AALIM MUHAMMED SALEGH COLLEGE OF ENGINEERING
ELECTRONICS AND COMMUNICATION ENGINEERING
FOURTH SEMESTER
EC8452 -ELECTRONIC CIRCUITS II
PART A
UNIT – I FEEDBACK AMPLIFIERS AND STABILITY

1. List the characteristics of an amplifier which are modified by the negative feedback.**[NOV/DEC 2013]**

Gain, stability, Frequency response, Frequency distortion, Noise and nonlinear distortion, Input and output impedances and bandwidth.

2. Calculate the closed loop gain of a negative feedback amplifier if the open loop gain is 100000 and the feedback factor is 0.01**.[MAY/JUNE 2013]**

$A_{vf} = A_v/(1+A_v\beta)$
$=100000 / (1+(100000*0.01))$
$=99.9$

3.Define Sensitivity and Desensitivity.

Sensitivity is defined as the ratio of percentage change in voltage gain with feedback to the percentage change in voltage gain without feedback. The reciprocal of sensitivity is called Desensitivity.

Sensitivity $D=1+A\beta$

4. Define feedback and What are the types of feedback?

A portion of the output signal is taken from the output of the amplifier and is combined with the normal input signal. This is known as feedback.

i. Voltage-series feedback
ii. Voltage-shunt feedback
iii. Current-series feedback
iv. Current-shunt feedback

5.What is the effect of input and output impedances of an amplifier if it employs voltage series negative feedback ?

Input resistance with feedback, $R_{if} = (1+A\beta) R_i$
Output resistance with feedback, Rof = $R_o / (1+A\beta)$.
Input impedance increases and output impedance decreases.

6. Give the properties of negative feedback. / What are the advantages of negative feedback over positive feedback? **[APRIL/MAY 2015]**

i. Negative feedback stabilizes the gain
ii. reduces the noise and the distortion.
iii. Improves the frequency response
iv. Increases the bandwidth.
v. Increases the input impedance and decreases the output impedance.

7. Give the effect of negative feedback on amplifier characteristics. **[APRIL/MAY 2014]**

Characteristics	Type of feedback			
	Current-series	Voltage-series	Voltage-shunt	Current-shunt
Voltage gain	Decreases	Decreases	Decreases	Decreases
Bandwidth	Increases	Increases	Increases	Increases
Input resistance	Increases	Increases	Decreases	Decreases
Output resistance	Increases	Decreases	Decreases	Increases

8. The voltage gain without negative feedback is 40 dB. What is the new voltage gain if 3% negative feedback is introduced? **[APRIL/MAY 2015]**

$$A_{vf} = A_v/(1+A_v\beta)$$
$$=18.18$$

9.Discuss the effect of negative feedback on the frequency response of an amplifier

Increase of Bandwidth (cut off frequencies)

$Bw = f_2 - f_1$

$$A_f \times Bw_f = A \times Bw$$

The gain bandwidth product of with feedback and gain bandwidth product of without feedback remains the same.

As the voltage gain of a feedback amplifier reduces by the factor $\frac{1}{1+A\beta}$ its bandwidth would be increased by $(1 + A\beta)$.

$$Bw_f = B(1 + A\beta)$$
$$A_f = \frac{A}{1 + A\beta}$$

Due to negative feedback in the amplifier, the upper cut off freq is increased by factor $(1 + A\beta)$ and the lower cut off frequency is decreased by the same factor $(HA\beta)$.

$$f_{2f} = f_2(1 + A\beta), f_{12} = \frac{f_i}{(1 + A\beta)}$$

Hence bandwidth is increased.

10. Negative feedback stabilizes the gain. Justify the statement. **[MAY/JUNE 2014]**

1) <u>Stablisation of Gain</u>

Gain with negative feedback

$$A_f = \frac{A}{1 + A\beta}$$

Diff $\frac{dA_f}{dA} = \frac{(1 + A\beta)1 - A(B)}{(1 + A\beta)^2}$

$= 1 + A\beta - A\beta/(1 + A\beta)^2$

$$\frac{dA_f}{dA} = \frac{1}{(1 + A\beta)^2}$$

$$= \frac{1}{1 + A\beta}\frac{1}{1 + A\beta}$$

$$\frac{dA_f}{A_f} = \frac{A_f}{A}\frac{1}{1 + A\beta}$$

$$\frac{dA_f}{A_f} = \frac{dA}{A}\frac{1}{1 + A\beta}$$

$\frac{dA_f}{A_f} \rightarrow fraction\ change\ in\ amp\ voltage\ gain\ with\ feedback$

$\frac{dA}{A} \longrightarrow fraction\ change\ in\ Amp\ voltage\ gain\ without\ feedback$

$$\text{Sensitivity} = \frac{\frac{dA_f}{A_f}}{A_f/_A} = \frac{1}{1 + A\beta}$$

The reciprocal of the term sensitivity is called densenbitivity (D)

$D = 1 + A\beta$

11.What is the impact of negative feedback on noise in the circuit

Decreased Noise

Noise is reduced with feedback by a factor of $\frac{1}{1+A\beta}$

$$N_f = \frac{1}{1 + A\beta}$$

12. What is the impact of negative feedback on input and output impedances.

Increase in Input Impedance.

An amplifier should have high input impedance so that it will not load the preceding stage (or) input voltage source.

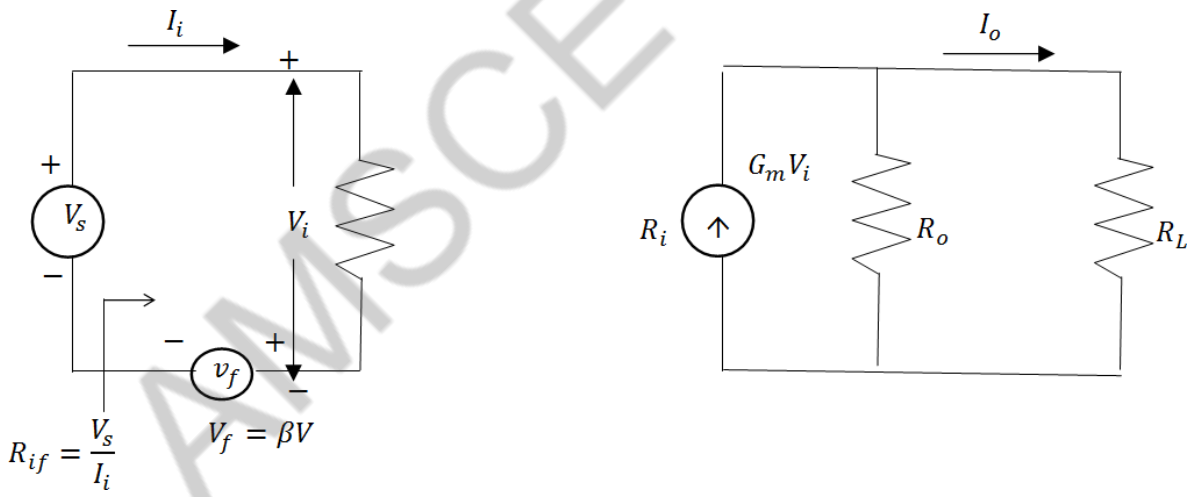
$$\boxed{Z_{if} = Z(1 + A\beta)}$$

Decrease in Output Impedance.

An amplifier with low output impedance is capable of delivering power to the load without much loss. It is achieved by Negative feedback.

$$\boxed{Z_{of} = \frac{Z_o}{1 + A\beta}}$$

13. Draw a single stage amplifier with current series feedback.[**MAY/JUNE 2014]**



14. Define positive feedback?

If the feedback signal is in phase with input signal, then the net effect of the feedback will increase the input signal given to the amplifier. This type of feedback is said to be positive or regenerative feedback.

15. Define negative feedback?

If the feedback signal is out of phase with the input signal then the input voltage applied to the basic amplifier is decreased and correspondingly the output is decreased. This type of feedback is known as negative or degenerative feedback.

16. Define feedback?

A portion of the output signal is taken from the output of the amplifier and is combined with the normal input signal. This is known as feedback.

17. Write the expression for input and output resistance of current shunt feedback amplifier?

Input resistance with feedback,

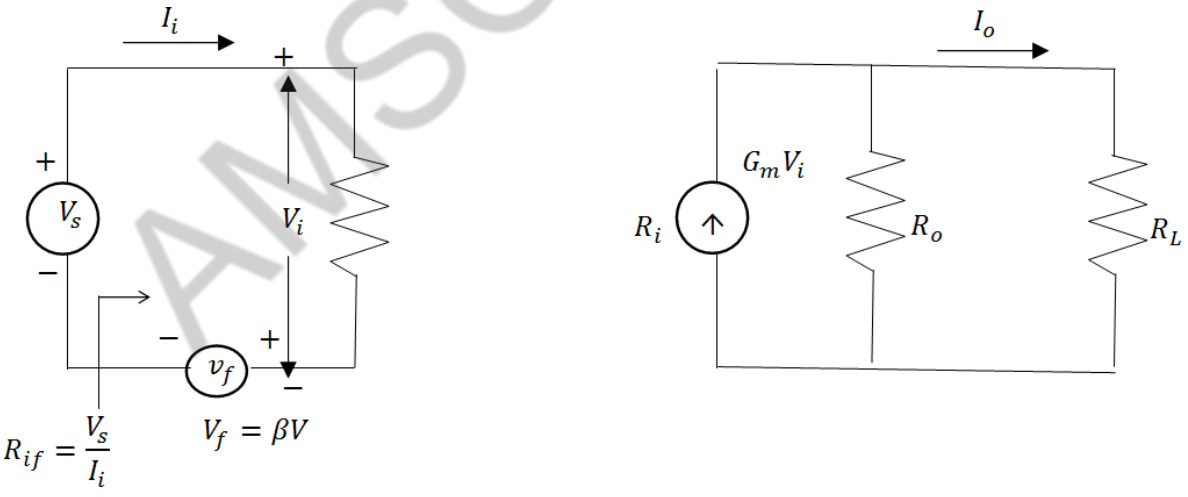
$$R_{if} = R_i / (1+A\beta)$$

Output resistance with feedback, $R_{of} = R_o (1+A\beta)$

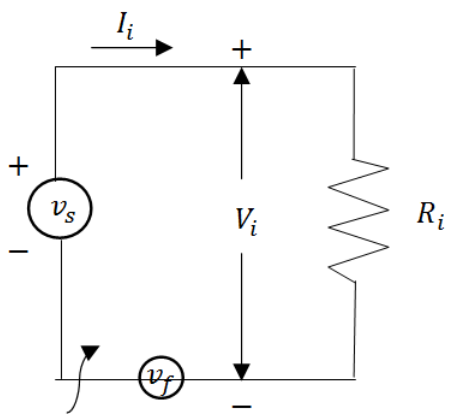
18. Mention the three networks that are connected around the basic amplifier to implement feedback concept.

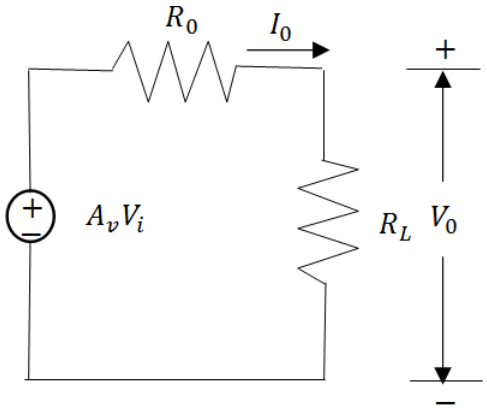
1)Mixing network
2)feedback network
3) sampling network

19. Draw the equivalent circuit of Transconductance amplifier.



20. Draw the equivalent circuit of series shunt amplifier.





UNIT – II OSCILLATORS

1. What is Oscillator circuit? And What are the classifications of Oscillators?

A circuit with an active device is used to produce an alternating current is called an oscillator circuit.

*Based on wave generated:

i. Sinusoidal Oscillator,

ii. Non-sinusoidal Oscillator or Relaxation Oscillator

Ex: Square wave, Triangular wave, Rectangular wave etc.

*According to principle involved:

i. Negative resistance Oscillator,

ii. Feedback Oscillator.

*According to frequency generated:

i. Audio frequency oscillator 20 Hz – 20 kHz

ii. Radio frequency Oscillator 30 kHz– 30 MHz

iii. Ultrahigh frequency Oscillator 30 MHz – 3GHz

iv. Microwave Oscillator 3 GHz – above.

* According to circuit components

i.RC-Phase shift Oscillator,

ii. LC-Oscillators

i. Tuned collector Oscillator

ii. Hartley Oscillator

iii. Colpits Oscillator

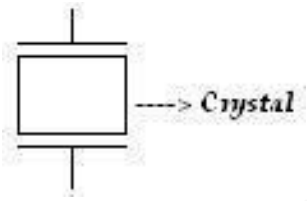
iv. Clap Oscillator

2. Define Barhausen Criterion. / What are the conditions for oscillation **?**
[APRIL/MAY 2015] [MAY/JUNE 2014] [NOV/DEC 2013]

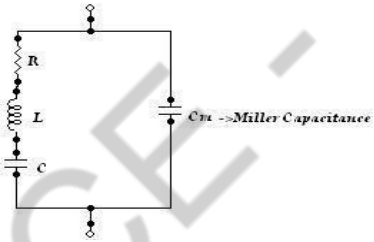
i.The total phase shift around the loop as the signal proceed from input through amplifier feedback network back to input again completing a loop is 0 or 360 degree or multiple of 2π.
ii.The magnitude of the product of the loop gain(A) of the amplifier and the feedback(β) is unity |Aβ|=1

3. Define Piezoelectric effect.

When applying mechanical energy to some type of crystals called piezoelectric crystals the mechanical energy is converted into electrical energy is called piezoelectric effect.



4. Draw the equivalent circuit of crystal oscillator. **[MAY/JUNE 2014] [NOV/DEC 2013]**



5. What is Miller crystal oscillator? Explain its operation.

It is nothing but a Hartley oscillator its feedback Network is replaced by a crystal. Crystal normally generate higher frequency reactance due to the miller capacitance are in effect between the transistor terminal.

6. State the frequency for RC phase shift oscillator.

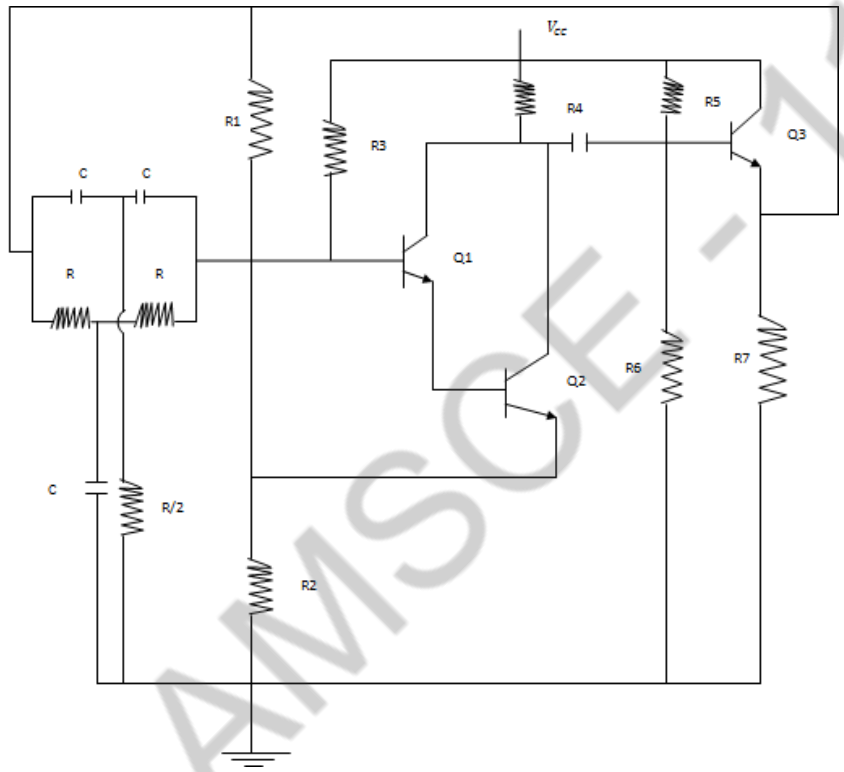
The frequency of oscillation of RC-phase shift oscillator is
$f=1/(2\pi RC\sqrt{6})$

7.Write the feedback factor expression for BJT Transistor based Wein bridge oscillator. **[APRIL/MAY 2015]**

$\beta=SCR/(1+S^2C^2R^2+3SCR)$

8.State the expression for the frequency of operation of Hartley oscillator.
$f=1/(2\pi\sqrt{C(L1+L2)}$)

9.Draw the circuit diagram of a Twin-T oscillator. **[MAY/JUNE 2014]**



10.What is the advantage of a clapp oscillator over colpitts oscillator?
i.Frequency is stable and accurate.
ii.Good frequency stability
iii.Stray capacitance has no effect on C3 which decides the frequency.

11.Mention the features of crystal oscillator.
i. It produces the extremely stable outputs.
ii. The temperature has no effect on the frequency.
iii. It has very much reduced phase noise.

12.A Wein bridge oscillator is used for operation at 10KHz. If the value of the resistance is 100 KΩ. What is the value of C? **[MAY/JUNE 2013]**

$f=1/(2\pi RC)$
f=10KHz
R=100 KΩ
Substituting, C=159.155pf

13. How does the crystal oscillator maintains stable frequency?

The frequency stability of the oscillator depends on the $d\theta/d\omega$ that is rate of change of phase with respect to frequency. Higher the value of $d\theta/d\omega$ stability of oscillator increases.

In crystal oscillator, the crystal oscillates at resonant frequency at which $d\theta/d\omega$ is extremely high. Hence the frequency becomes independent of the circuit features. The frequency drift with time for the crystal is also negligibily small. Hence the crystal oscillator maintains stable frequency.

14. Why is difficult to have a variable frequency operation with an RC phase shift oscillator?

By changing the values of R and C, the frequency of the oscillator can be changed. But the value of R and C of all three sections of RC phase shift oscillator must be changed simultaneously to satisfy the oscillating conditions. The exact changes in R and C values of all three sections is practically impossible. Hence it is difficult to have a variable frequency operation with RC phase shift oscillator.

15. What is the principle behind the operation of crystal oscillator?

At the series resonant frequency the crystal appears resistive in the circuit, impedance is at a minimum and current flow is maximum. As the frequency is increased beyond the point of series resonance, the crystal appears inductive in the circuit. Thus the operating the crystal at a frequency slightly higher than series resonant frequency it operates as an inductor. And replacing inductor by such a crystal in oscillator tank circuit, a stable frequency as decided by the crystal can be achieved.

16. What are the advantages and disadvantages of RC phase shift oscillator?

Advantages

1) The circuit is simple to design
2) It can produce output over audio frequency range.
3) It is fixed frequency oscillator.

Disadvantages

1) The frequency stability is poor.

17. What is frequency stability of an oscillator?

The measure of ability of an oscillator to maintain the desired frequency for long time as possible is called frequency stability of an oscillator.

The factor affecting the frequency stability are, changes in temperature , Changes in values of the components in tank circuit,variation power supply.

18. State the frequency of RC and LC oscillator.

RC oscillator-low frequency-20Hz to 200 KHz

LC oscillator-High frequency range-200 KHz to few gigaHz

19. What is the major disadvantage of a Twin-T oscillator?

It can be operated at one frequency and frequency cannot be varied.

20. What is the necessary conditions for a wein bridge oscillator to have sustained oscillations?

1) A>=3 and
2) Phase shift must be 360°

UNIT-III TUNED AMPLIFIERS

1. What is a tuned amplifier? **[NOV/DEC 2013]**

The amplifier with a circuit that is capable of amplifying a signal over a narrow band of frequencies are called tuned amplifiers.

2. What is the expression for resonant frequency?

$$fr=1/2\pi\sqrt{LC}$$

3. What are the different coil losses?

Hysteresis loss
Copper loss
Current loss

4. What is the classification of tuned amplifiers? **[NOV/DEC 2013]**

Single tuned amplifiers
Double tuned amplifiers
Stagger tuned amplifiers

5. What is a single tuned amplifier?

An amplifier circuit that uses a single parallel tuned circuit as a load is called single tuned amplifier.

6. What are the advantages of tuned amplifiers

They amplify defined frequencies.
Signal to noise ratio at output is good
They are suited for radio transmitters and receivers

7. What are the disadvantages of tuned amplifiers?

The circuit is bulky and costly
The design is complex.
They are not suited to amplify audio frequencies.

8. What is neutralization? **[MAY/JUNE 2014] [NOV/DEC 2013] [MAY/JUNE 2013]**

The effect of collector to base capacitance of the transistor is neutralized by introducing a signal that cancels the signal coupled through collector base capacitance.
This process is called neutralization.

9. What are double tuned amplifiers?

The amplifiers having two parallel resonant circuit in its load are called double tuned amplifiers.

10. What is a stagger tuned amplifier?

It is a circuit in which two single tuned cascaded amplifiers having certain bandwidth are taken and their resonant frequencies are adjusted that they are

separated by an amount equal to the bandwidth of each stage. Since resonant frequencies are displaced it is called stagger tuned amplifier.

11. What are the advantages of stagger tuned amplifier? **[MAY/JUNE 2013]**

The advantage of stagger tuned amplifier is to have better flat, wideband characteristics.

12. What are the advantages of double tuned over single tuned?

1. Possess flatter response having steeper sides
2. Provides larger 3 db bandwidth

Provides large gain-bandwidth product.

13. What are the different types of neutralization?

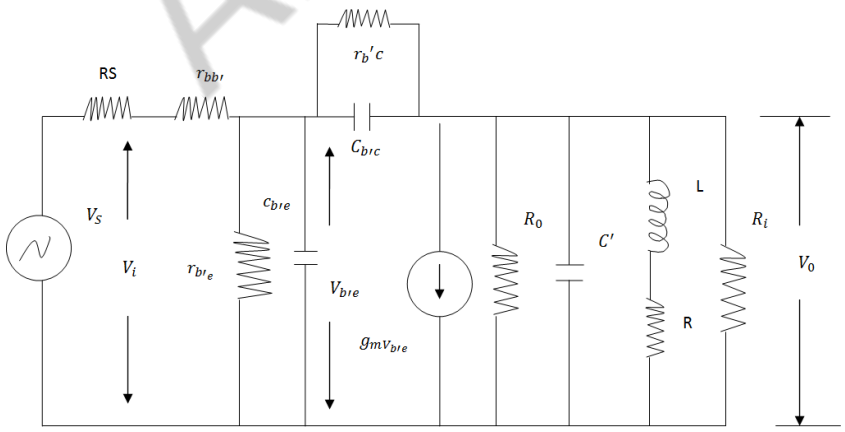
1. Hazeltine neutralization
2. Rice neutralization
3. Neutrodyne neutralization.

14. What are loaded and unloaded Q?(APR/MAY 2019)

When the tank circuit is not connected to any external circuit or load Q account for the internal losses and it is known as unloaded Q(Qu)
Qu=2π*(maximum energy stored per cycle/energy dissipated per cycle)

In practice the tank is connected to the load. Hence the energy dissipated takes place in the tank circuitas well as in the external load.
Ql=2π*(maximum energy stored per cycle/energy dissipated per cycle+ energy dissipated per cycle due to the precence of external load)

15. Draw the small signal model of single tuned amplifier. **[APRIL/MAY 2015]**



16. Determine the bandwidth of two stage synchronous tuned amplifier. Assume the bandwidth of individual stage is 310 KHz **[APRIL/MAY 2014]**

$$B_{2n}=B_2\sqrt{2^{(1/n)}-1}$$
$$B_{2n}=199.46KHz$$

17. How class C amplifier is used as frequency multiplier ?

Class C tuned is used as a mixer or frequency converter circuit. Frequency conversion is a process of translating modulating signal to a higher or lower frequency while retaining the original information.

18. A tuned amplifier has its maximum gain at a frequency of 2 MHz and has a bandwidth of 50 KHz. Calculate the Q factor.

$Q=f_r/BW$

=2MHz/50 KHz =40

19. What is the relation between bandwidth and Q factor and what is the effect of Q on the resonance circuit?

$Q=f_r/BW$

Increase in Q reduces bandwidth and increase selectivity of the resonance circuit.

20. Mention the application of Class C tuned amplifier.

1) Used in high power , High frequency applications such as radio frequency transmitters.
2) Class-C amplifier has higher efficiency than other amplifiers.

21. Mention the applications of tuned amplifiers.

1) They are used in radio receivers to amplify a particular band of frequencies for which the radio receiver is tuned.
2) Tuned class B and Class C amplifiers are used as an output RF amplifiers in radio transmitters to increase the output efficiency and to reduce harmonics.

UNIT – IV WAVE SHAPING AND MULTIVIBRATOR CIRCUITS

1. Differentiate between clipper and clamper circuits. **[APRIL/MAY 2015]**

Clipper circuits are used to clip unwanted portion of the waveform without distorting the remaining waveform.

The circuit which is used to add a DC level as per the requirement to the AC output signals are called clamper circuits

2.What is the role of commutation capacitor in bistable multivibrator circuit? **[APRIL/MAY 2015]**

3. What is a Multivibrator?

The electronic circuits which are used to generate nonsinusoidal waveforms are called Multivibrators.

4,.Name the types of Multivibrators?

Bistable Multivibrator, Monostable Multivibrator,Astable Multivibrator

5. When will the circuit change from stable state in bistable Multivibrator ?

When an external trigger pulse is applied, the circuit changes from one stable state to another.

6. What are the applications of bistable Multivibrator?

It is used in the performance of many digital operations such as counting and storing of the Binary information. It also finds applications in the generation and processing of pulse – type waveforms.

7. Why is monostable Multivibrator called gatting circuit?

The circuit is used to generate the rectangular waveform and hence can be used to gate other Circuits hence called gating circuit.

8. Why is monostable Multivibrator called delay circuit?

The time between the transition from quasi-stable state to stable state can be predetermined and hence it can be used to introduce time delays with the help of fast transition. Due to this application is Called delay circuit.

9,What is the main characteristics of Astable Multivibrator?

The Astable Multivibrator automatically makes the successive transitions from one quasi- stable State to other without any external triggering pulse.

10, What are the two stable states of bistable Multivibrator?

i. Q1 OFF (cut off) and Q2 ON (Saturation)
ii. Q2 OFF (Cut off) and Q1 On (Saturation)

11. What are the advantages of monostable Multivibrator. **[APRIL/MAY 2014]**

- used to introduce time delays as gate width is adjustable
- used to produce rectangular waveform and hence can be used as gating circuit.

12. What are the applications of astable Multivibtrator. **[APRIL/MAY 2014]**

- used as a clock for binary login signals
- used as a square wave generator, voltage to frequency converter.

13. What is UTP of the Schmitt trigger

When Vi reaches to VBE1 +VE the Q1 gets driven to active region. This input voltage level is called upper threshold point.

14.What is the important application of Schmitt trigger?

- It is used as an amplitude comparator
- It is used as a squaring circuit.

15.Name the types of Multivibrators?
Bistable Multivibrator, Monostable Multivibrator,Astable Multivibrator.

16. What are the other names of monostable Multivibrator?

One-shot, Single-shot, a single-cycle, a single swing, a single step Multivibrator, Univibrator.

17. What is the other name of Astable Multivibrator- why is it called so?
As it does not require any external pulse for transition, it is called free running Multivibrator.

18.Why does one of the transistor start conducting ahead of other?
The characteristic of both the transistors are never identical hence after giving supply one of the transistors start conducting ahead of the other.

19. Define transition time?
It is defined as the time interval during which conduction transfers from one transistor to other.

20. What is LTP Schmitt trigger.
The level of Vi at which Q1 becomes OFF and Q2 on is called lower threshold point.

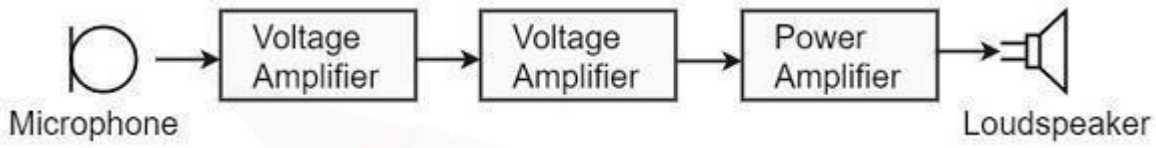
21. Define transfer Characteristics
The graph of output voltage against input voltage is called transfer characteristics of Schmitt trigger.

Unit 5
POWER AMPLIFIERS AND DC CONVERTERS

PART A

1. Define Power Amplifier

After the audio signal is converted into electrical signal, it has several voltage amplifications done, after which the power amplification of the amplified signal is done just before the loud speaker stage. This is clearly shown in the below figure.



While the voltage amplifier raises the voltage level of the signal, the power amplifier raises the power level of the signal. Besides raising the power level, it can also be said that a power amplifier is a device which converts DC power to AC power and whose action is controlled by the input signal.

2. What is Power Transistor

For Power amplification, a normal transistor would not do. A transistor that is manufactured to suit the purpose of power amplification is called as a **Power transistor**.A Power transistor differs from the other transistors, in the following factors.It is larger in size, in order to handle large powers.The collector region of the transistor is made large and a heat sink is placed at the collector-base junction in order to minimize heat generated.

The emitter and base regions of a power transistor are heavily doped.Due to the low input resistance, it requires low input power.Hence there is a lot of difference in voltage amplification and power amplification. So, let us now try to get into the details to understand the differences between a voltage amplifier and a power amplifier.

3. Write the Difference between Voltage and Power Amplifiers

Voltage Amplifier

The function of a voltage amplifier is to raise the voltage level of the signal. A voltage amplifier is designed to achieve maximum voltage amplification.

The voltage gain of an amplifier is given by

$$Av=\beta(RcRin)Av=\beta(RcRin)$$

The characteristics of a voltage amplifier are as follows −

The base of the transistor should be thin and hence the value of β should be greater than 100.The resistance of the input resistor R_{in} should be low when compared to collector load R_C.The collector load R_C should be relatively high. To permit high collector load, the voltage amplifiers are always operated at low collector current.The voltage amplifiers are used for small signal voltages.

Power Amplifier

The function of a power amplifier is to raise the power level of input signal. It is required to deliver a large amount of power and has to handle large current.

The characteristics of a power amplifier are as follows −

The base of transistor is made thicken to handle large currents. The value of β being (β > 100) high.The size of the transistor is made larger, in order to dissipate more heat, which is

produced during transistor operation.Transformer coupling is used for impedance matching.

4. What are all the types of Signal Amplifier

Type of Signal		Classification	Frequency of
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

Amplifiers can be thought of as a simple box or block containing the amplifying device, such as a Bipolar Transistor, Field Effect Transistor or Operational Amplifier, 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".

An ideal signal amplifier will have 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.

5. What are all the advantages of class A Power amplifier

- The current flows for complete input cycle
- It can amplify small signals
- The output is same as input
- No distortion is present

6. Define Class C Power Amplifier

When the collector current flows for less than half cycle of the input signal, the power amplifier is known as **class C power amplifier**.

