiency.
- ✓ It is relatively simple to match the amplifier and load impedance using a transformer.
- ✓ A transformer-coupled circuit can easily be converted to a tuned amplifier; that is, a circuit that provides a specific value of gain over a specified range of operating frequencies.

2 Class B Amplifiers

The class B amplifier is a two-transistor circuit that is designed to improve on the efficiency characteristics of class A amplifiers. A class B amplifier is shown in Figure The Q-point values for the circuit in Figure 11.3 are found using

$$V_{CEQ} = \frac{V_{CC}}{2} \quad \text{and} \quad I_{CQ} = I_{CO} \cong 0 \text{ A}$$

where I_{CO} is the collector cutoff current rating for the transistor.

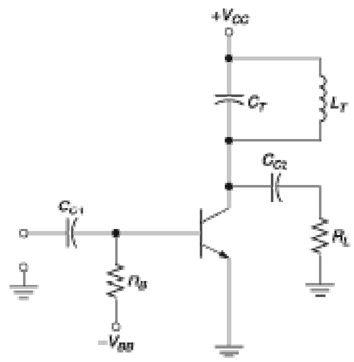


Class B amplifier.

The circuit shown in Figure 11.3 is a complementary-symmetry amplifier, or a push-pull emitter follower. The circuit contains one npn transistor (Q_1) and one pnp transistor (Q_2). The circuit contains complementary transistors; that is, npn and pnp transistors with identical characteristics

3.Class C Amplifiers

Class C amplifiers were briefly mentioned in Chapter 11. The transistor in a class C amplifier conducts for less than 180° of the input cycle. A basic class C amplifier is illustrated in Figure 17.14.



4.Class C amplifier

- ✓ The most important aspect of the dc operation of this amplifier is that it is biased deeply into cutoff, meaning that $V_{CEQ} \cong V_{CC}$ and $I_{CQ} \cong 0$ A.
- ✓ If a negative supply is used to bias the base circuit, the value of V_{BB} usually fulfills the following relationship:
    - $-V_{BB} = 1\ V - V_{in(pk)}$
- ✓ The ac operation of the class C amplifier is based on the characteristics of the parallel-resonant tank circuit.
- ✓ If a single current pulse is applied to the tank circuit, the result is a decaying sinusoidal waveform (as shown in Figure 17.43b of the text). The waveform
- ✓ shown is a result of the charge/discharge cycle of the capacitor and inductor in the tank circuit, and is commonly referred to as the flywheel effect.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=hzGRkhscQ9k&list=PLaw_G9VPLLHvs5mDWUH_hZ2TMEDboHaTp

Important Books/Journals for further learning including the page nos.:

Sedha.R.S, A Text Book of Applied Electronics, Sultan Chand Publishers, 2010. (Page num -484)

Course Faculty

Course Name with Code: 19GES33 / ELECTRONIC DEVICES AND CIRCUITS

Course Faculty : Dr. R. PRAKASH

Unit : V- Feedback Amplifiers and Oscillators **Date of Lecture:**

Topic of Lecture: Advantages of negative feedback, Voltage Current feedback

Introduction :

Negative feedback. When the feedback energy (voltage or current) is out of phase with the input signal and thus opposes it, it is called negative feedback. This is illustrated in Fig. 1.2. As you can see, the amplifier introduces a phase shift of 180° into the circuit while the feedback network is so designed that it introduces no phase shift (i.e., 0° phase shift). The result is that the feedback voltage Vf is 180° out of phase with the input signal Vin.

Advantages:

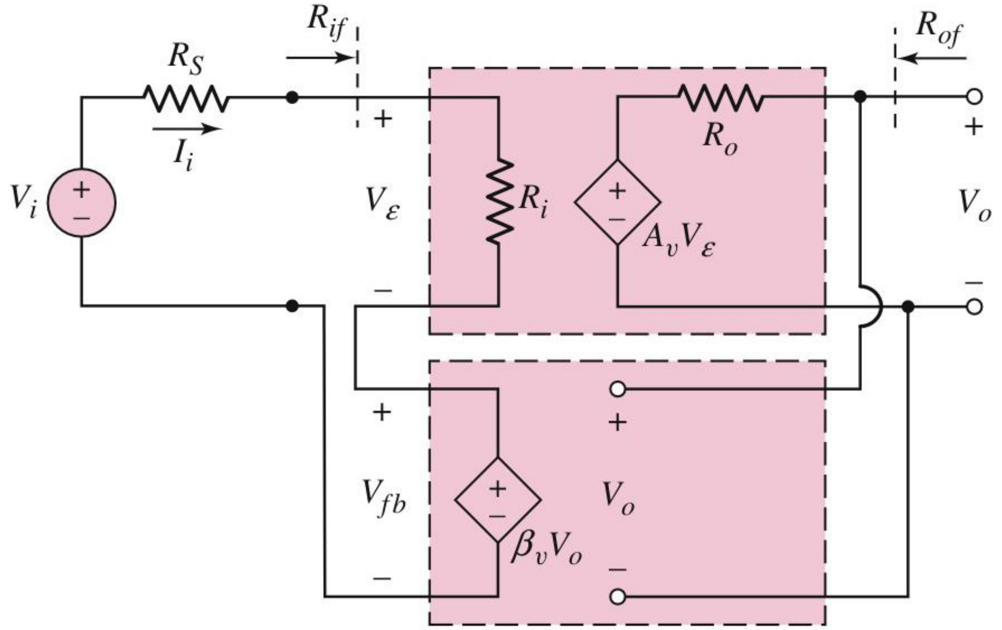
- Gain Sensitivity – variations in gain is reduced.
- Bandwidth Extension – larger than that of basic amplified.
- Noise Sensitivity – may increase S-N ratio.
- Reduction of Nonlinear Distortion
- Control of Impedance Levels – input and output impedances can be increased or decreased.

