14 EC/EI 503 EC/EI 313

Hall Ticket Number:

III/IV B.Tech (Regular\Supplementary) DEGREE EXAMINATION

November, 2019 — **Common to ECE & EIE**

Fifth Semester — **Electronic Circuits-II**

Time: Three Hours — **Maximum:** 60 Marks

Answer Question No.1 compulsorily. (1X12 = 12 Marks)

Answer ONE question from each unit. (4X12=48 Marks)

1. Answer all questions (1X12=12 Marks)
   - a) Draw the hybrid-π CE transistor model
   - b) Define f_T& f_β
   - c) Draw the high frequency response of CE short circuit current gain
   - d) Draw the circuit diagram of zener diode voltage regulator.
   - e) Compare series and shunt voltage regulators.
   - f) Draw the FET small signal model at high frequencies
   - g) What are the different types of distortions in amplifiers
   - h) Give the relation between rise time and higher-3dB frequency
   - i) Three identical amplifiers with each 50HZ lower-3dB frequencies are connected in cascade. What is the overall lower-3dB frequency?
   - j) Define selectivity of tuned amplifiers
   - k) Give the relation between quality factor and bandwidth
   - l) What is meant by stagger tuning?

UNIT I

2. a) Derive the relation between transistor hybrid –π conductance and low frequency h-parameters — 6M

   b) A transistor has h_{ie}=1.1kΩ h_{fe} =50 h_{re}=2.5X10^{-4} h_{oe}=25µA/V, Vcc=10V at I_c=1.3mA and at room temp, g_m=50mA/V compute all hybrid –π conductances, $r_{bb'}$, $r_{b'e}$, r_{ce}, $r_{b'c}$ — 6M

(OR)

3. a) Derive a higher-3dB frequency of short circuit current gain of CE amplifier. — 6M

   b) A single stage CE amplifier is measured to have voltage gain bandwidth f_H of 5 MHz with R_L=500Ω Assume h_{fe} =100, g_m=100mA/V, $r_{bb'}$=100 Ω, Cc =1pf and f_T =100Mhz. Find the value of the source resistance that will give the required bandwidth. — 6M

UNIT II

4. a) Draw the high frequency equivalent circuit of Common Source amplifier and derive the expression for Voltage gain and Output impedance. — 6M

   b) Illustrate series voltage regulator with neat diagram. — 6M

(OR)

5. a) Briefly explain about protection techniques in regulators — 6M

   b) Explain about online and offline UPS systems — 6M

UNIT III

6. a) Derive the expression for overall higher-3dB frequency of n cascaded stages with non-interacting amplifiers. — 6M

   b) Three identical CE amplifiers are connected in cascade and found to have overall f^*_H and f^*_L as 40 kHz and 600 Hz respectively.Find the individual f_H and f_L by considering non identical stages. — 6M

(OR)

7. a) Briefly explain high frequency response of two cascaded CE-transistor stages — 6M

   b) Explain effect of emitter bypass capacitor on low frequency response of CE amplifier — 6M

UNIT IV

8. a) Derive the equation for the gain bandwidth product of a single tuned amplifier circuit — 6M

   b) A tank circuit has capacitor of 100pf and an inductor of 150µH. The series resistance is 15Ω find the impedance and bandwidth of a resonant circuit — 6M

(OR)

9. a) Draw and explain the double tuned amplifier in detail — 6M

   b) Draw and explain stagger tuned amplifier — 6M

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   c) Draw the high frequency response of CE short circuit current gain
   d) Draw the circuit diagram of zener diode voltage regulator.
   e) Compare series and shunt voltage regulators.
   f) Draw the FET small signal model at high frequencies
   g) What are the different types of distortions in amplifiers
   h) Give the relation between rise time and higher-3dB frequency
   i) Three identical amplifiers with each 50HZ lower-3dB frequencies are connected in cascade. What is the overall lower-3dB frequency?
   j) Define selectivity of tuned amplifiers
   k) Give the relation between quality factor and bandwidth
   l) What is meant by stagger tuning?

UNIT I

2. a) Derive the relation between transistor hybrid –π conductance and low frequency h-parameters 6M

   Sol: Four parameters 4x1.5=6M.

   b) A transistor has h_{ie}=1.1kΩ h_{fe} =50 h_{re}=2.5X10^{-4} h_{oe}=25μA/V, Vcc=10V at I_c=1.3mA and at room temp, g_m=50mA/V compute all hybrid –π conductances, $r_{bb'}$, $r_{b'e}$, r_{ce}, $r_{b'c}$ 6M

   Sol: Four parameters 4x1.5=6M.

(OR)

3. a) Derive a higher-3dB frequency of short circuit current gain of CE amplifier. 6M

   Sol: Amplifier main circuit =2M
   Hybrid equivalent circuit=1M
   Derivation=3M

   b) A single stage CE amplifier is measured to have voltage gain bandwidth f_H of 5 MHz with R_L=500Ω Assume h_{fe} =100, g_m=100mA/V, $r_{bb'}$=100 Ω, Cc =1pf and f_T =100Mhz. Find the value of the source resistance that will give the required bandwidth. 6M

   Sol: For formulas=2M
   Calculation=4M

UNIT II

4. a) Draw the high frequency equivalent circuit of Common Source amplifier and derive the expression for Voltage gain and Output impedance. 6M

   Sol: Amplifier main circuit =2M
   High frequency equivalent circuit=1M
   Derivation (voltage gain =2M output impedance =1M)

   b) Illustrate series voltage regulator with neat diagram. 6M

   Sol: Circuit or Block Diagram=3m

operation = 3M

(OR)

5. a) Briefly explain about protection techniques in regulators 6M

Sol: For at least two techniques 3+3=6M.

b) Explain about online and offline UPS systems 6M

Sol: For two systems 3+3=6M.

UNIT III

6. a) Derive the expression for overall higher-3dB frequency of n cascaded stages with non-interacting amplifiers. 6M

b) Three identical CE amplifiers are connected in cascade and found to have overall f^*_H and f^*_L as 40 kHz and 600 Hz respectively. Find the individual f_H and f_L by considering non identical stages. 6M

Sol: For formulas=3M

Calculation=3M

(OR)

7. a) Briefly explain high frequency response of two cascaded CE-transistor stages 6M

Sol: Amplifier main circuit =2M

High frequency equivalent circuit=2M

Explanation = 2M

b) Explain effect of emitter bypass capacitor on low frequency response of CE amplifier 6M

Sol: Amplifier main circuit =2M

Equivalent circuit=1M

Derivation and Graph =3M

UNIT IV

8. a) Derive the equation for the gain bandwidth product of a single tuned amplifier circuit 6M

Sol: Circuit & Equivalent Circuit =3M

Derivation=3M

b) A tank circuit has capacitor of 100pf and an inductor of 150µH. The series resistance is 15Ω find the impedance and bandwidth of a resonant circuit. 6M

Sol: Impedance =3M

Bandwidth = 3M

(OR)

9. a) Draw and explain the double tuned amplifier in detail. 6M

Sol: Circuit =2M

Equivalent Circuit=2M

Explanation = 2M

b) Draw and explain stagger tuned amplifier 6M

Sol: Circuit =2M

Pole Zero Diagram =2M

Explanation = 2M

Scheme of Evaluation

Electronic Circuits-II

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Answer Question No.1 compulsorily. (1X12 = 12 Marks)
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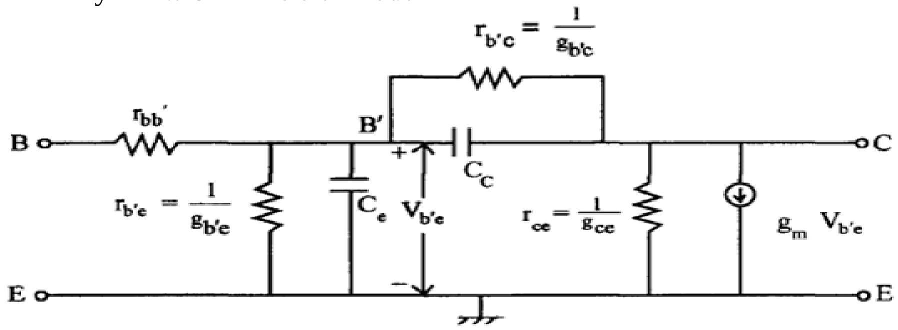
1. Answer all questions (1X12=12 Marks)

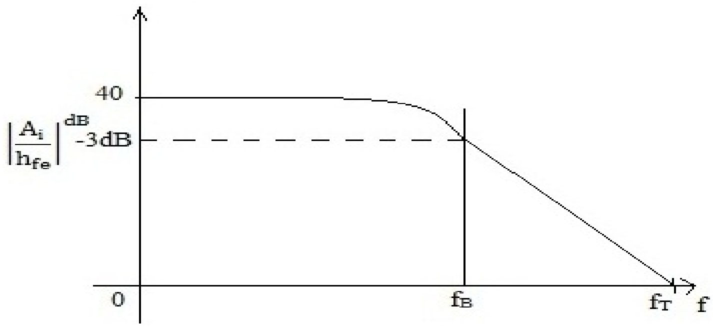
a) Draw the hybrid-π CE transistor model



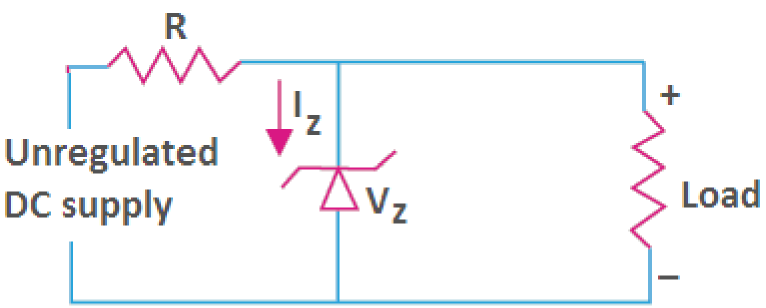
b) Define f_T& f_β.

f_β.-Is the current gain cutoff frequency of short circuit CE amplifier ,where gain becomes $\frac{1}{\sqrt{2}}$ times the maximum.
f_T.-Is the unity current gain frequency of short circuit CE amplifier.
Another interpretation is gain bandwidth product i.e $f_T = h_{fe}\ f_\beta$.

c) Draw the high frequency response of CE short circuit current gain.



d) Draw the circuit diagram of zener diode voltage regulator.

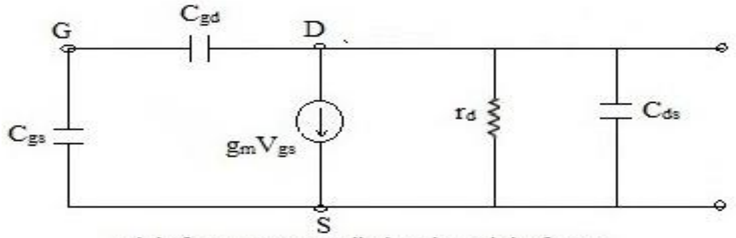


e) Compare series and shunt voltage regulators.