7. What are all the Applications of Power MOSFET

- The power MOSFET's are used in the power supplies
- DC to DC converters
- Low voltage motor controllers
- These are widely used in the low voltage switches which are less than the 200V

8. What are all the Advantages of Buck Boost Converter

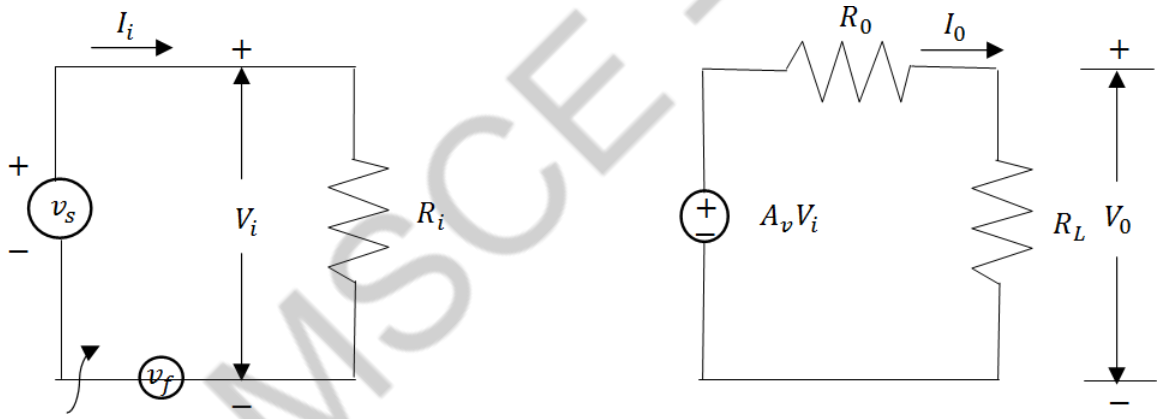
- It gives higher output voltage.
- Low operating duct cycle.
- Low voltage on MOSFETs

UNIT – I

FEEDBACK AMPLIFIERS

PART B

1) Determine the input impedance and output impedance of transistor based voltage series feedback amplifiers.**[APRIL/MAY 2015][MAY/JUNE 2014][NOV/DEC 2013]**



Input Resistance

Input resistance with feedback $R_{if} = \frac{V_s}{I_i}$

Applying KVL to the input,

$V_s - I_i R_i - V_f = O$

$V_s = I_i R_i + V_f$

$V_s = I_i R_i + \beta V_o$

O/p Voltage $V_o = A_v V_i$

$AV = \frac{V_o}{V_i}$

$$AV = \frac{A_v R_L}{R_o + R_L}$$

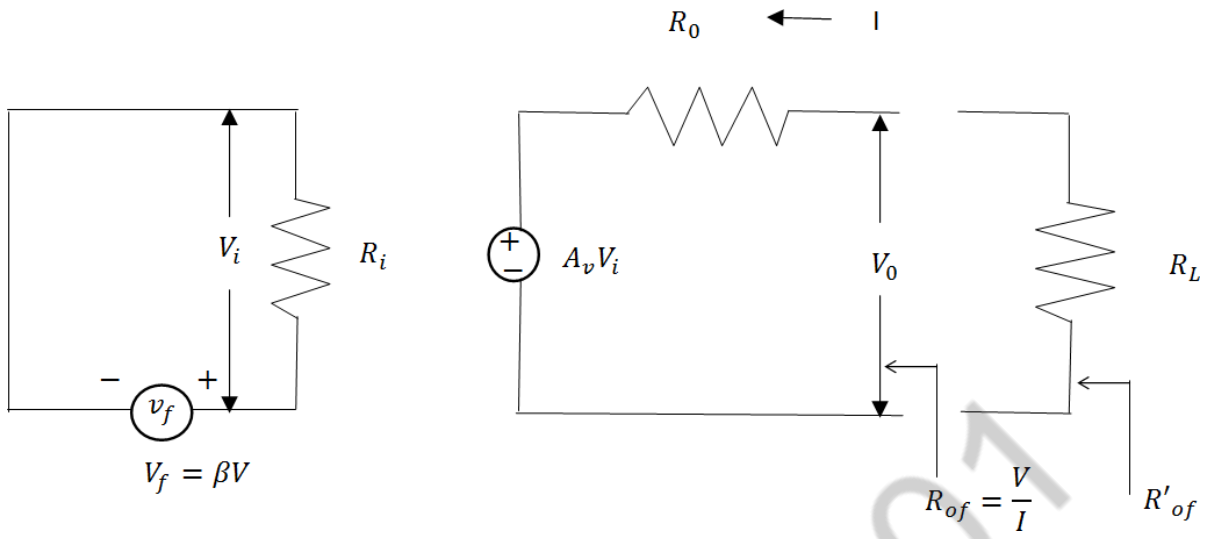
Substituting the value V_o

$$V_s = I_i R_i + \beta A_v V_i R_i$$

$$\frac{V_s}{I_i} = R_i + \beta A_v R_i$$

$$R_{if} = R(1 + \beta A_v)$$

O/p Resistance



Applying KVL to the o/p side,

$A_v V_i + I R_o - V = o$

$$I = \frac{V - A_v V_i}{R_o}$$

$V_i = -V_f = -\beta v\, V_s = o$

$$I = \frac{V + A_v \beta_v}{R_o}$$

$$I = \frac{V(+\beta A_v)}{R_o}$$

$R_{of} = V/I$

$$\boxed{R_{of} = \frac{R_o}{1 + \beta A_v}}$$

$R_o = R_{of} \| R_L$

$$= \frac{R_{of} R_L}{R_{of} + R_L} = \frac{\frac{R_o}{1 + \beta A_v} \times R_L}{\frac{R_o}{1 + \beta A_v} + R_L}$$

$$= \frac{R_o R_L}{R_o + R_L (1 + \beta A_v)}$$

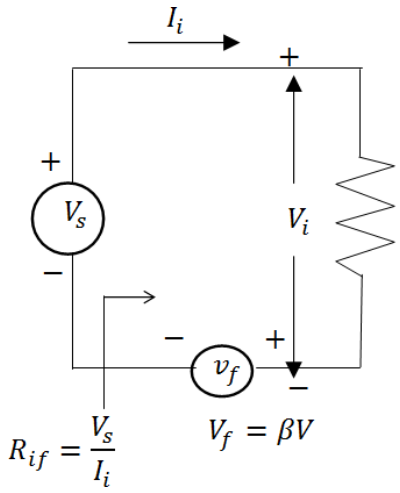
$$= \frac{R_o R_L}{R_o + R_L + \beta A_v R_L}$$

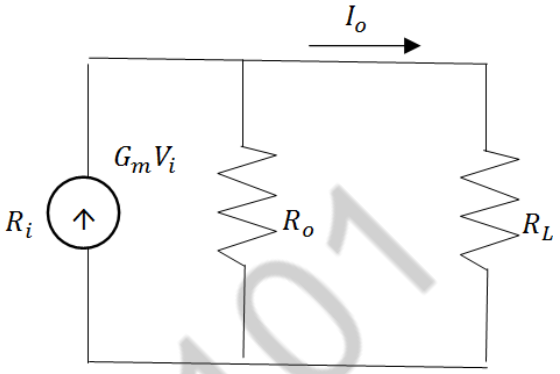
$$= \frac{R_o R_L / R_o + R_L}{1 + \beta A_v \frac{R_L}{R_o + R_L}}$$

$$\boxed{R_{o'f} = \frac{R_o'}{1 + \beta A_v}}$$

2) Determine input impedance and output impedance of transistor based current series feedback Amplifier **[NOV/DEC 2012][NOV/DEC 2013]**

I/p Resistance





$$R_{if} = \frac{V_s}{I_i}$$

Applying KVL to the input side,

$$V_s - I_i R_i - V_f = o$$

$$V_s = I_i R_i + V_f$$

$$V_s - I_i R_i + \beta I_o$$

$$I_o = \frac{G_m V; R_o}{R_o + R_L} = G_m V_i$$

$$G_m = \frac{G_m R_o}{R_o + R_L}$$

Substituting I_o in V_s

$$V_s = I_i R_i + \beta I_o$$

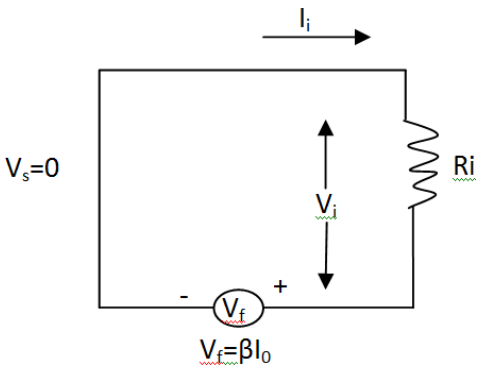
$$= I_i R_i + \beta G_m V_i$$

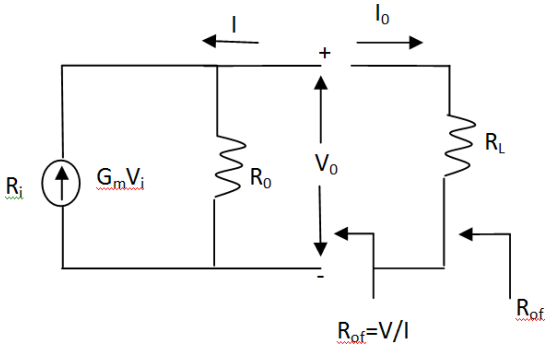
$$= I_i R_i + \beta G_m V_i R_i$$

$$\frac{V_s}{I_i} = R(1 + \beta G_m)$$

$$\boxed{R_{if} = R(1 + \beta G_m)}$$

O/p Resistance





Applying KCL to the output,

$$I = \frac{V}{R_o} = -G_m V_i$$

$$V_i = -V_f = \beta I_o$$

$$= \beta I \; I_o = I$$

$$I = \frac{V}{R_o} - G_m \beta I$$

$$I + G_m \beta I = {}^{V}/_{R_o}$$

$$I + G_m \beta = {}^{V}/_{R_o}$$

$$\boxed{R_{of} = {}^{V}/_{I} = R(1 + G_m \beta)}$$

$$R_{of}{}' = R_{of}\, 11 R_L = \frac{R_{of} R_L}{R_{of} + R_L}$$

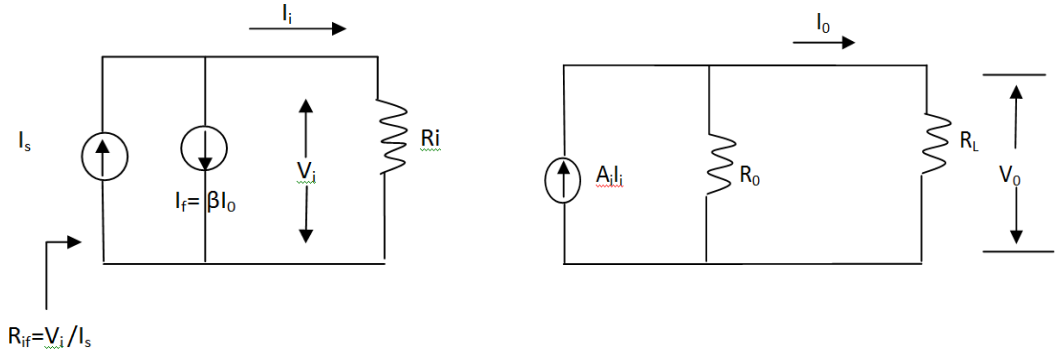
$$= \frac{R(1 + \beta G_m) R_L}{R(1 + \beta G_m) + R_L}$$

$$= \frac{R_o R(1 + \beta G_m)}{R_o R_L + R_o \beta G_m} = \frac{R_o R_L (1 + \beta G_m)}{1 + \beta G_m \frac{R_o}{R_o + R_L}}$$

$$\boxed{R_{of}{}' = \frac{R_o{}'(1 + \beta G_m)}{1 + \beta G_m}}$$

3) Determine input impedance and output impedance of transistor based current shunt feedback Amplifier.

I/p Resistance



Applying KCL to the input node,

$I_s - I_i - I_f + I_f = o$

$I_s = I_i + I_f$

$= I_i + \beta I_o$

O/p Current I_o is given as,

$$I_o = \frac{A_i I; R_o}{R_o + R_L}$$

$I_o = A_I I;$

Substituting the value of I_o,

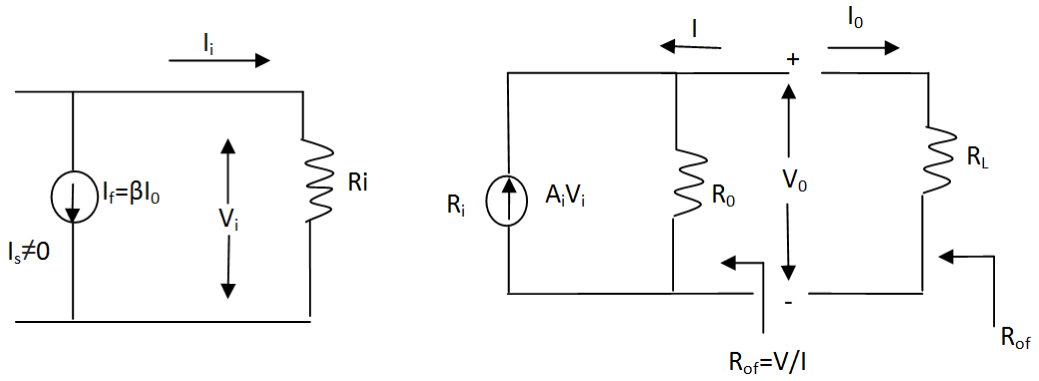
$I_s = I_i + \beta A_i I;$

$I_s = I(1 + \beta A_I)$

$$R_{if} = \frac{V_i}{I_s} = \frac{V_i}{I_i(1 + \beta\ )_I}$$

$$\boxed{R_{if} = \frac{R_i}{(1 + \beta\ )_I}}$$

O/p Resistance



Applying the KCL to the output node,

$$I = \frac{V}{R_o} - A_i I;$$

$$I_i = -I_f = -\beta I_o$$

$$= \beta I$$

$$\therefore I_s = o$$

$$I = -I_o$$

Substituting value of I_i

$$I = \frac{V}{R_o} - A_i \beta I$$

$$I + A_i \beta I = {}^{V}/_{R_o}$$

$$(1 + A_i\beta) = \frac{V}{R_o}$$

$$\boxed{R_{of} = {}^{V}/_{I} = R(1 + \beta A_i)}$$

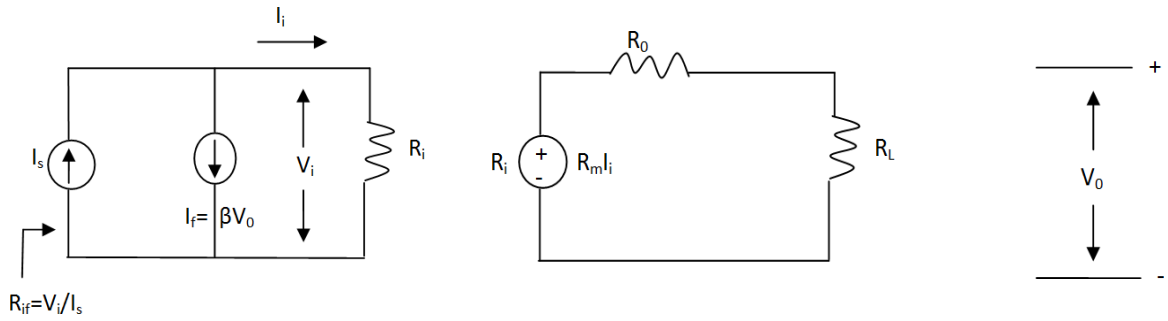
$$R_{of}{}' = R_{of}\,11R_L = \frac{R_{of} \times R_L}{R_{of} + R_L}$$

$$= \frac{R(1+\beta A_i)R_L}{R_o(1+\beta)\#R_i{}_L} = \frac{R_o R_L(1+\beta A_i)}{R_o + R_L + \beta A_i R_o}$$

$$R_o{}'_f = \frac{\frac{R_o R_L}{R_o + R_L}(1+\beta A_i)}{1 + \frac{\beta A_i R_o}{R_o + R_L}} = \frac{R_o'(1+\beta A_i)}{1+\beta A_I}$$

4) Determine input impedance and output impedance of transistor based voltage shunt feedback Amplifier**[NOV/ DEC 2012]**

I/p Resistance



Otherwise called, Trans Resistance Amplifier.
Applying KCL at input node we get,

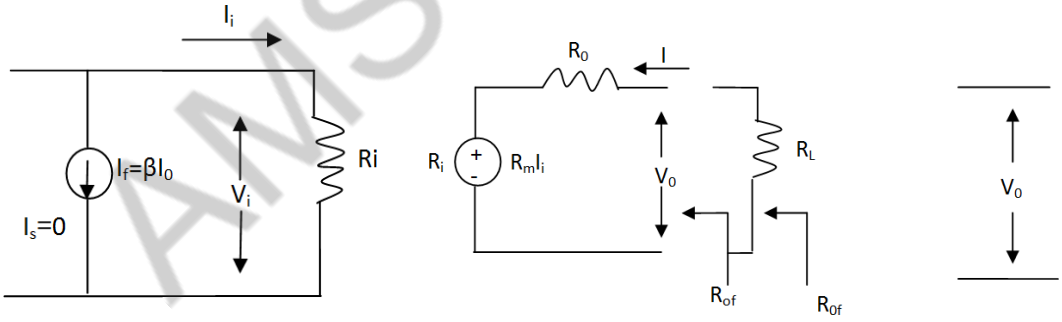
$$I_s - I_i - I_f = o$$
$$I_s = I_i + I_f$$
$$= I_i + \beta V_o$$
$$V_o = \frac{R_m I_i R_L}{R_o + R_L}$$
$$V_o = R_m I_i$$

Substituting value of V_o

$$I_s = I_i + \beta R_m I_i$$
$$= {}_i(1 + \beta R_m)$$
$$R_{if} = \frac{V_i}{I_s} = \frac{V_i}{I_i(1+\beta)_m}$$

$$\boxed{R_{if} = \frac{R_i}{1 + \beta R_m}}$$

O/p Resistance



Applying KVL to o/p side,

$$R_m I_i + I R_o - V = o$$
$$I R_o = V - R_m I_i$$
$$I = \frac{V - R_m I_i}{R_o}$$
$$I_i = -I_f = -\beta V$$

Substituting I_i

$$I = \frac{V + R_m\beta V}{R_o} = \frac{(1 + R_m\beta)}{R_o}$$

$$R_{of} = V/I$$

$$\boxed{R_o = \frac{R_o}{1 + R_m\beta}}$$

$$R_{of}' = R_{of} 11 R_L$$

$$= \frac{R_{of} R_L}{R_{of} + R_L}$$

$$= \frac{\frac{R_o}{1 + R_m\beta} R_L}{\frac{R_o}{1 + R_m\beta} + R_L}$$

$$= \frac{R_o R_L}{R_o + R + L R R_{m\ L\beta}} = \frac{\frac{R_o R_L}{R_o + R_L}}{1 + \frac{R_m R_L \beta}{R_o + R_L}}$$

$$\boxed{R_{of}' = \frac{R_o'}{1 + \beta R_m}}$$

5) Discuss Nyquist criterion for stability of feedback amplifiers, with the help of Nyquist plot **[NOV/DEC 2012]**

A negative feedback amplifier designed for a particular frequency range and may break out into oscillation at some high or low frequency. When the loop gain has more than two real poles, the stability problem arises in feedback amplifiers. If a system is to be stable, then the poles of the transfer function must lie in the left-hand half of the complex-frequency plane.

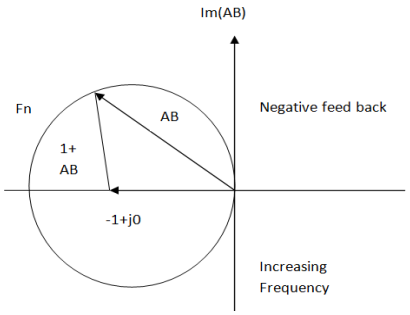
From equation $Af = A/HA\beta$, the stability condition requires that the zeroes of HAβ lie in the left-hand half of the complex-frequency plane.

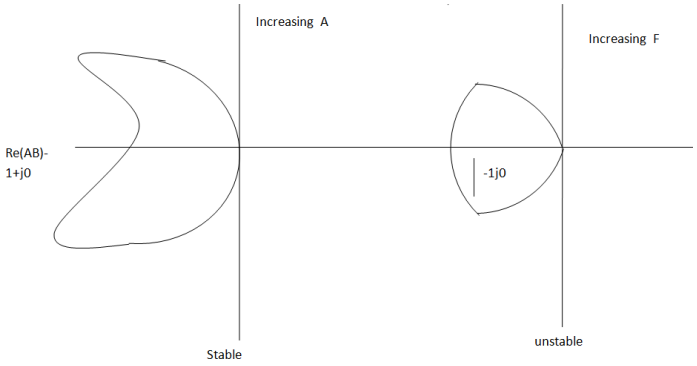
Nyquist Criterion

The Nyquist criteria express condition for stability in terms of steady state, or frequency response characteristics.

Since the product Aβ is a complex number, it represented in complex plane, where the real component being plotted along X axis and the j component plotted along y axis. Aβ is a function of frequency. The points in the complex plane are obtained for the values of Aβ corresponding to all values of f from -∞ to +∞. The locus of all these points forms a closed curve

Locus of $11 + A\beta I = 1$





The criterion of Nyquist is that, the amplifier is unstable if this curve encloses the point -1 + jo, and the amplifier is stable if the curve does not enclose this point.

Locus of $11 + A\beta I = 1$

It is a circle of unit radius, with its center at -1 + jo. If for any frequency, Aβ extends outside this circle, the feedback is negative since $11 + A\beta I > 1$. If Aβ lies within this circle, then $11 + A\beta I < 1$, and the feedback is positive

Stability condition using Nyquist Criterion

The locus is stable if it is not enclose the pint -1 + jo and the locus is unstable if it enclose the point -1 + jo.

PART C

6) Determine the gain with feedback for the amplifier with open loop gain of 300 and feedback factor of 0.1.

$$A_{vf} = \frac{A_v}{1 + \beta A_{\ v}} = \frac{300}{1 + 0.1 \times 300} = 9.677$$

7) Calculate the closed loop gain of a negative feedback amplifier if its open loop gain is 1,00,000 and feedback factor is 0.01

A = 1,00,000 β = 0.01

$$A_{vf} = \frac{A}{1 + A\beta}$$

$$= \frac{1{,}00{,}000}{1 + 1{,}00{,}000 \times 0.01} = 99.9$$

8) An amplifier has a mid frequency gain of 100 and a bandwidth of 200 KHz.

1. What will be the new bandwidth and gain, if 5% negative feedback is introduced?
2. What should be the amount of feedback, if the bandwidth is to be restricted to 1 MHz?

Av = 100, BW = 200 KHz and β = 0.05**.[MAY/JUNE 2013]**

1. $A_v = \dfrac{A_v}{1+\beta A_v} = \dfrac{100}{1+(0.05\times 100)} = 16.67$

$Bw_f = Bw \times (1+\beta A_v)$

$= 200 \times 10^3 \times (1 + 0.05 \times 100)$

$= 1.2\ MHz$

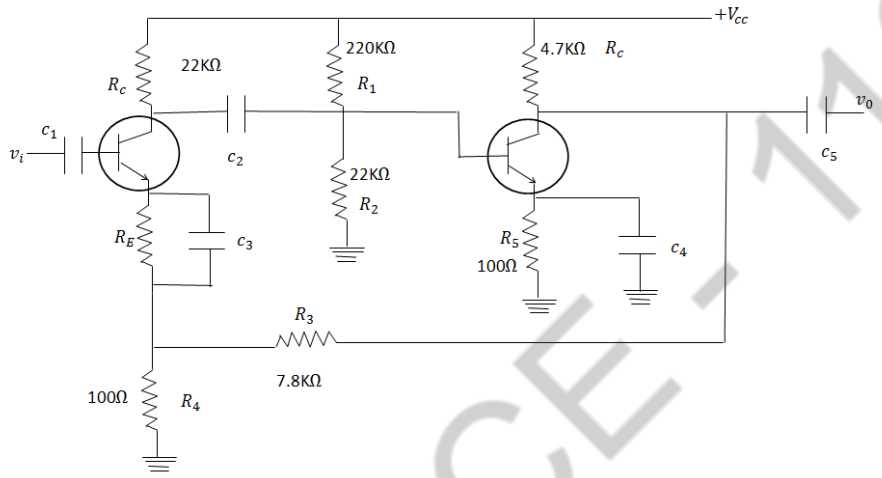
2. $Given\ BW_f = 1\ MHz$

$1 \times 10^6 = BW\ (1+\beta A_v)$

$1 \times 10^6 = 200 \times 10^3 \times (1+\beta \times 100)$

$\therefore \beta = 0.04$

9) Find the voltage gain, feedback factor, input resistance an output resistance of a series-shut pair type two stage feedback amplifier using transistors with $h_{fe} = 99$ and $h_{ie} = 2k\Omega$, shown in Fig,

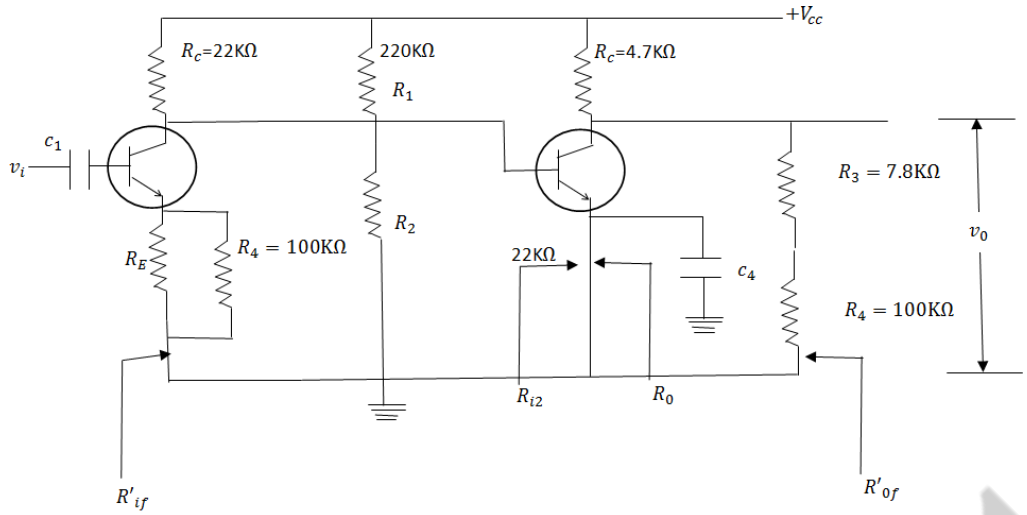


Soln:

The feedback voltage is applied across the resistance R_4 and it is in series with input signal. Hence feedback is voltage series feedback.

To find input circuit, set $V_o = o$, which gives parallel combination of R_4 with R_3 at E_1.

To find output circuit, set $I_i = o$, which gives series combination of R_3 and R_4 across the output. The resultant circuit will be,



$R_{L2} = R_C \, 11 \, (R_4 + R_3) = 4.7K \, 11 \, (100 + 7.8K)$
$= 2.946K\Omega$
$A_{i2} = -h_{fe} = -99$
$R_{i2} = h_{ie} = 2k\Omega$
$A_{v2} = \dfrac{A_{i2}R_{L2}}{R_{i2}} = \dfrac{-99 \times 2.946K}{2K}$
$\boxed{A_{v2} = -145.827}$
$A_{i1} = -h_{fe} = -99$
$R_{L1} = R_{c1} \, 11R_1 \, 11R_2 \, 11R_{i2}$
$= \; 22k \, 11200k \, 1122k \, 112k$
$\boxed{R_{L1} = 1.679 \; K\Omega}$
$R_{il} = h_{ie} + (1 + h_{fe})_e$
$= h_{ie} + (1 + h_{fe})(R_4 11 R_{3)}$
$= 2k + (1 + 99)(100 \; 11 \; 7.8k)$
$\boxed{R_{i1} = 11.873 \; K\Omega}$
$A_{v1} = \dfrac{A_{i1} \, R_{L1}}{R_{i1}} = \dfrac{-99 \times .679k}{11.873k}$
$\boxed{A_{v1} = -14}$
$A_v = A_{v1} \times A_{v2}$
$= -145.827 \times -14$
$\boxed{A_v = 2041.578}$
$\beta = \dfrac{V_f}{V_o} = \dfrac{100}{100 + 7.8k} = 0.01265$
$D = 1 + \beta AV = 1 + 0 + 01265 \times 2041.578$
$D = 26.8259$

$A_{vf} = \frac{Av}{D} = \frac{2041.578}{26.8259} = 76.1$

$A_{vf} = 76.1$

$R_{if} = R_i \, 11D = 318.5k\Omega$

$R_{of}' = \frac{o}{D} = \frac{R_{L2}}{D} = 109.82\Omega$

PART B

10)Explain the Effect of Feedback on the Amplifier poles.(APR/MAY 2019)

The amplifier frequency response and stability are determined by its poles.

ii) Stability and Pole Location

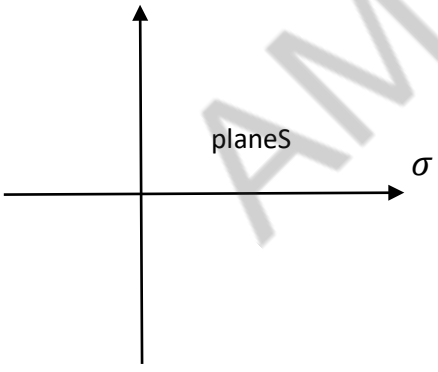
For an amplifier or any other system to be stable, it poles should lie in the left half of the s plane. A pair of complex-conjugate, poles on the jw axis fives rise to sustained sinusoidal oscillations. Poles in the right half of the s plane give rise to glowing oscillations.

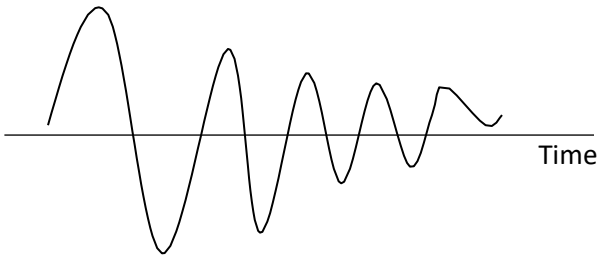
Consider an amplifier with a pole pair at $s = \sigma o \pm jw_n$. If this amplifier is subjected to a disturbance, such as that caused by closure of the power-supply switch, its transient response will contain terms of the form,

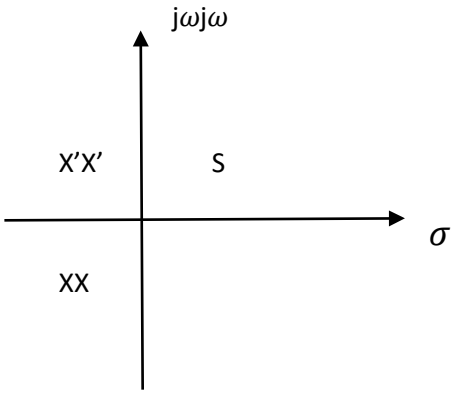
$V(t) = e^{\sigma ot}[e^{+jwnt} + e^{-jwnt}]$

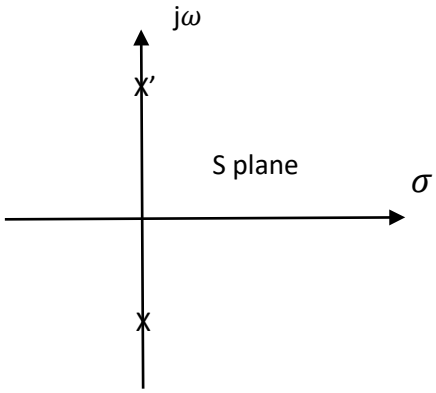
$= 2e^{\sigma ot} \cos(wnt)$

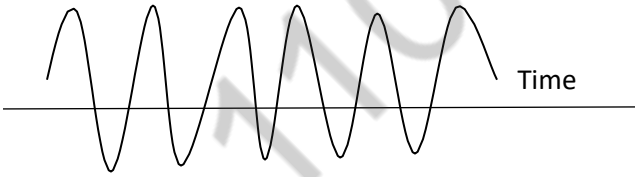
This is a sinusoidal signal with an envelope $e^{\sigma ot}$. Now of the poles are in the left half of the s plane, then σo will be negative and the oscillation will delay exponentially towards zero, indicating that the system is stable. If on the other hand, the poles are in the right half-plane, then σo will be positive, and the oscillation will glow exponentially.











ii) Poles of the Feedback Amplifier.

From the closed-loop transfer further the poles of the feedback amplifier one the zeros of $1 + (s)\,\beta(s)$. The feedback-amplifier poles are obtained by solving the equation,

$1 + (s)\,\beta(s) = 0$

Which is called the characteristic equation of the feedback loop.

iii) Amplifier with a Single Pole Response

Open loop transfer function of an amplifier

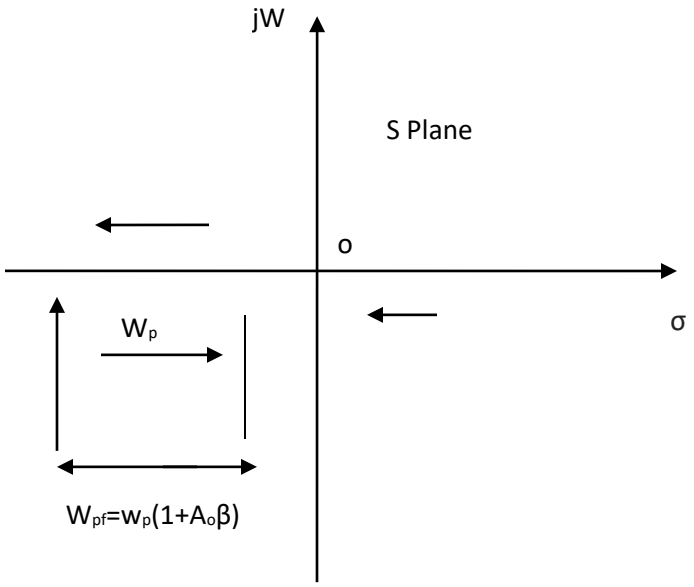
$$A(s) = \frac{A_o}{1 + {}^{s}/_{w_p}}$$

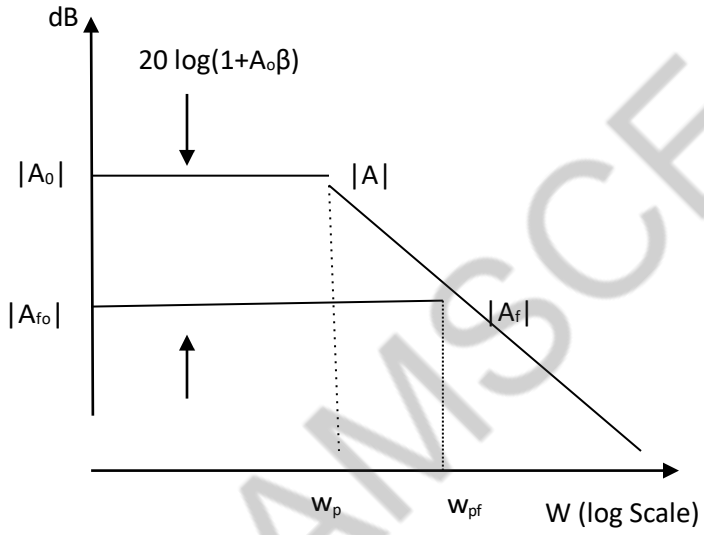
Closed loop transfer function,

$$A(s) = \frac{{}^{A_o}/_{1 + A_o\beta}}{1 + {}^{s}/_{W_0(1 + A\,\beta)}}$$

The feedback moves the pole along the negative real axis to a frequency W_{pf},

$W_{pf} = W(1 + A_o\beta)$





While at low frequencies the difference between the two plots is 20kg $(1 + A_o\beta)$, the two curves coincide at high frequencies

$A_f(s) v \frac{A_o W_p}{s} v\, A(s)$.

At such high frequencies the loop gain is much smaller than unity and the feedback is ineffective. Applying negative feedback to an amplifier results in extending its bandwidth at the expense of a reduction in gain. Since the pole of the closed-loop

amplifier never enters the night half of the s-plane, the single-pole amplifier is stable for nay value of β. This amplifier is called unconditionally stable.

(iv) Amplifier with Two-pole Response

Open loop transfer function of an amplifier is,

$$A(s) = \frac{A_o}{(1 + s/w_{p1})\,(1 + s/w_{p2})}$$

$$(s) = \frac{A(s)}{1 + \beta A(s)} = \frac{A_o}{(1 + s/w_{p1})\,(1 + s/w_{p2}) + A_o\beta}$$

then closed loop poles are obtained from $1 + A(s)\beta = 0$, with leads to

$s^2 + (w_{p1} + w_{p2}) + (1 + A_{o\beta})\, w_{p1}\, w_{p2} = 0$

The closed loop poles are given by,

$$s = -1/2\,(w_{p1} + w_{p2}) \pm 1/2\,\sqrt{(w_{p1} + w_{p2})^2 - 4\,(1 + A_{o\beta})\, w_{p1}\, w_{p2}}$$

From this eqn, as the loop gain $A_{o\beta}$ is increased from zero, the poles are brought closer together. Then a value of loop gain is reached at which the poles become coincident. If the loop gain is further increased, the poles become complex conjugate and move along a vertical line.

Z

Root locus diagram for a feedback amplifier whose open-loop transfer function has two real poles.

This shows the locus of the poles for increasing loop gain. From the root locus we see that feedback amplifier is also unconditionally stable.

(V) Amplifier with three or more poles.

Two poles move closer coincide as the value of $A_{o\beta}$ increases.