Prerequisite knowledge for Complete understanding and learning of Topic:

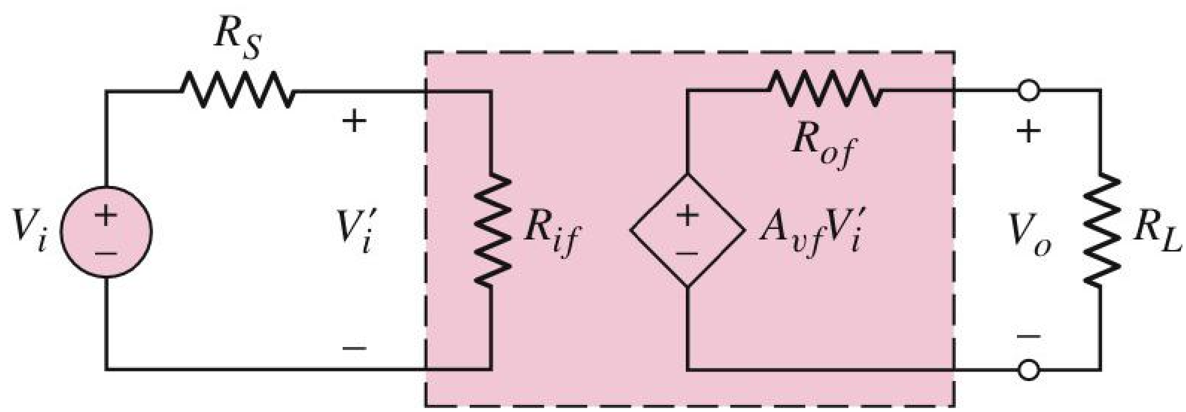
- ✓ Amplifiers
- ✓ Feedback System

Detailed content of the Lecture:

Voltage Series feedback:



- ☐ Series input connection increase input resistance – avoid loading effects on the input signal source.
- ☐ Shunt output connection decrease the output resistance - avoid loading effects on the output signal when output load is connected.



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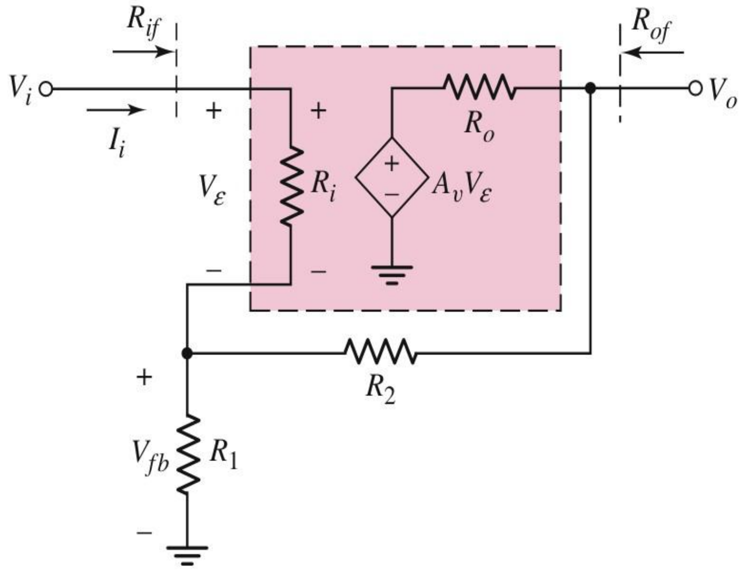


$$V_o = A_v V_\varepsilon$$

$$V_\varepsilon = V_i - V_{fb}$$

$$V_{fb} \cong \left(\frac{R_1}{R_1 + R_2}\right) V_o$$

$$A_{vf} = \frac{V_o}{V_i} = \frac{A_v}{1 + \dfrac{A_v}{\left(\dfrac{R_1}{R_1 + R_2}\right)}} = \frac{A_v}{1 + \beta A_v}$$

$$V_i = V_\varepsilon + \left(\frac{R_1}{R_1 + R_2}\right) V_o = V_\varepsilon + \frac{A_v V_\varepsilon}{\left(1 + \dfrac{R_2}{R_1}\right)}$$

$$R_{if} = \frac{V_i}{I_i} = \frac{V_i}{V_\varepsilon / R_i} = R_i (1 + \beta A_v)$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=eaxdzwpmzVc

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 488-491)

Course Faculty

Course Name with Code: 19GES33 / **ELECTRONIC DEVICES AND CIRCUITS**

Course Faculty : **Dr. R. PRAKASH**

Unit : **V- Feedback Amplifiers and Oscillators**

Date of Lecture:

Topic of Lecture: **Voltage Shunt Feedback amplifier**

Introduction :

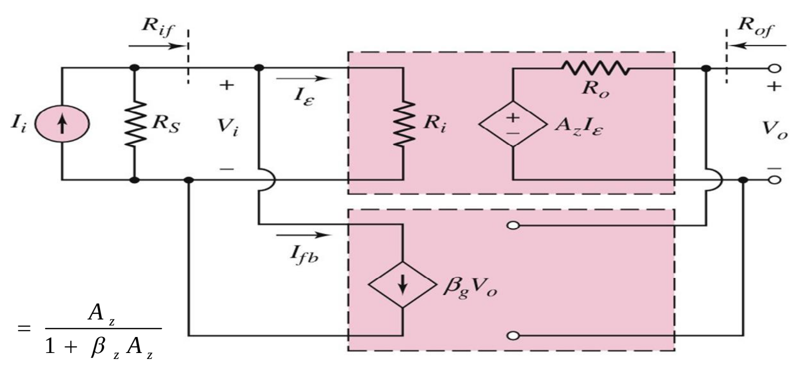
- Gain Sensitivity – variations in gain is reduced.
- Bandwidth Extension – larger than that of basic amplified.
- Noise Sensitivity – may increase S-N ratio.
- Reduction of Nonlinear Distortion
- Control of Impedance Levels – input and output impedances can be increased or decreased.

Prerequisite knowledge for Complete understanding and learning of Topic:

✓ Amplifiers
✓ Diodes

Detailed content of the Lecture:

Voltage – Shunt Configuration



$$A_{zf} = \frac{A_z}{1 + \beta_z A_z}$$

- The feedback samples a portion of the output voltage and converts it to a current – current-to-voltage amplifier.
- The circuit consist of a basic amplifier that converts the error current to an output voltage with a gain factor, A_z and that has an input resistance, R_i.
- The feedback circuit samples the output voltage and produces a feedback current, I_{fb}, which is in shunt with the input current, I_i.