S.No	series voltage regulators	shunt voltage regulators
1	Control element is in parallel with the load.	Control element is in series with the load.

2	It is appropriate for light loads.	It is appropriate for heavy loads.
3	The control element has to bear the load voltage across it. So, it is a high voltage low current device.	The control element has to carry the load current. So, it is a high current low voltage device.
4	Not suitable for varying load conditions. Preferred for fixed voltage applications.	Preferred for fixed as well as variable voltage applications.

f) Draw the FET small signal model at high frequencies



High frequency small signal model of FET

g) What are the different types of distortions in amplifiers?

1.Amplitude Distortion 2.Frequency distortion 3.phase distortion

h) Give the relation between rise time and higher-3dB frequency.

$$\text{Rise Time } = \frac{0.35}{f_H}$$

i) Three identical amplifiers with each 50HZ lower-3dB frequencies are connected in cascade. What is the overall lower-3dB frequency?

$$f_L^* = \frac{f_L}{\sqrt{2^{1/n} - 1}}$$

$$f_L^* = \frac{50}{\sqrt{2^{1/3} - 1}}$$

=98.07 Hz.

j) Define selectivity of tuned amplifiers.
It is ability of Tuned amplifier to select desired frequencies and rejecting all other unwanted frequencies.

k) Give the relation between quality factor and bandwidth.
Band width $= \frac{f_0}{Q}$.

l) What is meant by stagger tuning?
Staggered tuning is a technique used in the design of multi-stage tuned amplifiers whereby each stage is tuned to a slightly different frequency.

UNIT I

2. a) Derive the relation between transistor hybrid –π conductance and low frequency h-parameters. 6M

Sol: Four parameters 4x1.5=6M.

<u>Trans Conductance(g_m):</u>

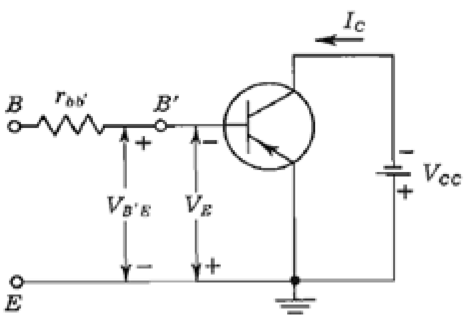


Fig. 11-2 Pertaining to the derivation of g_m.

Transistor collector current is given by

$$I_C = I_{CO} - \alpha_o I_E$$

Short circuited collector current is $I_C = g_m v_{b'e}$

Trans conductance is defined as

$$g_m = \frac{\partial I_C}{\partial V_{BE}} \, with V_{CE} \; constent = g_m = \frac{\alpha_o I_E}{V_{BE}} = \frac{\alpha_o I_E}{V_E} = \frac{\alpha_o}{r_e}$$

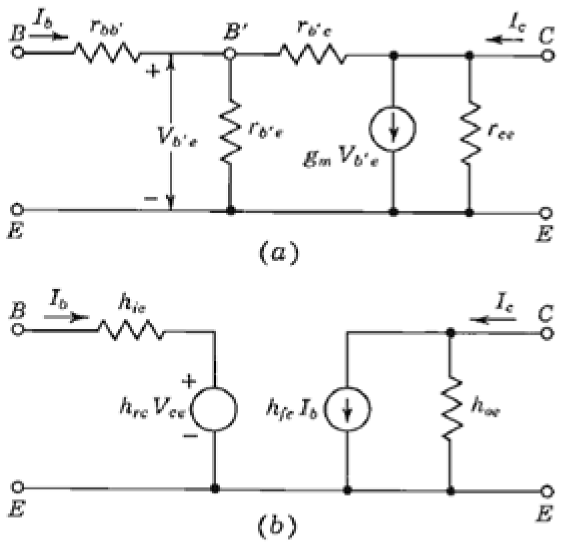
Where r_e *is dynamic resistance of in put junction and is defind as* $r_e = \frac{V_T}{I_E}$.

Where V_T *is volt equivalent of temperature.*

With this $g_m = \frac{\alpha_o I_E}{V_T} = \frac{I_{CO} - I_C}{V_T} = \frac{|I_C|}{V_T}$.

In put conductance($g_{b'e}$):

Fig. 11-3 (a) The hybrid-Π model at low frequencies; (b) the h-parameter model at low frequencies.



Short circuited collector current is $I_C = g_m v_{b'e} \, with \, V_{CE} \; constent \approx g_m I_b r_{b'e}$.

$$we \; know \; that \; I_C = h_{fe} I_b$$

From above two equations $r_{b'e} = \frac{h_{fe}}{g_m}$ and

$$g_{b'e} = \frac{g_m}{h_{fe}}.$$

The Feedback Conductance $g_{b'c}$ With the input open-circuited, h_{re} is defined as the reverse voltage gain, or from Fig. 11-3a with $I_b = 0$,

$$h_{re} = \frac{V_{b'e}}{V_{ce}} = \frac{r_{b'e}}{r_{b'e} + r_{b'c}}$$

or

$$r_{b'e}(1 - h_{re}) = h_{re} r_{b'c}$$

Since $h_{re} \ll 1$, then to a good approximation

$$r_{b'e} = h_{re} r_{b'c} \qquad \text{or} \qquad g_{b'c} = h_{re} g_{b'e}$$

The Base-spreading Resistance $r_{bb'}$ The input resistance with the output shorted is h_{ie}. Under these conditions $r_{b'e}$ is in parallel with $r_{b'c}$. Using we have $r_{b'e} \| r_{b'c} \approx r_{b'e}$, and hence

$$h_{ie} = r_{bb'} + r_{b'e}$$

b) A transistor has h_{ie}=1.1kΩ h_{fe} =50 h_{re}=2.5X10^{-4} h_{oe}=25μA/V, Vcc=10V at I_c=1.3mA and at room temp, g_m=50mA/V compute all hybrid –π conductances, $r_{bb'}$, $r_{b'e}$, r_{ce}, $r_{b'c}$ 6M

Sol: Four parameters 4x1.5=6M.

$$g_m = \frac{|I_C|}{V_T} = \frac{1.3m}{26m} = 50m\,mho.$$

$$r_{b'e} = \frac{h_{fe}}{g_m} = \frac{50}{50m} = 1K\Omega.$$

$$r_{b'b} = h_{ie} - r_{b'b} = 1.1K - 1K = 100\Omega.$$

$$r_{b'c} = \frac{r_{b'e}}{h_{re}} = \frac{1K}{2.5X10^{-4}} = 4M\Omega.$$

$$g_{ce} = h_{oe} - (1+h_{fe})g_{b'c} = 25\mu - \frac{(1+50)}{4M} = 25\mu - 12.75\mu = 12.25\mu.$$

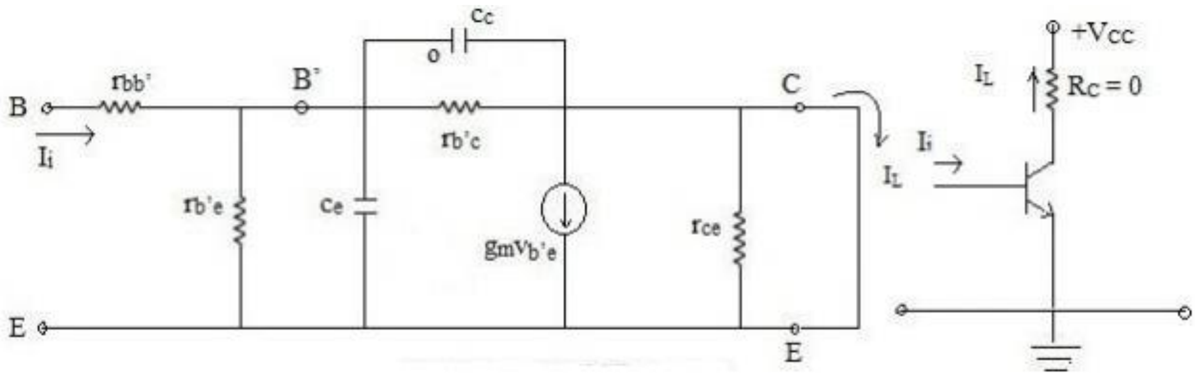
$$r_{ce} = \frac{1}{g_{ce}} = \frac{1}{12.25\mu} = 81.63K\Omega.$$

(OR)

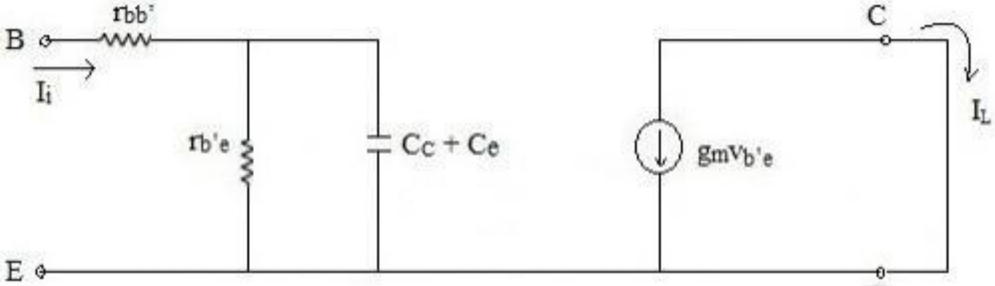
3. a) Derive a higher-3dB frequency of short circuit current gain of CE amplifier. 6M

Sol: Amplifier main circuit =2M
Hybrid equivalent circuit=1M
Derivation=3M

CE amplifier circuit and equivalent circuit is shown in following figure.



(1) The components in shunt with short circuit behave as open circuit and hence is removed from the equivalent circuit.
(2) $r_{b'e} \| r_{b'c} = r_{b'e}$
(3) Two capacitances in parallel so C=C_C ∥ C_e = C_C + C_e.



