KARAPAGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE-21

Semester–V

		L T P C
15PHU504	**BASIC ELECTRONICS**	**5 - - 5**

Scope: This paper explains the basic concepts of electronic devices, their applications in the consturction of different electronic devices etc.

Objectives: We are living in a wonder world of Electronics. To know the physical principles and applications of Electronics is most necessary for a Physics student. This course is intended to provide this know-how.

UNIT I

Basic concepts of semiconductors

P-N junction Diode-Diode Characteristics-Expression for Diode current (Expression without derivation)-Static and Dynamic resistances-Junction capacitance-Equivalent circuit-Avalanche and Zener breakdown-PIV -Voltage regulation-Line regulation and load regulation- Rectifiers-Half wave-Centre tapped full wave and Bridge rectifiers-Derivation of efficiency and ripple factor of half wave and full wave rectifiers,LED,SCR.

UNIT II

Transistors

Transistors-Bipolar junction transistors-Mechanism of amplification in a transistor- Common base, common emitter and common collector configurations and their characteristics-Active, saturation and Cut-off regions-Current gain α , β , γ and their relationships-Experiment to draw the characteristics of transistor in the CB and CE modes-Leakage currents-Expressions for output currents in the three modes-Transistor as a switch,FET,MOSFET,UJT.

UNIT III

Amplfiers

Different transistor amplifier configurations:- C-B, C-E, C-C, their characteristics, amplification factors, their relationships, Load line Analysis, Expressions for voltage gain, current gain and power gain of C.E amplifier, cut-off and saturation points, Transistor biasing, Different types of biasing - Base resistor, voltage divider bias method, single stage transistor amplifier circuit, load line analysis, DC and AC equivalent circuits.

UNIT IV

Operational amplifer

Operational amplifier- Block diagram-characteristics-parameters- Applications of Op-amp: Inverting-Non-inverting-differentiator-integrator-comparator-adder-subtractor- Active filters using 741: high pass and low pass filters- band pass filter-Schmitt trigger.

UNIT V

Oscillators

Oscillatory Circuits-LC, RC oscillators, tuned collector oscillator, Hartley, Colpitt's, phase shift Oscillators, Weinbridge oscillators. Multivibrators-Astable ,monostable and Bistablemultivibrtors(using 555 Timer)

Text Books

1. V.K. METHA Principles of Electronics S Chand & co Newdelhi 11th edition 2014
2. Solid State Electronics-B.L.Theraja: S.Chand C 5th edition 2014.

References:

1. A Text Book of Applied Electronics-R.S.Sedha: S.Chand Co. Multi Colour Edn.
2. Malvino A.P. 7th edition 2013, Electronics Principles, Tata McGraw Hill, New Delhi
3. Milmann and Halkias, 48th reprint 2008, Integrated Electronics, Tata McGraw Hill, New Delhi.

KARAPAGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE-21

DEPARTMENT OF PHYSICS

LECTURE PLAN (2017-2018 ODD SEMESTER)

III B.SC PHYSICS (2015-2018 BATCH)

BASIC ELECTRONICS (15PHU504)

UNIT – I

S.No	Lecture duration	Topic to be covered	Support material
1	1 hr	P-N junction Diode-Diode Characteristics	T1-64-70
2	1 hr	Continuation	
3	1 hr	Expression for Diode current (Expression without derivation)-Static and Dynamic resistances	T1-79
4	1 hr	Continuation	
5	1 hr	Junction capacitance-Equivalent circuit-	T1-77
6	1 hr	Continuation	
7	1 hr	Avalanche and Zener breakdown	T1-72
8	1 hr	Continuation	
9	1 hr	PIV -Voltage regulation	T1-87
10	1 hr	Continuation	
11	1 hr	Line regulation and load regulation	T1-94-101
12	1 hr	Continuation	
13	1 hr	Rectifiers-Half wave-Centre tapped full wave and Bridge rectifiers	T1-126
14	1 hr	Continuation	
15	1 hr	Derivation of efficiency and ripple factor of half wave and full wave rectifiers, LED, SCR	T1-129
16	1 hr	Revision	

Text Books

T1: V.K. METHA, Principles of Electronics S Chand & co NewDelhi 11th edition 2014

UNIT – II

S.No	Lecture duration	Topic to be covered	Support material
1	1 hr	Transistors-Bipolar junction transistors	T1-142
2	1 hr	Continuation	
3	1 hr	Mechanism of amplification in a transistor	T1- 145
4	1 hr	Continuation	
5	1 hr	Common base, common emitter configurations	T1- 148-150
6	1 hr	Continuation	
7	1 hr	common collector configurations and their characteristics	T1-154-156
8	1 hr	Continuation	
9	1 hr	Active, saturation and Cut-off regions	T1-174
10	1 hr	Continuation	
11	1 hr	Current gain α , β , γ and their relationships	T1-173
12	1 hr	Continuation	
13	1 hr	Experiment to draw the characteristics of transistor in the CB and CE modes	T1-154
14	1 hr	Continuation	
15	1 hr	Leakage currents-Expressions for output currents in the three modes	T1-474
16	1 hr	Transistor as a switch,FET,MOSFET,UJT.	T1-177
17	1 hr	Revision	

Text Books

T1: V.K. METHA, Principles of Electronics S Chand & co NewDelhi 11th edition 2014

UNIT – III

S.No	Lecture duration	Topic to be covered	Support material
1	1 hr	Different transistor amplifier configurations:- C-B, C-E, C-C	T1-164
2	1 hr	Continuation	
3	1 hr	Their characteristics, amplification factors, their relationships	T1- 167
4	1 hr	Continuation	
5	1 hr	Load line Analysis, Expressions for voltage gain	T1- 251
6	1 hr	Continuation	
7	1 hr	Current gain and power gain of C.E amplifier	T1-252
8	1 hr	Continuation	
9	1 hr	Cut-off and saturation points	T1-123
10	1 hr	Continuation	
11	1 hr	Transistor biasing, Different types of biasing	T1-212
12	1 hr	Continuation	
13	1 hr	Base resistor, voltage divider bias method	T1-212
14	1 hr	Continuation	
15	1 hr	single stage transistor amplifier circuit, load line analysis	T1-241
16	1 hr	Continuation	
17	1 hr	DC and AC equivalent circuits.	T1-247
18	1 hr	Revision	

Text Books

T1: V.K. METHA, Principles of Electronics S Chand & co NewDelhi 11th edition 2014

UNIT – IV

S.No	Lecture duration	Topic to be covered	Support material
1	1 hr	Operational amplifier- Block diagram	T1-663
2	1 hr	Characteristics-parameters	T1- 690
3	1 hr	Applications of Op-amp: Inverting	T1- 694
4	1 hr	Non-inverting-differentiator	T1-698
5	1 hr	Integrator-comparator-adder-subtractor	T1-711-712
6	1 hr	Active filters using 741: high pass	T1-249
7	1 hr	low pass filters - Band pass filter	T1-276
8	1 hr	Schmitt trigger.	T1-300
9	1 hr	Revision	

Text Books

T1: V.K. METHA, Principles of Electronics S Chand & co NewDelhi 11th edition 2014

UNIT – V

S.No	Lecture duration	Topic to be covered	Support material
1	1 hr	Oscillatory Circuits-LC, RC oscillators	T1- 364-370
2	1 hr	Continuation	
3	1 hr	Tuned collector oscillator	T1- 371-372
4	1 hr	Hartley oscillator	T1- 374-376
5	1 hr	Continuation	
6	1 hr	Colpitt's oscillator	T1-372-374
7	1 hr	Continuation	
8	1 hr	phase shift Oscillators,	T1-376-377
9	1 hr	Wein bridge oscillators.	T1-378-383
10	1 hr	Multi vibrators-Astable ,monostable and	T1-446- 447
11	1 hr	Bistable multivibrtors(using 555 Timer)	T1-447-444
12	1 hr	Revision	
13	1 hr	Old question paper revision	
14	1 hr	Old question paper revision	
15	1 hr	Old question paper revision	

Text Books

T1: V.K. METHA, Principles of Electronics S Chand & co NewDelhi 11th edition 2014

UNIT I

Basic concepts of semiconductors

P-N junction Diode-Diode Characteristics-Expression for Diode current (Expression without derivation)-Static and Dynamic resistances-Junction capacitance-Equivalent circuit-Avalanche and Zener breakdown-PIV -Voltage regulation-Line regulation and load regulation- Rectifiers-Half wave-Centre tapped full wave and Bridge rectifiers-Derivation of efficiency and ripple factor of half wave and full wave rectifiers,LED,SCR.

PN Junction Theory

When the N-type semiconductor and P-type semiconductor materials are first joined together a very large density gradient exists between both sides of the PN junction. The result is that 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.

However, because the electrons have moved across the PN junction from the N-type silicon to the P-type silicon, they leave behind positively charged donor ions (N_D) on the negative side and now the holes from the acceptor impurity migrate across the junction in the opposite direction into the region where there are large numbers of free electrons.

As a result, the charge density of the P-type along the junction is filled with negatively charged acceptor ions (N_A), and the charge density of the N-type along the junction becomes positive. This charge transfer of electrons and holes across the PN junction is known as **diffusion**. The width of these P and N layers depends on how heavily each side is doped with acceptor density N_A, and donor density N_D, respectively.

This process continues back and forth until the number of electrons which have crossed the junction have a large enough electrical charge to repel or prevent any more charge carriers from crossing over the junction. Eventually a state of equilibrium (electrically neutral situation) will occur producing a “potential barrier” zone around the area of the junction as the donor atoms repel the holes and the acceptor atoms repel the electrons.

Since no free charge carriers can rest in a position where there is a potential barrier, the regions on either sides of the junction now become completely depleted of any more free carriers in comparison to the N and P type materials further away from the junction. This area around the **PN Junction** is now called the **Depletion Layer**.

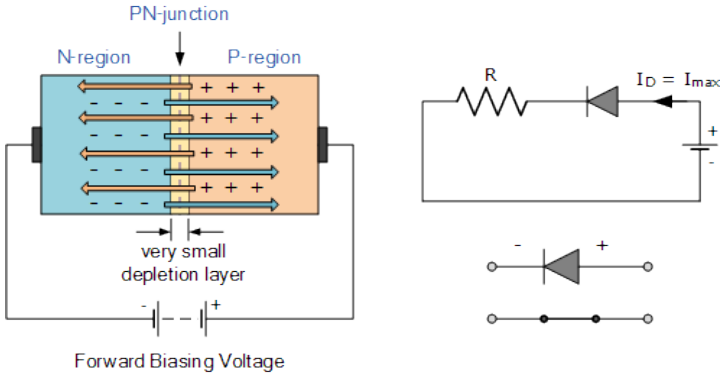


Fig1.1

The PN junction

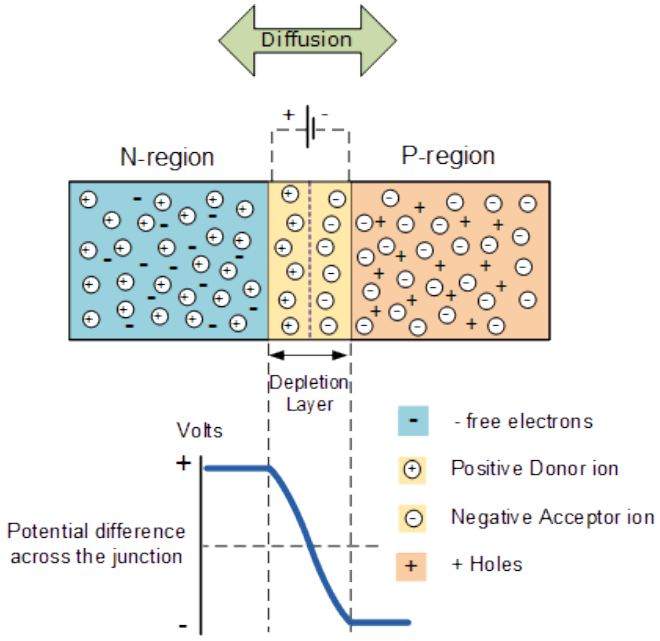


Fig1.2

The total charge on each side of a *PN Junction* must be equal and opposite to maintain a neutral charge condition around the junction. If the depletion layer region has a distance D, it therefore must therefore penetrate into the silicon by a distance of Dp for the positive side, and a distance of Dn for the negative side giving a relationship between the two of $Dp.N_A = Dn.N_D$ in order to maintain charge neutrality also called equilibrium.

DIODE CHARACTERISTICS:

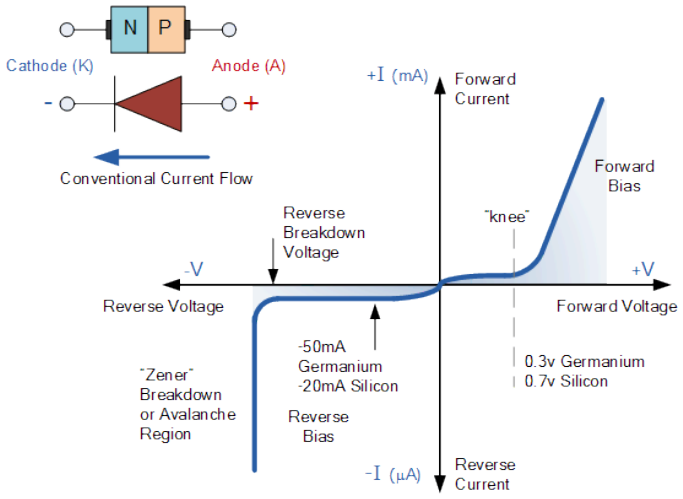


Fig1.3

There are two operating regions and three possible "biasing" conditions for the standard **Junction Diode** and these are:

- Zero Bias – No external voltage potential is applied to the PN junction diode.
- Reverse Bias – The voltage potential is connected negative, (-ve) to the P-type material and positive, (+ve) to the N-type material across the diode which has the effect of **Increasing** the PN junction diode's width.
- Forward Bias – The voltage potential is connected positive, (+ve) to the P-type material and negative, (-ve) to the N-type material across the diode which has the effect of **Decreasing** the PN junction diodes width.

ZERO BIASED JUNCTION DIODE

When a diode is connected in a **Zero Bias** condition, no external potential energy is applied to the PN junction. However if the diodes terminals are shorted together, a few holes (majority carriers) in the P-type material with enough energy to overcome the potential barrier will move across the junction against this barrier potential. This is known as the "**Forward Current**" and is referenced as I_F

Likewise, holes generated in the N-type material (minority carriers), find this situation favourable and move across the junction in the opposite direction. This is known as the "**Reverse Current**" and is referenced as I_R. This transfer of electrons and holes back and forth across the PN junction is known as diffusion, as shown below.

ZERO BIASED PN JUNCTION DIODE

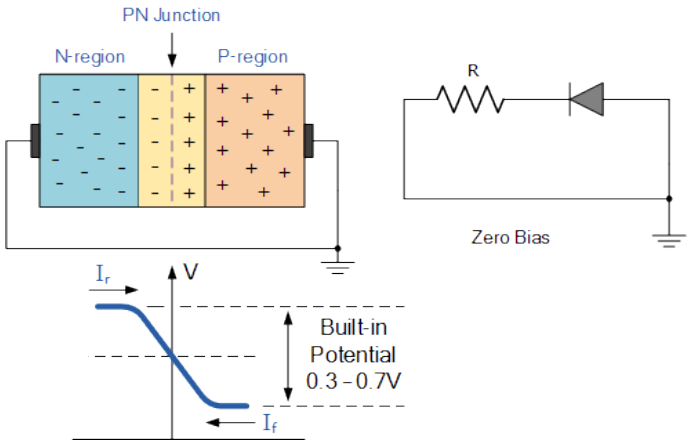


Fig 1.4

The potential barrier that now exists discourages the diffusion of any more majority carriers across the junction. However, the potential barrier helps minority carriers (few free electrons in the P-region and few holes in the N-region) to drift across the junction.

Then an "Equilibrium" or balance will be established when the majority carriers are equal and both moving in opposite directions, so that the net result is zero current flowing in the circuit. When this occurs the junction is said to be in a state of "**Dynamic Equilibrium**".

The minority carriers are constantly generated due to thermal energy so this state of equilibrium can be broken by raising the temperature of the PN junction causing an increase in the generation of minority carriers, thereby resulting in an increase in leakage current but an electric current cannot flow since no circuit has been connected to the PN junction.

REVERSE BIASED PN JUNCTION DIODE:

When a diode is connected in a **Reverse Bias** condition, a positive voltage is applied to the N-type material and a negative voltage is applied to the P-type material.

The positive voltage applied to the N-type material attracts electrons towards the positive electrode and away from the junction, while the holes in the P-type end are also attracted away from the junction towards the negative electrode.

The net result is that the depletion layer grows wider due to a lack of electrons and holes and presents a high impedance path, almost an insulator. The result is that a high potential barrier is created thus preventing current from flowing through the semiconductor material.

Increase in the Depletion Layer due to Reverse Bias

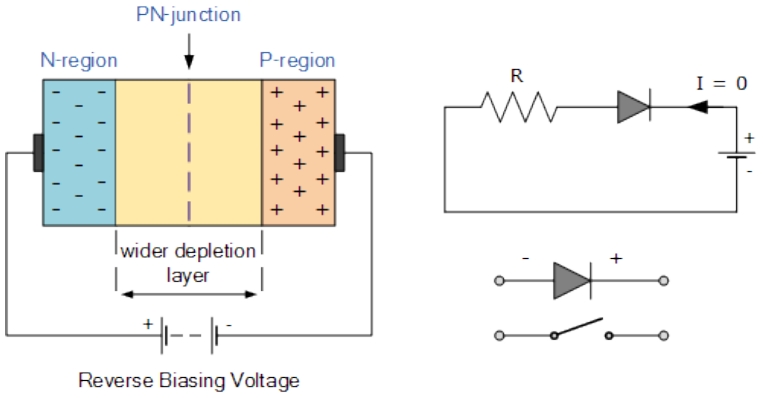


Fig 1.5

This condition represents a high resistance value to the PN junction and practically zero current flows through the junction diode with an increase in bias voltage. However, a very small **leakage current** does flow through the junction which can be measured in micro-amperes, (μA).

One final point, if the reverse bias voltage Vr applied to the diode is increased to a sufficiently high enough value, it will cause the diode's PN junction to overheat and fail due to the avalanche effect around the junction. This may cause the diode to become shorted and will result in the flow of maximum circuit current and this shown as a step downward slope in the reverse static characteristics curve below.

Reverse Characteristics Curve for a Junction Diode

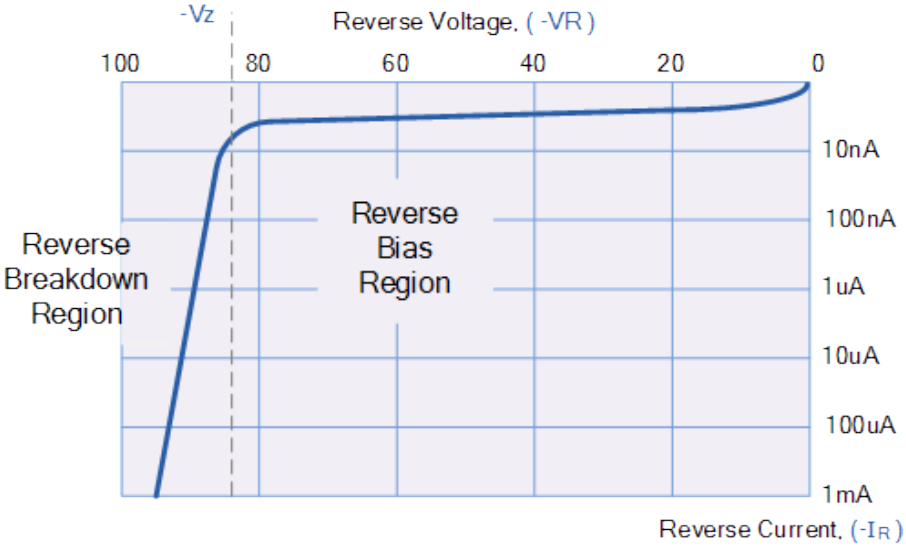


Fig 1.6

Sometimes this avalanche effect has practical applications in voltage stabilising circuits where a series limiting resistor is used with the diode to limit this reverse breakdown current to a preset maximum value thereby producing a fixed voltage output across the diode. These types of diodes are commonly known as **Zener Diodes** and are discussed in a later tutorial.

Forward Biased PN Junction Diode

When a diode is connected in a **Forward Bias** condition, a negative voltage is applied to the N-type material and a positive voltage is applied to the P-type material. If this external voltage becomes greater than the value of the potential barrier, approx. 0.7 volts for silicon and 0.3 volts for germanium, the potential barriers opposition will be overcome and current will start to flow.

This is because the negative voltage pushes or repels electrons towards the junction giving them the energy to cross over and combine with the holes being pushed in the opposite direction towards the junction by the positive voltage. This results in a characteristics curve of zero current flowing up to this voltage point, called the "knee" on the static curves and then a high current flow through the diode with little increase in the external voltage as shown below.

FORWARD CHARACTERISTICS CURVE FOR A JUNCTION DIODE

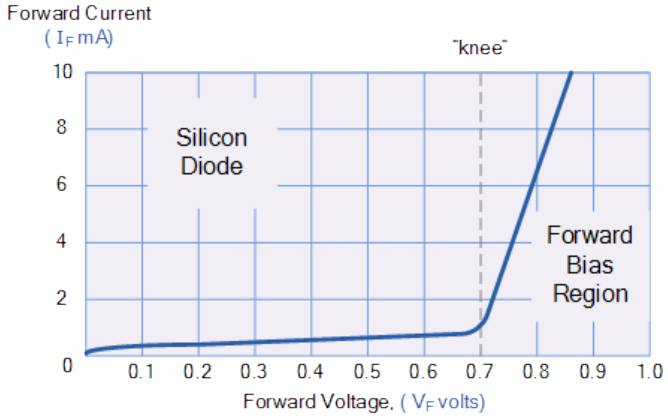


Fig 1.7

The application of a forward biasing voltage on the junction diode results in the depletion layer becoming very thin and narrow which represents a low impedance path through the junction thereby allowing high currents to flow. The point at which this sudden increase in current takes place is represented on the static I-V characteristics curve above as the "knee" point.

ZENER DIODE

The **Zener diode** behaves just like a normal general-purpose diode consisting of a silicon PN junction and when biased in the forward direction, that is Anode positive with respect to its Cathode, it behaves just like a normal signal diode passing the rated current.

However, unlike a conventional diode that blocks any flow of current through itself when reverse biased, that is the Cathode becomes more positive than the Anode, as soon as the reverse voltage reaches a pre-determined value, the zener diode begins to conduct in the reverse direction.

This is because when the reverse voltage applied across the zener diode exceeds the rated voltage of the device a process called *Avalanche Breakdown* occurs in the semiconductor depletion layer and a current starts to flow through the diode to limit this increase in voltage.

The current now flowing through the zener diode increases dramatically to the maximum circuit value (which is usually limited by a series resistor) and once achieved, this reverse saturation current remains fairly constant over a wide range of reverse voltages. The voltage point at which the voltage across the zener diode becomes stable is called the "zener voltage", (Vz) and for zener diodes this voltage can range from less than one volt to a few hundred volts.

Zener Diode I-V Characteristics

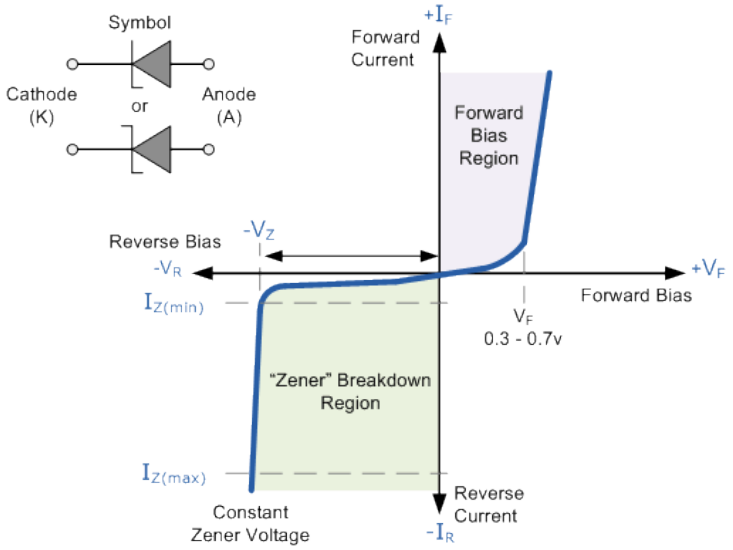


Fig 1.8

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 characteristics of almost a constant negative voltage regardless of the value of the current flowing through the diode and remains nearly constant even with large changes in current as long as the zener diodes current remains between the breakdown current $I_{Z(min)}$ and the maximum current rating $I_{Z(max)}$.

This ability to control itself can be used to great effect to regulate or stabilise a voltage source against supply or load variations. The fact that the voltage across the diode in the breakdown region is almost constant turns out to be an important characteristic of the zener diode as it can be used in the simplest types of voltage regulator applications.

The function of a regulator is to provide a constant output voltage to a load connected in parallel with it in spite of the ripples in the supply voltage or the variation in the load current and the zener diode will continue to regulate the voltage until the diodes current falls below the minimum $I_{Z(min)}$ value in the reverse breakdown region.

LINE REGULATION

Line regulation is the ability of the power supply to maintain its specified output voltage over changes in the input line voltage. It is expressed as percent of change in the output voltage relative to the change in the input line voltage.

LOAD REGULATION

Load regulation is the ability of the power supply to maintain its specified output voltage given changes in the load. This does not mean the tolerance applies when there are sudden changes in load, it means over the permissible load range the regulation can change by this amount.

Half Wave Rectifer

A rectifier is a circuit which converts the *Alternating Current* (AC) input power into a *Direct Current* (DC) output power. The input power supply may be either a single-phase or a multi-phase supply with the simplest of all the rectifier circuits being that of the **Half Wave Rectifier**.

The power diode in a half wave rectifier circuit passes just one half of each complete sine wave of the AC supply in order to convert it into a DC supply. Then this type of circuit is called a "half-wave" rectifier because it passes only half of the incoming AC power supply as shown below.

Half Wave Rectifier Circuit

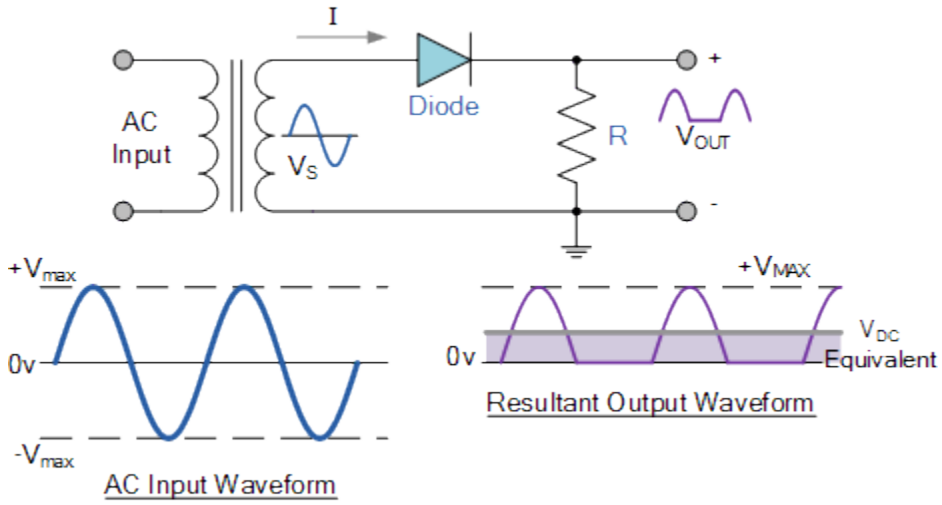


Fig1.9

During each "positive" half cycle of the AC sine wave, the diode is *forward biased* as the anode is positive with respect to the cathode resulting in current flowing through the diode.

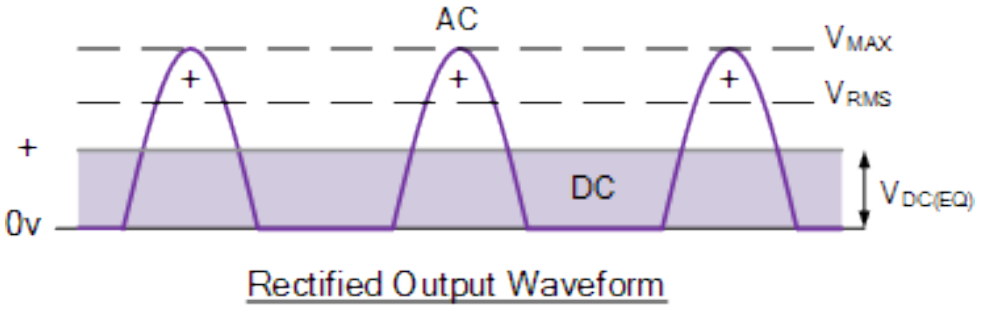
Since the DC load is resistive (resistor, R), the current flowing in the load resistor is therefore proportional to the voltage (**Ohm´s Law**), and the voltage across the load resistor will therefore be the same as the supply voltage, Vs (minus Vf), that is the "DC" voltage across the load is sinusoidal for the first half cycle only so Vout = Vs.

During each "negative" half cycle of the AC sinusoidal input waveform, the diode is *reverse biased* as the anode is negative with respect to the cathode. Therefore, NO current flows through the diode or circuit. Then in the negative half cycle of the supply, no current flows in the load resistor as no voltage appears across it so therefore, Vout = 0.

The current on the DC side of the circuit flows in one direction only making the circuit **Unidirectional**. As the load resistor receives from the diode a positive half of the waveform, zero volts, a positive half of the waveform, zero volts, etc, the value of this irregular

voltage would be equal in value to an equivalent DC voltage of 0.318 x Vmax of the input sinusoidal waveform or 0.45 x Vrms of the input sinusoidal waveform.

Then the equivalent DC voltage, V_{DC} across the load resistor is calculated as follows.



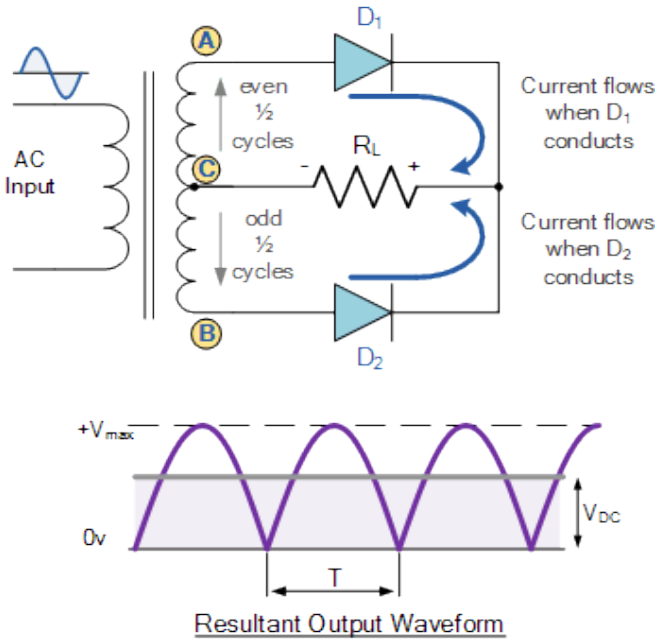
Rectified Output Waveform

Fig 1.10

$$V_{d.c.} = \frac{V_{max}}{\pi} = 0.318V_{max} = 0.45V_S$$

Where V_{max} is the maximum or peak voltage value of the AC sinusoidal supply, and V_S is the RMS (Root Mean Squared) value of the supply.

Full Wave Rectifier Circuit



Resultant Output Waveform

Fig 1.11

The full wave rectifier circuit consists of two *power diodes* connected to a single load resistance (R_L) with each diode taking it in turn to supply current to the load. When point A of the transformer is positive with respect to point C, diode D_1 conducts in the forward direction as indicated by the arrows.

When point B is positive (in the negative half of the cycle) with respect to point C, diode D_2 conducts in the forward direction and the current flowing through resistor R is in the same direction for both half-cycles. As the output voltage across the resistor R is the phasor sum of the two waveforms combined, this type of full wave rectifier circuit is also known as a "bi-phase" circuit.

Partsim Simulation Waveform

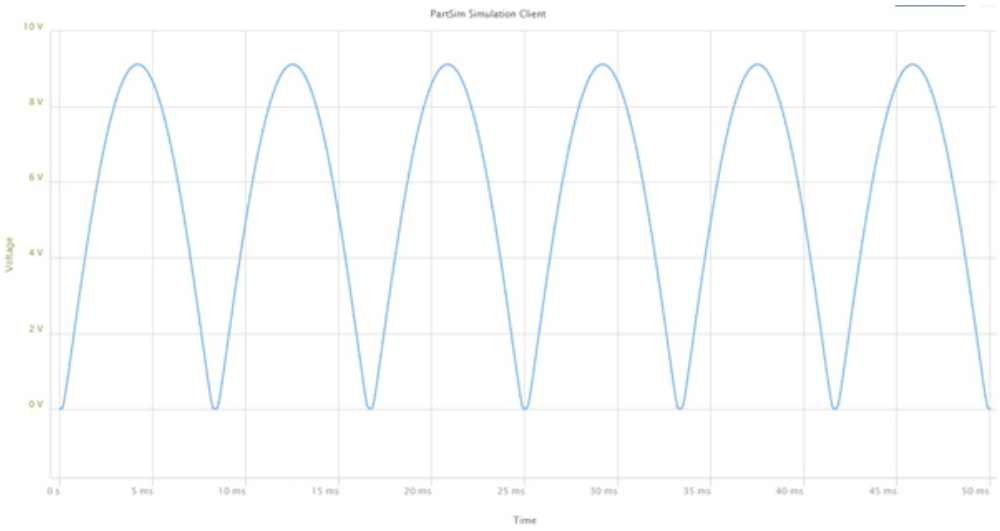


Fig 1.12

As the spaces between each half-wave developed by each diode is now being filled in by the other diode the average DC output voltage across the load resistor is now double that of the single half-wave rectifier circuit and is about $0.637V_{max}$ of the peak voltage, assuming no losses.

$$V_{d.c.} = \frac{2V_{\max}}{\pi} = 0.637V_{\max} = 0.9V_{RMS}$$

Where: V_{MAX} is the maximum peak value in one half of the secondary winding and V_{RMS} is the rms value.

The peak voltage of the output waveform is the same as before for the half-wave rectifier provided each half of the transformer windings have the same rms voltage value. To obtain a different DC voltage output different transformer ratios can be used.

The main disadvantage of this type of full wave rectifier circuit is that a larger transformer for a given power output is required with two separate but identical secondary windings making this type of full wave rectifying circuit costly compared to the "Full Wave Bridge Rectifier" circuit equivalent.

THE FULL WAVE BRIDGE RECTIFIER

Another type of circuit that produces the same output waveform as the full wave rectifier circuit above, is that of the **Full Wave Bridge Rectifier**. This type of single phase rectifier uses four individual rectifying diodes connected in a closed loop "bridge" configuration to produce the desired output.

The main advantage of this bridge circuit is that it does not require a special centre tapped transformer, thereby reducing its size and cost. The single secondary winding is connected to one side of the diode bridge network and the load to the other side as shown below.

THE DIODE BRIDGE RECTIFIER

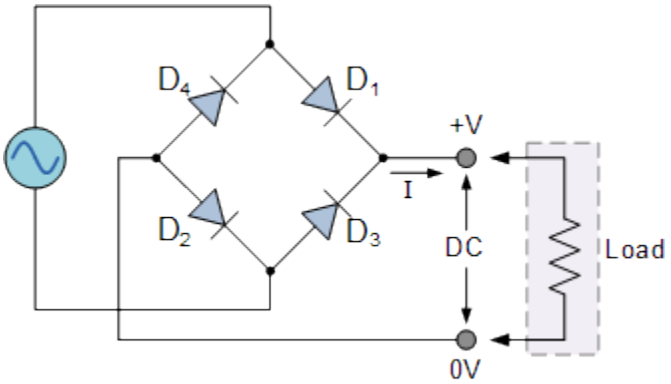


Fig 1.13

The four diodes labelled D_1 to D_4 are arranged in "series pairs" with only two diodes conducting current during each half cycle. During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodesD3 and D4 are reverse biased and the current flows through the load as shown below.

The Positive Half-cycle

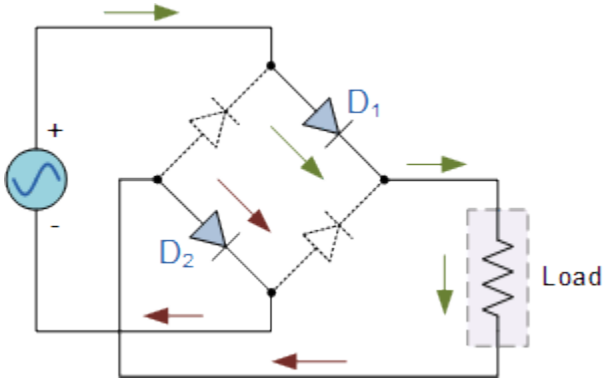


Fig 1.14

During the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 switch "OFF" as they are now reverse biased. The current flowing through the load is the same direction as before.

The Negative Half-cycle

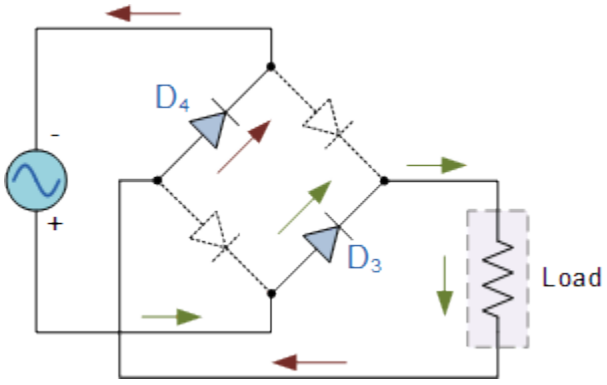


Fig 1.15

As the current flowing through the load is unidirectional, so the voltage developed across the load is also unidirectional the same as for the previous two diode full-wave rectifier, therefore the average DC voltage across the load is $0.637V_{max}$.

BRIDGE RECTIFIER RIPPLE VOLTAGE

$$V_{(ripple)} = \frac{I_{(load)}}{f \times C}, \text{ Volts}$$

THE LIGHT EMITTING DIODE

Light Emitting Diodes or **LED´s**, are among the most widely used of all the different types of semiconductor diodes available today and are commonly used in TV's and colour displays.

They are the most visible type of diode, that emit a fairly narrow bandwidth of either visible light at different coloured wavelengths, invisible infra-red light for remote controls or laser type light when a forward current is passed through them.

The "**Light Emitting Diode**" or **LED** as it is more commonly called, is basically just a specialised type of diode as they have very similar electrical characteristics to a PN junction diode. This means that an LED will pass current in its forward direction but block the flow of current in the reverse direction.

Light emitting diodes are made from a very thin layer of fairly heavily doped semiconductor material and depending on the semiconductor material used and the amount of doping, when forward biased an LED will emit a coloured light at a particular spectral wavelength.

When the diode is forward biased, electrons from the semiconductors conduction band recombine with holes from the valence band releasing sufficient energy to produce photons which emit a monochromatic (single colour) of light. Because of this thin layer a reasonable number of these photons can leave the junction and radiate away producing a coloured light output.

Then we can say that when operated in a forward biased direction **Light Emitting Diodes** are semiconductor devices that convert electrical energy into light energy.

The construction of a Light Emitting Diode is very different from that of a normal signal diode. The PN junction of an LED is surrounded by a transparent, hard plastic epoxy resin hemispherical shaped shell or body which protects the LED from both vibration and shock.

LED junction does not actually emit that much light so the epoxy resin body is constructed in such a way that the photons of light emitted by the junction are reflected away from the surrounding substrate base to which the diode is attached and are focused upwards through the domed top of the LED, which itself acts like a lens concentrating the amount of light. This is why the emitted light appears to be brightest at the top of the LED.

However, not all LEDs are made with a hemispherical shaped dome for their epoxy shell. Some indication LEDs have a rectangular or cylindrical shaped construction that has a flat surface on top or their body is shaped into a bar or arrow. Generally, all LED's are manufactured with two legs protruding from the bottom of the body.

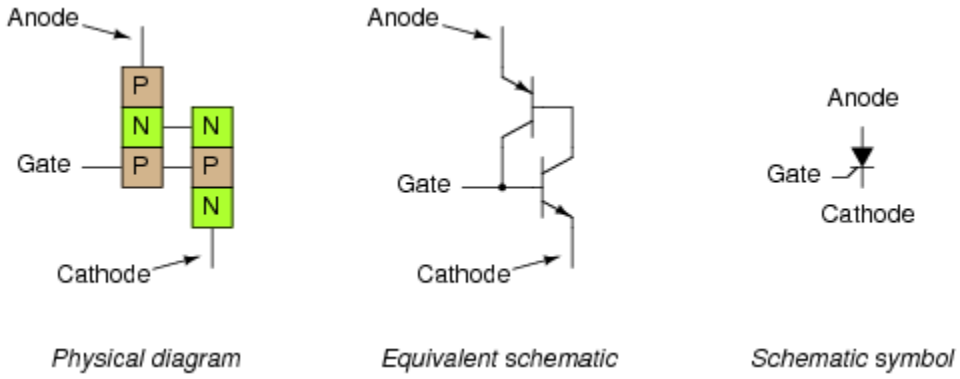
Also, nearly all modern light emitting diodes have their cathode, (–) terminal identified by either a notch or flat spot on the body or by the cathode lead being shorter than the other as the anode (+) lead is longer than the cathode (k).

Unlike normal incandescent lamps and bulbs which generate large amounts of heat when illuminated, the light emitting diode produces a "cold" generation of light which leads to high efficiencies than the normal "light bulb" because most of the generated energy radiates away within the visible spectrum. Because LEDs are solid-state devices, they can be extremely small and durable and provide much longer lamp life than normal light sources.

SILICON CONTROLLED RECTIFIER (SCR)

Silicon Controlled Rectifier (SCR) is a unidirectional semiconductor device made of silicon which can be used to provide a selected power to the load by switching it ON for variable amount of time. These devices are solid-state equivalent of thyratrons and are hence referred to as thyristors or thyrode transistors. In fact, SCR is a trade name of General Electric (GE) to the thyristor. Basically **SCR** is a three terminal, four-layer (hence of three junctions J1, J2 and J3) semiconductor device consisting of alternate layers of p- and n-type material doping. Figure 1a shows the SCR with the layers pnpn which has the terminals Anode (A), Cathode (K) and the

Gate (G). Further it is to be noted that the Gate terminal will generally be the p-layer nearer to the Cathode terminal. The symbol of the SCR used in case of circuit diagrams is shown in Figure



These SCRs can be considered equivalent to two inter-connected transistors as shown by the Figure. Here it is seen that a single **SCR** is equal to a combination of pnp (Q_1) and npn (Q_2) transistors where the emitter of Q_1 will act as the anode terminal of the SCR while the emitter of Q_2 will be its cathode. Further, the base of Q_1 is connected to the collector of Q_2 and the collector of Q_1 is shorted with the base of Q_2 to result in the gate terminal of the SCR.

KARAPAGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE-21

POSSIBLE QUESTIONS

UNIT- I

EIGHT MARK QUESTIONS:

1. What is pn junction ? Explain the formation of potential barrier in a pn junction.
2. Discuss the behaviour of pn junction under forward and reverse biasing.
3. Draw and explain the V-I charactersitics of pn junction diode.
4. Explain the working of fullwave rectifier and calculate rectification efficiency and ripple factor
5. Discuss the working principle of Bridge Rectifiers with the help of a neat diagram.
6. Explain working principle and structure of LED
7. Explain working principle and structure of SCR
8. Explain the working of centertap fullwave rectifier and calculate rectification efficiency and ripple factor
9. Explain the working of Half wave rectifier and calculate rectification efficiency and ripple factor

KARPAGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE-21

DEPARTMENT OF PHYSICS

III B.SC PHYSICS **BATCH: 2015-2019**

BASIC ELECTRONICS (15PHU504)

MULTIPLE CHOICE QUESTIONS

Questions	opt1	opt2	opt3	opt4	Answer
UNIT I					
A zener diode has ……..	one pn junction	two pn junctions	three pn junctions	four junction	one pn junction
A zener diode is used as …….	an amplifier	a voltage regulator	a rectifier	a multivibrator	voltage regulator
The doping level in a zener diode is …… that of a crystal diode	the same as	less than	more than	equal	more than
A zener diode is always …… connected	reverse	forward	both forward and reverse	opposite	reverse
In the breakdown region, a zener didoe behaves like a …… source.	constant voltage	constant current	constant resistance	variable voltage	constant voltage
A zener diode is destroyed if it……..	is forward biased	is reverse biased	carrier more than rated current	carrier is less than rated current	carrier more than rated current
A zener diode is ……. device	a non-linear	a linear	an amplifying	unilateral	a non-linear
What circuit activity may shift a characteristic curve so that diode operating points are different?	higher power (heat)	higher resistance	lower current	lower voltage	higher resistance
The diode _____.	is the simplest of conductor devices	has characteristics that closely match those of a oscillator	is a two-terminal device	lower current device	is a two-terminal device
What does a high resistance reading in both forward- and reverse-bias directions indicate?	A good diode	An open diode	A shorted diode	A defective ohmmeter	An open diode
Which capacitance dominates in the reverse-bias region?	depletion	conversion	Ω 40 Diffusion	Ω coupling	depletion
What is the state of an ideal diode in the region of nonconduction?	An open circuit	A short circuit	Unpredictable	Undefined	An open circuit
How many orbiting electrons does the germanium atom have?	4	12	32	45	32
How many terminals does a diode have?	2	3	4	6	2
What unit is used to represent the level of a diode forward current I_F?	A	mA	v	mV	mA
The diffused impurities with _____ valence electrons are called donor atoms.	4	3	5	0	5
Which of the following devices can check the condition of a semiconductor diode?	Digital display meter (DDM)	Multimeter	galvanometer	DDM and Multimeter	DDM and Multimeter

Which of the following is an atom composed of?	Electrons	neutinos	Neutrons	electrons ,neutron , protons	electrons ,neutron , protons
How many valence electrons does a silicon atom have?	1	2	3	4	4
What is the resistor value of an ideal diode in the region of conduction?	0 ohm	5 k ohm	15 Kohm	9 K ohm	0 0hm
Which of the following elements is most frequently used for doping pure Ge or Si?	Boron	Gallium	Indium	boron,indium and galium	boron,indium and galium
Which of the following ratings is true?	Si diodes have higher PIV and narrower temperature ranges than Ge diodes.	Si diodes have higher PIV and wider temperature ranges than Ge diodes	Si diodes have lower PIV and narrower temperature ranges than Ge diodes.	Si diodes have lower PIV and wider temperature ranges than Ge diodes.	Si diodes have higher PIV and wider temperature ranges than Ge diodes
The ideal diode is a(n) _____ circuit in the region of nonconduction.	open	closed	neutal	virtual	open
Which capacitance dominates in the forward-bias region?	Diffusion	Transition	Depletion	absorption	Diffusion
In what state is a silicon diode if the voltage drop across it is about 0.7 V?	No bias	Forward bias	Reverse bias	Zener region	Forward bias
A semiconductor has …… temperature coefficient of resistance.	Positive	Zero	Negative	no polarity	Negative
The most commonly used semiconductor is ……..	silicon	Bermanium	carbon	copper	silicon
When a pentavalent impurity is added to a pure semiconductor, it becomes ……	An insulator	An intrinsic semiconductor	p-type semiconductor	n-type semiconductor	n-type semiconductor
Addition of pentavalent impurity to a semiconductor creates many ……..	Free electrons	Holes	Valence electrons	Bound electrons	Free electrons
. A pentavalent impurity has ……. Valence electrons	3	2	5	4	5
An n-type semiconductor is ……	Positively charged	Negatively charged	. Electrically neutral	no polarity	Negatively charged
A trivalent impurity has ….. valence electrons	3	4	5	6	3
Addition of trivalent impurity to a semiconductor creates many ……..	Free electrons	Holes	Valence electrons	Bound electrons	Holes
A hole in a semiconductor is defined as	A free electron	The incomplete part of an electron pair bond	A free proton	A free neutron	The incomplete part of an electron pair bond
In a semiconductor, current conduction is due to ……..	Only holes	Only free electrons	Holes and free electrons	ions	Holes and free electrons
The battery connections required to forward bias a pn junction are	positive terminal to p and –ve terminal to n	-ve terminal to p and +ve terminal to n	-ve terminal to p and –ve terminal to n	positive teminal to positive	+ve terminal to p and –ve terminal to n
In the depletion region of a pn junction, there is a shortage of ……..	Acceptor ions	Holes and electrons	Donor ions	electrons ,neutron , protons	. Holes and electrons

A pn junction acts as a …….	Controlled switch	Bidirectional switch	Unidirectional switch	oscillator	Unidirectional switch
A crystal diode has ……	one pn junction	two pn junctions	three pn junctions	four junction	one pn junction
A crystal diode has forward resistance of	kΩ	Ω	MΩ	KV	Ω
If the arrow of crystal diode symbol is positive w.r.t. bar, then diode is …….. Biased	forward	reverse	opposite	rotating	forward
The reverse current in a diode is of the order	kA	mA	μA	A	μA
The forward voltage drop across a silicon diode is about ……	2.5 V	3 V	10 V	0.7 V	0.7 V
A crystal diode is used as ……	an amplifier	a rectifier	an oscillator	a voltage regulator	a rectifier
The d.c. resistance of a crystal diode is …….. its a.c. resistance	the same as	more than	less than	equal	less than
An ideal crystal diode is one which behaves as a perfect …….. when forward biased	conductor	insulator	resistance material	inductor	conductor
The ratio of reverse resistance and forward resistance of a germanium crystal d	1 : 1	100 : 1	1000 : 1	40,000 : 1	40,000 : 1
The leakage current in a crystal diode is due to …….	. minority carriers	majority carriers	junction capacitance	ions	minority carriers
If the temperature of a crystal diode increases, then leakage current ……..	remains the same	decreases	increases	becomes zero	increases
The PIV rating of a crystal diode is ……..	the same as	lower than	more than	equal	lower than
. If the doping level of a crystal diode is increased, the breakdown voltage…….	remains the same	is increased	is decreased	equal	is decreased
The knee voltage of a crystal diode is approximately	applied voltage	breakdown voltage	forward voltage	barrier potential	barrier potential
When the graph between current through and voltage across a device is a straight line, the device is referred to as …….	linear	. active	nonlinear	passive	linear
When the crystal current diode current is large, the bias is ……	forward	inverse	poor	reverse	forward
A crystal diode is a …… device	non-linear	bilateral	linear	unilateral	non-linear
A crystal diode utilises ……..	reverse	forward	forward or reverse	opposite	forward
If the doping level in a crystal diode is increased, the width of depletion layer……..	remains the same	is decreased	is increased	equal	in increased
In a semiconductor diode, the depletion region is removed when:	the diode is in its forward conducting state	the diode is in its reverse non-conducting state	there is no potential difference between the anode and cathode	diode is nonconducting	the diode is in its forward conducting state
The forward threshold voltage for a germanium diode is about:	0.2 V	0.4 V	0.6 V	,8V	0.2V

The term 'covalent bonding' refers to:	the introduction of an impurity	the sharing of valence electrons	the generation of surplus electrons	recombination	the sharing of valence electrons
Why is heat produced in a diode?	due to the power rating of the diode	due to voltage across the diode	due to the PN junction of the diode	due to current passing through the diode	due to current passing through the diode

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TRANSISTORS

Transistors-Bipolar junction transistors-Mechanism of amplification in a transistor-Common base, common emitter and common collector configurations and their characteristics-Active, saturation and Cut-off regions-Current gain α , β , γ and their relationships-Experiment to draw the characteristics of transistor in the CB and CE modes-Leakage currents-Expressions for output currents in the three modes-Transistor as a switch,FET,MOSFET,UJT.

TRANSISTOR

Transistor is a semiconductor device that can both conduct and insulate. A transistor can act as a switch and an amplifier. It converts audio waves into electronic waves and resistor, controlling electronic current. Transistors have very long life, smaller in size, can operate on lower voltage supplies for greater safety and required no filament current. The first transistor was fabricated with germanium. A transistor performs the same function as a vacuum tube triode, but using semiconductor junctions instead of heated electrodes in a vacuum chamber. It is the fundamental building block of modern electronic devices and found everywhere in modern electronic systems.

Transistors are three terminal active devices made from different semiconductor materials that can act as either an insulator or a conductor by the application of a small signal voltage. The transistor's ability to change between these two states enables it to have two basic functions: "switching" (digital electronics) or "amplification" (analogue electronics). Then bipolar transistors have the ability to operate within three different regions:

- Active Region – the transistor operates as an amplifier and$Ic = \beta.Ib$
- Saturation – the transistor is "Fully-ON" operating as a switch and Ic = I(saturation)
- Cut-off – the transistor is "Fully-OFF" operating as a switch and Ic = 0

TRANSISTOR BASICS:

A transistor is a three terminal device. Namely,

- Base: This is responsible for activating the transistor.
- Collector: This is the positive lead.
- Emitter: This is the negative lead.

The basic idea behind a transistor is that it lets you control the flow of current through one channel by varying the intensity of a much smaller current that's flowing through a second channel.

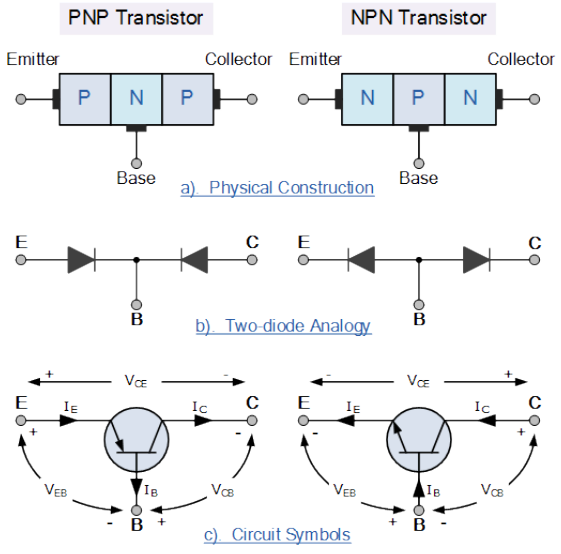
BIPOLAR JUNCTION TRANSISTOR:

A Bipolar Junction Transistor (BJT) has three terminals connected to three doped semiconductor regions. It comes with two types, P-N-P and N-P-N.

P-N-P transistor consists of a layer of N-doped semiconductor material between two layers of P-doped material. The base current entering in the collector is amplified at its output.That is when PNP transistor is ON when its base is pulled low relative to the emitter. The arrows of PNP transistor symbol the direction of current flow when the device is in forward active mode.

N-P-N transistor consists of a layer of P-doped semiconductor between two layers of N-doped material. By amplifying current the base we get the high collector and emitter current. That is when NPN transistor is ON when its base is pulled low relative to the emitter. When the transistor is in ON state, current flow is in between the collector and emitter of the transistor. Based on minority carriers present in P-type region the electrons moving from emitter to collector. It allows the greater current and faster operation; because of this reason most bipolar transistors used today are NPN.

BIPOLAR TRANSISTOR CONSTRUCTION



The construction and circuit symbols for both the PNP and NPN bipolar transistor are given above with the arrow in the circuit symbol always showing the direction of "conventional current flow" between the base terminal and its emitter terminal. The direction of the arrow always points from the positive P-type region to the negative N-type region for both transistor types, exactly the same as for the standard diode symbol.

BIPOLAR TRANSISTOR CONFIGURATIONS

As the **Bipolar Transistor** is a three terminal device, there are basically three possible ways to connect it within an electronic circuit with one terminal being common to both the input and output. Each method of connection responding differently to its input signal within a circuit as the static characteristics of the transistor vary with each circuit arrangement.

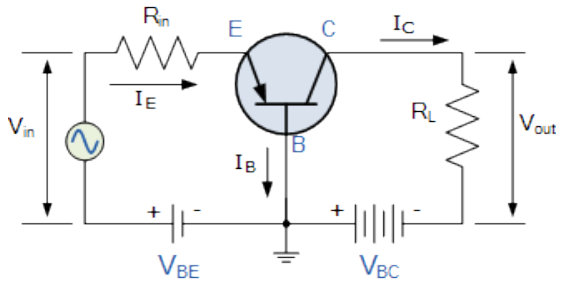
- Common Base Configuration – has Voltage Gain but no Current Gain.
- Common Emitter Configuration – has both Current and Voltage Gain.
- Common Collector Configuration – has Current Gain but no Voltage Gain.

THE COMMON BASE (CB) CONFIGURATION

As its name suggests, in the **Common Base** or grounded base configuration, the BASE connection is common to both the input signal AND the output signal. The input signal is applied between the transistors base and the emitter terminals, while the corresponding output signal is taken from between the base and the collector terminals as shown. The base terminal is grounded or can be connected to some fixed reference voltage point.

The input current flowing into the emitter is quite large as its the sum of both the base current and collector current respectively therefore, the collector current output is less than the emitter current input resulting in a current gain for this type of circuit of "1" (unity) or less, in other words the common base configuration "attenuates" the input signal.

THE COMMON BASE TRANSISTOR CIRCUIT



This type of amplifier configuration is a non-inverting voltage amplifier circuit, in that the signal voltages Vin and Vout are "in-phase". This type of transistor arrangement is not very common due to its unusually high voltage gain characteristics. Its input characteristics represent that of a forward biased diode while the output characteristics represent that of an illuminated photo-diode.

Also this type of bipolar transistor configuration has a high ratio of output to input resistance or more importantly "load" resistance (RL) to "input" resistance (Rin) giving it a value of "Resistance Gain". Then the voltage gain (Av) for a common base configuration is therefore given as:

COMMON BASE VOLTAGE GAIN

$$A_V = \frac{Vout}{Vin} = \frac{I_C \times R_L}{I_E \times R_{IN}}$$

Where: I_c/I_e is the current gain, alpha (α) and R_L/R_{in} is the resistance gain.

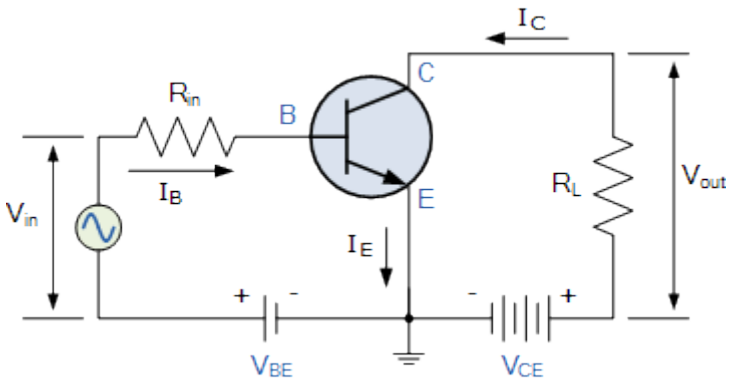
The common base circuit is generally only used in single stage amplifier circuits such as microphone pre-amplifier or radio frequency (Rf) amplifiers due to its very good high frequency response.

THE COMMON EMITTER (CE) CONFIGURATION

In the **Common Emitter** or grounded emitter configuration, the input signal is applied between the base and the emitter, while the output is taken from between the collector and the emitter as shown. This type of configuration is the most commonly used circuit for transistor based amplifiers and which represents the "normal" method of bipolar transistor connection.

The common emitter amplifier configuration produces the highest current and power gain of all the three bipolar transistor configurations. This is mainly because the input impedance is LOW as it is connected to a forward biased PN-junction, while the output impedance is HIGH as it is taken from a reverse biased PN-junction.

THE COMMON EMITTER AMPLIFIER CIRCUIT



In this type of configuration, the current flowing out of the transistor must be equal to the currents flowing into the transistor as the emitter current is given as Ie = Ic + Ib.

As the load resistance (RL) is connected in series with the collector, the current gain of the common emitter transistor configuration is quite large as it is the ratio of Ic/Ib. A transistors current gain is given the Greek symbol of Beta, (β).

As the emitter current for a common emitter configuration is defined asIe = Ic + Ib, the ratio of Ic/Ie is called Alpha, given the Greek symbol of α. Note: that the value of Alpha will always be less than unity.

Since the electrical relationship between these three currents, Ib, Ic and Ieis determined by the physical construction of the transistor itself, any small change in the base current (Ib), will result in a much larger change in the collector current (Ic).

Then, small changes in current flowing in the base will thus control the current in the emitter-collector circuit. Typically, Beta has a value between 20 and 200 for most general purpose transistors. So if a transistor has a Beta value of say 100, then one electron will flow from the base terminal for every 100 electrons flowing between the emitter-collector terminal.

By combining the expressions for both Alpha, α and Beta, β the mathematical relationship between these parameters and therefore the current gain of the transistor can be given as:

$$\text{Alpha},(\alpha) = \frac{I_C}{I_E} \quad \text{and} \quad \text{Beta},(\beta) = \frac{I_C}{I_B}$$

$$\therefore I_C = \alpha . I_E = \beta . I_B$$

$$\text{as: } \alpha = \frac{\beta}{\beta + 1} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

$$I_E = I_C + I_B$$

Where: “Ic” is the current flowing into the collector terminal, “Ib” is the current flowing into the base terminal and “Ie” is the current flowing out of the emitter terminal.

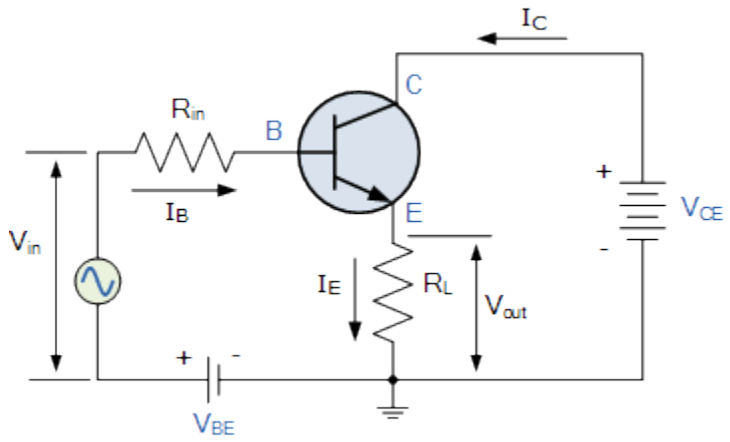
This type of bipolar transistor configuration has a greater input impedance, current and power gain than that of the common base configuration but its voltage gain is much lower. The common emitter configuration is an inverting amplifier circuit. This means that the resulting output signal is 180º “out-of-phase” with the input voltage signal.

THE COMMON COLLECTOR (CC) CONFIGURATION

In the **Common Collector** or grounded collector configuration, the collector is now common through the supply. The input signal is connected directly to the base, while the output is taken from the emitter load as shown. This type of configuration is commonly known as a**Voltage Follower** or **Emitter Follower** circuit.

The common collector, or emitter follower configuration is very useful for impedance matching applications because of the very high input impedance, in the region of hundreds of thousands of Ohms while having a relatively low output impedance.

THE COMMON COLLECTOR TRANSISTOR CIRCUIT



The common emitter configuration has a current gain approximately equal to the β value of the transistor itself. In the common collector configuration the load resistance is situated in series with the emitter so its current is equal to that of the emitter current.

As the emitter current is the combination of the collector AND the base current combined, the load resistance in this type of transistor configuration also has both the collector current and the input current of the base flowing through it. Then the current gain of the circuit is given as:

THE COMMON COLLECTOR CURRENT GAIN

$$I_E = I_C + I_B$$

$$A_i = \frac{I_E}{I_B} = \frac{I_C + I_B}{I_B}$$

$$A_i = \frac{I_C}{I_B} + 1$$

$$A_i = \beta + 1$$

This type of bipolar transistor configuration is a non-inverting circuit in that the signal voltages of Vin and Vout are “in-phase”. It has a voltage gain that is always less than “1” (unity). The load resistance of the common collector transistor receives both the base and collector

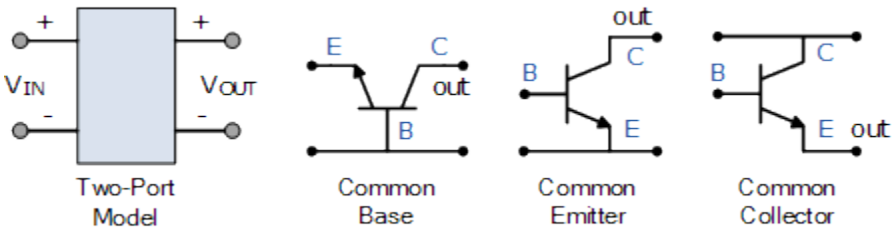
currents giving a large current gain (as with the common emitter configuration) therefore, providing good current amplification with very little voltage gain.

We can now summarize the various relationships between the transistors individual DC currents flowing through each leg and its DC current gains given above in the following table.

RELATIONSHIP BETWEEN DC CURRENTS AND GAINS

$I_E = I_B + I_C$ $I_C = I_E - I_B$ $I_B = I_E - I_C$	$\alpha = \frac{I_C}{I_E} = \frac{\beta}{1+\beta}$ $\beta = \frac{I_C}{I_B} = \frac{\alpha}{1-\alpha}$
$I_B = \frac{I_C}{\beta} = \frac{I_E}{1+\beta} = I_E(1-\alpha)$	
$I_C = \beta . I_B = \alpha . I_E$	$I_E = \frac{I_C}{\alpha} = I_B(1+\beta)$

BIPOLAR TRANSISTOR CONFIGURATIONS



The generalized characteristics of the different transistor configurations given in the following table:

Characteristic	Common Base	Common Emitter	Common Collector
Input Impedance	Low	Medium	High
Output Impedance	Very High	High	Low
Phase Angle	0^o	180^o	0^o
Voltage Gain	High	Medium	Low
Current Gain	Low	Medium	High
Power Gain	Low	Very High	Medium

TRANSISTOR CHARACTERISTICS:

Transistor Characteristics are the plots which represent the relationships between the current and the voltages of a transistor in a particular configuration. By considering the transistor configuration circuits to be analogous to two-port networks, they can be analyzed using the characteristic-curves which can be of the following types

Input Characteristics: These describe the changes in input current with the variation in the values of input voltage keeping the output voltage constant.

Output Characteristics: This is a plot of output current versus output voltage with constant input current.

Current Transfer Characteristics: This characteristic curve shows the variation of output current in accordance with the input current, keeping output voltage constant.

COMMON BASE (CB) CONFIGURATION OF TRANSISTOR

In CB Configuration, the base terminal of the transistor will be common between the input and the output terminals as shown by Figure 1. This configuration offers low input impedance, high output impedance, high resistance gain and high voltage gain.

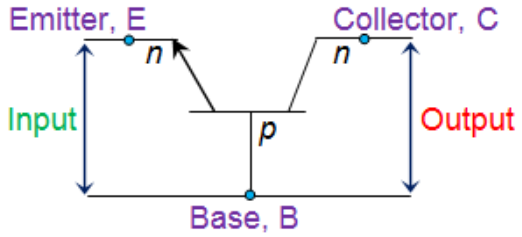


Figure 1 Common Base (CB) Configuration

Input Characteristics for CB Configuration of Transistor

Figure 2 shows the input characteristics of a CB configuration circuit which describes the variation of emitter current, IE with Base-Emitter voltage, VBEkeeping Collector-Base voltage, VCB constant.

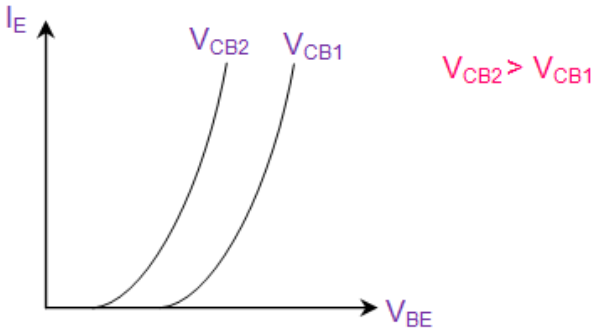


Figure 2 Input Characteristics for CB Configuration

This leads to the expression for the input resistance as

$$R_{in} = \left.\frac{\Delta V_{BE}}{\Delta I_E}\right|_{V_{CB}=constant}$$

OUTPUT CHARACTERISTICS FOR CB CONFIGURATION OF TRANSISTOR

The output characteristics of CB configuration (Figure 3) show the variation of collector current, IC with VCB when the emitter current, IE is held constant. From the graph shown, the output resistance can be obtained as

$$R_{out} = \left.\frac{\Delta V_{CB}}{\Delta I_C}\right|_{I_E=constant}$$

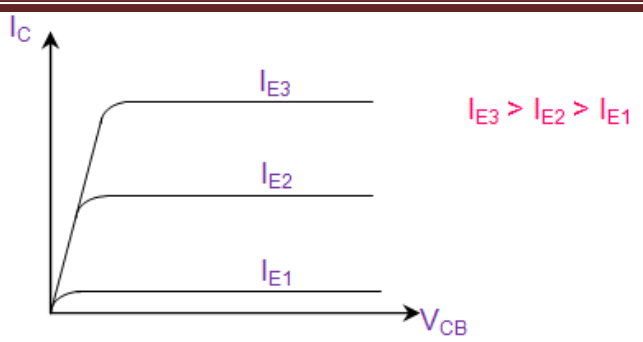


Figure 3 Output Characteristics for CB Configuration

CURRENT TRANSFER CHARACTERISTICS FOR CB CONFIGURATION OF TRANSISTOR

Figure 4 shows the current transfer characteristics for CB configuration which illustrates the variation of IC with the IE keeping VCB as a constant. The resulting current gain has a value less than 1 and can be mathematically expressed as

$$\alpha = \frac{\Delta I_C}{\Delta I_E}\Big|_{V_{CB}=constant}$$

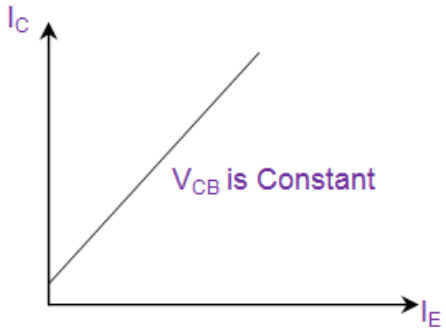


Figure 4 Current Transfer Characteristics for CB Configuration

COMMON COLLECTOR (CC) CONFIGURATION OF TRANSISTOR

This transistor configuration has the collector terminal of the transistor common between the input and the output terminals (Figure 5) and is also referred to as emitter follower configuration. This offers high input impedance, low output impedance, voltage gain less than one and a large current gain.

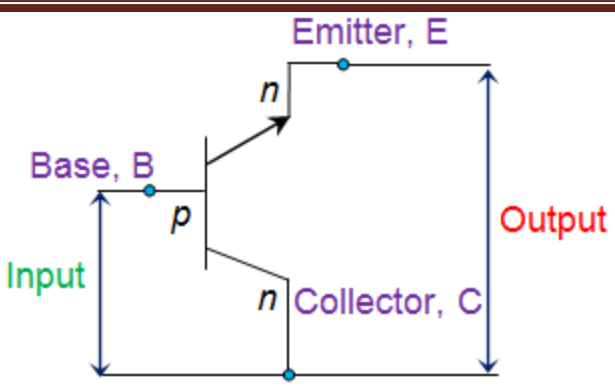


Figure 5 Common Collector (CC) Configuration

INPUT CHARACTERISTICS FOR CC CONFIGURATION OF TRANSISTOR

Figure 6 shows the input characteristics for CC configuration which describes the variation in IB in accordance with VCB, for a constant value of Collector-Emitter voltage, V_{CE}.

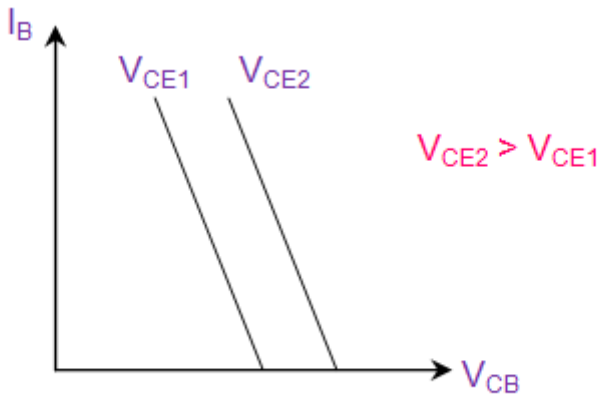


Figure 6 Input Characteristics for CC Configuration

OUTPUT CHARACTERISTICS FOR CC CONFIGURATION OF TRANSISTOR

Figure 7 shows the output characteristics for the CC configuration which exhibit the variations in IE against the changes in V_{CE} for constant values of I_B.

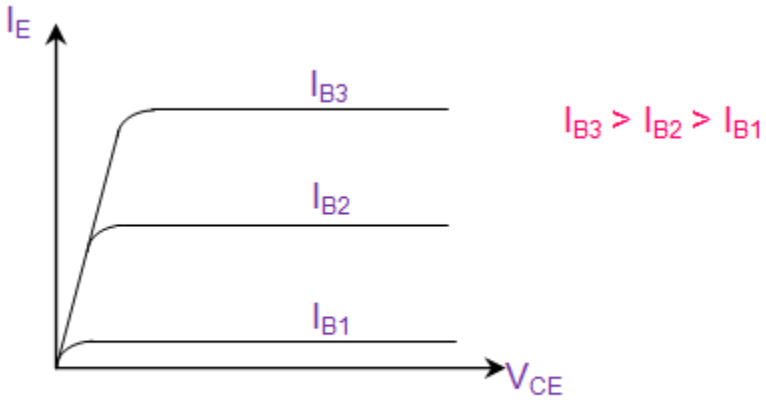


Figure 7 Output Characteristics for CC Configuration

CURRENT TRANSFER CHARACTERISTICS FOR CC CONFIGURATION OF TRANSISTOR

This characteristic of CC configuration (Figure 8) shows the variation of I_E with I_B keeping V_{CE} as a constant.

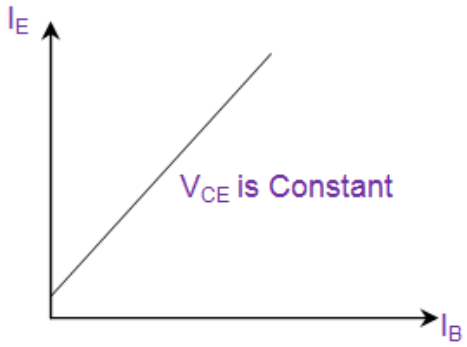


Figure 8 Current Transfer Characteristics for CC Configuration

COMMON EMITTER (CE) CONFIGURATION OF TRANSISTOR

In this configuration, the emitter terminal is common between the input and the output terminals as shown by Figure 9. This configuration offers medium input impedance, medium output impedance, medium current gain and voltage gain.

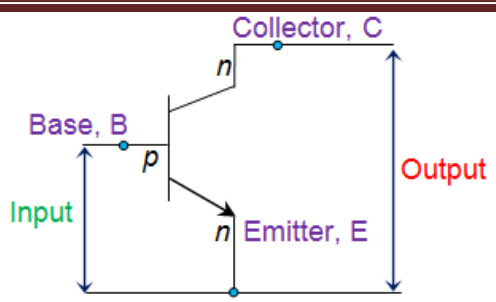


Figure 9 Common Emitter (CE) Configuration

INPUT CHARACTERISTICS FOR CE CONFIGURATION OF TRANSISTOR

Figure 10 shows the input characteristics for the CE configuration of transistor which illustrates the variation in I_B in accordance with V_{BE} when V_{CE} is kept constant.

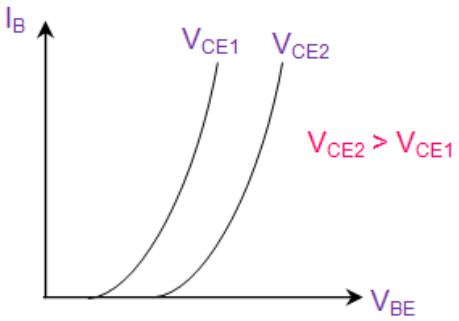


Figure 10 Input Characteristics for CE Configuration

From the graph shown, the input resistance of the transistor can be obtained as

$$R_{in} = \left.\frac{\Delta V_{BE}}{\Delta I_B}\right|_{V_{CE}=constant}$$

OUTPUT CHARACTERISTICS FOR CE CONFIGURATION OF TRANSISTOR

The output characteristics of CE configuration (Figure 11) are also referred to as collector characteristics. This plot shows the variation in I_C with the changes in V_{CE} when I_B is held constant. From the graph shown, the output resistance can be obtained as

$$R_{out} = \left.\frac{\Delta V_{CE}}{\Delta I_C}\right|_{I_B=constant}$$

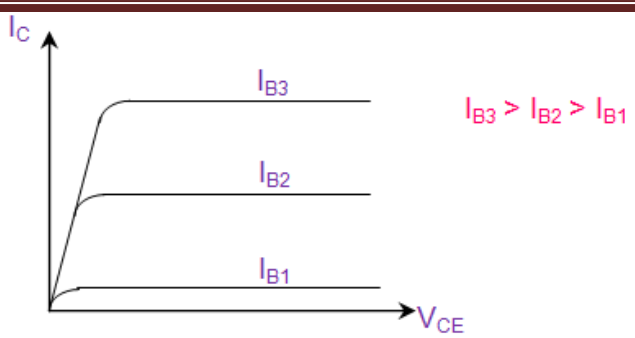


Figure 11 Output Characteristics for CE Configuration

CURRENT TRANSFER CHARACTERISTICS FOR CE CONFIGURATION OF TRANSISTOR

This characteristic of CE configuration shows the variation of IC with IB keeping VCEas a constant. This can be mathematically given by

$$\beta = \frac{\Delta I_C}{\Delta I_B}\Big|_{V_{CE}=constant}$$

This ratio is referred to as common-emitter current gain and is always greater than 1.

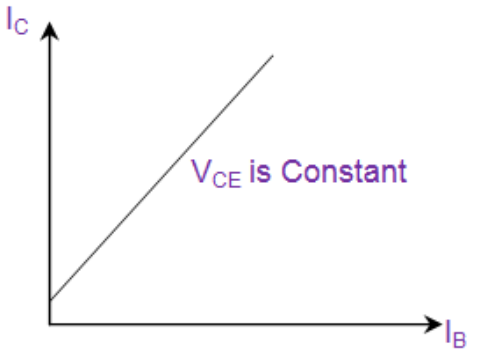


Figure 12 Transfer Characteristics for CE Configuration

Lastly, it is to be noted that although the characteristic curves explained are for BJTs, similar analysis holds good even in the case of FETs.

TRANSISTOR AS A SWITCH

When used as an AC signal amplifier, the transistors Base biasing voltage is applied in such a way that it always operates within its "active" region, that is the linear part of the output characteristics curves are used.

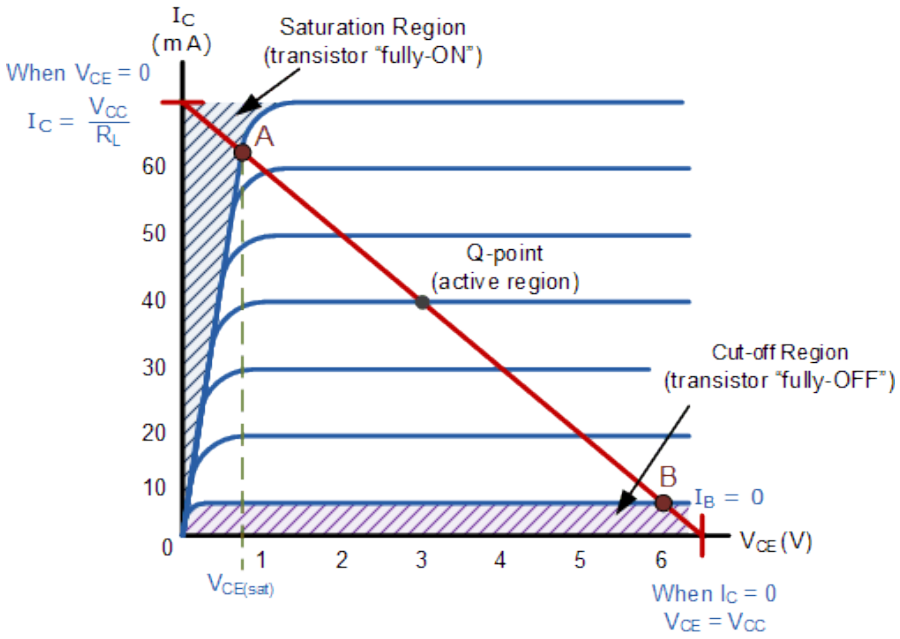
However, both the NPN & PNP type bipolar transistors can be made to operate as "ON/OFF" type solid state switch by biasing the transistors Base terminal differently to that for a signal amplifier.

Solid state switches are one of the main applications for the use of transistor to switch a DC output "ON" or "OFF". Some output devices, such as LED's only require a few milliamps at logic level DC voltages and can therefore be driven directly by the output of a logic gate. However, high power devices such as motors, solenoids or lamps, often require more power than that supplied by an ordinary logic gate so transistor switches are used.

If the circuit uses the **Bipolar Transistor as a Switch**, then the biasing of the transistor, either NPN or PNP is arranged to operate the transistor at both sides of the " I-V " characteristics curves we have seen previously.

The areas of operation for a transistor switch are known as the **Saturation Region** and the **Cut-off Region**. This means then that we can ignore the operating Q-point biasing and voltage divider circuitry required for amplification, and use the transistor as a switch by driving it back and forth between its "fully-OFF" (cut-off) and "fully-ON" (saturation) regions as shown below.

OPERATING REGIONS

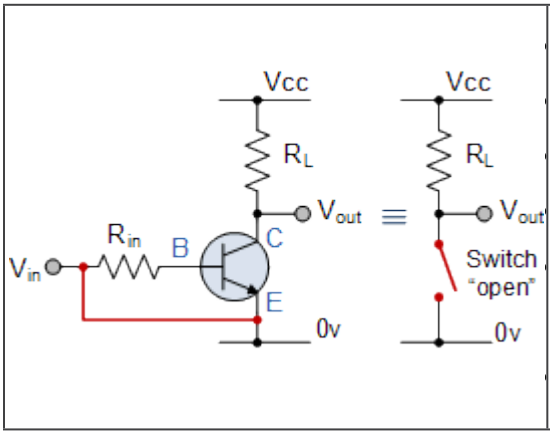


The pink shaded area at the bottom of the curves represents the "Cut-off" region while the blue area to the left represents the "Saturation" region of the transistor. Both these transistor regions are defined as:

1. CUT-OFF REGION

Here the operating conditions of the transistor are zero input base current (I_B), zero output collector current (I_C) and maximum collector voltage (V_{CE}) which results in a large depletion layer and no current flowing through the device. Therefore the transistor is switched "Fully-OFF".

CUT-OFF CHARACTERISTICS



- The input and Base are grounded (0v)
- Base-Emitter voltage $V_{BE} < 0.7v$
- Base-Emitter junction is reverse biased
- Base-Collector junction is reverse biased
- Transistor is "fully-OFF" (Cut-off region)
- No Collector current flows ($I_C = 0$)

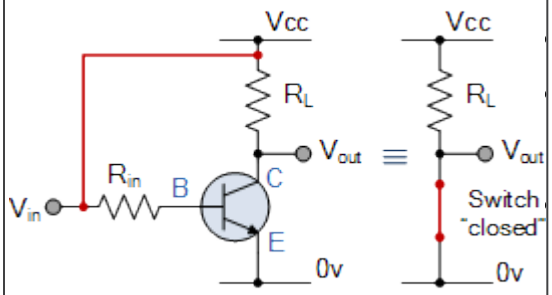
	• $V_{OUT} = V_{CE} = V_{CC} = "1"$ • Transistor operates as an "open switch"

Then we can define the "cut-off region" or "OFF mode" when using a bipolar transistor as a switch as being, both junctions reverse biased, $V_B < 0.7v$ and $I_C = 0$. For a PNP transistor, the Emitter potential must be negative with respect to the Base.

2. SATURATION REGION

Here the transistor will be biased so that the maximum amount of base current is applied, resulting in maximum collector current resulting in the minimum collector emitter voltage drop which results in the depletion layer being as small as possible and maximum current flowing through the transistor. Therefore the transistor is switched "Fully-ON".

SATURATION CHARACTERISTICS

	• The input and Base are connected to V_{CC} • Base-Emitter voltage $V_{BE} > 0.7v$ • Base-Emitter junction is forward biased • Base-Collector junction is forward biased • Transistor is "fully-ON" (saturation region) • Max Collector current flows ($I_C = Vcc/R_L$) • $V_{CE} = 0$ (ideal saturation) • $V_{OUT} = V_{CE} = "0"$ • Transistor operates as a "closed switch"

Then we can define the "saturation region" or "ON mode" when using a bipolar transistor as a switch as being, both junctions forward biased, $V_B > 0.7v$ and I_C = Maximum. For a PNP transistor, the Emitter potential must be positive with respect to the Base.