11) Explain the impact of negative feedback on bandwidth, stability, gain, noise and distortion, input and output impedances of an amplifier.**[APRIL/MAY 2015][MAY/JUNE 2013][NOV/DEC 2013](APR/MAY 2019)**

1) Stablisation of Gain

Gain with negative feedback

$$A_f = \frac{A}{1 + A\beta}$$

Diff $\dfrac{dA_f}{dA} = \dfrac{(1 + A\beta)1 - A(B)}{(1 + A\beta)^2}$

$= 1 + A\beta - A\beta/(1 + A\beta)^2$

$$\frac{dA_f}{dA} = \frac{1}{(1+A\beta)^2}$$

$$= \frac{1}{1+A\beta}\ \frac{1}{1+A\beta}$$

$$\frac{dA_f}{A_f} = \frac{A_f}{A}\ \frac{1}{1+A\beta}$$

$$\frac{dA_f}{A_f} = \frac{dA}{A}\ \frac{1}{1+A\beta}$$

$\frac{dA_f}{A_f} \rightarrow fraction\ change\ in\ amp\ voltage\ gain\ with\ feedback$

$\frac{dA}{A} \rightarrow fraction\ change\ in\ Amp\ voltage\ gain\ without\ feedback$

$$\text{Sensitivity} = \frac{\frac{dA_f}{A_f}}{A_f/_A} = \frac{1}{1+A\beta}$$

The reciprocal of the term sensitivity is called densenbitivity (D)

$D = 1 + A\beta$

Increase of Bandwidth (cut off frequencies)

$Bw = f_2 - f_1$

$$\boxed{A_f \times Bw_f = A \times Bw}$$

The gain bandwidth product of with feedback and gain bandwidth product of without feedback remains the same.

As the voltage gain of a feedback amplifier reduces by the factor $\frac{1}{1+A\beta}$ its bandwidth would be increased by $(1 + A\beta)$.

$$\boxed{\begin{aligned} Bw_f &= B(1+A\beta) \\ A_f &= \frac{A}{1+A\beta} \end{aligned}}$$

Due to negative feedback in the amplifier, the upper cut off freq is increased by factor $(1 + A\beta)$ and the lower cut off frequency is decreased by the same factor $(HA\beta)$.

$$\boxed{f_{2f} = f_2(1+A\beta), f_{12} = \frac{f_i}{(1+A\beta)}}$$

Hence bandwidth is increased.

Decreased Distortion

Negative feedback reduces the distortion

$$D_f = \frac{D}{1+A\beta}$$

Decreased Noise

Noise is reduced with feedback by a factor of $\frac{1}{1+A\beta}$

$$N_f = \frac{1}{1 + A\beta}$$

Increase in Input Impedance.

An amplifier should have high input impedance so that it will not load the preceding stage (or) input voltage source.

$$\boxed{Z_{if} = Z(1 + A\beta)}$$

Decrease in Output Impedance.

An amplifier with low output impedance is capable of delivering power to the load without much loss. It is achieved by Negative feedback.

$$\boxed{Z_{of} = \frac{Z_o}{1 + A\beta}}$$

PART C

Problems

12) An Amplifier has a midband gain 125 and BW of 250 KHz.

(a) if 4% negative feedback is introduced find new b.w and gain

A=125, BW=250 KHz, B=0.04.**[MAY / JUNE 2013]**

$BW_f = B.W\ (1 + A\beta)$

=1.5MHz.

$$A_f = \frac{A}{1 + \beta A} = 20.83.$$

(b) if BW restricted to 1 MHz find feedback ratio.

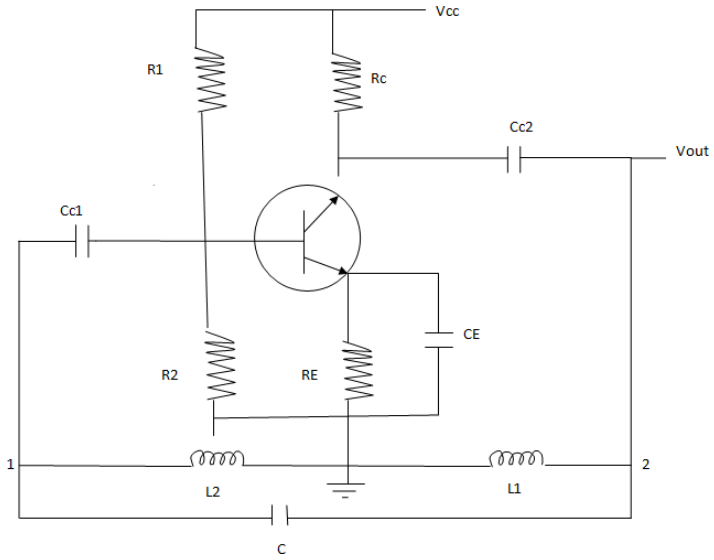
$$\frac{1 \times 10^6}{250 \times 10^3} = (1 + 25\beta) \times 250 \times 10^3$$

B=0.024=2.4%

UNIT – II
OSCILLATORS

PART B

1) Draw Hartley oscillator ,explain and derive the condition for oscillation**[APRIL/MAY 2015][NOV/DEC 2013]**



Z_1, Z_2 are inductors, Z_3 is a capacity, R_1, R_2 and R_E provide necessary d.c. bias to the transistor. C_E is a bypass capacitor.
C_{c1} and C_{c2} are coupling capacitors. The feedback network consisting of inductors L_1 and L_2, capacitor c determines the frequency of the oscillator.
When the supply voltage $+V_{cc}$ is switched ON, a transient current is produced at the tank circuit. It produces a.c voltages across L_1 and L_2. As terminal 3 is earthed, it is at zero potential. If terminal 1 is at a positive potential with respect to 3 and terminal 2 is negative potential with respect to 3. Thus the phase diff b/w terminal 1 and 2 is always 180°. In the CE mode, the transistor provides the phase difference of 180° b/w the input and output.
The total phase shift is 360°.
If the feedback is adjusted so that the loop gain Aβ=1, the circuit acts as an oscillator.
The frequency of oscillation is,

$$f_o = \frac{1}{2\pi\sqrt{LC}}, \; where \; L = L_1 + L_2 + 2M.$$

M is mutual inductance b/w coils L_1&L_2.
The condition for sustained oscillation is

$$h_{fe} \geq \frac{L_1 + M}{L_2 + M}$$

Analysis
In Harley oscillator,

Z_1, Z_2 are inductive reactance,
$Z_3 \rightarrow$ capacitive reactance.
$Z_1 = jwL_1+jwM$
$Z_2 = jwL_2+jwM$
$Z_3 = \frac{1}{jwc} = \frac{-j}{wc}$
The general eqn for the oscillator is,

$$h_i(Z_1 + Z_2 + Z_3) + Z_1Z_2(1 + h_{fe}) + Z_1Z_3 = 0$$

$$h_{ie}\,(jwL_1 + jwL_2 + jwM + jwM - \frac{j}{wc}) + (jwL_1 + jwM)\,(jwL_2 + jwM)\,(1 + h_{fe}) + (jwL_1 + jwM)\,(\frac{-j}{wc}) = 0$$

$$h_{ie}jw\,[L_1 + L_2 + 2M - \frac{1}{w^2c}] + j(L_1 + M)\,jw(L_2 + M)\,(1 + h_{fe}) - jw\,(L_1 + M)\,\frac{j}{wc} = 0$$

$$h_{ie}\,jw\,[L_1 + L_2 + 2M - \frac{1}{w^2c}] - w^2\,(L_1 + M)\,(L_2 + M)\,(1 + h_{fe}) + (L_1 + M)\,\frac{1}{c} = 0$$

$$\boxed{h_{ie}\,jw\,[L_1 + L_2 + 2M - \frac{1}{w^2c}] - w^2\,(L_1 + M)\,(L_2 + M)\,(1 + h_{fe}) - \frac{1}{w^2c}] = 0}$$

The freq of oscillation $f_o = \frac{w_o}{2\pi}$ can be determined by equating the imaginary part to zero.

$$[L_1 + L_2 + 2M - \frac{1}{w_0{}^2c}] = 0.$$

$$f_o = \frac{w_o}{2\pi} \Rightarrow$$

$$\frac{1}{w_0{}^2c} = L_1 + L_2 + 2M$$

$$\frac{1}{w_0{}^2} = c\,[L_1 + L_2 + 2M]$$

$$w_0{}^2 = \frac{1}{\sqrt{c\,(L_1 + L_2 + 2M)}}$$

$$f_o = \frac{w_o}{2} = \frac{1}{\sqrt{2\pi\,(L_1 + L_2 + 2M)\,c}}$$

The condition for maintenance of oscillator is obtained by substituting f_o into general eqn,
Now the real part becomes zero and hence,

$$[(L_2 + M)\,(1 + h_{fe}) - \frac{1}{w_0{}^2c}] = 0 \qquad (1)$$

Simplifying,

$$\frac{w_o}{2\pi} = \frac{1}{\sqrt{2\pi\,(L_1 + L_2 + 2M)\,c}}$$

$$w_o = \frac{1}{\sqrt{(L_1+L_2+2M)\,c}} \qquad (2)$$

Subsisting the value of w_o,

$$(L_2 + M)\,(1 + h_{fe}) - \frac{1}{w_0^2 c} = 0$$

$$[(L_2 + M)\,(1 + h_{fe}) - \frac{1}{\frac{1}{(L_1 + L_2 + 2M)\,c} \times c}] = 0$$

$$(L_2 + M)\,(1 + h_{fe}) - (L_1 + L_2 + 2M) = 0$$

$$(L_2 + M)\,(1 + h_{fe}) = (L_1 + L_2 + 2M)$$

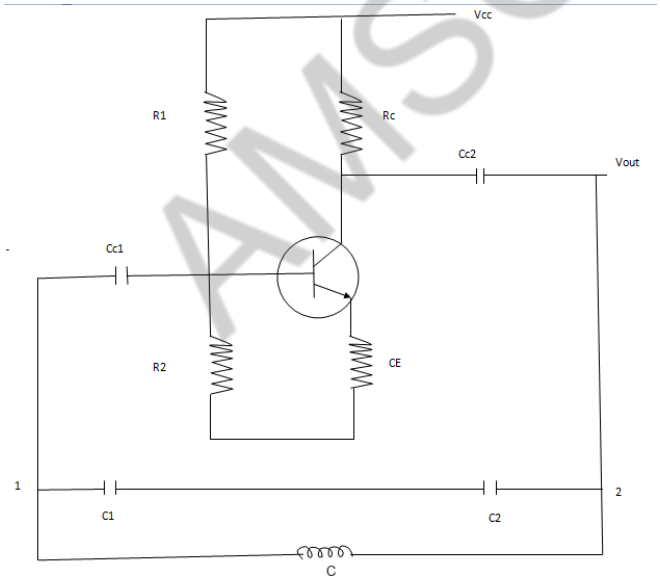
$$1 + h_{fe} = \frac{L_1 + L_2 + 2M}{L_2 + M}$$

$$h_{fe} = \frac{L_1 + L_2 + 2M}{L_2 + M} - 1$$

$$= \frac{L_1 + L_2 + 2M - L_2 - M}{L_2 + M}$$

$$\boxed{h_{fe} = \frac{L_1 + M}{L_2 + M}}$$

2) With neat diagram, explain the operation of colpitts oscillator and obtain the expression of frequency of oscillation.**[APRIL/MAY 2015] [NOV/DEC 2012]**



Z_1, Z_2 are capacitors and Z_3 is an inductor. The resistor R_1, R_2 and R_E provides the necessary d.c bias to the transistor, C_E is a bypass capacitor. C_{c1} and C_{c2} are coupling capacitors. The feedback network consisting capacitors c_1 and c_2 and an inductor L determines the frequencies of the oscillator.

When the supply voltage $+V_{cc}$ is switched ON, a transient current is produced in the tank circuit. The oscillatory current in the tank circuit produces a.c. voltages across c_1 and c_2. As terminal 3 us earthed, it will be at zero potential. If terminal 1 is a positive potential with respect to 3 and terminal 2 will be negative with respect to 3. Thus the phase difference between 1 and 2 is always 180°. In the CE mode, the transistor provides the phase difference of 180° b/w input and output. The total phase shift is 360°.

If the feedback is adjusted so that the loop gain Aβ=1, the circuit act as an oscillator. The frequency of oscillation is

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

$$\frac{1}{C} = \frac{1}{c_1} + \frac{1}{c_2}$$

$$C = \frac{c_1 c_2}{c_1 + c_2}$$

It is widely used in commercial signal generator for frequencies b/w 1 MHz and 500 MHz. It is also used as a local oscillator in super heterodyne radio receiver.

Analysis,

$$Z_1 = \frac{1}{jwc_1} = \frac{-j}{wc_1}$$

$$Z_2 = \frac{1}{jwc_2} = \frac{-j}{wc_2}$$

$$Z_3 = jwL$$

Sub in general eqn,

$$h_i(Z_1 + Z_2 + Z_3) + (1 + h_{fe})Z_1Z_2 + Z_1Z_3 = 0$$

$$h_{ie}\left(\frac{-j}{wc_1} - \frac{j}{wc_2} + jwL\right) + (1 + h_{fe})\left(\frac{-j}{wc_1}\right)\left(\frac{-j}{wc_2}\right) + \left(\frac{-j}{wc_1}\right)(jwL) = 0$$

$$j\,h_{ie}\left(\frac{-1}{wc_1} - \frac{1}{wc_2} + wL\right) - \frac{(1 + h_{fe})}{w^2 c_1 c_2} + \frac{L}{c_1} = 0$$

$$\boxed{j\,h_{ie}\left(\frac{1}{wc_1} + \frac{1}{wc_2} - wL\right) + \frac{1 + h_{fe}}{w^2 c_1 c_2} - \frac{L}{c_1} = 0}$$

The freq of oscillation, $f_o = \frac{w_o}{2\pi}$ is found by equating the imaginary part to zero.

$$h_{ie}\left(\frac{1}{wc_1} + \frac{1}{wc_2} - wL\right) = 0.$$

$$\frac{1}{wc_1} + \frac{1}{wc_2} - wL = 0.$$

$$\frac{c_2 + c_1 - w^2 c_1 c_2 L}{w c_1 c_2} = 0.$$

$$c_1 + c_2 - w^2 c_1 c_2 L = 0.$$

$$w^2 c_1 c_2 L = c_1 + c_2$$

$$w^2 = \frac{c_1 + c_2}{c_1 c_2 L} \Rightarrow w = \sqrt{\frac{c_1 + c_2}{L c_1 c_2}}$$

$$\therefore f_o = \frac{w_o}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{c_1 + c_2}{L c_1 c_2}}$$

Sub $\frac{w^o}{2\pi}$ into general eqns, real part we get the condition for maintenance of oscillation as,

$$w_o = \sqrt{\frac{c_1 + c_2}{L c_1 c_2}}$$

$$\frac{1 + h_{fe}}{w^2 c_1 c_2} - \frac{L}{c_1} = 0$$

$$\frac{1 + h_{fe}}{\frac{c_1 + c_2}{L c_1 c_2} c_1 c_2} - \frac{L}{c_1} = 0$$

$$\frac{(1 + h_{fe})}{c_1 + c_2} - \frac{L}{c_1} = 0$$

$$\frac{(1 + h_{fe})}{c_1 + c_2} = \frac{L}{c_1}$$

$$1 + h_{fe} = \frac{c_1 + c_2}{c_1}$$

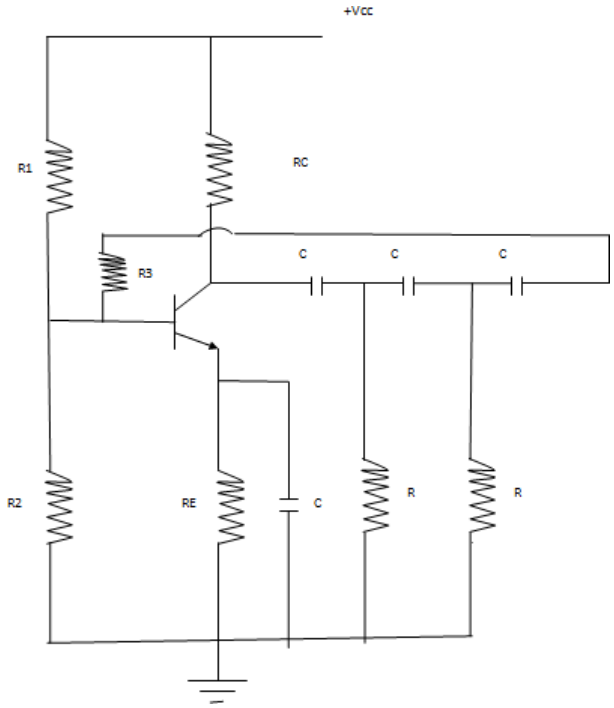
$$h_{fe} = \frac{c_1 + c_2}{c_1} - 1$$

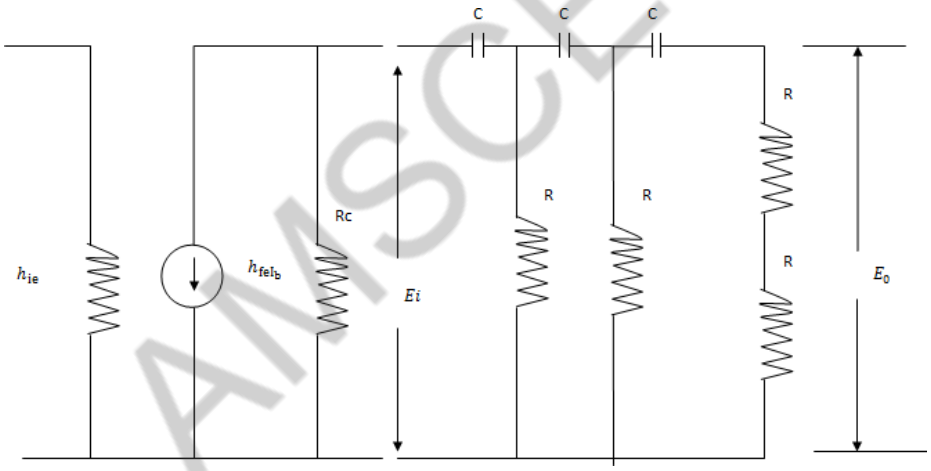
$$= \frac{c_1 + c_2 - c_1}{c_1}$$

$$\boxed{h_{fe} = \frac{c_2}{c_1}}$$

3) Draw RC- phase shift oscillator using BJT, explain and derive the condition for oscillation **[APRIL/MAY 2015][MAY/JUNE 2013] [MAY/JUNE 2014]**

In this oscillator the required phase shift of 180° is the feedback loop from output to input is obtained by using R and C components instead of tank circuit.





RC phase shift oscillator using cascade connection of high pass filter.

Equivalent circuit

Here, a common emitter amplifier is followed by three sections of RC phase shift network, the output of the last section being returned to the input. In order to make the three RC sections identical, R_3 is chosen as $R_3=R-R_i$, $R_i \longrightarrow$ input impedance.

If the value R and C are so chosen that, for the given frequency f_o, the phase shift of each RC section is 60°. Thus such a RC ladder network produces a total phase shift of 180° b/w input and o/p voltages for the given frequency.
Therefore the total phase shift is 360°, satisfying Barkhassen condition. The frequency of oscillation is given by $f_o = \frac{1}{2\pi Rc\sqrt{6}}$

RC phase shift oscillator is suitable for audio frequencies only. Its main drawback are that the three capacitors or resistors should be changed simultaneously to change the frequency of oscillation and it is difficult to control the amplitude of oscillation without affecting the frequency of oscillation.

From Eqn circuit,

$$I_1\left(R + \frac{1}{jwc}\right) - I_2R = E_i \quad \text{——————} \quad (1)$$

$$-I_1R + I_2\left(2R + \frac{1}{jwc}\right) - I_3R = 0 \quad \text{——————} \quad (2)$$

$$-I_2R + I_3\left(2R + \frac{1}{jwc}\right) = 0 \quad \text{——————} \quad (3)$$

From (3),

$$\boxed{I_2 = \frac{I_3}{R}\left[2R + \frac{1}{jwc}\right]} \quad \text{——————} \quad (4)$$

Sub it in (1),

$$I_1\left(R + \frac{1}{jwc}\right) - \frac{I_3}{R}\left[2R + \frac{1}{jwc}\right] = E_i$$

Sub it in (2),

$$-I_1R + \frac{I_3}{R}\left(2R + \frac{1}{jwc}\right)^2 - I_3R = 0$$

$$-I_1R + \frac{I_3}{R}\left(4R + \frac{4}{jwc} + \frac{-1}{w^2c^2}\right) - I_3R = 0$$

$$-I_1R + I_3\left(4R + \frac{4}{jwc} - \frac{1}{w^2c^2R}\right) - I_3R = 0$$

$$\boxed{I_1 = \frac{I_3}{R}\left[3R + \frac{4}{jwc} - \frac{1}{w^2c^2R}\right]} \quad \text{——————} \quad (5)$$

Sub (4) & (5) in (1),

$$\frac{I_3}{R}\left[3R + \frac{4}{jwc} - \frac{1}{w^2c^2R}\right]\left(R + \frac{1}{jwc}\right) - \frac{I_3}{R}\left(2R + \frac{1}{jwc}\right) = E_i$$

$$I_3\left(3 + \frac{4}{jwcR} - \frac{1}{w^2c^2R^2}\right)\left(R + \frac{1}{jwc}\right) - I_3\left(2 + \frac{1}{jwcR}\right) = E_i$$

$$I_3\left[3R + \frac{4}{jwc} - \frac{1}{w^2c^2R} + \frac{3}{jwc} - \frac{4}{w^2c^2R^2} + \frac{j}{w^3c^3R^2} - 2 - \frac{1}{jwcR}\right] = E_i$$

$$I_3R\left[3 + \frac{4}{jwcR} - \frac{1}{w^2c^2R^2} + \frac{3}{jwcR} - \frac{4}{w^2c^2R^2} + \frac{j}{w^3c^3R^3} - 2 - \frac{1}{jwcR}\right] = E_i$$

$$I_3[3 - j4\alpha - \alpha^2 - 3j\alpha - 4\alpha^2 + j\alpha^3 - 2 + j\alpha] = \frac{E_i}{R}$$

$I_3[(1-5\alpha^2)+j(\alpha^2-6)] = \frac{E_i}{R}$

$I_3R = E_i\left[\frac{1}{(1-5\alpha^2)+j(\alpha^2-6)}\right]$

$E_o = E_i\left[\frac{1}{(1-5\alpha^2)+j(\alpha^2-6)}\right]$

$\beta = \frac{E_o}{E_i} = \frac{1}{(1-5\alpha^2)+j(\alpha^2-6)}$

Equating imaginary part is = 0

$(\alpha^2-6)=0$

$\alpha = 0, \alpha^2 = 6$

$\alpha = \pm\sqrt{6}$

$\frac{1}{w_o cR} = \pm\sqrt{6}$

$wRc = \frac{1}{\sqrt{6}} \Rightarrow w = \frac{1}{Rc\sqrt{6}}$

$\boxed{\frac{1}{2\pi Rc\sqrt{6}} = f_o}$

The condition for maintanence of oscillation is obtained by sub $\alpha = \sqrt{6}, \beta = -1/29 = \frac{1}{29}\lfloor 180°$

4) With neat diagram, explain the operation of wein bridge oscillator and obtain the expression of frequency of oscillation.**[APRIL/MAY 2015] [NOV/DEC 2012](APR/MAY 2019)**

The circuit consists a two stage RC coupled amplifier which provides a phase shift of 360° or 0°. A balanced bridge is used as the feedback network which has no need to provide any additional phase shift. The feedback network consists of a lead-lag network (R_1–C_1) and R_2–C_2 and voltage divider R_3–R_4. The lead lag network provides a positive feedback to the input of the first stage and the voltage divider provides a negative feedback to the emitter of Q_1.

If the bridge is balanced,

$\frac{R_3}{R_4} = \frac{R_1 - j\times c_1}{\left[\frac{R_2(-j\times c_2)}{R_2 - j\times c_2}\right]}$

Freq of oscillation $f_o = \frac{1}{2\pi\sqrt{R_1R_2c_1c_2}}$

$f_o = \frac{1}{2\pi Rc}$ if $R_1 = R_2 = R$ and $c_1 = c_2 = c$

<u>To determine the gain of Wien Bridge oscillator using BJT amplifier</u>

$R_1 = R_2 = R$ and $c_1 = c_2 = c$

$$V_f(s) = V_o(s)\frac{R11\frac{1}{sc}}{R+\frac{1}{sc}+(R11\frac{1}{sc})}$$

$$= V_o(s)\frac{R\frac{1}{sc}/R+\frac{1}{sc}}{R+\frac{1}{sc}+\frac{R\frac{1}{sc}}{R+\frac{1}{sc}}}$$

$$= V_o(s)\frac{\frac{R}{1+Rsc}}{R+\frac{1}{sc}+\frac{R}{1+Rsc}}$$

$$= V_o(s)\frac{\frac{R}{1+Rsc}}{\frac{(1+Rsc)(sc)+(HRsc)+Rsc}{(1+Rsc)\,sc}}$$

$$= V(s)\frac{Rsc}{Rsc+R^2s^2c^2+HRsc+Rsc}$$

$$V_f(s) = V(s)\frac{Rsc}{R^2s^2c^2+3Rsc+1}$$

$$\beta = \frac{V_f(s)}{V_o(s)} = \frac{sRc}{s^2R^2c^2+3Rsc+1}$$

$$A\beta = 1$$

$$\therefore A = 1/\beta = \frac{s^2R^2c^2+3Rsc+1}{sRc}$$

Sub S = jw_o

$$A = \frac{-w_o^2R^2c^2+3jw_oRc+1}{jw_oRc}$$

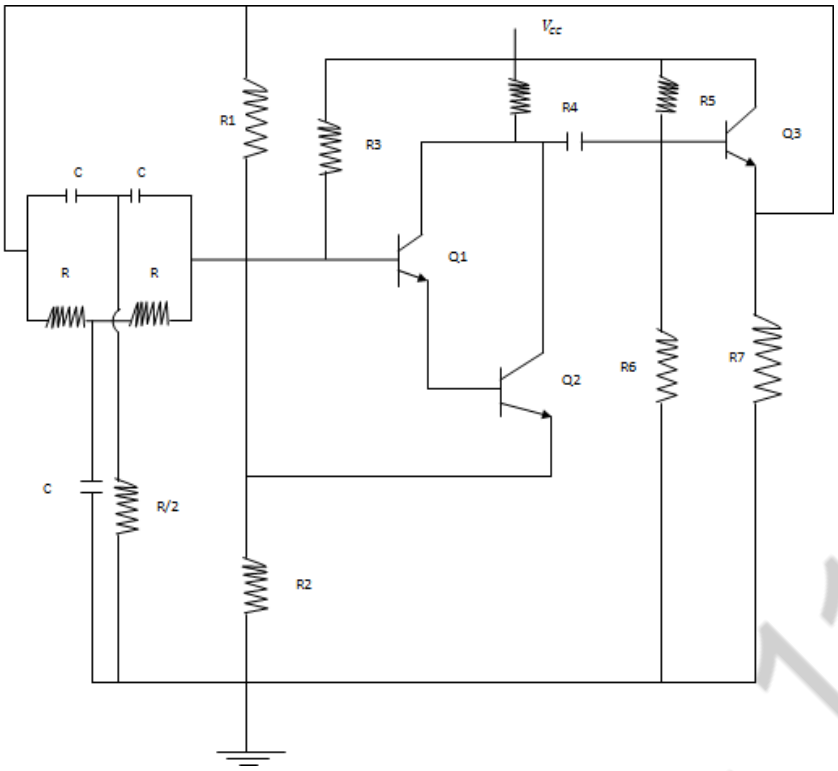
Sub $w_o = \frac{1}{RC}$

$$A = \frac{-1+3j+1}{j}$$

$$\therefore \boxed{A = 3}$$

A should be at least equal is 3 for oscillations to occur.

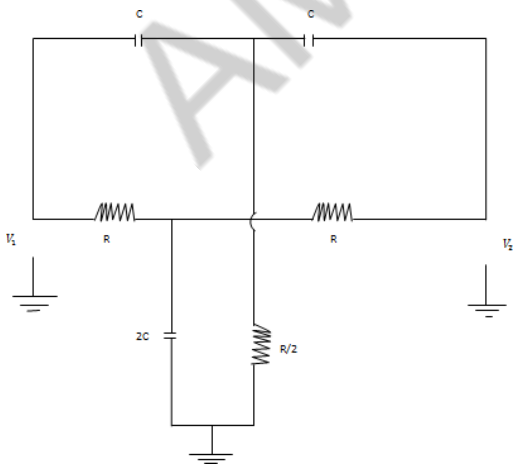
5) Describe the operation of Twin-T Oscillator**[NOV/DEC 2013]**

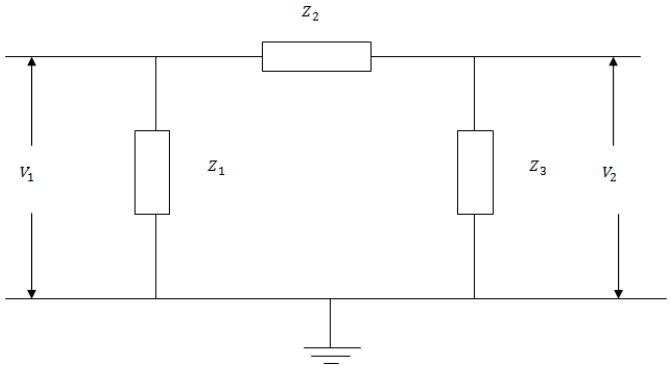


This circuit consists of Darlington Pair (Q_1 and Q_2) and it is followed by emitter follower (Q_3). The Twin-T network is used as the feedback circuit, which is used as a notch filter. The Darlington pair circuit proves 180° phase shift and the feedback network also introduces 180° phase shift. The total phase shift around the circuit is 360° or 0°. The twin-T network oscillator yields better freq stability.

Freq of oscillator $f_o = \frac{1}{2\pi Rc}$

Analysis





By sing Star-Delta conversion formulae,

$$Z_1 = Z_3 = \frac{SCR + 1}{2SC}$$

$$Z_2 = 2R \frac{(ScR + 1)}{S^2c^2R^2 + 1}$$

$$\frac{V_2}{V_1} = \frac{S^2c^2R^2 + 1}{S^2c^2R^2 + 4ScR + 1}$$

Sub S = jw,

$$\frac{V_2}{V_1} = \frac{(jw)^2c^2R^2 + 1}{(jw)^2c^2R^2 + 4jwcR + 1}$$

$$= \frac{1 - w^2c^2R^2}{1 - w^2c^2R^2 + 4jwRc}$$

Setting real part = 0

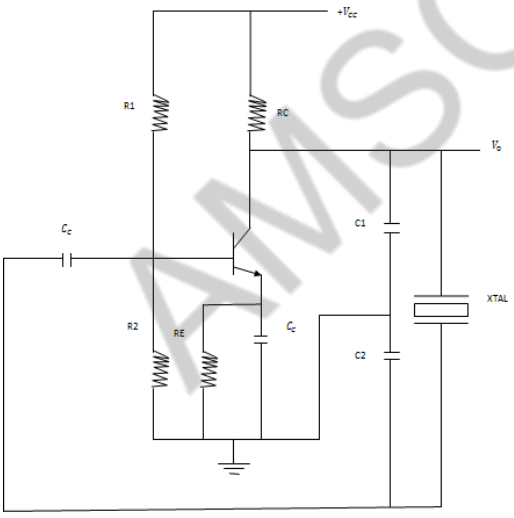
$$1 - w^2c^2R^2 = 0$$

$$w^2c^2R^2 = 1$$

$$w^2 = \frac{1}{c^2R^2} \Rightarrow w = \frac{1}{Rc}$$

PART C

6) What is the principle of oscillation ofcrystals? Sketch the equivalent circuit and impedance –frequency graph of crystals and obtain its series and parallel resonant frequency and explain how crystals are employed in oscillators for stabilization**.[MAY/JUNE 2013](APR/MAY 2019)**



In a colpitts oscillator, if the L is replaced by a crystal, then it becomes crystal oscillator. In this type, a piezo-electric crystal, usually quartz is used as a resonant circuit replacing an LC circuit.

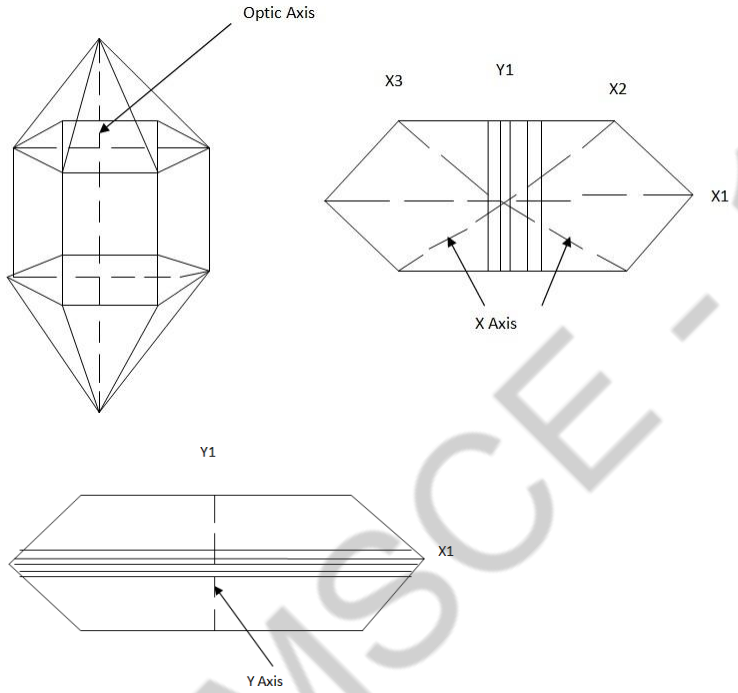
The crystal is a thin slice of piezo-electric material such as quartz, tourmaline and rochelle salt, which exhibit a property called piezo electric effect.

Piezo electric Effect:

This represents the characteristics that the crystal reacts to any mechanical stress by producing an electric charge. In reverse effect, an electric field results in mechanical strain.

Quartz Crystal Construction:

In order to obtain high degree of freq stability, crystal oscillators are used. Generally, the crystal is a ground wafer of translucent quartz or tourmaline stone placed b/w two metal plates and housed in a stamp sized package. The method of cutting the crystal wafer determines the natural resonant frequency and temperature co-efficient of the crystal. When the wafer is cut in such a way that its flat surface are perpendicular to its electrical axis (x axis), it is called an X-cut crystal. When the wafer is cut in such a way that its flat surfaces are perpendicular to its mechanical axis (y axis) it is called Y-cut crystal.



If an alternating voltage is applied, then the crystal wafer is set into vibration. The frequency of vibration equal to the resonant frequency of the crystal is determined by its structural characteristics.