From above circuit $I_L = -g_m v_{b'e}$

By neglecting $r_{bb'}$, $v_{b'e} = \frac{I_i}{Y_i} = \frac{I_i}{g_{b'e} + jw(C_e + C_c)}$

With this $\frac{I_L}{I_i} = \frac{-g_m \ r_{b'e}}{1 + j(\frac{f}{f_\beta})}$ $where\ f_\beta = \frac{1}{2\pi \ r_{b'e}\ (C_e + C_c)}$

Where f_β higher three dB frequency.

b) A single stage CE amplifier is measured to have voltage gain bandwidth f_H of 5 MHz with R_L=500Ω Assume h_{fe} =100, g_m=100mA/V, $r_{bb'}$=100 Ω, Cc =1pf and f_T =100Mhz. Find the value of the source resistance that will give the required bandwidth. 6M

Sol: For formulas=2M

Calculation=4M

$$f_H = \frac{1}{2\pi RC}$$

Where $R = (R_s + r_{b'b})||r_{b'e}$ **and** $C = C_e + C_c\,(1 + g_m R_L)$**. And we know that**

$$Ce = \frac{g_m}{2\pi f_T}$$

With the above formulas $R_S = 86.37\Omega$

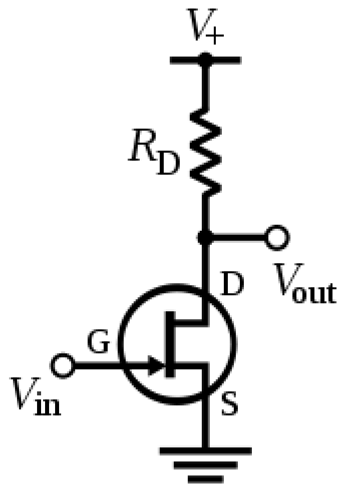
UNIT II

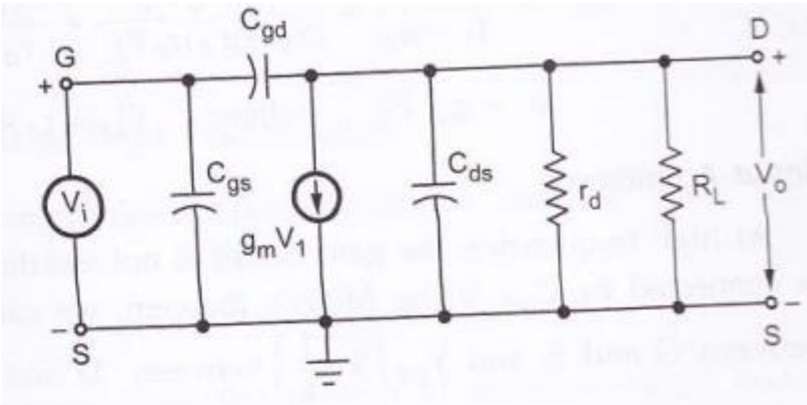
4. a) Draw the high frequency equivalent circuit of Common Source amplifier and derive the expression for Voltage gain and Output impedance. 6M

Sol: Amplifier main circuit =2M High frequency equivalent circuit=1M

Derivation (voltage gain =2M output impedance =1M)

Common source amplifier at high frequencies:





Small signal equivalent circuit at high frequencies

$$Y = \frac{1}{Z} = Y_L + Y_{ds} + g_d + Y_{gd}$$

where

$Y_L = \frac{1}{R_L}$: admittance corresponding to R_L

$Y_{ds} = j\omega C_{ds}$: admittance corresponding to C_{ds}

$g_d = \frac{1}{r_d}$: conductance corresponding to r_d

$Y_{gd} = j\omega C_{gd}$: admittance corresponding to C_{gd}

$$I = -g_m V_i + V_i Y_{gd} = V_i(-g_m + Y_{gd})$$

Voltage gain:

The voltage gain for common source amplifier circuit with the load R_L is given by,

$$A_v = \frac{V_o}{V_i} = \frac{IZ}{V_i} = \frac{I}{V_i Y}$$

Substituting the values of I and Y from equations (2) and (3) we have,

$$A_v = \frac{-g_m + Y_{gd}}{Y_L + Y_{ds} + g_d + Y_{gd}}$$

At low frequencies, Y_{ds} and $Y_{gd} = 0$ and hence equation (4) reduces to

$$A_v = \frac{-g_m}{Y_L + g_d} = \frac{-g_m r_d Z_L}{(Y_L + g_d) r_d Z_L} = \frac{-g_m r_d Z_L}{r_d + Z_L}$$

$$= -g_m Z_L' \qquad \text{where} \qquad Z_L' = r_d \,||\, Z_L$$

Output Admittance:

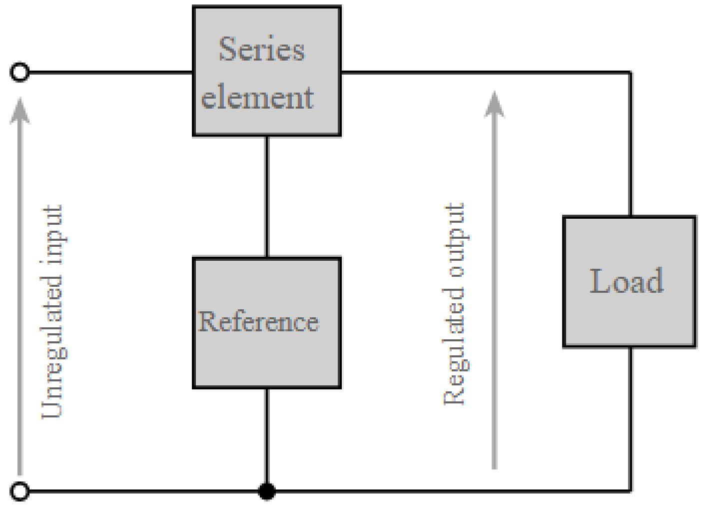
From above figure, the output impedance is obtained by looking into the drain with the input voltage set equal to zero. If $V_i = 0$ in figure, r_d, C_{ds} and C_{gd} in parallel. Hence the output admittance with R_L considered external to the amplifier is given by

$$Y_o = g_d + Y_{ds} + Y_{gd}$$

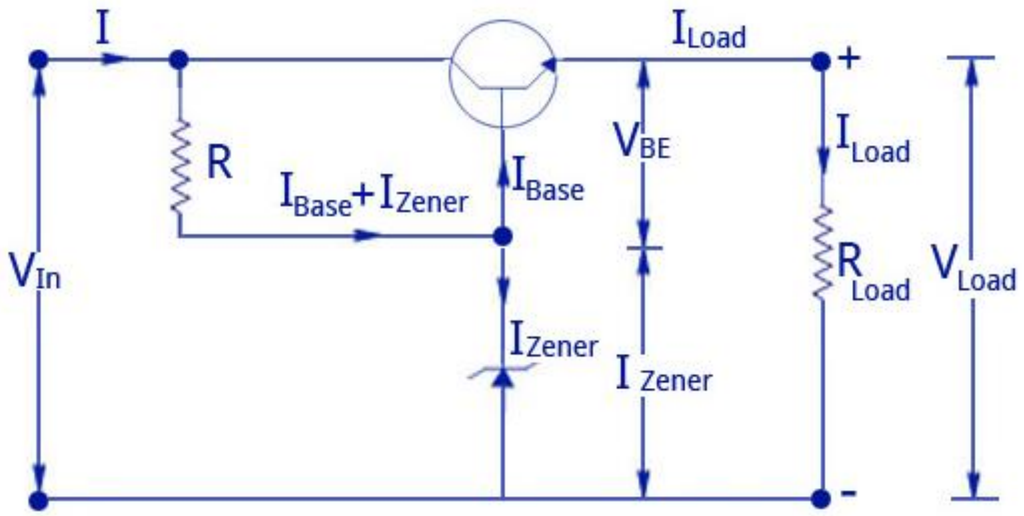
b) Illustrate series voltage regulator with neat diagram. 6M

Sol: Circuit or Block Diagram=3m

operation = 3M



Block diagram of a series voltage regulator



The output of the rectifier that is filtered is then given to the input terminals and regulated output voltage Vload is obtained across the load resistor Rload. The reference voltage is provided by the zener diode and the transistor acts as a variable resistor, whose resistance varies with the operating conditions of base current, Ibase.

The main principle behind the working of such a regulator is that a large proportion of the change in supply or input voltage appears across the transistor and thus the utput voltage tends to remain constant.

The output voltage can thus be written as

Vout = Vzener – Vbe

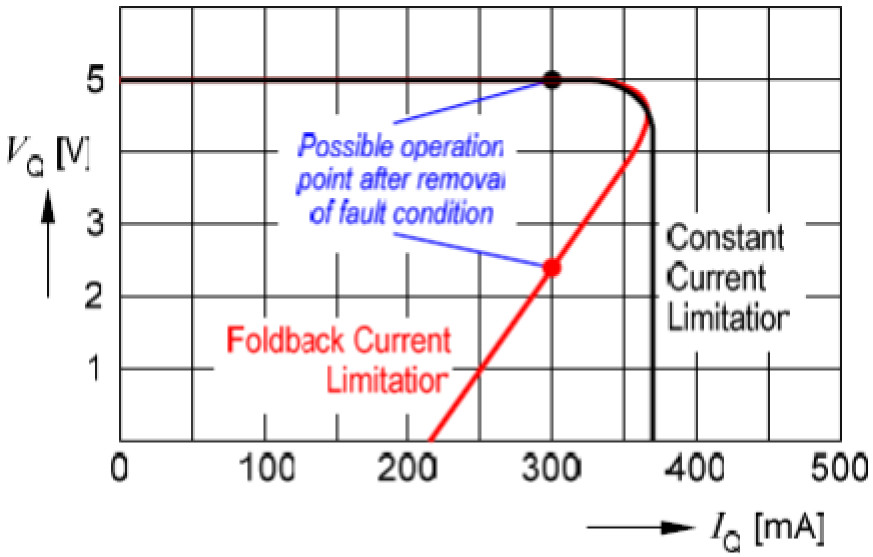
The transistor base voltage Vbase and the zener diode voltage Vzener are equal and thus the value of Vbase remains almost constant.

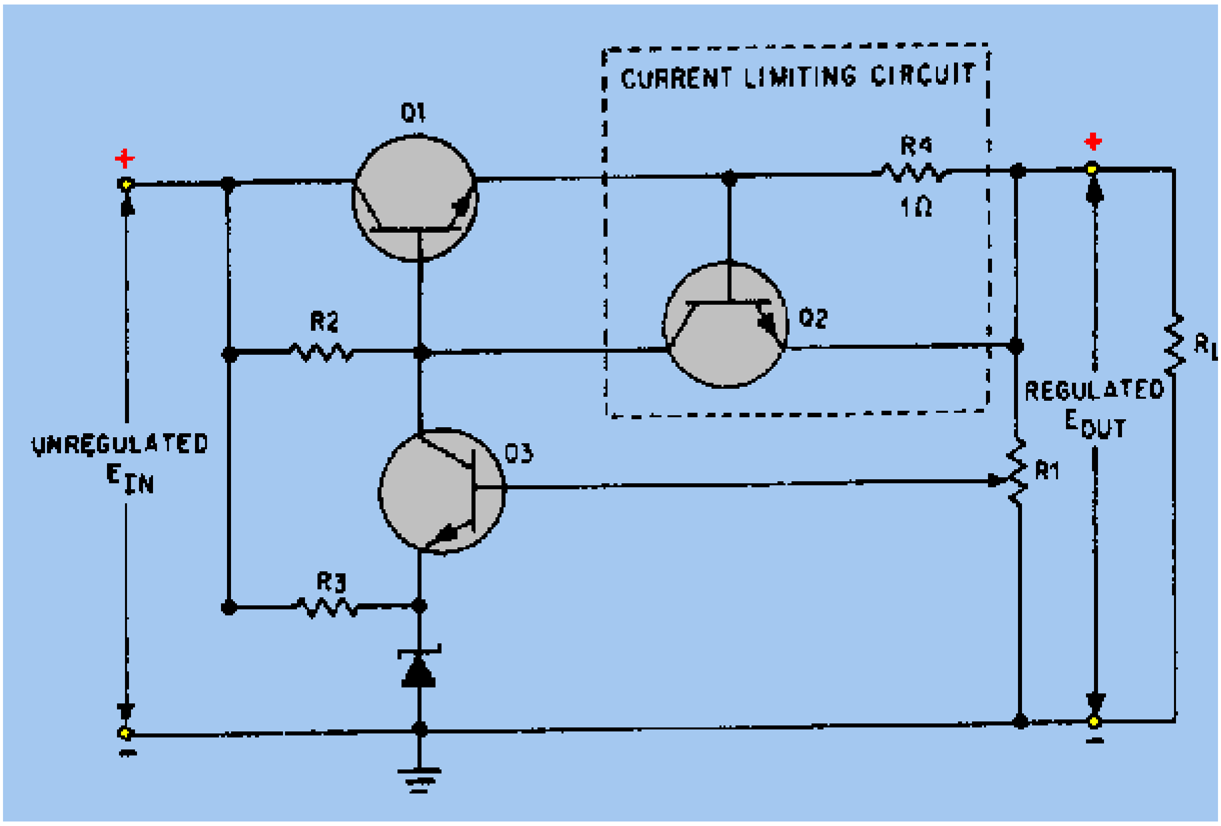
(OR)