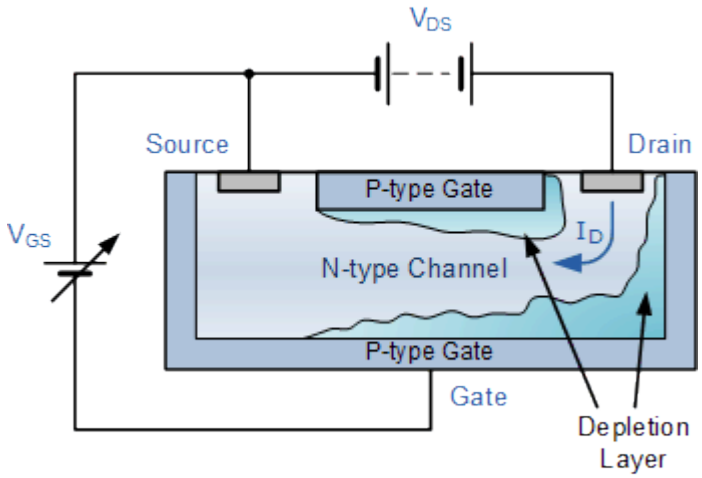
Then the transistor operates as a "single-pole single-throw" (SPST) solid state switch. With a zero signal applied to the Base of the transistor it turns "OFF" acting like an open switch and zero collector current flows. With a positive signal applied to the Base of the transistor it turns "ON" acting like a closed switch and maximum circuit current flows through the device.

The simplest way to switch moderate to high amounts of power is to use the transistor with an open-collector output and the transistors Emitter terminal connected directly to ground. When used in this way, the transistors open collector output can thus "sink" an externally supplied voltage to ground thereby controlling any connected load.

JUNCTION FIELD EFFECT TRANSISTOR

THE FIELD EFFECT TRANSISTOR

In the Bipolar Junction Transistor tutorials, we saw that the output Collector current of the transistor is proportional to input current flowing into the Base terminal of the device, thereby making the bipolar transistor a "CURRENT" operated device (Beta model) as a smaller current can be used to switch a larger load current.



The Field Effect Transistor, or simply FET however, uses the voltage that is applied to their input terminal, called the Gate to control the current flowing through them resulting in the output current being proportional to the input voltage. As their operation relies on an electric field (hence the name field effect) generated by the input Gate voltage, this then makes the Field Effect Transistor a "VOLTAGE" operated device.

The Field Effect Transistoris a three terminal unipolar semiconductor device that has very similar characteristics to those of their Bipolar Transistor counterparts ie, high efficiency, instant

operation, robust and cheap and can be used in most electronic circuit applications to replace their equivalent bipolar junction transistors (BJT) cousins.

THE JUNCTION FIELD EFFECT TRANSISTOR

We saw previously that a bipolar junction transistor is constructed using two PN-junctions in the main current carrying path between the Emitter and the Collector terminals. The **Junction Field Effect Transistor** (JUGFET or JFET) has no PN-junctions but instead has a narrow piece of high resistivity semiconductor material forming a "Channel" of either N-type or P-type silicon for the majority carriers to flow through with two ohmic electrical connections at either end commonly called the Drain and theSource respectively.

There are two basic configurations of junction field effect transistor, the N-channel JFET and the P-channel JFET. The N-channel JFET's channel is doped with donor impurities meaning that the flow of current through the channel is negative (hence the term N-channel) in the form of electrons.

Likewise, the P-channel JFET's channel is doped with acceptor impurities meaning that the flow of current through the channel is positive (hence the term P-channel) in the form of holes. N-channel JFET's have a greater channel conductivity (lower resistance) than their equivalent P-channel types, since electrons have a higher mobility through a conductor compared to holes. This makes the N-channel JFET's a more efficient conductor compared to their P-channel counterparts.

THE MOSFET

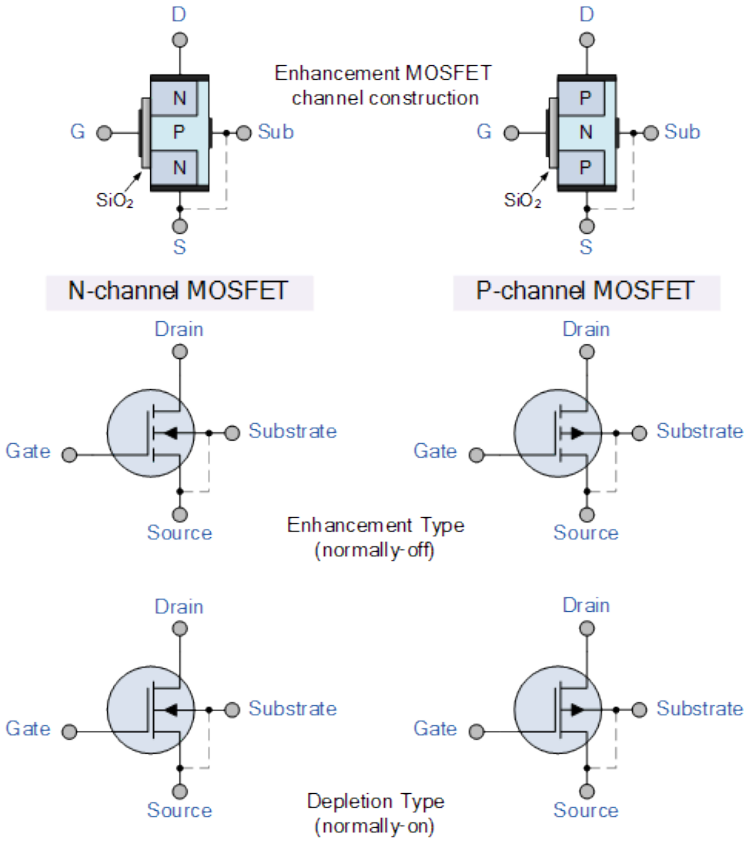
As well as the Junction Field Effect Transistor (JFET), there is another type of Field Effect Transistor available whose Gate input is electrically insulated from the main current carrying channel and is therefore called an **Insulated Gate Field Effect Transistor**.

MOSFETs are three terminal devices with aGate, Drain and Source and both P-channel (PMOS) and N-channel (NMOS) MOSFETs are available. The main difference this time is that **MOSFET**s are available in two basic forms:

- Depletion Type – the transistor requires the Gate-Source voltage, (V_{GS}) to switch the device "OFF". The depletion mode MOSFET is equivalent to a "Normally Closed" switch.

- Enhancement Type – the transistor requires a Gate-Source voltage, (V_{GS}) to switch the device "ON". The enhancement mode MOSFET is equivalent to a "Normally Open" switch.

The symbols and basic construction for both configurations of MOSFETs are shown below.



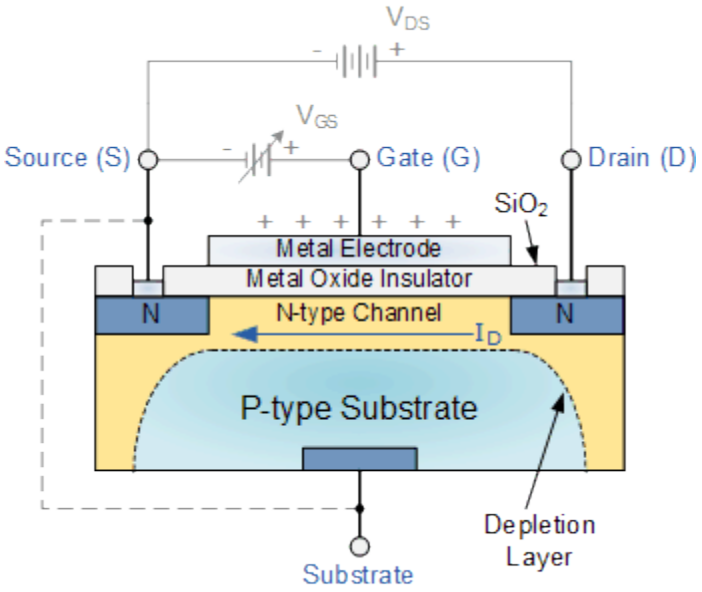
The four MOSFET symbols above show an additional terminal called theSubstrate and is not normally used as either an input or an output connection but instead it is used for grounding the substrate. It connects to the main semiconductive channel through a diode junction to the body or metal tab of the MOSFET.

Usually in discrete type MOSFETs, this substrate lead is connected internally to the source terminal. When this is the case, as in enhancement types it is omitted from the symbol for clarification.

The line between the drain and source connections represents the semiconductive channel. If this is a solid unbroken line then this represents a "Depletion" (normally-ON) type MOSFET as drain current can flow with zero gate potential. If the channel line is shown dotted

or broken it is an "Enhancement" (normally-OFF) type MOSFET as zero drain current flows with zero gate potential. The direction of the arrow indicates whether the conductive channel is a p-type or an n-type semiconductor device.

Basic MOSFET Structure and Symbol



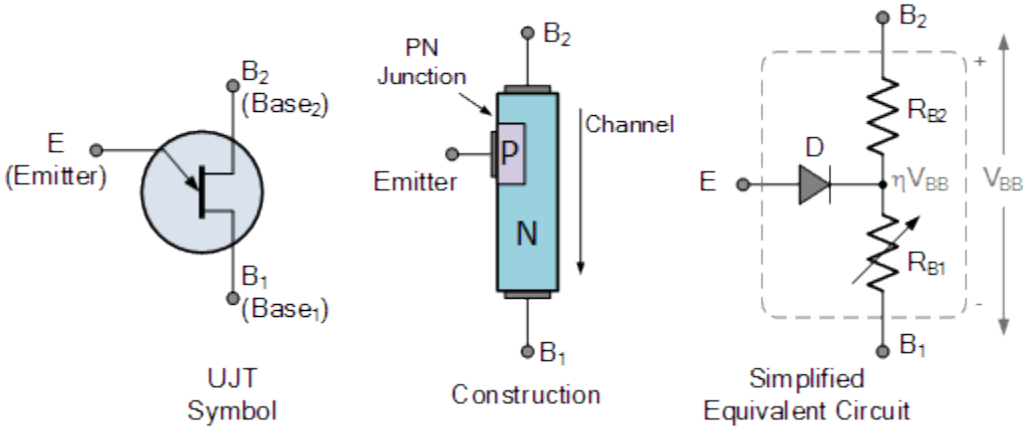
The construction of the Metal Oxide Semiconductor FET is very different to that of the Junction FET. Both the Depletion and Enhancement type MOSFETs use an electrical field produced by a gate voltage to alter the flow of charge carriers, electrons for n-channel or holes for P-channel, through the semiconductive drain-source channel. The gate electrode is placed on top of a very thin insulating layer and there are a pair of small n-type regions just under the drain and source electrodes.

We saw in the previous tutorial, that the gate of a junction field effect transistor, JFET must be biased in such a way as to reverse-bias the pn-junction. With a insulated gate MOSFET device no such limitations apply so it is possible to bias the gate of a MOSFET in either polarity, positive (+ve) or negative (-ve).

This makes the MOSFET device especially valuable as electronic switches or to make logic gates because with no bias they are normally non-conducting and this high gate input resistance means that very little or no control current is needed as MOSFETs are voltage controlled devices. Both the p-channel and the n-channel MOSFETs are available in two basic forms, the **Enhancement** type and the **Depletion** type.

UNIJUNCTION TRANSISTOR (UJT)

The **Uni-junction Transistor** or **UJT** for short is another solid state three terminal device that can be used in gate pulse, timing circuits and trigger generator applications to switch and control either thyristors and triacs for AC power control type applications.



Like diodes, unijunction transistors are constructed from separate P-type and N-type semiconductor materials forming a single (hence its name Uni-Junction) PN-junction within the main conducting N-type channel of the device.

Although the *Unijunction Transistor* has the name of a transistor, its switching characteristics are very different from those of a conventional bipolar or field effect transistor as it cannot be used to amplify a signal but instead is used as a ON-OFF switching transistor. UJT's have unidirectional conductivity and negative impedance characteristics acting more like a variable voltage divider during breakdown.

Like N-channel FET's, the UJT consists of a single solid piece of N-type semiconductor material forming the main current carrying channel with its two outer connections marked as *Base 2* (B_2) and *Base 1* (B_1). The third connection, confusingly marked as the *Emitter* (E) is located along the channel. The emitter terminal is represented by an arrow pointing from the P-type emitter to the N-type base.

The Emitter rectifying p-n junction of the unijunction transistor is formed by fusing the P-type material into the N-type silicon channel. However, P-channel UJT's with an N-type Emitter terminal are also available but these are little used.

The Emitter junction is positioned along the channel so that it is closer to terminal B_2 than B_1. An arrow is used in the UJT symbol which points towards the base indicating that the Emitter terminal is positive and the silicon bar is negative material.

KARAPAGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE-21

POSSIBLE QUESTIONS

UNIT- II

EIGHT MARK QUESTIONS:

1. .Explain in detail about n-p-n and p-n-p transistors
2. Derive the relations between α and β
3. Explain the input and output characteristics of CE configuration
4. Explain different configuration of transistor.
5. Explain working principle and structure of FET
6. Explain the working principle and charactersitcs of JFET
7. Explain the working principle and charactersitcs of MOSFET
8. Explain the working principle and charactersitcs of UJT.

KARPAGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE-21

DEPARTMENT OF PHYSICS

III B.SC PHYSICS **BATCH: 2015-2019**

BASIC ELECTRONICS (15PHU504)

MULTIPLE CHOICE QUESTIONS

Questions	opt1	opt2	opt3	opt4	Answer
UNIT II					
The most widely used rectifier is …….	half-wave rectifier	centre-tap full-wave rectifier	bridge full-wave rectifier	filter	bridge full-wave rectifier
If the junction temperature of LED is increased the radiant output power:	Decreases	Increases	same	propotional	decreases
The LED is usually made of materials like:	GaAs	CU	C	Al	GaAS
What does LED stands for	Light emitting doide	Light emitting detector	light energy disply	light emitting disply	Light emitting doide
The most commonly used semiconductor in the manufacture of a transistor is ……	germanium	Silicon	Aluminium	galium	Silicon
The arrow in the symbol of a transistor indicates the direction of	electron current in the emitter	electron current in the collector	hole current in the emitter	donor ion current	hole current in the emitter
In a transistor, signal is transferred from a …… circuit	high resistance to low resistance	low resistance to high resistance	high resistance to high resistance	. low resistance to low resistance	low resistance to high resistance
As the temperature of a transistor goes up, the base-emitter resistance ……	Decreases	Increases	same	propotional	decreases
The voltage gain in a transistor connected in ……. arrangement is the highest	CE	CB	CC	CBE	CE
The power gain in a transistor connected in ……. arrangement is the highest	CE	CB	CC	CBE	CE
The most commonly used transistor arrangement is …… arrangement	CE	CB	CC	CBE	CE
The collector of a transistor is ……. doped	heavily	moderately	lightly	no doping	moderately
The emitter of a transistor is …… doped	heavily	moderately	lightly	no doping	heavily
The input impedance of a transistor is …….	low	high	0	very high	low
A transistor is a …… operated device	current	voltage	both voltage and current	resistance	current
The element that has the biggest size in a transistor is …….	collector	base	emitter,	emitter and collector	collector
The base of a transistor is ……. . doped	heavily	moderately	lightly	no doping	lightly
The number of depletion layers in a transistor is ……	3	2	1	4	2

It is generally desired that a transistor should have ……. input impedance	low	high	very low	very high	high
The phase difference between the output and input voltages of a CE amplifier is ……. .	180	0	90	270	180
The dc load line on a family of collector characteristic curves of a transistor shows the	saturation region.	cutoff region.	saturation, cuttoff region.	depletion region	saturation, cuttoff region.
A transistor data sheet usually identifies β_{DC} as	h_{re}.	h_{fe}.	I_C.	V_{CE}.	h_{fe}
When a transistor is used as a switch, it is stable in which two distinct regions?	saturation and active	active and cutoff	saturation and cutoff	active	saturation and cutoff
For a silicon transistor, when a base-emitter junction is forward-biased, it has a nominal voltage drop of	0. 7 V.	0. 3 V.	0. 2 V.	V_{CC}.	0. 7 V
The value of β_{DC}	is fixed for any particular transistor.	varies with temperature.	varies with I_C.	varies with temperature and I_C.	varies with temperature and I_C.
The term BJT is short for	base junction transistor.	binary junction transistor.	both junction transistor.	bipolar junction transistor.	bipolar junction transistor
A BJT has an I_B of 50 μA and a βDC of 75; I_C is:	375 mA	37. 5 mA	3. 75 mA	0. 375 mA	3. 75 mA
A certain transistor has I_C = 15 mA and I_B = 167 μA; β_{DC} is:	15	167	0. 011	90	90
For normal operation of a pnp BJT, the base must be _____ with respect to the emitter and _____ with respect to the collector.	positive, negative	positive, positive	negative, positive	negative, negative	negative, positive
A transistor amplifier has a voltage gain of 100. If the input voltage is 75 mV, the output voltage is:	1. 33 V	7. 5 V	13. 3 V	15 V	7. 5 V
A 35 mV signal is applied to the base of a properly biased transistor with an r'_e = 8 Ω and R_C = 1 kΩ. The output signal voltage at the collector is:	3. 5 V	28. 57 V	4. 375 V	4. 375 mV	4. 375 V
What is the order of doping, from heavily to lightly doped, for each region?	base, collector, emitter	emitter, collector, base	emitter, base, collector	collector, emitter, base	emitter, collector, base
What are the two types of bipolar junction transistors?	npn and pnp	pnn and nnp	ppn and nnp	pts and stp	npn and pnp
Which of the following is true for an npn or pnp transistor?	$I_E = I_B + I_C$	$I_B = I_C + I_E$	$I_C = I_B + I_E$	IC = IB	$I_E = I_B + I_C$
What is the ratio of I_C to I_B?	β_{DC}	h_{FE}	α_{DC}	either β_{DC} or h_{FE}, but not α_{DC}	either β_{DC} or h_{FE}, but not α_{DC}
What is the ratio of I_C to I_E?	β_{DC}	$\beta_{DC} / (\beta_{DC} + 1)$	α_{DC}	either $\beta_{DC} / (\beta_{DC} + 1)$ or α_{DC}, but not β_{DC}	either $\beta_{DC} / (\beta_{DC} + 1)$ or α_{DC}, but not β_{DC}

In what range of voltages is the transistor in the linear region of its operation?	$0 < V_{CE}$	$0.7 < V_{CE} < V_{CE(max)}$	$V_{CE(max)} > V_{CE}$	Vce.	$0.7 < V_{CE} < V_{CE(max)}$
What does DC vary with?	I_C	ºC	both I_C and ºC	I_C, but not ºC	both I_C and ºC
What is (are) general-purpose/small-signal transistors case type(s)?	TO-18	TO-92	TO-39	TO-92,TO-18 ,TO-39	TO-92,TO-18 ,TO-39
The magnitude of dark current in a phototransistor usually falls in what range?	mA	μA	nA	pA	nA
First solar cell was invented in 1883 by	George Fritts.	Jefferson Fritts.	Charles Fritts.	Fornster Fritts.	Charles Fritts.
Most of the majority carriers from the emitter …….. .	recombine in the base	recombine in the emitter	pass through the base region to the collector	recombine in collector	pass through the base region to the collector
The current IB is ……	electron current	hole current	donor ion current	acceptor ion current	electron current
In a transistor …	IC = IE + IB	IB = IC + IE	IE = IC – IB	IE = IC + IB	IE = IC + IB
The value of α of a transistor is ……	1	>1	<1	0	<1
The output impedance of a transistor is …	low	high	0	very low	high
If the value of α is 0.9, then value of β is ……. .	90	10	30	55	90
The leakage current in CE arrangement is ……. that in CB arrangemen	more than	less than	the same as	equal	more than
The collector-base junction in a transistor has …	forward bias at all times	reverse bias at all times	low resistance	high resistance	reverse bias at all times
The emitter-base junction in a transistor has …	forward bias at all times	reverse bias at all times	low resistance	high resistance	forward bias at all times

PREPARED BY: Mrs. A. SAHANA FATHIMA, ASSISTANT PROFESSOR, DEPARTMENT OF PHYSICS, KAHE-CBE-21

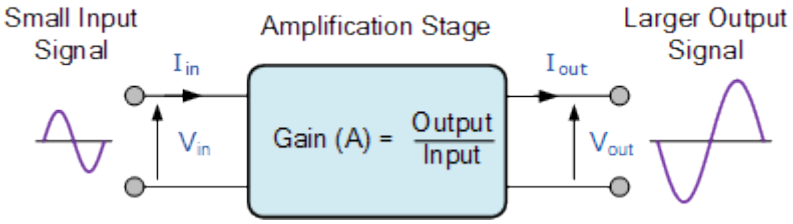
UNIT III

Amplifiers

Different transistor amplifier configurations:- C-B, C-E, C-C, their characteristics, amplification factors, their relationships, Load line Analysis, Expressions for voltage gain, current gain and power gain of C.E amplifier, cut-off and saturation points, Transistor biasing, Different types of biasing - Base resistor, voltage divider bias method, single stage transistor amplifier circuit, load line analysis, DC and AC equivalent circuits.

INTRODUCTION TO THE AMPLIFIER

Amplifier is the generic term used to describe a circuit which increases its input signal, but not all amplifiers are the same as they are classified according to their circuit configurations and methods of operation.



CLASSIFICATION OF AMPLIFIERS

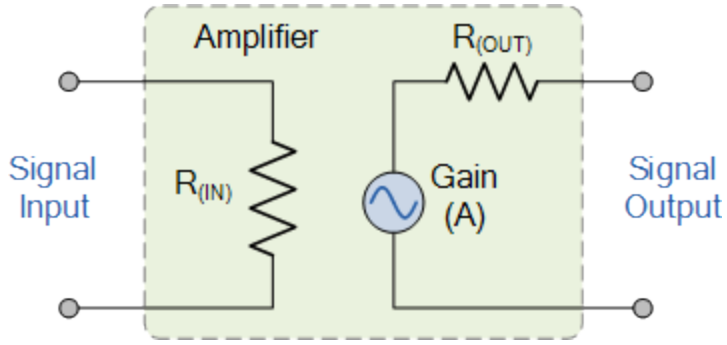
Classification

Type of Signal	Type of Configuration	Frequency of Operation	
Small Signal	Common Emitter	Class A Amplifier	Direct Current (DC)
Large Signal	Common Base	Class B Amplifier	Audio Frequencies (AF)
	Common Collector	Class AB Amplifier	Radio Frequencies (RF)
		Class C Amplifier	VHF, UHF and SHF Frequencies

Amplifiers can be thought of as a simple box or block containing the amplifying device, such as a transistor, field effect transistor or op-amp, which has two input terminals and two output terminals (ground being common) with the output signal being much greater than that of the input signal as it has been "Amplified".

Generally, an ideal signal amplifier has three main properties, Input Resistance or (Rin), Output Resistance or (Rout) and of course amplification known commonly as Gain or (A). No matter how complicated an amplifier circuit is, a general amplifier model can still be used to show the relationship of these three properties.

IDEAL AMPLIFIER MODEL



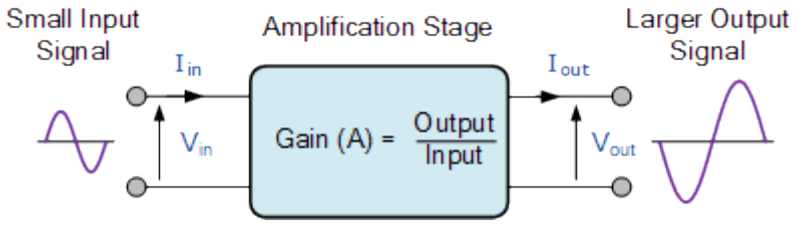
The difference between the input and output signals is known as the Gainof the amplifier and is basically a measure of how much an amplifier "amplifies" the input signal. For example, if we have an input signal of 1 volt and an output of 50 volts, then the gain of the amplifier would be "50". In other words, the input signal has been increased by a factor of 50. This increase is called **Gain**.

Amplifier gain is simply the ratio of the output divided-by the input. Gain has no units as its a ratio, but in Electronics it is commonly given the symbol "A", for Amplification. Then the gain of an amplifier is simply calculated as the "output signal divided by the input signal".

AMPLIFIER GAIN

The introduction to the amplifier gain can be said to be the relationship that exists between the signal measured at the output with the signal measured at the input. There are three different kinds of amplifier gain which can be measured and these are: *Voltage Gain* (Av), *Current Gain* (Ai) and *Power Gain* (Ap) depending upon the quantity being measured with examples of these different types of gains are given below.

AMPLIFIER GAIN OF THE INPUT SIGNAL



VOLTAGE AMPLIFIER GAIN

$$Voltage\,Gain\,(A_v) = \frac{Output\ Voltage}{Input\ Voltage} = \frac{Vout}{Vin}$$

CURRENT AMPLIFIER GAIN

$$Current\,Gain\,(A_i) = \frac{Output\ Current}{Input\ Current} = \frac{Iout}{Iin}$$

POWER AMPLIFIER GAIN

$$Power\,Gain\,(A_p) = A_v\ x\ A_i$$

Note that for the Power Gain you can also divide the power obtained at the output with the power obtained at the input. Also when calculating the gain of an amplifier, the subscripts v, i and p are used to denote the type of signal gain being used.

The power Gain or power level of the amplifier can also be expressed in**Decibels**, (**dB**). The Bel (B) is a logarithmic unit (base 10) of measurement that has no units. Since the Bel is too large a unit of measure, it is prefixed with *deci* making it **Decibels** instead with one decibel being one tenth (1/10th) of a Bel. To calculate the gain of the amplifier in Decibels or dB, we can use the following expressions.

- Voltage Gain in dB: $a_v = 20 \log Av$
- Current Gain in dB: $a_i = 20 \log Ai$
- Power Gain in dB: $a_p = 10 \log Ap$

Note that the DC power gain of an amplifier is equal to ten times the common log of the output to input ratio, where as voltage and current gains are 20 times the common log of the ratio. Note however, that 20dB is not twice as much power as 10dB because of the log scale.

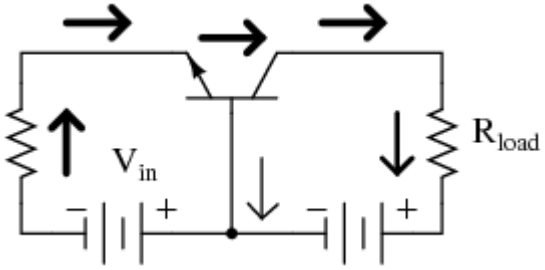
Also, a positive value of dB represents a **Gain** and a negative value of dB represents a **Loss** within the amplifier. For example, an amplifier gain of +3dB indicates that the amplifiers output signal has "doubled", (x2) while an amplifier gain of -3dB indicates that the signal has "halved", (x0.5) or in other words a loss.

The -3dB point of an amplifier is called the **half-power point** which is -3dB down from maximum, taking 0dB as the maximum output value.

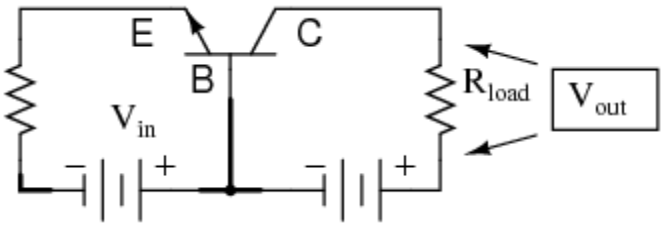
DIFFERENT TRANSISTOR AMPLIFER CONFIGURATIONS:

Common base transistor amplifier basics

The final transistor amplifier configuration (Figure below) we need to study is the common-base. This configuration is more complex than the other two, and is less common due to its strange operating characteristics.



It is called the common-base configuration because (DC power source aside), the signal source and the load share the base of the transistor as a common connection point shown in Figure below.

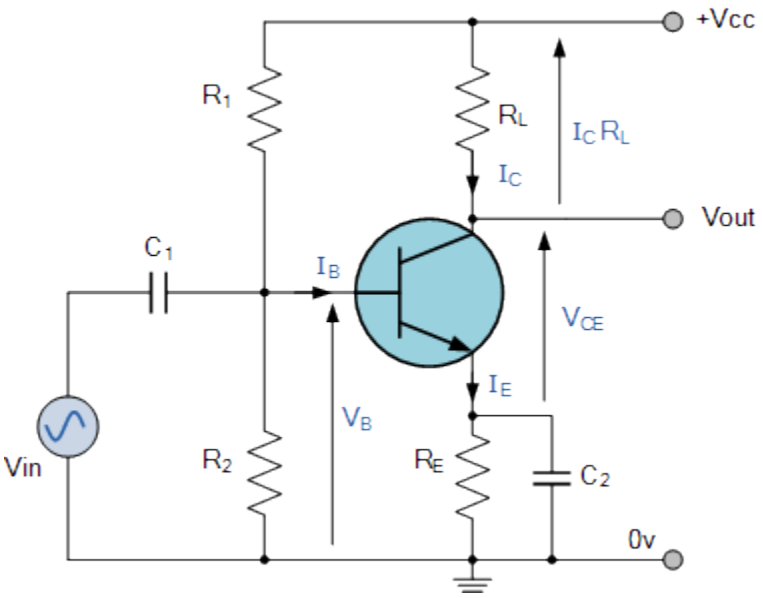


Common-base amplifier: Input between emitter and base, output between collector and base.

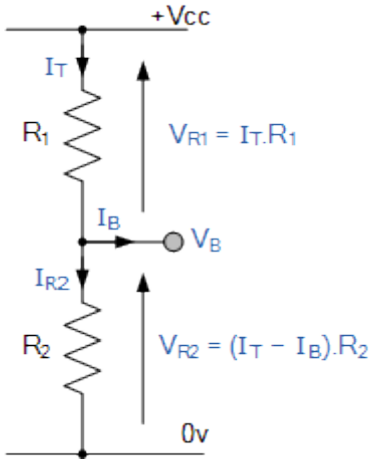
Common Emitter Amplifier

In the Bipolar Transistor tutorial, we saw that there are different ways to connect a transistor but the most common circuit configuration for an NPN transistor is that of the Common Emitter Amplifier circuit.

THE COMMON EMITTER AMPLIFIER CIRCUIT



The single stage common emitter amplifier circuit shown above uses what is commonly called "Voltage Divider Biasing". This type of biasing arrangement uses two resistors as a potential divider network across the supply with their center point supplying the required Base bias voltage to the transistor. Voltage divider biasing is commonly used in the design of bipolar transistor amplifier circuits.



This method of biasing the transistor greatly reduces the effects of varying Beta, (β) by holding the Base bias at a constant steady voltage level allowing for best stability. The quiescent Base voltage (Vb) is determined by the potential divider network formed by the two

resistors, R1, R2 and the power supply voltage Vcc as shown with the current flowing through both resistors.

Then the total resistance RT will be equal to R1 + R2 giving the current as i = Vcc/RT. The voltage level generated at the junction of resistors R1 and R2 holds the Base voltage (Vb) constant at a value below the supply voltage.

Then the potential divider network used in the common emitter amplifier circuit divides the supply voltage in proportion to the resistance. This bias reference voltage can be easily calculated using the simple voltage divider formula below:

Bias Voltage

$$V_B = \frac{V_{CC} R_2}{R_1 + R_2}$$

The same supply voltage, (Vcc) also determines the maximum Collector current, Ic when the transistor is switched fully "ON" (saturation), Vce = 0. The Base current Ib for the transistor is found from the Collector current, Ic and the DC current gain Beta, β of the transistor.

BETA VALUE

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

Beta is sometimes referred to as hFE which is the transistors forward current gain in the common emitter configuration. Beta has no units as it is a fixed ratio of the two currents, Ic and Ib so a small change in the Base current will cause a large change in the Collector current.

One final point about Beta. Transistors of the same type and part number will have large variations in their Beta value for example, the BC107 NPN Bipolar transistor has a DC current gain Beta value of between 110 and 450 (data sheet value) this is because Beta is a characteristic of their construction and not their operation.

As the Base/Emitter junction is forward-biased, the Emitter voltage, Vewill be one junction voltage drop different to the Base voltage. If the voltage across the Emitter resistor is

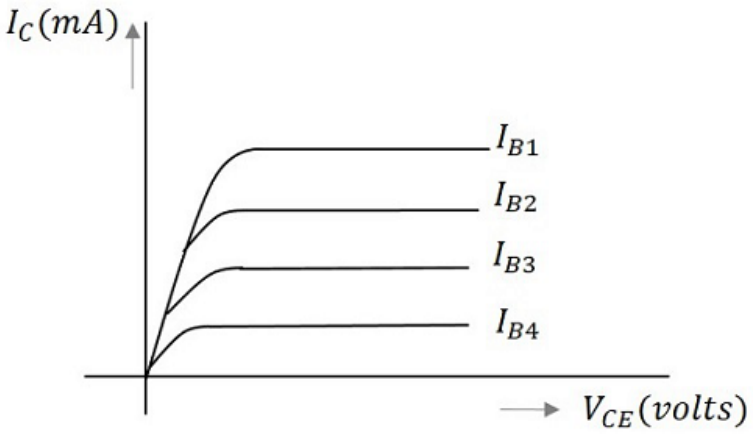
known then the Emitter current, Iecan be easily calculated using Ohm's Law. The Collector current, Ic can be approximated, since it is almost the same value as the Emitter current.

TRANSISTOR LOAD LINE ANALYSIS

We have discussed different regions of operation for a transistor. But among all these regions, we have found that the transistor operates well in active region and hence it is also called as **linear region**. The outputs of the transistor are the collector current and collector voltages.

OUTPUT CHARACTERISTICS

When the output characteristics of a transistor are considered, the curve looks as below for different input values.



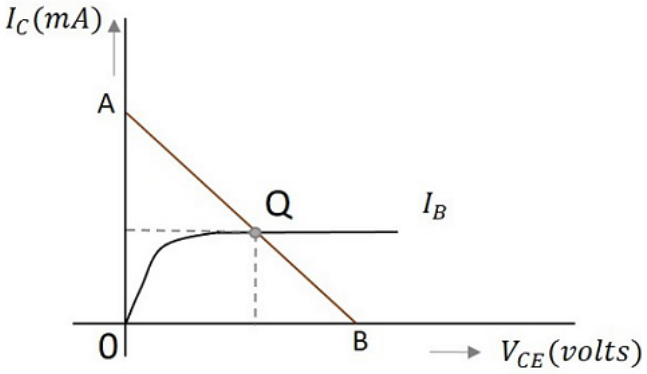
In the above figure, the output characteristics are drawn between collector current $\mathbf{I_C}$ and collector voltage $\mathbf{V_{CE}}$ for different values of base current $\mathbf{I_B}$. These are considered here for different input values to obtain different output curves.

OPERATING POINT

When a value for the maximum possible collector current is considered, that point will be present on the Y-axis, which is nothing but the **saturation point**. As well, when a value for the maximum possible collector emitter voltage is considered, that point will be present on the X-axis, which is the **cutoff point**.

When a line is drawn joining these two points, such a line can be called as **Load line**. This is called so as it symbolizes the output at the load. This line, when drawn over the output characteristic curve, makes contact at a point called as **Operating point**.

This operating point is also called as **quiescent point** or simply **Q-point**. There can be many such intersecting points, but the Q-point is selected in such a way that irrespective of AC signal swing, the transistor remains in active region. This can be better understood through the figure below.

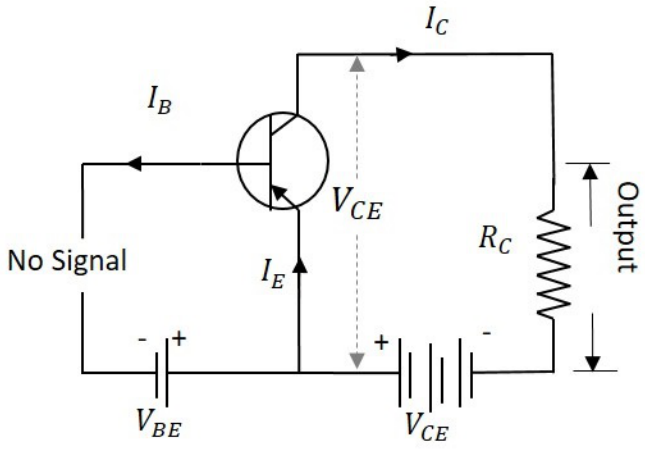


The load line has to be drawn in order to obtain the Q-point. A transistor acts as a good amplifier when it is in active region and when it is made to operate at Q-point, faithful amplification is achieved.

Faithful amplification is the process of obtaining complete portions of input signal by increasing the signal strength. This is done when AC signal is applied at its input. This is discussed in AMPLIFIERS tutorial.

DC LOAD LINE

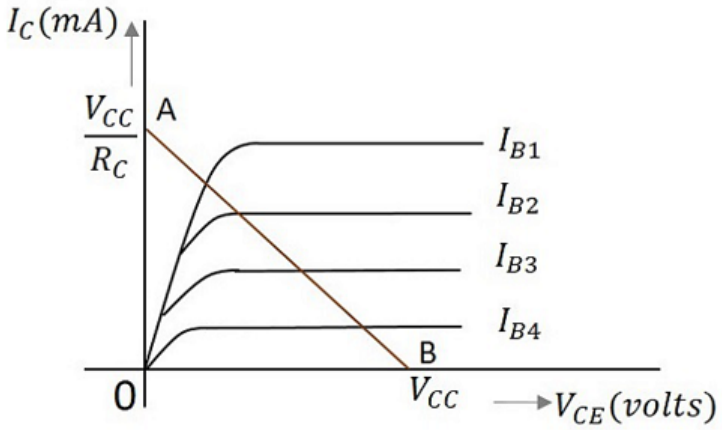
When the transistor is given the bias and no signal is applied at its input, the load line drawn at such condition can be understood as **DC** condition. Here there will be no amplification as the signal is absent. The circuit will be as shown below.



The value of collector emitter voltage at any given time will be

$V_{CE}=V_{CC}-I_CR_CV_{CE}=V_{CC}-I_CR_C$

As V_{CC} and R_C are fixed values, the above one is a first degree equation and hence will be a straight line on the output characteristics. This line is called as **D.C. Load line**. The figure below shows the DC load line.



To obtain the load line, the two end points of the straight line are to be determined. Let those two points be A and B.

To obtain A

When collector emitter voltage V_{CE} = 0, the collector current is maximum and is equal to V_{CC}/R_C. This gives the maximum value of V_{CE}. This is shown as

$$V_{CE}=V_{CC}-I_CR_CV_{CE}=V_{CC}-I_CR_C$$

$$0=V_{CC}-I_CR_{C0}=V_{CC}-I_CR_C$$

$$I_C=V_{CC}R_CI_C=V_{CC}R_C$$

This gives the point A (OA = V_{CC}/R_C) on collector current axis, shown in the above figure.

To obtain B

When the collector current IC = 0, then collector emitter voltage is maximum and will be equal to the VCC. This gives the maximum value of IC. This is shown as

$$V_{CE}=V_{CC}-I_CR_CV_{CE}=V_{CC}-I_CR_C$$

$$=V_{CC}=V_{CC}$$

(As $I_C = 0$)

This gives the point B, which means (OB = V_{CC}) on the collector emitter voltage axis shown in the above figure.

Hence we got both the saturation and cutoff point determined and learnt that the load line is a straight line. So, a DC load line can be drawn.

TRANSISTOR BIASING AND DIFFERENT TYPES OF BIASING

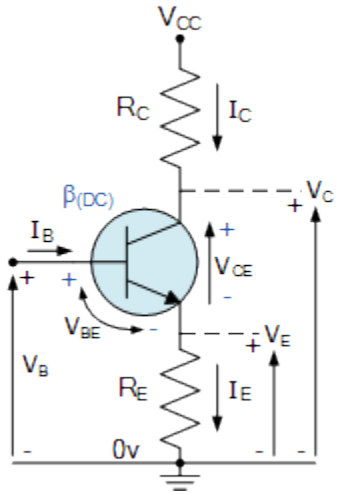
Transistor Biasing is the process of setting a transistors DC operating voltage or current conditions to the correct level so that any AC input signal can be amplified correctly by the transistor.

A transistors steady state of operation depends a great deal on its base current, collector voltage, and collector current and therefore, if a transistor is to operate as a linear amplifier, it must be properly biased to have a suitable operating point.

Establishing the correct operating point requires the proper selection of bias resistors and load resistors to provide the appropriate input current and collector voltage conditions. The correct biasing point for a bipolar transistor, either NPN or PNP, generally lies somewhere between the two extremes of operation with respect to it being either “fully-ON” or “fully-OFF” along its load line. This central operating point is called the “Quiescent Operating Point”, or **Q-point** for short.

When a bipolar transistor is biased so that the Q-point is near the middle of its operating range, that is approximately halfway between cut-off and saturation, it is said to be operating as a Class-A amplifier. This mode of operation allows the output current to increase and decrease around the amplifiers Q-point without distortion as the input signal swings through a complete

cycle. In other words, the output current flows for the full 360ºof the input cycle. The correct biasing of the transistor is achieved using a process know commonly as **Base Bias**.



The function of the "DC Bias level" or "no input signal level" is to correctly set the transistors Q-point by setting its Collector current (I_C) to a constant and steady state value without an input signal applied to the transistors Base.

This steady-state or DC operating point is set by the values of the circuits DC supply voltage (Vcc) and the value of the biasing resistors connected the transistors Base terminal.

Since the transistors Base bias currents are steady-state DC currents, the appropriate use of coupling and bypass capacitors will help block bias current setup for one transistor stage affecting the bias conditions of the next. Base bias networks can be used for Common-base (CB), common-collector (CC) or common-emitter (CE) transistor configurations. In this simple transistor biasing tutorial we will look at the different biasing arrangements available for a Common Emitter Amplifier.

Base Biasing a Common Emitter Amplifier

One of the most frequently used biasing circuits for a transistor circuit is with the self-bias of the emitter-bias circuit where one or more biasing resistors are used to set up the initial DC values of transistor currents, (I_B), (I_C) and (I_E).

The two most common forms of transistor biasing are: *Beta Dependent*and *Beta Independent*. Transistor bias voltages are largely dependent on transistor beta, (β) so the biasing set up for one transistor may not necessarily be the same for another transistor. Transistor biasing

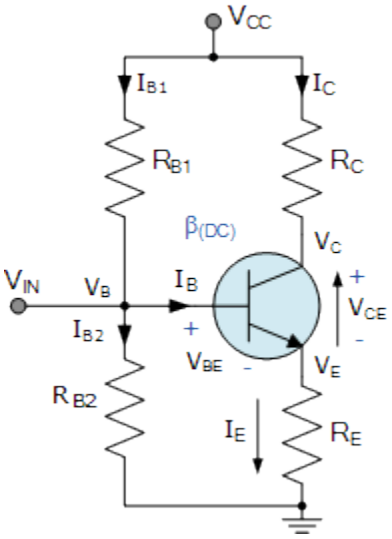
can be achieved either by using a single feed back resistor or by using a simple voltage divider network to provide the required biasing voltage.

The following are five examples of transistor Base bias configurations from a single supply (Vcc).