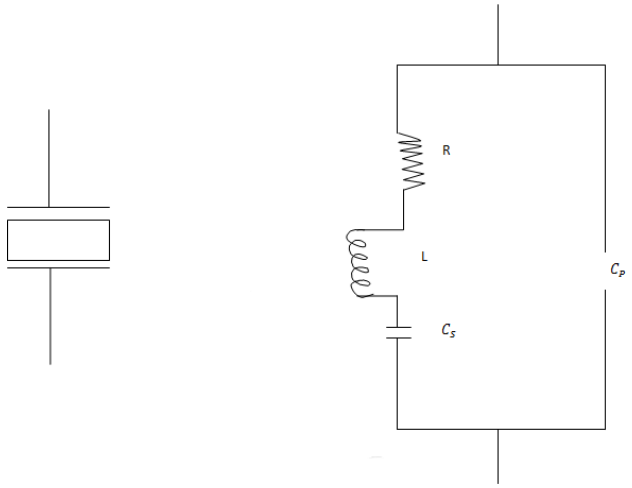
If the frequency of the applied a.c voltage equal to the natural resonant freq, then the maximum amplitude of vibration will be obtained.

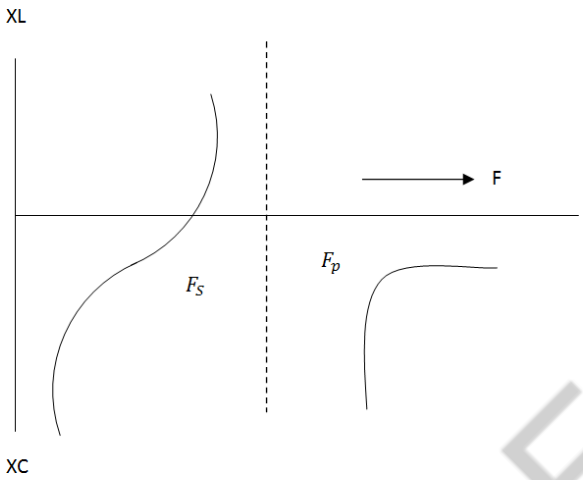
The freq of vibration is $f = \frac{1}{2l}\sqrt{\frac{Y}{P}}$

Y – young modulus

P – density of the material

The crystal is suitably cut & polished to vibrate at a certain frequency and mounted b/w two metal plates as shown.





$$jx = \frac{1}{jwc_p} \cdot \frac{w^2 - w_{s^2}}{w^2 - w_{p^2}}$$

$$w_{s^2} = \frac{1}{\boldsymbol{L}\boldsymbol{c}_s}$$

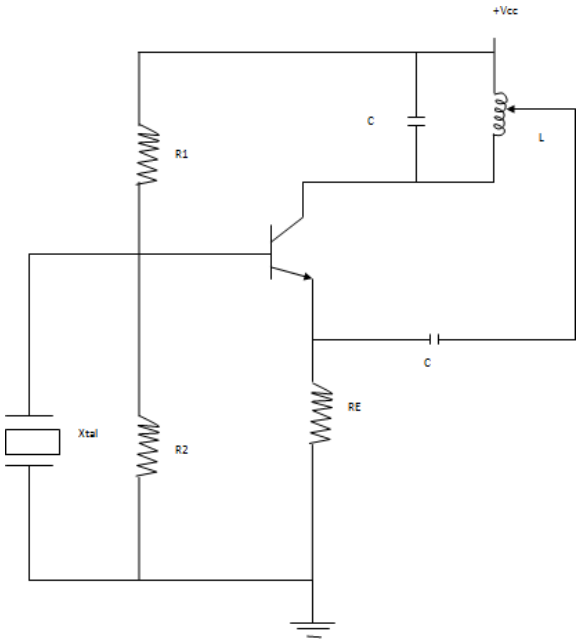
$$w_{p^2} = \frac{1}{L\left(\frac{1}{c_s} + \frac{1}{c_p}\right)}$$

Since $c_p \gg c_s, w_p \equiv w_s$

The adv of the crystal is its very high Q as a resonant circuit, which results in good frequency stability for the oscillator.

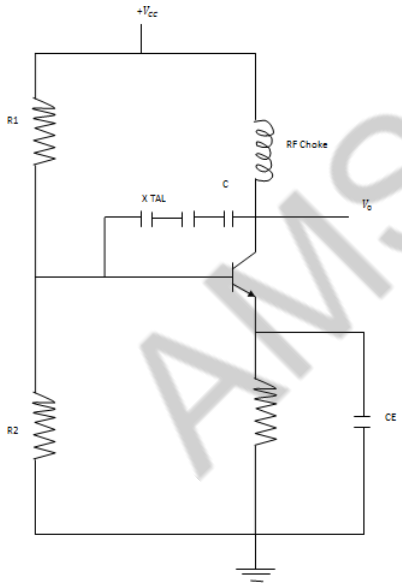
$$f = \frac{1}{2\pi\sqrt{(L_1 + L_2)c}}$$

Miller Oscillator



The Miller crystal controlled oscillator is shown. The crystal has two resonant frequencies. In between Ws & Wp, the reactance of the XTAL becomes inductive and hence can be used as inductor. One of the inductor in Harley OSC can be replaced by the crystal which acts as an inductor when freq is greater than Ws. The inter electrode capacitance is used as a capacitor to generate the oscillations.

Pierce Crystal Oscillator



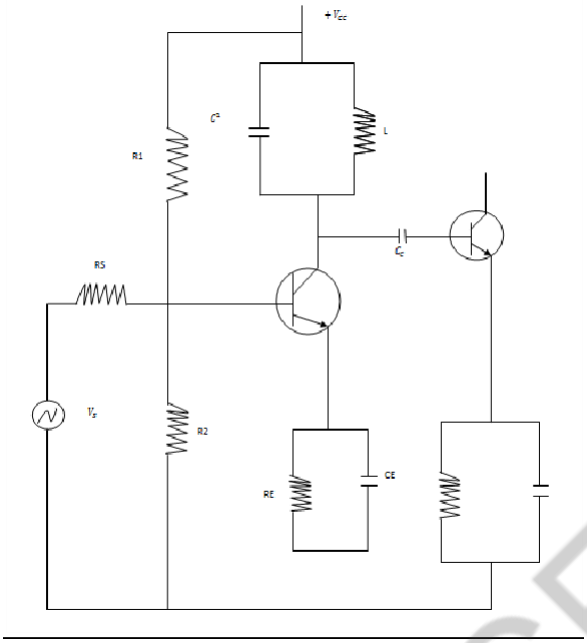
Here the crystal is connected as a series element in the feedback path from the collector to the base. The resistor R_1, R_2 and R_E provide the necessary d.c bias to the transistor and C_E is an emitter by pass capacitor. The radio freq (RF) choke coil provides d.c bias while de coupling any a.c. signal on the power lines from affecting the output signal. The coupling capacitor C blocks any d.c between collector and base, and has negligible impedance at the operating freq of the oscillator.

$$f_o = \frac{1}{2\pi\sqrt{Lc_s}}$$

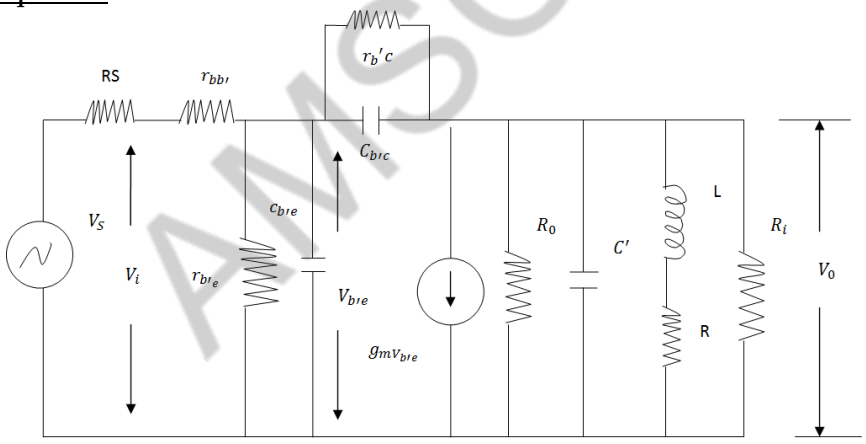
UNIT – III
TUNED AMPLIFIERS

PART B

1) Explain the functioning of a capacitor coupled single tuned amplifier. With the high frequency transistor model, carry out an analysis and obtain the gain and bandwidth of the amplifier. Plot its frequency response.**[APRIL/MAY 2015] [MAY/JUNE 2014]**
[MAY/JUNE 2013][NOV/DEC 2013]

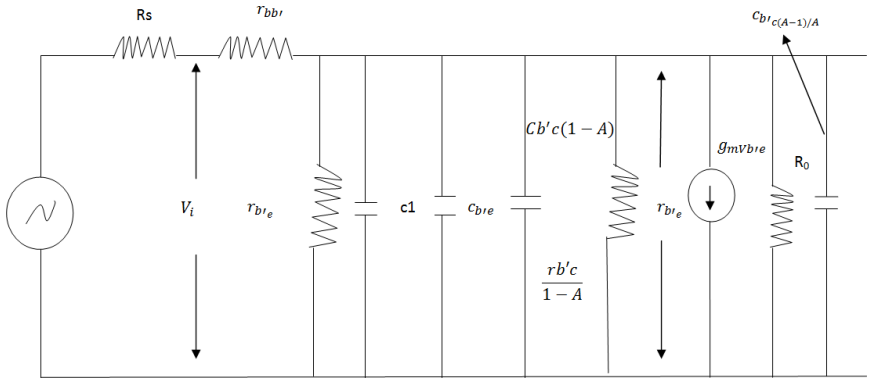


Eqn Ckt



Modified Eqn Ckt

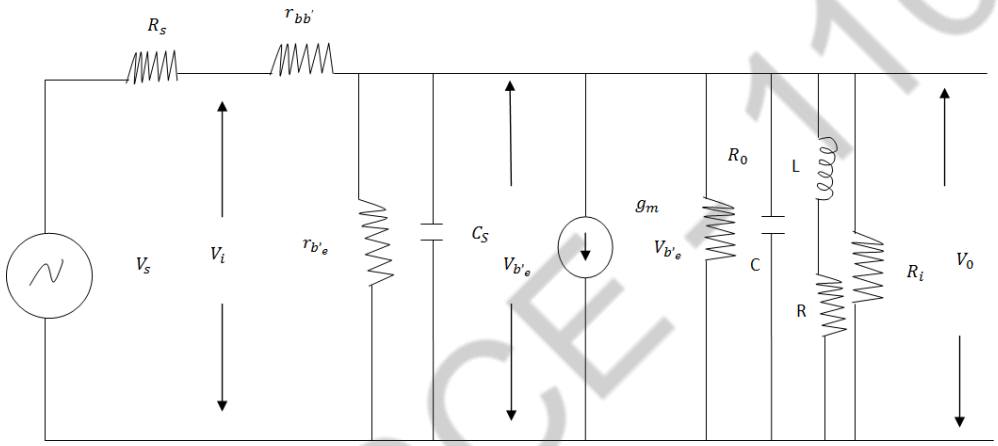
$$Z_1 = \frac{Z}{1 - Av} \quad Z_2 = \frac{Z.Av}{Av - 1}$$



Let-us take,

$$C_{b'e} + C_1 + C_{b'}(1-A) = C_s$$
$$C_{b'c}\frac{(A-1)}{A} + C_2 + C' = C$$

Simplified Eqn Ckt



$$Y_i = \frac{1}{R+jwL} = \frac{R-jwL}{(R+jwL)(R-jwL)}$$
$$= \frac{R-jwL}{R^2-j^2w^2L^2} = \frac{R-jwL}{R^2+w^2L^2}$$
$$= \frac{R}{R^2+w^2L^2} - \frac{jwL}{R^2+w^2L^2}$$
$$= \frac{R}{R^2+w^2L^2} + \frac{w^2L}{j(R^2+w^2L^2)} \rightarrow (1)$$

if R_p & L_P are is parallel,

$$Y_i = \frac{1}{R_p} + \frac{1}{jwLp} \rightarrow (2)$$

Equate (1) & (2),

$$R_p = \frac{R^2+w^2L^2}{R}, \quad R = \frac{R^2+w^2L^2}{w^2L}$$

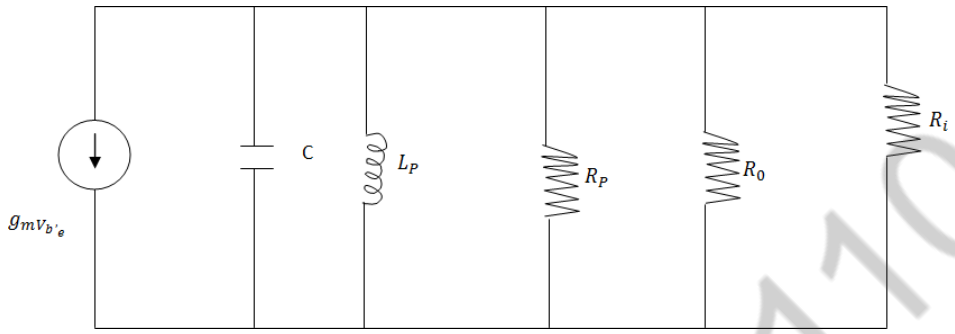
$$R_p = \frac{R\,(R^2 + \frac{w^2L^2}{R})}{R} = R + \frac{w^2L^2}{R}$$

$$\boxed{R_p \simeq \frac{w^2L^2}{R}}$$

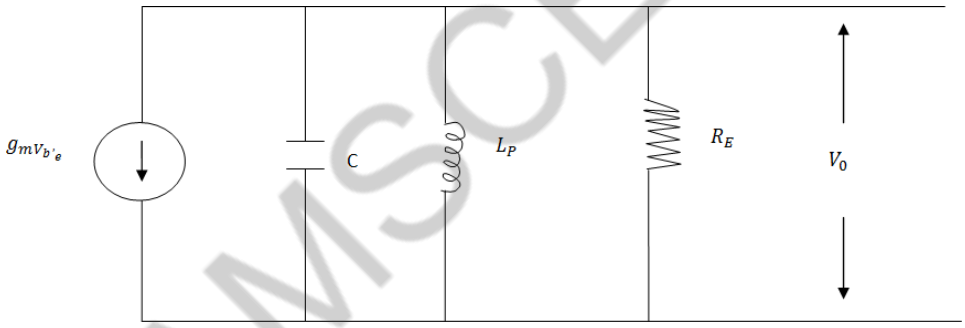
$$Lp = \frac{R^2 + W^2L^2}{W^2L} = \frac{R^2}{W^2L} + \frac{W^2L^2}{W^2L} = \frac{R^2}{W^2L} + L$$

$$\boxed{Lp \simeq L}$$

Eqn Ckt of Output Part,



$$\frac{1}{R_t} = \frac{1}{R_o} + \frac{1}{R_p} + \frac{1}{R_i}$$



Effective Quality factor,

$$Q_e = \frac{Susceptance\ of\ inductance\ (or)\ Capacitance}{Conductance\ of\ shunt\ Resistance\ R_t}$$

$$\boxed{Q_e = W_o R_t \frac{R_t}{W_o L}}$$

O/p Voltage,

$V_o = -g_m V_{b'e} Z.$

To find Z,

$Z = R_t\, 11L\, 11C$

$$1/Z = \frac{1}{R_t} + \frac{1}{jwL} + jwc$$

$$= \frac{1}{R_t}[1 + \frac{R_t}{jwL} + jwcR_t]$$

$$Y = \frac{1}{R_t}[1 + \frac{R_t W_o}{jwLW_o} + \frac{jw\boxed{W_o c R_t}}{W_o}]$$

$$Sub. \frac{R_t}{W_o L} = W_o c R_t = Q_e$$

$$Y = \frac{1}{R_t}[1 + \frac{Q_e W_o}{jw} + \frac{jwQ_e}{W_o}]$$

$$Y = \frac{1 + jQ_e[\frac{w}{w_o} - \frac{w_o}{w}]}{R_t}$$

$$\boxed{Z = \frac{1}{y} = \frac{R_t}{1 + jQ_e[\frac{w}{w_o} - \frac{w_o}{w}]}}$$

$\delta = fraactioned\ freq\ variation,$

$$\delta = \frac{w - w_o}{w_o} = \frac{w}{w_o} - \frac{w_o}{w} = \frac{w}{w_o} - 1$$

$$\boxed{\frac{w}{w_o} = \delta + 1}$$

$$Z = \frac{R_t}{1 + jQ_e[1 + \delta - \frac{1}{1+\delta}]}$$

$$= \frac{R_t}{1 + jQ_e[\frac{(1+\delta)^2 - 1}{1+\delta}]}$$

$$= \frac{R_t}{1 + jQ_e[\frac{1 + 2\delta + \delta^2 - 1}{1+\delta}]}$$

$$= \frac{R_t}{1 + jQ_e[\frac{\delta^2 + 2\delta}{1+}]} = \frac{R_t}{1 + j2[\frac{\delta/ + 1}{e\ 1+8}]}$$

$\delta << 1$

$$\boxed{Z = \frac{R_t}{1 + j2Q\delta}}$$

At resonance $w = w_o$, $\delta = 0$

$$\boxed{Z = R_t = R_o 11 R_p HR}$$

$$\boxed{V_{b'e} = V_i \frac{r_{b'e}}{r_{bb'} + r_{b'e}}}$$

$$V_o = -gmV_{b'e}Z$$

$$= -gm\left[V_i \frac{r_{b'e}}{r_{bb'} + r_{b'e}}\right]\left[\frac{Rt}{1 + j2Q_e\delta}\right]$$

$$A = \frac{V_o}{V_i} = -gm\left[\frac{r_{b'e}}{r_{bb'} + r_{b'e}}\right]\left[\frac{Rt}{1 + j2Q_e\delta}\right]$$

at Resonance, δ=0,

$$\boxed{A_{res} = -gm\left(\frac{r_{b'e}}{r_{bb'} + r_{b'e}}\right)Rt}$$

$$\frac{A}{A_{res}} = \frac{1}{1 + 2\delta Q_e}$$

$$\left|\frac{A}{A_{res}}\right| = \frac{1}{\sqrt{1 + (2\delta Q_e)^2}}$$

Phase angle of $\frac{A}{A_{res}}$

$$= -tan^{-1}(2\delta Q_e)$$

below Resonant freq,

$$Let\ \delta = -\frac{1}{2Q_e}$$

$$\left|\frac{A}{A_{res}}\right| = \frac{1}{\sqrt{1 + \left(2 \times \frac{-1}{2Q_e} Q_e\right)^2}}$$

$$= \frac{1}{\sqrt{1 + (-1)^2}} = \frac{1}{\sqrt{2}}$$

=0.707

above Resonant freq $\delta = +\frac{1}{2Q_e}$

$$\left|\frac{A}{A_{res}}\right| = \frac{1}{\sqrt{2}} = 0.707$$

<u>3 dB bandwidth</u>

$$\Delta w = 2\delta w$$

$$= \frac{1}{2Q_e}$$

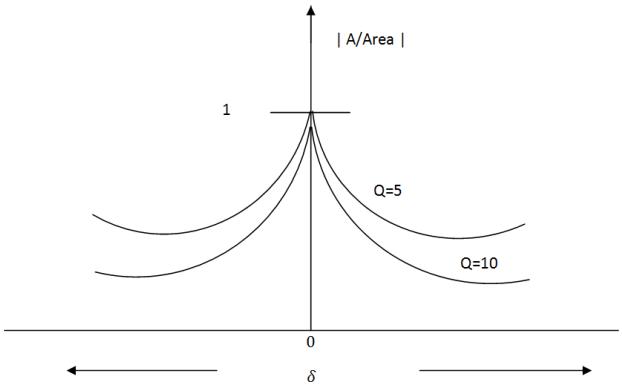
$$\Delta w = 2 \times \frac{1}{2Q_e} w_o = \frac{w_o}{Q_e}$$

$$\Delta w = \frac{w_o}{Q_e}$$

$$Q_e = w_o cRt = \frac{Rt}{w_o L}$$

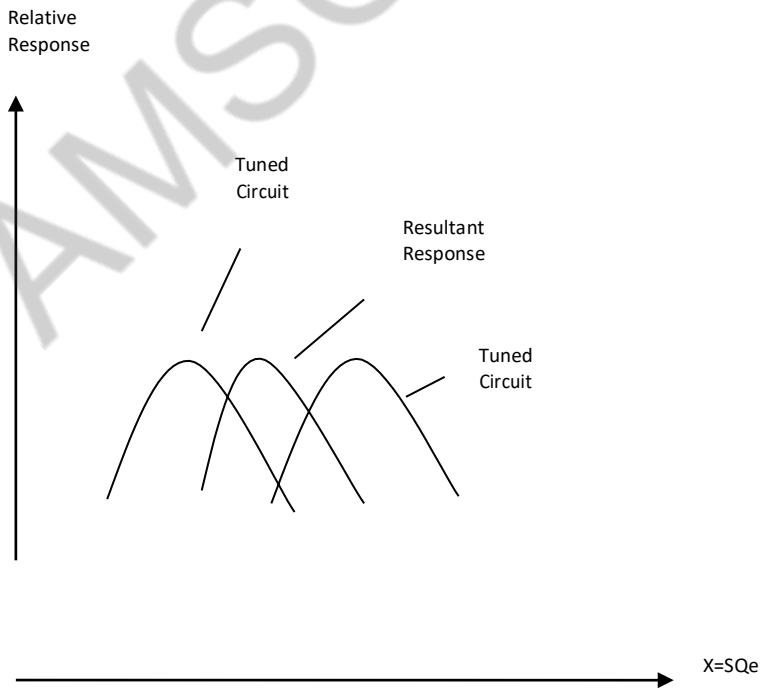
$$\therefore \Delta w = \frac{w_o}{w_o cRt} = \frac{1}{cRt} rad/s$$

Response to tuned amplifier



2)What is meant by stagger tuning of tuned amplifiers? **.[APRIL/MAY 2015] [MAY/JUNE 2014](APR/MAY 2019)**

In stagger tuned circuits, two single tuned cascade amplifiers having a certain bandwidth are taken. The resonant frequencies of the two tuned circuits are adjusted that they are separated by an amount equal to the bandwidth of each stage, since the resonant frequencies are displaced (or) staggered. They are known as stagger tuned circuits.



The resultant staggered pair will have the bandwidth (i.e) $\sqrt{2}$ times of that of each of the individual single tuned circuits.

$$\frac{A}{A_{res}} = \frac{1}{1 + j2\delta Q_e}$$

$$Let\ \frac{A}{A_{res}} = \frac{1}{1 + jX} where\ X = 2\delta Q_e$$

$$\left(\frac{A}{A_{res\,1}}\right) = \frac{1}{1 + (X-1)}, \qquad \left(\frac{A}{A_{res\,2}}\right) = \frac{1}{1 + (X+1)}$$

$$\left(\frac{A}{A_{res}}\right)_{pair} = \left(\frac{A}{A_{res\,1}}\right) \times \left(\frac{A}{A_{res\,2}}\right)$$

$$= \frac{1}{1 + (X-1)} \times \frac{1}{1 + j(X+1)}$$

$$= \frac{1}{1 + (X-1) + j(X+1) + j^2(X^2-1)}$$

$$= \frac{1}{1 + 2jX - (X^2-1)}$$

$$= \frac{1}{2 - X^2 + 2jX}$$

The magnitude of the resulting function is,

$$\left|\left(\frac{A}{A_{res\ 1}}\right) \times \left(\frac{A}{A_{res\ 2}}\right)\right| = \frac{1}{\sqrt{(2 - X^2)^2 + (2X)^2}}$$

$$= \frac{1}{\sqrt{4 - (2)\,2X^2 + X^4 + 4X^2}}$$

$$= \frac{1}{\sqrt{4 + X^4}}$$

$$= \frac{1}{\sqrt{4 + (2\delta_o Q_e)^4}} = \frac{1}{\sqrt{4 + 2^4\delta^4 Q e^4}}$$

$$= \frac{1}{\sqrt{4 + 16\delta^4 Q e^4}}$$

$$= \frac{1}{\sqrt{4(1 + 4\delta^4 Q e^4)}} = \frac{1}{2\sqrt{1 + 4\delta^4 Q e^4}}$$

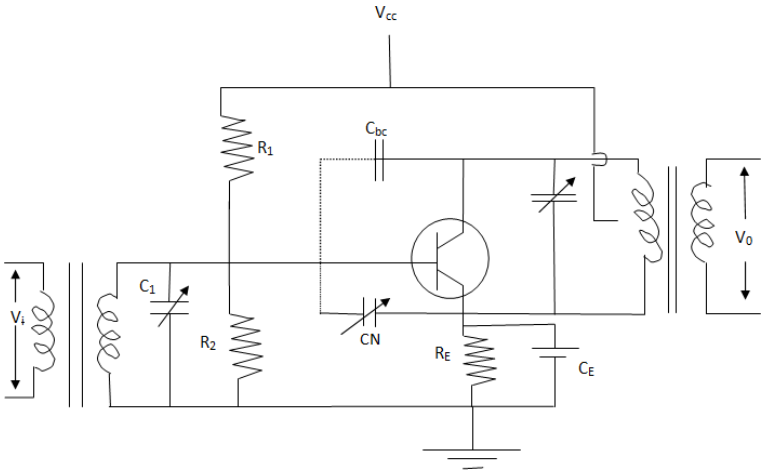
Advantages:

(i) Gain is constant.

(ii) Bandwidth is larger.

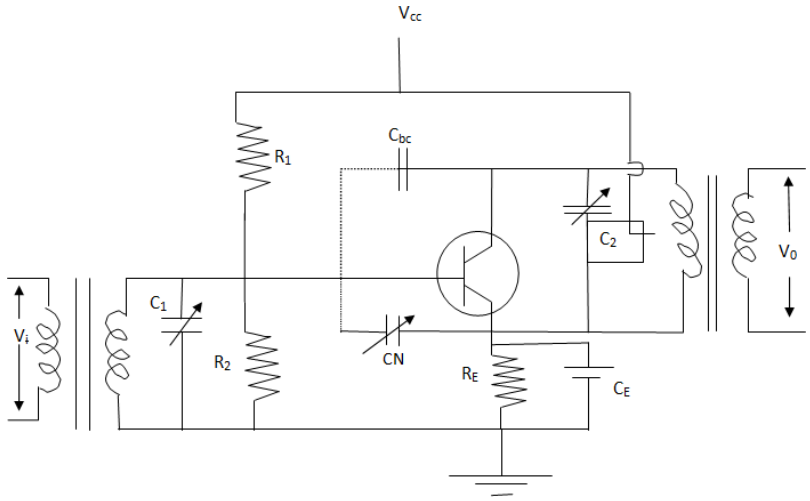
3)Why Neutralization is needed and explain the different Neutralization methods.
.[APRIL/MAY 2015] [MAY/JUNE 2014]

1) Hazeltine Neutralization



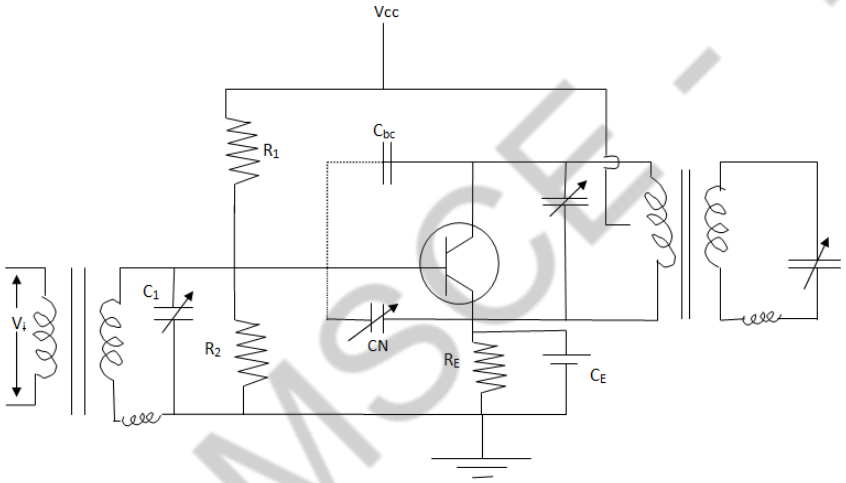
In this circuit, a small value of variable capacitance C_N is connected from the bottom of coil, point B to the base. Therefore the internal capacitance C_{bc}, feeds a signal from the top end of the coil, point A, to the transistor base and C_N feeds a signal of equal magnitude but opposite polarity from the bottom of the coil, point B to the base. The neutralizing capacitor C_N can be adjusted correctly to completely nultify the signal fed through the C_{bc}.

2) Modified Hazeltine (Neutrodyne) Neutralization



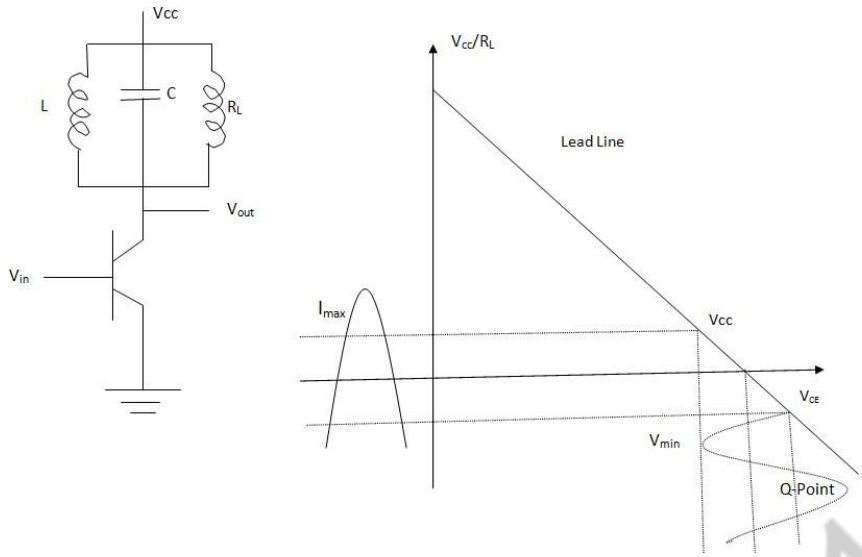
In this circuit, the neutralization capacitor is connected from the lower end of the base coil off the next stage to the base of the transistor.
This circuit functions is same manner as the Hazeltine neutralization circuit with the advantage that the neutralizing capacitor does not have the supply voltage across it.

3) Neutralization using coil



In this circuit, L part of the tuned circuit at the base of next stage is oriented for minimum coupling to the other windings. It is wound on a separate form and it is mounted at right angles to the coupled windings. If the windings are properly polarized, the voltage across L due to the circulating current in the base circuit will have the proper phase to cancel the signal coupled through the base to collector C_{bc} capacitance.

4) Draw Class- C tuned amplifier and derive its efficiency.**[APRIL/MAY 2015] [MAY/JUNE 2014]**

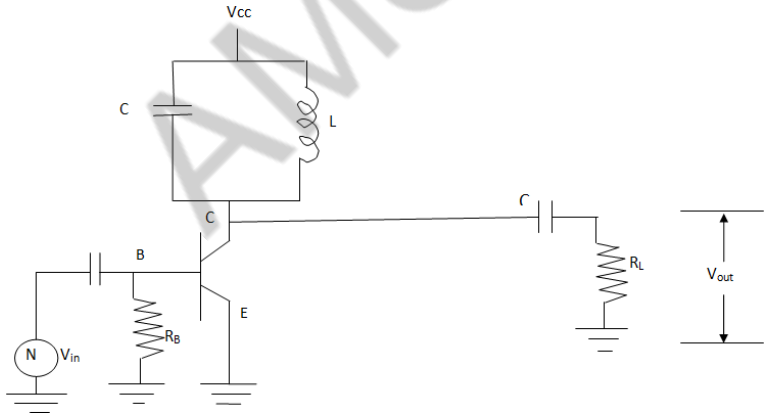


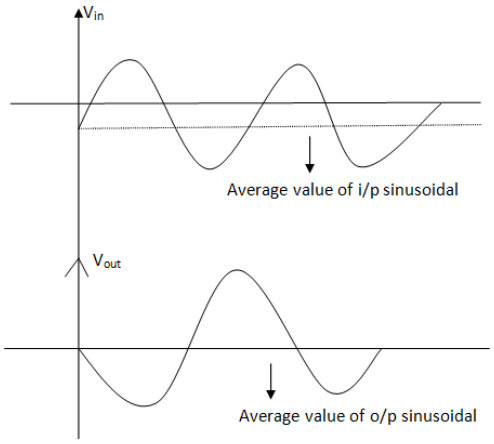
The large signal tuned amplifiers amplify high power signals of the radio freq range using class-c operation rather than class-A.

Class-c tuned amplifiers.

The amplifier is said to be a class-c amplifier if the output signal is obtained for less than half a cycle for a full input cycle. The Q point and the input signal are selected so as to achieve the conditions for a class-c amplifier.

The selection of Q point is made in such a way that the transistor remains active, for less than half a cycle so that only that much part of the input waveform is reproduced at the output with amplification. For the remaining part of the input, the transistor remains inactive and no corresponding output signal are produced. However the output pulses from the transistor triggers the tank circuit to produce continuous sinusoidal waveform.





Conduction angle θ_c

The conduction angle θ_c is defined as the total angle during which the collector current exists at the output.

The output of class-c amplifier consists of a series pulses with harmonics of input signal. The harmonic frequencies can be filtered out by using parallel tuned circuits to produce sine wave output.

θ_c is 360° in the small signal amplifier where class-A is generally used and θ is less than 180° in the large signal tuned amplifiers.

Efficiency of Class-c Tuned amplifier

The amplitude of the fundamental component of a class-c waveform depends on the conduction angle θ_c. The greater the conduction angle, the greater the ratio of the amplitude of the fundamental component the amplitude of the total waveform that includes harmonics.

Let r_1 be the ratio of the peak value of the fundamental component to the peak value of class-c waveform.

$r_1 = (-3.54 + 4.1\ \theta_c - 0.0072\ {\theta_c}^2) \times 10^{-3}$

$\theta° \leq \theta_c \leq 180°$

Values of r, varies from 0 to 0.5 as θ_c varies from 0° to 180°

Let $'r_0'$ be the ratio of the d.c value of the class-c waveform to its peak value.

$$r_0 = \frac{d.\ c\ value}{peak\ value\ \theta\ /_c \pi}$$

r_0 Varies from 0 to $^1/_\pi$ as θ_c varies from 0° to 180°.

The output power

$P_0 = r_1 I_p V_{cc}\ /2$

I_p - Peak output (collector) current.

The average power supplied by the d.c source is V_{cc} times the average current drawn from the source.