Shunt – Shunt Configuration

Assume the output is a open circuit, the output voltage:

$$\boldsymbol{V_o = A_z I_\varepsilon}$$

feedback voltage is:

$$\boldsymbol{I_{fb}} = \beta_g \boldsymbol{V}_o$$ where ßg is a conductance feedback transfer function

Input signal voltage (neglect Rs=∞):

$$\boldsymbol{I}_i = \boldsymbol{I}_\varepsilon + \boldsymbol{I}_{fb}$$

$$\therefore A_{zf} = \frac{V_o}{I_i} = \frac{A_z}{1+\beta_g A_z}$$

Shunt – Shunt Configuration

Input Resistance, R_{if}

$$I_i = I_\varepsilon + I_{fb} = I_\varepsilon + \beta_g (A_z I_\varepsilon)$$

$$I_\varepsilon = \frac{I_i}{(1+\beta_g A_z)}$$

- Inp

$$V_i = I_\varepsilon R_i = \frac{I_i R_i}{(1+\beta_g A_z)}$$

$$R_{if} = \frac{V_i}{I_i} = \frac{R_i}{(1+\beta_g A_z)}$$

Output Resistance, R_{of}

Assume Vi=0 and Vx applied to output terminal.

Or

$$V_\varepsilon + V_{fb} = V_\varepsilon + \beta_g V_x = 0$$

- In

$$V_\varepsilon = -\beta_g V_x$$

- R_o

$$I_i = \frac{V_x - A_z V_\varepsilon}{R_o} = \frac{V_x (1+\beta_g A_z)}{R_o}$$

$$R_{of} = \frac{V_x}{I_x} = \frac{R_o}{(1+\beta_g A_z)}$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=_3YK-FHJ3zI

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias," Electronic Devices and Circuits" Tata McGraw Hill 2012. Page Num – (493-511)

Course Faculty

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L 39

LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: 19GES33 / **ELECTRONIC DEVICES AND CIRCUITS**

Course Faculty : **Mr.S.SARANRAJ**

Unit : **V- Feedback Amplifiers and Oscillators**

Date of Lecture:

Topic of Lecture: Current Series Feedback amplifier

Introduction :

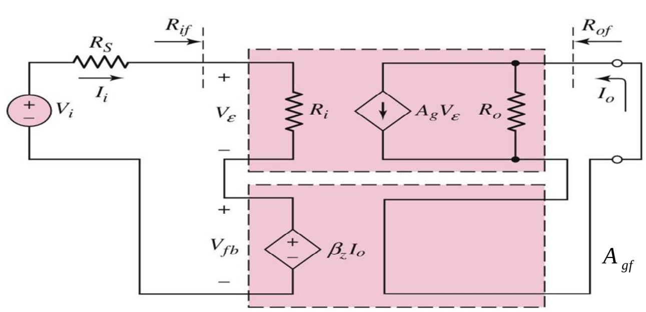
- Gain Sensitivity – variations in gain is reduced.
- Bandwidth Extension – larger than that of basic amplified.
- Noise Sensitivity – may increase S-N ratio.
- Reduction of Nonlinear Distortion
- Control of Impedance Levels – input and output impedances can be increased or decreased.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Amplifiers
- ✓ Diodes

Detailed content of the Lecture:

Current – Series Configuration



$$A_{gf} = \frac{A_g}{1 + \beta_g A_g}$$

- The feedback samples a portion of the output current and converts it to a voltage – voltage-to-current amplifier.
- The circuit consist of a basic amplifier that converts the error voltage to an output current with a gain factor, A_g and that has an input resistance, R_i.

- The feedback circuit samples the output current and produces a feedback voltage, V_{fb}, which is in series with the input voltage, V_i.

Current – Series Configuration

Assume the output is a short circuit, the output current:

$$I_o = A_g V_\varepsilon$$

feedback voltage is:

$$V_{fb} = \beta_z I_o$$ where ßz is a resistance feedback transfer function

Input signal voltage (neglect Rs=∞):

$$V_i = V_\varepsilon + V_{fb}$$

$$\therefore A_{gf} = \frac{I_o}{V_i} = \frac{A_g}{1+\beta_z A_g}$$

Current – Series Configuration

Input Resistance, R_{if}

$$V_i = V_\varepsilon + V_{fb} = V_\varepsilon + \beta_z (A_g V_\varepsilon)$$

$$V_\varepsilon = \frac{V_i}{(1+\beta_z A_g)}$$

- Inp

$$I_i = \frac{V_\varepsilon}{R_i} = \frac{V_i}{R_i(1+\beta_z A_g)}$$

- R_{if} with feedback

$$R_{if} = \frac{V_i}{I_i} = R_i(1+\beta_z A_g)$$

Output Resistance, R_{of}

Assume I_i=0 and I_x applied to output terminal.

$$I_\varepsilon + I_{fb} = I_\varepsilon + \beta_z I_x = 0$$

$$I_\varepsilon = -\beta_z I_x$$

$$V_x = (I_x - A_g I_\varepsilon) R_o$$

$$V_x = [I_x - A_g(-\beta_z I_x)] R_o$$

- R_o

$$V_x = I_x (1+\beta_z A_g) R_o$$

$$R_{of} = \frac{V_x}{I_x} = R_o(1+\beta_z A_g)$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=_3YK-FHJ3zI

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias," Electronic Devices and Circuits" Tata McGraw Hill 2012. Page Num – (493-511)

Course Faculty

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(An Autonomous Institution)

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 40

LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: 19GES33 / **ELECTRONIC DEVICES AND CIRCUITS**

Course Faculty : **Dr. R. PRAKASH**

Unit : **V- Feedback Amplifiers and Oscillators**

Date of Lecture:

Topic of Lecture: Current Shunt feedback amplifier

Introduction :

- Gain Sensitivity – variations in gain is reduced.
- Bandwidth Extension – larger than that of basic amplified.
- Noise Sensitivity – may increase S-N ratio.
- Reduction of Nonlinear Distortion

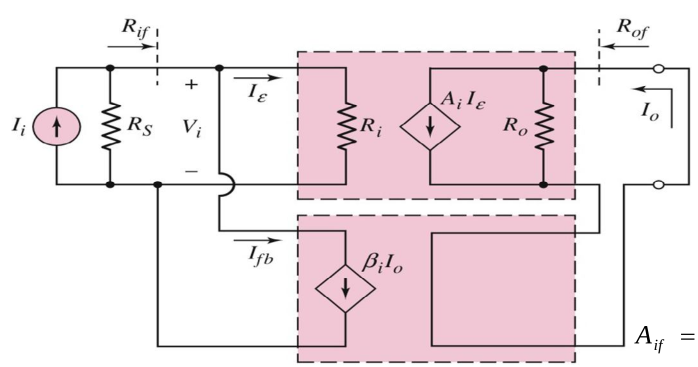
  Control of Impedance Levels – input and output impedances can be increased or decreased.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Amplifiers
- ✓ Diodes