Different types of biasing

- Fixed Base Biasing a Transistor
- Collector Feedback Biasing a Transistor
- Dual Feedback Transistor Biasing
- Transistor Biasing with Emitter Feedback
- Voltage Divider Transistor Biasing

Voltage Divider Transistor Biasing



$$V_C = V_{CC} - R_C I_C = (V_E + V_{CE})$$
$$V_E = I_E R_E = V_B - V_{BE}$$
$$V_{CE} = V_C - V_E = V_{CC} - (I_C R_C + I_E R_E)$$
$$V_B = V_{BE} + V_E = V_{RB2} = \left(\frac{R_{B2}}{R_{B1}+R_{B2}}\right) V_{CC}$$
$$I_{B2} = \frac{V_B}{R_{B2}}$$
$$I_{B1} = I_B + I_{B2} = \frac{V_{CC} - V_B}{R_{B1}}$$
$$R_B = \frac{R_{B1} \times R_{B2}}{R_{B1}+R_{B2}} \qquad I_B = \frac{V_B - V_{BE}}{R_B + (1+\beta) R_E}$$
$$I_C = \beta_{(DC)} I_B$$
$$I_E = I_C + I_B = \frac{V_E}{R_E}$$

The common emitter transistor is biased using a voltage divider network to increase stability. The name of this biasing configuration comes from the fact that the two resistors R_{B1} and R_{B2} form a voltage or potential divider network across the supply with their center point junction connected the transistors base terminal as shown.

This voltage divider biasing configuration is the most widely used transistor biasing method, as the emitter diode of the transistor is forward biased by the voltage dropped across resistor R_{B2}. Also, voltage divider network biasing makes the transistor circuit independent of changes in beta

as the voltages at the transistors base, emitter, and collector are dependant on external circuit values.

To calculate the voltage developed across resistor R_{B2} and therefore the voltage applied to the base terminal we simply use the voltage divider formula for **resistors in series**.

Generally the voltage drop across resistor R_{B2} is much less than for resistor R_{B1}. Then clearly the transistors base voltage V_B with respect to ground, will be equal to the voltage across R_{B2}.

The current flowing through resistor R_{B2} is generally set at 10 times the value of the required base current I_B so that it has no effect on the voltage divider current or changes in Beta.

The goal of **Transistor Biasing** is to establish a known Q-point in order for the transistor to work efficiently and produce an undistorted output signal. Correct biasing of the transistor also establishes its initial AC operating region with practical biasing circuits using either a two or four-resistor bias network.

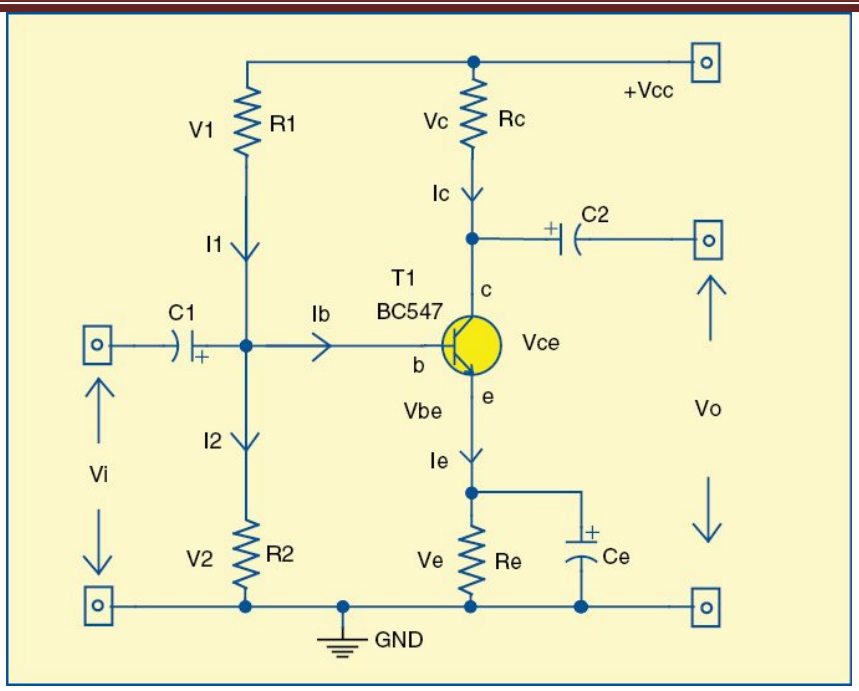
` In bipolar transistor circuits, the Q-point is represented by (V_{CE}, I_C) for the NPN transistors or (V_{EC}, I_C) for PNP transistors. The stability of the base bias network and therefore the Q-point is generally assessed by considering the collector current as a function of both Beta (β) and temperature.

Here we have looked briefly at five different configurations for "biasing a transistor" using resistive networks. But we can also bias a transistor using either silicon diodes, zener diodes or active networks all connected to the base terminal of the transistor or by biasing the transistor from a dual power supply.

Single-stage Transistor Amplifier

When only one transistor with associated circuitry is used for amplifying a weak signal, the circuit is known as single-stage amplifier.

Analyzing the working of a Single-stage amplifier circuit, makes us easy to understand the formation and working of Multi-stage amplifier circuits. A Single stage transistor amplifier has one transistor, bias circuit and other auxiliary components. The following circuit diagram shows how a single stage transistor amplifier looks like.



When a weak input signal is given to the base of the transistor as shown in the figure, a small amount of base current flows. Due to the transistor action, a larger current flows in the collector of the transistor. (As the collector current is β times of the base current which means IC = β IB). Now, as the collector current increases, the voltage drop across the resistor RC also increases, which is collected as the output. Hence a small input at the base gets amplified as the signal of larger magnitude and strength at the collector output. Hence this transistor acts as an amplifier.

Biasing Circuit

The resistors R1, R2 and RE form the biasing and stabilization circuit, which helps in establishing a proper operating point.

Input Capacitor C_{in}

This capacitor couples the input signal to the base of the transistor. The input capacitor C_{in} allows AC signal, but isolates the signal source from R_2. If this capacitor is not present, the input signal gets directly applied, which changes the bias at R_2.

Coupling Capacitor CC

This capacitor is present at the end of one stage and connects it to the other stage. As it couples two stages it is called as coupling capacitor. This capacitor blocks DC of one stage to

enter the other but allows AC to pass. Hence it is also called as blocking capacitor. Due to the presence of coupling capacitor CC, the output across the resistor RL is free from the collector's DC voltage. If this is not present, the bias conditions of the next stage will be drastically changed due to the shunting effect of RC, as it would come in parallel to R2 of the next stage.

Emitter by-pass capacitor CE

This capacitor is employed in parallel to the emitter resistor RE. The amplified AC signal is by passed through this. If this is not present, that signal will pass through RE which produces a voltage drop across RE that will feedback the input signal reducing the output voltage.

The Load resistor RL

The resistance RL connected at the output is known as Load resistor. When a number of stages are used, then RL represents the input resistance of the next stage.

VARIOUS CIRCUIT CURRENTS

(i) Base Current

When no signal is applied in the base circuit, d.c. base current I_B, also known as zero signal base current flows due to the biasing circuit.

When a.c. signal is applied, a.c. base current i_b flows in the base circuit.

Hence, the total base current i_B is given by :

$$i_B = I_B + i_b$$

(ii) Collector Current

When no signal is applied, a d.c. collector current I_C, also known as zero signal collector current flows due to the biasing circuit.

When a.c. signal is applied, a.c. collector current i_c also flows in the collector circuit.

Hence, the total collector current i_C is given by :

$$i_C = I_C + i_c$$

where

$I_C = \beta I_B$ = zero signal collector current

$i_c = \beta i_b$ = collector current due to signal.

(iii) Emitter Current

When no signal is applied, a d.c. emitter current $I_{E,}$ flows due to the biasing circuit.

When a.c. signal is applied, a.c. emitter current i_e also flows .

Hence, the total emitter current i_E is given by :

$$i_E = I_E + i_e$$

It is useful to keep in mind that :

$$I_E = I_B + I_C$$
$$i_e = i_b + i_c$$

Now base current is usually very small, therefore, we can take the approximation :

$$I_E \simeq I_C \quad \text{and} \quad i_e \simeq i_c$$

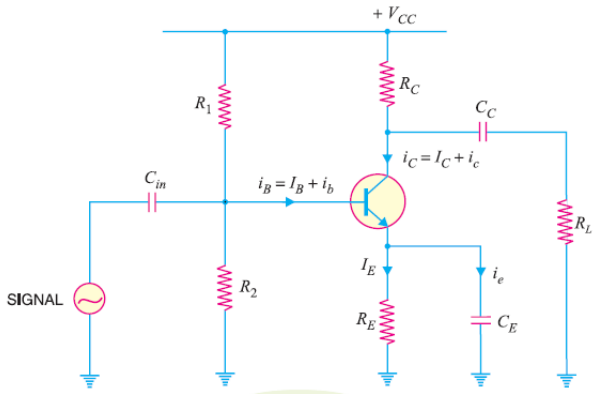
D.C. and A.C. Equivalent Circuits

To analyse the action of a transistor in a simple way, the analysis is divided into two parts such as; d.c. analysis and a.c. analysis.

In d.c. analysis, we will consider all the d.c. sources at the same time and work out the d.c. currents voltages in the circuit.

Similarly, in a.c. analysis, we will consider all the a.c. sources at the same time and work out the a.c. currents and voltages .

For this analysis let us consider the amplifier circuit shown in fig. below.



(1) D.C. Equivalent Circuit

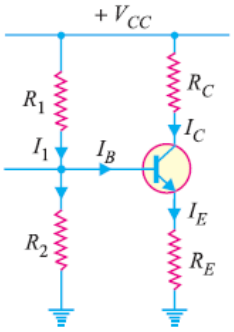
In the d.c. equivalent circuit of a transistor amplifier, only d.c. conditions must be considered. So let us assume there is no signal applied to the circuit.

Since, d.c. currents can not pass through the capacitors, hence, all the capacitors look like open circuits in the d.c. equivalent circuit.

Therefore, to draw the d.c. equivalent circuit, the following two steps are applied to the transistor amplifier circuit :

1. Make all the a.c. sources zero/Remove all the a.c sources
2. Open all the capacitors

Applying these two steps to the circuit shown in fig.3, we will get the d.c. equivalent circuit as shown in fig. below.



Now we can easily calculate the d.c. currents and voltages from this circuit.

(2) A.C. Equivalent Circuit

In the a.c. equivalent circuit of a transistor amplifier, only a.c. conditions must be considered.

In this case, d.c. voltage is not so important hence, may be assumed to be zero.

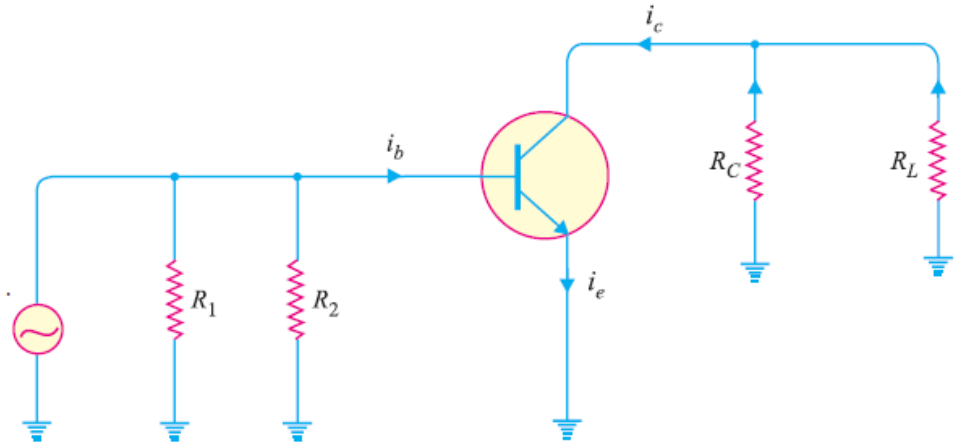
The capacitors are used in the circuit to couple or bypass the a.c. signal.

The capacitors are generally taken of large values so as to appear as short circuits to the a.c. signal.

Therefore, to draw the a.c. equivalent circuit, the following two steps are applied to the transistor amplifier circuit :

1. Make all the d.c. sources zero/Remove all the d.c. sources
2. Short all the capacitors

Applying these two steps to the circuit shown in fig.3, we will get the a.c. equivalent circuit as shown in fig. below.



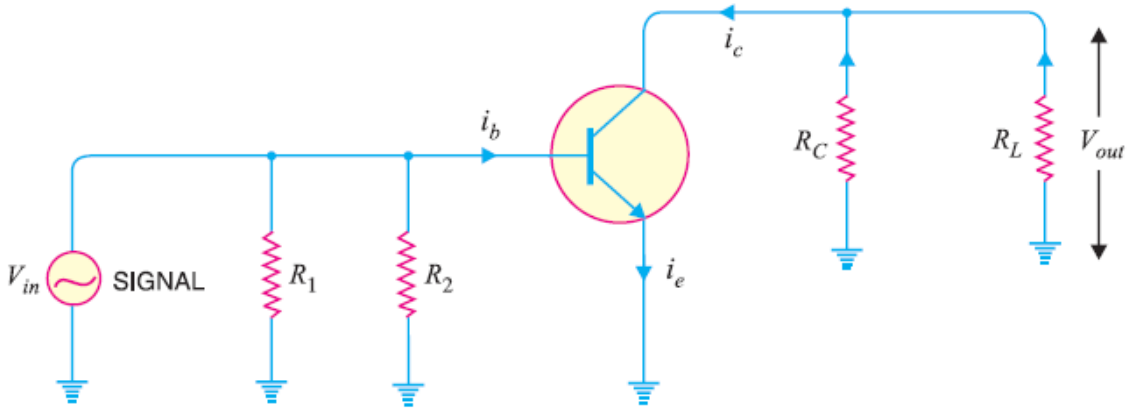
Now we can easily calculate the a.c. currents and voltages from this circuit.

Voltage Gain of Single stage Transistor Amplifier

The voltage gain of a single stage transistor amplifier is the ratio of a.c. output voltage to a.c. input signal voltage.

Hence, in order to determine the voltage gain, you should consider only the a.c. currents and voltages in the circuit. In other words you have to consider the a.c. equivalent circuit of the transistor amplifier.

The a.c. equivalent circuit of a transistor amplifier is shown in fig. below.



As far as a.c. signal is concerned, load R_C appears in parallel with R_L.

Therefore, the effective load resistance for a.c. is given by :

$$\text{a.c. load, } R_{AC} = R_C \| R_L = \frac{R_C \times R_L}{R_C + R_L}$$

$$\text{Output voltage, } V_{out} = i_c R_{AC}$$

$$\text{Input voltage, } V_{in} = i_b R_{in}$$

$$\therefore \quad \text{Voltage gain, } A_v = V_{out}/V_{in}$$

$$= \frac{i_c R_{AC}}{i_b R_{in}} = \beta \times \frac{R_{AC}}{R_{in}}$$

Incidentally, power gain is given by :

$$A_p = \frac{i_c^2 R_{AC}}{i_b^2 R_{in}} = \beta^2 \times \frac{R_{AC}}{R_{in}}$$

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POSSIBLE QUESTIONS

UNIT III

EIGHT MARK QUESTIONS:

1. Explain in detail about Base resistor and voltage divider bias
2. Discuss DC Load line and Q-point.
3. Explain Single stage amplifier and its frequency response.
4. Find out the amplifcation factor and charactersitics of CE transistor amplifier configuration
5. Find out the amplifcation factor and charactersitics of CB transistor amplifier configuration
6. Find out the amplifcation factor and charactersitics of CC transistor amplifier configuration

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DEPARTMENT OF PHYSICS

III B.SC PHYSICS **BATCH: 2015-2019**

BASIC ELECTRONICS (15PHU504)

MULTIPLE CHOICE QUESTIONS

Questions	opt1	opt2	opt3	opt4	Answer
UNIT III					
When negative voltage feedback is applied to an amplifier, its voltage gain	Is increased	Is reduced	Remains the same	equal	Is reduced
The value of negative feedback fraction is always	<1	>1	0	1	<1
There are …… *h* parameters of a transistor	2	3	5	6	2
The *h* parameter approach gives correct results for	Large signals only	Small signals only	Both small and large signals	no signal	Small signals only
The dimensions of *hie* parameter are	Mho	Ohm	Farad	Ampere	Ohm
If the operating point changes, the *h* parameters of transistor	Also change	Do not change	May or may not change	stable	Also change
If temperature changes, *h* parameters of a transistor	Also change	Do not change	May or may not change	stable	Also change
A feedback circuit usually employs …… network	Resistive	Capacitive	Inductive	transformer	Resistive
The gain of an amplifier with feedback is known as …….. gain	Resonant	Open loop	Closed loop	short circuit	Closed loop
When voltage feedback (negative) is applied to an amplifier, its input impedance	Is increased	Is reduced	Remains the same	equal	Is increased
When current feedback (negative) is applied to an amplifier, its input impedance …….	Is increased	Is reduced	Remains the same	equal	Is reduced
Negative feedback is employed in	Oscillators	Rectifiers	Amplifiers	filter	Amplifiers
Emitter follower is used for …	Current gain	Impedance matchin	Voltage gain	resistance	Impedance matchin
Quiescent power is the power dissipation of a transistor	with no signal input.	with no load.	under full load.	along the dc load line.	with no signal input
A class B amplifier operates in the linear region for	slightly more than 180° of the input cycle.	360° of the input cycle.	slightly less than 180° of the input cycle.	much less than 180° of the input cycle.	slightly less than 180° of the input cycle
In a class AB amplifier, if the V_{BE} drops are not matched to the diode drops or if the diodes are not in thermal equilibrium with the transistors, this can result in	a current mirror.	diode separation.	crossover distortion.	thermal runaway.	thermal runaway
Which amplifier is commonly used as a frequency multiplier?	class A	class B	class C	Class D	class C
The least efficient amplifier among all classes is	class B.	class A.	class AB.	class C.	class B
A class A amplifier has a voltage gain of 30 and a current gain of 25. What is the power gain?	30	25	1.2	750	750

You have an application for a power amplifier to operate on FM radio frequencies. The most likely choice would be a _____ amplifier.	class A	class B	class C	class AB	class C
A class A amplifier with R_C = 3.3 kΩ and R_E = 1.2 kΩ has a V_{CC} = 20 V. Find $I_{C(sat)}$.	4.4 mA	6.1 mA	16.7 mA	20 mA	4.4 mA
A class C amplifier has a tank circuit in the output. The amplifier is conducting only 28°. The output voltage is	0 V.	a dc value equal to V_{CC}.	a sine wave.	a square wave with a frequency determined by the tank.	a sine wave.
In practice, the efficiency of a capacitively coupled class A amplifier is about _____%.	25	40	70	10	10
The Q-point is at cutoff for class _____ operation.	A	B	C	AB	B
Class _____ amplifiers are normally operated in a push-pull configuration in order to produce an output that is a replica of the input.	A	B	C	AB	AB
The maximum efficiency of a class B amplifier is _____ percent.	50	25	70	79	79
A class _____ amplifier is biased slightly above cutoff and operates in the linear region for slightly more than 180º of the input cycle.	A	B	C	AB	AB
Which class of amplifier operates in the linear region for only a small part of the input cycle?	A	B	C	AB	C
Class D operation can achieve power efficiency of over _____.	90%	78.50%	50%	25%	90%
The beta of a power transistor is generally _____.	more than 200	100 to 200	less than 100	0	less than 100
A form of class A amplifier having maximum efficiency of _____ uses a transformer to couple the output signal to the load.	90%	78.50%	50%	25%	50%
The reflected impedance seen from one side of the transformer to the other side is _____.	N_1/N_2	$(N_1/N_2)^2$	$(N_1/N_2)^{1/3}$	$N_1 \times N_2$	$(N_1/N_2)^2$
In a class A transformer-coupled power amplifier, _____ winding resistance of the transformer determine(s) the dc load line for the circuit.	the ac	the dc	the ac and dc	neither the ac nor dc	the dc
The slope of the ac load line in the class A transformer-coupled transistor is _____.	$-1/R_L$ (load resistor)	$1/(a^2R_L)$	$-1/(a^2R_L)$	$1/R_L$	$-1/(a^2R_L)$
The amount of power dissipated by the transistor is the _____ of that drawn from the dc supply (set by the bias point) and the amount delivered to the ac load.	product	difference	average	sum of	difference
A class A amplifier dissipates _____ power when the load is drawing maximum power from the circuit.	the least	about the same	the most	equal	the least
In a class A transformer-coupled amplifier, the _____ the value of V_{CEmax} and the _____ the value of V_{CEmin}, the _____ the efficiency to (from) the theoretical limit of 50%.	larger, smaller, farther	larger, smaller, closer	smaller, larger, closer	larger	larger, smaller, closer
In class B operation, the current drawn from a single power supply has the form of _____ rectified signal.	a full-wave	a half-wave	both a full-wave and a half-wave	diode	a full-wave

The highest efficiency is obtained in class B operation when the level of $V_L(p)$ is equal to _____.	$0.25V_{CC}$	$0.50V_{CC}$	V_{CC}	$2V_{CC}$	V_{CC}
_____ transistors can be used to build a class B amplifier.	npn and pnp	nMOS and pMOS	Both npn and pnp or nMOS and pMOS	npn	Both npn and pnp or nMOS and pMOS
The complementary Darlington-connected transistor for a class B amplifier provides _____ output current and _____ output resistance.	higher, higher	higher, lower	lower, lower	lower, higher	higher, lower
The fundamental component is typically _____ any harmonic component.	larger than	the same as	smaller than	equal	larger than
An amplifier has a power gain of 100. Its db gain is ……	0 db	10db	20db	30db	20 db
In order to get more voltage gain from a transistor amplifier, the transistor used should have	Thin base	Thin collector	Wide emitter	wide collector	Thin base
The purpose of a coupling capacitor in a transistor amplifier is to	Increase the output impedance of transistor	Protect the transistor	Pass a.c. and block d.c.	Provide biasing	Pass a.c. and block d.c.
The purpose of emitter capacitor (i.e. capacitor across RE) is to	Avoid voltage gain drop	Forward bias the emitter	Reduce noise in the amplifier	reverse bias emitter	Avoid voltage gain drop
The ratio of output impedance of a CE amplifier is …	About 1	Low	high	moderate	moderate
If a transistor amplifier feeds a load of low resistance (e.g. speaker), then voltage gain will be …	. About 1	Low	high	moderate	Low
If the input capacitor of a transistor amplifier is short-circuited, then…	Transistor will be destroyed	Biasing conditions will change	Signal will not reach the base	no signal	Biasing conditions will change
A CE amplifier is also called …….. circuit	Grounded emitter	Grounded base	Grounded collector	signal at base	Grounded emitter
The value of collector load RC in a transistor amplifier is …… the output impedance of the transistor.	The same as	Less than	More than	equal	Less than
The d.c. load of a transistor amplifier is generally …….. that of a a.c. load	The same as	Less than	More than	equal	More than
In transistor amplifiers, we generally use …….. capacitors.	Electrolytic	Mica	Paper	Air	electrolytic
The output power of a transistor amplifier is more than the input power because the additional power is supplied by	Transistor	Biasing circuit	Collector supply VCC	filter	Collector supply VCC
A transistor amplifier has high output impedance because …	Emitter is heavily doped	Collector has reverse bias	Collector is wider than emitter or base	collector forward bias	Collector has reverse bias
For highest power gain, one would use …….. configuration	CC	Cb	CE	CBE	CE
RC coupling is used for ……. amplification	Voltage	Current	Power	resistance	Voltage

In an RC coupled amplifier, the voltage gain over mid-frequency range	Changes abruptly with frequency	Is constant	Changes uniformly with frequency	change with time	Is constant
An advantage of RC coupling scheme is the	Good impedance matching	Economy	High efficiency	good resistance	Economy
The best frequency response is of ……. coupling	RC	Transformer	Direct	indirect	Direct
Transformer coupling is used for …….. amplification	Voltage	Current	Power	capacitance	Power
In an RC coupling scheme, the coupling capacitor CC must be large enough …	To pass d.c. between the stages	Not to attenuate the low frequencies	To dissipate high power	To dissipate high heat	Not to attenuate the low frequencies
The noise factor of an ideal amplifier expressed in db is	0	1	10	20	0
When a multistage amplifier is to amplify d.c. signal, then one must use …….. coupling	RC	Transformer	Direct	indirect	Direct
……. coupling provides the maximum voltage gain	RC	Transformer	Direct	indirect	Transformer
RC coupling is not used to amplify extremely low frequencies because	There is considerable power loss	There is hum in the output	Electrical size of coupling capacitor becomes very large	there ia a hum in output	Electrical size of coupling capacitor becomes very large

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UNIT IV

Operational amplifer

Operational amplifier- Block diagram-characteristics-parameters- Applications of Op-amp: Inverting-Non-inverting-differentiator-integrator-comparator-adder-subtractor- Active filters using 741: high pass and low pass filters- band pass filter-Schmitt trigger.

OPERATIONAL AMPLIFIER (OP-AMP)

Operational amplifiers are linear devices that have all the properties required for nearly ideal DC amplification and are therefore used extensively in signal conditioning, filtering or to perform mathematical operations such as add, subtract, integration and differentiation.

Op-amp Parameter and Idealized Characteristic

Open Loop Gain, (Avo)

Infinite – The main function of an operational amplifier is to amplify the input signal and the more open loop gain it has the better. Open-loop gain is the gain of the op-amp without positive or negative feedback and for such an amplifier the gain will be infinite but typical real values range from about 20,000 to 200,000.

Input impedance, (Zin)

Infinite – Input impedance is the ratio of input voltage to input current and is assumed to be infinite to prevent any current flowing from the source supply into the amplifiers input circuitry (Iin = 0). Real op-amps have input leakage currents from a few pico-amps to a few milli-amps.

Output impedance, (Zout)

Zero – The output impedance of the ideal operational amplifier is assumed to be zero acting as a perfect internal voltage source with no internal resistance so that it can supply as much current as necessary to the load. This internal resistance is effectively in series with the load thereby reducing the output voltage available to the load. Real op-amps have output impedances in the 100-20kΩ range.

Bandwidth, (BW)

Infinite – An ideal operational amplifier has an infinite frequency response and can amplify any frequency signal from DC to the highest AC frequencies so it is therefore assumed to have an infinite bandwidth. With real op-amps, the bandwidth is limited by the Gain-

Bandwidth product (GB), which is equal to the frequency where the amplifiers gain becomes unity.

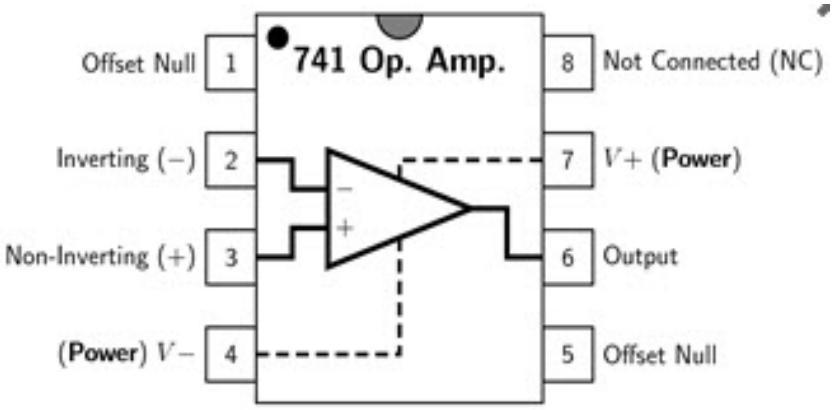
Offset Voltage, (Vio)

Zero – The amplifiers output will be zero when the voltage difference between the inverting and the non-inverting inputs is zero, the same or when both inputs are grounded. Real op-amps have some amount of output offset voltage.

OP AMP PIN CONFIGURATION

The 741IC op amp diagram is shown below that consists of 8 pins. The most important pins are pin-2, pin-3 and pin-6 because pin 2 and 3 represent inverting and non-inverting terminals where pin6 represents voltage out. The triangular diagram in the op-amp represents an Op-Amp integrated circuit. The modern version of the IC is represented by the famous 741 op-amp. Op-amp is mainly used to perform mathematical operations in various electronic circuits. It is the common feature of analog electronics. 741 IC is built from various transistor stages which commonly contain a differential i/p stage, a push-pull o/p stage and an intermediate gain stage. The differential op-amps comprises of a matched pair of FETs or bipolar junction transistors.

The pin diagram of the IC 741 op amp is shown below. It consists of 8 pins where each pin having some functionality which is discussed in the following.

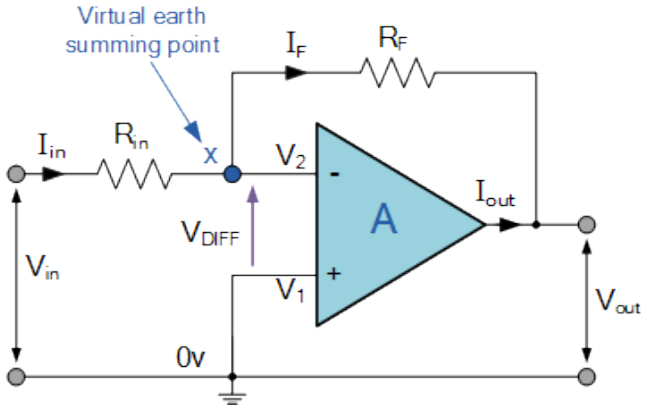


Pin configuration of IC 741 op amp is shown above

- Pin 1 is Offset null.
- Pin 2 is Inverting input terminal.
- Pin 3 is a non-inverting input terminal.
- Pin 4 is negative voltage supply (VCC)

- Pin 5 is offset null.
- Pin 6 is the output voltage.
- Pin 7 is positive voltage supply (+VCC)
- Pin 8 has no connection.

INVERTING OPERATIONAL AMPLIFIER



In this **Inverting Amplifier** circuit the operational amplifier is connected with feedback to produce a closed loop operation. When dealing with operational amplifiers there are two very important rules to remember about inverting amplifiers, these are: "No current flows into the input terminal" and that "V1 always equals V2". However, in real world op-amp circuits both of these rules are slightly broken.

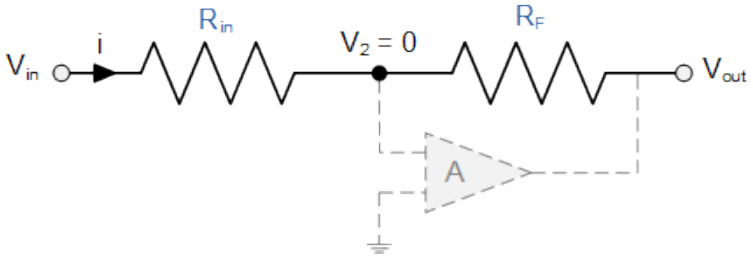
This is because the junction of the input and feedback signal (X) is at the same potential as the positive (+) input which is at zero volts or ground then, the junction is a **"Virtual Earth"**. Because of this virtual earth node the input resistance of the amplifier is equal to the value of the input resistor, Rin and the closed loop gain of the inverting amplifier can be set by the ratio of the two external resistors.

We said above that there are two very important rules to remember about**Inverting Amplifiers** or any operational amplifier for that matter and these are.

- No Current Flows into the Input Terminals
- The Differential Input Voltage is Zero as V1 = V2 = 0 (Virtual Earth)

Then by using these two rules we can derive the equation for calculating the closed-loop gain of an inverting amplifier, using first principles.

Current (i) flows through the resistor network as shown.



$$i = \frac{Vin - Vout}{Rin + Rf}$$

$$\text{therefore, } i = \frac{Vin - V2}{Rin} = \frac{V2 - Vout}{Rf}$$

$$i = \frac{Vin}{Rin} - \frac{V2}{Rin} = \frac{V2}{Rf} - \frac{Vout}{Rf}$$

$$\text{so, } \frac{Vin}{Rin} = V2\left[\frac{1}{Rin} + \frac{1}{Rf}\right] - \frac{Vout}{Rf}$$

$$\text{and as, } i = \frac{Vin - 0}{Rin} = \frac{0 - Vout}{Rf} \qquad \frac{Rf}{Rin} = \frac{0 - Vout}{Vin - 0}$$

$$\text{the Closed Loop Gain (Av) is given as, } \frac{Vout}{Vin} = -\frac{Rf}{Rin}$$

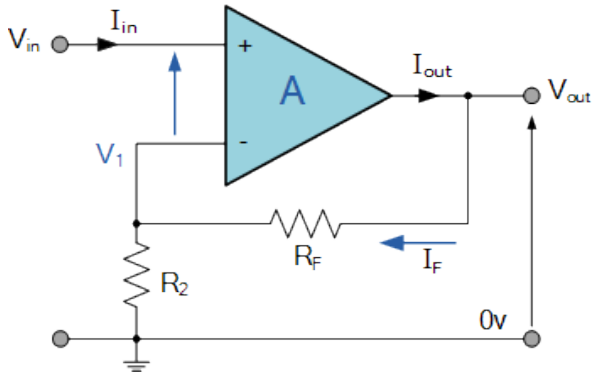
Then, the **Closed-Loop Voltage Gain** of an Inverting Amplifier is given as.

$$\text{Gain (Av)} = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

and this can be transposed to give Vout as:

$$Vout = -\frac{Rf}{Rin} \times Vin$$

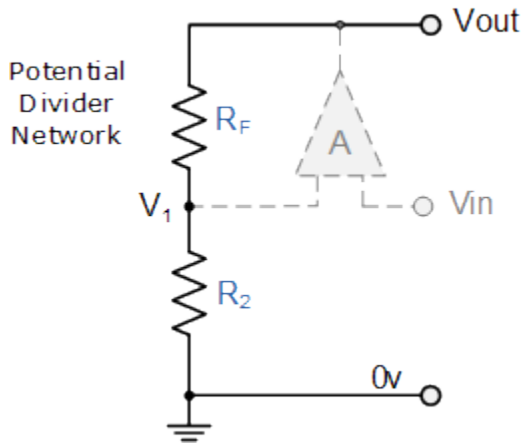
NON-INVERTING OPERATIONAL AMPLIFIER



In the Inverting Amplifier , an ideal op-amp "No current flows into the input terminal" of the amplifier and that"V1 always equals V2". This was because the junction of the input and feedback signal (V1) are at the same potential.

In other words the junction is a "virtual earth" summing point. Because of this virtual earth node the resistors, R*f* and R2 form a simple potential divider network across the non-inverting amplifier with the voltage gain of the circuit being determined by the ratios of R2 and R*f* as shown below.

Equivalent Potential Divider Network



Then using the formula to calculate the output voltage of a potential divider network, we can calculate the closed-loop voltage gain (A_V) of the **Non-inverting Amplifier** as follows:

$$V_1 = \frac{R_2}{R_2 + R_F} \times V_{OUT}$$

Ideal Summing Point: $V_1 = V_{IN}$

Voltage Gain, $A_{(V)}$ is equal to: $\frac{V_{OUT}}{V_{IN}}$

Then, $A_{(V)} = \frac{V_{OUT}}{V_{IN}} = \frac{R_2 + R_F}{R_2}$

Transpose to give: $A_{(V)} = \frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_F}{R_2}$

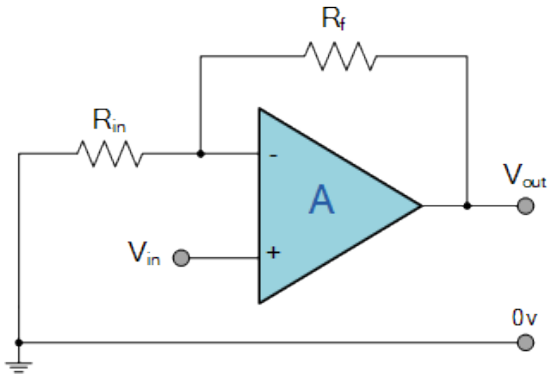
Then the closed loop voltage gain of a **Non-inverting Operational Amplifier** will be given as:

$$A_{(V)} = 1 + \frac{R_F}{R_2}$$

We can see from the equation above, that the overall closed-loop gain of a non-inverting amplifier will always be greater but never less than one (unity), it is positive in nature and is determined by the ratio of the values of R*f* and R2.

If the value of the feedback resistor R*f* is zero, the gain of the amplifier will be exactly equal to one (unity). If resistor R2 is zero the gain will approach infinity, but in practice it will be limited to the operational amplifiers open-loop differential gain, (Ao).

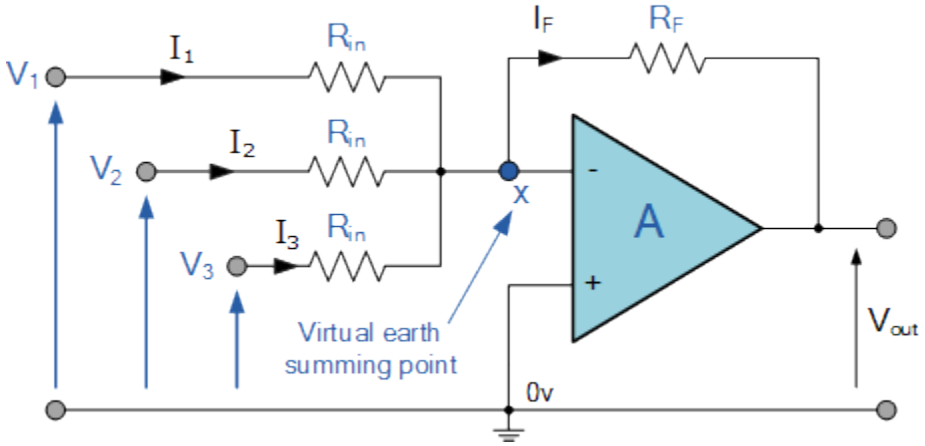
We can easily convert an inverting operational amplifier configuration into a non-inverting amplifier configuration by simply changing the input connections as shown.



THE SUMMING AMPLIFIER

The **Summing Amplifier** is another type of operational amplifier circuit configuration that is used to combine the voltages present on two or more inputs into a single output voltage.

SUMMING AMPLIFIER CIRCUIT



In this simple summing amplifier circuit, the output voltage, (Vout) now becomes proportional to the sum of the input voltages, V1, V2, V3, etc. Then we can modify the original equation for the inverting amplifier to take account of these new inputs thus:

$$I_F = I_1 + I_2 + I_3 = -\left[\frac{V1}{Rin} + \frac{V2}{Rin} + \frac{V3}{Rin}\right]$$

$$\text{Inverting Equation: } Vout = -\frac{Rf}{Rin} \times Vin$$

$$\text{then, } -Vout = \left[\frac{R_F}{Rin}V1 + \frac{R_F}{Rin}V2 + \frac{R_F}{Rin}V3\right]$$

However, if all the input impedances, (Rin) are equal in value, we can simplify the above equation to give an output voltage of:

SUMMING AMPLIFIER EQUATION

$$-Vout = \frac{R_F}{R_{IN}}\left(V1 + V2 + V3 \ldots . etc\right)$$

We now have an operational amplifier circuit that will amplify each individual input voltage and produce an output voltage signal that is proportional to the algebraic "SUM" of the three individual input voltagesV_1, V_2 and V_3. We can also add more inputs if required as each individual input "see's" their respective resistance, Rin as the only input impedance.

This is because the input signals are effectively isolated from each other by the "virtual earth" node at the inverting input of the op-amp. A direct voltage addition can also be obtained when all the resistances are of equal value and R*f* is equal to Rin.

Note that when the summing point is connected to the inverting input of the op-amp the circuit will produce the negative sum of any number of input voltages. Likewise, when the summing point is connected to the non-inverting input of the op-amp, it will produce the positive sum of the input voltages.

A **Scaling Summing Amplifier** can be made if the individual input resistors are "NOT" equal. Then the equation would have to be modified to:

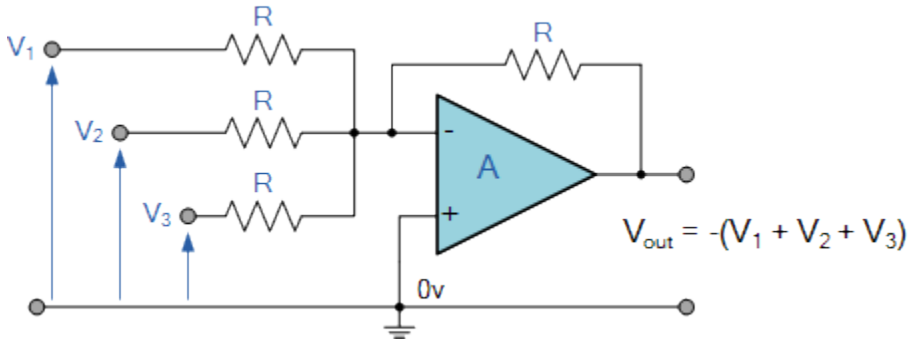
$$-Vout = V1\left(\frac{Rf}{R1}\right) + V2\left(\frac{Rf}{R2}\right) + V3\left(\frac{Rf}{R3}\right) \ldots.etc$$

To make the math's a little easier, we can rearrange the above formula to make the feedback resistor R_F the subject of the equation giving the output voltage as:

$$-Vout = Rf\left(\frac{V1}{R1} + \frac{V2}{R2} + \frac{V3}{R3}\right) \ldots.etc$$

This allows the output voltage to be easily calculated if more input resistors are connected to the amplifiers inverting input terminal. The input impedance of each individual channel is the value of their respective input resistors, ie, R_1, R_2, R_3 … etc.

Sometimes we need a summing circuit to just add together two or more voltage signals without any amplification. By putting all of the resistances of the circuit above to the same value R, the op-amp will have a voltage gain of unity and an output voltage equal to the direct sum of all the input voltages as shown:

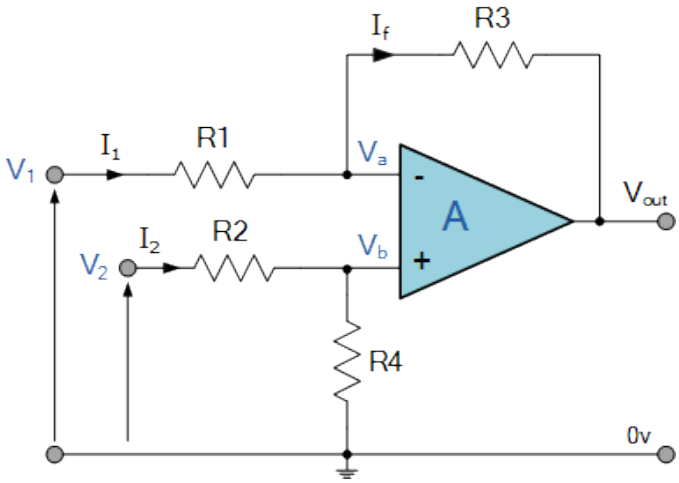


The **Summing Amplifier** is a very flexible circuit indeed, enabling us to effectively "Add" or "Sum" (hence its name) together several individual input signals. If the inputs resistors, R_1, R_2, R_3 etc, are all equal a "unity gain inverting adder" will be made. However, if the input resistors are of different values a "scaling summing amplifier" is produced which will output a weighted sum of the input signals.

The Differential Amplifier

Thus far we have used only one of the operational amplifiers inputs to connect to the amplifier, using either the "inverting" or the "non-inverting" input terminal to amplify a single input signal with the other input being connected to ground.