The average supplied power (P) is,

$P_s = (r_0 I_p)\ V_{cc}$

The efficiency is,

$$\eta = {}^{P_o}/_{P_s} = \frac{r_1 I_p V_{cc}}{2 r_0 I_p V_{cc}}$$

$$\boxed{\eta = \frac{r_1}{2 r_0}}$$

Applications of class-c tuned Amplifiers.

Class-c amplifiers are used in high power, high frequency applications such as radio-frequency transmitters. In these application, the high frequency pulses handled by the amplifier are not themselves the signal, but constituted what is called the carrier for the signal. The principal advantage of class-c amplifier is that it has a higher efficiency than the other amplifiers.

UNIT – IV
WAVE SHAPING AND MULTIVIBRATOR CIRCUITS

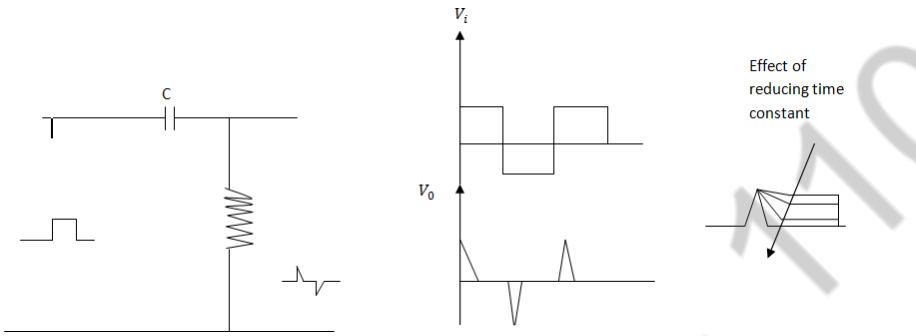
PART B

1) Sketch the response of RC high pass filter for the following inputs and explain (1) Ramp (2) Pulse**[NOV/DEC 2013]**

RC Circuits

The waveform shaping circuits like differenting and integrating circuits are used in multivibrators as triggering and synchronizing pulse generators. The triggering pulses to the multivibrator are to be reshaped using differentiating and integrating RC circuits.

Differentiating Circuit (High Pass RC Circuit)



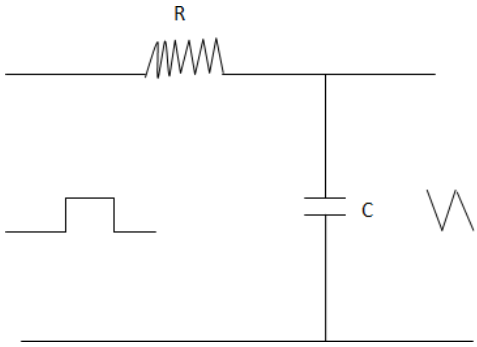
The circuit consists of a series capacitor sand a shunt resistor reactance of a capacitor $X_c = \frac{1}{2\pi fc}$. X_c decreases with increasing frequency. Therefore at very high frequencies, the capacitor acts as short circuit and all the higher frequency components appear at the output with less attenuation than lower frequency components. This circuit is called high pass filters.

Time constant $I = RC$, with reducing time constant, the pulse at the output becomes narrower, with negligible sag. If the time constant is reduced, the output will be a series alternate positive and negative spikes.

Mathematically, such a waveform is the first derivative of the input waveform, $V_o = RC\frac{dvi}{dt}$ hence, this circuit is called differentiator.

2)Discuss the effect of RC time constant and condition for the circuit to operate as integrator. (Low – Pass RC circuit)**[APRIL/MAY 2015]**

(APR/MAY 2019)



It consists of series resistor and a shunt capacitor. This circuit passes low frequencies of the input and alternates high frequencies because the reactance of the capacitor C decreases with increasing freq. At the very high frequencies, the capacitor acts as a virtual short circuit and the output falls to zero. Hence this circuit is called low pass filter.

$V_o = \frac{1}{RC}\int V_i dt. \; The \; o/p \;\; is \; given \; by$

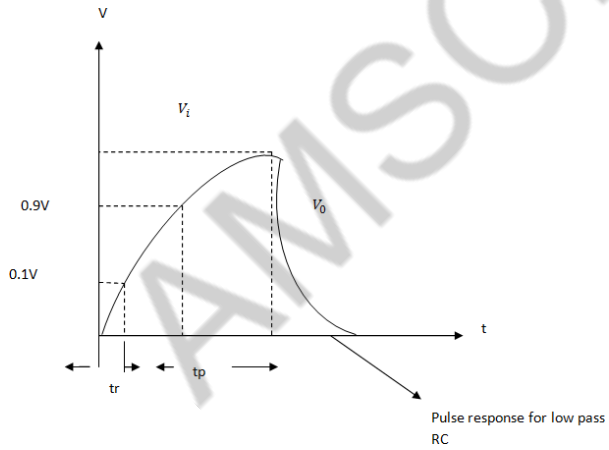
$V_o = V[1 - e^{-t/RC}]$

Rise time

The rise time t_r is the time taken for the voltage to rise from 10% to 90% of its final value.

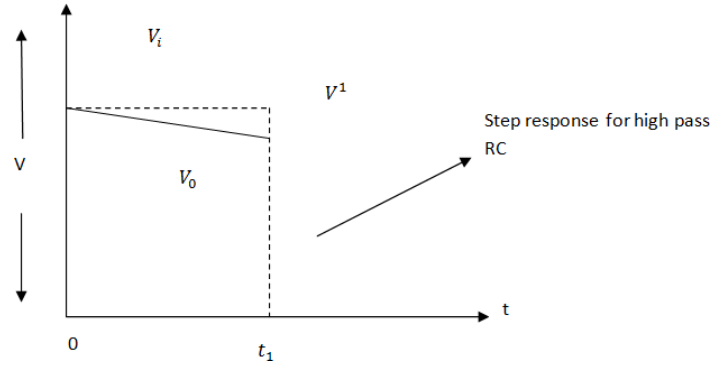
For low pass RC,

$t_r = 2.2\,RC = \frac{0.35}{BW}$



Pulse response for low pass RC

Sat (or) tilt.



The response $V_o$which exhibits a tilt when a step $V_i$is applied to a high pass RC circuit. Since the capacitor is initially uncharged, the o/p at t=0, will be V. V_o= $e^{-t/RC}$.

at $t = t_1$, if time constant RC is very large, $RC >> t_1$, there is only a slight tilt to the o/p pulse

$At\ t = t_1, V_o = V^1$

$V^1 = V\ (1 - {}^{t_1}/_{R_1}\ )_1$

$$\%\ of\ tilt\ p = \frac{V - V^1}{V} \times 100 = \frac{t_1}{R_1 C_1} \times 100\%$$

Duty Cycle: It is the ratio of ON period Tow to the total period ($T = Tow + Toff$).

$$\boxed{duty\ cycle = \frac{Tow}{T}}$$

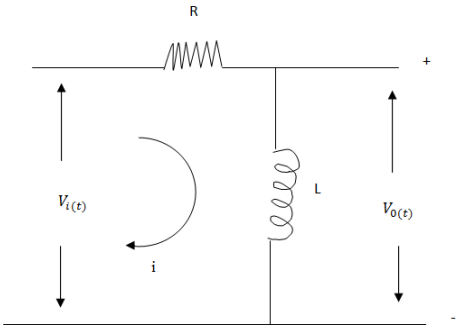
3.If the rise time of a BJT is 35 nanosec. What is the bandwidth that can be obtained using this BJT?

$tr - 35ns$

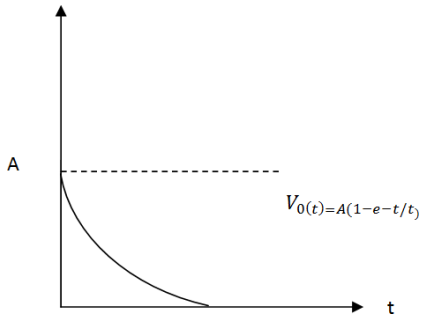
$tr - \frac{0.35}{BW}$

$BW = \frac{0.35}{tr} = \frac{35ns}{0.35} = toMHz$

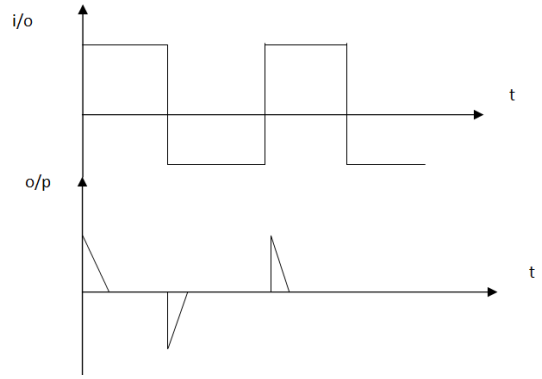
4. Explain in detail about High Pass RL Circuit



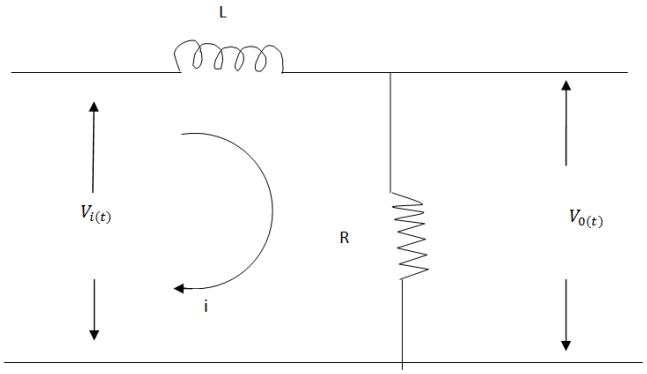
It consists of a series resistor (R) and shunt inductor (L). $X_L = 2\pi fL$ at $f = 0$, the realtance becomes zero, and inductor acts as a short circuit and the o/p falls to zero. Since the inductor acts as a short circuit, for a certain low freq range, the circuit doesnot pass low freq of the input.
At high freq, open circuit, and all high freq components appear at the output. Hence the circuit is called high pass filter.
Time constant $I = {}^{L}/_{R}$



Step response for high pass RL
For a step of A volts applied to the high pass RL circuits, initially the o/p voltage is A volts. At $t \rightarrow \infty$, the input voltage is constant A volts. Hence the current reaches a steady state value equal to A/R. Amperes since the current is constant, d_i/d_t is zero. ∴ voltage across the inductor $L\,{}^{d_i}/_{d_t} = 0$. ∴ The o/p voltage is zero in the steady state.
$V_o = A\,[1 - e^{-({}^{R}/_{L})t}]$. The o/p is exponentially decreased from A to zero.
<u>Square wave response of high pass RL.</u>

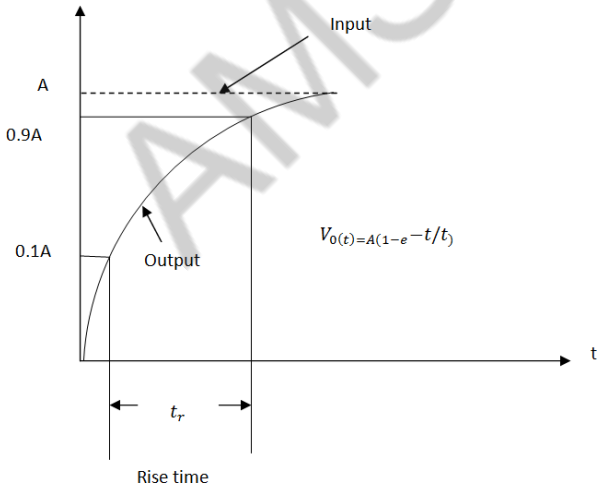


5.Explain in detail about Low Pass RL Circuit



It consists of a series inductor and a shunt resistor. The circuit passes low frequencies of the input and alternates high frequencies because the reactance of the inductor L is directly proportional to the frequency. At very high frequencies, the inductor acts as a virtual open circuit and the output falls to zero. Hence this circuit is called low pass filter.

<u>Step response of low Pass RL Circuit</u>



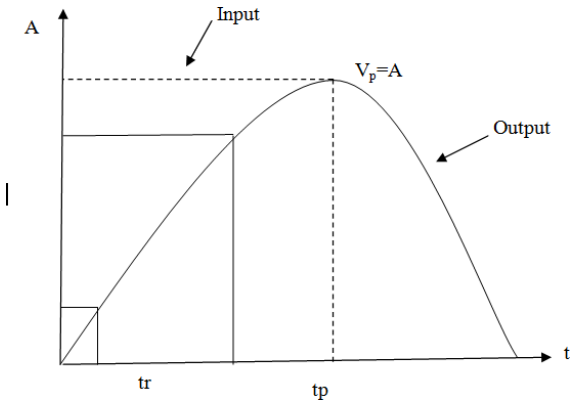
For a step of A volts applied to the low pass RL circuit, the input changes from 0 to A volts. At $t = 0$, the output voltage is zero. As $t \rightarrow \infty$, the input is constant

equal to A volts. $\therefore \frac{d_i}{d_t} = 0$, and the voltage drop across the inductor is zero. The entire voltage A appears at the output. Hence the output voltage increases exponentially from 0 to A volts.

The output voltage is expressed by

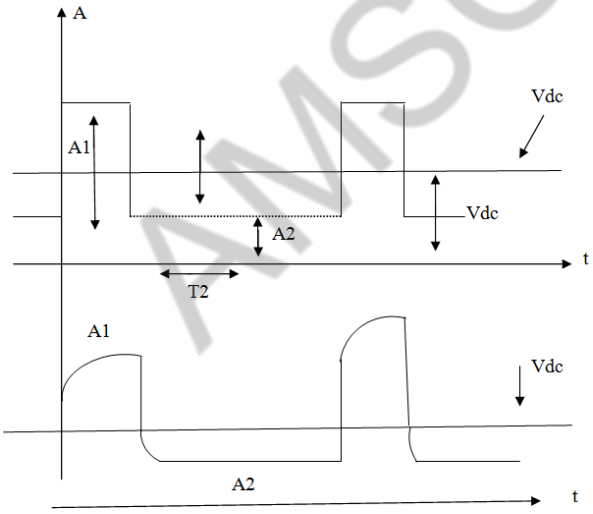
$V_0(t) = A\,[1 - e^{-(R/L)t}]$

Pulse response of low pass RL



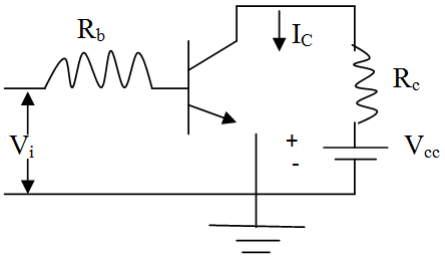
If the rise time t_r, is equal to $0.35t_p$, then the output is reproduction of the input.

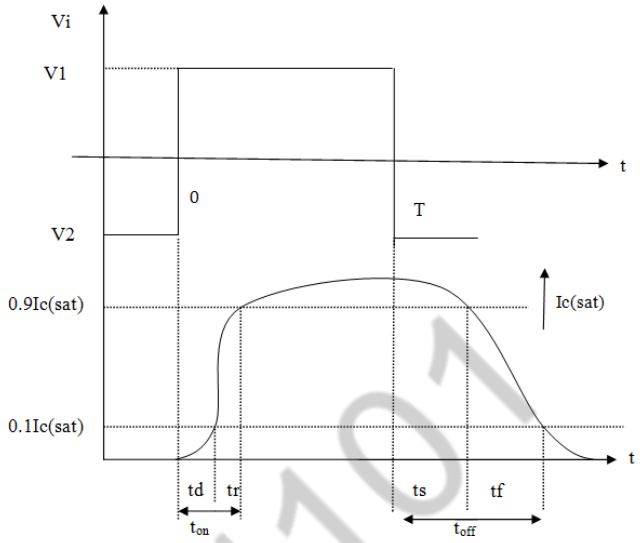
Square wave response of low pass RL circuit.



When the time constant of the circuit is very small, the output is almost similar to the input.

6)A rectangular pulse of voltage is applied to the base of a transistor driving it from cut off to saturation. Explain the various times involved in the switching process**..[MAY/JUNE 2014] [NOV/DEC 2013] [MAY/JUNE 2013] [NOV/DEC 2012]**





Transistor switching circuit.

When a pulse is applied to the input of a transistor, the output current does not directly follow the input waveform. Instead, there will always be some delay because the transistor operates from cutoff to saturation and then returns to cutoff.

Delay time (td)

The time needed for the current to rise to 10% of its maximum (saturation) value. $I_{c\,(sat)} = \frac{V_{cc}}{R_s}$. It is called delay time (td). The reason for delay is that the transistor requires a non-zero time to charge up the emitter junction transistor capacitance in order to bring the transistor to the active region from the cutoff region.

Rise time (tr)

The time required for the collector current to rise from 10% to 90% of the maximum value is called rise time (tr).

Turn ON time (tON)

The sum of the delay time and the rise time is called the turn ON time (tON)

tON=td+tr

Storage time (ts)

The interval which elapses between the transition of the input voltage waveform and the time when collector current (ic) dropped to 90% of its maximum value is called the storage time.

Fall time (tf)

The time required for the collector current to fall from 90% to 10% of its maximum value is called of all time (tf)

Turn-off time (toff)

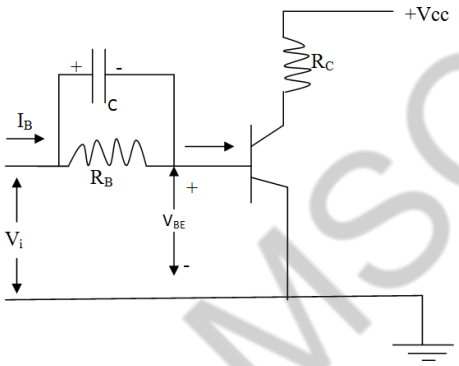
The sum of storage time (ts) and fall time (tf) is called toff.

toff = ts+tf

7.Explain in detail about Speed up Capacitor.

(1) Speed up capacitor is used to improve the switching times. If the base-emitter junction of the transistor is reverse biased before switch-on, the delay is longer compared to the case when V_{BE} is initially zero. This is because the transistor input capacitance needs to charge to the reverse-bias voltage and allowed to discharge before V_{BE} becomes positive.
(2) The delay time and the rise time can be reduced if the transistor is overdriven, (i.e) if I_B is made larger than the minimum required for saturation. With a larger I_B the junction capacitance charges faster, thus reducing the turn-on time.
(3) The turn-off time may be reduced by providing a large negative input voltage during switch-off. This produces a reverse base current flow which causes the junction capacitance to discharge rapidly.
(4) For faster switching, V_{BE} is to be fixed at zero volts, & I_B is to be made large at switch-on and it should be rapidly allowed to settle down to the minimum value required for saturation.
(5) Swtich off should be accomplished by a large reverse bias voltage which rapidly returns to zero. These can be achieved by speed up capacitor (or) commutating capacitor which is connected in parallel with R_B.
(6) The speed up capacitor tends to reduce td & ts as well as tr & tf.

Calculation of the Speedup Capacitor



Transistor circuit with the speedup capacitor

The capacitor charging current drops by 10% from its maximum level with the capacitor is permitted to charge by 10% during the turn-on time.

$t_{on} = 0.1\ R_s C,$

$\therefore C = \frac{t_{on}}{0.1 R_s}$

The maximum value of C depends on the maximum frequency of the signal. When the transistor is switched off, C discharges through R_B. For perfect switching C must be at least 90% discharged during the time interval between transistor switch off and switch on. The time needed for the capacitor to return to its discharged condition is called settling time (or) the recovery time t_{re} of the circuit.

$t = 2.3\ R_B C$ $t_{re} = 2.3\ R_B C$

$$\therefore C = \frac{t_{re}}{2.3 R_B}$$

8) Explain in detail about diode clippers.

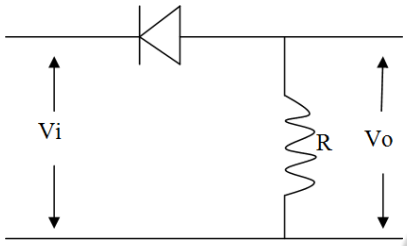
The circuit with which the waveform is shaped by removing (or clipping) a portion of the input signal without distorting the remaining part of the alternating waveform is called a clipper.

Clipper circuits are also referred as voltage (or) current limiters, amplitude selectors, slicers. These circuits are used in radars, digital computers, radio and television receivers etc.

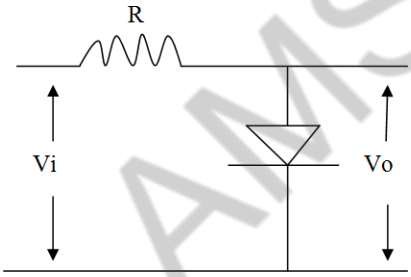
The four general categories of clippers,

1) Positive clipper
2) Negative clipper
3) Biased clipper
4) Combination clipper
5) Two level slicer

1) Positive Clipper

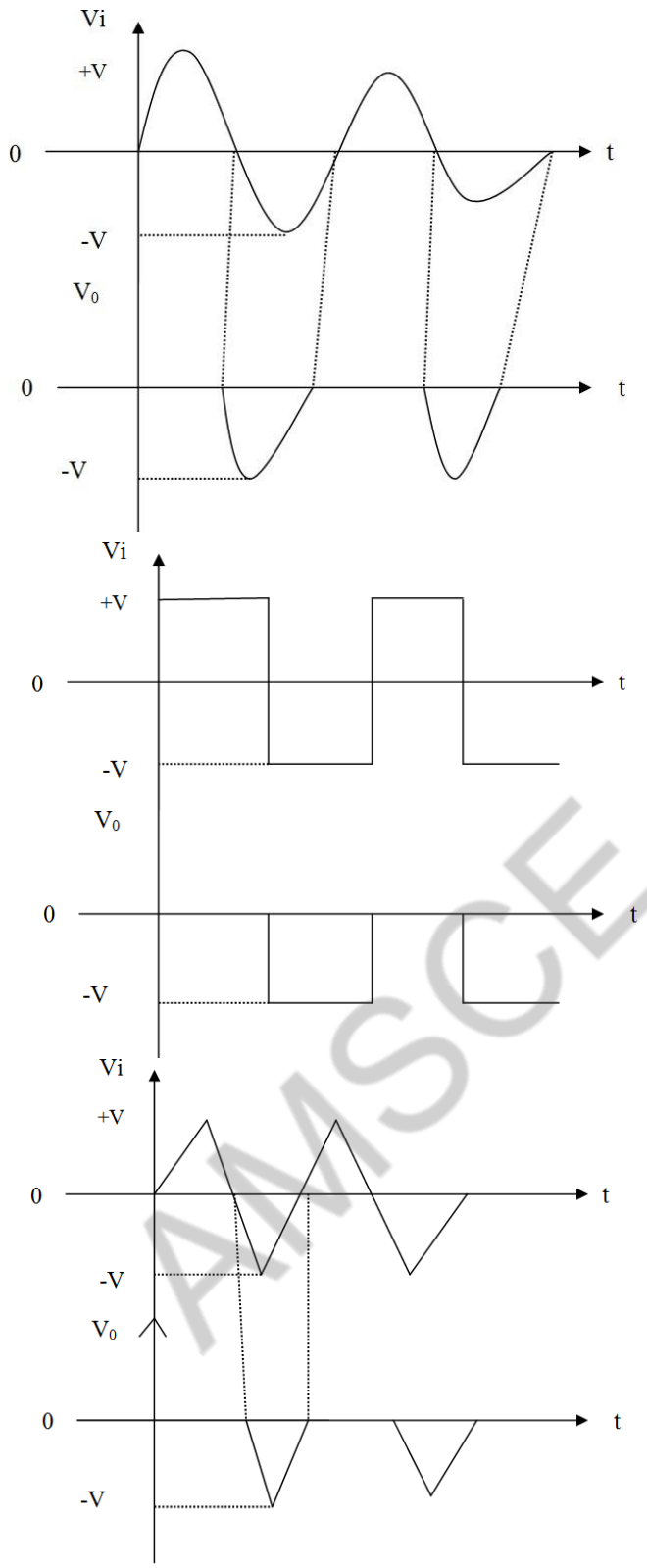


Series Positive clipper



Shunt Positive clipper

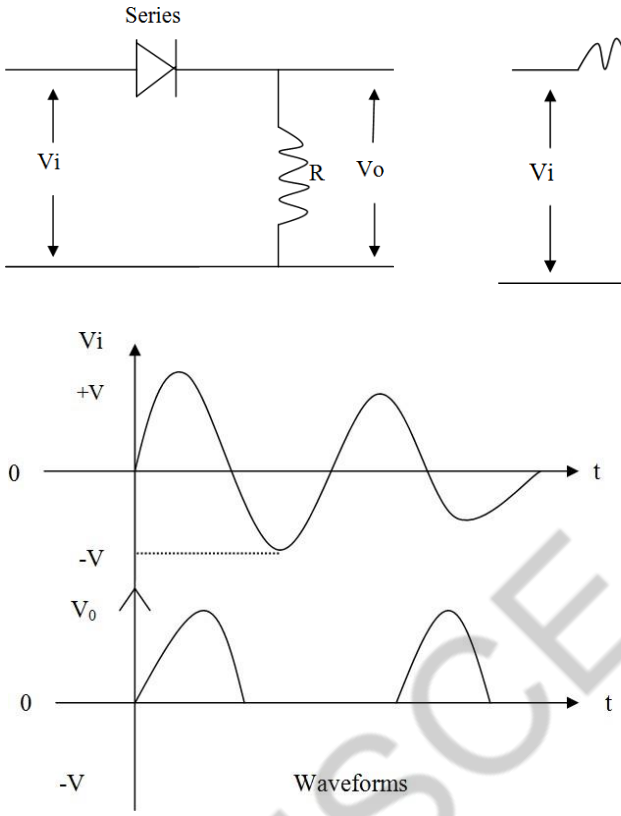
Input and o/p signal waveforms



In the series positive clipper, when the input voltage is positive, the diode does not conduct and acts as an open circuit and hence the positive half cycle does not appear at the output. (i.e) the positive half cycle is clipped off. When the input

signal is negative, the diode conduct and act as a closed switch (short circuit) the negative half cycle appear at the output.
In the shunt positive clipper, when the input voltage is positive, diode conducts and acts as short circuit and hence there is zero signal at the output. (i.e) the positive ex half cycle is clipped off. When the input signal is negative, the diode does not conduct and acts as an open switch, the negative half cycle appears at the output.
∴ The positive clippers act as as half wave rectifier.

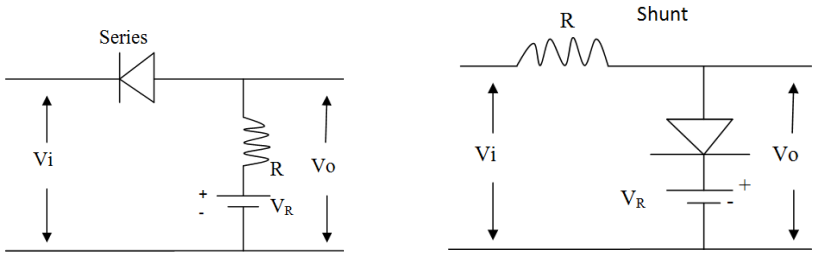
2) Negative Clipper



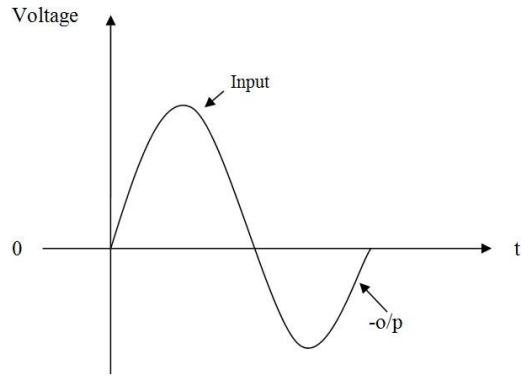
In the series negative clipper, during positive, half cycle of the input signal, the diode conducts and acts as a short circuit, and hence the positive half cycle of the input signal will appear at the output.
During negative half cycle of the input signal, the diode does not conduct and acts as an open circuit. The negative half cycle will not appear at the output.
The negative clippers of both series and shunt types work as half wave rectifier.

3) Biased Clipper

(i) Biased Positive Clipper



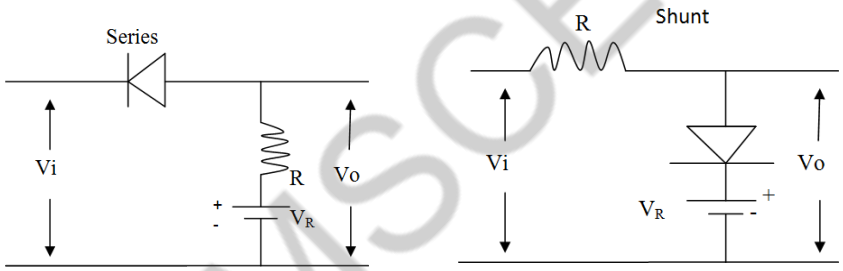
o/p waveform for sine wave i/p.

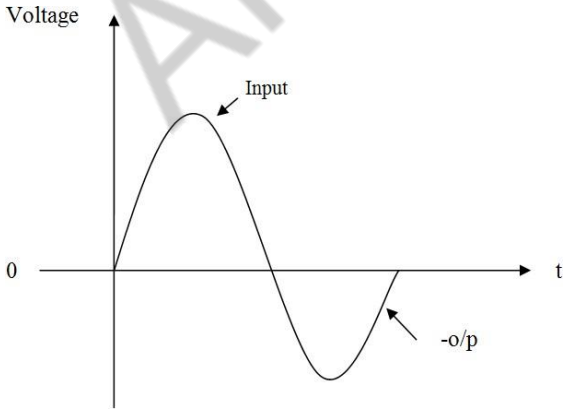


In the biased series positive clipper the diode does not conduct as long as the the input voltage is greater than $+V_R$ and hence, the output remains at $+V_R$. When the input voltage becomes less than $+V_R$, the diode conduct and acts as a short circuit. Hence all the input signal having less than $+V_R$ as well as negative half cycle of the input wave will appear at the output.

In the biased shunt positive clipper, the diode conducts as long as the input voltage is greater than $+V_R$ and output remains at $+V_R$ until the input voltage becomes less than $+V_R$. When the input voltage is less than $+V_R$, the diode does not conduct and acts as an open switch. Hence all the input signal having less $+V_R$ as well as negative half cycle of the input wave will appear at the output.

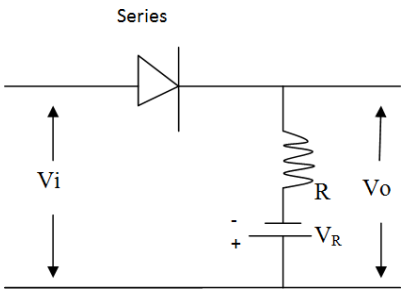
(ii) Biased positive clipper with reverse polarity of the battery V_R

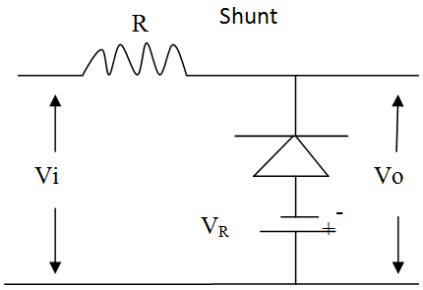




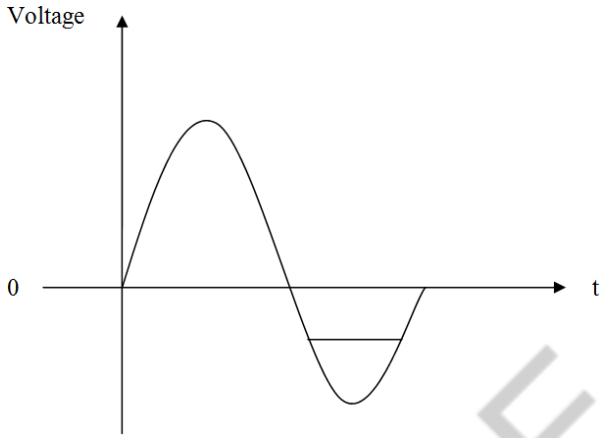
Here the entire signal above $-V_R$ is clipped off.

(iii) Biased negative clipper





o/p waveform for sine wave input



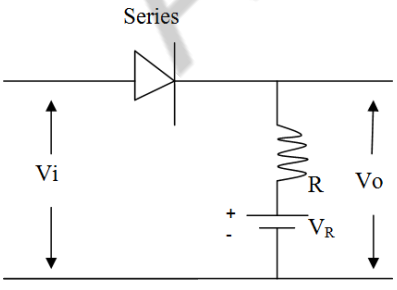
In the biases series negative clipper,

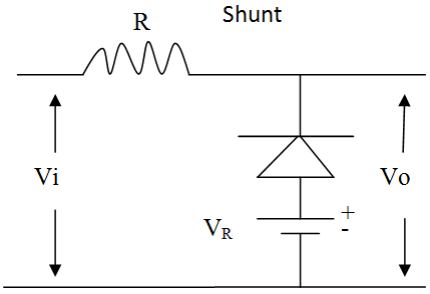
When the input voltage $V_i \leq -V_R$ the diode does not conduct and clipping takes place.

In the biased shunt negative clipper,

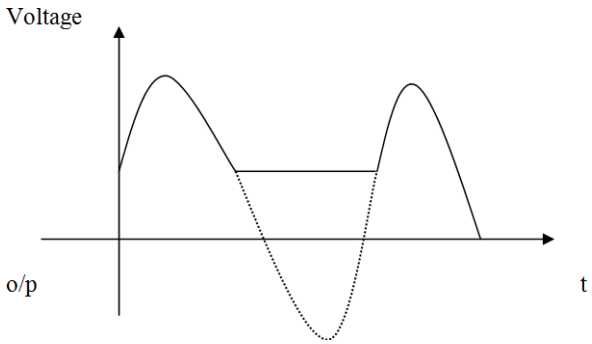
$V_i \leq -V_R$, the diode conducts and clipping take place. The clipping level can be shifted up and down by varying the bias voltage ($-V_R$)

(iv) Biased negative clipper with reverse polarity of the battery V_R.