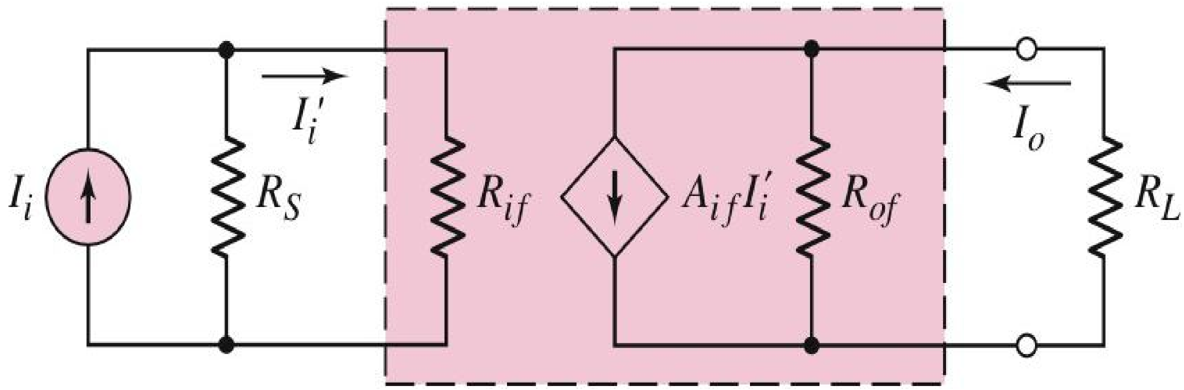
Detailed content of the Lecture:

Current Shunt Configuration



$$A_{if} = \frac{A_i}{1 + \beta_i A_i}$$

- Basic current amplifier with input resistance, Ri and an open-loop current gain, Ai.
- Current I_E is the difference between input signal current and feedback current.
- Feedback circuit samples the output current – provide feedback signal in shunt with signal current.

- Increase in output current – increase feedback current – decrease error current.
- Smaller error current – small output current – stabilize output signal.
- 

if $R_i << R_s$ then $I_i \approx I_\varepsilon$

then the output is a short circuit; output current is:

$$I_o = A_i I_\varepsilon$$

feedback current is:

$I_{fb} = \beta_i I_o$ where ßi is closed-loop current transfer function

Input signal current:

$$I_i = I_\varepsilon + I_{fb}$$

$$\therefore A_{if} = \frac{I_o}{I_i} = \frac{A_i}{1+\beta_i A_i}$$

Input Resistance, R_{if}

C $I_i = I_\varepsilon + I_{fb} = I_\varepsilon + \beta_i (A_i I_\varepsilon)$

- Inp $I_\varepsilon = \frac{I_i}{(1+\beta_i A_i)}$

$$V_i = I_\varepsilon R_i = \frac{I_i R_i}{(1+\beta_i A_i)}$$

- R_{if} with feedback

$$R_{if} = \frac{V_i}{I_i} = \frac{R_i}{(1+\beta_i A_i)}$$

Output Resistance, R_{of}

Assume I_i=0 and I_x applied to output terminal.

$$I_\varepsilon + I_{fb} = I_\varepsilon + \beta_i I_x = 0$$
$$I_\varepsilon = -\beta_i I_x$$
$$V_x = (I_x - A_i I_\varepsilon) R_o$$
$$V_x = [I_x - A_i(-\beta_i I_x)] R_o$$
$$V_x = I_x (1+\beta_i A_i) R_o$$

- R_{of} with feedback

$$R_{of} = \frac{V_x}{I_x} = R_o(1+\beta_i A_i)$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=_3YK-FHJ3zI

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias," Electronic Devices and Circuits" Tata McGraw Hill 2012.
Page Num – (493-511)

Course Faculty

L 41

LECTURE HANDOUTS

EEE

II/III

Course Name with Code: 19GES33 / **ELECTRONIC DEVICES AND CIRCUITS**

Course Faculty : **Dr. R. PRAKASH**

Unit : **V- Feedback Amplifiers and Oscillators**

Date of Lecture:

Topic of Lecture: Positive feedback & Condition for oscillations

Introduction :

- Oscillator is an electronic circuit that generates a periodic waveform on its output without an external signal source. It is used to convert dc to ac.
- Oscillators are circuits that produce a continuous signal of some type without the need of an input.
- These signals serve a variety of purposes.
- Communications systems, digital systems (including computers), and test equipment make use of oscillators

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Amplifiers
- ✓ Positive feedback

Detailed content of the Lecture:

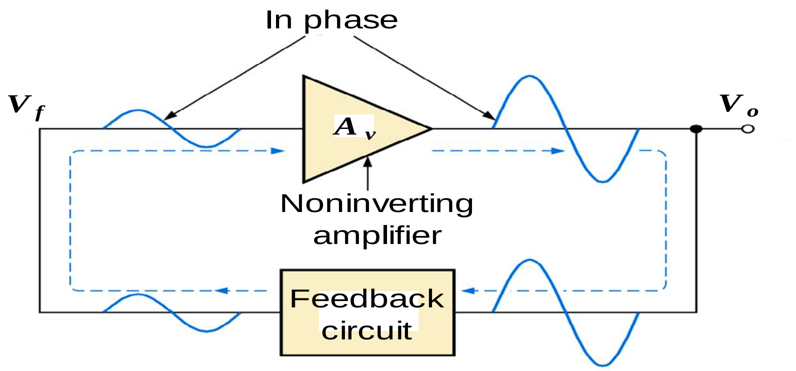
- Thus, the condition for sinusoidal oscillation of frequency f_0 is;

$$A(j\omega_0)\beta(j\omega_0) = 1$$

- This is known as Barkhausen criterion.
- The frequency of oscillation is solely determined by the phase characteristic of the feedback loop – the loop oscillates at the frequency for which the phase is zero.