DIFFERENTIAL AMPLIFIER



By connecting each input in turn to 0v ground we can use superposition to solve for the output voltage Vout. Then the transfer function for a**Differential Amplifier** circuit is given as:

$$I_1 = \frac{V_1 - V_a}{R_1}, \quad I_2 = \frac{V_2 - V_b}{R_2}, \quad I_f = \frac{V_a - (V_{out})}{R_3}$$

$$\text{Summing point } V_a = V_b$$

$$\text{and } V_b = V_2\left(\frac{R_4}{R_2 + R_4}\right)$$

$$\text{If } V_2 = 0, \text{ then: } V_{out(a)} = -V_1\left(\frac{R_3}{R_1}\right)$$

$$\text{If } V_1 = 0, \text{ then: } V_{out(b)} = V_2\left(\frac{R_4}{R_2 + R_4}\right)\left(\frac{R_1 + R_3}{R_1}\right)$$

$$V_{out} = -V_{out(a)} + V_{out(b)}$$

$$\therefore V_{out} = -V_1\left(\frac{R_3}{R_1}\right) + V_2\left(\frac{R_4}{R_2 + R_4}\right)\left(\frac{R_1 + R_3}{R_1}\right)$$

When resistors, R1 = R2 and R3 = R4 the above transfer function for the differential amplifier can be simplified to the following expression:

DIFFERENTIAL AMPLIFIER EQUATION

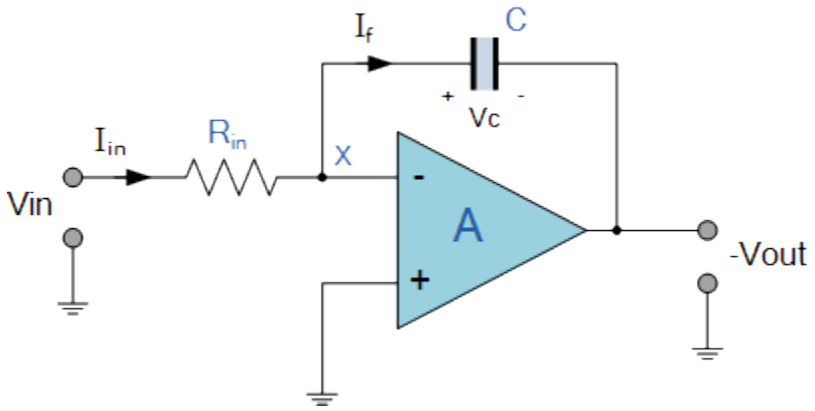
$$V_{OUT} = \frac{R_3}{R_1}\left(V_2 - V_1\right)$$

If all the resistors are all of the same ohmic value, that is: R1 = R2 = R3 = R4 then the circuit will become a **Unity Gain Differential Amplifier** and the voltage gain of the amplifier will be exactly one or unity. Then the output expression would simply be Vout = V2 – V1. Also note that if inputV1 is higher than input V2 the output voltage sum will be negative, and ifV2 is higher than V1, the output voltage sum will be positive.

THE INTEGRATOR AMPLIFIER

In the previous circuits which show how an operational amplifier can be used as part of a positive or negative feedback amplifier or as an adder or subtractor type circuit using just pure resistances in both the input and the feedback loop.

OP-AMP INTEGRATOR CIRCUIT



As its name implies, the **Op-amp Integrator** is an operational amplifier circuit that performs the mathematical operation of **Integration**, that is we can cause the output to respond to changes in the input voltage over time as the op-amp integrator produces an *output voltage which is proportional to the integral of the input voltage*.

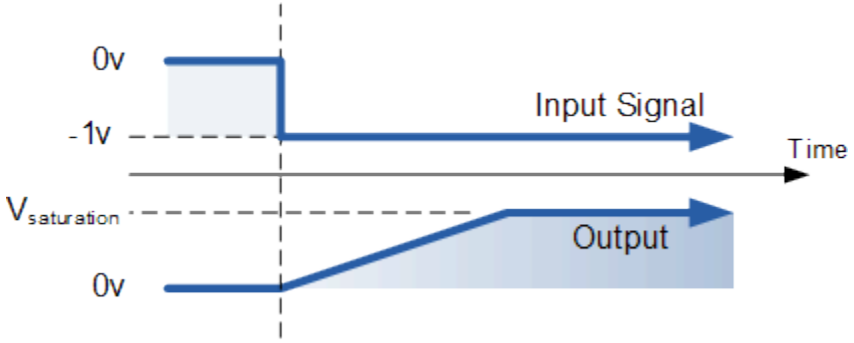
In other words the magnitude of the output signal is determined by the length of time a voltage is present at its input as the current through the feedback loop charges or discharges the capacitor as the required negative feedback occurs through the capacitor.

When a step voltage, Vin is firstly applied to the input of an integrating amplifier, the uncharged capacitor C has very little resistance and acts a bit like a short circuit allowing maximum current to flow via the input resistor, Rin as potential difference exists between the two plates. No current flows into the amplifiers input and point X is a virtual earth resulting in zero output. As the impedance of the capacitor at this point is very low, the gain ratio of Xc/Rin is also very small giving an overall voltage gain of less than one, (voltage follower circuit).

As the feedback capacitor, C begins to charge up due to the influence of the input voltage, its impedance Xc slowly increase in proportion to its rate of charge. The capacitor charges up at a rate determined by the RC time constant, (τ) of the series RC network. Negative feedback forces the op-amp to produce an output voltage that maintains a virtual earth at the op-amp's inverting input.

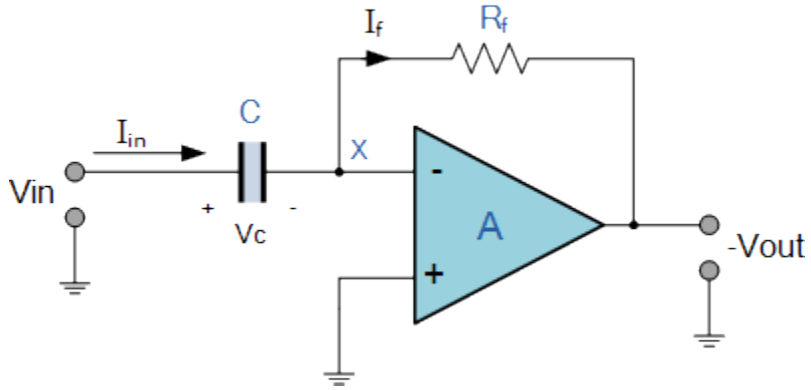
Since the capacitor is connected between the op-amp's inverting input (which is at earth potential) and the op-amp's output (which is negative), the potential voltage, Vc developed across the capacitor slowly increases causing the charging current to decrease as the impedance of the capacitor increases. This results in the ratio of Xc/Rin increasing producing a linearly increasing ramp output voltage that continues to increase until the capacitor is fully charged.

At this point the capacitor acts as an open circuit, blocking any more flow of DC current. The ratio of feedback capacitor to input resistor (Xc/Rin) is now infinite resulting in infinite gain. The result of this high gain (similar to the op-amps open-loop gain), is that the output of the amplifier goes into saturation as shown below. (Saturation occurs when the output voltage of the amplifier swings heavily to one voltage supply rail or the other with little or no control in between).



The rate at which the output voltage increases (the rate of change) is determined by the value of the resistor and the capacitor, "RC time constant". By changing this RC time constant value, either by changing the value of the Capacitor, C or the Resistor, R, the time in which it takes the output voltage to reach saturation can also be changed.

OP-AMP DIFFERENTIATOR CIRCUIT



The input signal to the differentiator is applied to the capacitor. The capacitor blocks any DC content so there is no current flow to the amplifier summing point, X resulting in zero output voltage. The capacitor only allows AC type input voltage changes to pass through and whose frequency is dependant on the rate of change of the input signal.

At low frequencies the reactance of the capacitor is "High" resulting in a low gain (R*f*/Xc) and low output voltage from the op-amp. At higher frequencies the reactance of the capacitor is much lower resulting in a higher gain and higher output voltage from the differentiator amplifier.

However, at high frequencies an op-amp differentiator circuit becomes unstable and will start to oscillate. This is due mainly to the first-order effect, which determines the frequency response of the op-amp circuit causing a second-order response which, at high frequencies gives an output voltage far higher than what would be expected. To avoid this the high frequency gain of the circuit needs to be reduced by adding an additional small value capacitor across the feedback resistor R*f*.

$$I_{IN} = I_F \text{ and } I_F = -\frac{V_{OUT}}{R_F}$$

The charge on the capacitor equals Capacitance x Voltage across the capacitor

$$Q = C \times V_{IN}$$

The rate of change of this charge is:

$$\frac{dQ}{dt} = C\frac{dV_{IN}}{dt}$$

but dQ/dt is the capacitor current,i

$$I_{IN} = C\frac{dV_{IN}}{dt} = I_F$$

$$\therefore -\frac{V_{OUT}}{R_F} = C\frac{dV_{IN}}{dt}$$

from which we have an ideal voltage output for the op-amp differentiator is given as:

$$V_{OUT} = -R_F C\frac{dV_{IN}}{dt}$$

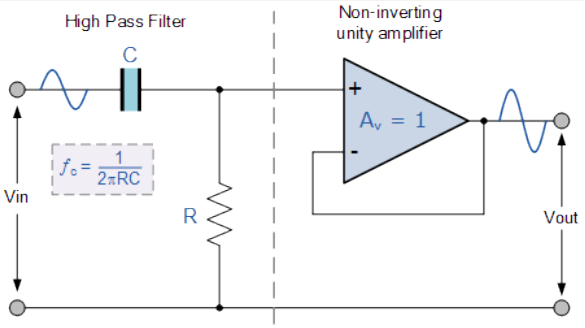
Therefore, the output voltage Vout is a constant -R*f*.C times the derivative of the input voltage Vin with respect to time. The minus sign indicates a 180^o phase shift because the input signal is connected to the inverting input terminal of the operational amplifier.

One final point to mention, the **Op-amp Differentiator** circuit in its basic form has two main disadvantages compared to the previous operational amplifier integrator circuit. One is that it suffers from instability at high frequencies as mentioned above, and the other is that the capacitive input makes it very susceptible to random noise signals and any noise or harmonics present in the source circuit will be amplified more than the input signal itself. This is because the output is proportional to the slope of the input voltage so some means of limiting the bandwidth in order to achieve closed-loop stability is required.

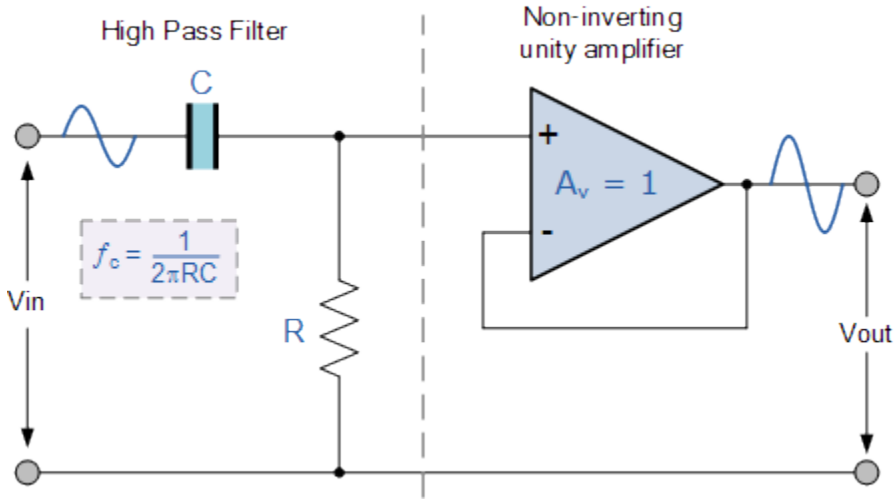
HIGH PASS FILTER

The basic operation of an **Active High Pass Filter** (HPF) is the same as for its equivalent RC passive high pass filter circuit, except this time the circuit has an operational amplifier or included within its design providing amplification and gain control

The simplest form of an*active high pass filter* is to connect a standard inverting or non-inverting operational amplifier to the basic RC high pass passive filter circuit as shown.



First Order High Pass Filter



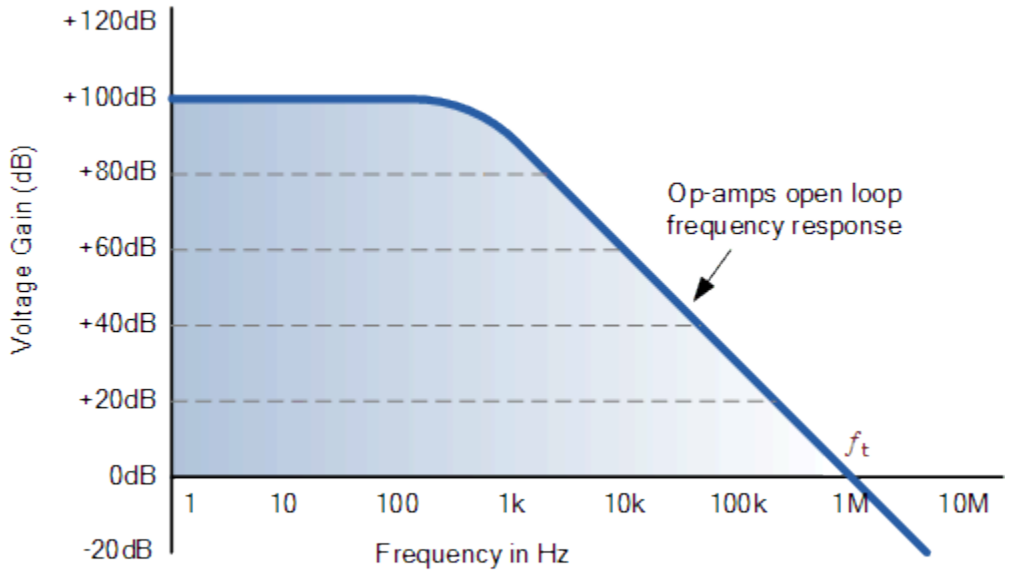
Technically, there is no such thing as an **active high pass filter**. Unlike Passive High Pass Filters which have an "infinite" frequency response, the maximum pass band frequency response of an active high pass filter is limited by the open-loop characteristics or bandwidth of the operational amplifier being used, making them appear as if they are band pass filters with a high frequency cut-off determined by the selection of op-amp and gain.

In the Operational Amplifier tutorial we saw that the maximum frequency response of an op-amp is limited to the Gain/Bandwidth product or open loop voltage gain (A_V) of the operational amplifier being used giving it a bandwidth limitation, where the closed loop response of the op amp intersects the open loop response.

A commonly available operational amplifier such as the uA741 has a typical "open-loop" (without any feedback) DC voltage gain of about 100dB maximum reducing at a roll off rate of -20dB/Decade (-6db/Octave) as the input frequency increases. The gain of the uA741 reduces

until it reaches unity gain, (0dB) or its "transition frequency" (ft) which is about 1MHz. This causes the op-amp to have a frequency response curve very similar to that of a first-order low pass filter and this is shown below.

FREQUENCY RESPONSE CURVE OF A TYPICAL OPERATIONAL AMPLIFIER.



Then the performance of a "high pass filter" at high frequencies is limited by this unity gain crossover frequency which determines the overall bandwidth of the open-loop amplifier. The gain-bandwidth product of the op-amp starts from around 100kHz for small signal amplifiers up to about 1GHz for high-speed digital video amplifiers and op-amp based active filters can achieve very good accuracy and performance provided that low tolerance resistors and capacitors are used.

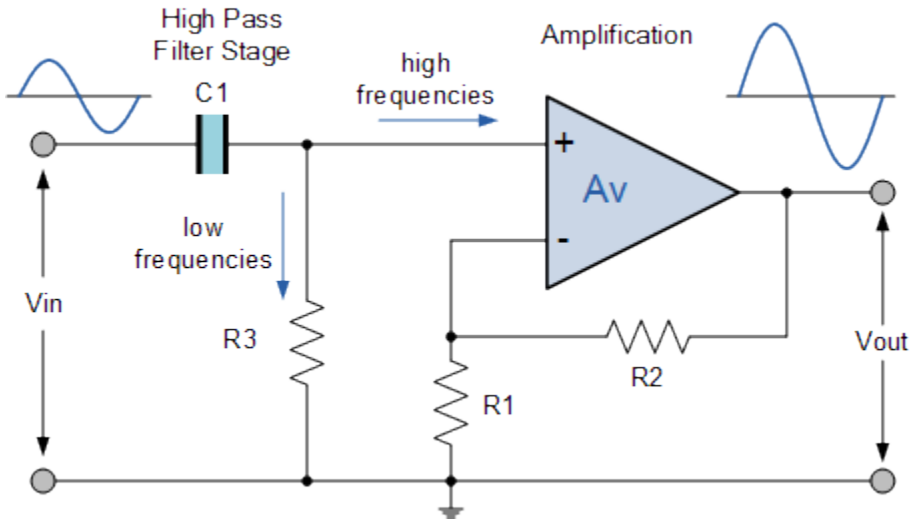
Under normal circumstances the maximum pass band required for a closed loop active high pass or band pass filter is well below that of the maximum open-loop transition frequency. However, when designing active filter circuits it is important to choose the correct op-amp for the circuit as the loss of high frequency signals may result in signal distortion.

ACTIVE HIGH PASS FILTER

A first-order (single-pole) **Active High Pass Filter** as its name implies, attenuates low frequencies and passes high frequency signals. It consists simply of a passive filter section followed by a non-inverting operational amplifier. The frequency response of the circuit is the

same as that of the passive filter, except that the amplitude of the signal is increased by the gain of the amplifier and for a non-inverting amplifier the value of the pass band voltage gain is given as 1 + R2/R1, the same as for the low pass filter circuit.

ACTIVE HIGH PASS FILTER WITH AMPLIFICATION



This *first-order high pass filter*, consists simply of a passive filter followed by a non-inverting amplifier. The frequency response of the circuit is the same as that of the passive filter, except that the amplitude of the signal is increased by the gain of the amplifier.

For a non-inverting amplifier circuit, the magnitude of the voltage gain for the filter is given as a function of the feedback resistor (R2) divided by its corresponding input resistor (R1) value and is given as:

Gain for an Active High Pass Filter

$$\text{Voltage Gain, (Av)} = \frac{\text{Vout}}{\text{Vin}} = \frac{A_F\left(\frac{f}{fc}\right)}{\sqrt{1+\left(\frac{f}{fc}\right)^2}}$$

- Where:
- A_F = the Pass band Gain of the filter, (1 + R2/R1)

- f = the Frequency of the Input Signal in Hertz, (Hz)
- fc = the Cut-off Frequency in Hertz, (Hz)

Just like the low pass filter, the operation of a high pass active filter can be verified from the frequency gain equation above as:

- 1. At very low frequencies, $f < f$c $\frac{Vout}{Vin} < A_F$
- 2. At the cut-off frequency, $f = f$c $\frac{Vout}{Vin} = \frac{A_F}{\sqrt{2}} = 0.707\,A_F$
- 3. At very high frequencies, $f > f$c $\frac{Vout}{Vin} \cong A_F$

Then, the **Active High Pass Filter** has a gain A_F that increases from 0Hz to the low frequency cut-off point, f_C at 20dB/decade as the frequency increases. At f_C the gain is $0.707A_F$, and after f_C all frequencies are pass band frequencies so the filter has a constant gain A_F with the highest frequency being determined by the closed loop bandwidth of the op-amp.

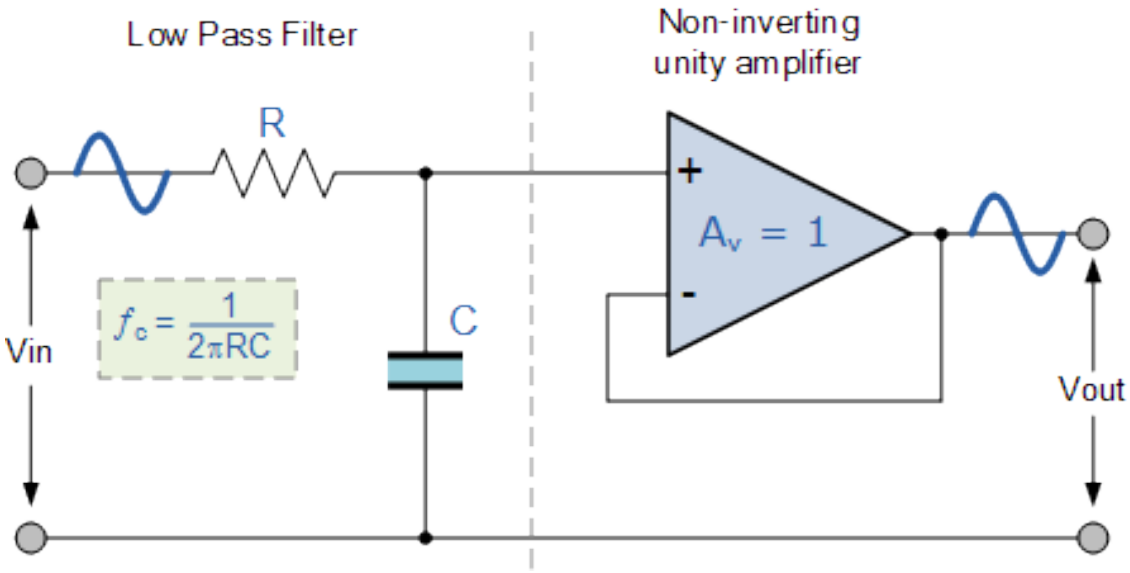
Active Low Pass Filter

In the RC Passive Filter tutorials, we saw how a basic first-order filter circuits, such as the low pass and the high pass filters can be made using just a single resistor in series with a non-polarized capacitor connected across a sinusoidal input signal.

ACTIVE LOW PASS FILTER

The most common and easily understood active filter is the **Active Low Pass Filter**. Its principle of operation and frequency response is exactly the same as those for the previously seen passive filter, the only difference this time is that it uses an op-amp for amplification and gain control. The simplest form of a low pass active filter is to connect an inverting or non-inverting amplifier, the same as those discussed in theOp-amp tutorial, to the basic RC low pass filter circuit as shown.

FIRST ORDER LOW PASS FILTER

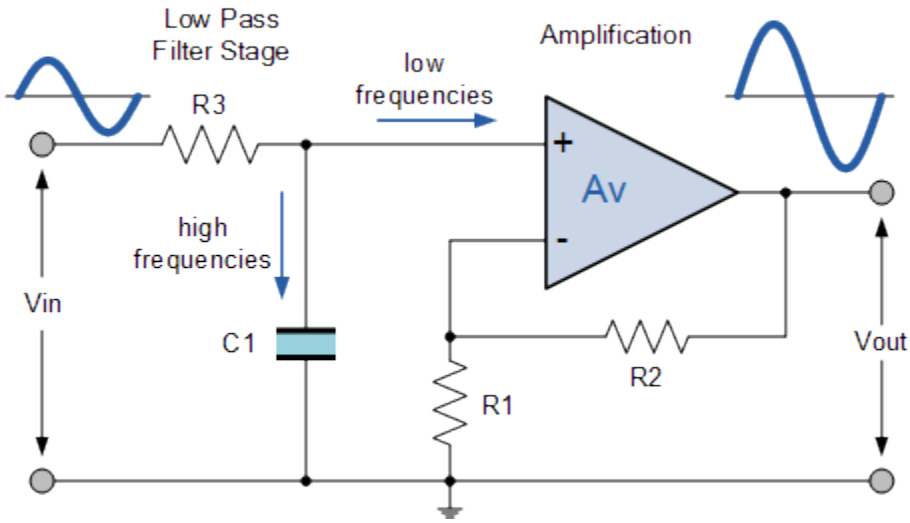


This first-order low pass active filter, consists simply of a passive RC filter stage providing a low frequency path to the input of a non-inverting operational amplifier. The amplifier is configured as a voltage-follower (Buffer) giving it a DC gain of one, Av = +1 or unity gain as opposed to the previous passive RC filter which has a DC gain of less than unity.

The advantage of this configuration is that the op-amps high input impedance prevents excessive loading on the filters output while its low output impedance prevents the filters cut-off frequency point from being affected by changes in the impedance of the load.

While this configuration provides good stability to the filter, its main disadvantage is that it has no voltage gain above one. However, although the voltage gain is unity the power gain is very high as its output impedance is much lower than its input impedance. If a voltage gain greater than one is required we can use the following filter circuit.

ACTIVE LOW PASS FILTER WITH AMPLIFICATION



The frequency response of the circuit will be the same as that for the passive RC filter, except that the amplitude of the output is increased by the pass band gain, A_F of the amplifier. For a non-inverting amplifier circuit, the magnitude of the voltage gain for the filter is given as a function of the feedback resistor (R_2) divided by its corresponding input resistor (R_1) value and is given as:

$$\text{DC gain} = \left(1 + \frac{R_2}{R_1}\right)$$

Therefore, the gain of an active low pass filter as a function of frequency will be:

GAIN OF A FIRST-ORDER LOW PASS FILTER

$$Voltage\ Gain, (Av) = \frac{Vout}{Vin} = \frac{A_F}{\sqrt{1 + \left(\frac{f}{fc}\right)^2}}$$

- Where:
- A_F = the pass band gain of the filter, (1 + R2/R1)
- f = the frequency of the input signal in Hertz, (Hz)

- fc = the cut-off frequency in Hertz, (Hz)

Thus, the operation of a low pass active filter can be verified from the frequency gain equation above as:

- 1. At very low frequencies, $f < f$c $\frac{Vout}{Vin} \cong A_F$
- 2. At the cut-off frequency, $f = f$c $\frac{Vout}{Vin} = \frac{A_F}{\sqrt{2}} = 0.707 A_F$
- 3. At very high frequencies, $f > f$c $\frac{Vout}{Vin} < A_F$

Thus, the **Active Low Pass Filter** has a constant gain A_F from 0Hz to the high frequency cut-off point, f_C. At f_C the gain is $0.707A_F$, and after f_C it decreases at a constant rate as the frequency increases. That is, when the frequency is increased tenfold (one decade), the voltage gain is divided by 10.

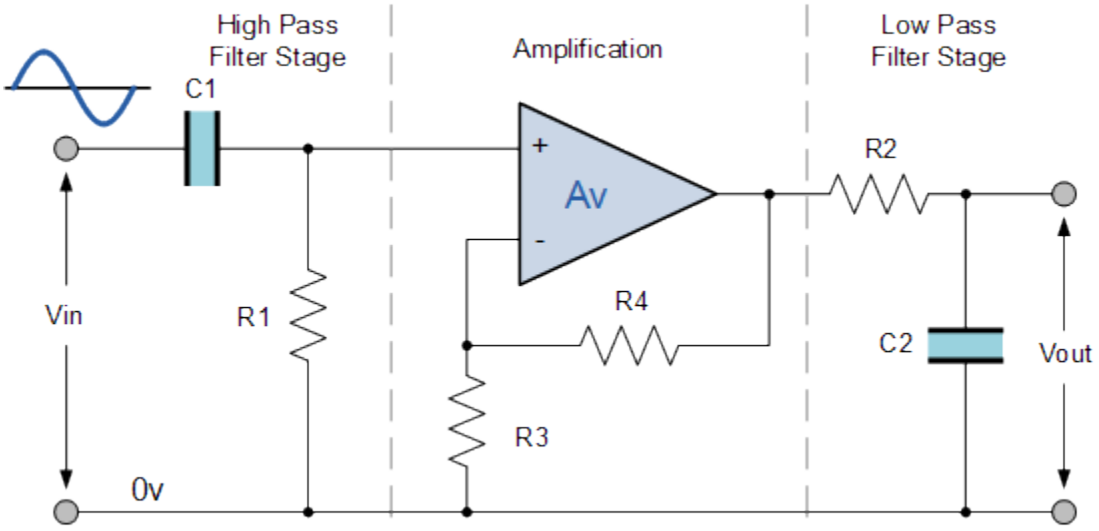
ACTIVE BAND PASS FILTER

The principal characteristic of a **Band Pass Filter** or any filter for that matter, is its ability to pass frequencies relatively unattenuated over a specified band or spread of frequencies called the "Pass Band".

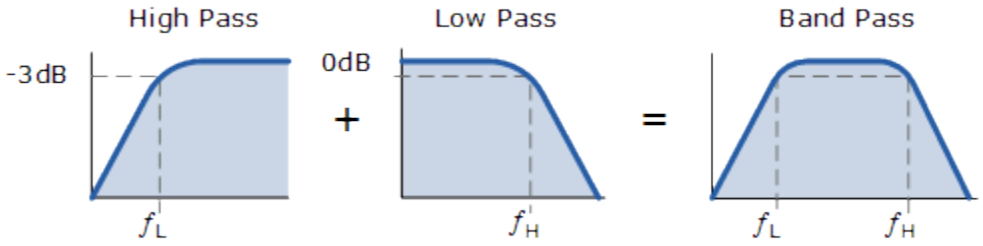
Simple **Active Band Pass Filter** can be easily made by cascading together a single Low Pass Filter with a single High Pass Filter as shown.

The cut-off or corner frequency of the low pass filter (LPF) is higher than the cut-off frequency of the high pass filter (HPF) and the difference between the frequencies at the -3dB point will determine the "bandwidth" of the band pass filter while attenuating any signals outside of these points. One way of making a very simple **Active Band Pass Filter**is to connect the basic passive high and low pass filters we look at previously to an amplifying op-amp circuit as shown.

ACTIVE BAND PASS FILTER CIRCUIT



This cascading together of the individual low and high pass passive filters produces a low "Q-factor" type filter circuit which has a wide pass band. The first stage of the filter will be the high pass stage that uses the capacitor to block any DC biasing from the source. This design has the advantage of producing a relatively flat asymmetrical pass band frequency response with one half representing the low pass response and the other half representing high pass response as shown.

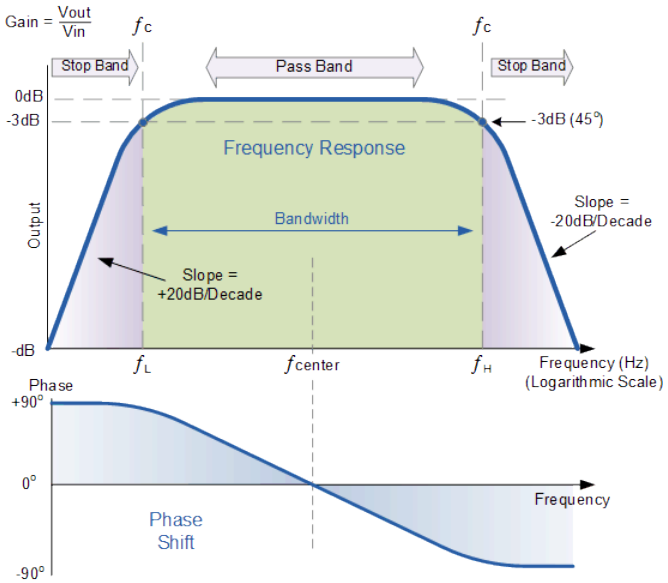


The higher corner point (f_H) as well as the lower corner frequency cut-off point (f_L) are calculated the same as before in the standard first-order low and high pass filter circuits. Obviously, a reasonable separation is required between the two cut-off points to prevent any interaction between the low pass and high pass stages. The amplifier also provides isolation between the two stages and defines the overall voltage gain of the circuit.

The bandwidth of the filter is therefore the difference between these upper and lower -3dB points. For example, suppose we have a band pass filter whose -3dB cut-off points are set at 200Hz and 600Hz. Then the bandwidth of the filter would be given as: Bandwidth (BW) = 600 – 200 = 400Hz.

The normalised frequency response and phase shift for an active band pass filter will be as follows.

ACTIVE BAND PASS FREQUENCY RESPONSE



While the above passive tuned filter circuit will work as a band pass filter, the pass band (bandwidth) can be quite wide and this may be a problem if we want to isolate a small band of frequencies. Active band pass filter can also be made using inverting operational amplifier.

So by rearranging the positions of the resistors and capacitors within the filter we can produce a much better filter circuit as shown below. For an active band pass filter, the lower cut-off -3dB point is given by f_{C1} while the upper cut-off -3dB point is given by f_{C2}.

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POSSIBLE QUESTIONS

UNIT-IV

1. Explain the characteristics of an Ideal and Practical Op-Amp.and Explain the concept of Virtual ground
2. Explain in Op amp principle with the help of block diagram
3. Explain in detail about Differentiator and Integrator
4. Explain in detail about inverting and non inverting amplifier.
5. Explain in detail about Adder and Subtractor
6. Explain the working principle of High Pass filter using IC 741 and plot the frequency response.
7. Explain the working principle of Low Pass filter using IC 741 and plot the frequency response.
8. Explain the working principle of Band Pass filter using IC 741 and plot the frequency response.
9. Explain in detail about schmitt trigger.

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DEPARTMENT OF PHYSICS

III B.SC PHYSICS **BATCH: 2015-2019**

BASIC ELECTRONICS (15PHU504)

MULTIPLE CHOICE QUESTIONS

Questions	opt1	opt2	opt3	opt4	Answer
UNIT IV					
CMRR stands for _____	Common Modulation Rejection Ratio	Common Mode Rejection Ratio	Collector Mode Resictor Ratio	Collector Mode Rejection Ratio	Common Mode Rejection Ratio
The range of the input common-mode voltage is_____	13V	12V	14V	10V	13V
Output Resistance of IC 741_____	60 Ohm	50 Ohm	75 Ohm	80 Ohm	75 Ohm
PSRR Stands for _____	Power Sector Resistance Range	Pulse Signal Rejetion Ratio	Power Supply Resictor Ratio	Power Supply Rejection Ratio	Power Supply Rejection Ratio
CMRR is typically _____dB	100dB	90dB	75dB	60dB	90dB
Built in short circuit protection is guaranteed to withstand_____of current	10 mA	50mA	25mA	100mA	25mA
Supply current in IC 741 is____mA	1.5	2.8	3.17	5.2	2.8
Power consumption in operational amplifier is_____	85mW	75mW	50mW	100mW	85mW
The slew rate of operational amplifier is_____	Zero	5V/uS	1.5V/uS	0.5V/uS	0.5V/uS
The small voltage applied at the input terminals to make output voltage zero is called_____	Input bias current	Thermal drift	Input offset voltage	Input offset current	Input offset voltage
The total number of Inputs in IC741____	1	2	3	4	2
The power supply voltage to op-amp may ranges from_____	5v to 12v	5v to 22v	9v to 12v	5v to 30v	5v to 22v
In operational amplifier pin 2 is called____	Power supply terminal	Inverting input terminal	Non inverting input terminal	Output treminal	Inverting input terminal
In operational amplifier pin 3 is called____	Power supply terminal	Inverting input terminal	Non inverting input terminal	Output treminal	Non inverting input terminal
In operational amplifier pin 6 is called____	Power supply terminal	Inverting input terminal	Non inverting input terminal	Output treminal	Output treminal
In operational amplifier pin 7 and 4 are connected to ____	Power supply terminal	Inverting input terminal	Non inverting input terminal	Output treminal	Power supply terminal
In operational amplifier pin 1 and 5 are used for____	dc offset	ac offset	Connect with AFO	Connect with power supply	dc offset
Operational amplifier have _____basic terminals	Two	Three	eight	one	eight
Operational amplifier have _____output impedance	High	Low	Zero	Infinite	Zero
Operational amplifier have _____open loop voltage gain	Infinite	Zero	High	Low	Infinite
Operational amplifier is a voltage controlled_____source	Current	Voltage	Amplifier	Convertor	Voltage
The operational amplifier is a_____ terminal device	Single	Multi	Duel	widely	Multi
The operating temperature range of IC 741 is__	0*C to 70*c	70*c to 100*c	>100*c	<0*c	0*C to 70*c
An ideal op-amp has no current from source and its response is independent of_____	Voltage	Noise	Current	Temperature	Temperature
An op-amp with open loop gain of 90dB with dc signal has gain of_____through audio and radio frequencies	70dB	80dB	90dB	100dB	90dB
The rate of which the voltage across the capacitor in operational amplifier is given by_____	I/C	C/I	V/I	I/V	I/C
The input offset voltage is measured is_____	V	KV	mV	uV	mV
The common mode rejection ratio is measured in____	V	mV	dB	uV	dB

The unit of slew rate is__	mV/sec	dB	V/uS	uV/Sec	V/uS
Op-amp IC 741 has a slew rate	Low	High	Moderate	Unity	Low
The open-loop gain of the op-amp decreases at the rate of____	(-10)dB decade	(-20)dB decade	(-30)dB decade	(-40)dB decade	(-20)dB decade
The _____ is a miniature, low cost electronic circuit consisting of active and passive components that are joined on a single crystal chip.	Integrated Resistor	Integrated Capacitor	Integrated Circuit	Integrated Inductor	Integrated Circuit
GSI stands for	Giant Scale Integration	Gun Scale Integration	Greater Scale Integration	Geometric Scale Integration	Giant Scale Integration
A small single crystal rod of silicon is called	Ingot	wafer	plasma	seed crystal	seed crystal
The Instrumentation amplifier is used in_____	Communication based circuits	Computer applications	Electronic circuits	industrial and consumer applications	industrial and consumer applications
The function of a _____ is used to compare the peak values of the input	Comparator	Encoder	Peak detector	Clipper	Peak detector
In differentiator the output waveform is the _____ of input waveform	Equal	Derivative	NonDerivative	Multiplier	Derivative
If we interchange the resistor and capacitor of the differentiator the circuit is _____	Integrated	Summing	Non-inverting	Inverting	Integrated
A_____ is used for low voltage dc and ac volt meter, LED and zener diode tester	V-I convertor	I-V converter	Peak detector	Comparator	V-I convertor
The reference voltage is set to zero in_____	Window detector	Zero crossing detector	Peak detector	Level detector	Zero crossing detector
The other name of zero crossing detector is_____	Triangular wave to square wave generator	Sine wave to square wave generator	Square wave to triangular wave generator	Square wave to sine wave generator	Sine wave to square wave generator
The sine wave to square wave generator is other wise known as____	Window detector	Zero crossing detector	Peak detector	Level detector	Zero crossing detector
The type of circuit in which unknown input is marked between 2 threshold levels is known as	Zero crossing detector	Level detector	Peak detector	Window detector	Window detector
The output of schmitt trigger circuit is _____	Sine wave	Square wave	Triangular	saw tooth wave	Square wave
Hysteresis in schmitt tigger is also known as____	Phase meter	Timer	Backlash	Regenarative	Backlash
Backlash refers to _____ phenomenon	Phase meter	Timer	Regenarative	Hysteresis	Hysteresis
In astable multivibrator,both the states are_____state	Bistable	Monostable	Quasi stable	Tri stable	Quasi stable
A _____ is a circuit which compares a signal voltage applied at one input of an op-amp with known reference voltage.	Rectifier	amplifier	Op-amp	Comparator	Comparator
The smallest amount of difference in voltage required at the inputs of comparator to make the output change its state is known as_____	Response time	Threshold	Accuracy	Resolution	Accuracy
Which converters uses integrating op-amp	Parallel A/D	Single slope A/D	Dual slop A/D	triple A/D	Dual slop A/D
A differential amplifier	is a part of an Op-amp	has one input and one output	has two outputs	is a part of an Op-amp& has one input and one output	is a part of an Op-amp& has one input and one output
When a differential amplifier is operated single-ended,	the output is grounded	one input is grounded and signal is applied to the other	both inputs are connected together	the output is not inverted	one input is grounded and signal is applied to the other
In differential-mode,	opposite polarity signals are applied to the inputs	the gain is one	the outputs are of different amplitudes	only one supply voltage is used	opposite polarity signals are applied to the inputs

In the common mode, ……	both inputs are grounded	the outputs are connected together	an identical signal appears on both the inputs	the output signal are in-phase	an identical signal appears on both the inputs
The Op-amp can amplify	a.c. signals only	d.c. signals only	a.c. and d.c. signals	neither d.c. nor a.c. signals	a.c. and d.c. signals
A comparator is an example of a(n)	current source	active filter	nonlinear circuit	linear circuit	nonlinear circuit
A digital-to-analog converter is an application of the	adjustable bandwidth circuit	voltage-to-current converter	scaling adder	noninverting amplifier	scaling adder
The ramp voltage at the output of an op-amp integrator	increases or decreases exponentially	increases or decreases at a linear rate	is constant	is always increasing and never decreasing	increases or decreases at a linear rate
Another name for a unity gain amplifier is:	difference amplifier	comparator	single ended	voltage follower	voltage follower
A noninverting closed-loop op-amp circuit generally has a gain factor:	<1	>1	0	1	>1
In order for an output to swing above and below a zero reference, the op-amp circuit requires:	a resistive feedback network	zero offset	a wide bandwidth	a negative and positive supply	a negative and positive supply
Input impedance [Z_{in}(I)] of an inverting amplifier is approximately equal to:	R_i	$R_f + R_i$	∞	$R_f - R_i$	R_i
The closed-loop voltage gain of an inverting amplifier equals:	the ratio of the input resistance to the feedback resistance	the open-loop voltage gain	the feedback resistance divided by the input resistance	the input resistance	the feedback resistance divided by the input resistance

UNIT V

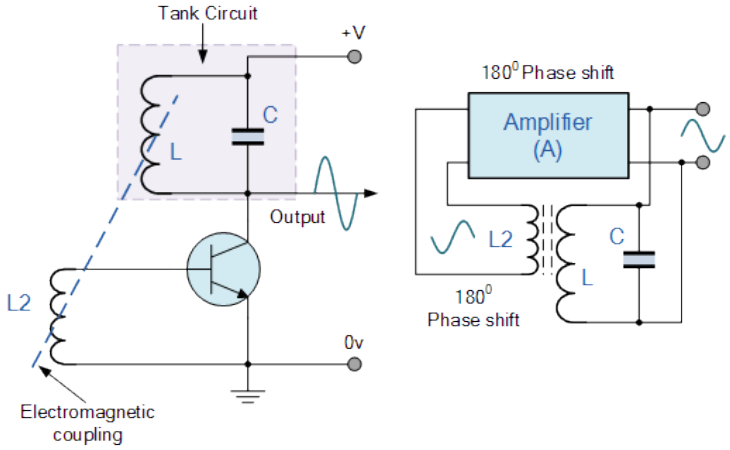
Oscillators

Oscillatory Circuits-LC, RC oscillators, tuned collector oscillator, Hartley, Colpitt's, phase shift Oscillators, Weinbridge oscillators. Multivibrators-Astable ,monostable and Bistablemultivibrtors(using 555 Timer)

Oscillators are used in many electronic circuits and systems providing the central "clock" signal that controls the sequential operation of the entire system.

Oscillators convert a DC input (the supply voltage) into an AC output (the waveform), which can have a wide range of different wave shapes and frequencies that can be either complicated in nature or simple sine waves depending upon the application.

Oscillators are also used in many pieces of test equipment producing either sinusoidal sine waves, square, sawtooth or triangular shaped waveforms or just a train of pulses of a variable or constant width. **LC Oscillators** are commonly used in radio-frequency circuits because of their good phase noise characteristics and their ease of implementation.



A Bipolar Transistor is used as the LC oscillators amplifier with the tuned LC tank circuit acts as the collector load. Another coil L2 is connected between the base and the emitter of the transistor whose electromagnetic field is "mutually" coupled with that of coil L.