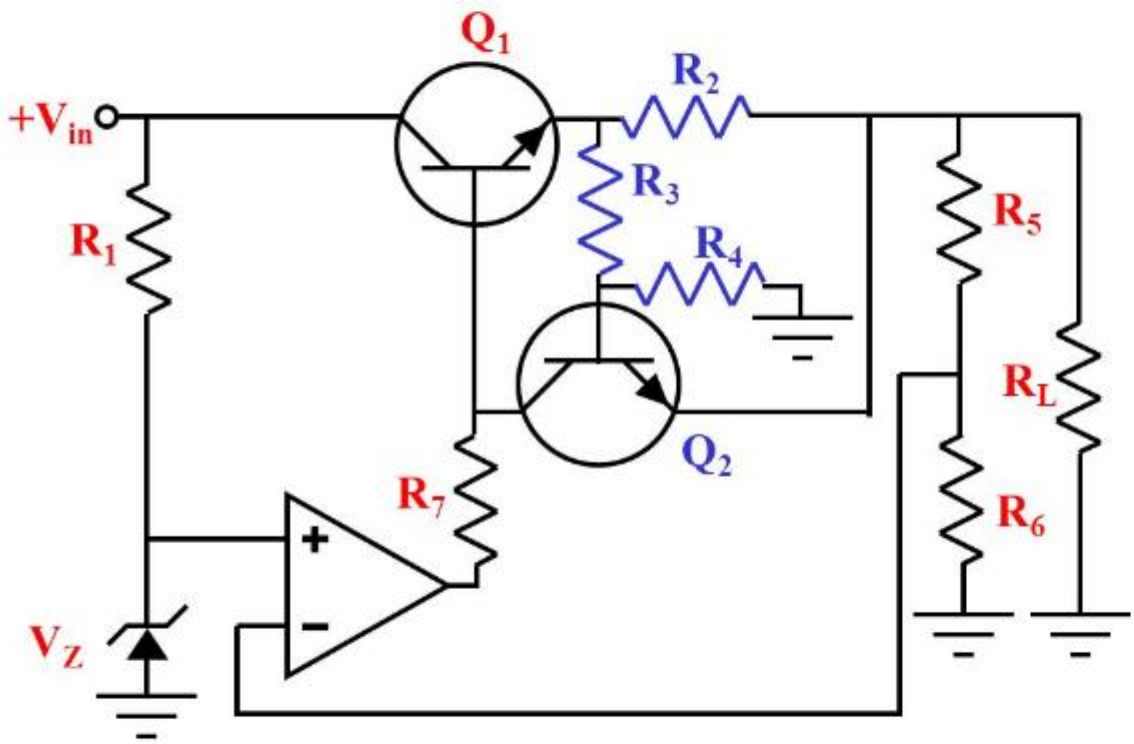
5. a) Briefly explain about protection techniques in regulators 6M

Sol: For at least two techniques 3+3=6M.

In case of short-circuiting the output to GND or in case of excessive load condition, the regulator is forced to deliver a very high output current. To prevent the application as well as the regulator itself from destruction, the IC limits the output current to a reasonable value specified in the data sheet. For controlling the short-circuit current, two types of protection on chip are common: constant or foldback current limitation. Infineon linear regulators use a Constant Current Limitation in order to overcome "latchup" problems with the foldback limiting method: If the load draws a current anywhere along the foldback curve after removing the fault condition, the output will never reestablish its original voltage.







Fold back Current limiting circuit

b) Explain about online and offline UPS systems 6M

Sol: For two systems 3+3=6M.

Off-line UPS(short break)

This UPS is also called as Standby UPS system which can give only the most basic features. Here, the primary source is the filtered AC mains (shown in solid path). When the power breakage occurs, the transfer switch will select the backup source (shown in dashed path). Thus we can clearly see that the stand by system will start working only when there is any failure in mains. In this system, the AC voltage is first rectified and stored in the storage battery connected to the rectifier.

When power breakage occurs, this DC voltage is converted to AC voltage by means of inverter and given to the load connected to it. This is the least expensive UPS system and it provides surge protection in addition to back up. The transfer time can be about 25 milliseconds which can be related to the time taken by the UPS system to detect the utili

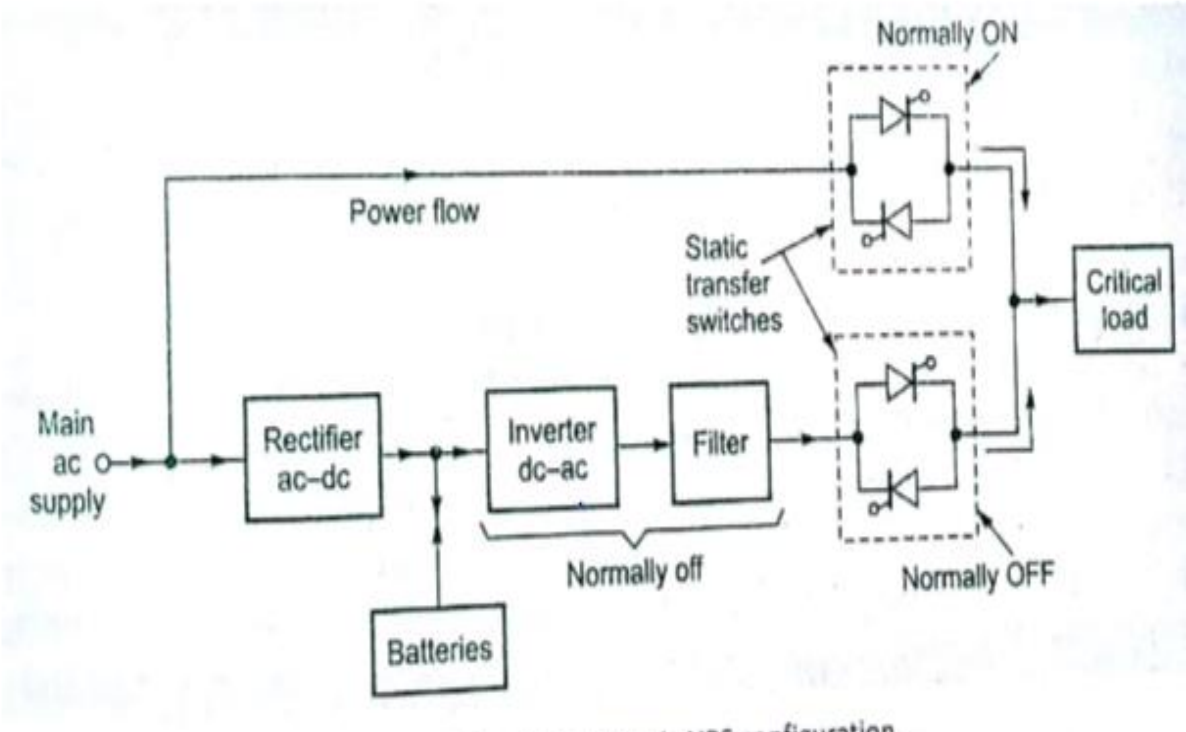


Fig. 11.8. Short-break static UPS configuration.

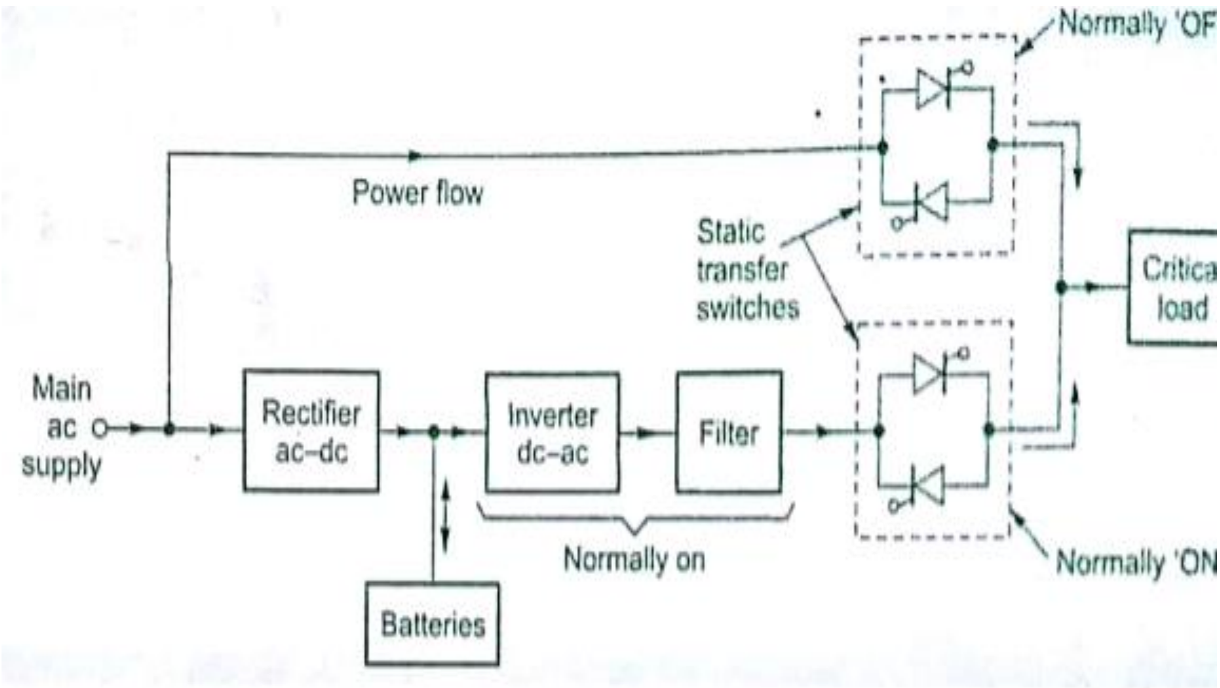


Fig. 11.9. No-break UPS configuration.