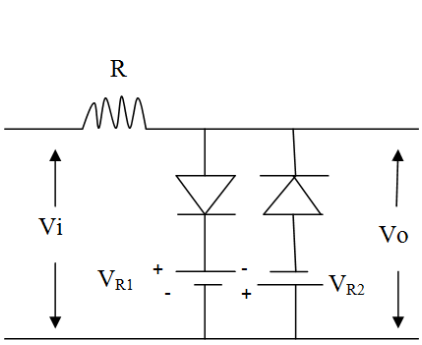


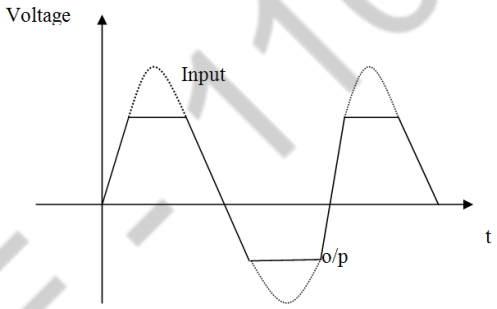
o/p waveform for sine wave input



Here the entire signal below $+V_R$ is clipped off.

4. Combination Clipper





When the input signal voltage $V_i \geq +V_{R1}$ diode D_1 conducts and acts as a closed switch, while diode D_2 is reverse biased and D_2 acts as open switch. Hence the output voltage cannot exceed the voltage level of $+V_{R1}$ during the positive half cycle.

When the input signal voltage $V_i \leq -V_{R2}$, diode D_2 conducts and acts as a closed switch, while diode D_1 is reverse biased and D_1 acts as an open switch. Hence the output voltage V_o cannot go below the voltage level of $-V_{R2}$ during the negative half cycle.

If $V_{R1} = V_{R2}$, the circuit will clip both the positive and negative half cycles at the same voltage. This is called combination clipper or symmetrical clipper.

5. Two Level Slicer

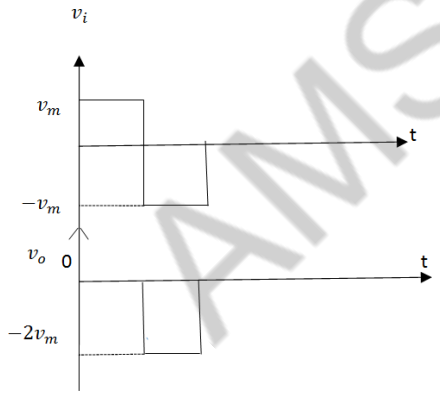
It is similar to the combination clipper but with the diode connections reversed.

9) Explain in detail about diode comparator.

The nonlinear circuit which is used to perform the operation of clipping may also used to perform the operation of comparison is called the comparator.

The comparator circuit compares an input signal $V_i(t)$ with a reference voltage V. The comparator output is independent of the signal until it attains the reference level. When the signal and reference level become equal, there will be a sharp pulse at the comparator output.
The input signal is considered as a ramp. At $t = t_1$, $V_i(t) = V_R + V_r and\ V_o = V_r$ until $t = t_1$, Beyond $t = t_1$, the output rises with the input signal. At some later time, $t = t_2$, the device responds in the range ΔV_o for a input voltage ΔV_t corresponding to Δt.
When $V_R = 0$, the output will respond everytime the input passes through zero. This arrangement is called a zero-crossing detector.
The most important systems using comparators are,
(i) Square waves from a sine wave.
(ii) Timing markers generator.
(iii) Phase meter.
(iv) Amplitude – distribution analyzer.
(v) Pulse time modulation.
(vi) Pulse, square wave and triangular wave generators.
(vii) Analog to digital converter.
Clamping network shifts (clamps) a signal to a different dc level, (i.e.). It introduces a dc level to an ac signal. Hence the clamping network is also known as dc restorer. These circuits applicable in television receivers to restore the dc references signal to the video signal.
time constant I = RC.

10) With a circuit diagram and waveforms , explain the working of a negative clamping circuit.



During the first quarter of positive cycle of the input voltage V_i, the capacitor gets charged through forward biased diode up to maximum value V_m.
When D is ON, the output voltage V_o is zero. As input voltage decreases after attaining its maximum value V_m, the capacitor remains charged to V and the diode becomes reverse biased.
o/p voltage V_o
$V_o = V_i - V_c = V_i - V_m$.

In the negative half cycle of V_i, the diode will remains reverse biased. The capacitor starts discharging through the resistance R_L. As the time constant R_{LC} is large, the capacitor holds all its charge and remains charged to V_m

$V_o = V_i - V_c = V_i - V_m$

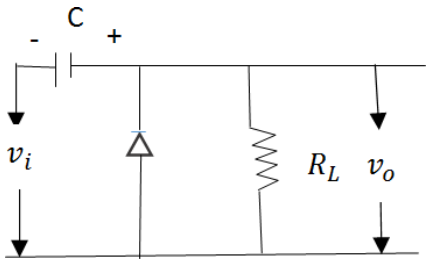
$V_o = -V_m \, for \, V_i = 0.$

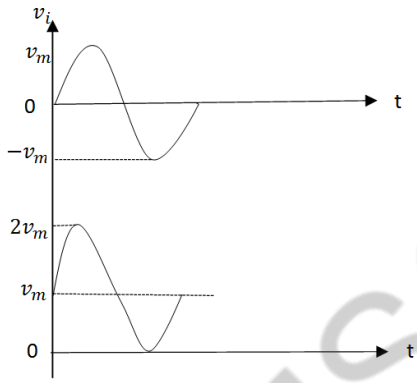
$V_o = 0, for \, V_i = V_m$

$V = -2 \, V_m, for \, V_i = -V_m$

The total swing of the output is always same as the total, swing of the input.

11) With a circuit diagram and waveforms , explain the working of a positive clamping circuit. **[MAY/JUNE 2013] [MAY/JUNE 2014]**





During the first quarter of negative half cycle of the input voltage V_i, diode gets forward biased and capacitor gets charged equal to the maximum value V_m. Since RC time constant is very large, the capacitor holds its entire charge all the time.

$V_o = V_i + V_m$.

In the positive half cycle, diode is reverse biased. The capacitor starts discharging through RL. But due to large time constant, it hardly gets discharged during positive half cycle of V_i

$V_o = V_i + V_m$

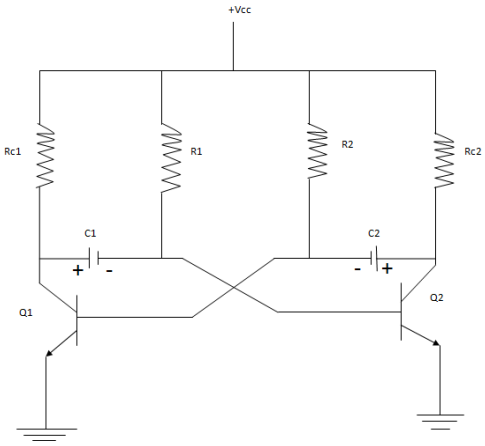
$V_o = V \, , for \, V_i = 0$

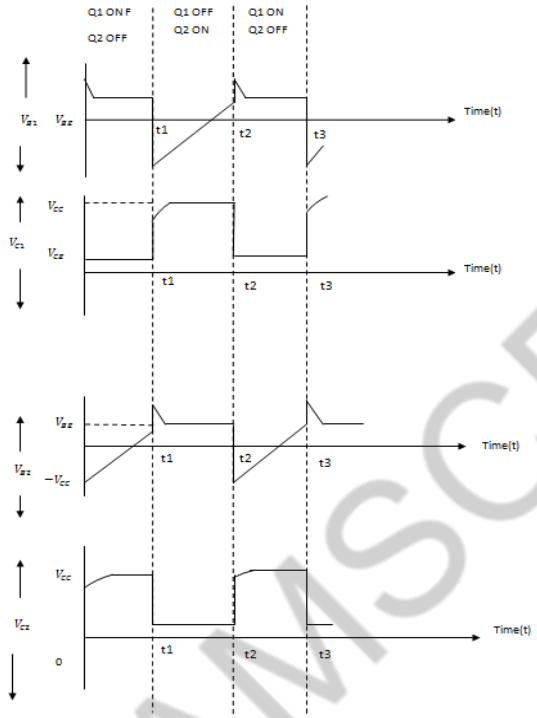
$V_o = 2V_m \, for \, V_i = V_m$

$V_o = O \, for \, V_i = -V_m$

Application used in the television receivers as d.c restorer.

12)With the help of a circuit diagram and wave forms , explain the operation of a collector coupled astable multivibrator[MAY/ JUNE 2014] [MAY/ JUNE 2013][NOV/DEC 2012]





The astable or free running multivibrator generates square without any exernal triggering pulse. It has no stable state. (i.e.) It switches back and forth from one state to the other, remaining in each state for a time depending upon the discharging of a capacitive circuit.

When the supply voltage $+V_{cc}$ is applied, one transistor will conduct more than the other due to some circuit imbalance.

Assume Q_1 is conducting & Q_2 is cut off the output of Q_1 is equal to $V_{CE\,(sat)}$ (i.e.) approximately zero volt and $V_{c2} = +V_{cc}$. At this instant, C_1 charges exponentially with a time constant R_1C_1 towards the supply voltage through R_1 and correspondingly V_{B2} also increases exponentially towards V_{cc}.

When V_{B2} crosses the cult in voltage, Q_2 starts conducting and V_{c2} falls to $V_{CE\ (sat)}$. Also V_{B1} falls due to capacitive coupling b/w collector of Q_2 and base of Q_1. Therefore driving Q_1 into off state. Thus Q_1 is off and Q_2 is ON. At this instant, V_{B1} is negative.

$V_{C1} = V_c$, $V_{B2} = V_{BE(sat)}$, $V_{C2} = V_{CE\ (sat)}$.

When Q_1 is off and Q_2 is ON, the voltage V_{B1} increases exponentially with a time constant R_2C_2 towards V_c.

$\therefore Q_1$ is driven into saturation and Q_2 is cut off. $\therefore$ the voltage levels are, $V_{B1} = V_{B(sat)}$, $V_{C1} = V_{CE\ (sat)}$, V_{B2} is negative and $V_{c2} = V_{cc}$.

When Q_2 is ON, the falling voltage V_{c2} permits the discharging of the capacitor c_2 which drives Q_1 into cutoff. The rising voltage of V_{c1} feeds back to the base of Q_2 tending to turn it ON. This process is said to be regenerative.

The ON time for Q_1 is $T_1 = R_1C_1ln_2$

$= 0.693\ R_1\ C_1$

ON time for Q_2 is $T_2 = R_2C_2ln_2$

$= 0.693\ R_2\ C_2$

The total period of the wave is $T = T_1 + T_2$

$= 0.693\ (R_1\ C_1 + R_2\ C_2)$

If $R_1 = R_2 = R\ and\ C_1 = C_2 = C$

$= 1.386\ RC, f = {}^{1}/_{T} = \dfrac{1}{1.386\ RC}$.

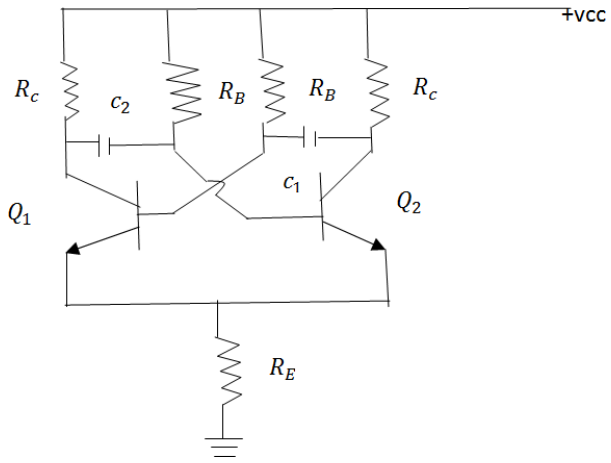
$R_1 \leq h_{f(min)}RC_1$

$R_2 \leq h_{fe(min)}RC_2$

Applications.

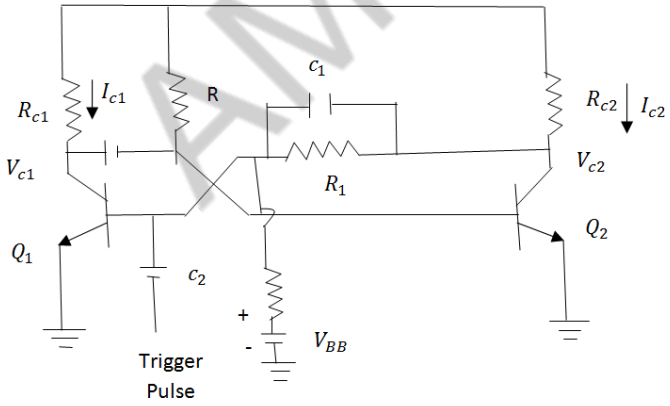
1. The astable multivibrator is used as square wave generator, Voltage to Frequency Convertor and in Pulse Synchronisation, as clock for binary logic signals
2. It is used in the Construction of Digital Voltmeter and SMPS.
3. It can be operated as an Oscillator over a wide range of audio and radio frequencies.

13)With the help of a circuit diagram and wave forms , explain the operation of a emitter coupled astable multivibrator



Due to the circuit symmetry of collector coupled astable multivibrator sometimes both the transistor Q_1 and Q_2 maybe ON or remain off. ∴ When the supply voltage V_{cc} is supplied, the circuit may not start oscillating. By shorting the base and emitter terminals of one of the transistors for a short time, the oscillation can be started. By solving this problem, the emitter coupled astable multivibrator is used. In this, one transistor starts conducting, the emitter voltage of the other one increases and its base voltage decreases. Thus the presence of R_E eliminates the possibility of both transistors remaining ON at same time and ensure that the circuit oscillates. $R_E = {}^{V_{cc}}/_{2}$.

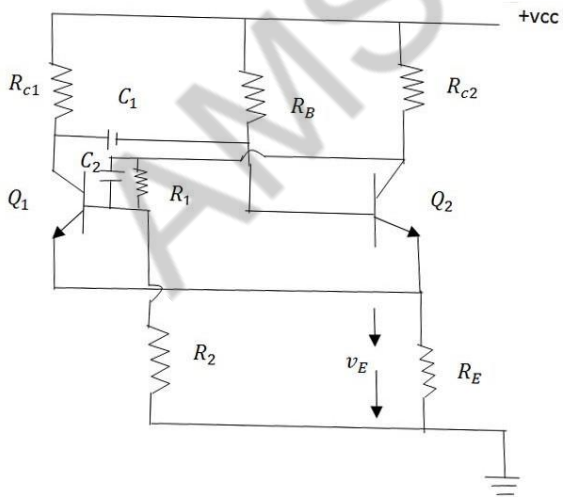
14)With the help of a circuit diagram and wave forms , explain the operation of a collector coupled monostable multivibrator.



Monostable multivibrator has one stable state and on quasi-stable state. It is also known as one shot multivibrator or univibrator. It remains into its quasi-stable state

for a time determined by discharging an RC circuit and the circuit returns to its original stable state automatically.
It consists of two identical transistor Q_1 and Q_2 with equal collector resistance R_{c1} and R_{c2}. The values of R_2 and $-V_{BB}$ are chosen so as to reverse bias Q_1 and keep it in the OFF state. $+V_{cc}$ and R will forward bias Q_2 and keep it in the ON state.
When a positive trigger pulse of short duration and sufficient magnitude is applied to the base of Q_1 through C_2, transistor Q_1 starts conducting and thereby decreasing the voltage at its collector V_{c1} which is couple to the base of Q_2 through capacitor C. This decreases the forward bias on Q_2 and its collector current decreases. This increasing positive potential on the collector of Q_2 is applied to the base of Q_1 through R_1. This further increases the base potential of Q_1 and Q_1 is quickly driven to saturation and Q_2 to cut off.
The capacitor C charged to approximate $+V_{cc}$, through the path V_{cc}, R and Q_1. As the capacitor C discharges, the base of Q_2 is forward biased and collector current starts to flow into Q_2. Thus Q_2 is quickly driven to saturation and Q_1 is cutoff. This is the stable state for the circuit and remains in this condition until another trigger pulse causes the circuit to switch over the states.
T = 0.693 RC
Applications
1. The monostable multivibrator is used to function as an adjustable pulse width generator.
2. It is used to generate uniform width pulses from a variable width input pulse train.

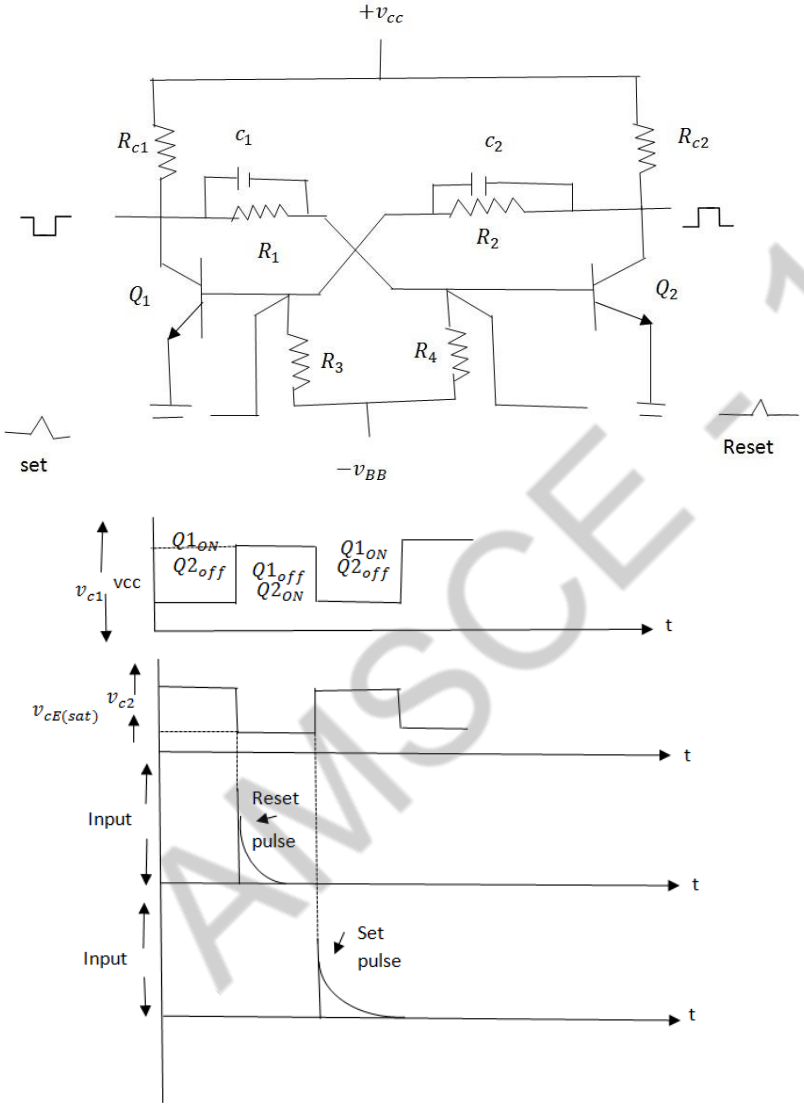
15)With the help of a circuit diagram and wave forms , explain the operation of a emitter coupled monostable multivibrator.



As the transistor Q_2 is supplied the base current via R_B, it is normally ON and so a voltage drop V_E across R_E. The voltage V_{c2} at collector of Q_2 becomes lower than

the supply voltage V_{cc}. The base of Q_1 is biased from V_{c2} through the potential divider R_1 and R_2 whose values are selected so that V_{B1} is less than V_E to keep Q_1 off and Q_2 ON. Therefore V_{c1} is equal to V_{cc} and voltage across the capacitor c_1 is equal to $V_{cc}-V_{B2}$.
When Q_1 is triggered ON, V_{c1} falls and the charge on c_1 causes V_{B2} to drop. When Q_2 is off, V_{c2} starts to increase, thus increasing V_{B1}. Now V_E becomes $V_{B1}-V_{BE1}$. The Q_2 remain off until C_1 has discharged enough to allow V_{B2} to increase above V_E.

16) With circuit diagram and waveforms expain the operation of transistor based bistable multivibrator**[APRIL/MAY 2015]**



In this circuit the output of transistor Q_2 is coupled to the base of Q_1 through a resistor R_2 similarly the output of Q_1 is coupled to the base of Q_2 through resistor R_1. C_1 and C_2 are called speed up capacitors.
When the circuit is first switched on, one of the transistors will start conducting more than the other.

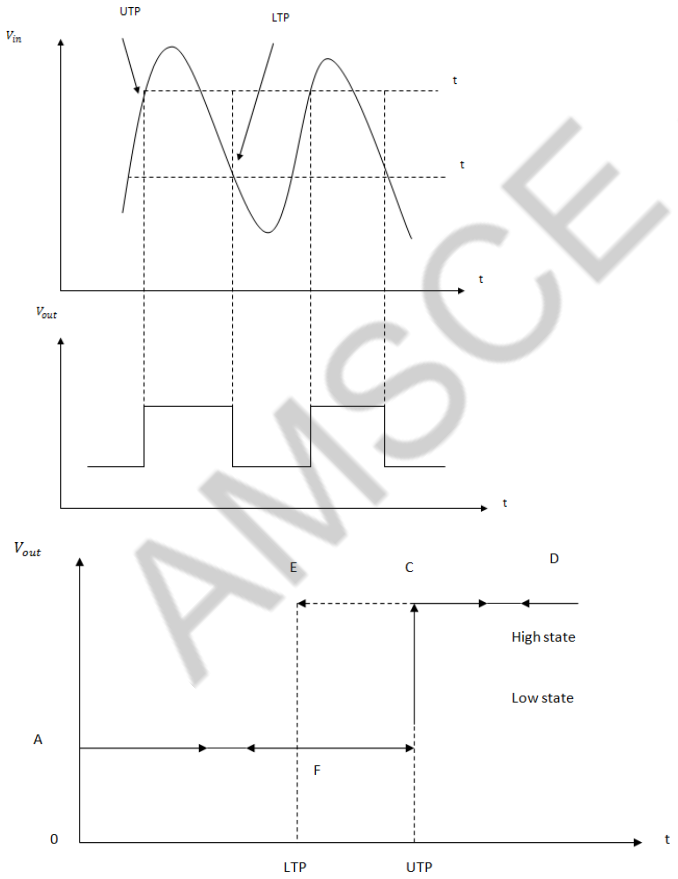
Let us assume that transistor Q1 is ON and Q2 is off. It is a stable state of the circuit and will remain in this state till a trigger pulse is applied from outside. A positive triggering pulse applied to the reset input (base of Q_2) increases its forward bias, thereby turning transistor Q_2 ON and an increase in collector current and a decrease in collector voltage. It is coupled to the base of Q_1, therefore Q_1 is off. The circuit is then in its second stable state and remains so till a positive trigger pulse is applied to set input.

A similar action can be achieved by applying a negative pulse at the set input for transition from the first stable state to the second stable state to the second stable state and by applying a negative pulse at the reset input, reverse transition can be obtained.

Applications

1. It is used as memory elements in shift registers, counters, and so on.
2. It is used as frequency divider.

17) Explain the transfer characteristics of Schmitt trigger with circuit diagram.[MAY/JUNE 2014][NOV/DEC 2013]



Schmitt trigger is a wave shaping circuit, used for generation of a square wave from a since wave input.

It consists of two identical transistors Q_1 and Q_2 coupled through an emitter register R_E. Resistor R_1 and R_2 provides a small forward bias to the base-emitter junction of transistor Q_2.

When the supply is switched ON, with no input signal, transistor Q_2 starts conducting. The rise in current (I_E) of Q_2 causes a voltage drop across R_E (i.e.) $V_{RE} = I_E R_E$. This voltage provides a reverse bias across the emitter-base junction of Q_1 and it is driven into cutoff state.

Since Q_1 is in the OFF state, the voltage at its collector rises to V_c. Since the collector of Q_1 is coupled to the base of Q_2 through the resistor R_1, the forward bias for the driven into saturation. At this instant the collector voltage levels are $V_{C1} = V_{cc}$ and $V_{C2} = V_{C(sat)} + V_{RE}$

Consider an a.c signal of sinusoidal or triangular variation applied to the base of Q_1. When the voltage increases above zero, nothing will happen till it crosses the upper trigger level (UTL). As the input voltage increases above UTL. (i.e.) $V_{in} \leq V_{RE} + V_{BE1}$, Q_1 conducts. The point at which Q_1 starts conducting is known as upper trigger point (UTP). As transistor Q_1 conducts, its collector voltage falls below V_c. Since the collector of Q_1 is coupled to the base of Q_2, the forward bias to Q_2 is reduced. This in turn reduces the current of transistor Q_2 and hence the voltage drop across R_E. As a result, the reverse bias of transistor Q_1 is reduced and it conducts more which drives Q_2 to nearer to cutoff. This process continues till Q_1 is driven into saturation and Q_2 is cutoff. At this instant $V_{c1} = V_{C(sat)} + V_{RE}$ and $V_{c2} = V_c$.

The transistor Q_1 continued to conduct till the input voltage crosses the lower trigger level (LTL). When the input voltage becomes equal to LTL, the emitter base junction of Q_1 becomes reverse biases. (i.e.) $V_{in} < V_{RE} + V_{BE1}$. Hence its collector voltage starts rising towards V_c. This forward biases Q_2 and it starts conducting. The point at which Q_2 starts conducting is called lower trigger point (LTP).

Then Q_2 is driver into saturation and Q_1 is cutoff. At this instant $V_{c1} = V_{cc}$ and $V_{c2} = V_{CE\ (sat)} + V_R$. No change in state will occur during the negative half cycle of the input voltage.

The difference between UTP and LTP is known as Hysteresis Voltage (V). V_H is also known as Dead Zone of the submit trigger. The logging of the lower threshold voltage from the upper threshold voltage is known as the Hysteresis.

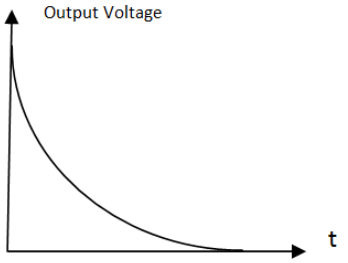
Applications

1. Schmitt trigger is used for wave shaping circuits.
2. It can be used for generation of a rectangular waveforms with sharp edges form a sine wave or any other waveform.
3. It can be used as voltage comparator

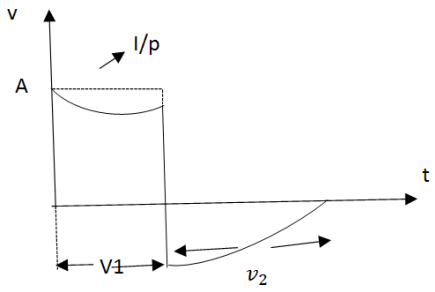
PART C

18. Explain the Output waveforms of Various Inputs of RC and RL Circuits

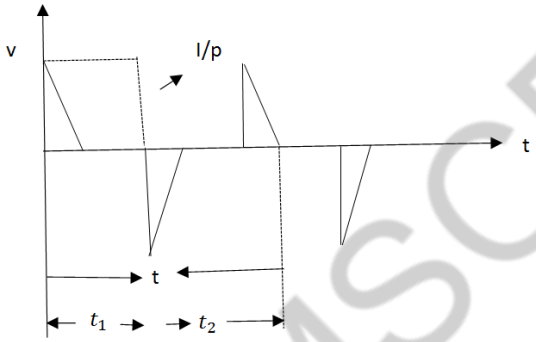
1) Step response of high pass RC



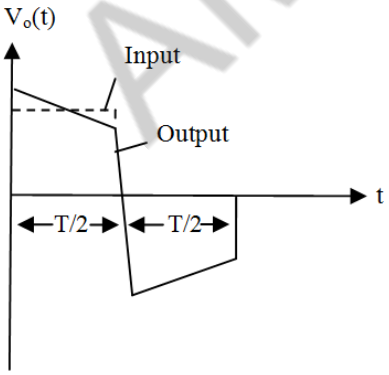
2) Pulse response of high pass RC



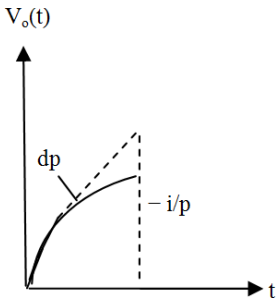
3) Square wave response of high pass RC Circuit



4) Symmetric square wave response of high pass RC

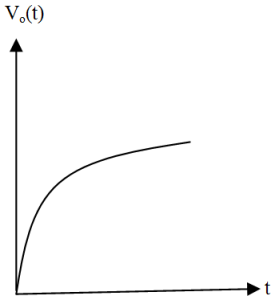


5) Ramp response of high pass RC

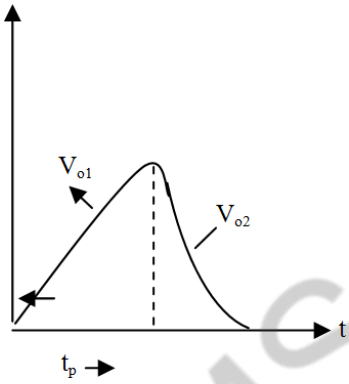


Low Pass RC

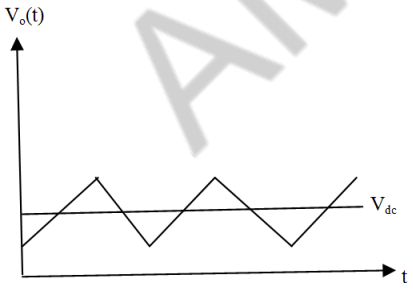
1) Step response of low pass RC



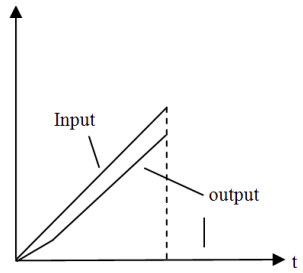
2) Pulse response of low pass RC



3) Square response of low pass RC

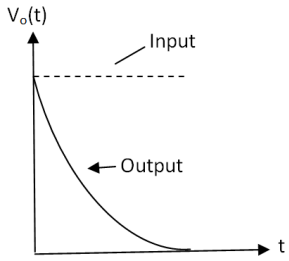


4) Ramp response of low pass RC

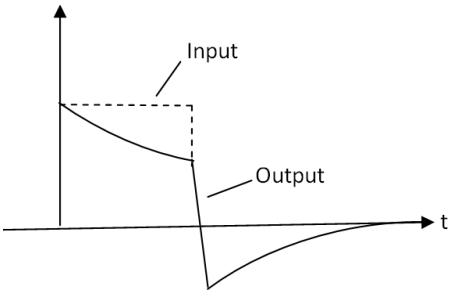


High Pass RL

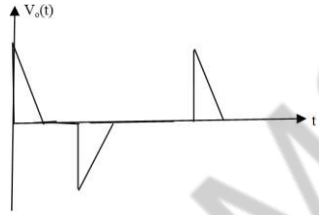
1) Step response of high pass RL



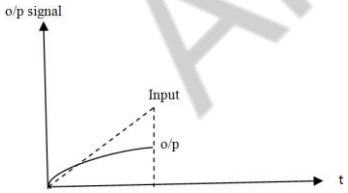
2) Pulse response



3) Square

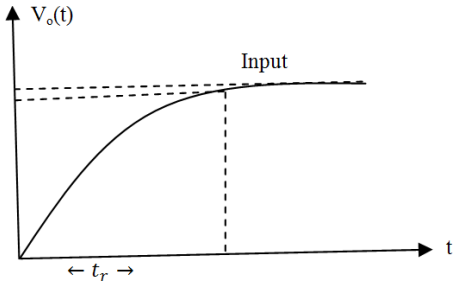


4) Ramp response

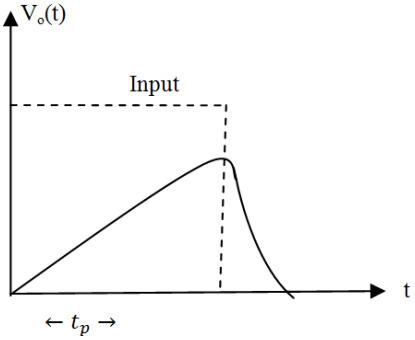


Low Pass RL

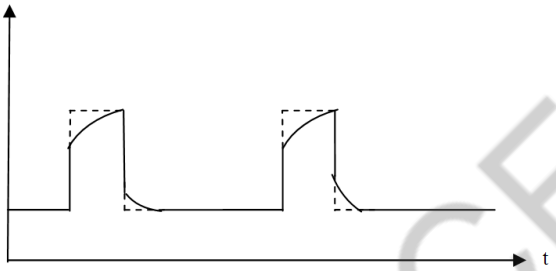
1) Step response



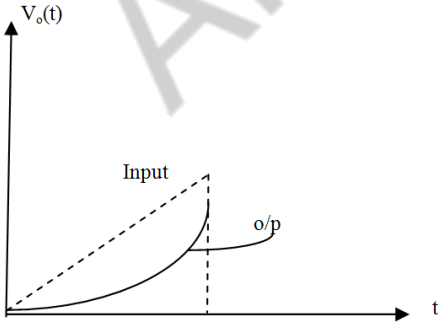
2) Pulse response



3) Square wave response



4) Ramp response of low pass RL

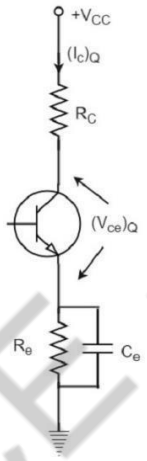


Unit 5
POWER AMPLIFIERS AND DC CONVERTERS

PART B

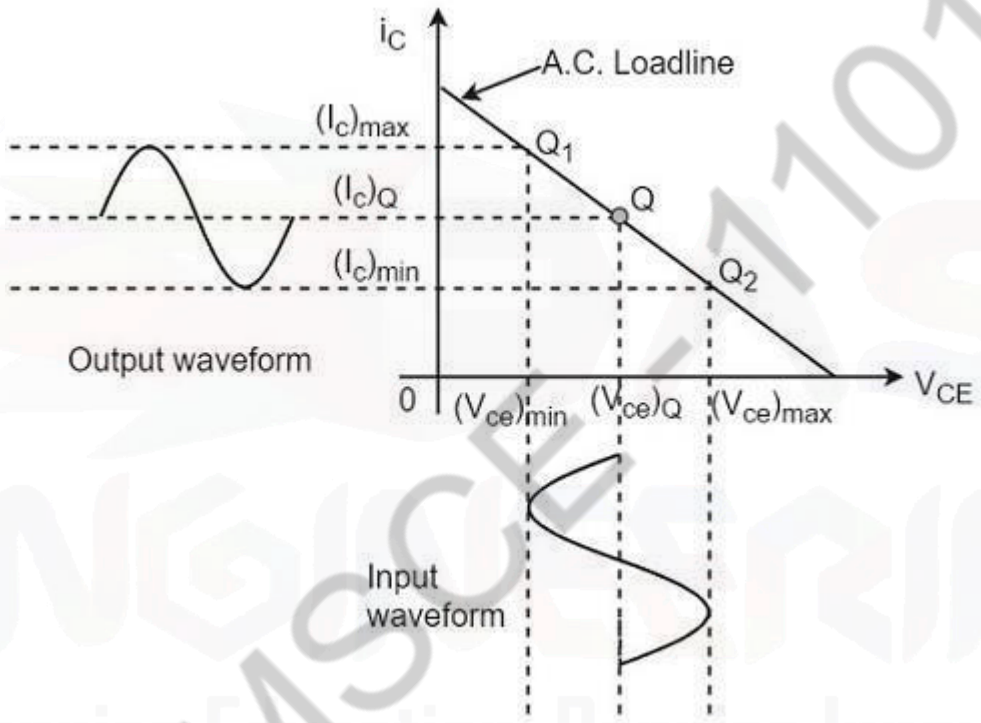
1.Explain Class A Power Amplifier in detail.(APR/MAY 2019)

A Class A power amplifier is one in which the output current flows for the entire cycle of the AC input supply. Hence the complete signal present at the input is amplified at the output. The following figure shows the circuit diagram for Class A Power amplifier.