"Mutual inductance" exists between the two circuits and the changing current flowing in one coil circuit induces, by electromagnetic induction, a potential voltage in the other (transformer effect) so as the oscillations occur in the tuned circuit, electromagnetic energy is transferred from coil L to coil L2 and a voltage of the same frequency as that in the tuned circuit is applied between the base and emitter of the transistor. In this way the necessary automatic feedback voltage is applied to the amplifying transistor.

The amount of feedback can be increased or decreased by altering the coupling between the two coils L and L2. When the circuit is oscillating its impedance is resistive and the collector and base voltages are 180^o out of phase. In order to maintain oscillations (called frequency stability) the voltage applied to the tuned circuit must be "in-phase" with the oscillations occurring in the tuned circuit.

Therefore, we must introduce an additional 180^o phase shift into the feedback path between the collector and the base. This is achieved by winding the coil of L2 in the correct direction relative to coil L giving us the correct amplitude and phase relationships for the **Oscillators** circuit or by connecting a phase shift network between the output and input of the amplifier.

The **LC Oscillator** is therefore a "Sinusoidal Oscillator" or a "Harmonic Oscillator" as it is more commonly called. LC oscillators can generate high frequency sine waves for use in radio frequency (RF) type applications with the transistor amplifier being of a Bipolar Transistor or FET.

Harmonic Oscillators come in many different forms because there are many different ways to construct an LC filter network and amplifier with the most common being the **Hartley LC Oscillator**, **Colpitts LC Oscillator**,**Armstrong Oscillator** and **Clapp Oscillator** to name a few.

RESONANT FREQUENCY OF A LC OSCILLATOR

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Where:

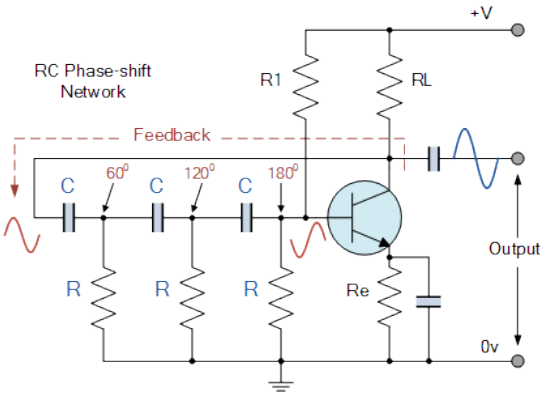
L is the Inductance in Henries

C is the Capacitance in Farads

fr is the Output Frequency in Hertz

This equation shows that if either L or C are decreased, the frequency increases. This output frequency is commonly given the abbreviation of (fr) to identify it as the "resonant frequency".

RC OSCILLATOR CIRCUIT



The basic **RC Oscillator** which is also known as a **Phase-shift Oscillator**, produces a sine wave output signal using regenerative feedback obtained from the resistor-capacitor combination. This regenerative feedback from the RC network is due to the ability of the capacitor to store an electric charge, (similar to the LC tank circuit).

This resistor-capacitor feedback network can be connected as shown above to produce a leading phase shift (phase advance network) or interchanged to produce a lagging phase shift (phase retard network) the outcome is still the same as the sine wave oscillations only occur at the frequency at which the overall phase-shift is 360^{o}.

By varying one or more of the resistors or capacitors in the phase-shift network, the frequency can be varied and generally this is done by keeping the resistors the same and using a 3-ganged variable capacitor.

If all the resistors, R and the capacitors, C in the phase shift network are equal in value, then the frequency of oscillations produced by the RC oscillator is given as:

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

Where:

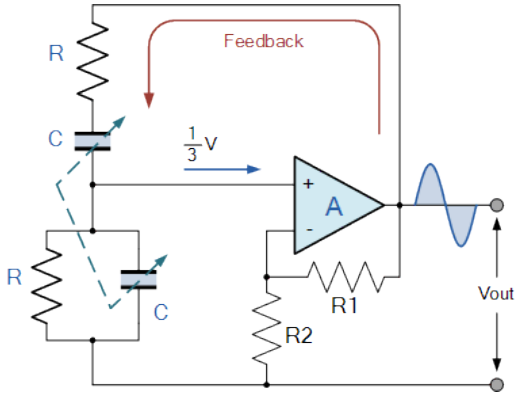
- f_r is the Output Frequency in Hertz
- R is the Resistance in Ohms
- C is the Capacitance in Farads
- N is the number of RC stages. (N = 3)

Since the resistor-capacitor combination in the **RC Oscillator** circuit also acts as an attenuator producing an attenuation of -1/29th (Vo/Vi = β) per stage, the gain of the amplifier must be sufficient to overcome the circuit losses. Therefore, in our three stage RC network above the amplifier gain must be greater than 29.

The loading effect of the amplifier on the feedback network has an effect on the frequency of oscillations and can cause the oscillator frequency to be up to 25% higher than calculated. Then the feedback network should be driven from a high impedance output source and fed into a low impedance load such as a common emitter transistor amplifier but better still is to use an **Operational Amplifier** as it satisfies these conditions perfectly.

WIEN BRIDGE OSCILLATOR.

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 called a Wien Bridge 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 or degenerative 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, which forms the series and parallel combinations of R and C forms the feedback network and are fed back to the non-inverting input terminal (positive or regenerative feedback) via the RC Wien Bridge network and it is this positive feedback combination that gives rise to the oscillation.

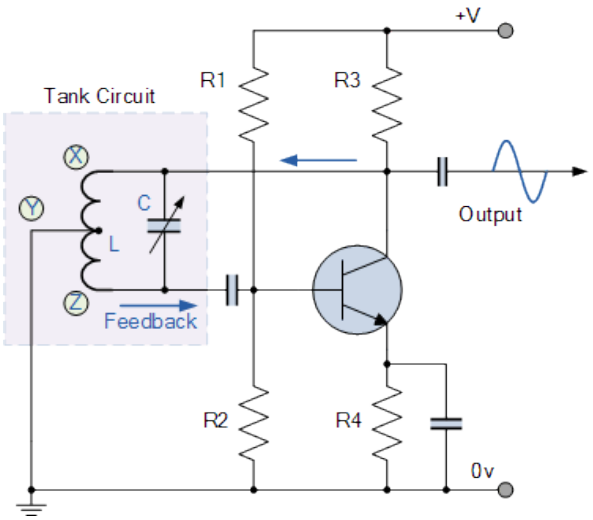
The RC network is connected in the positive feedback path of the amplifier and has zero phase shift a just one frequency. Then at the selected resonant frequency, (fr) the voltages applied to the inverting and non-inverting inputs will be equal and "in-phase" so the positive feedback will cancel out the negative feedback signal causing the circuit to oscillate.

The voltage gain of the amplifier circuit MUST be equal to or greater than three "Gain = 3" for oscillations to start because as we have seen above, the input is 1/3 of the output. This value, ($Av \geq 3$) is set by the feedback resistor network, R1 and R2 and for a non-inverting amplifier this is given as the ratio 1+(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.

HARTLEY OSCILLATOR

The Hartley Oscillator design uses two inductive coils in series with a parallel capacitor to form its resonance tank circuit and produce sinusoidal oscillations.



When the circuit is oscillating, the voltage at point X (collector), relative to point Y (emitter), is 180° 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.

Then there is a 180° phase change in the voltage between the Base and Collector and this along with the original 180° phase shift in the feedback loop provides the correct phase relationship of positive feedback for oscillations to be maintained.

The amount of feedback depends upon the position of the "tapping point" of the inductor. If this is moved nearer to the collector the amount of feedback is increased, but the output taken between the Collector and earth is reduced and vice versa. Resistors, R1 and R2 provide the usual stabilizing DC bias for the transistor in the normal manner while the capacitors act as DC-blocking capacitors.

In this **Hartley Oscillator** circuit, the DC Collector current flows through part of the coil and for this reason the circuit is said to be "Series-fed" with the frequency of oscillation of the Hartley Oscillator being given as.

$$f = \frac{1}{2\pi\sqrt{L_T C}}$$

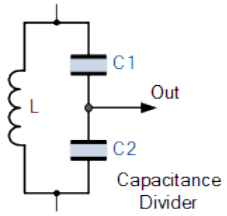
where: $L_T = L_1 + L_2 + 2M$

Note: L_T is the total cumulatively coupled inductance if two separate coils are used including their mutual inductance, M.

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.

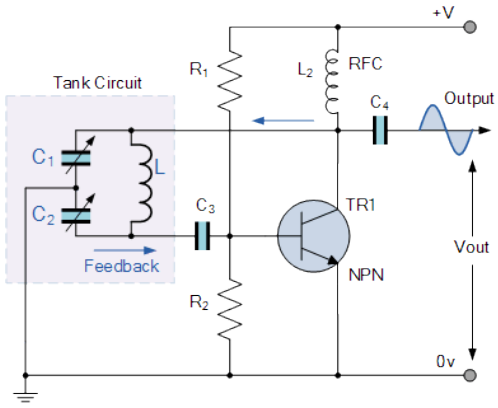
THE COLPITTS OSCILLATOR

The Colpitts Oscillator design uses two centre-tapped capacitors in series with a parallel inductor to form its resonance tank circuit and produce sinusoidal oscillations.



The Colpitts oscillator uses a capacitive voltage divider network as its feedback source. The two capacitors, C1 and C2 are placed across a single common inductor, L as shown. Then C1, C2 and Lform the tuned tank circuit with the condition for oscillations being: $X_{C1} + X_{C2} = X_L$, the same as for the Hartley oscillator circuit.

The advantage of this type of capacitive circuit configuration is that with less self and mutual inductance within the tank circuit, frequency stability of the oscillator is improved along with a more simple design.



The emitter terminal of the transistor is effectively connected to the junction of the two 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.

Resistors, R1 and R2 provide the usual stabilizing DC bias for the transistor in the normal manner while the additional capacitors act as a DC-blocking bypass capacitors. A radio-frequency choke (RFC) is used in the collector circuit to provide a high reactance (ideally open circuit) at the frequency of oscillation, (fr) and a low resistance at DC to help start the oscillations.

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 undamped oscillations. The amount of feedback is determined by the ratio of C1 and C2. These two capacitances are generally "ganged" together to provide a constant amount of feedback so that 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 or 360^o.

The amount of feedback depends on the values of C1 and C2. We can see that the voltage across C1 is the the same as the oscillators output voltage,Vout and that the voltage across C2 is the oscillators feedback voltage. Then the voltage across C1 will be much greater than that across C2.

Therefore, by changing the values of capacitors, C1 and C2 we can adjust the amount of feedback voltage returned to the tank circuit. However, large amounts of feedback may cause the output sine wave to become distorted, while small amounts of feedback may not allow the circuit to oscillate.

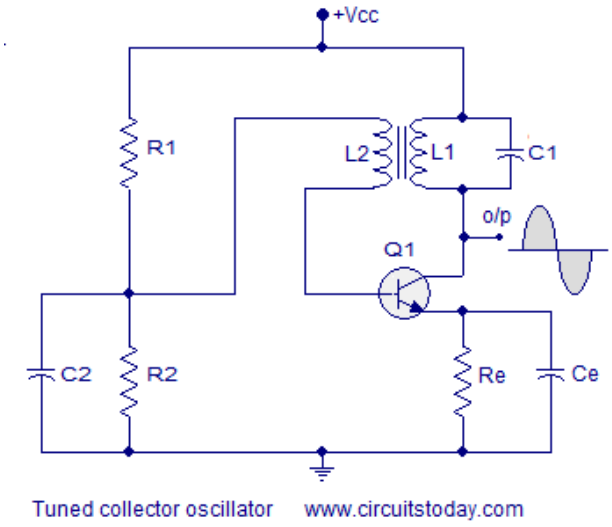
Then the amount of feedback developed by the Colpitts oscillator is based on the capacitance ratio of C1 and C2 and is what governs the the excitation of the oscillator. This ratio is called the "feedback fraction" and is given simply as:

$$\text{Feedback Fraction} = \frac{C_1}{C_2}\,\%$$

TUNED COLLECTOR OSCILLATOR.

Tuned collector oscillation is a type of transistor LC oscillator where the tuned circuit (tank) consists of a transformer and a capacitor is connected in the collector circuit of the transistor. Tuned collector oscillator is of course the simplest and the basic type of LC oscillators. The tuned circuit connected at the collector circuit behaves like a purely resistive load at resonance and determines the oscillator frequency.The common applications of tuned collector oscillator are RF oscillator circuits, mixers, frequency demodulators, signal generators etc. The circuit diagram of a conventional tuned collector oscillator is shown in the figure below.

CIRCUIT DIAGRAM.



Tuned collector oscillator www.circuitstoday.com

In the circuit diagram resistor R1 and R2 forms a voltage divider bias for the transistor. Re is the emitter resistor which is meant for thermal stability. It also limits the collector current of the transistor. Ce is the emitter by-pass capacitor. The job of Ce is to by-pass the amplified oscillations. If Ce is not there, the amplified AC oscillations will drop across Re and will add on to the base-emitter voltage (Vbe) of the transistor and this will alter the DC biasing conditions. Capacitor C1 and primary of the transformer L1 forms the tank circuit. C2 is the by-pass capacitor for resistor R2.

WORKING OF THE TUNED COLLECTOR OSCILLATOR.

When the power supply is switched ON, the transistor starts conducting and the capacitor C1 starts charging. When the capacitor is fully charged, it starts discharging through the primary coil L1. When the capacitor is fully discharged, the energy stored in the capacitor as electrostatic field will be moved to the inductor as electromagnetic field. Now there will be no more voltage across the capacitor to keep the current through the coil starts to collapse. In order to oppose this the coil L1 generates a back emf (by electromagnetic induction) and this back emf charges the capacitor again. Then capacitor discharges through the coil and the cycle is repeated. This charging and discharging sets up a series of oscillations in the tank circuit.

The oscillations produced in the tank circuit is fed back to the base of transistor Q1 by the secondary coil by inductive coupling. The amount of feedback can be adjusted by varying the turns ratio of the transformer. The winding direction of the secondary coil (L2) is in such a way that the voltage across it will be 180° phase opposite to that of the voltage across primary (L1). Thus the feedback circuit produces a phase shift of 180° and the transistor alone produces a phase shift of another 180°. As a result a total phase shift of 360° is obtained between input and output and it is a very necessary condition for positive feedback and sustained oscillations.

The collector current of the transistor compensates the energy lost in the tank circuit. This is done by taking a small amount of voltage from the tank circuit, amplifying it and applying it back to the tank circuit. Capacitor C1 can be made variable in variable frequency applications.

The frequency of oscillations of the tank circuit can be expressed using the following equation:

$$F = 1/[2\pi\sqrt{(L1C1)}]$$

Where

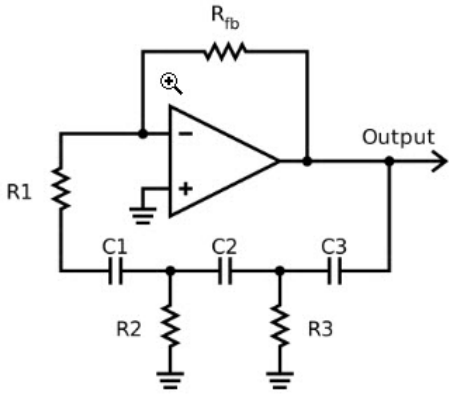
F is the frequency of oscillation.

L1 is the inductance of the transformer primary and

C1 is the capacitance.

RC Phase Shift Oscillator Using Op-Amp

An RC phase shift oscillator is a sinusoidal oscillator used to produce the well shaped sine wave oscillations. This oscillator is used in numerous applications like as a local oscillator for synchronous receivers, study purposes, musical instruments. The essential component used in an RC phase shift oscillator is an operational amplifier inverting amplifier with its output fed back into its input using a regenerative feedback RC filter n/w, hence the name is called an RC phase shift oscillator. The frequency of oscillations can be changed by changing the capacitor.



he feedback RC network has a phase shift of 60 degrees each, hence the total phase shift provided by the three RC network is 180 degrees. The op amp is connected as an inverting amplifier, so hence the total phase shift around the loop will be 360 degrees. This condition is essential for continued oscillations.

Working of RC Phase Shift Oscillator

- The feedback network offers 1800 phase shift at the oscillation frequency and the operational amplifier is arranged as an Inverting amplifier, and it also provide 180 degrees phase shift. Hence, the total phase shift around the loop is 360 degrees, it is essential for sustained oscillations.
- At the oscillation frequency each of the capacitor, resistor, filter produces a phase shift of 60° so the whole filter circuit generates 180° of a phase shift of.
- The energy storage capacity of a capacitor in this circuit produces a noise voltage which is like to a small sine wave, it is then amplified using an op amp inverting amplifier.
- By taking feedback, the o/p sine wave also reduces 1/29 times while passing through the RC network, so the gain of the inverting amplifier should be 29 in order to keep the loop gain as unity.
- The unity loop gain and 360 degree phase shift are essential for the continued oscillation.
- RC Oscillators are constant and provide a well shaped sine wave output with the frequency being proportional to 1/RC and therefore, when we are using a variable capacitor a wide frequency range is possible.

MULTIVIBRATORS

Individual **Sequential Logic** circuits can be used to build more complex circuits such as Multivibrators, Counters, Shift Registers, Latches and Memories.

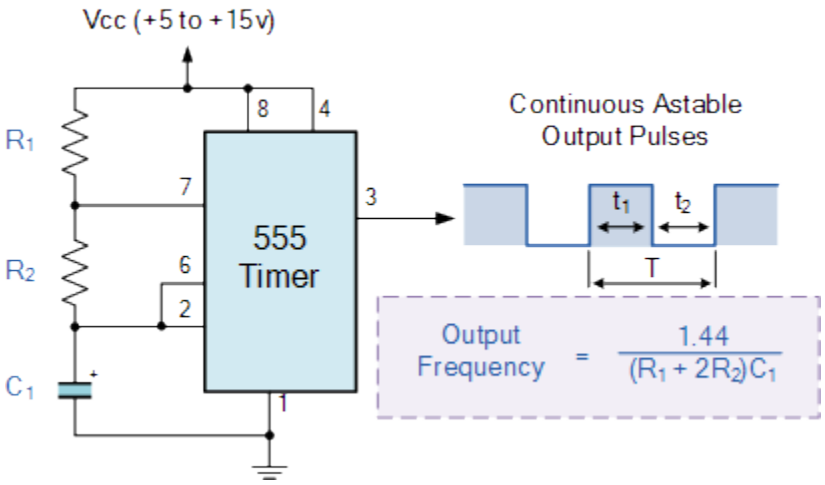
- Astable – A *free-running multivibrator* that has **NO** stable states but switches continuously between two states this action produces a train of square wave pulses at a fixed frequency.

- Monostable – A *one-shot multivibrator* that has only **ONE**stable state and is triggered externally with it returning back to its first stable state.
- Bistable – A *flip-flop* that has **TWO** stable states that produces a single pulse either positive or negative in value.

ASTABLE MULTIVIBRATOR USING 555 TIMER

An Astable Multivibrator is an oscillator circuit that continuously produces rectangular wave without the aid of external triggering. So Astable Multivibrator is also known as Free Running Multivibrator.

Astable Multivibrator using 555 – Circuit



Astable Multivibrator using 555 Timer Circuit Diagram

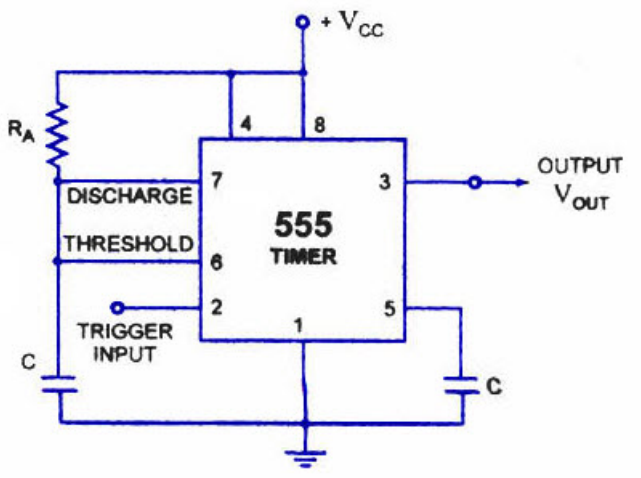
Above figure shows the circuit diagram of a 555 Timer wired in Astable Mode. 8th pin and 1st pin of the IC are used to give power, Vcc and GND respectively. The 4th pin is RESET pin which is active low and is connected to Vcc to avoid accidental resets. 5th pin is the Control Voltage pin which is not used. So to avoid high frequency noises it is connected to a capacitor C' whose other end is connected to ground. Usually C' = 0.01μF. The Trigger (pin 2) and Threshold (pin 6) inputs are connected to the capacitor which determines the output of the timer. Discharge pin (pin 7) is connected to the resistor Rb such that the capacitor can discharge through Rb. Diode D connected in parallel to Rb is only used when an output of duty cycle less than or equal to 50% is required. For the sake of explaing the working Circuit Diagram with Internal Block diagram is shown below.

Working

- When the circuit is switched ON, the capacitor (C) voltage will be less than 1/3 Vcc. So the output of the lower comparator will be HIGH and of the higher comparator will be LOW. This SETs the output of the SR Flip-flop.
- Thus the discharging transistor will be OFF and the capacitor C starts charging from Vcc through resistor Ra & Rb.
- When the capacitor voltage will become greater than 1/3 Vcc (less than 2/3 Vcc), the output of both comparators will be LOW and the output of SR Flip-flop will be same as the previous condition. Thus the capacitor continuous to charge.
- When the capacitor voltage will becomes slightly greater than 2/3 Vcc the output of the higher comparator will be HIGH and of lower comparator will be LOW. This resets the SR Flip-flop.
- Thus the discharging transistor turns ON and the capacitor starts discharging through resistor Rb.
- Soon the capacitor voltage will be less than 2/3 Vcc and output of both comparators will be LOW. So the output of the SR Flip-flop will be the previous state.
- So the discharging of capacitor continuous.
- When the capacitor voltage will become less than 1/3 Vcc, the output SETs since the output of lower comparator is HIGH and of higher comparator is LOW and the capacitor starts charging again.
- This process continuous and a rectangular wave will be obtained at the output.

MONOSTABLE MULTIVIBRATOR USING 555 TIMER

Monostable Multivibrator is also known as One Short Multivibrator. As its name indicates it has one stable state and it switches to unstable state for a predetermined time period T when it is triggered. The time period T is determined by the RC time constant in the circuit. Monostable mode of 555 Timer is commonly used for generating Pulse Width Modulated(PWM) waves.



This is the circuit diagram of 555 Timer wired in Monostable mode. 8th pin and 1stpin of the 555 timer are used to given power Vcc and Ground respectively. 4th pin is the Reset pin of 555 Timer, which is active low so it is connected to Vcc to avoid accidental resets. 5th pin is the Control Voltage pin used to provide external reference voltage to internal comparators. Since it is not used here, it is grounded via a capacitor C' (0.01µF) to avoid high frequency noises. When a negative trigger is applied on the Trigger input of 555, output goes high and capacitor starts charging through resistor R. When the capacitor voltage becomes greater than 2/3 Vcc, ouput goes low and capacitor starts discharging through the Discharge pin of 555 Timer. Time period of the unstable state is given the tye expression, T = 1.1RC.

WORKING

- The Monostable Multivibrator will be in its stable state (Output LOW) until it is triggered.
- When a negative trigger is applied to the Trigger pin of 555 Timer, output of lower comparator will become HIGH and output of upper comparator will be LOW, since the capacitor voltage is zero. This makes the output HIGH.
- The Discharge transistor turns OFF and the capacitor starts charges through resistor R to Vcc.

- After the negative trigger, output of lower comparator becomes LOW and that of upper comparator remains LOW. Since both inputs of the SR Flip Flop are LOW, output will not change, so the output is HIGH.
- When the capacitor voltage will become greater than 2/3 Vcc, output of upper comparator becomes HIGH and that of lower comparator remains LOW, so the output becomes LOW.
- This turns ON the discharge transistor and the capacitor discharges.
- The circuit remains in its stable state (Output LOW) until next trigger occurs.

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POSSIBLE QUESTIONS

UNIT-V

EIGHT MARK QUESTIONS

1. Explain the working principle of RC Phase shift oscillator.
2. Explain working principle of Colpitts oscillators with diagram
3. Explain working principle of Hartley oscillators with diagram
4. Explain working principle of Wein Bridge oscillators with diagram
5. Explain working principle of Astable mutlivibrator using 555 timer.
6. Explain working principle of Monostable mutlivibrator using 555 timer.
7. Explain working principle of Bistable mutlivibrator using 555 timer.

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DEPARTMENT OF PHYSICS

III B.SC PHYSICS **BATCH: 2015-2019**

BASIC ELECTRONICS (15PHU504)

MULTIPLE CHOICE QUESTIONS

Questions	opt1	opt2	opt3	opt4	Answer
UNIT I					
. An oscillator produces……. oscillations	Damped	Undamped	Modulated	unmodulated	Undamped
An oscillator employs …… feedback	Positive	Negative	Neither positive nor negative	Data insufficient	Positive
Hartley oscillator is commonly used in …	Radio receivers	Radio transmitters	TV receivers	transmitters	Radio receivers
In a phase shift oscillator, we use ……. RC sections	1	23	2	3	3
In a phase shift oscillator, the frequency determining elements are	L and C	R, L and C	R and C	R and L	R and C
An oscillator differs from an amplifier because it	Has more gain	Requires no input signal	Requires no d.c. supply	Always has the same input	Requires no input signal
One condition for oscillation is	A phase shift around the feedback loop of 180o	A gain around the feedback loop of one-third	A phase shift around the feedback loop of 0o	A gain around the feedback loop of less than 1	A phase shift around the feedback loop of 0o
A second condition for oscillations is …	A gain of 1 around the feedback loop	No gain around the feedback loop	The attention of the feedback circuit must be one-third	The feedback circuit must be capacitive	A gain of 1 around the feedback loop
For an oscillator to properly start, the gain around the feedback loop must initially be	1	>1	<1	0	>1
In Colpitt's oscillator, feedback is obtained …	By magnetic induction	By a tickler coil	. From the centre of split capacitors	by self induction	From the centre of split capacitors
…….. is a fixed frequency oscillator	Phase-shift oscillator	Hartely-oscillator	Colpitt's oscillator	Crystal oscillator	Crystal oscillator
An oscillator converts …	dc. power into d.c. power	.d c. power into a.c. power	mechanical power into a.c. power	ac to ac	.d c. power into a.c. power
In an LC transistor oscillator, the active device is …	LC tank circuit	Biasing circuit	Transistor	transformer	Transistor
In an LC circuit, when the capacitor is maximum, the inductor energy is	. Minimum	Maximum	Half-way between maximum and minimum	moderate	Minimum
In an LC oscillator, the frequency of oscillator is ……. L or C.	Proportional to square of	Directly proportional to	Independent of the values of	Inversely proportional to square root of	Inversely proportional to square root of
An LC oscillator cannot be used to produce …….. frequencies	High	Audio	Very low	Very high	Very low
Quartz crystal is most commonly used in crystal oscillators because	It has superior electrical properties	It is easily available	It is quite inexpensive	very costly	It has superior electrical properties
The signal generator generally used in the laboratories is …….. oscillator	Wien-bridge	Hartely	Crystal	Phase shift	Wien-bridge
An important limitation of a crystal oscillator is …	Its low output	Its high Q	Less availability of quartz crystal	Its high output	Its low output
In an LC oscillator, if the value of L is increased four times, the frequency of oscillations is	Increased 2 times	Decreased 4 time	Increased 4 times	Decreased 2 times	Decreased 2 times
All of the following are basic op-amp input modes of operation EXCEPT	inverting mode	common-mode	double-ended	single-ended	inverting mode
A circuit whose output is proportional to the difference between the input signals is considered to be which type of amplifier?	common-mode	double-ended	darlington	differential	differential
If the input to a comparator is a sine wave, the output is a:	ramp voltage	sine wave	rectangular wave	sawtooth wave	rectangular wave

The major difference between ground and virtual ground is that virtual ground is only a	voltage reference	current reference	power reference	difference reference	voltage reference
The Schmitt trigger is a two-state device that is used for:	pulse shaping	peak detection	input noise rejection	filtering	pulse shaping
When a capacitor is used in place of a resistor in an op-amp network, its placement determines:	open- or closed-loop gain	integration or differentiation	saturation or cutoff	addition or subtraction	integration or differentiation
An output that is proportional to the addition of two or more inputs is from which type of amplifier?	differentiator	difference	summing	analog subtractor	summing
An ideal amplifier should have:	high input current	zero offset	high output impedance	moderate gain	zero offset
Which of the following is a type of error associated with digital-to-analog converters (DACs)?	nonmonotonic error	incorrect output codes	offset error	nonmonotonic and offset error	nonmonotonic and offset error
A 4-bit R/2R digital-to-analog (DAC) converter has a reference of 5 volts. What is the analog output for the input code 0101.	3.125	0.3125	30.12	312.5	3.125
Ω binary-weighted digital-to-analog converter has an input resistor of 100 k. If the resistor is connected to a 5 V source, the current through the resistor is:	50 micro A	5000A	50mA	5mA	50 micro A
The practical use of binary-weighted digital-to-analog converters is limited to:	R/2R ladder D/A converters	4-bit D/A converters	8-bit D/A converters	op-amp comparators	4-bit D/A converters
The difference between analog voltage represented by two adjacent digital codes, or the analog step size, is the:	quantization	accuracy	resolution	monotonicity	resolution
The primary disadvantage of the flash analog-to digital converter (ADC) is that:	it requires the input voltage to be applied to the inputs simultaneously	a long conversion time is required	a large number of output lines is required to simultaneously decode the input voltage	a large number of comparators is required to represent a reasonable sized binary number	a large number of comparators is required to represent a reasonable sized binary number
What is the major advantage of the R/2R ladder digital-to-analog (DAC), as compared to a binary-weighted digital-to-analog DAC converter?	It only uses two different resistor values.	It has fewer parts for the same number of inputs.	Its operation is much easier to analyze.	The virtual ground is eliminated and the circuit is therefore easier to understand and troubleshoot.	It only uses two different resistor values.
The resolution of a 0–5 V 6-bit digital-to-analog converter (DAC) is:	64%	63%	1.56%	15.60%	1.56%
Which is not an analog-to-digital (ADC) conversion error?	differential nonlinearity	missing code	incorrect code	offset	differential nonlinearity

PREPARED BY: Mrs. A. SAHANA FATHIMA, ASSISTANT PROFESSOR, DEPARTMENT OF PHYSICS, KAHE-CBE-21

Reg. No……..

[15PHU504]

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Under Section 3 of UGC Act 1956)

COIMBATORE -641 201

(For the candidates admitted from 2015 onwards)

I INTERNAL EXAMINATIONS, AUGUST - 2017

Fifth Semester

III B.Sc PHYSICS

BASIC ELECTRONICS

Time: 2 hours Maximum: 50 marks

PART-A (20 x 1 = 20 Marks)

Answer all the questions

1. A crystal diode has
   a**.one pn junction** b. two pn junctions c. three pn junctions d. four pn junctions
2. A zener diode has ……..
   a. **one pn junction** b. two pn junctions c. three pn junctions d. four pn junctions
3. A zener diode is ……. device
   a a non-linear b. a linear c an amplifying d. none of the above
4. A transistor is a …… operated device
   a**. current** b. voltage c. both voltage and current d. none of the above
5. The base of a transistor is …….. doped
   a.heavily b. moderately c**. lightly** d. volume
6. There are …… *h* parameters of a transistor
   a. 2 **b. 3** c. 4 d. 5
7. An ideal crystal diode is one which behaves as a perfect …….. when forward biased
   a.conductor b. insulator c. resistance material d. none of the above
8. The leakage current in a crystal diode is due to …….
   a. . **minority carriers** b. majority carriers c. junction capacitance d. none of the above
9. If the temperature of a crystal diode increases, then leakage current ……..
   a. remains the same b. decreases c. **increases** d. becomes zero
10. The knee voltage of a crystal diode is approximately
    a.applied voltage b**. breakdown voltage** c. forward voltage d. barrier potential
11. The voltage gain in a transistor connected in ……. arrangement is the highest
    a.CE b. CB c. CC d. CBE
12. The emitter of a transistor is …… doped
    a. heavily b. moderately c. lightly d none of the above
13. The input impedance of a transistor is ……
    a. low b. high c. 0 d. very high
14. The phase difference between the output and input voltages of a CE amplifier is ……..
    a.0 **b. 180** c. 90 d. 270
15. A crystal diode utilises ……..
    a. reverse **b. forward** c. forward or reverse d. none of the above

16. The reverse current in a diode is of the order
    a. kA b. mA c. **μA** d. MA
17. A crystal diode utilises ……..
    a. forward b. Reverse c. direct d. none of these
18. When the crystal current diode current is large, the bias is ……
    a. reverse **b. forward** c. direct d. none of these
19. The LED is usually made of materials like:
    a.GaAs b. Al c. Cu d. C
20. The most commonly used semiconductor in the manufacture of a transistor is
    a. germanium **b. Silicon** c. Aluminium d. galium

PART-B (3 x 10 = 30 Marks)

Answer all the questions

21. (a) Draw and explain the V-I charactersitics of pn junction diode.

PN Junction Theory

When the N-type semiconductor and P-type semiconductor materials are first joined together a very large density gradient exists between both sides of the PN junction. The result is that 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.

However, because the electrons have moved across the PN junction from the N-type silicon to the P-type silicon, they leave behind positively charged donor ions (N_D) on the negative side and now the holes from the acceptor impurity migrate across the junction in the opposite direction into the region where there are large numbers of free electrons.

As a result, the charge density of the P-type along the junction is filled with negatively charged acceptor ions (N_A), and the charge density of the N-type along the junction becomes positive. This charge transfer of electrons and holes across the PN junction is known as **diffusion**. The width of these P and N layers depends on how heavily each side is doped with acceptor density N_A, and donor density N_D, respectively.

This process continues back and forth until the number of electrons which have crossed the junction have a large enough electrical charge to repel or prevent any more charge carriers from crossing over the junction. Eventually a state of equilibrium (electrically neutral situation) will occur producing a “potential barrier” zone around the area of the junction as the donor atoms repel the holes and the acceptor atoms repel the electrons.

Since no free charge carriers can rest in a position where there is a potential barrier, the regions on either sides of the junction

now become completely depleted of any more free carriers in comparison to the N and P type materials further away from the junction. This area around the **PN Junction** is now called the **Depletion Layer**.

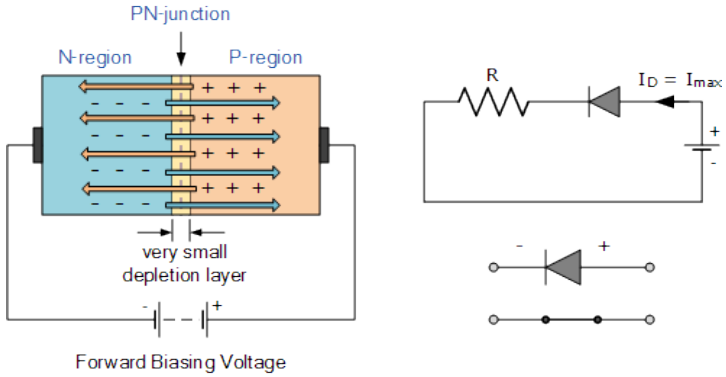


Fig1.1

The PN junction

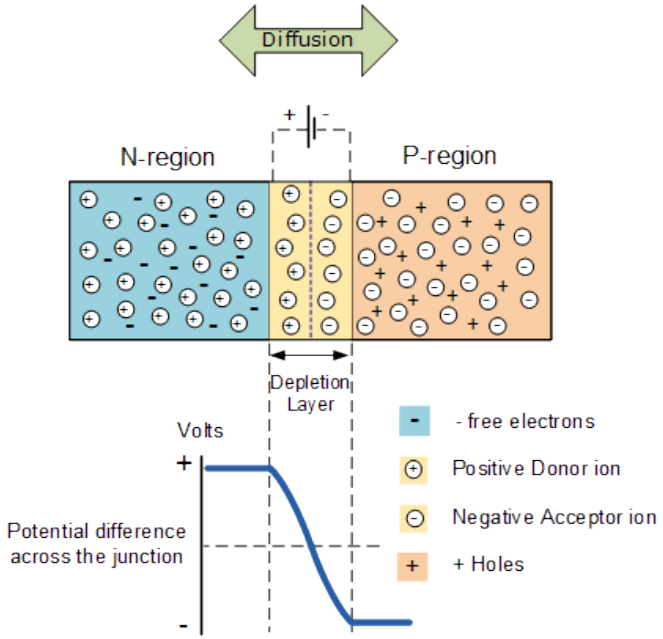


Fig1.2

The total charge on each side of a *PN Junction* must be equal and opposite to maintain a neutral charge condition around the junction. If the depletion layer region has a distance D, it therefore must therefore penetrate into the silicon by a distance of Dp for the positive side, and a distance of Dn for the negative side giving a relationship between the two of $Dp.N_A = Dn.N_D$ in order to maintain charge neutrality also called equilibrium.

DIODE CHARACTERISTICS:

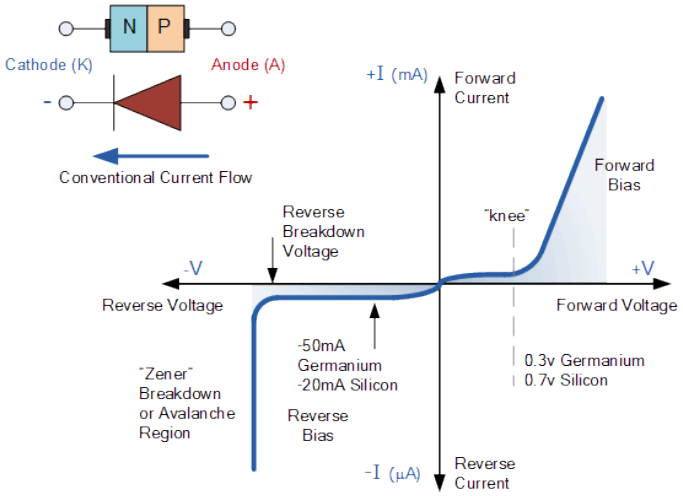


Fig1.3

There are two operating regions and three possible "biasing" conditions for the standard **Junction Diode** and these are:

- Zero Bias – No external voltage potential is applied to the PN junction diode.
- Reverse Bias – The voltage potential is connected negative, (-ve) to the P-type material and positive, (+ve) to the N-type material across the diode which has the effect of **Increasing** the PN junction diode's width.
- Forward Bias – The voltage potential is connected positive, (+ve) to the P-type material and negative, (-ve) to the N-type material across the diode which has the effect of **Decreasing** the PN junction diodes width.

(or)

(b)Explain the working of fullwave rectifier and calculate rectification efficiency and ripple factor

Full Wave Rectifier Circuit

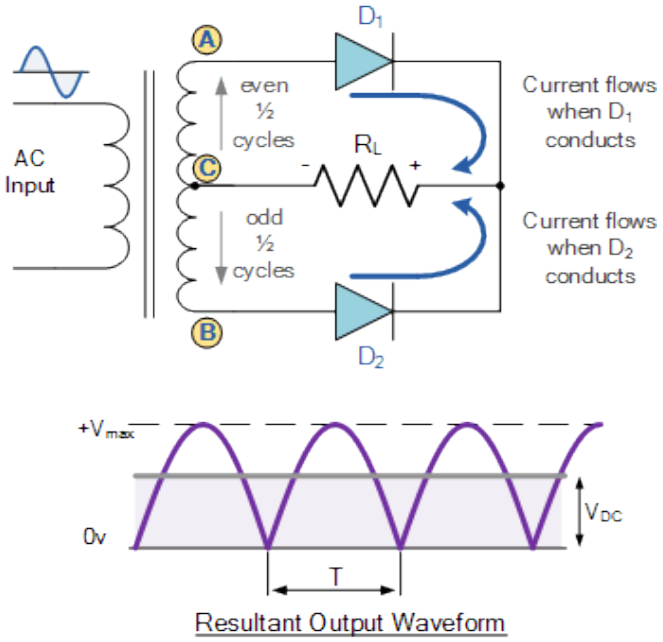


Fig 1.11

The full wave rectifier circuit consists of two *power diodes* connected to a single load resistance (R_L) with each diode taking it in turn to supply current to the load. When point A of the transformer is positive with respect to point C, diode D_1 conducts in the forward direction as indicated by the arrows.

When point B is positive (in the negative half of the cycle) with respect to point C, diode D_2 conducts in the forward direction and the current flowing through resistor R is in the same direction for both half-cycles. As the output voltage across the resistor R is the phasor sum of the two waveforms combined, this type of full wave rectifier circuit is also known as a "bi-phase" circuit.

Partsim Simulation Waveform

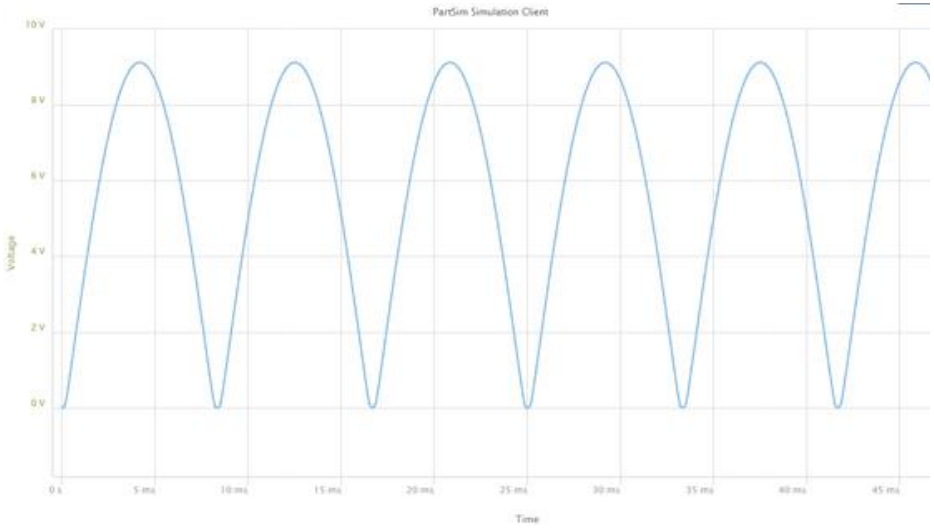


Fig 1.12

As the spaces between each half-wave developed by each diode is now being filled in by the other diode the average DC output voltage across the load resistor is now double that of the single half-wave rectifier circuit and is about $0.637V_{max}$ of the peak voltage, assuming no losses.

$$V_{d.c.} = \frac{2V_{\max}}{\pi} = 0.637V_{\max} = 0.9V_{RMS}$$

Where: V_{MAX} is the maximum peak value in one half of the secondary winding and V_{RMS} is the rms value.

The peak voltage of the output waveform is the same as before for the half-wave rectifier provided each half of the transformer windings have the same rms voltage value. To obtain a different DC voltage output different transformer ratios can be used.