Online UPS(No –break UPS)

The online UPS is also called as double conversion online uninterruptible power supply. This is the most commonly used UPS and the block diagram of this UPS is shown below. The designing of this UPS is similar to the Standby UPS, excluding that the primary power source is the inverter instead of the AC main. In this UPS design, damage of the i/p AC does not cause triggering of the transfer switch, because the i/p AC is charging the backup battery source which delivers power to the o/p inverter. So, during failure of an i/p AC power, this UPS operation results in no transfer time.

UNIT III

6. a) Derive the expression for overall higher-3dB frequency of n cascaded stages with non-interacting amplifiers. 6M

12-6 BANDPASS OF CASCADED STAGES

The high 3-dB frequency for n cascaded stages is f_H^* and equals the frequency for which the overall voltage gain falls 3 dB to $1/\sqrt{2}$ of its midband value. To obtain the overall transfer function of *noninteracting* stages, the transfer gains of the individual stages are multiplied together. Hence, if each stage has a dominant pole and if the high 3-dB frequency of the ith stage is f_{Hi}, where $i = 1, 2, \ldots, n$, then f_H^* can be calculated from the product

$$\frac{1}{\sqrt{1+(f_H^*/f_{H1})^2}} \cdots \frac{1}{\sqrt{1+(f_H^*/f_{Hi})^2}} \cdots \frac{1}{\sqrt{1+(f_H^*/f_{Hn})^2}} = \frac{1}{\sqrt{2}}$$

For n stages with identical upper 3-dB frequencies we have

$$f_{H1} = f_{H2} = \cdots = f_{Hi} = \cdots = f_{Hn} = f_H$$

Thus f_H^* is calculated from

12-6 BANDPASS OF CASCADED STAGES

The high 3-dB frequency for n cascaded stages is f_H^* and equals the frequency for which the overall voltage gain falls 3 dB to $1/\sqrt{2}$ of its midband value. To obtain the overall transfer function of *noninteracting* stages, the transfer gains of the individual stages are multiplied together. Hence, if each stage has a dominant pole and if the high 3-dB frequency of the ith stage is f_{Hi}, where $i = 1, 2, \ldots, n$, then f_H^* can be calculated from the product

$$\frac{1}{\sqrt{1+(f_H^*/f_{H1})^2}} \cdots \frac{1}{\sqrt{1+(f_H^*/f_{Hi})^2}} \cdots \frac{1}{\sqrt{1+(f_H^*/f_{Hn})^2}} = \frac{1}{\sqrt{2}}$$

For n stages with identical upper 3-dB frequencies we have

$$f_{H1} = f_{H2} = \cdots = f_{Hi} = \cdots = f_{Hn} = f_H$$

Thus f_H^* is calculated from

$$\left[\frac{1}{\sqrt{1+(f_H^*/f_H)^2}}\right]^n = \frac{1}{\sqrt{2}}$$

to be

$$\frac{f_H^*}{f_H} = \sqrt{2^{1/n} - 1}$$

For example, for $n = 2$, $f_H^*/f_H = 0.64$. Hence two cascaded stages, each with a bandwidth $f_H = 10$ kHz, have an overall bandwidth of 6.4 kHz. Similarly, three cascaded 10-kHz stages give a resultant upper 3-dB frequency of 5.1 kHz, etc.

b) Three identical CE amplifiers are connected in cascade and found to have overall f^*_H and f^*_L as 40 kHz and 600 Hz respectively. Find the individual f_H and f_L by considering identical stages. 6M

Sol: For formulas=3M

Calculation=3M

$$f_H = \frac{f_H^*}{\sqrt{2^{\frac{1}{n}} - 1}}$$

$f_H = \frac{40K}{\sqrt{2^{\frac{1}{3}}-1}}$ =78.46KHz

$f_L = f_L^*\sqrt{2^{\frac{1}{n}} - 1}$ = 305.88HZ

Sol: For formulas=3M

Calculation=3M

(OR)

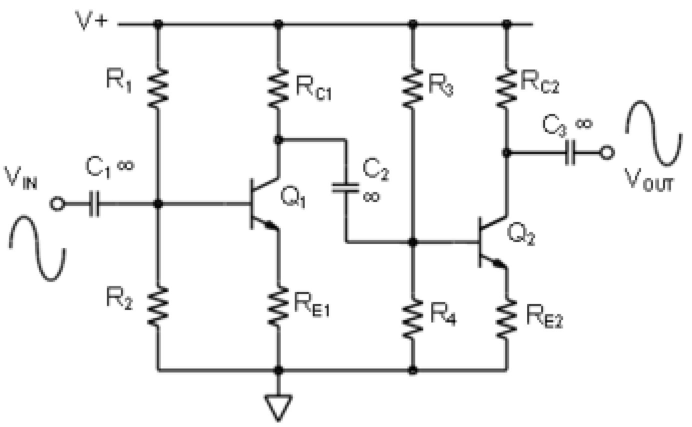
7. a) Briefly explain high frequency response of two cascaded CE-transistor stages 6M

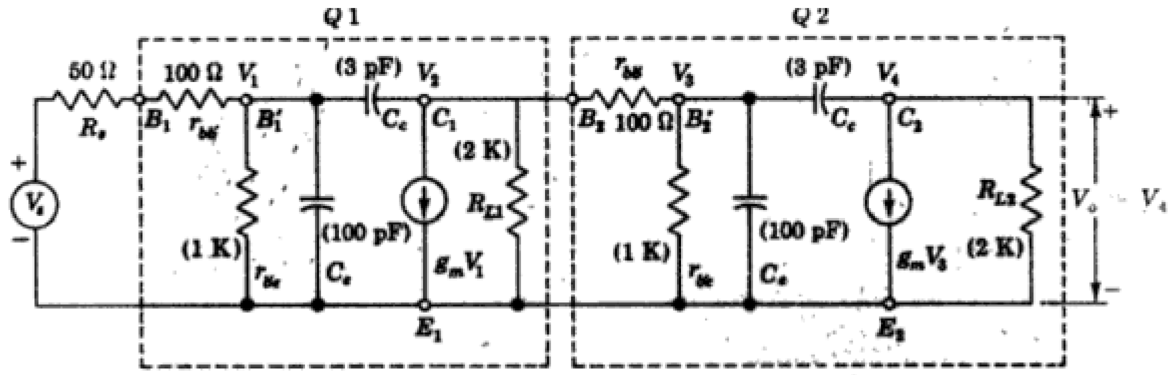
Sol: Amplifier main circuit =2M High frequency equivalent circuit=2M

Explanation = 2M

<u>high frequency response of two cascaded CE-transistor stages:</u>

For small signal model each transistor can be replaced by its equivalent hybrid pi model.$r_{b'c}$,r_{ce} *can be neglected because of their impedence is very high*. Values of R1 & R_2 Are very large compared to source resistance R_S and by assuming coupling and blocking capacitances are short circuited at operating frequencies, the resultant small signal model is shown in figure.





Two-stage interacting CE amplifier ($g_m = 50$ mA/V).

For small signal model each transistor can be replaced by its equivalent hybrid pi model.

The network can be described by four nodal equations. If

$$R'_s \equiv R_s + r_{bb'} = 1/G'_s,\ G_{L1} = 1/R_{L1},\ G_{L2} = 1/R_{L2},\ \text{and}\ g_{bb'} = 1/r_{bb'}$$

these equations are

$$G'_s V_s = [G'_s + g_{b'e} + s(C_e + C_c)]V_1 - sC_c V_2$$

$$0 = (g_m - sC_c)V_1 + (G_{L1} + g_{bb'} + sC_c)V_2 - g_{bb'}V_3$$

$$0 = -g_{bb'}V_2 + [g_{b'e} + g_{bb'} + s(C_e + C_c)]V_3 - sC_c V_4$$

$$0 = (g_m - sC_c)V_3 + (G_{L2} + sC_c)V_4$$

With the Cramer's rule

$$A_V \equiv \frac{V_4}{V_s} = \frac{G'_s \Delta_{14}}{\Delta} = \text{transfer function}$$

And transfer function consists of the form

$$A_V = \frac{K(s - s_5)(s - s_6)}{(s - s_1)(s - s_2)(s - s_3)(s - s_4)}$$

Obtained with 2 zeros at $s = s_5, s_6$ and 4 poles at $s = s_1, s_2, s_3, s_4$. CORNAP computer program can be used for obtaining location of poles and zeros.
With the application of miller's theorem analysis complexity can be reduced.

The effect of C_c is approximated using Miller's theorem and the midband value of the stage gain. Thus C_c of Q_2 is replaced by a capacitance

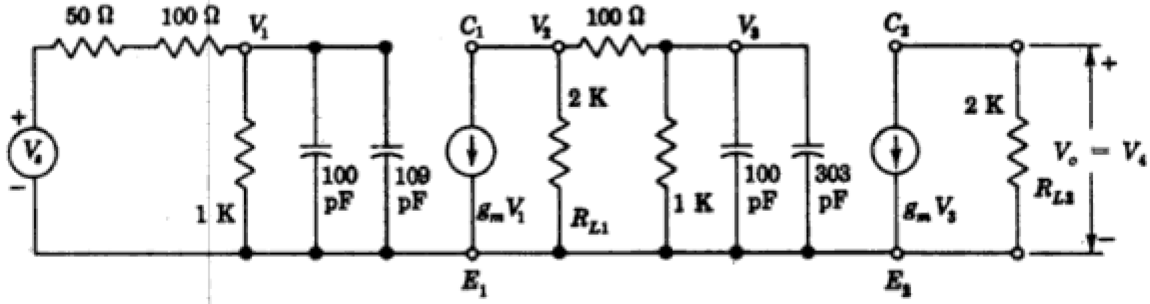
$$C_c(1 + g_m R_{L2}) = 3(1 + 50 \times 2) = 303\ \text{pF}$$

across the input of Q2. Similarly, C_c of Q1 is replaced by

$$C_c[1 + g_m R_{L1}||(r_{b'e} + r_{bb'})] = 3(1 + 50 \times 0.709) = 109\ \text{pF}$$

across the input of Q1.

Now circuit with only two time constants as shown in following figure with only two poles.



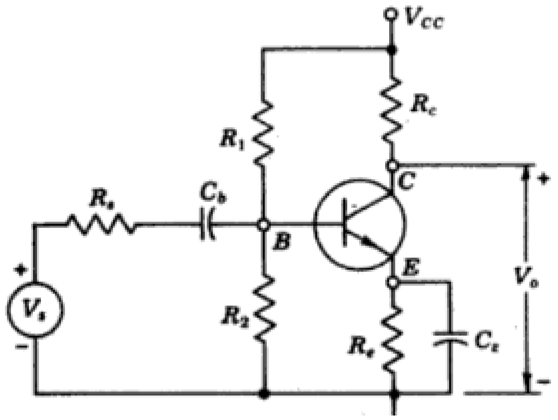
Two-stage interacting CE amplifier using Miller approximation.