Basic Principles of Oscillation:

- The feedback oscillator is widely used for generation of sine wave signals.
- The positive (in phase) feedback arrangement maintains the oscillations.
- The feedback gain must be kept to unity to keep the output from distorting.



1. The magnitude of the loop gain must be unity or slightly larger

$$|A\beta| = 1 \quad \text{– Barkhaussen criterion}$$

2. Total phase shift, ϕ of the loop gain mus t be Nx360° where N=0, 1, 2, …

Practical Design Consideration:

- Usually, oscillators are designed so that the loop gain magnitude is slightly higher than unity at the desired frequency of oscillation
- This is done because if we designed for unity loop gain magnitude a slight reduction in gain would result in oscillations that die to zero
- The drawback is that the oscillation will be slightly distorted (the higher gain results in oscillation that grows up to the point that will be clipped)

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=_3YK-FHJ3zI

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias," Electronic Devices and Circuits" Tata McGraw Hill 2012. Page Num – (493-511)

Course Faculty

L 42

LECTURE HANDOUTS

EEE **II/III**

Course Name with Code: 19GES33 / ELECTRONIC DEVICES AND CIRCUITS

Course Faculty : Dr. R. PRAKASH

Unit : V – Feedback amplifiers and Oscillators

Date of Lecture:

Topic of Lecture: Phase shift oscillators

Introduction :

- A phase-shift oscillator is a linear electronic oscillator circuit that produces a sine wave output. It consists of an inverting amplifier element such as a transistor or op amp with its output fed back to its input through a phase-shift network consisting of resistors and capacitors in a ladder network.

Prerequisite knowledge for Complete understanding and learning of Topic:

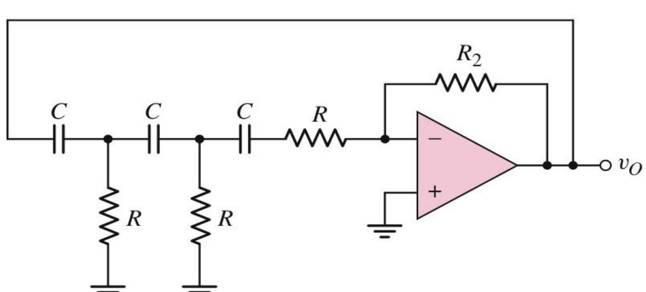
1. oscillation
2. Feedback

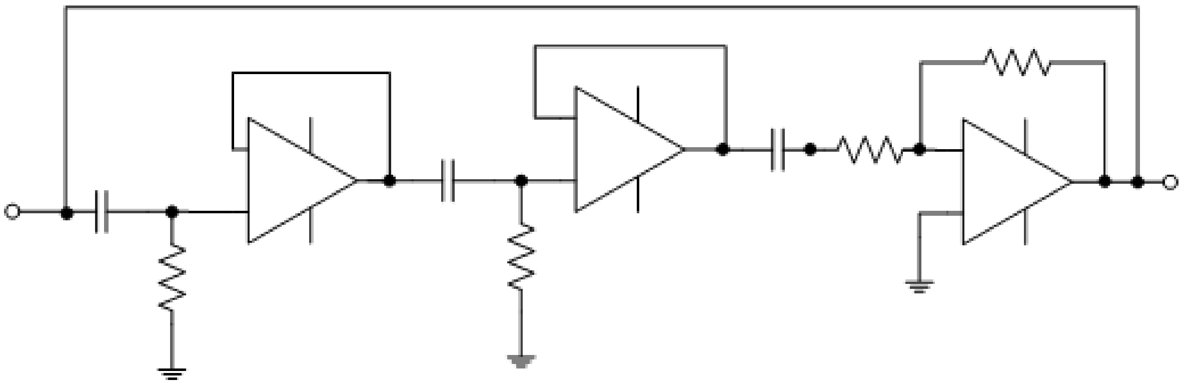
Detailed content of the Lecture:

Phase shift oscillators:

- ✓ The phase shift oscillator utilizes **three RC circuits to provide 180° phase shift** that when coupled with the 180° of the op-amp itself provides the necessary feedback to sustain oscillations.
- ✓ The **gain must be at least 29** to maintain the oscillations.
- ✓ The frequency of resonance for the this type is similar to any RC circuit oscillator.

$$f_r = \frac{1}{2\pi\sqrt{6}RC}$$





$$v_1 = \left(\frac{sRC}{1+sRC}\right)v_i \qquad v_3 = \left(\frac{sRC}{1+sRC}\right)^3 v_i \qquad v_2 = \left(\frac{sRC}{1+sRC}\right)^2 v_i \qquad \frac{v_3}{v_i} = \beta(s) = \left(\frac{sRC}{1+sRC}\right)^3$$

$$T(s) = A(s)\beta(s) = \left(\frac{R_2}{R}\right)\left(\frac{sRC}{1+sRC}\right)^3$$

$$T(j\omega) = \left(\frac{R_2}{R}\right)\left(\frac{j\omega RC}{1+j\omega RC}\right)^3$$

$$T(j\omega) = -\left(\frac{R_2}{R}\right)\frac{(j\omega RC)(\omega RC)^2}{\left[1-3\omega^2R^2C^2\right]+j\omega RC\left[3-\omega^2R^2C^2\right]}$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=Gvb4GIV5ig8

Important Books/Journals for further learning including the page nos.:
Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 525).

Course Faculty

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

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L 43

LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: 19GES33 / ELECTRONIC DEVICES AND CIRCUITS

Course Faculty : Dr. R. PRAKASH

Unit : V- Feedback Amplifiers and Oscillators

Date of Lecture:

Topic of Lecture: Wien bridge oscillators

Introduction :

One of the simplest sine wave oscillators which uses a RC network in place of the conventional LC tuned tank circuit to produce a sinusoidal output waveform, is the Wien Bridge Oscillator.