The main disadvantage of this type of full wave rectifier circuit is that a larger transformer for a given power output is required with two separate but identical secondary windings making this type of full wave rectifying circuit costly compared to the "Full Wave Bridge Rectifier" circuit equivalent.

22. (a). Discuss the working principle of Bridge Rectifiers with the help of a neat diagram.

THE FULL WAVE BRIDGE RECTIFIER

Another type of circuit that produces the same output waveform as the full wave rectifier circuit above, is that of the **Full Wave Bridge Rectifier**. This type of single phase rectifier uses four individual rectifying diodes connected in a closed loop "bridge" configuration to produce the desired output.

The main advantage of this bridge circuit is that it does not require a special centre tapped transformer, thereby reducing its size and cost. The single secondary winding is connected to one side of the diode bridge network and the load to the other side as shown below.

THE DIODE BRIDGE RECTIFIER

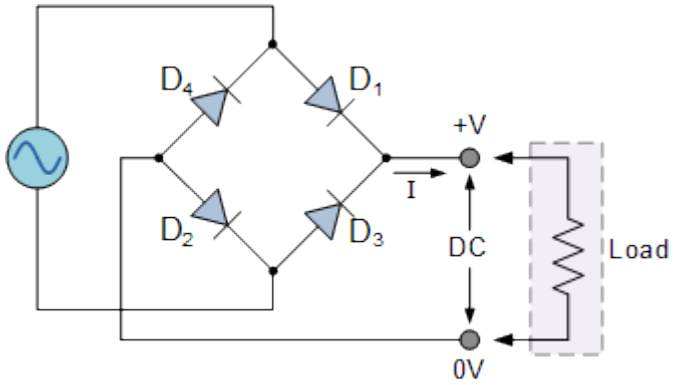


Fig 1.13

The four diodes labelled D_1 to D_4 are arranged in "series pairs" with only two diodes conducting current during each half cycle. During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodesD3 and D4 are reverse biased and the current flows through the load as shown below.

The Positive Half-cycle

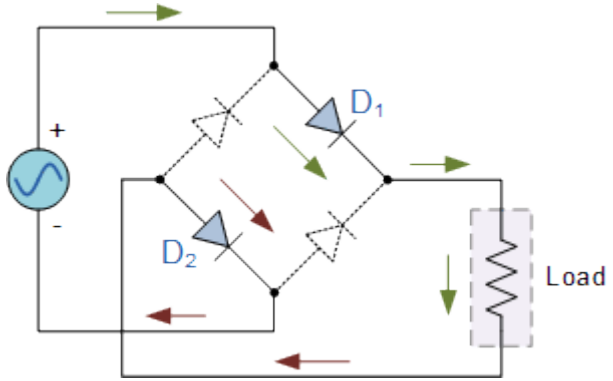


Fig 1.14

During the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 switch "OFF" as they are now reverse biased. The current flowing through the load is the same direction as before.

The Negative Half-cycle

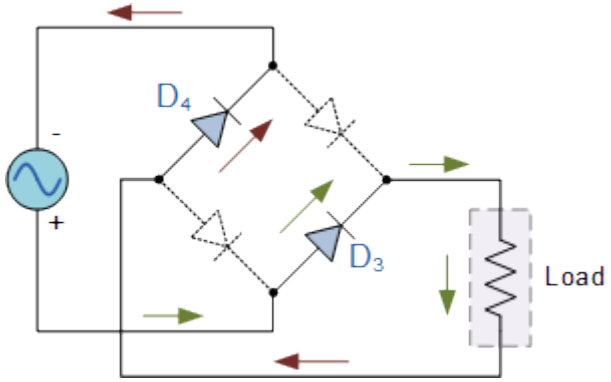


Fig 1.15

As the current flowing through the load is unidirectional, so the voltage developed across the load is also unidirectional the same as for the previous two diode full-wave rectifier, therefore the average DC voltage across the load is $0.637V_{max}$.

BRIDGE RECTIFIER RIPPLE VOLTAGE

$$V_{(ripple)} = \frac{I_{(load)}}{f \times C}, \text{ Volts}$$

(Or)

(b) Explain in detail about n-p-n and p-n-p transitor

TRANSISTOR

Transistor is a semiconductor device that can both conduct and insulate. A transistor can act as a switch and an amplifier. It converts audio waves into electronic waves and resistor, controlling electronic current. Transistors have very long life, smaller in size, can operate on lower voltage supplies for greater safety and required no filament current. The first transistor was fabricated with germanium. A transistor performs the same function as a vacuum tube triode, but using semiconductor junctions instead of heated electrodes in a vacuum chamber. It is the fundamental building block of modern electronic devices and found everywhere in modern electronic systems.

Transistors are three terminal active devices made from different semiconductor materials that can act as either an insulator or a conductor by the application of a small signal voltage. The transistor's ability to change between these two states enables it to have two basic functions: "switching" (digital electronics) or "amplification" (analogue electronics). Then bipolar transistors have the ability to operate within three different regions:

- Active Region – the transistor operates as an amplifier andIc = β.Ib

- Saturation – the transistor is “Fully-ON” operating as a switch and Ic = I(saturation)
- Cut-off – the transistor is “Fully-OFF” operating as a switch and Ic = 0

TRANSISTOR BASICS:

A transistor is a three terminal device. Namely,

- Base: This is responsible for activating the transistor.
- Collector: This is the positive lead.
- Emitter: This is the negative lead.

The basic idea behind a transistor is that it lets you control the flow of current through one channel by varying the intensity of a much smaller current that’s flowing through a second channel.

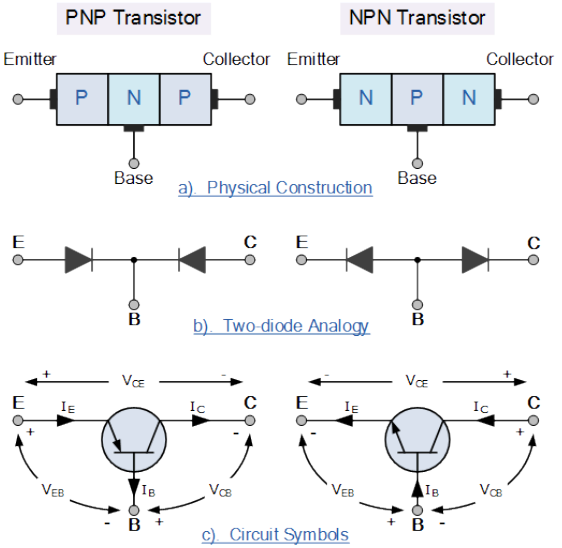
BIPOLAR JUNCTION TRANSISTOR:

A Bipolar Junction Transistor (BJT) has three terminals connected to three doped semiconductor regions. It comes with two types, P-N-P and N-P-N.

P-N-P transistor consists of a layer of N-doped semiconductor material between two layers of P-doped material. The base current entering in the collector is amplified at its output.That is when PNP transistor is ON when its base is pulled low relative to the emitter. The arrows of PNP transistor symbol the direction of current flow when the device is in forward active mode.

N-P-N transistor consists of a layer of P-doped semiconductor between two layers of N-doped material. By amplifying current the base we get the high collector and emitter current. That is when NPN transistor is ON when its base is pulled low relative to the emitter. When the transistor is in ON state, current flow is in between the collector and emitter of the transistor. Based on minority carriers present in P-type region the electrons moving from emitter to collector. It allows the greater current and faster operation; because of this reason most bipolar transistors used today are NPN.

BIPOLAR TRANSISTOR CONSTRUCTION



The construction and circuit symbols for both the PNP and NPN bipolar transistor are given above with the arrow in the circuit symbol always showing the direction of "conventional current flow" between the base terminal and its emitter terminal. The direction of the arrow always points from the positive P-type region to the negative N-type region for both transistor types, exactly the same as for the standard diode symbol.

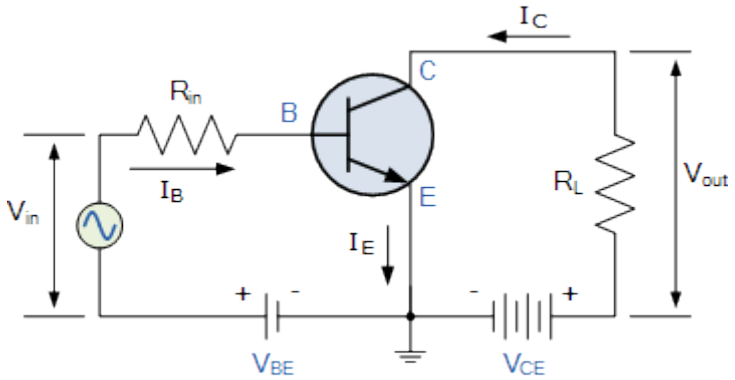
BIPOLAR TRANSISTOR CONFIGURATIONS

As the **Bipolar Transistor** is a three terminal device, there are basically three possible ways to connect it within an electronic circuit with one terminal being common to both the input and output. Each method of connection responding differently to its input signal within a circuit as the static characteristics of the transistor vary with each circuit arrangement.

- Common Base Configuration – has Voltage Gain but no Current Gain.
- Common Emitter Configuration – has both Current and Voltage Gain.
- Common Collector Configuration – has Current Gain but no Voltage Gain.

23. (a) Derive the relations between α and β

THE COMMON EMITTER AMPLIFIER CIRCUIT



In this type of configuration, the current flowing out of the transistor must be equal to the currents flowing into the transistor as the emitter current is given as Ie = Ic + Ib.

As the load resistance (RL) is connected in series with the collector, the current gain of the common emitter transistor configuration is quite large as it is the ratio of Ic/Ib. A transistors current gain is given the Greek symbol of Beta, (β).

As the emitter current for a common emitter configuration is defined asIe = Ic + Ib, the ratio of Ic/Ie is called Alpha, given the Greek symbol of α. Note: that the value of Alpha will always be less than unity.

Since the electrical relationship between these three currents, Ib, Ic and Ieis determined by the physical construction of the transistor itself, any small change in the base current (Ib), will result in a much larger change in the collector current (Ic).

Then, small changes in current flowing in the base will thus control the current in the emitter-collector circuit. Typically, Beta has a value between 20 and 200 for most general purpose transistors. So if a transistor has a Beta value of say 100, then one electron will flow from the base terminal for every 100 electrons flowing between the emitter-collector terminal.

By combining the expressions for both Alpha, α and Beta, β the mathematical relationship between these parameters and therefore the current gain of the transistor can be given as:

$$\text{Alpha},(\alpha) = \frac{I_C}{I_E} \quad \text{and} \quad \text{Beta},(\beta) = \frac{I_C}{I_B}$$

$$\therefore I_C = \alpha . I_E = \beta . I_B$$

$$\text{as:} \quad \alpha = \frac{\beta}{\beta + 1} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

$$I_E = I_C + I_B$$

Where: “Ic” is the current flowing into the collector terminal, “Ib” is the current flowing into the base terminal and “Ie” is the current flowing out of the emitter terminal.

This type of bipolar transistor configuration has a greater input impedance, current and power gain than that of the common base configuration but its voltage gain is much lower. The common emitter configuration is an inverting amplifier circuit. This means that the resulting output signal is 180^{o} “out-of-phase” with the input voltage signal.

Reg. No……..

[15PHU504]

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Under Section 3 of UGC Act 1956)

COIMBATORE -641 201

(For the candidates admitted from 2015 onwards)

II INTERNAL EXAMINATIONS

Fifth Semester

III B.Sc PHYSICS

BASIC ELECTRONICS

Time: 2 hours Maximum: 50 marks

PART-A (20 x 1 = 20 Marks)

Answer all the questions

1. A crystal diode has

   a**.one pn junction** b. two pn junctions c. three pn junctions d. four pn junctions

2. A zener diode has ……..

   a. **one pn junction** b. two pn junctions c. three pn junctions d. four pn junctions

3. A zener diode is ……. device

   a a non-linear b. a linear c an amplifying d. none of the above

4. A transistor is a …… operated device

   a**. current** b. voltage c. both voltage and current d. none of the above

5. The base of a transistor is …….. doped

   a.heavily b. moderately c**. lightly** d. volume

6. There are …… *h* parameters of a transistor

   a. 2 **b. 3** c. 4 d. 5

7. An ideal crystal diode is one which behaves as a perfect …….. when forward biased

   a.conductor b. insulator c. resistance material d. none of the above

8. The leakage current in a crystal diode is due to …….

   a. . **minority carriers** b. majority carriers c. junction capacitance d. none of the above

9. If the temperature of a crystal diode increases, then leakage current ……..

   a. remains the same b. decreases c. **increases** d. becomes zero

10. The knee voltage of a crystal diode is approximately

    a.applied voltage b**. breakdown voltage** c. forward voltage d. barrier potential

11. The voltage gain in a transistor connected in ……. arrangement is the highest

    a.CE b. CB c. CC d. CBE

12. The emitter of a transistor is …… doped

    a. heavily b. moderately c. lightly d none of the above

13. The input impedance of a transistor is ……

    a. low b. high c. 0 d. very high

14. The phase difference between the output and input voltages of a CE amplifier is ……..

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15. A crystal diode utilises ……..

    a. reverse **b. forward** c. forward or reverse d. none of the above

16. The reverse current in a diode is of the order
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17. A crystal diode utilises ……..
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18. When the crystal current diode current is large, the bias is ……
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19. The LED is usually made of materials like:
    a.GaAs b. Al c. Cu d. C
20. The most commonly used semiconductor in the manufacture of a transistor is
    a. germanium **b. Silicon** c. Aluminium d. galium

PART-B (3 x 10 = 30 Marks)

Answer all the questions

21. (a) Draw and explain the V-I charactersitics of pn junction diode.

PN Junction Theory

When the N-type semiconductor and P-type semiconductor materials are first joined together a very large density gradient exists between both sides of the PN junction. The result is that 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.

However, because the electrons have moved across the PN junction from the N-type silicon to the P-type silicon, they leave behind positively charged donor ions (N_D) on the negative side and now the holes from the acceptor impurity migrate across the junction in the opposite direction into the region where there are large numbers of free electrons.

As a result, the charge density of the P-type along the junction is filled with negatively charged acceptor ions (N_A), and the charge density of the N-type along the junction becomes positive. This charge transfer of electrons and holes across the PN junction is known as **diffusion**. The width of these P and N layers depends on how heavily each side is doped with acceptor density N_A, and donor density N_D, respectively.

This process continues back and forth until the number of electrons which have crossed the junction have a large enough electrical charge to repel or prevent any more charge carriers from crossing over the junction. Eventually a state of equilibrium (electrically neutral situation) will occur producing a “potential barrier” zone around the area of the junction as the donor atoms repel the holes and the acceptor atoms repel the electrons.

Since no free charge carriers can rest in a position where there is a potential barrier, the regions on either sides of the junction

now become completely depleted of any more free carriers in comparison to the N and P type materials further away from the junction. This area around the **PN Junction** is now called the **Depletion Layer**.

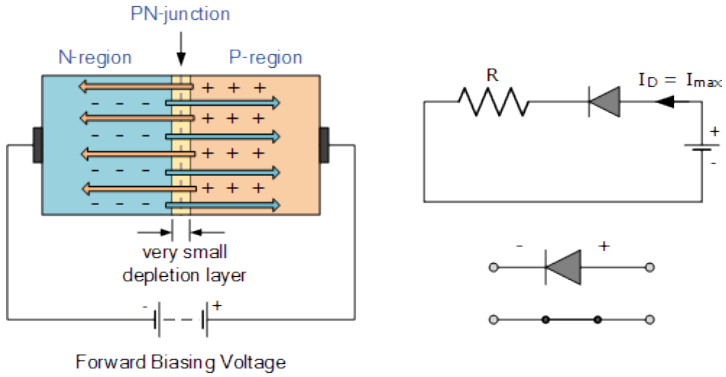


Fig1.1

The PN junction

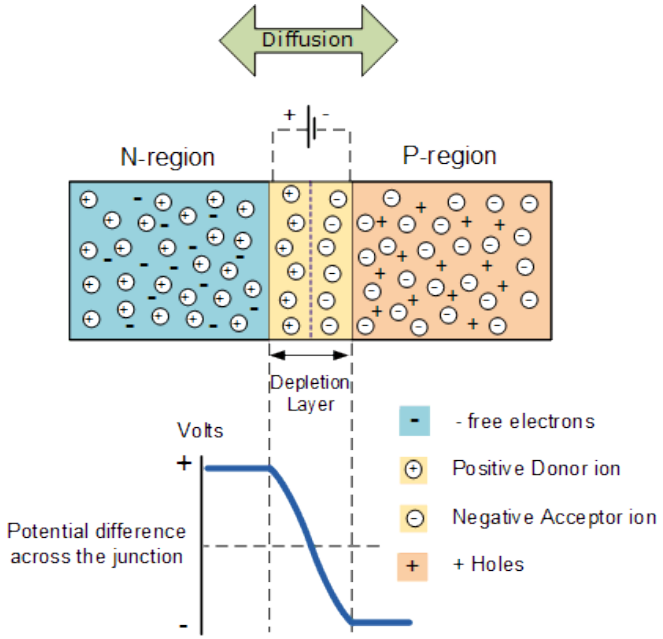


Fig1.2

The total charge on each side of a *PN Junction* must be equal and opposite to maintain a neutral charge condition around the junction. If the depletion layer region has a distance D, it therefore must therefore penetrate into the silicon by a distance of Dp for the positive side, and a distance of Dn for the negative side giving a relationship between the two of $Dp.N_A = Dn.N_D$ in order to maintain charge neutrality also called equilibrium.

DIODE CHARACTERISTICS:

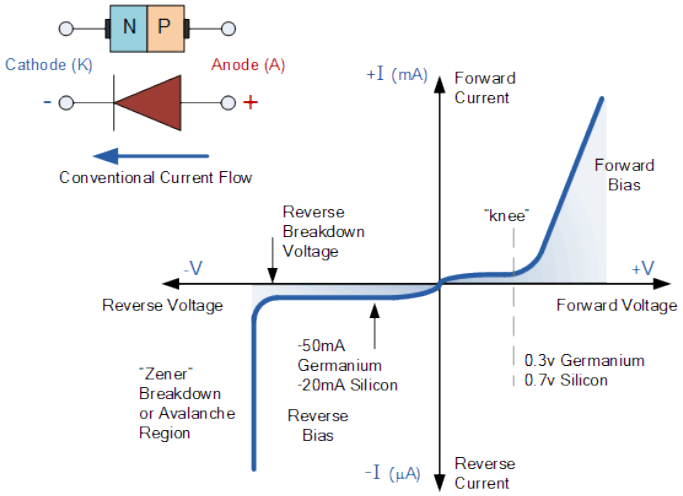


Fig1.3

There are two operating regions and three possible "biasing" conditions for the standard **Junction Diode** and these are:

- Zero Bias – No external voltage potential is applied to the PN junction diode.
- Reverse Bias – The voltage potential is connected negative, (-ve) to the P-type material and positive, (+ve) to the N-type material across the diode which has the effect of **Increasing** the PN junction diode's width.
- Forward Bias – The voltage potential is connected positive, (+ve) to the P-type material and negative, (-ve) to the N-type material across the diode which has the effect of **Decreasing** the PN junction diodes width.

(or)

(b)Explain the working of fullwave rectifier and calculate rectification efficiency and ripple factor

Full Wave Rectifier Circuit

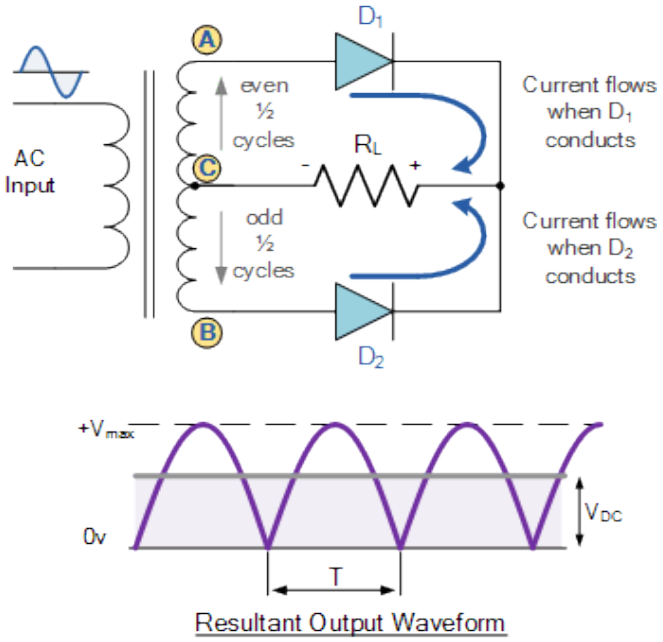


Fig 1.11

The full wave rectifier circuit consists of two *power diodes* connected to a single load resistance (R_L) with each diode taking it in turn to supply current to the load. When point A of the transformer is positive with respect to point C, diode D_1 conducts in the forward direction as indicated by the arrows.

When point B is positive (in the negative half of the cycle) with respect to point C, diode D_2 conducts in the forward direction and the current flowing through resistor R is in the same direction for both half-cycles. As the output voltage across the resistor R is the phasor sum of the two waveforms combined, this type of full wave rectifier circuit is also known as a "bi-phase" circuit.

Partsim Simulation Waveform

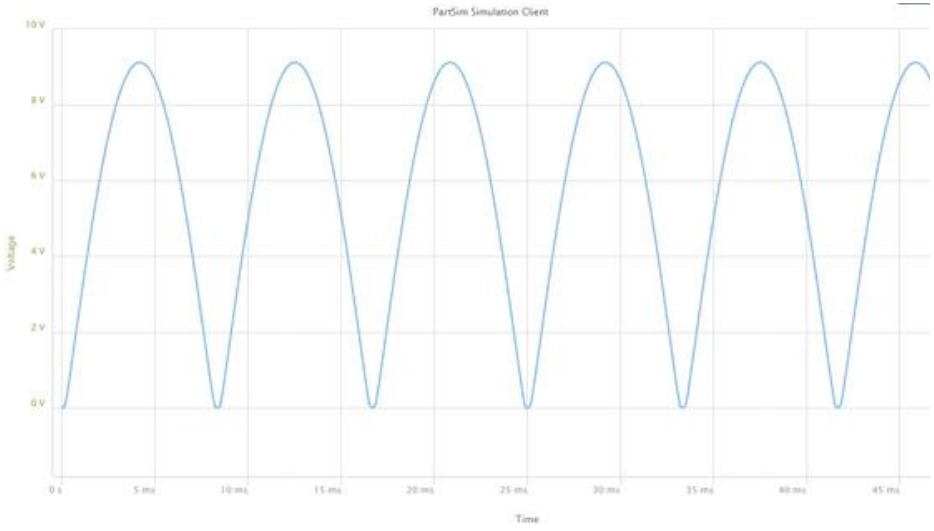


Fig 1.12

As the spaces between each half-wave developed by each diode is now being filled in by the other diode the average DC output voltage across the load resistor is now double that of the single half-wave rectifier circuit and is about $0.637V_{max}$ of the peak voltage, assuming no losses.

$$V_{d.c.} = \frac{2V_{\max}}{\pi} = 0.637V_{\max} = 0.9V_{RMS}$$

Where: V_{MAX} is the maximum peak value in one half of the secondary winding and V_{RMS} is the rms value.

The peak voltage of the output waveform is the same as before for the half-wave rectifier provided each half of the transformer windings have the same rms voltage value. To obtain a different DC voltage output different transformer ratios can be used.

The main disadvantage of this type of full wave rectifier circuit is that a larger transformer for a given power output is required with two separate but identical secondary windings making this type of full wave rectifying circuit costly compared to the "Full Wave Bridge Rectifier" circuit equivalent.

22. (a). Discuss the working principle of Bridge Rectifiers with the help of a neat diagram.

THE FULL WAVE BRIDGE RECTIFIER

Another type of circuit that produces the same output waveform as the full wave rectifier circuit above, is that of the **Full Wave Bridge Rectifier**. This type of single phase rectifier uses four individual rectifying diodes connected in a closed loop "bridge" configuration to produce the desired output.

The main advantage of this bridge circuit is that it does not require a special centre tapped transformer, thereby reducing its size and cost. The single secondary winding is connected to one side of the diode bridge network and the load to the other side as shown below.

THE DIODE BRIDGE RECTIFIER

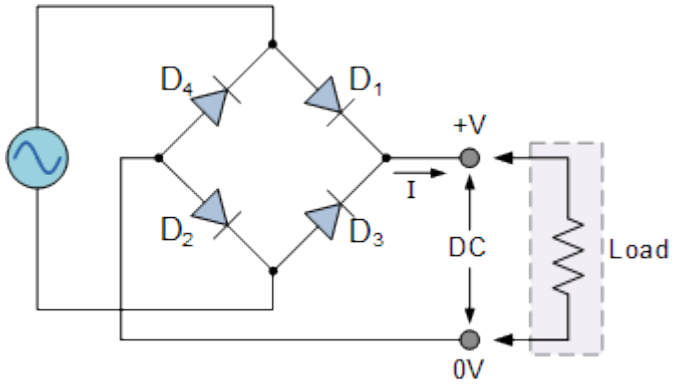


Fig 1.13

The four diodes labelled D_1 to D_4 are arranged in "series pairs" with only two diodes conducting current during each half cycle. During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodesD3 and D4 are reverse biased and the current flows through the load as shown below.

The Positive Half-cycle

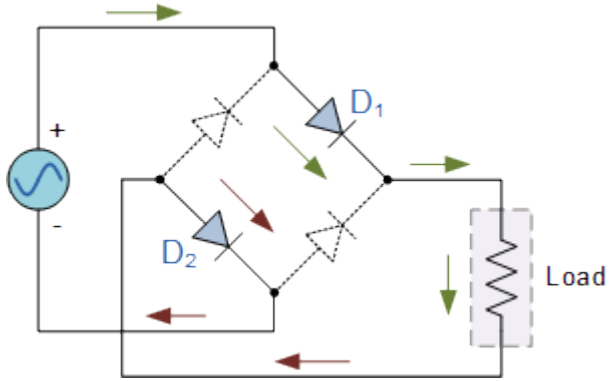


Fig 1.14

During the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 switch "OFF" as they are now reverse biased. The current flowing through the load is the same direction as before.

The Negative Half-cycle

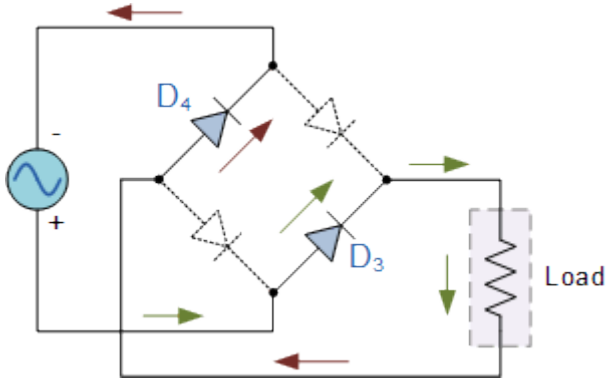


Fig 1.15

As the current flowing through the load is unidirectional, so the voltage developed across the load is also unidirectional the same as for the previous two diode full-wave rectifier, therefore the average DC voltage across the load is $0.637V_{max}$.

BRIDGE RECTIFIER RIPPLE VOLTAGE

$$V_{(ripple)} = \frac{I_{(load)}}{f \times C}, \text{ Volts}$$

(Or)

(b) Explain in detail about n-p-n and p-n-p transitor

TRANSISTOR

Transistor is a semiconductor device that can both conduct and insulate. A transistor can act as a switch and an amplifier. It converts audio waves into electronic waves and resistor, controlling electronic current. Transistors have very long life, smaller in size, can operate on lower voltage supplies for greater safety and required no filament current. The first transistor was fabricated with germanium. A transistor performs the same function as a vacuum tube triode, but using semiconductor junctions instead of heated electrodes in a vacuum chamber. It is the fundamental building block of modern electronic devices and found everywhere in modern electronic systems.

Transistors are three terminal active devices made from different semiconductor materials that can act as either an insulator or a conductor by the application of a small signal voltage. The transistor's ability to change between these two states enables it to have two basic functions: "switching" (digital electronics) or "amplification" (analogue electronics). Then bipolar transistors have the ability to operate within three different regions:

- Active Region – the transistor operates as an amplifier andIc = β.Ib

- Saturation – the transistor is “Fully-ON” operating as a switch and Ic = I(saturation)
- Cut-off – the transistor is “Fully-OFF” operating as a switch and Ic = 0

TRANSISTOR BASICS:

A transistor is a three terminal device. Namely,

- Base: This is responsible for activating the transistor.
- Collector: This is the positive lead.
- Emitter: This is the negative lead.

The basic idea behind a transistor is that it lets you control the flow of current through one channel by varying the intensity of a much smaller current that’s flowing through a second channel.

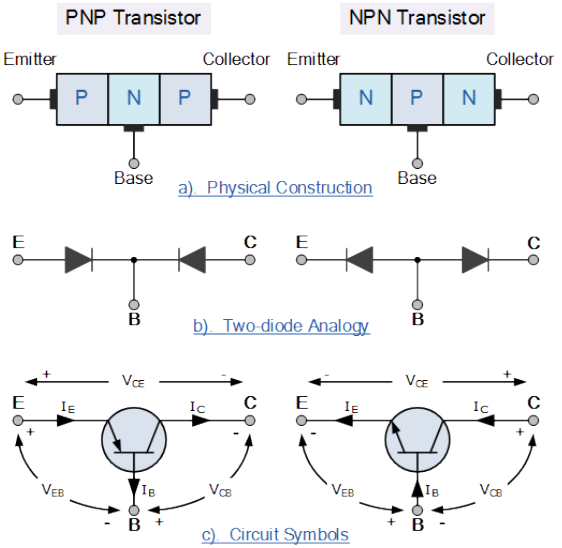
BIPOLAR JUNCTION TRANSISTOR:

A Bipolar Junction Transistor (BJT) has three terminals connected to three doped semiconductor regions. It comes with two types, P-N-P and N-P-N.

P-N-P transistor consists of a layer of N-doped semiconductor material between two layers of P-doped material. The base current entering in the collector is amplified at its output.That is when PNP transistor is ON when its base is pulled low relative to the emitter. The arrows of PNP transistor symbol the direction of current flow when the device is in forward active mode.

N-P-N transistor consists of a layer of P-doped semiconductor between two layers of N-doped material. By amplifying current the base we get the high collector and emitter current. That is when NPN transistor is ON when its base is pulled low relative to the emitter. When the transistor is in ON state, current flow is in between the collector and emitter of the transistor. Based on minority carriers present in P-type region the electrons moving from emitter to collector. It allows the greater current and faster operation; because of this reason most bipolar transistors used today are NPN.

BIPOLAR TRANSISTOR CONSTRUCTION



The construction and circuit symbols for both the PNP and NPN bipolar transistor are given above with the arrow in the circuit symbol always showing the direction of "conventional current flow" between the base terminal and its emitter terminal. The direction of the arrow always points from the positive P-type region to the negative N-type region for both transistor types, exactly the same as for the standard diode symbol.

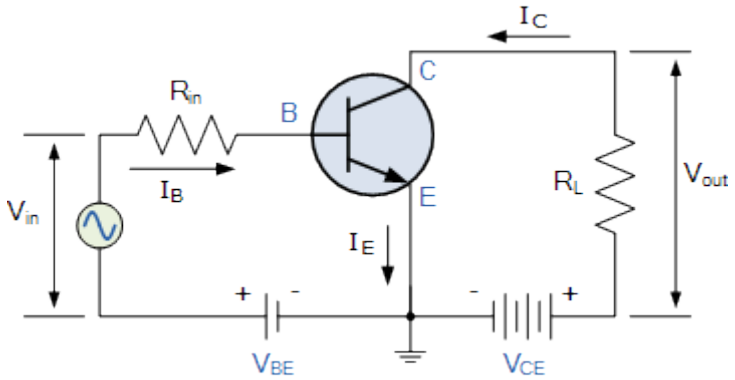
BIPOLAR TRANSISTOR CONFIGURATIONS

As the **Bipolar Transistor** is a three terminal device, there are basically three possible ways to connect it within an electronic circuit with one terminal being common to both the input and output. Each method of connection responding differently to its input signal within a circuit as the static characteristics of the transistor vary with each circuit arrangement.

- Common Base Configuration – has Voltage Gain but no Current Gain.
- Common Emitter Configuration – has both Current and Voltage Gain.
- Common Collector Configuration – has Current Gain but no Voltage Gain.

23. (a) Derive the relations between α and β

THE COMMON EMITTER AMPLIFIER CIRCUIT



In this type of configuration, the current flowing out of the transistor must be equal to the currents flowing into the transistor as the emitter current is given as Ie = Ic + Ib.

As the load resistance (RL) is connected in series with the collector, the current gain of the common emitter transistor configuration is quite large as it is the ratio of Ic/Ib. A transistors current gain is given the Greek symbol of Beta, (β).

As the emitter current for a common emitter configuration is defined asIe = Ic + Ib, the ratio of Ic/Ie is called Alpha, given the Greek symbol of α. Note: that the value of Alpha will always be less than unity.

Since the electrical relationship between these three currents, Ib, Ic and Ieis determined by the physical construction of the transistor itself, any small change in the base current (Ib), will result in a much larger change in the collector current (Ic).

Then, small changes in current flowing in the base will thus control the current in the emitter-collector circuit. Typically, Beta has a value between 20 and 200 for most general purpose transistors. So if a transistor has a Beta value of say 100, then one electron will flow from the base terminal for every 100 electrons flowing between the emitter-collector terminal.

By combining the expressions for both Alpha, α and Beta, β the mathematical relationship between these parameters and therefore the current gain of the transistor can be given as:

$$\text{Alpha},(\alpha) = \frac{I_C}{I_E} \quad \text{and} \quad \text{Beta},(\beta) = \frac{I_C}{I_B}$$

$$\therefore I_C = \alpha . I_E = \beta . I_B$$

$$\text{as:} \quad \alpha = \frac{\beta}{\beta + 1} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

$$I_E = I_C + I_B$$

Where: “Ic” is the current flowing into the collector terminal, “Ib” is the current flowing into the base terminal and “Ie” is the current flowing out of the emitter terminal.

This type of bipolar transistor configuration has a greater input impedance, current and power gain than that of the common base configuration but its voltage gain is much lower. The common emitter configuration is an inverting amplifier circuit. This means that the resulting output signal is 180^{o} “out-of-phase” with the input voltage signal.

Reg. No……..

[15PHU504]

KARPAGAM UNIVERSITY

(Under Section 3 of UGC Act 1956)

COIMBATORE -641 201

(For the candidates admitted from 2015 onwards)

B.Sc. DEGREE EXAMINATIONS, NOVEMBER - 2017

Fifth Semester

PHYSICS

BASIC ELECTRONICS

Time: 3 hours Maximum: 60 marks

PART-A (20 x 1 = 20 Marks)

Answer all the questions

1. A crystal diode utilises ……..
   a. reverse b. **forward** c. forward or reverse d. none of the above
2. The reverse current in a diode is of the order
   a. kA b. **mA** **c.** μA d. MA
3. A crystal diode utilises ……..
   a. **forward** b**.** Reverse c. direct d. none of these
4. When the crystal current diode current is large, the bias is ……
   a. reverse b**. forward** c. direct d. none of these
5. The LED is usually made of materials like:
   a.**GaAs** b. Al c. Cu d. C
6. The most commonly used semiconductor in the manufacture of a transistor is
   a. germanium **b. Silicon** c. Aluminium d. galium
7. At The power gain in a transistor connected in ……. arrangement is the highest
   a.CE **b. CB** c. CC d.CBE
8. For a silicon transistor, when a base-emitter junction is forward-biased, it has a nominal voltage drop of
   a. **0.7 V.**b. 0.3 V. c. 0.2 V. d. V_{CC}.
9. A feedback circuit usually employs …… network
   a. **Resistive** b. Capacitive c. Inductive d. none of the above
10. In transistor amplifiers, we generally use …….. capacitors.
    a. **Electrolytic** b. Mica c. Paper d**.** Air
11. Emitter follower is used for …
    a. Current gain b. Impedance matching c. **Voltage gain** d. none of the above
12. IC 741 offset Voltage adjustment range is____
    a.15mV b**.** 10 mV c. 12 mV d. 14 mV
13. CMRR is typically _____dB
    a100dB b. **90dB** c. 75dB d. 60dB
14. The Op-amp can amplify
    a. a.c. signals only b. d.c. signals only c. **both a.c. and d.c. signals** d. neither d.c. nor a.c. signals

15. Another name for a unity gain amplifier is:
    a.difference amplifier b. comparator c. single ended d. voltage follower
16. In differentiator the output waveform is the _____ of input waveform
    aEqual **b.Derivative** c.NonDerivative d.Multiplie
17. If we interchange the resistor and capacitor of the differentiator the circuit is
    a.Integrated b.Summing c.Non-inverting d.Inverting
18. A_____ is used for low voltage dc and ac volt meter, LED and zener diode tester
    a.V-I convertor b.I-V converter c.Peak detector d.Comparator
19. The reference voltage is set to zero in_____
    a.window detector b.peak detector c.**zero crossing detector** d.comparator
20. The term 'covalent bonding' refers to:
    a.the introduction of an impurity **b.the sharing of valence electrons** c.the generation of surplus electrons d.generation of holes

PART-B (5 x 8 = 40 Marks)

Answer all the questions

21. (a) What is pn junction ? Explain the formation of potential barrier in a pn junction

PN Junction Theory

When the N-type semiconductor and P-type semiconductor materials are first joined together a very large density gradient exists between both sides of the PN junction. The result is that 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.

However, because the electrons have moved across the PN junction from the N-type silicon to the P-type silicon, they leave behind positively charged donor ions (N_D) on the negative side and now the holes from the acceptor impurity migrate across the junction in the opposite direction into the region where there are large numbers of free electrons.

As a result, the charge density of the P-type along the junction is filled with negatively charged acceptor ions (N_A), and the charge density of the N-type along the junction becomes positive. This charge transfer of electrons and holes across the PN junction is known as **diffusion**. The width of these P and N layers depends on how heavily each side is doped with acceptor density N_A, and donor density N_D, respectively.

This process continues back and forth until the number of electrons which have crossed the junction have a large enough electrical charge to repel or prevent any more charge carriers from crossing over the junction. Eventually a state of equilibrium (electrically neutral situation) will occur producing a “potential barrier” zone around the area of the junction as the donor atoms repel the holes and the acceptor atoms repel the electrons.

Since no free charge carriers can rest in a position where there is a potential barrier, the regions on either sides of the junction now become completely depleted of any more free

carriers in comparison to the N and P type materials further away from the junction. This area around the **PN Junction** is now called the **Depletion Layer**.

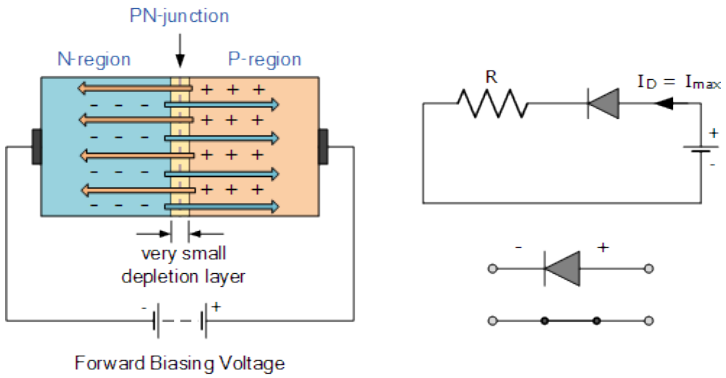


Fig1.1

The PN junction

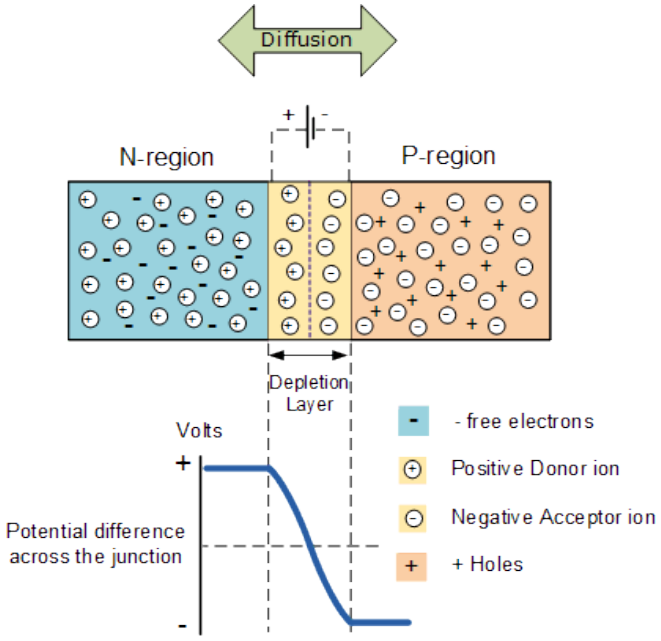


Fig1.2

The total charge on each side of a *PN Junction* must be equal and opposite to maintain a neutral charge condition around the junction. If the depletion layer region has a distance D, it therefore must therefore penetrate into the silicon by a distance of Dp for the positive side, and a distance of Dn for the negative side giving a relationship between the two of $Dp.N_A = Dn.N_D$ in order to maintain charge neutrality also called equilibrium.

DIODE CHARACTERISTICS:

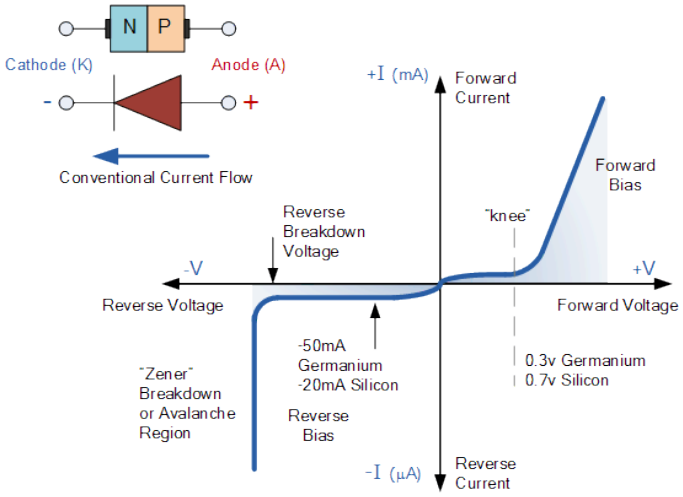


Fig1.3

There are two operating regions and three possible "biasing" conditions for the standard **Junction Diode** and these are:

- Zero Bias – No external voltage potential is applied to the PN junction diode.
- Reverse Bias – The voltage potential is connected negative, (-ve) to the P-type material and positive, (+ve) to the N-type material across the diode which has the effect of **Increasing** the PN junction diode's width.
- Forward Bias – The voltage potential is connected positive, (+ve) to the P-type material and negative, (-ve) to the N-type material across the diode which has the effect of **Decreasing** the PN junction diodes width.