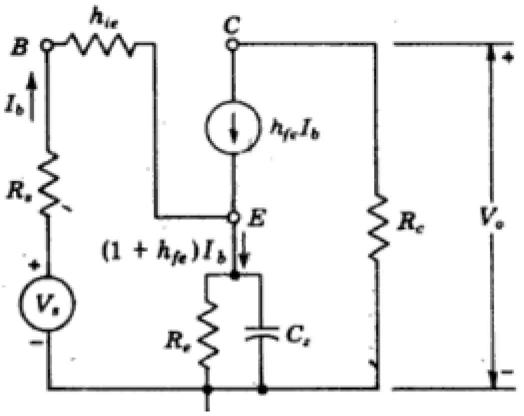
b) Explain effect of emitter bypass capacitor on low frequency response of CE amplifier

Sol: Amplifier main circuit =2M Equivalent circuit=1M Derivation and Graph =3M

In a normal CE amplifier, the bypass capacitor decides the lower cutoff frequency. This is because; a capacitor offers high impedance for lower frequency. The parallel combination of emitter resistance and bypass capacitor in the CE amplifier forms significant impedance for low frequency and would not allow much emitter current to flow. Hence the gain would be reduced for low frequency.

Whereas for higher frequencies, the impedance offered would be low and don't affect the higher frequency currents.





The output voltage V_o is given by

$$V_o = -I_b h_{fe} R_c = -\frac{V_s h_{fe} R_c}{R_s + h_{ie} + Z'_e}$$

where

$$Z'_e = (1 + h_{fe}) \frac{R_e}{1 + j\omega C_z R_e}$$

Substituting the above equations and solving for the voltage gain A_V, we find

$$A_V = \frac{V_o}{V_s} = -\frac{h_{fe}R_c}{R + R'} \frac{1 + j\omega C_z R_e}{1 + j\omega C_z[R_e R/(R + R')]}$$

where

$$R \equiv R_s + h_{ie} \qquad \text{and} \qquad R' \equiv (1 + h_{fe})R_e$$

The midband gain A_o is obtained as $\omega \to \infty$, or

$$A_o = -\frac{h_{fe}R_c}{R} = \frac{-h_{fe}R_c}{R_s + h_{ie}}$$

Hence

$$\frac{A_V}{A_o} = \frac{1}{1 + R'/R} \frac{1 + jf/f_o}{1 + jf/f_p}$$

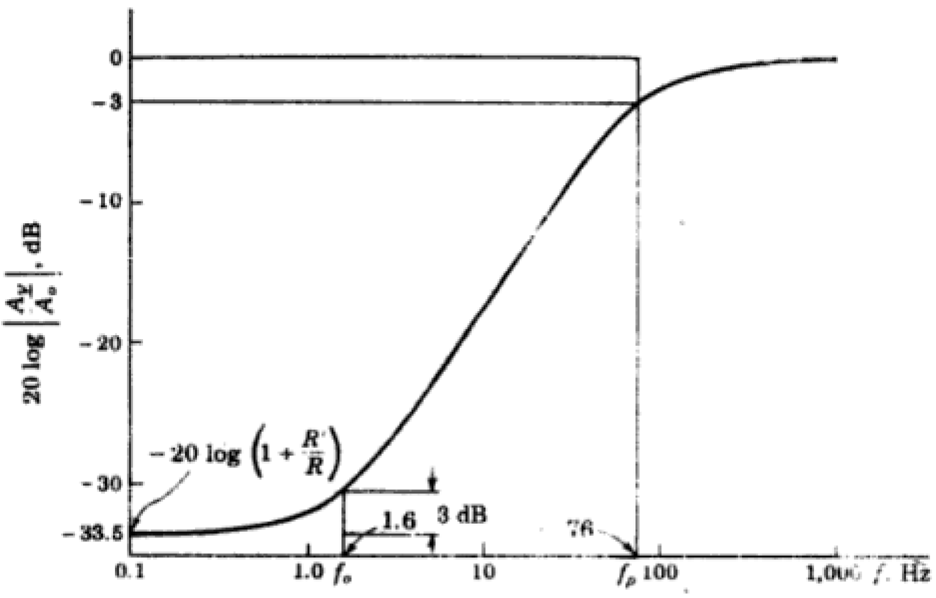
where

$$f_o \equiv \frac{1}{2\pi C_z R_e} \qquad f_p \equiv \frac{1 + R'/R}{2\pi C_z R_e}$$

Note that f_o determines the zero and f_p the pole of the gain A_V/A_o. Since, usually, $R'/R \gg 1$, then $f_p \gg f_o$, so that the pole and zero are widely separated. For example, assuming $R_s = 0$, $R_e = 1$ K, $C_z = 100\ \mu$F, $h_{fe} = 50$, $h_{ie} = 1.1$ K, and $R_c = 2$ K, we find $f_o = 1.6$ Hz and $f_p = 76$ Hz.

The magnitude of $|A_V/A_o|$ in decibels is given by

$$20 \log \left| \frac{A_V}{A_o} \right| = -20 \log \left(1 + \frac{R'}{R}\right) + 20 \log \sqrt{1 + \left(\frac{f}{f_o}\right)^2} - 20 \log \sqrt{1 + \left(\frac{f}{f_p}\right)^2}$$



The frequency response of an amplifier with a bypassed emitter resistor.

When an emitter resistance is added in a CE (Common Emitter) amplifier, its voltage gain is reduced, but the input impedance increases. Whenever bypass capacitor is connected in parallel with an emitter resistance, the voltage gain of CE amplifier increases. If the bypass capacitor is removed, an extreme degeneration is produced in the amplifier circuit and the voltage gained will be reduced.

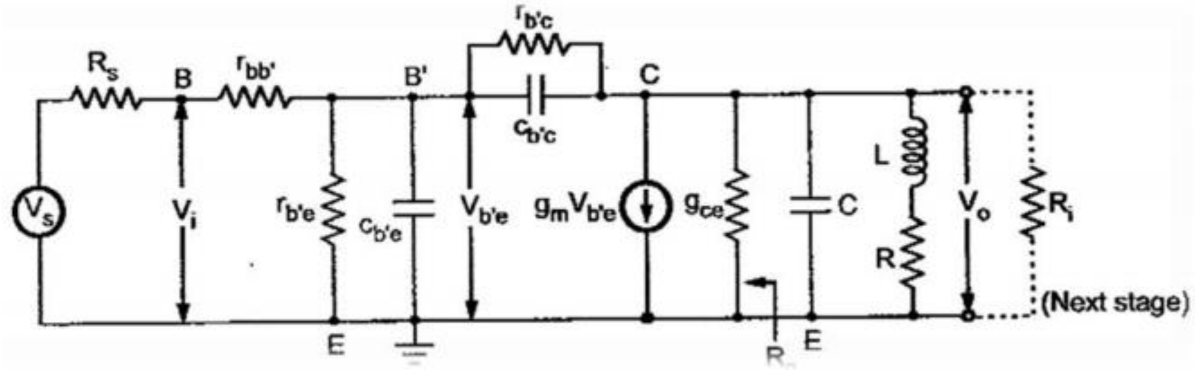
UNIT IV

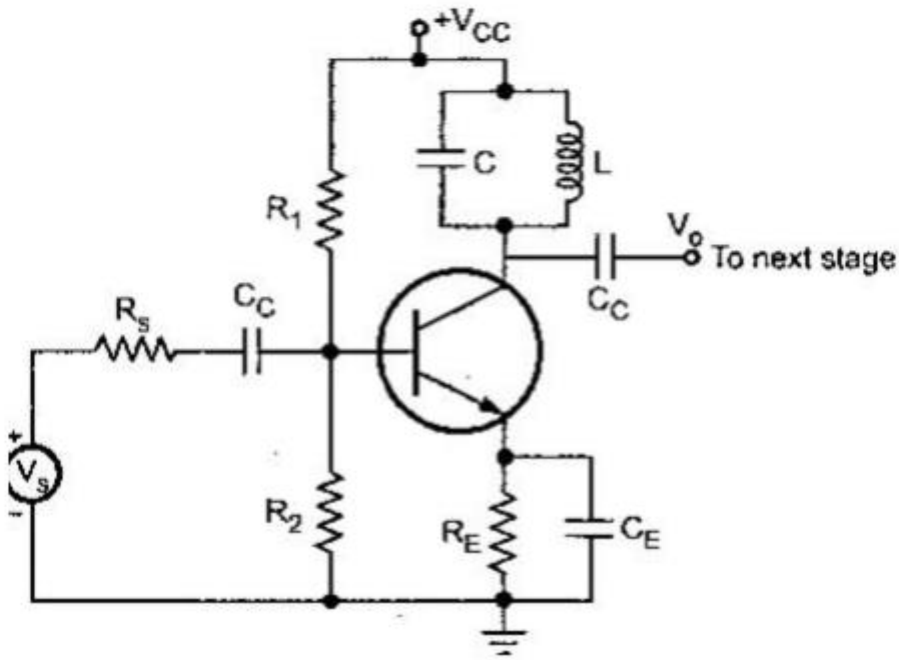
8. a) Derive the equation for the gain bandwidth product of a single tuned amplifier circuit 6M

Sol: Circuit & Equivalent Circuit =3M Derivation=3M

Single Tuned Amplifier

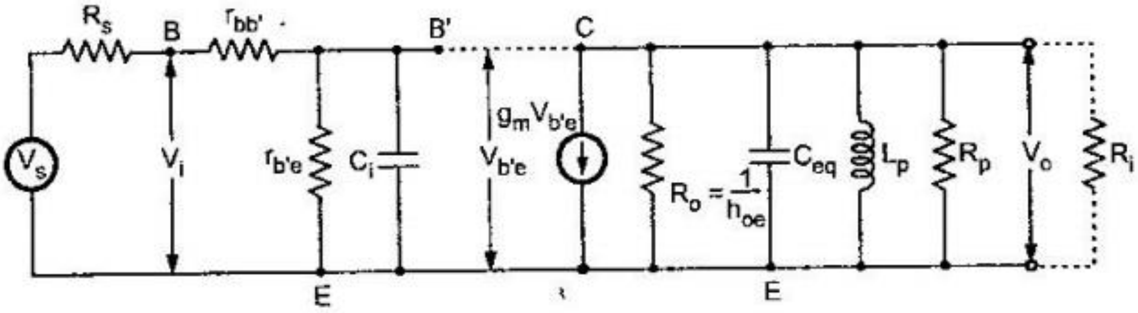
Single tuned amplifier Single Tuned Amplifiers consist of only one Tank Circuit and the amplifying frequency range is determined by it. By giving signal to its input terminal of various Frequency Ranges. The Tank Circuit on its collector delivers High Impedance on resonant Frequency, Thus the amplified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