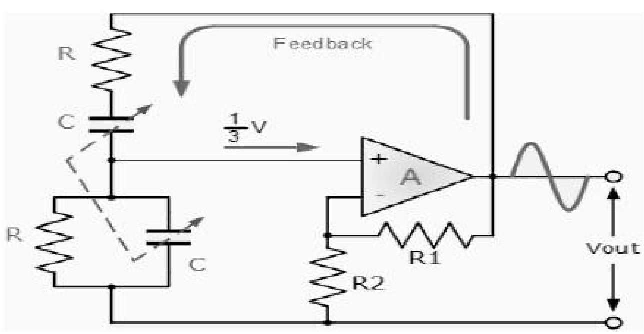
Prerequisite Knowledge For Complete Understanding And Learning Of Topic:

1. Bridges
2. Oscillator

Detailed content of the Lecture:

WIEN BRIDGE OSCILLATOR:

- ✓ The Wien Bridge Oscillator is so called because the circuit is based on a frequency-selective form of the Whetstone bridge circuit.
- ✓ The Wien Bridge oscillator is a two-stage RC coupled amplifier circuit that has good stability at its resonant frequency, low distortion and is very easy to tune making it a popular circuit as an audio frequency oscillator



- ✓ The output of the operational amplifier is fed back to both the inputs of the amplifier. One part of the feedback signal is connected to the inverting input terminal (negative feedback) via the resistor divider network of R1 and R2 which allows the amplifiers voltage gain to be adjusted within narrow limits.

- ✓ The other part is fed back to the non-inverting input terminal (positive feedback) via the RC Wien Bridge network.
- ✓ The RC network is connected in the positive feedback path of the amplifier and has zero phase shift a just one frequency.
- ✓ Then at the selected resonant frequency, (ƒr) the voltages applied to the inverting and non-inverting inputs will be equal and "in-phase" so the positive feedback will cancel out the negative feedback signal causing the circuit to oscillate.
- ✓ Also the voltage gain of the amplifier circuit MUST be equal to three "Gain =3" for oscillations to start. This value is set by the feedback resistor network, R1 and R2 for an inverting amplifier and is given as the ratio -R1/R2.Also, due to the open-loop gain limitations of operational amplifiers, frequencies above 1MHz are unachievable without the use of special high frequency op-amps.
- ✓ Then for oscillations to occur in a Wien Bridge Oscillator circuit the following conditions must apply.
- ✓ With no input signal the Wien Bridge Oscillator produces output oscillations.The Wien Bridge Oscillator can produce a large range of frequencies.
- ✓ The Voltage gain of the amplifier must be at least 3.The network can be used with a Non-inverting amplifier.
- ✓ Some method of stabilizing the amplitude of the oscillations must be provided because if the voltage gain of the amplifier is too small the desired oscillation will decay and stop and if it is too large the output amplitude rises to the value of the supply rails, which saturates the op-amp and causes the output waveform to become distorted.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=gbUXbaxvX94

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias," Electronic Devices and Circuits" Tata McGraw Hill 2012. (Page Num – 534)

Course Faculty

Course Name with Code: 19GES33 / **ELECTRONIC DEVICES AND CIRCUITS**

Course Faculty : **Dr. R. PRAKASH**

Unit : **V- Feedback Amplifiers and Oscillators**

Date of Lecture:

Topic of Lecture: Hartley & Colpitts oscillators

Introduction :

- ✓ An Hartley Oscillator circuit can be made from any configuration that uses either a single tapped coil (similar to an autotransformer) or a pair of series connected coils in parallel with a single capacitor.
- ✓ The Colpitts Oscillator, named after its inventor Edwin Colpitts is another type of LC oscillator design.
- ✓ In many ways, the Colpitts oscillator is the exact opposite of the Hartley Oscillator we looked at in the previous tutorial.
- ✓ Just like the Hartley oscillator, the tuned tank circuit consists of an LC resonance sub-circuit connected between the collector and the base of a single stage transistor amplifier producing a sinusoidal output waveform.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Oscillator
- ✓ FET

Detailed content of the Lecture:

Hartley Oscillator:

- ✓ The main disadvantages of the basic LC Oscillator circuit we looked at in the previous tutorial is that they have no means of controlling the amplitude of the oscillations and also, it is difficult to tune the oscillator to the required frequency.
- ✓ If the cumulative electromagnetic coupling between L1 and L2 is too small there would be insufficient feedback and the oscillations would eventually die away to zero Likewise if the feedback was too strong the oscillations would continue to increase in amplitude until they were limited by the circuit conditions producing signal distortion.
- ✓ So it becomes very difficult to "tune" the oscillator.

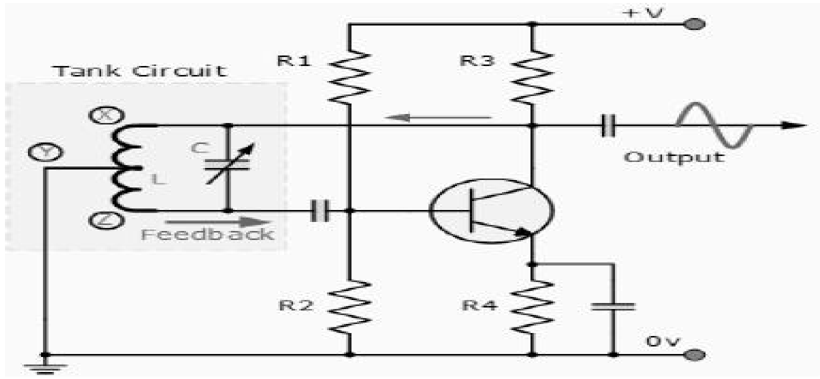
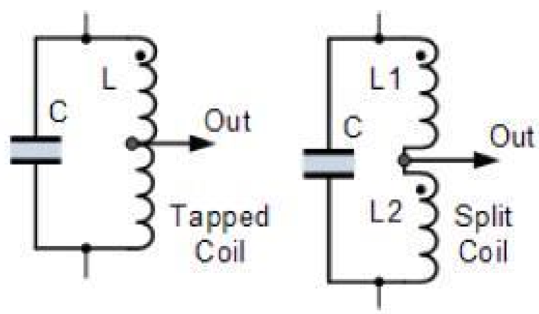


Fig. Basic Hartley Oscillator Circuit

- ✓ However, it is possible to feed back exactly the right amount of voltage for constant amplitude oscillations.
- ✓ If we feed back more than is necessary the amplitude of the oscillations can be controlled by biasing the amplifier in such a way that if the oscillations increase in amplitude, the bias is increased and the gain of the amplifier is reduced.
- ✓ If the amplitude of the oscillations decreases the bias decreases and the gain of the amplifier increases, thus increasing the feedback. In this way the amplitude of the oscillations are kept constant using a process known as Automatic Base Bias**.**