OR

(b) Explain working principle and structure of LED

THE LIGHT EMITTING DIODE

Light Emitting Diodes or **LED´s**, are among the most widely used of all the different types of semiconductor diodes available today and are commonly used in TV's and colour displays.

They are the most visible type of diode, that emit a fairly narrow bandwidth of either visible light at different coloured wavelengths, invisible infra-red light for remote controls or laser type light when a forward current is passed through them.

The "**Light Emitting Diode**" or **LED** as it is more commonly called, is basically just a specialised type of diode as they have very similar electrical characteristics to a PN junction diode. This means that an LED will pass current in its forward direction but block the flow of current in the reverse direction.

Light emitting diodes are made from a very thin layer of fairly heavily doped semiconductor material and depending on the semiconductor material used and the amount of

doping, when forward biased an LED will emit a coloured light at a particular spectral wavelength.

When the diode is forward biased, electrons from the semiconductors conduction band recombine with holes from the valence band releasing sufficient energy to produce photons which emit a monochromatic (single colour) of light. Because of this thin layer a reasonable number of these photons can leave the junction and radiate away producing a coloured light output.

Then we can say that when operated in a forward biased direction **Light Emitting Diodes** are semiconductor devices that convert electrical energy into light energy.

The construction of a Light Emitting Diode is very different from that of a normal signal diode. The PN junction of an LED is surrounded by a transparent, hard plastic epoxy resin hemispherical shaped shell or body which protects the LED from both vibration and shock.

LED junction does not actually emit that much light so the epoxy resin body is constructed in such a way that the photons of light emitted by the junction are reflected away from the surrounding substrate base to which the diode is attached and are focused upwards through the domed top of the LED, which itself acts like a lens concentrating the amount of light. This is why the emitted light appears to be brightest at the top of the LED.

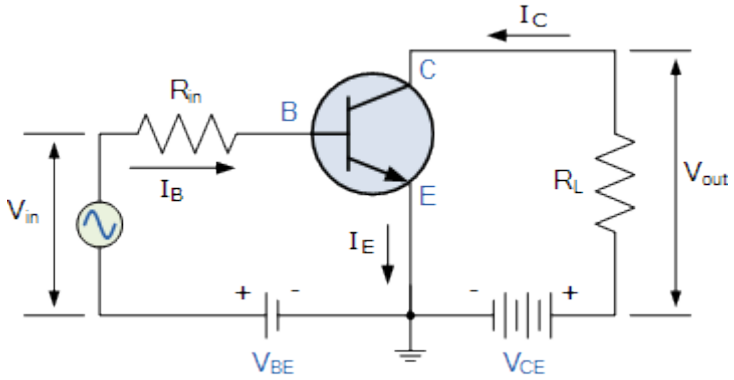
However, not all LEDs are made with a hemispherical shaped dome for their epoxy shell. Some indication LEDs have a rectangular or cylindrical shaped construction that has a flat surface on top or their body is shaped into a bar or arrow. Generally, all LED's are manufactured with two legs protruding from the bottom of the body.

Also, nearly all modern light emitting diodes have their cathode, (–) terminal identified by either a notch or flat spot on the body or by the cathode lead being shorter than the other as the anode (+) lead is longer than the cathode (k).

Unlike normal incandescent lamps and bulbs which generate large amounts of heat when illuminated, the light emitting diode produces a "cold" generation of light which leads to high efficiencies than the normal "light bulb" because most of the generated energy radiates away within the visible spectrum. Because LEDs are solid-state devices, they can be extremely small and durable and provide much longer lamp life than normal light sources.

22. (a) Explain the input and output characteristics of CE configuration

THE COMMON EMITTER AMPLIFIER CIRCUIT



In this type of configuration, the current flowing out of the transistor must be equal to the currents flowing into the transistor as the emitter current is given as Ie = Ic + Ib.

As the load resistance (RL) is connected in series with the collector, the current gain of the common emitter transistor configuration is quite large as it is the ratio of Ic/Ib. A transistors current gain is given the Greek symbol of Beta, (β).

As the emitter current for a common emitter configuration is defined asIe = Ic + Ib, the ratio of Ic/Ie is called Alpha, given the Greek symbol of α. Note: that the value of Alpha will always be less than unity.

Since the electrical relationship between these three currents, Ib, Ic and Ieis determined by the physical construction of the transistor itself, any small change in the base current (Ib), will result in a much larger change in the collector current (Ic).

Then, small changes in current flowing in the base will thus control the current in the emitter-collector circuit. Typically, Beta has a value between 20 and 200 for most general purpose transistors. So if a transistor has a Beta value of say 100, then one electron will flow from the base terminal for every 100 electrons flowing between the emitter-collector terminal.

By combining the expressions for both Alpha, α and Beta, β the mathematical relationship between these parameters and therefore the current gain of the transistor can be given as:

$$\text{Alpha},(\alpha) = \frac{I_C}{I_E} \quad \text{and} \quad \text{Beta},(\beta) = \frac{I_C}{I_B}$$

$$\therefore I_C = \alpha.I_E = \beta.I_B$$

$$\text{as:}\ \alpha = \frac{\beta}{\beta + 1} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

$$I_E = I_C + I_B$$

Where: “Ic” is the current flowing into the collector terminal, “Ib” is the current flowing into the base terminal and “Ie” is the current flowing out of the emitter terminal.

This type of bipolar transistor configuration has a greater input impedance, current and power gain than that of the common base configuration but its voltage gain is much lower. The common emitter configuration is an inverting amplifier circuit. This means that the resulting output signal is 180° “out-of-phase” with the input voltage signal.

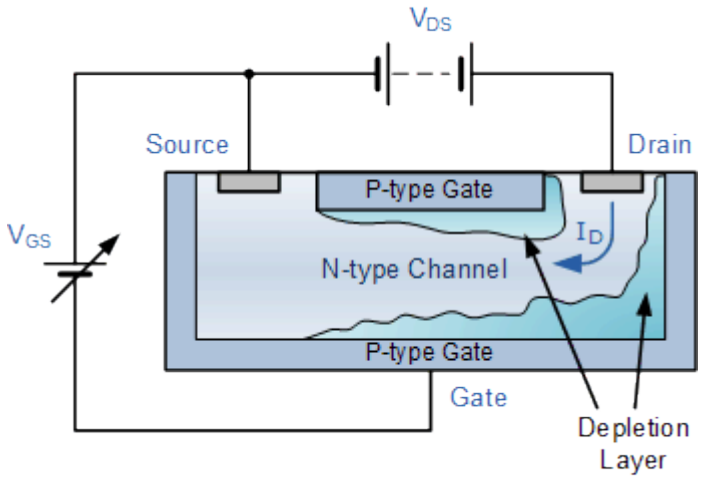
OR

(b) Explain the working principle and charactersitcs of JFET

JUNCTION FIELD EFFECT TRANSISTOR

THE FIELD EFFECT TRANSISTOR

In the Bipolar Junction Transistor tutorials, we saw that the output Collector current of the transistor is proportional to input current flowing into the Base terminal of the device, thereby making the bipolar transistor a “CURRENT” operated device (Beta model) as a smaller current can be used to switch a larger load current.



The Field Effect Transistor, or simply FET however, uses the voltage that is applied to their input terminal, called the Gate to control the current flowing through them resulting in the output current being proportional to the input voltage. As their operation relies on an electric field (hence the name field effect) generated by the input Gate voltage, this then makes the Field Effect Transistor a "VOLTAGE" operated device.

The Field Effect Transistoris a three terminal unipolar semiconductor device that has very similar characteristics to those of their Bipolar Transistor counterparts ie, high efficiency, instant operation, robust and cheap and can be used in most electronic circuit applications to replace their equivalent bipolar junction transistors (BJT) cousins.

THE JUNCTION FIELD EFFECT TRANSISTOR

We saw previously that a bipolar junction transistor is constructed using two PN-junctions in the main current carrying path between the Emitter and the Collector terminals. The **Junction Field Effect Transistor** (JUGFET or JFET) has no PN-junctions but instead has a narrow piece of high resistivity semiconductor material forming a "Channel" of either N-type or P-type silicon for the majority carriers to flow through with two ohmic electrical connections at either end commonly called the Drain and theSource respectively.

There are two basic configurations of junction field effect transistor, the N-channel JFET and the P-channel JFET. The N-channel JFET's channel is doped with donor impurities meaning that the flow of current through the channel is negative (hence the term N-channel) in the form of electrons.

Likewise, the P-channel JFET's channel is doped with acceptor impurities meaning that the flow of current through the channel is positive (hence the term P-channel) in the form of holes. N-channel JFET's have a greater channel conductivity (lower resistance) than their equivalent P-channel types, since electrons have a higher mobility through a conductor compared to holes. This makes the N-channel JFET's a more efficient conductor compared to their P-channel counterparts.

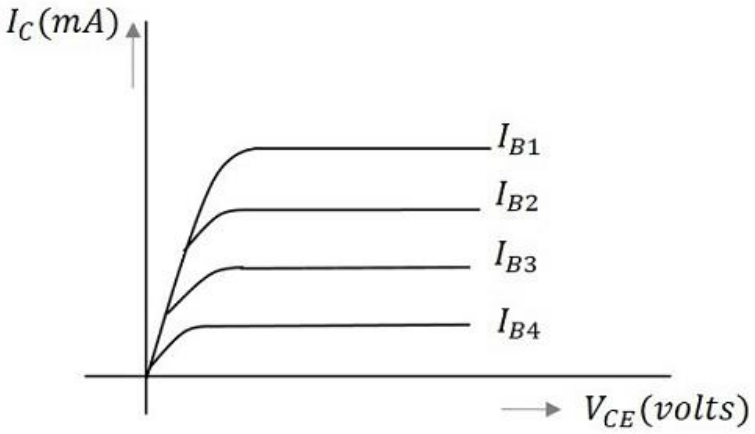
23. (a) Discuss DC Load line and Q-point.

TRANSISTOR LOAD LINE ANALYSIS

We have discussed different regions of operation for a transistor. But among all these regions, we have found that the transistor operates well in active region and hence it is also called as **linear region**. The outputs of the transistor are the collector current and collector voltages.

OUTPUT CHARACTERISTICS

When the output characteristics of a transistor are considered, the curve looks as below for different input values.



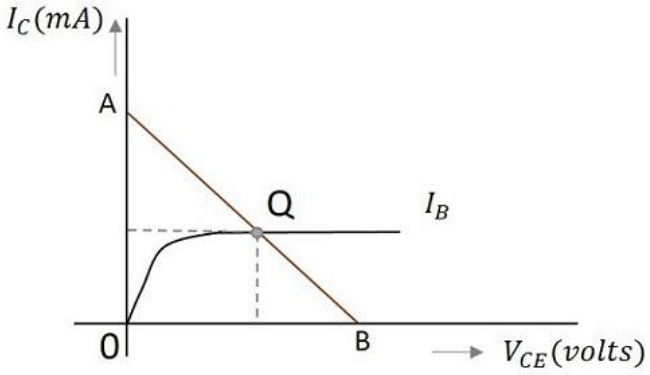
In the above figure, the output characteristics are drawn between collector current $\mathbf{I_C}$ and collector voltage $\mathbf{V_{CE}}$ for different values of base current $\mathbf{I_B}$. These are considered here for different input values to obtain different output curves.

OPERATING POINT

When a value for the maximum possible collector current is considered, that point will be present on the Y-axis, which is nothing but the **saturation point**. As well, when a value for the maximum possible collector emitter voltage is considered, that point will be present on the X-axis, which is the **cutoff point**.

When a line is drawn joining these two points, such a line can be called as **Load line**. This is called so as it symbolizes the output at the load. This line, when drawn over the output characteristic curve, makes contact at a point called as **Operating point**.

This operating point is also called as **quiescent point** or simply **Q-point**. There can be many such intersecting points, but the Q-point is selected in such a way that irrespective of AC signal swing, the transistor remains in active region. This can be better understood through the figure below.

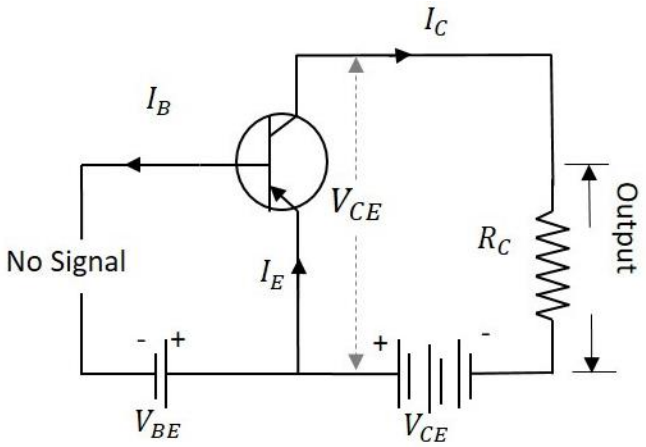


The load line has to be drawn in order to obtain the Q-point. A transistor acts as a good amplifier when it is in active region and when it is made to operate at Q-point, faithful amplification is achieved.

Faithful amplification is the process of obtaining complete portions of input signal by increasing the signal strength. This is done when AC signal is applied at its input. This is discussed in AMPLIFIERS tutorial.

DC LOAD LINE

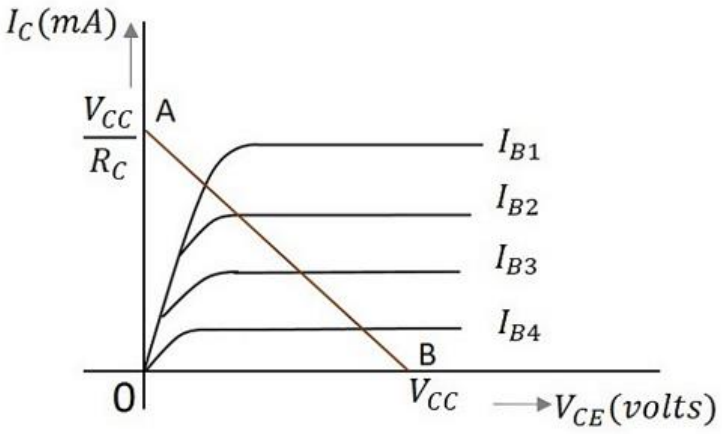
When the transistor is given the bias and no signal is applied at its input, the load line drawn at such condition can be understood as **DC** condition. Here there will be no amplification as the signal is absent. The circuit will be as shown below.



The value of collector emitter voltage at any given time will be

$V_{CE}=V_{CC}-I_CR_CV_{CE}=V_{CC}-I_CR_C$

As V_{CC} and R_C are fixed values, the above one is a first degree equation and hence will be a straight line on the output characteristics. This line is called as **D.C. Load line**. The figure below shows the DC load line.



To obtain the load line, the two end points of the straight line are to be determined. Let those two points be A and B.

To obtain A

When collector emitter voltage V_{CE} = 0, the collector current is maximum and is equal to V_{CC}/R_C. This gives the maximum value of V_{CE}. This is shown as

$$V_{CE}=V_{CC}-I_CR_CV_{CE}=V_{CC}-I_CR_C$$

$$0=V_{CC}-I_CR_{C0}=V_{CC}-I_CR_C$$

$$I_C=V_{CC}R_CI_C=V_{CC}R_C$$

This gives the point A (OA = V_{CC}/R_C) on collector current axis, shown in the above figure.

To obtain B

When the collector current IC = 0, then collector emitter voltage is maximum and will be equal to the VCC. This gives the maximum value of IC. This is shown as

$$V_{CE}=V_{CC}-I_CR_CV_{CE}=V_{CC}-I_CR_C$$

$$=V_{CC}=V_{CC}$$

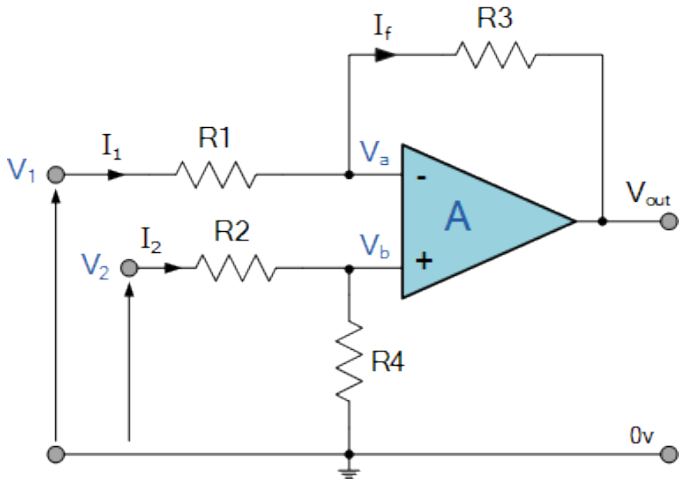
(As I_C = 0)

This gives the point B, which means (OB = V_{CC}) on the collector emitter voltage axis shown in the above figure.

Hence we got both the saturation and cutoff point determined and learnt that the load line is a straight line. So, a DC load line can be drawn.

24. (a) Explain in detail about Differentiator and Integrator

DIFFERENTIAL AMPLIFIER



By connecting each input in turn to 0v ground we can use superposition to solve for the output voltage Vout. Then the transfer function for a**Differential Amplifier** circuit is given as:

$$I_1 = \frac{V_1 - V_a}{R_1}, \quad I_2 = \frac{V_2 - V_b}{R_2}, \quad I_f = \frac{V_a - (V_{out})}{R_3}$$

$$\text{Summing point } V_a = V_b$$

$$\text{and } V_b = V_2\left(\frac{R_4}{R_2 + R_4}\right)$$

$$\text{If } V_2 = 0, \text{ then: } V_{out(a)} = -V_1\left(\frac{R_3}{R_1}\right)$$

$$\text{If } V_1 = 0, \text{ then: } V_{out(b)} = V_2\left(\frac{R_4}{R_2 + R_4}\right)\left(\frac{R_1 + R_3}{R_1}\right)$$

$$V_{out} = -V_{out(a)} + V_{out(b)}$$

$$\therefore V_{out} = -V_1\left(\frac{R_3}{R_1}\right) + V_2\left(\frac{R_4}{R_2 + R_4}\right)\left(\frac{R_1 + R_3}{R_1}\right)$$

When resistors, R1 = R2 and R3 = R4 the above transfer function for the differential amplifier can be simplified to the following expression:

DIFFERENTIAL AMPLIFIER EQUATION

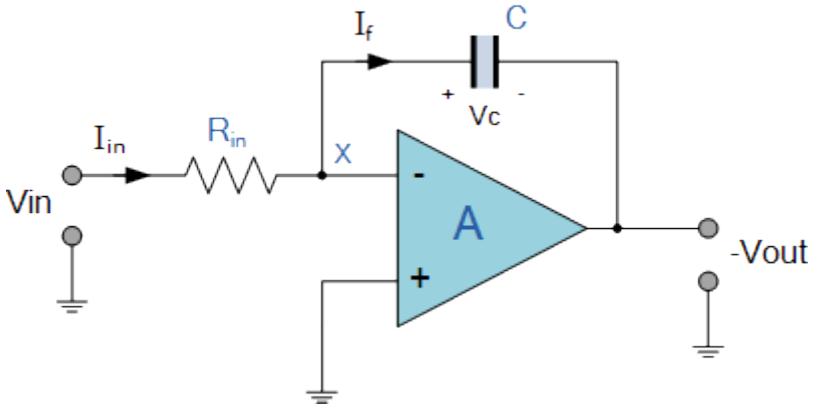
$$V_{OUT} = \frac{R_3}{R_1}\left(V_2 - V_1\right)$$

If all the resistors are all of the same ohmic value, that is: R1 = R2 = R3 = R4 then the circuit will become a **Unity Gain Differential Amplifier** and the voltage gain of the amplifier will be exactly one or unity. Then the output expression would simply be Vout = V2 – V1. Also note that if inputV1 is higher than input V2 the output voltage sum will be negative, and ifV2 is higher than V1, the output voltage sum will be positive.

THE INTEGRATOR AMPLIFIER

In the previous circuits which show how an operational amplifier can be used as part of a positive or negative feedback amplifier or as an adder or subtractor type circuit using just pure resistances in both the input and the feedback loop.

OP-AMP INTEGRATOR CIRCUIT



As its name implies, the **Op-amp Integrator** is an operational amplifier circuit that performs the mathematical operation of **Integration**, that is we can cause the output to respond to changes in the input voltage over time as the op-amp integrator produces an *output voltage which is proportional to the integral of the input voltage*.

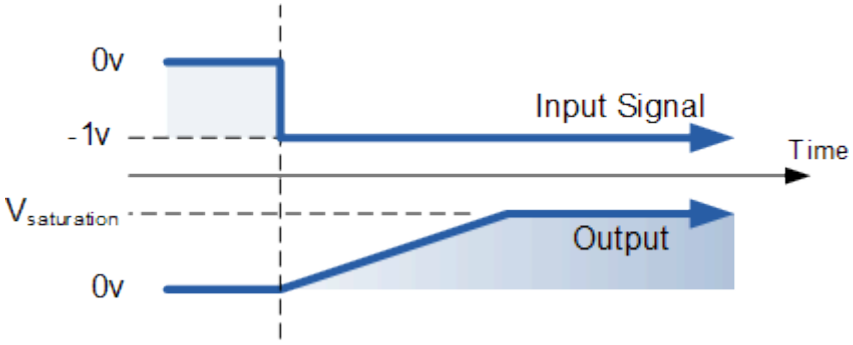
In other words the magnitude of the output signal is determined by the length of time a voltage is present at its input as the current through the feedback loop charges or discharges the capacitor as the required negative feedback occurs through the capacitor.

When a step voltage, Vin is firstly applied to the input of an integrating amplifier, the uncharged capacitor C has very little resistance and acts a bit like a short circuit allowing maximum current to flow via the input resistor, Rin as potential difference exists between the two plates. No current flows into the amplifiers input and point X is a virtual earth resulting in zero output. As the impedance of the capacitor at this point is very low, the gain ratio of Xc/Rin is also very small giving an overall voltage gain of less than one, (voltage follower circuit).

As the feedback capacitor, C begins to charge up due to the influence of the input voltage, its impedance Xc slowly increase in proportion to its rate of charge. The capacitor charges up at a rate determined by the RC time constant, (τ) of the series RC network. Negative feedback forces the op-amp to produce an output voltage that maintains a virtual earth at the op-amp's inverting input.

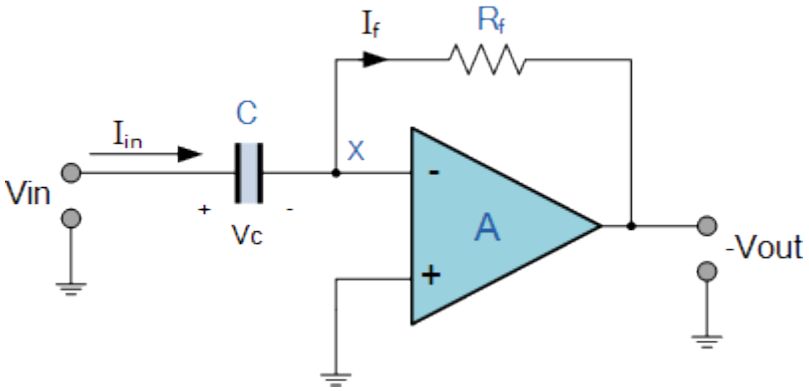
Since the capacitor is connected between the op-amp's inverting input (which is at earth potential) and the op-amp's output (which is negative), the potential voltage, Vc developed across the capacitor slowly increases causing the charging current to decrease as the impedance of the capacitor increases. This results in the ratio of Xc/Rin increasing producing a linearly increasing ramp output voltage that continues to increase until the capacitor is fully charged.

At this point the capacitor acts as an open circuit, blocking any more flow of DC current. The ratio of feedback capacitor to input resistor (Xc/Rin) is now infinite resulting in infinite gain. The result of this high gain (similar to the op-amps open-loop gain), is that the output of the amplifier goes into saturation as shown below. (Saturation occurs when the output voltage of the amplifier swings heavily to one voltage supply rail or the other with little or no control in between).



The rate at which the output voltage increases (the rate of change) is determined by the value of the resistor and the capacitor, "RC time constant". By changing this RC time constant value, either by changing the value of the Capacitor, C or the Resistor, R, the time in which it takes the output voltage to reach saturation can also be changed.

OP-AMP DIFFERENTIATOR CIRCUIT



The input signal to the differentiator is applied to the capacitor. The capacitor blocks any DC content so there is no current flow to the amplifier summing point, X resulting in zero output voltage. The capacitor only allows AC type input voltage changes to pass through and whose frequency is dependant on the rate of change of the input signal.

At low frequencies the reactance of the capacitor is "High" resulting in a low gain (R*f*/Xc) and low output voltage from the op-amp. At higher frequencies the reactance of the capacitor is much lower resulting in a higher gain and higher output voltage from the differentiator amplifier.

However, at high frequencies an op-amp differentiator circuit becomes unstable and will start to oscillate. This is due mainly to the first-order effect, which determines the frequency response of the op-amp circuit causing a second-order response which, at high frequencies gives an output voltage far higher than what would be expected. To avoid this the high frequency gain of the circuit needs to be reduced by adding an additional small value capacitor across the feedback resistor R*f*.

$$I_{IN} = I_F \text{ and } I_F = -\frac{V_{OUT}}{R_F}$$

The charge on the capacitor equals Capacitance x Voltage across the capacitor

$$Q = C \times V_{IN}$$

The rate of change of this charge is:

$$\frac{dQ}{dt} = C\frac{dV_{IN}}{dt}$$

but dQ/dt is the capacitor current,i

$$I_{IN} = C\frac{dV_{IN}}{dt} = I_F$$

$$\therefore -\frac{V_{OUT}}{R_F} = C\frac{dV_{IN}}{dt}$$

from which we have an ideal voltage output for the op-amp differentiator is given as:

$$V_{OUT} = -R_F C\frac{dV_{IN}}{dt}$$

Therefore, the output voltage Vout is a constant -R*f*.C times the derivative of the input voltage Vin with respect to time. The minus sign indicates a 180^o phase shift because the input signal is connected to the inverting input terminal of the operational amplifier.

One final point to mention, the **Op-amp Differentiator** circuit in its basic form has two main disadvantages compared to the previous operational amplifier integrator circuit. One is that it suffers from instability at high frequencies as mentioned above, and the other is that the capacitive input makes it very susceptible to random noise signals and any noise or harmonics present in the source circuit will be amplified more than the input signal itself. This is because the output is proportional to the slope of the input voltage so some means of limiting the bandwidth in order to achieve closed-loop stability is required.

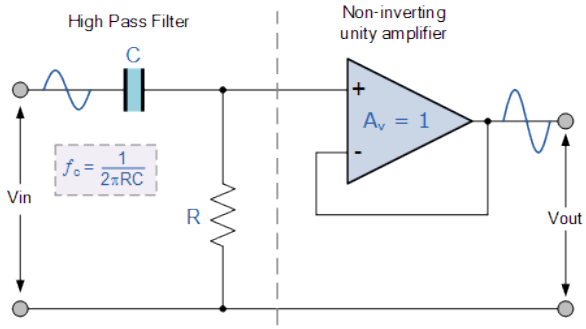
OR

(b) Explain the working principle of High Pass filter using IC 741 and plot the frequency response.

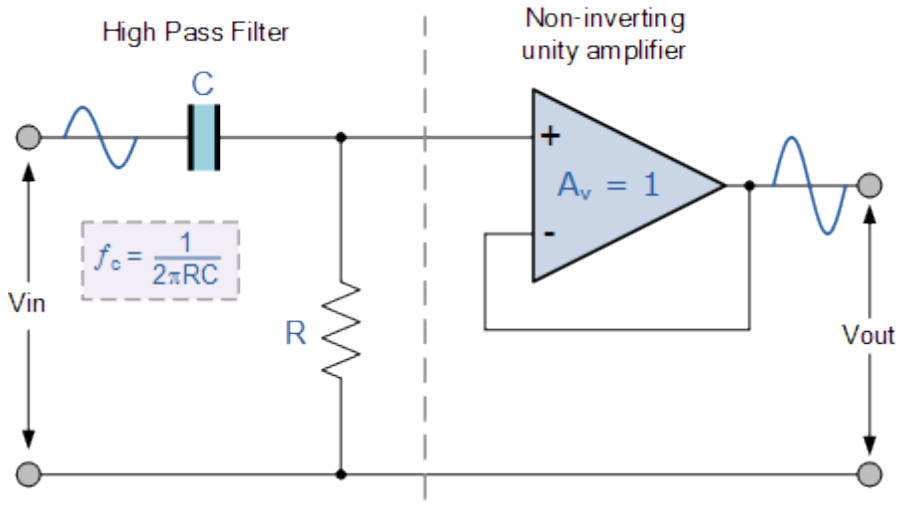
HIGH PASS FILTER

The basic operation of an **Active High Pass Filter** (HPF) is the same as for its equivalent RC passive high pass filter circuit, except this time the circuit has an operational amplifier or included within its design providing amplification and gain control

The simplest form of an*active high pass filter* is to connect a standard inverting or non-inverting operational amplifier to the basic RC high pass passive filter circuit as shown.



First Order High Pass Filter



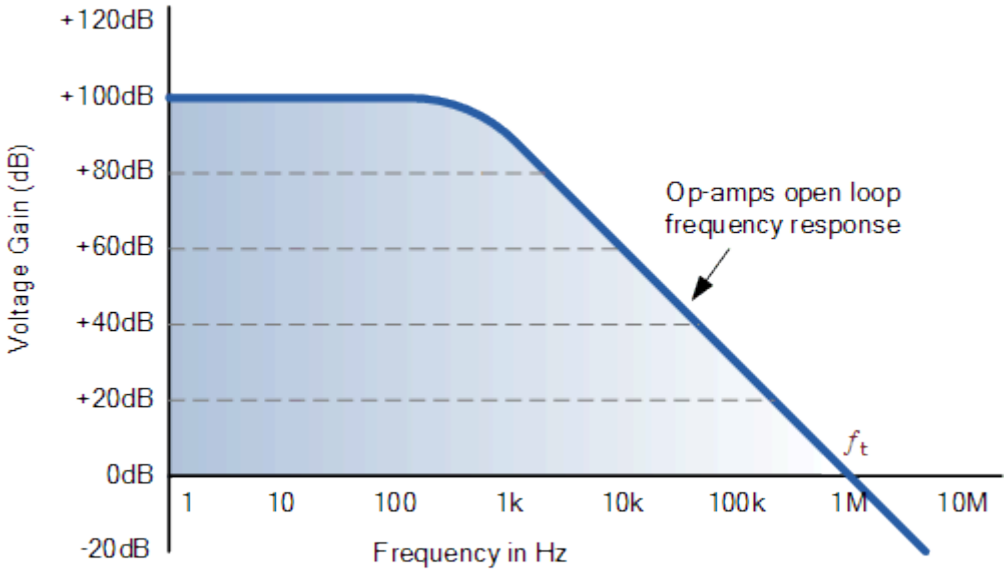
Technically, there is no such thing as an **active high pass filter**. Unlike Passive High Pass Filters which have an "infinite" frequency response, the maximum pass band frequency response of an active high pass filter is limited by the open-loop characteristics or bandwidth of the operational amplifier being used, making them appear as if they are band pass filters with a high frequency cut-off determined by the selection of op-amp and gain.

In the Operational Amplifier tutorial we saw that the maximum frequency response of an op-amp is limited to the Gain/Bandwidth product or open loop voltage gain (A_V) of the

operational amplifier being used giving it a bandwidth limitation, where the closed loop response of the op amp intersects the open loop response.

A commonly available operational amplifier such as the uA741 has a typical "open-loop" (without any feedback) DC voltage gain of about 100dB maximum reducing at a roll off rate of -20dB/Decade (-6db/Octave) as the input frequency increases. The gain of the uA741 reduces until it reaches unity gain, (0dB) or its "transition frequency" (ft) which is about 1MHz. This causes the op-amp to have a frequency response curve very similar to that of a first-order low pass filter and this is shown below.

FREQUENCY RESPONSE CURVE OF A TYPICAL OPERATIONAL AMPLIFIER.



Then the performance of a "high pass filter" at high frequencies is limited by this unity gain crossover frequency which determines the overall bandwidth of the open-loop amplifier. The gain-bandwidth product of the op-amp starts from around 100kHz for small signal amplifiers up to about 1GHz for high-speed digital video amplifiers and op-amp based active filters can achieve very good accuracy and performance provided that low tolerance resistors and capacitors are used.

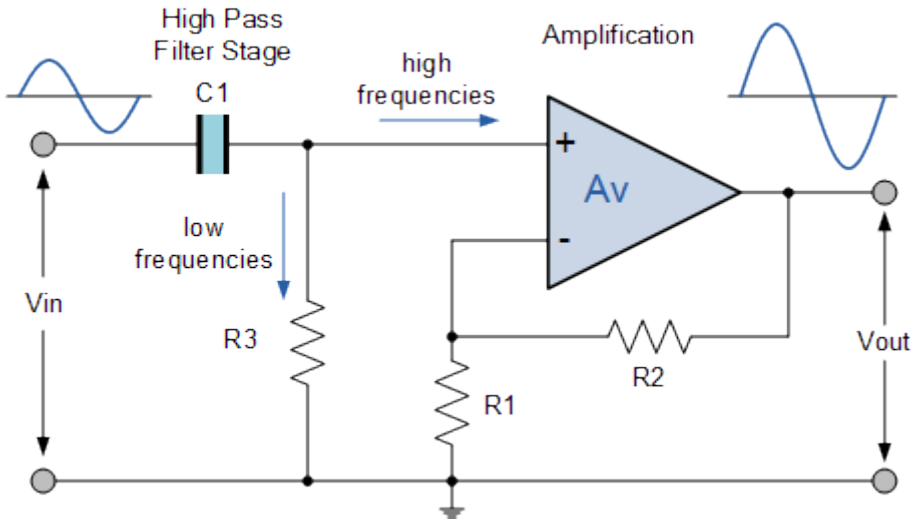
Under normal circumstances the maximum pass band required for a closed loop active high pass or band pass filter is well below that of the maximum open-loop transition frequency. However, when designing active filter circuits it is important to choose the correct op-amp for the circuit as the loss of high frequency signals may result in signal distortion.

ACTIVE HIGH PASS FILTER

A first-order (single-pole) **Active High Pass Filter** as its name implies, attenuates low frequencies and passes high frequency signals. It consists simply of a passive filter

section followed by a non-inverting operational amplifier. The frequency response of the circuit is the same as that of the passive filter, except that the amplitude of the signal is increased by the gain of the amplifier and for a non-inverting amplifier the value of the pass band voltage gain is given as 1 + R2/R1, the same as for the low pass filter circuit.

ACTIVE HIGH PASS FILTER WITH AMPLIFICATION



This *first-order high pass filter*, consists simply of a passive filter followed by a non-inverting amplifier. The frequency response of the circuit is the same as that of the passive filter, except that the amplitude of the signal is increased by the gain of the amplifier.

For a non-inverting amplifier circuit, the magnitude of the voltage gain for the filter is given as a function of the feedback resistor (R2) divided by its corresponding input resistor (R1) value and is given as:

Gain for an Active High Pass Filter

$$\text{Voltage Gain, (Av)} = \frac{\text{Vout}}{\text{Vin}} = \frac{A_F\left(\frac{f}{fc}\right)}{\sqrt{1+\left(\frac{f}{fc}\right)^2}}$$

- Where:
- A_F = the Pass band Gain of the filter, (1 + R2/R1)
- f = the Frequency of the Input Signal in Hertz, (Hz)
- fc = the Cut-off Frequency in Hertz, (Hz)

Just like the low pass filter, the operation of a high pass active filter can be verified from the frequency gain equation above as:

- 1. At very low frequencies, $f < fc$ $\frac{Vout}{Vin} < A_F$
- 2. At the cut-off frequency, $f = fc$ $\frac{Vout}{Vin} = \frac{A_F}{\sqrt{2}} = 0.707\,A_F$
- 3. At very high frequencies, $f > fc$ $\frac{Vout}{Vin} \cong A_F$

Then, the **Active High Pass Filter** has a gain A_F that increases from 0Hz to the low frequency cut-off point, f_C at 20dB/decade as the frequency increases. At f_C the gain is $0.707A_F$, and after f_C all frequencies are pass band frequencies so the filter has a constant gain A_F with the highest frequency being determined by the closed loop bandwidth of the op-amp.

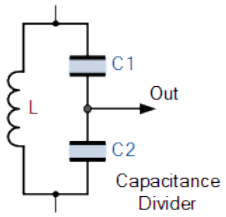
Active Low Pass Filter

In the RC Passive Filter tutorials, we saw how a basic first-order filter circuits, such as the low pass and the high pass filters can be made using just a single resistor in series with a non-polarized capacitor connected across a sinusoidal input signal.

25. (a) Explain working principle of Colpitts oscillators with diagram

THE COLPITTS OSCILLATOR

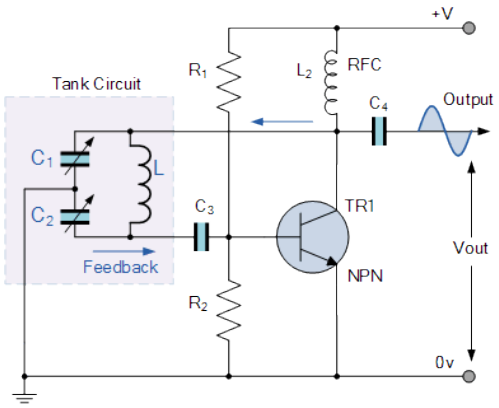
The Colpitts Oscillator design uses two centre-tapped capacitors in series with a parallel inductor to form its resonance tank circuit and produce sinusoidal oscillations.



The Colpitts oscillator uses a capacitive voltage divider network as its feedback source. The two capacitors, C1 and C2 are placed across a single common inductor, L as shown.

Then C1, C2 and Lform the tuned tank circuit with the condition for oscillations being: $X_{C1} + X_{C2} = X_L$, the same as for the Hartley oscillator circuit.

The advantage of this type of capacitive circuit configuration is that with less self and mutual inductance within the tank circuit, frequency stability of the oscillator is improved along with a more simple design.



The emitter terminal of the transistor is effectively connected to the junction of the two 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.

Resistors, R1 and R2 provide the usual stabilizing DC bias for the transistor in the normal manner while the additional capacitors act as a DC-blocking bypass capacitors. A radio-frequency choke (RFC) is used in the collector circuit to provide a high reactance (ideally open circuit) at the frequency of oscillation, (fr) and a low resistance at DC to help start the oscillations.

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 undamped oscillations. The amount of feedback is determined by the ratio of C1 and C2. These two capacitances are generally "ganged" together to provide a constant amount of feedback so that 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 or 360^o.

The amount of feedback depends on the values of C1 and C2. We can see that the voltage across C1 is the the same as the oscillators output voltage,Vout and that the voltage across C2 is the oscillators feedback voltage. Then the voltage across C1 will be much greater than that across C2.

Therefore, by changing the values of capacitors, C1 and C2 we can adjust the amount of feedback voltage returned to the tank circuit. However, large amounts of feedback may cause the output sine wave to become distorted, while small amounts of feedback may not allow the circuit to oscillate.

Then the amount of feedback developed by the Colpitts oscillator is based on the capacitance ratio of C1 and C2 and is what governs the the excitation of the oscillator. This ratio is called the "feedback fraction" and is given simply as:

$$\text{Feedback Fraction} = \frac{C_1}{C_2}\,\%$$

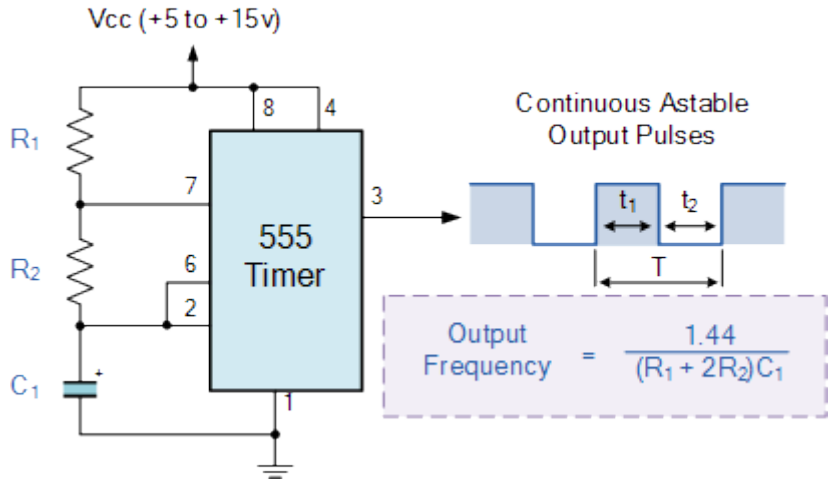
OR

(b)Explain working principle of Astable mutlivibrator using 555 timer.

ASTABLE MULTIVIBRATOR USING 555 TIMER

An Astable Multivibrator is an oscillator circuit that continuously produces rectangular wave without the aid of external triggering. So Astable Multivibrator is also known as Free Running Multivibrator.

Astable Multivibrator using 555 – Circuit



Astable Multivibrator using 555 Timer Circuit Diagram

Above figure shows the circuit diagram of a 555 Timer wired in Astable Mode. 8th pin and 1st pin of the IC are used to give power, Vcc and GND respectively. The 4th pin is RESET pin which is active low and is connected to Vcc to avoid accidental resets. 5th pin is the Control Voltage pin which is not used. So to avoid high frequency noises it is connected

to a capacitor C' whose other end is connected to ground. Usually C' = 0.01μF. The Trigger (pin 2) and Threshold (pin 6) inputs are connected to the capacitor which determines the output of the timer. Discharge pin (pin 7) is connected to the resistor Rb such that the capacitor can discharge through Rb. Diode D connected in parallel to Rb is only used when an output of duty cycle less than or equal to 50% is required. For the sake of explaing the working Circuit Diagram with Internal Block diagram is shown below.

Working

- When the circuit is switched ON, the capacitor (C) voltage will be less than 1/3 Vcc. So the output of the lower comparator will be HIGH and of the higher comparator will be LOW. This SETs the output of the SR Flip-flop.
- Thus the discharging transistor will be OFF and the capacitor C starts charging from Vcc through resistor Ra & Rb.
- When the capacitor voltage will become greater than 1/3 Vcc (less than 2/3 Vcc), the output of both comparators will be LOW and the output of SR Flip-flop will be same as the previous condition. Thus the capacitor continuous to charge.
- When the capacitor voltage will becomes slightly greater than 2/3 Vcc the output of the higher comparator will be HIGH and of lower comparator will be LOW. This resets the SR Flip-flop.
- Thus the discharging transistor turns ON and the capacitor starts discharging through resistor Rb.
- Soon the capacitor voltage will be less than 2/3 Vcc and output of both comparators will be LOW. So the output of the SR Flip-flop will be the previous state.
- So the discharging of capacitor continuous.
- When the capacitor voltage will become less than 1/3 Vcc, the output SETs since the output of lower comparator is HIGH and of higher comparator is LOW and the capacitor starts charging again.
- This process continuous and a rectangular wave will be obtained at the output.