Ri- input resistance of the next stage R0-output resistance of the generator gmVb'e Cc & CE are negligible small The equivalent circuit is simplified by

The equivalent circuit is simplified by



Simplified equivalent circuit

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

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

Where,

A-Voltage gain of the amplifier

C-tuned circuit capacitance

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

Or

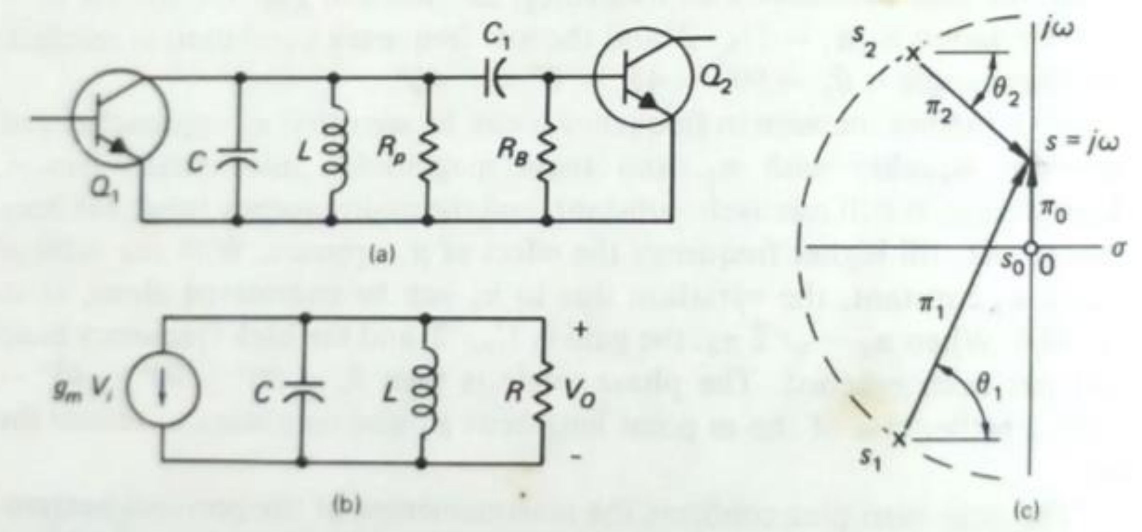


Figure 10.7. (a) Narrow-band interstage coupling; (b) equivalent circuit; (c) pole–zero diagram.

The impedance of the parallel circuit can be written as a function of s:

$$Z(s) = \frac{1}{1/R + 1/sL + sC} \qquad (10.27)$$

Using the voltage gain as $A_v = -g_m Z(s)$, we have

$$A_v(s) = -\frac{g_m}{C}\frac{1}{s^2 + s/CR + 1/LC} \qquad (10.28)$$

we have

$$CR = \frac{Q}{\omega_o} \tag{10.29}$$

Then we can write Eq. 10.27 as

$$A_v(s) = -\frac{g_m}{C}\frac{s}{s^2 + s(\omega_o/Q) + \omega_o^2} \tag{10.30}$$

Factoring the denominator, we have

$$A_v(s) = -\frac{g_m}{C}\frac{s}{(s + s_1)(s + s_2)} \tag{10.31}$$

Equations 10.30 and 10.31 are standard forms for a band-pass response.

The numerator produces a zero at $s = 0$, at the origin. The roots of the denominator are

$$s_1, s_2 = -\frac{\omega_o}{2Q} \pm \sqrt{\frac{\omega_o^2}{4Q^2} - \omega_0^2} \tag{10.32}$$

For narrow-band response, we will have a circuit with large R and large Q, and the real component of pole location, $-\omega_o/2Q$, will be small. The poles at s_1 and s_2 represent a complex-conjugate pair, since the expression for A_v must be real. Then

$$s_1, s_2 = -\frac{\omega_o}{2Q} \pm j\frac{\omega_o}{2Q}\sqrt{4Q^2 - 1} \tag{10.33}$$

A geometric interpretation for Eq. 10.31 follows if the poles and zeros are plotted on the complex plane as in Fig. 10.7(c). From Eq. 10.33 we see that the pole cordinates are

$$x = -\frac{\omega_o}{2Q} \qquad y = \frac{\omega_0}{2Q}\sqrt{4Q^2 - 1}$$

Squaring and adding the results, it is found that

$$x^2 + y^2 = \omega_o^2 \tag{10.34}$$

This shows the locus of the conjugate pole pairs to be a circle of radius ω_o, with center at the origin, and this locus is sketched in Fig. 10.8(a).

With Q values ranging from 50 upward for good selectivity, the distance of the poles from the j axis is very small compared to the distance ω_0 on

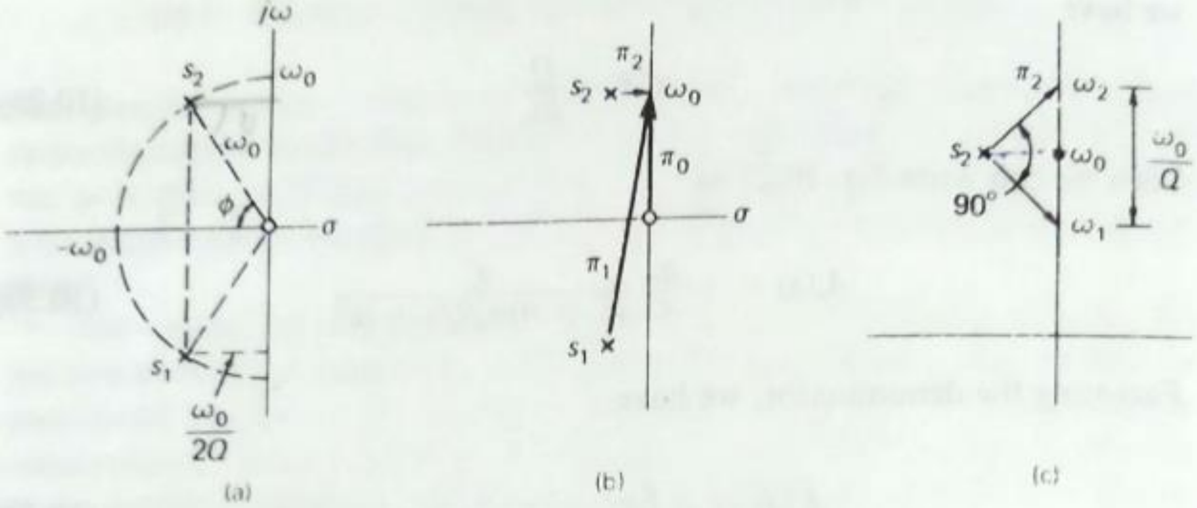


Figure 10.8. (a) Root locus of narrow-band amplifier; (b) variation of factors; (c) at the band limits.

the j axis. This is confirmed by

$$\tan \Phi = \frac{y}{x} \cong \frac{\omega_0}{\omega_0/2Q} = 2Q$$

indicating that Φ is usually an angle in excess of 89°. To accurately portray such a pole location would extend the figure off the page, and Fig. 10.8(b) is only an indication of the situation when $\omega \cong \omega_0$.

The vectors $\pi_o = s_o$, $\pi_1 = (j\omega - s_1)$, and $\pi_2 = (j\omega - s_2)$ are measured on the diagram and transform the gain expression to

$$|A_v(\omega)| = K\frac{\pi_0}{\pi_1\pi_2} \tag{10.35}$$

$$\theta_v = 90° - \theta_1 - \theta_2 \tag{10.36}$$

The point ω traverses all points on the j axis, and the diagram permits visualization of the changes of $|A_v(\omega)|$ with frequency.

As ω approaches ω_o, π_0 and π_1 are large and of magnitude such that $\pi_1/\pi_0 \cong \frac{1}{2}$. These vectors change very slowly with frequency, and their ratio introduces only a constant factor $\frac{1}{2}$ into the gain expression. However, π_2 changes very rapidly in magnitude as ω passes ω_0. Following this reasoning we can predict the resonant-frequency gain as

$$|A_v(\omega)| = -\frac{g_m}{C}\frac{1}{2\pi_2} = -\frac{g_m}{2C\omega_o/2Q}$$

Using $R = Q/\omega_o C$, we have

$$|A_v(\omega)| = -g_m R \tag{10.37}$$

which is the expected result for the CE form of circuit.

The bandwidth is measured at the frequencies at which π_2 is at $\pm 45°$, as in Fig. 10.8(c). At ω_1 or ω_2 we have

$$\pi_2 = \sqrt{2}\frac{\omega_o}{2Q} = \frac{\omega_o}{\sqrt{2}}$$

From the geometry, the bandwidth between ω_1 and ω_2 is

$$BW = \frac{2\pi_2}{\sqrt{2}} = \frac{\omega_o}{Q}$$

in radians, or

$$BW = \frac{f_0}{Q} \qquad (10.38)$$

in hertz. This is the previously obtained result.

Thus we have demonstrated some of the properties of the pole-zero diagram.

b) A tank circuit has capacitor of 100pf and an inductor of 150µH. The series resistance is 15Ω find the impedance and bandwidth of a resonant circuit. 6M

$$w_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{100PX150\mu}} = 8.16\,M\,radian$$

$$R_{P=} \frac{w_o^2\,L^2}{R_S} = \frac{(8.16XM)^2(150\mu)^2}{15} = 99.87K$$

$Q = R_P\sqrt{\frac{C}{L}}$ =99.87K$\sqrt{\frac{100P}{150\mu}}$ =99.87X.8164=81.54

Band width=$\frac{f_o}{Q} = \frac{8.16M}{2X\pi X81.54} = 15.9KHz.$

Sol: Impedance =3M

Bandwidth = 3M

(OR)

9. a) Draw and explain the double tuned amplifier in detail. 6M

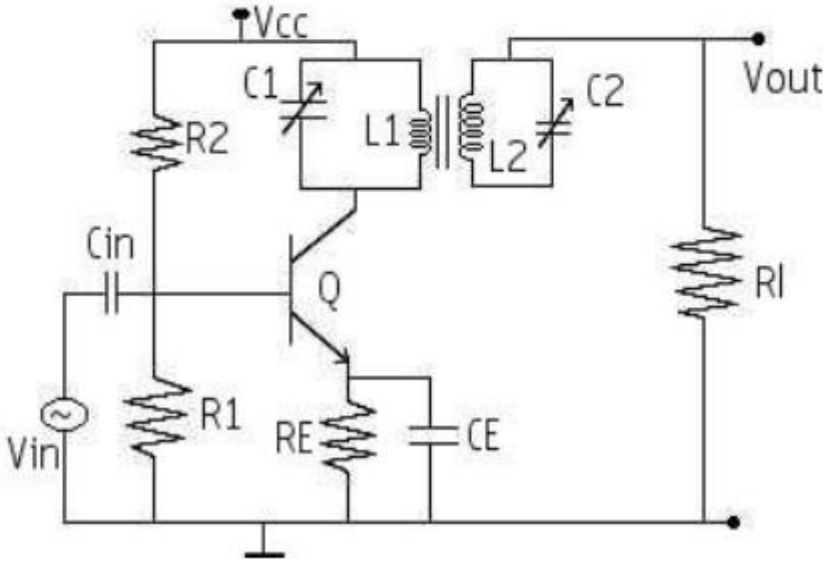
Sol: Circuit =2M, Equivalent Circuit=2M, Explanation = 2M