From the above figure, it can be observed that the transformer is present at the collector as a load. The use of transformer permits the impedance matching, resulting in the transference of maximum power to the load e.g. loud speaker.

The operating point of this amplifier is present in the linear region. It is so selected that the current flows for the entire ac input cycle. The below figure explains the selection of operating point.



The output characteristics with operating point Q is shown in the figure above. Here $(I_c)_Q$ and $(V_{ce})_Q$ represent no signal collector current and voltage between collector and emitter respectively. When signal is applied, the Q-point shifts to Q_1 and Q_2. The output current increases to $(I_c)_{max}$ and decreases to $(I_c)_{min}$. Similarly, the collector-emitter voltage increases to $(V_{ce})_{max}$ and decreases to $(V_{ce})_{min}$.

Power drawn from collector battery V_{cc} is given by

Pin=voltage×current=VCC(IC)QPin=voltage×current=VCC(IC)Q

This power is used in the following two parts −

Power dissipated in the collector load as heat is given by

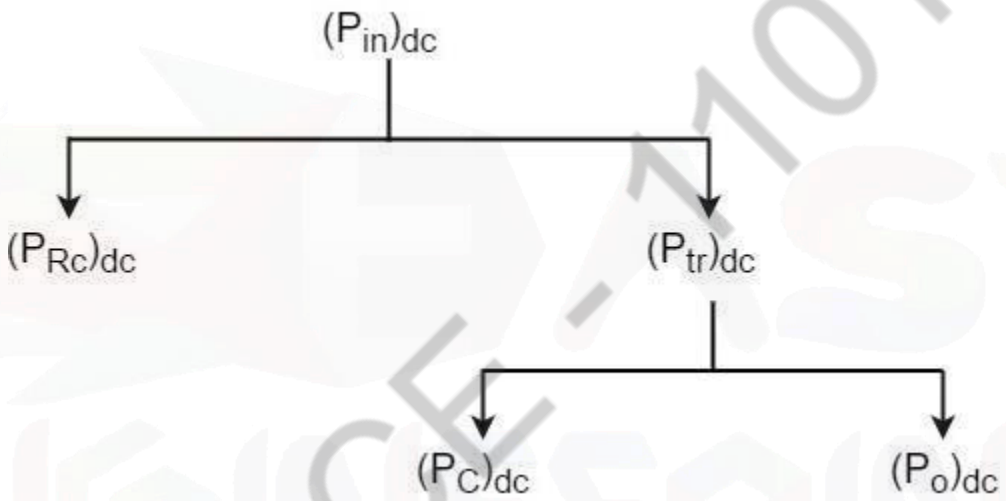
$$PRC=(current)2\times resistance=(IC)2QRC$$

Power given to transistor is given by

$$Ptr=Pin-PRC=VCC-(IC)2QRCPtr=Pin-PRC=VCC-(IC)Q2RC$$

When signal is applied, the power given to transistor is used in the following two parts −

The D.C. power dissipated by the transistor (collector region) in the form of heat, i.e., $(P_C)_{dc}$



This class A power amplifier can amplify small signals with least distortion and the output will be an exact replica of the input with increased strength.

Overall Efficiency

The overall efficiency of the amplifier circuit is given by

$$(\eta)overall=a.cpowerdeliveredtotheloadtotalpowerdeliveredbyd.csupply(\eta)overall=a.cpowerdeliveredtotheloadtotalpowerdeliveredbyd.csupply$$

$$=(PO)ac(Pin)dc=(PO)ac(Pin)dc$$

Collector Efficiency

The collector efficiency of the transistor is defined as

$$(\eta)collector=averagea.cpoweroutputaveraged.cpowerinputtotransistor(\eta)collector=averagea.cpoweroutputaveraged.cpowerinputtotransistor$$

$$=(PO)ac(Ptr)dc$$

Expression for overall efficiency

$$(PO)ac=Vrms\times Irms(PO)ac=Vrms\times Irms$$

$$=12-\sqrt{[(Vce)max-(Vce)min2]}\times 12-\sqrt{[(IC)max-(IC)min2]}=12[(Vce)max-(Vce)min2]\times 12[(IC)max-(IC)min2]$$

$$=[(Vce)max-(Vce)min]\times[(IC)max-(IC)min]8=[(Vce)max-(Vce)min]\times[(IC)max-(IC)min]8$$

Therefore

$$(\eta)overall=[(Vce)max-(Vce)min]\times[(IC)max-(IC)min]8\times VCC(IC)Q(\eta)overall=[(Vce)max-(Vce)min]\times[(IC)max-(IC)min]8\times VCC(IC)Q$$

Advantages of Class A Amplifiers

The advantages of Class A power amplifier are as follows −

- The current flows for complete input cycle
- It can amplify small signals
- The output is same as input
- No distortion is present

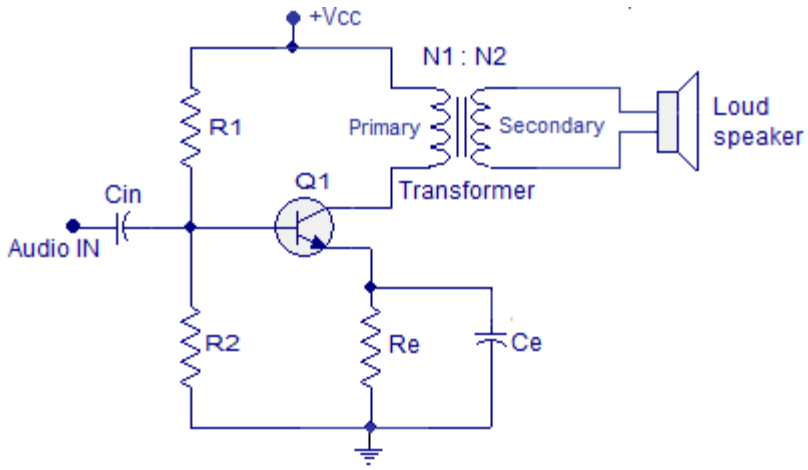
Disadvantages of Class A Amplifiers

The advantages of Class A power amplifier are as follows −

- Low power output
- Low collector efficiency

2. Explain Transformer coupled Class A

An amplifier where the load is coupled to the output using a transformer is called a transformer coupled amplifier. Using transformer coupling the efficiency of the amplifier can be improved to a great extend. The coupling transformer provides good impedance matching between the output and load and it is the main reason behind the improved efficiency. Impedance matching means making the output impedance of the amplifier equal to the input impedance of the load and this is an important criteria for the transfer of maximum power. Circuit diagram of typical single stage Class A amplifier is shown in the circuit diagram below.



Tranformer coupled Class A amplifier www.circuitstoday.com

Impedance matching can be attained by selecting the number of turns of the primary so that its net impedance is equal to the transistors output impedance and selecting the number of turns of the secondary so that its net impedance is equal to the loudspeakers input impedance.

Advantages of transformer coupled amplifier.

- Main advantage is the improvement of efficiency.
- Provides good DC isolation as there is no physical connection between amplifier output and load. Audio signals pass from one side to other by virtue of induction.

Disadvantages of transformer coupled amplifier.

- It is a bit hard to make/find an exactly matching transformer.
- Transformers are bulky and so it increases the cost and size of the amplifier.
- Transformer winding does not provide any resistance to DC current. If any DC components if present in the amplifier output, it will flow through the primary winding and saturate the core. This will result in reduced transformer action.
- Transformer coupling reduces the low frequency response of the amplifier.
- Transformer coupling induces hum in the output.
- Transformer coupling can be employed only for small loads.

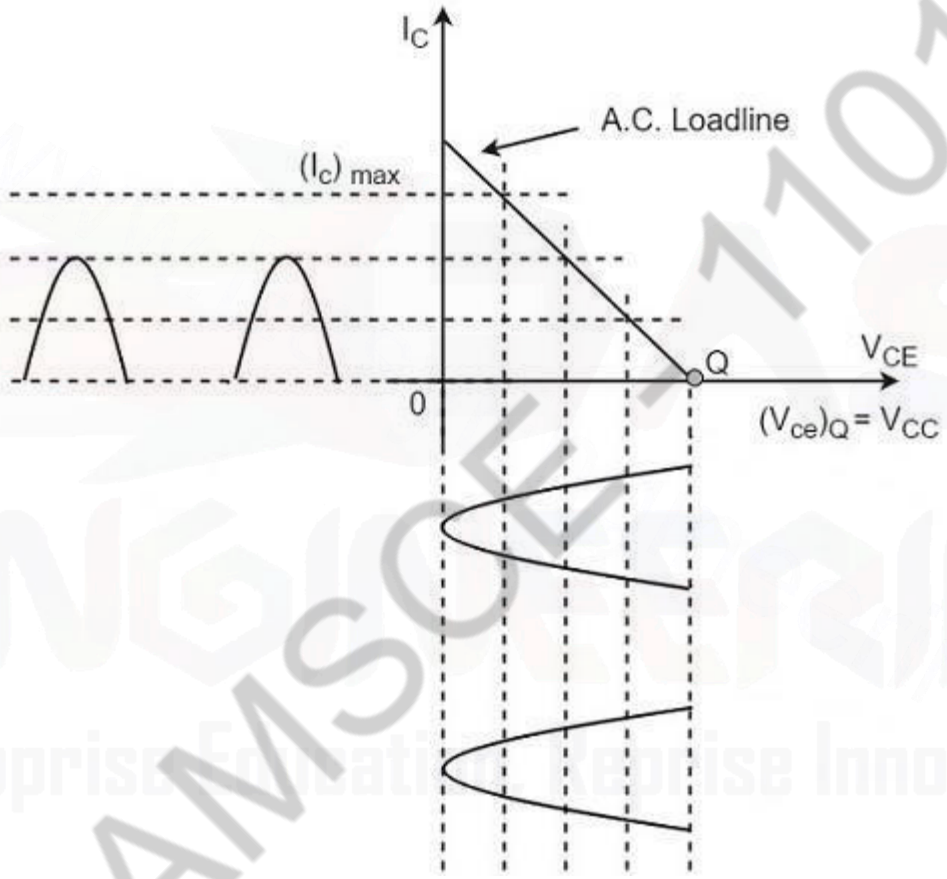
3.Explain Class B Power Amplifier in detail.(APR/MAY 2019)

When the collector current flows only during the positive half cycle of the input signal, the power amplifier is known as **class B power amplifier**.

Class B Operation

The biasing of the transistor in class B operation is in such a way that at zero signal condition, there will be no collector current. The **operating point** is selected to be at collector cut off voltage. So, when the signal is applied, **only the positive half cycle** is amplified at the output.

The figure below shows the input and output waveforms during class B operation.



When the signal is applied, the circuit is forward biased for the positive half cycle of the input and hence the collector current flows. But during the negative half cycle of the input, the circuit is reverse biased and the collector current will be absent. Hence **only the positive half cycle** is amplified at the output.

As the negative half cycle is completely absent, the signal distortion will be high. Also, when the applied signal increases, the power dissipation will be more. But when compared to class A power amplifier, the output efficiency is increased.

Well, in order to minimize the disadvantages and achieve low distortion, high efficiency and high output power, the push-pull configuration is used in this class B amplifier.

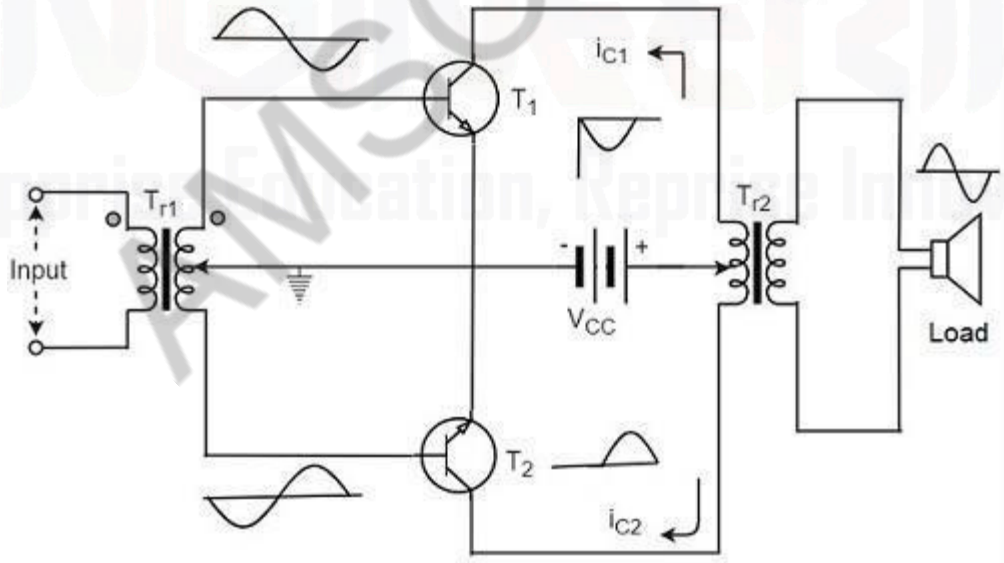
4.Explain the operation of Class B Push-Pull Amplifier in detail

Though the efficiency of class B power amplifier is higher than class A, as only one half cycle of the input is used, the distortion is high. Also, the input power is not completely utilized. In order to compensate these problems, the push-pull configuration is introduced in class B amplifier.

Construction

The circuit of a push-pull class B power amplifier consists of two identical transistors T_1 and T_2 whose bases are connected to the secondary of the center-tapped input transformer T_{r1}. The emitters are shorted and the collectors are given the V_{CC} supply through the primary of the output transformer T_{r2}.

The circuit arrangement of class B push-pull amplifier, is same as that of class A push-pull amplifier except that the transistors are biased at cut off, instead of using the biasing resistors. The figure below gives the detailing of the construction of a push-pull class B power amplifier.

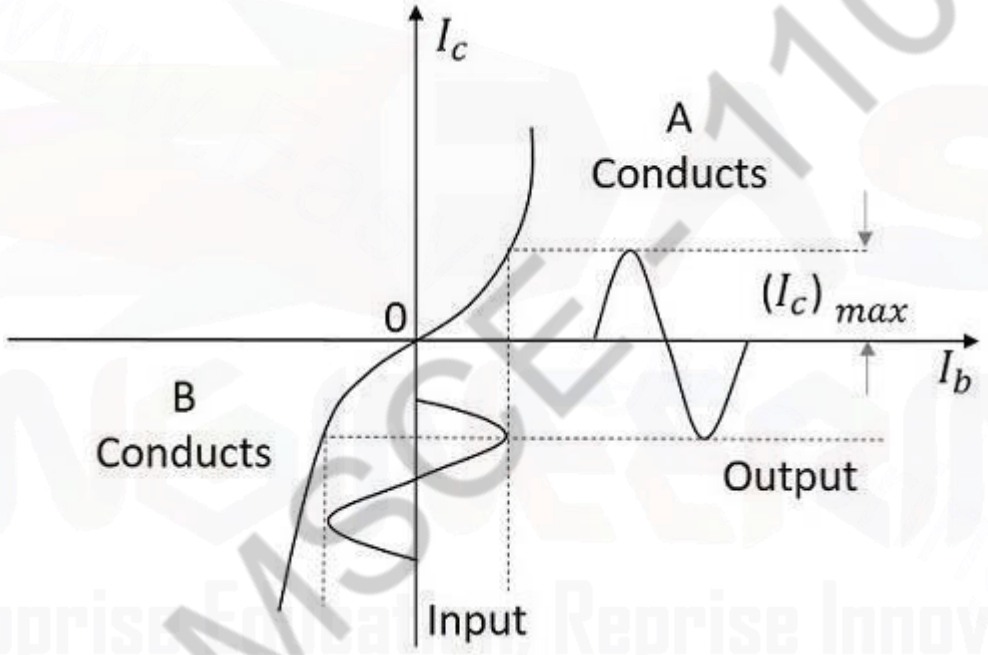


Operation

The circuit of class B push-pull amplifier shown in the above figure clears that both the transformers are center-tapped. When no signal is applied at the input, the transistors T_1 and

T_2 are in cut off condition and hence no collector currents flow. As no current is drawn from V_{CC}, no power is wasted.

When input signal is given, it is applied to the input transformer T_{r1} which splits the signal into two signals that are 180^o out of phase with each other. These two signals are given to the two identical transistors T_1 and T_2. For the positive half cycle, the base of the transistor T_1 becomes positive and collector current flows. At the same time, the transistor T_2 has negative half cycle, which throws the transistor T_2 into cutoff condition and hence no collector current flows. The waveform is produced as shown in the following figure.



For the next half cycle, the transistor T_1 gets into cut off condition and the transistor T_2 gets into conduction, to contribute the output. Hence for both the cycles, each transistor conducts alternately. The output transformer T_{r3} serves to join the two currents producing an almost undistorted output waveform.

Power Efficiency of Class B Push-Pull Amplifier

The current in each transistor is the average value of half sine loop.

For half sine loop, I_{dc} is given by

$$Idc=(IC)max\pi Idc=(IC)max\pi$$

Therefore,

$$(pin)dc=2\times[(IC)max\pi\times VCC](pin)dc=2\times[(IC)max\pi\times VCC]$$

Here factor 2 is introduced as there are two transistors in push-pull amplifier.

R.M.S. value of collector current = $(IC)max/2–\sqrt{}(IC)max/2$
R.M.S. value of output voltage = $VCC/2–\sqrt{}VCC/2$
Under ideal conditions of maximum power

Therefore,

$$(PO)ac=(IC)max2–\sqrt{}\times VCC2–\sqrt{}=(IC)max\times VCC2(PO)ac=(IC)max2\times VCC2=(IC)max\times VCC2$$

Now overall maximum efficiency

$$\eta overall=(PO)ac(Pin)dc\eta overall=(PO)ac(Pin)dc$$

$$=(IC)max\times VCC2\times\pi2(IC)max\times VCC=(IC)max\times VCC2\times\pi2(IC)max\times VCC$$

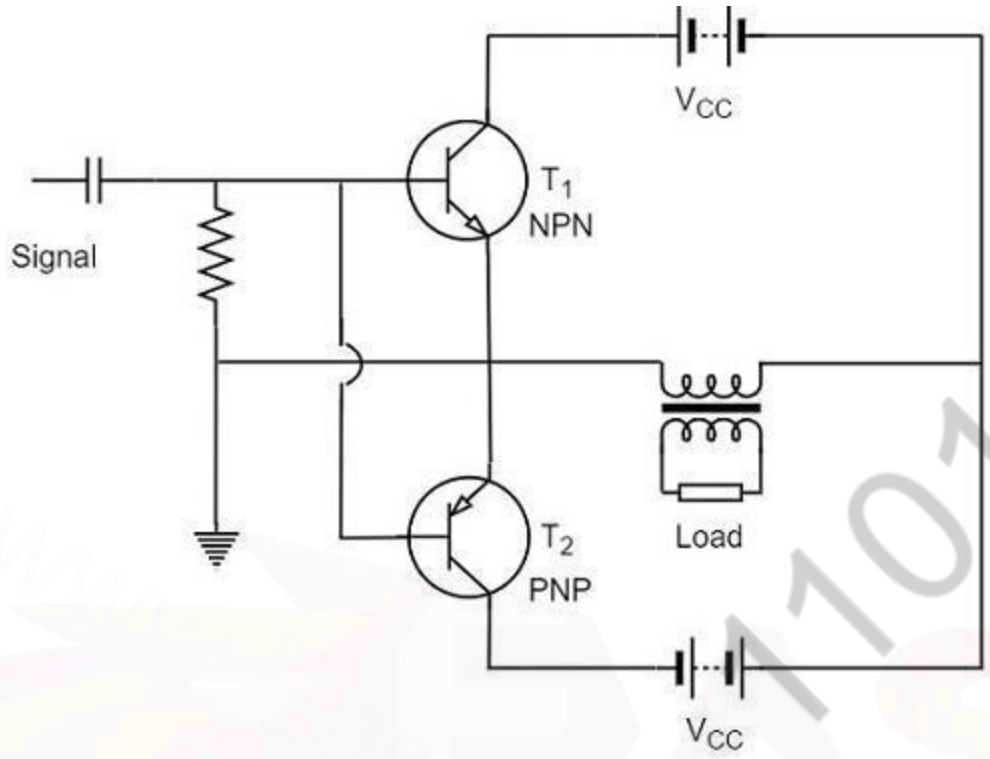
$$=\pi4=0.785=78.5\%=\pi4=0.785=78.5\%$$

The collector efficiency would be the same.

Hence the class B push-pull amplifier improves the efficiency than the class A push-pull amplifier.

5.<u>Explain the operation of</u> <u>Complementary Symmetry Push-Pull Class B Amplifier</u>

The push pull amplifier which was just discussed improves efficiency but the usage of center-tapped transformers makes the circuit bulky, heavy and costly. To make the circuit simple and to improve the efficiency, the transistors used can be complemented, as shown in the following circuit diagram.



The above circuit employs a NPN transistor and a PNP transistor connected in push pull configuration. When the input signal is applied, during the positive half cycle of the input signal, the NPN transistor conducts and the PNP transistor cuts off. During the negative half cycle, the NPN transistor cuts off and the PNP transistor conducts.

In this way, the NPN transistor amplifies during positive half cycle of the input, while PNP transistor amplifies during negative half cycle of the input. As the transistors are both complement to each other, yet act symmetrically while being connected in push pull configuration of class B, this circuit is termed as

Complementary symmetry push pull class B amplifier.

Advantages

The advantages of Complementary symmetry push pull class B amplifier are as follows.

- As there is no need of center tapped transformers, the weight and cost are reduced.
- Equal and opposite input signal voltages are not required.

Disadvantages

The disadvantages of Complementary symmetry push pull class B amplifier are as follows.

- It is difficult to get a pair of transistors (NPN and PNP) that have similar characteristics.
- We require both positive and negative supply voltages.

6. Explain the operation of Class AB and Class C Power Amplifiers

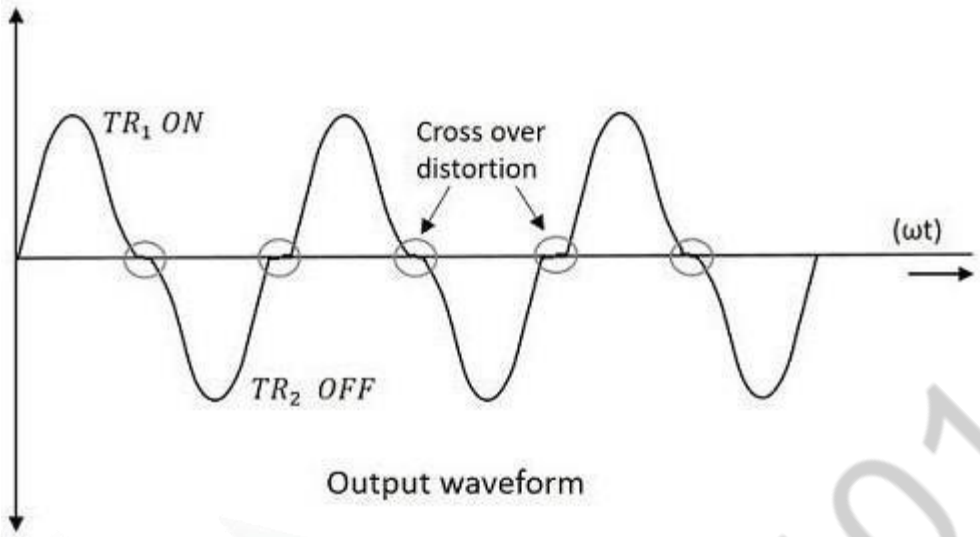
The class A and class B amplifier so far discussed has got few limitations. Let us now try to combine these two to get a new circuit which would have all the advantages of both class A and class B amplifier without their inefficiencies. Before that, let us also go through another important problem, called as **Cross over distortion**, the output of class B encounters with.

Cross-over Distortion

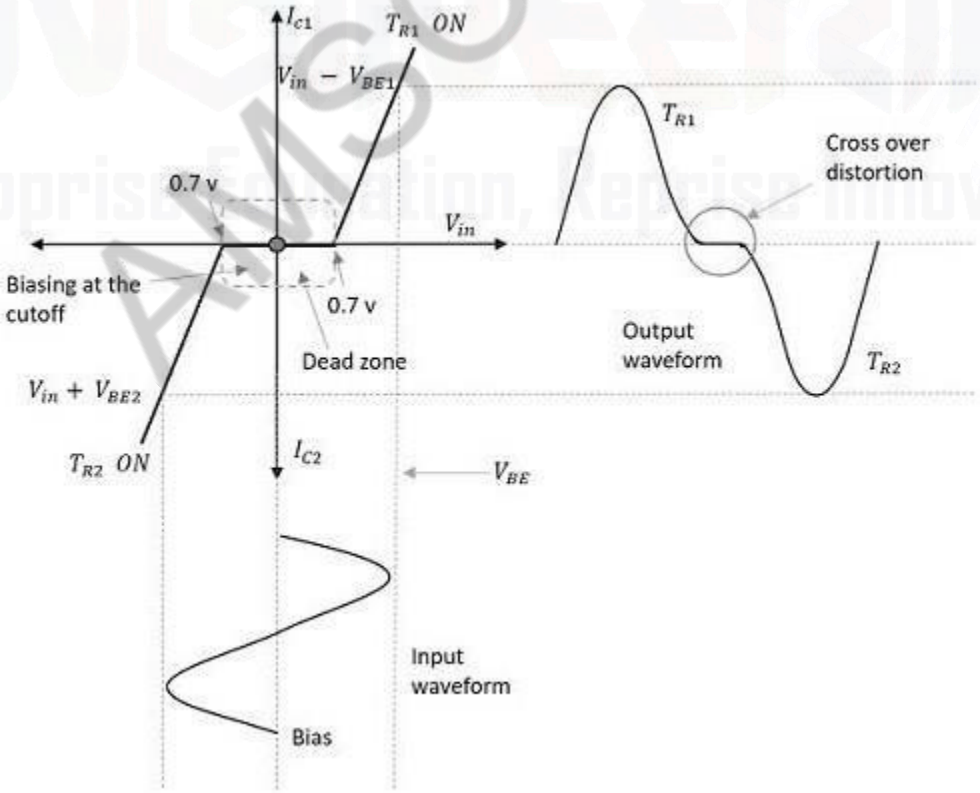
In the push-pull configuration, the two identical transistors get into conduction, one after the other and the output produced will be the combination of both.

When the signal changes or crosses over from one transistor to the other at the zero voltage point, it produces an amount of distortion to the output wave shape. For a transistor in order to conduct, the base emitter junction should cross 0.7v, the cut off voltage. The time taken for a transistor to get ON from OFF or to get OFF from ON state is called the **transition period**.

At the zero voltage point, the transition period of switching over the transistors from one to the other, has its effect which leads to the instances where both the transistors are OFF at a time. Such instances can be called as **Flat spot** or **Dead band** on the output wave shape.



The above figure clearly shows the cross over distortion which is prominent in the output waveform. This is the main disadvantage. This cross over distortion effect also reduces the overall peak to peak value of the output waveform which in turn reduces the maximum power output. This can be more clearly understood through the non-linear characteristic of the waveformas shown below.



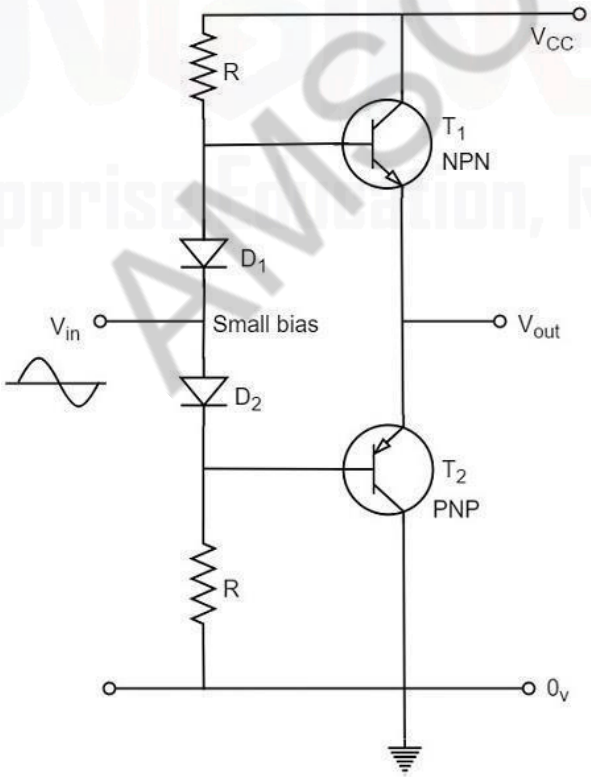
It is understood that this cross-over distortion is less pronounced for large input signals, where as it causes severe disturbance for small input signals. This cross over distortion can be eliminated if the conduction of the amplifier is more than one half cycle, so that both the transistors won't be OFF at the same time.

This idea leads to the invention of class AB amplifier, which is the combination of both class A and class B amplifiers, as discussed below.

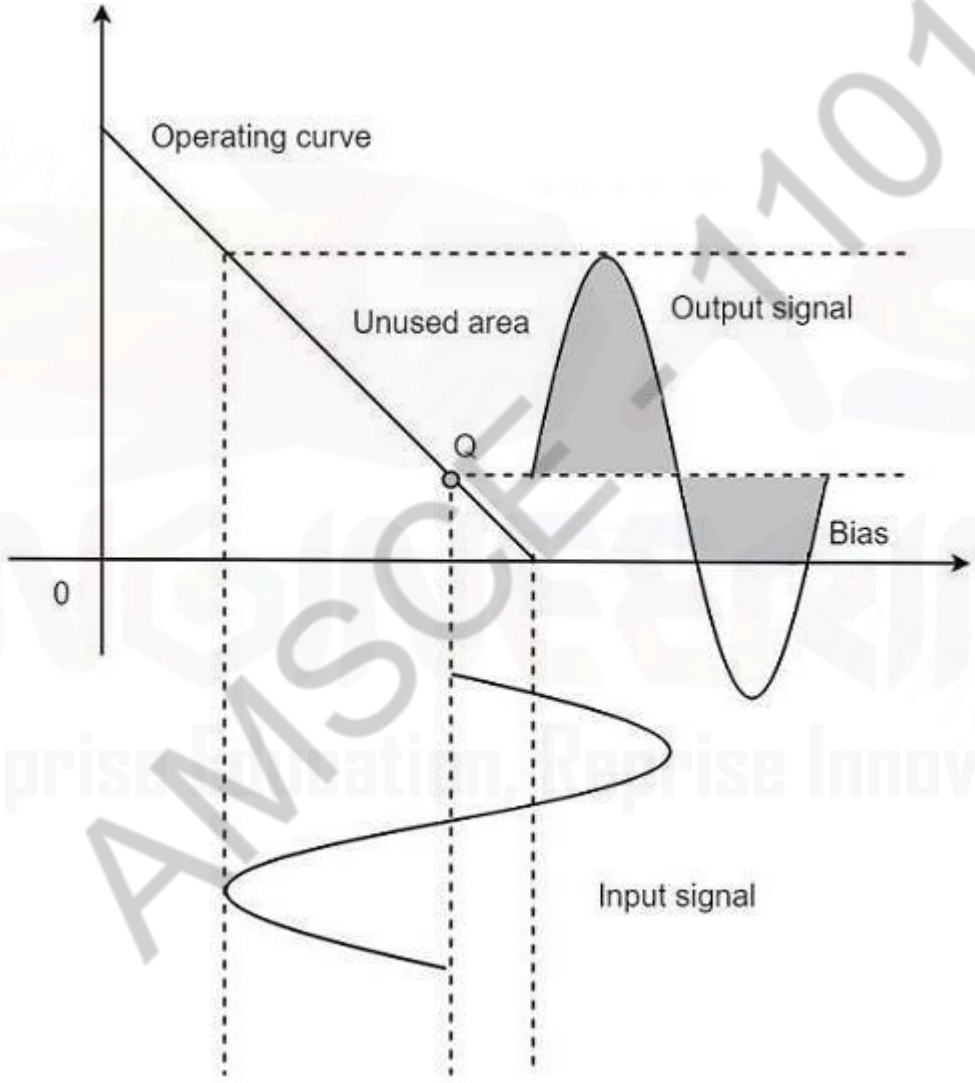
Class AB Power Amplifier

As the name implies, class AB is a combination of class A and class B type of amplifiers. As class A has the problem of low efficiency and class B has distortion problem, this class AB is emerged to eliminate these two problems, by utilizing the advantages of both the classes.

The cross over distortion is the problem that occurs when both the transistors are OFF at the same instant, during the transition period. In order to eliminate this, the condition has to be chosen for more than one half cycle. Hence, the other transistor gets into conduction, before the operating transistor switches to cut off state. This is achieved only by using class AB configuration, as shown in the following circuit diagram.



Therefore, in class AB amplifier design, each of the push-pull transistors is conducting for slightly more than the half cycle of conduction in class B, but much less than the full cycle of conduction of class A. The conduction angle of class AB amplifier is somewhere between 180^o to 360^o depending upon the operating point selected. This is understood with the help of below figure.



The small bias voltage given using diodes D_1 and D_2, as shown in the above figure, helps the operating point to be above the cutoff point. Hence the output waveform of class AB results as seen in the above figure. The crossover distortion created by class B is overcome by this class AB, as well the inefficiencies of class A and B don't affect the circuit.