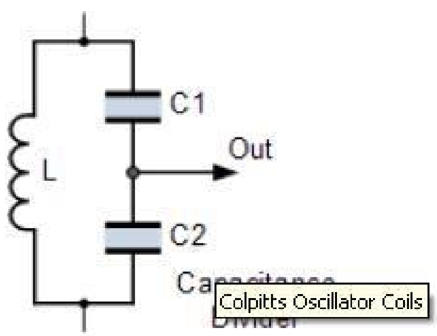
- ✓ When the circuit is oscillating, the voltage at point X (collector), relative to point Y (emitter), is 180^{o} out-of-phase with the voltage at point Z (base) relative to point Y. At the frequency of oscillation, the impedance of the Collector load is resistive and an increase in Base voltage causes a decrease in the Collector voltage.
- ✓ The frequency of oscillations can be adjusted by varying the "tuning" capacitor, C or by varying the position of the iron-dust core inside the coil (inductive tuning) giving an output over a wide range of frequencies making it very easy to tune.
- ✓ Also the Hartley Oscillator produces an output amplitude which is constant over the entire frequency range.

Advantage:

- ✓ Automatic base bias in a voltage controlled oscillator, is that the oscillator can be made more efficient by providing a Class-B bias or even a Class-C bias condition of the transistor. This has the advantage that the collector current only flows during part of the oscillation cycle so the quiescent collector current is very small.

Colpitts Oscillator:

- ✓ The Colpitts oscillator is a type of oscillator that uses an LC circuit in the feed-back loop.
- ✓ The feedback network is made up of a pair of tapped capacitors (C1 and C2) and an inductor L to produce a feedback necessary for oscillations.
- ✓ The output voltage is developed across C1.
- ✓ The feedback voltage is developed across C2.
- ✓ The basic configuration of the Colpitts Oscillator resembles that of the Hartley Oscillator but the difference this time is that the centre tapping of the tank sub-circuit is now made at the junction of a "capacitive voltage divider" network instead of a tapped autotransformer type inductor as in the Hartley oscillator.



Colpitts Oscillator :

- ✓ The Colpitts oscillator uses a capacitor voltage divider as its feedback source.
- ✓ The two capacitors, C1 and C2 are placed across a common inductor, L as shown so that C1, C2 and
- ✓ L forms the tuned tank circuit the same as for the Hartley oscillator circuit.
- ✓ The transistor amplifiers emitter is connected to the junction of capacitors, C1 and C2 which are connected in series and act as a simple voltage divider. When the power supply is firstly applied, capacitors C1 and C2 charge up and then discharge through the coil L.
- ✓ The oscillations across the capacitors are applied to the base-emitter junction and

appear in the amplified at the collector output. The amount of feedback depends on the values of C1 and C2 with the smaller the values of C the greater will be the feedback.

- ✓ The required external phase shift is obtained in a similar manner to that in the Hartley oscillator circuit with the required positive feedback obtained for sustained un-damped oscillations.
- ✓ The amount of feedback is determined by the ratio of C1 and C2 which are generally "ganged" together to provide a constant amount of feedback so as one is adjusted the other automatically follows.
- ✓ The frequency of oscillations for a Colpitts oscillator is determined by the resonant frequency of the LC tank circuit and is given as:

$$f_r = \frac{1}{2\pi\sqrt{L C_T}}$$

where C_T is the capacitance of C1 and C2 connected in series and is given as:.

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} \quad \text{or} \quad C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

- ✓ The configuration of the transistor amplifier is of a Common Emitter Amplifier with the output signal 180^o out of phase with regards to the input signal.
- ✓ The additional 180^o phase shift require for oscillation is achieved by the fact that the two capacitors are connected together in series but in parallel with the inductive coil resulting in overall phase shift of the circuit being zero

Video Content / Details of website for further learning (if any):

https: / / www.youtube.com / watch?v=ndla86HEg-Q

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 534)

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L 45

LECTURE HANDOUTS

EEE | **II/III**

Course Name with Code: 19GES33 / **ELECTRONIC DEVICES AND CIRCUITS**

Course Faculty : **Dr. R. PRAKASH**

Unit : **V- Feedback Amplifiers and Oscillators**

Date of Lecture:

Topic of Lecture: Crystal oscillators

Introduction :

- ✓ Most communications and digital applications require the use of oscillators with extremely stable output. Crystal oscillators are invented to overcome the output fluctuation experienced by conventional oscillators.
- ✓ Crystals used in electronic applications consist of a quartz wafer held between two metal plates and housed in a a package

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Oscillator
- ✓ FET

Detailed content of the Lecture:

Piezoelectric Effect :

- ✓ The quartz crystal is made of silicon oxide (SiO_2) and exhibits a property called the piezoelectric
- ✓ When a changing an alternating voltage is applied across the crystal, it vibrates at the frequency of the applied voltage. In the other word, the frequency of the applied ac voltage is equal to the natural resonant frequency of the crystal.
- ✓ The thinner the crystal, higher its frequency of vibration. This phenomenon is called piezoelectric effect.

Crystal Oscillator:

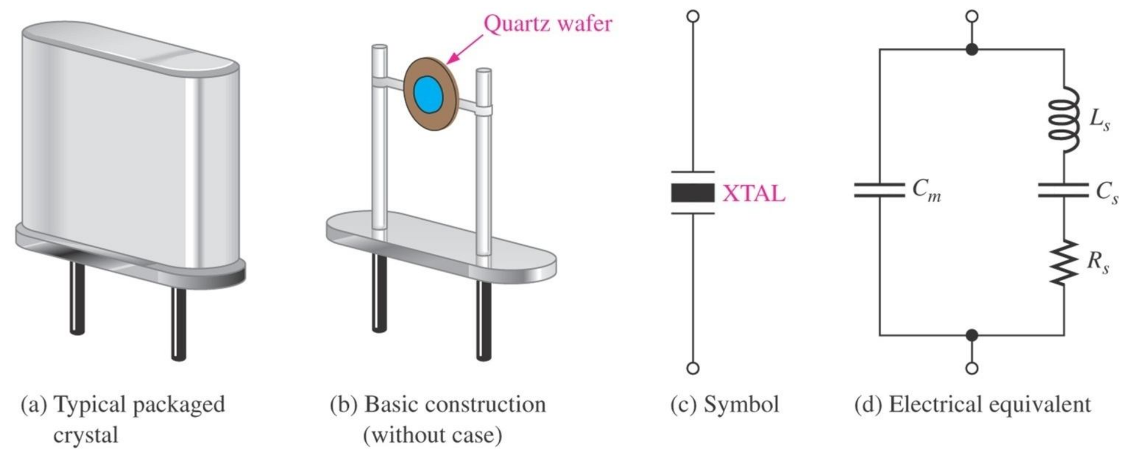

Fig. Basic Crystal Circuit

Characteristic of Quartz Crystal:

- ✓ The crystal can have two resonant frequencies;
- ✓ One is the series resonance frequency f_1 which occurs when $X_L = X_C$. At this frequency, crystal offers a very low impedance to the external circuit where Z = R.
- ✓ The other is the parallel resonance (or antiresonance) frequency f_2 which occurs when reactance of the series leg equals the reactance of C_M. At this frequency, crystal offers a very high impedance to the external circuit

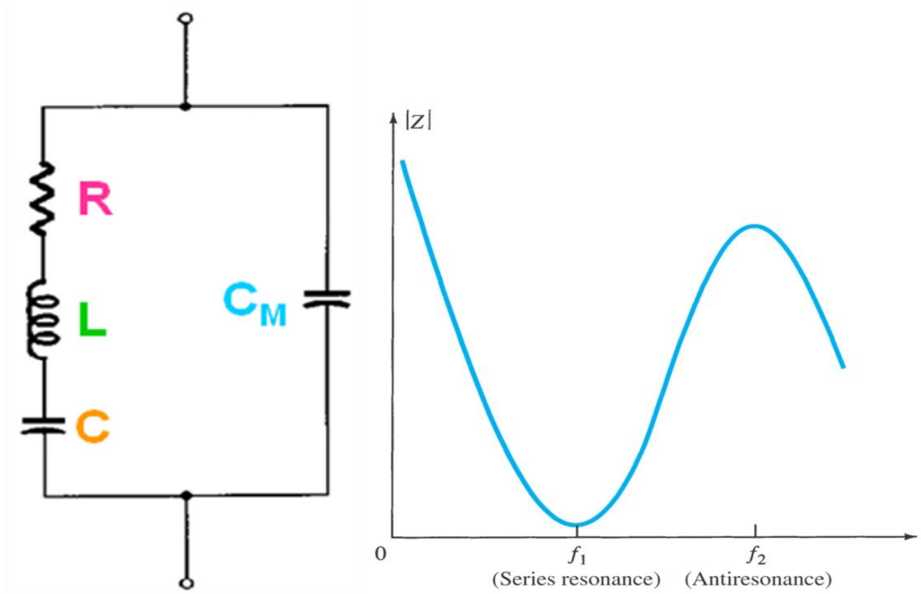

Fig. connection of Crystal Circuit

- ✓ The crystal is connected as a series element in the feedback path from collector to the base so that it is excited in the series-resonance mode
- ✓ Since, in series resonance, crystal impedance is the smallest that causes the crystal provides the largest positive feedback.
- ✓ Resistors R_1, R_2, and R_E provide a voltage-divider stabilized dc bias circuit. Capacitor C_E provides ac bypass of the emitter resistor, R_E to avoid degeneration.
- ✓ The RFC coil provides dc collector load and also prevents any ac signal from entering

the dc supply.

- ✓ The coupling capacitor C_C has negligible reactance at circuit operating frequency but blocks any dc flow between collector and base.
- ✓ The oscillation frequency equals the series-resonance frequency of the crystal and is given by: $$f_o = \frac{1}{2\pi\sqrt{LC_C}}$$

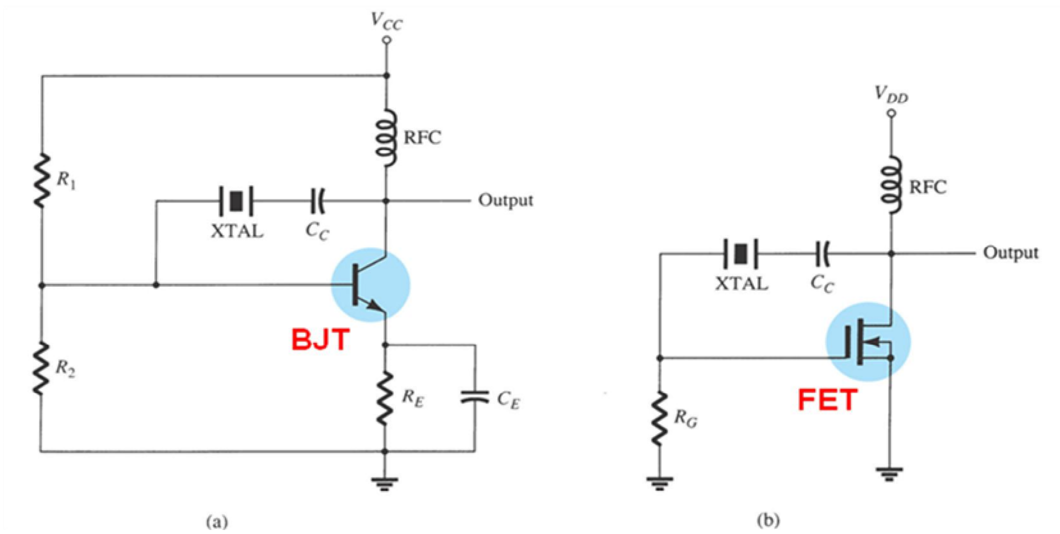

Fig.crystal scillator using Transistors

Advantages:

- ✓ The crystal oscillator has very low frequency drift due to change in temperature and other parameters.
- ✓ The crystal oscillator Q is very high.
- ✓ It has Automatic amplitude control.
- ✓ It has very high frequency stability.
- ✓ The crystal oscillator is possible to obtain very high precise and stable frequency of oscillators.

Disadvantages:

- ✓ These are suitable for high frequency application.
- ✓ Crystals of low fundamental frequencies are not easily available.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=YzcKQWwkzWs

Important Books/Journals for further learning including the page nos.:

Jacob. Millman, Christos C.Halkias, Electronic Devices and Circuits, Tata McGraw Hill , 2012. (Page Num – 535-537)

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