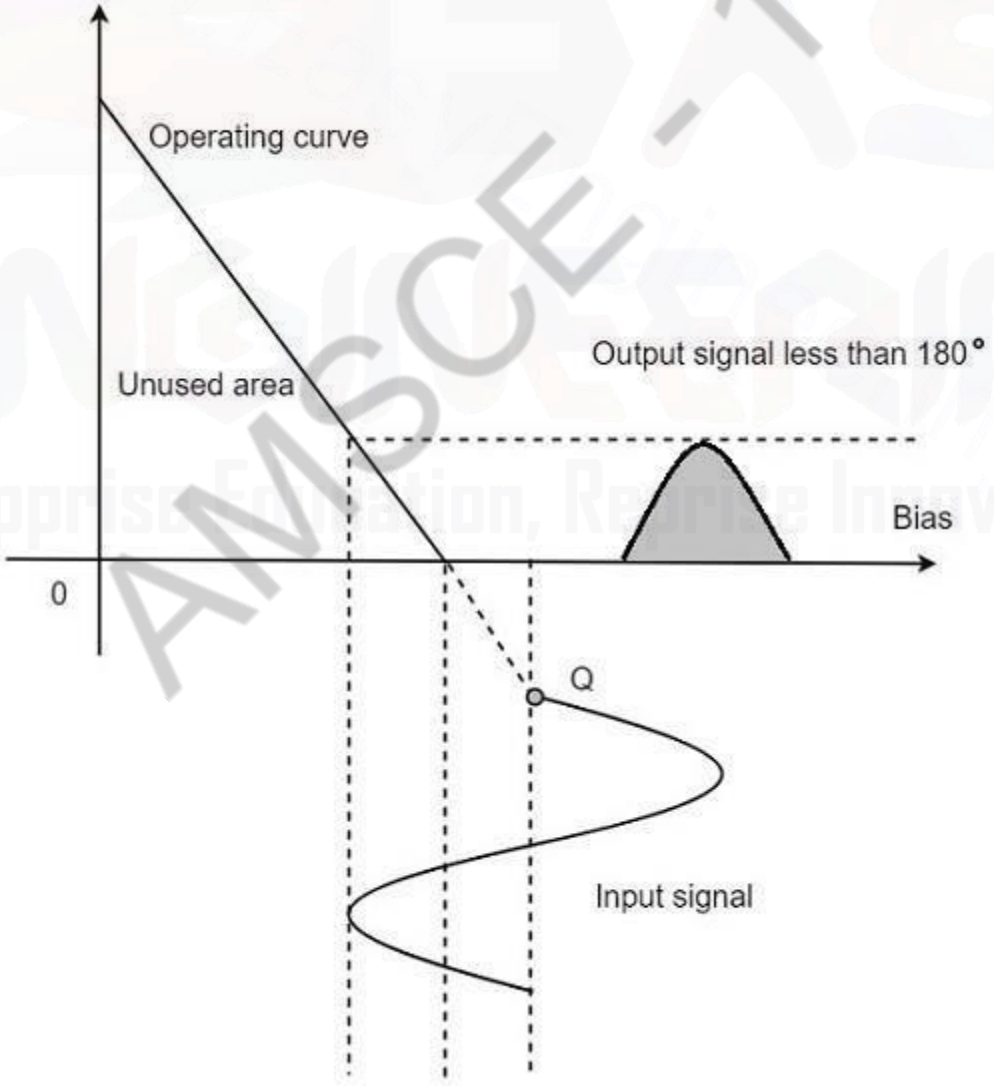
So, the class AB is a good compromise between class A and class B in terms of efficiency and linearity having the efficiency reaching about 50% to 60%. The class A, B and AB amplifiers are called as **linear amplifiers** because the output signal amplitude and phase are linearly related to the input signal amplitude and phase.

Class C Power Amplifier

When the collector current flows for less than half cycle of the input signal, the power amplifier is known as **class C power amplifier**.

The efficiency of class C amplifier is high while linearity is poor. The conduction angle for class C is less than 180^o. It is generally around 90^o, which means the transistor remains idle for more than half of the input signal. So, the output current will be delivered for less time compared to the application of input signal.

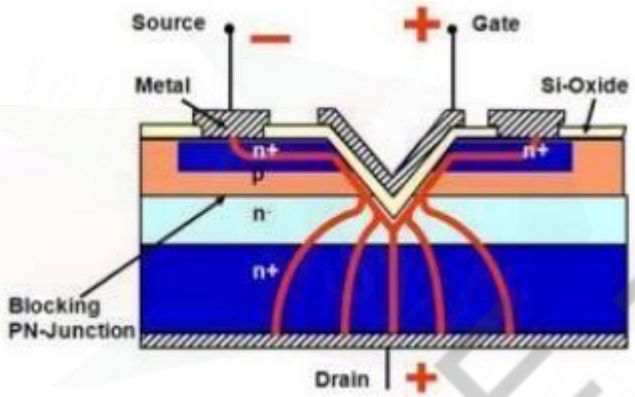
The following figure shows the operating point and output of a class C amplifier.



This kind of biasing gives a much improved efficiency of around 80% to the amplifier, but introduces heavy distortion in the output signal. Using the class C amplifier, the pulses produced at its output can be converted to complete sine wave of a particular frequency by using LC circuits in its collector circuit.

7. Explain the operation of Power MOSFET

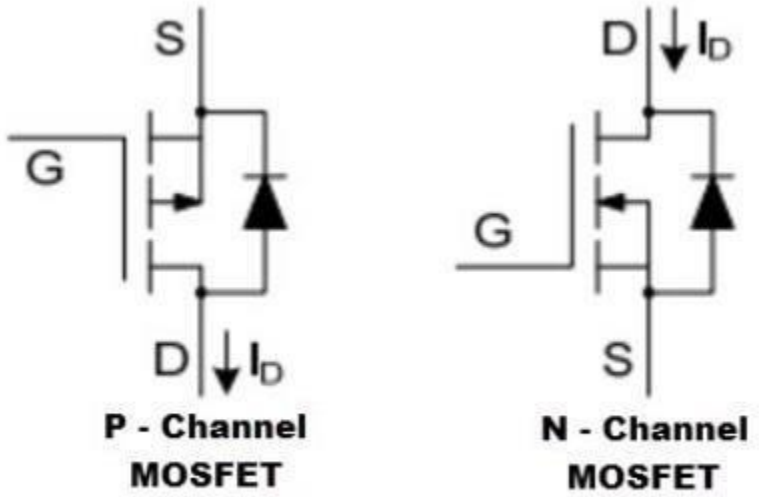
Working Principle and Applications



Power MOSFET

The Power MOSFET is a type of MOSFET. The operating principle of power MOSFET is similar to the general MOSFET. The power MOSFETS are very special to handle the high level of powers. It shows the high switching speed and by comparing with the normal MOSFET, the power MOSFET will work better. The power MOSFETs is widely used in the n-channel enhancement mode, p-channel enhancement mode, and in the nature of n-channel depletion mode. Here we have explained about the N-channel power MOSFET. The design of power MOSFET was made by using the CMOS technology and also used for development of manufacturing the integrated circuits in the 1970s.

A power MOSFET is a special type of metal oxide semiconductor field effect transistor. It is specially designed to handle high-level powers. The power MOSFET's are constructed in a V configuration. Therefore, it is also called as V-MOSFET, VFET. The symbols of N- channel & P- channel power MOSFET are shown in the below figure.



Power MOSFET

Basic Statures of Power MOSFET

There is three basic status in the power MOSFET which is following.

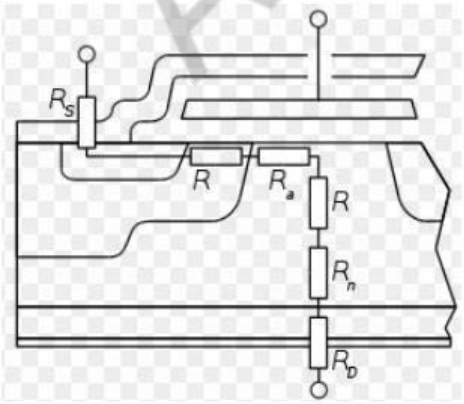
On sate resistance

Breakdown voltage

Body diode

On State Resistance

If the power MOSFET is in ON sate, then it produces the resistive behavior in-between the drain & source terminals. We can see in the following figure, that the resistance is the sum of many elementary contributions. The RS resistance is the source resistance. It will show all resistance between the source terminals of the package to the channel of the MOSFET.



On State Resistance

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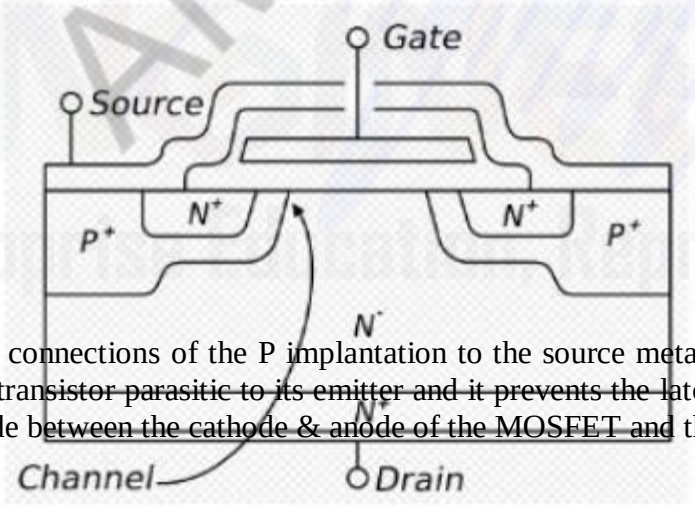
Body Diode

The body diode can be seen in the following figure that the source metallization is connected to both the N+ and P implantations. Even though the basic principle of the MOSFET requires only that the source should be connected to the N+ zone. Thus, this would result in a floating P zone between the N-doped source and drain. It is equivalent to an NPN transistor with a nonconnected base. Under some conditions like high drain current, in the order of the same volts of an on-state drain to source voltage, this parasitic transistor of NPN should be triggered and make the MOSFET uncontrollable.



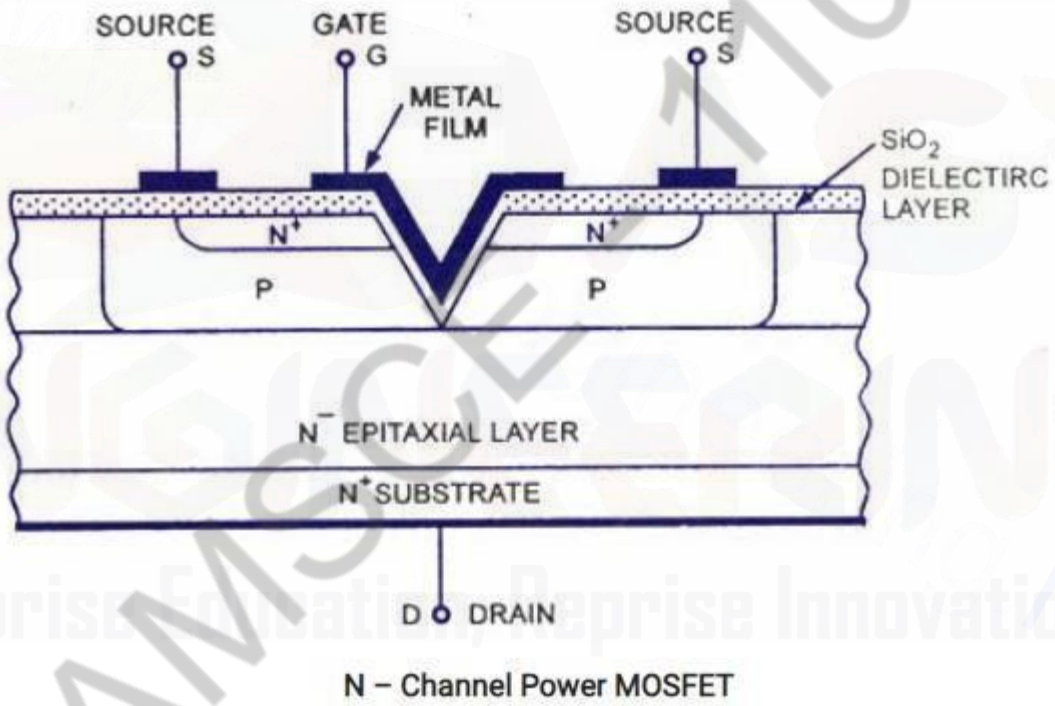
Body Diode

The connections of the P implantation to the source metallization short the base terminal of the transistor parasitic to its emitter and it prevents the latching. Hence this solution creates a diode between the cathode & anode of the MOSFET and the current blocks in one direction.

For inductive loads, the body diodes utilize the freewheeling diodes in the configuration of H Bridge & half bridge. Generally, these diodes will have a high forward voltage drop, the current is high. They are sufficient in many applications like reducing part count.

Working with Power MOSFET and Characteristics

The construction of the power MOSFET is in V-configurations, as we can see in the following figure. Thus the device is also called as the V-MOSFET or V-FET. The V- the shape of power MOSFET is cut to penetrate from the device surface is almost to the N+ substrate to the N+, P, and N – layers. The N+ layer is the heavily doped layer with a low resistive material and the N- layer is a lightly doped layer with the high resistance region.



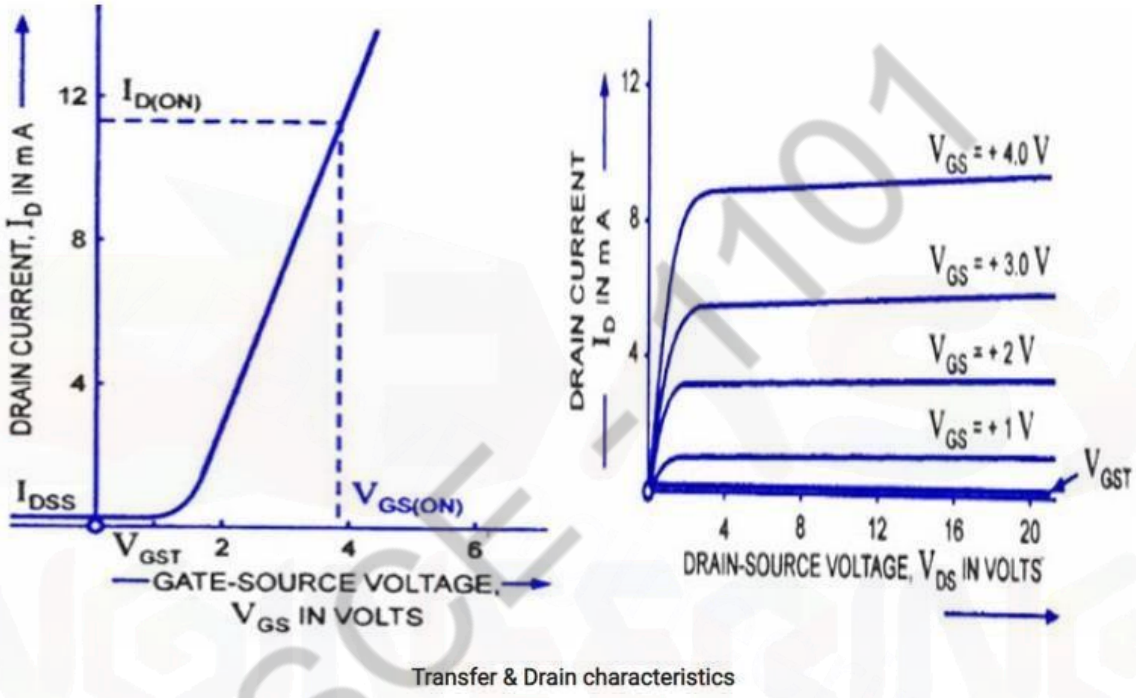
N – Channel Power MOSFET

Both the horizontal and the V cut surface are covered by the silicon dioxide dielectric layer and the insulated gate metal film is deposited on the SiO2 in the V shape. The source terminal contacts with the both N+ and P- layers through the SiO2 layer. The drain terminal of this device is N+.

The V-MOSFET is an E-mode FET and there is no exists of the channel in between the drain & source till the gate is positive with respect to the source. If we consider the gate is positive with respect to the source, then there is a formation of the N-type channel which is close to the gate and it is in the case of the E-MOSFET. In the case of E-MOSFET, the N-type channel provides the vertical path for the charge carriers. To flow between the drain and

source terminals. If the VGS is zero or negative, then there is no channel of presence and the drain current is zero.

The following figures show the drain & transfer characteristics for the enhancement mode of N-channel power MOSFET is similar to the E-MOSFET. If there is an increase in the gate voltage then the channel resistance is reduced, therefore the drain current ID is increased. Hence the drain current ID is controlled by the gate voltage control. So that for a given level of VGS, ID is remaining constant through a wide range of VDS levels.



Transfer & Drain characteristics

.

The channel length of the power MOSFET is in the diffusion process, but in the MOSFET the channel length is in the dimensions of the photographic masks employed in the diffusion process. By controlling the doping density and diffusion time, the channel length will become shorter. The shorter channels will give, the more current densities which will contribute again to larger power dissipation. It also allows a larger transconductance gm to be attained in the V-FET.

In the geometry of power MOSFET, there is an important factor which is the presence of lightly doped, N- epitaxial layer which is close to the N+ substrate. If the VGS is at zero or negative, then the drain is positive with respect to the source and there is a reverse biased between the P- layer & N- layer. At the junction the depletion region penetrates into the N- layer, therefore it punch-through the drain to the source are avoided. Hence, relatively high VDS are applied without any danger of device breakdown.

Applications of Power MOSFET

- The power MOSFET's are used in the power supplies
- DC to DC converters
- Low voltage motor controllers
- These are widely used in the low voltage switches which are less than the 200V

8 . Explain the operation of DC-to-DC converter(APR/MAY 2019)

Buck Converter

A **buck converter** (**step-down converter**) is a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).[1]

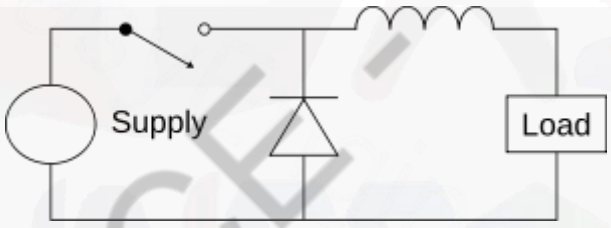
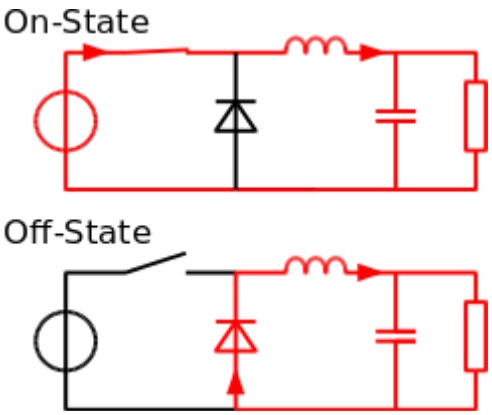


Fig. : Buck converter circuit diagram.

Switching converters (such as buck converters) provide much greater power efficiency as DC-to-DC converters than linear regulators, which are simpler circuits that lower voltages by dissipating power as heat, but do not step up output current.[2]

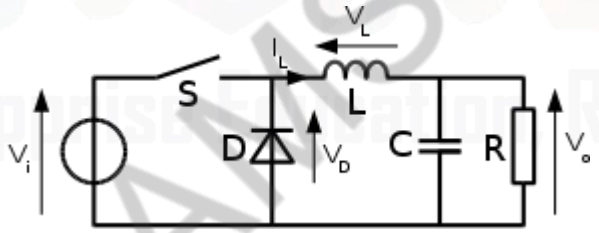
Buck converters can be highly efficient (often higher than 90%), making them useful for tasks such as converting a computer's main (bulk) supply voltage (often 12 V) down to lower voltages needed by USB, DRAM and the CPU (1.8 V or less).

The basic operation of the buck converter has the current in an inductorcontrolled by two switches (usually a transistor and a diode). In the idealised converter, all the components are considered to be perfect. Specifically, the switch and the diode have zero voltage drop when on and zero current flow when off, and the inductor has zero series resistance. Further, it is assumed that the input and output voltages do not change over the course of a cycle (this would imply the output capacitance as being infinite).



The conceptual model of the buck converter is best understood in terms of the relation between current and voltage of the inductor. Beginning with the switch open (off-state), the current in the circuit is zero. When the switch is first closed (on-state), the current will begin to increase, and the inductor will produce an opposing voltage across its terminals in response to the changing current. This voltage drop counteracts the voltage of the source and therefore reduces the net voltage across the load. Over time, the rate of change of current decreases, and the voltage across the inductor also then decreases, increasing the voltage at the load.

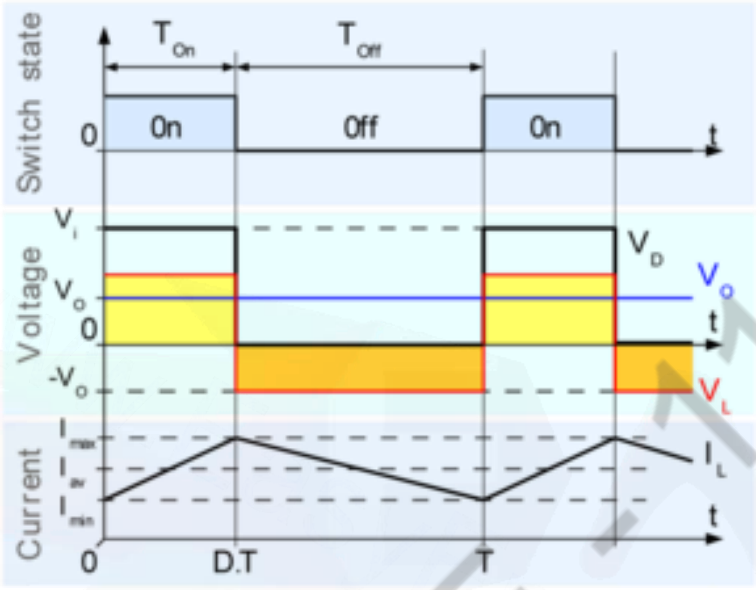
During this time, the inductor stores energy in the form of a magnetic field. If the switch is opened while the current is still changing, then there will always be a voltage drop across the inductor, so the net voltage at the load will always be less than the input voltage source. When the switch is opened again (off-state), the voltage source will be removed from the circuit, and the current will decrease.



The decreasing current will produce a voltage drop across the inductor (opposite to the drop at on-state), and now the inductor becomes a Current Source. The stored energy in the inductor's magnetic field supports the current flow through the load. This current, flowing while the input voltage source is disconnected, when concatenated with the current flowing during on-state, totals to current greater than the average input current (being zero during off-state).

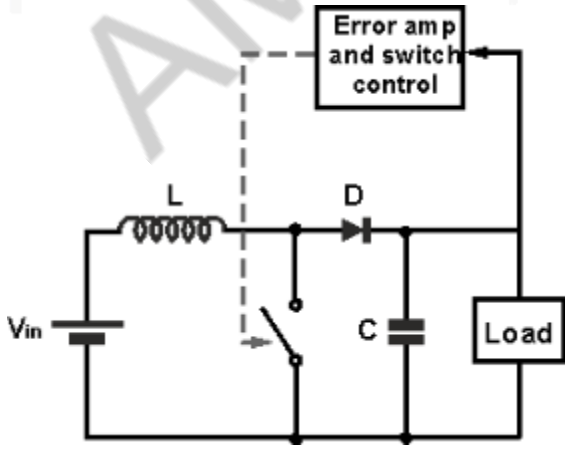
The "increase" in average current makes up for the reduction in voltage, and ideally preserves the power provided to the load. During the off-state, the inductor is discharging its

stored energy into the rest of the circuit. If the switch is closed again before the inductor fully discharges (on-state), the voltage at the load will always be greater than zero.



Boost Converter

The boost converter circuit has many similarities to the buck converter. However the circuit topology for the boost converter is slightly different. The fundamental circuit for a boost converter or step up converter consists of an inductor, diode, capacitor, switch and error amplifier with switch control circuitry.



The circuit for the step-up boost converter operates by varying the amount of time in which inductor receives energy from the source.

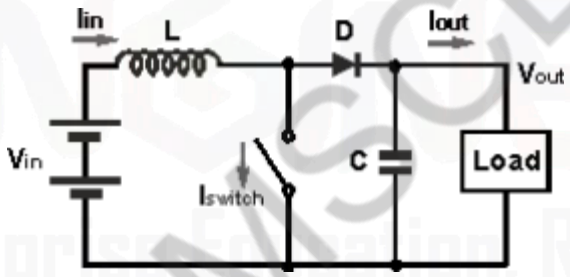
In the basic block diagram the operation of the boost converter can be seen that the output voltage appearing across the load is sensed by the sense / error amplifier and an error voltage is generated that controls the switch.

Typically the boost converter switch is controlled by a pulse width modulator, the switch remaining on of longer as more current is drawn by the load and the voltage tends to drop and often there is a fixed frequency oscillator to drive the switching.

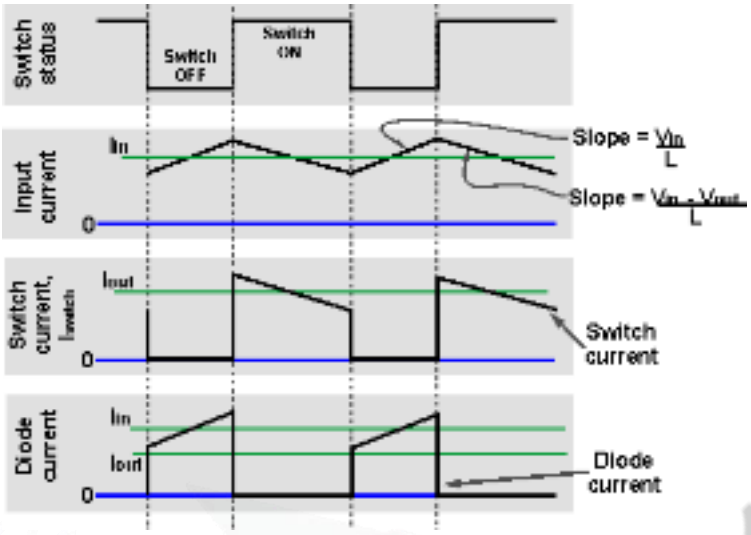
Boost converter operation

The operation of the boost converter is relatively straightforward.When the switch is in the ON position, the inductor output is connected to ground and the voltage Vin is placed across it. The inductor current increases at a rate equal to Vin/L.

When the switch is placed in the OFF position, the voltage across the inductor changes and is equal to Vout-Vin. Current that was flowing in the inductor decays at a rate equal to (Vout-Vin)/L.



Referring to the boost converter circuit diagram, the current waveforms for the different areas of the circuit can be seen as below.



It can be seen from the waveform diagrams that the input current to the boost converter is higher than the output current. Assuming a perfectly efficient, i.e. lossless, boost converter, the power out must equal the power in, i.e. Vin · Iin = Vout · Iout. From this it can be seen if the output voltage is higher than the input voltage, then the input current must be higher than the output current.

In reality no boost converter will be lossless, but efficiency levels of around 85% and more are achievable in most supplies.

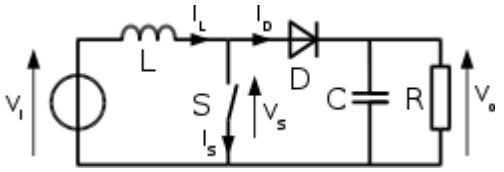
The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in Figure

When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive.

When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed and the right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy to the load. During this time, the blocking diode prevents the capacitor from

discharging through the switch. The switch must of course be opened again fast enough to prevent the capacitor from discharging too much.



The basic principle of a Boost converter consists of 2 distinct states (see figure 2):

in the On-state, the switch S (see figure 1) is closed, resulting in an increase in the inductor current;in the Off-state, the switch is open and the only path offered to inductor current is through the flyback diode D, the capacitor C and the load R. This results in transferring the energy accumulated during the On-state into the capacitor.

The input current is the same as the inductor current as can be seen in figure 2. So it is not discontinuous as in the buck converterand the requirements on the input filter are relaxed compared to a buck converter.The buck boost converter is a DC to DC converter. The output voltage of the DC to DC converter is less than or greater than the input voltage. The output voltage of the magnitude depends on the duty cycle. These converters are also known as the step up and step down transformers and these names are coming from the analogous step up and step down transformer. The input voltages are step up/down to some level of more than or less than the input voltage. By using the low conversion energy, the input power is equal to the output power. The following expression shows the low of a conversion.

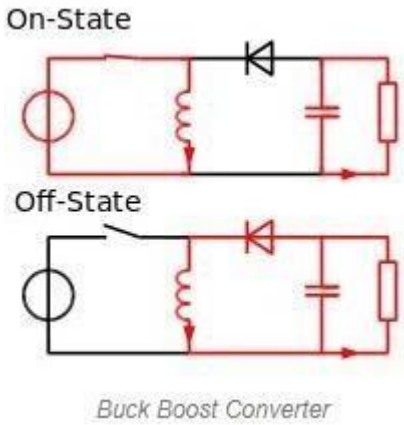
Input power (Pin) = Output power (Pout)

For the step up mode, the input voltage is less than the output voltage (Vin < Vout). It shows that the output current is less than the input current. Hence the buck booster is a step up mode. Vin < Vout and Iin > Iout

In the step down mode the input voltage is greater than the output voltage (Vin > Vout). It follows that the output current is greater the input current. Hence the buck boost converter is a step down mode.

Vin > Vout and Iin < Iout

It is a type of DC to DC converter and it has a magnitude of output voltage. It may be more or less than equal to the input voltage magnitude. The buck boost converter is equal to the fly back circuit and single inductor is used in the place of the transformer. There are two types of converters in the buck boost converter that are buck converter and the other one is boost converter. These converters can produce the range of output voltage than the input voltage. The following diagram shows the basic buck boost converter.



Buck Boost Converter

Working principle of Buck Boost Converter

The working operation of the DC to DC converter is the inductor in the input resistance has the unexpected variation in the input current. If the switch is ON then the inductor feed the energy from the input and it stores the energy of magnetic energy. If the switch is closed it discharges the energy. The output circuit of the capacitor is assumed as high sufficient than the time constant of an RC circuit is high on the output stage. The huge time constant is compared with the switching period and make sure that the steady state is a constant output voltage Vo(t) = Vo(constant) and present at the load terminal.

There are two different types of working principles in the buck boost converter.

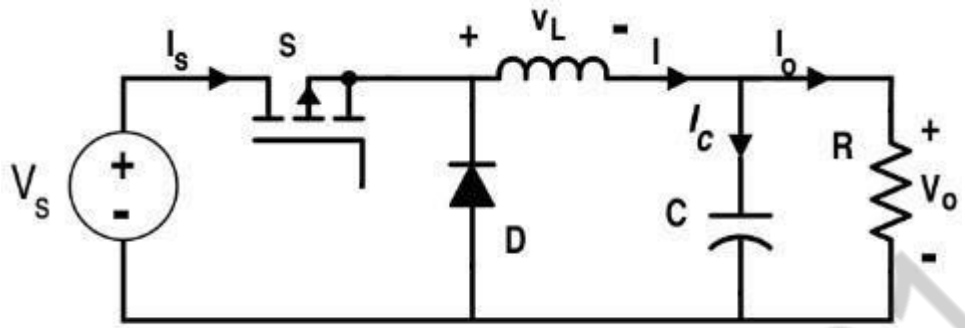
Buck converter.
Boost converter.
Buck Converter Working

The following diagram shows the working operation of the buck converter.

In the buck converter first transistor is turned ON and second transistor is switched OFF due to high square wave frequency. If the gate terminal of the first transistor is more than the current pass through the magnetic field, charging C, and it supplies the load. The D1 is the Schottky diode and it is turned OFF due to the positive voltage to the cathode.

The inductor L is the initial source of current. If the first transistor is OFF by using the control unit then the current flow in the buck operation. The magnetic field of the inductor is collapsed and the back e.m.f is generated collapsing field turn around the polarity of the voltage

across the inductor. The current flows in the diode D2, the load and the D1 diode will be turned ON



Buck Converter Working

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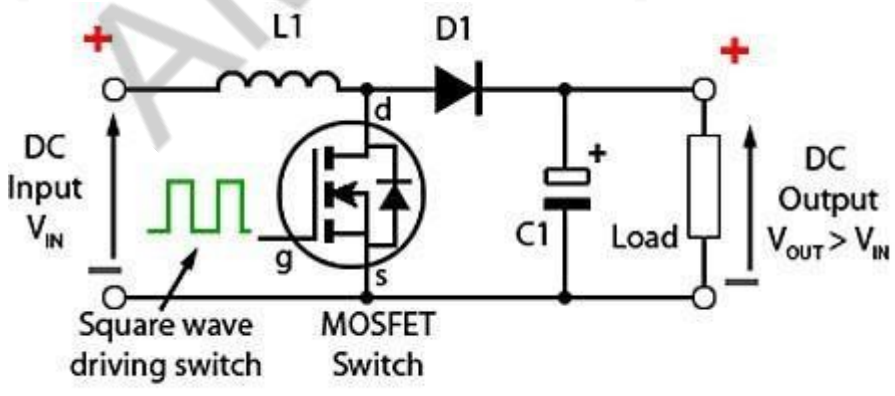
The discharge of the inductor L decreases with the help of the current. During the first transistor is in one state the charge of the accumulator in the capacitor. The current flows through the load and during the off period keeping Vout reasonably. Hence it keeps the minimum ripple amplitude and Vout closes to the value of Vs

Boost Converter Working

In this converter the first transistor is switched ON continually and for the second transistor the square wave of high frequency is applied to the gate terminal. The second transistor is in conducting when the on state and the input current flow from the inductor L through the second transistor. The negative terminal charging up the magnetic field around the inductor. The D2 diode cannot conduct because the anode is on the potential ground by highly onducting the second transistor.



Boost Converter Working

By charging the capacitor C the load is applied to the entire circuit in the ON State and it can construct earlier oscillator cycles. During the ON period the capacitor C can discharge regularly and the amount of high ripple frequency on the output voltage. The approximate potential difference is given by the equation below.

VS + VL

During the OFF period of second transistor the inductor L is charged and the capacitor C is discharged. The inductor L can produce the back e.m.f and the values are depending up on the rate of change of current of the second transistor switch. The amount of inductance the coil can occupy. Hence the back e.m.f can produce any different voltage through a wide range and

zero. Hence the inductor partially discharges earlier than the switching cycle.

Discontinuous Conduction Mode

In this mode the current through the inductor goes to zero. Hence the inductor will totally discharge at the end of switching cycles.

Applications of Buck boost converter

- It is used in the self regulating power supplies.
- It has consumer electronics.
- It is used in the Battery power systems.
- Adaptive control applications.

- Power amplifier applications.

Advantages of Buck Boost Converter

- It gives higher output voltage.
- Low operating duct cycle.
- Low voltage on MOSFETs