<u>Double tuned amplifier:</u>

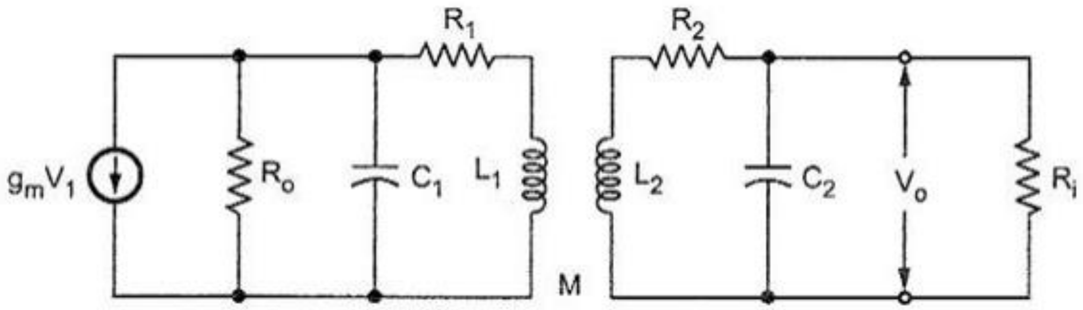
An amplifier that uses a pair of mutually inductively coupled coils where both primary and secondary are tuned, such a circuit is known as "double tuned amplifier". Its response will provide substantial rejection of frequencies near the pass band as well as relative flat pass band response. The disadvantage of POTENTIAL INSTABILITY in single tuned amplifiers can be overcome in Double tuned amplifiers. A double tuned amplifier consists of inductively coupled two tuned circuits. One L1, C1 and the other L2, C2 in the Collector terminals. A change in the coupling of the two tuned circuits results in change in the shape of the Frequency response curve.

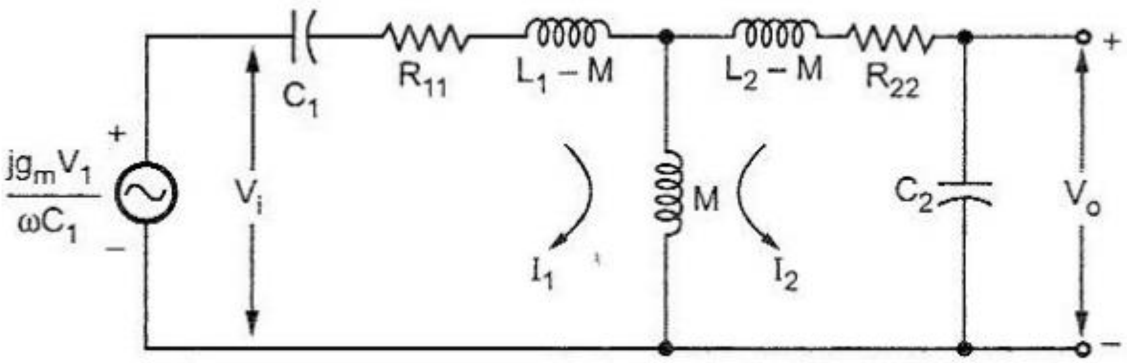
By proper adjustment of the coupling between the two coils of the two tuned circuits, the required results (High selectivity, high Voltage gain and required bandwidth) may be obtained. Operation: The high Frequency signal to be amplified is applied to the input terminal of the amplifier. The resonant Frequency of TUNED CIRCUIT connected in the Collector circuit is made equal to signal Frequency by varying the value of C1. Now the tuned circuit L1, C1 offers very high Impedance to input signal Frequency and therefore, large output is developed across it. The output from the tuned circuit L1,C1 is transferred to the second tuned circuit L2, C2 through Mutual Induction. Hence the Frequency response in Double Tuned amplifier depends on the Magnetic Coupling of L1 and L2 Equivalent circuit of double tuned amplifier:

Equivalent circuit of double tuned amplifier:



Equivalent circuit of double tuned amplifier:





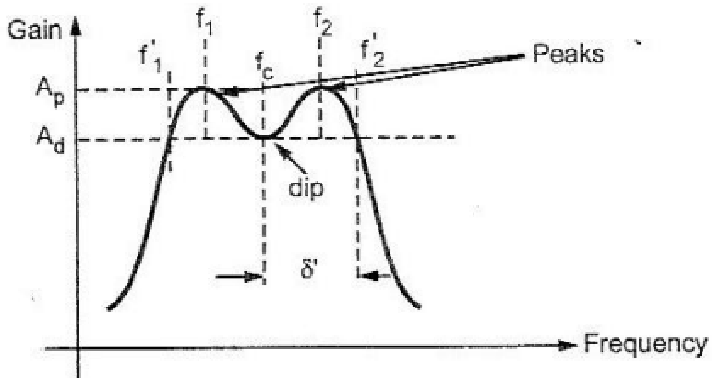
$$\dot{Y}_T = \frac{kQ^2}{\omega_r \sqrt{L_1 L_2}\left[4Q\delta - j(1+k^2Q^2-4Q^2\delta^2)\right]}$$

$$|A_v| = g_m \omega_r \sqrt{L_1 L_2}\, Q \frac{kQ}{\sqrt{1+k^2Q^2-4Q^2\delta^2+16Q^2\delta^2}}$$

Two gain peaks in frequencies f_1 and f_2

$$f_1 = f_r\left(1-\frac{1}{2Q}\sqrt{k^2Q^2-1}\right) \text{ and}$$

$$f_2 = f_r\left(1+\frac{1}{2Q}\sqrt{k^2Q^2-1}\right)$$



AT

$$k^2Q^2 = 1, \text{ i.e. } k = \frac{1}{Q}, f_1 = f_2 = f_r.$$

This condition is known as critical coupling.

For the values of $k<1/Q$ the peak gain is less than the maximum gain and the coupling is poor. For the values $k>\frac{1}{Q}$, the circuit is overcoupled and the response shows double peak. This double peak is useful when more bandwidth is required

The gain magnitude at peak is given as,

$$|A_p| = \frac{g_m \omega_o \sqrt{L_1 L_2}\, kQ}{2}$$

And gain at the dip at $\delta = 0$ is given as,

$$|A_d| = |A_p| \frac{2kQ}{1+k^2Q^2}$$

The ratio of peak and dip gain is denoted as γ and it represents the magnitude of the ripple in the gain curve.

$$\gamma = \left|\frac{A_p}{A_d}\right| = \frac{1+k^2Q^2}{2\,kQ}$$

Using quadratic simplification and positive sign

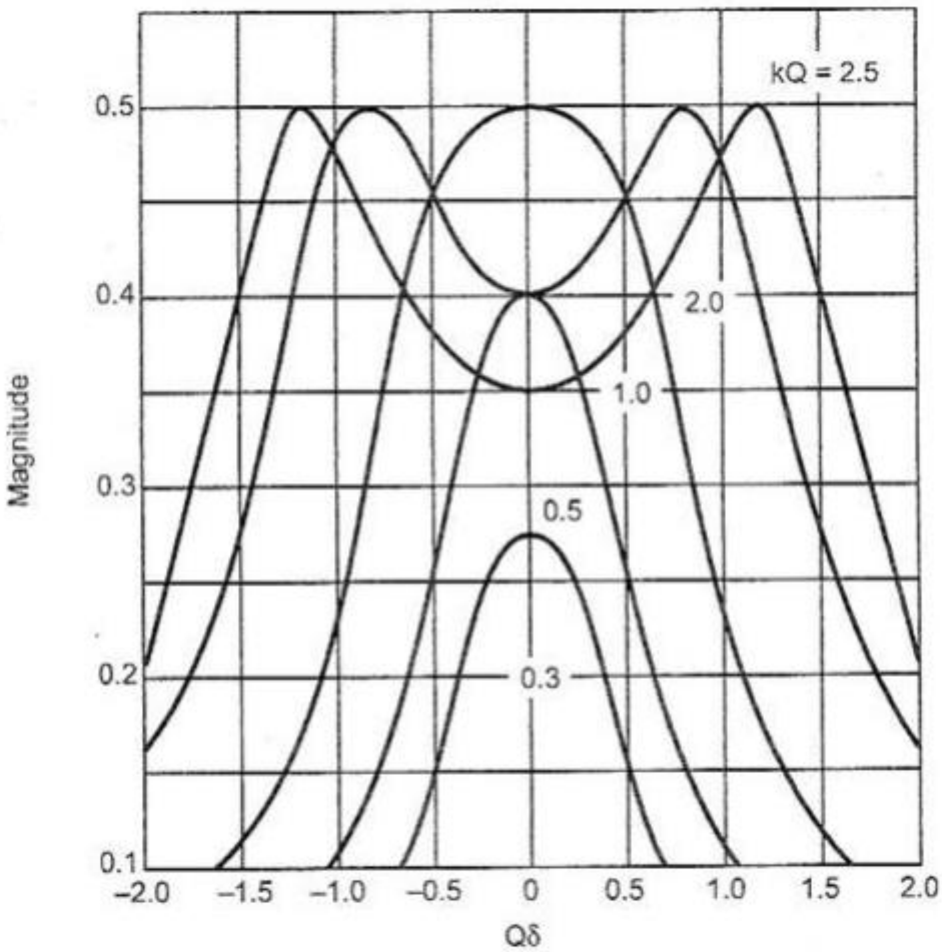
$$kQ = \gamma + \sqrt{\gamma^2 - 1}$$

Bandwidth:

$$BW = 2\,\delta' = \sqrt{2}\,(f_2 - f_1)$$

At 3dB Bandwidth

$$3\text{ dB BW} = \frac{3.1\,f_r}{Q}$$



b) Draw and explain stagger tuned amplifier 6M

Sol: Circuit =2M, Pole Zero Diagram =2M, Explanation = 2M

stagger tuned amplifier:

In this configuration one or more tuned amplifiers are cascaded each amplifier stage is tuned to different frequencies. This results in decreased gain and increased bandwidth.

A cascade of *stagger-tuned circuits*, as in Fig. 10.17(a), may be employed to provide a wide pass-band response along with a reduction of skirt response to give a closer approach to the ideal response rectangle. With the several resonant circuits isolated by the amplifiers, the adjustment is simple, and the method may be extended to three or four stages, to provide a wide response band. The flatness of the top of the response, as well as the magnitude of any response ripple, is dependent on the spacing and sharpness of the separate resonances, or the placement of the mathematical poles in a pole-zero analysis.

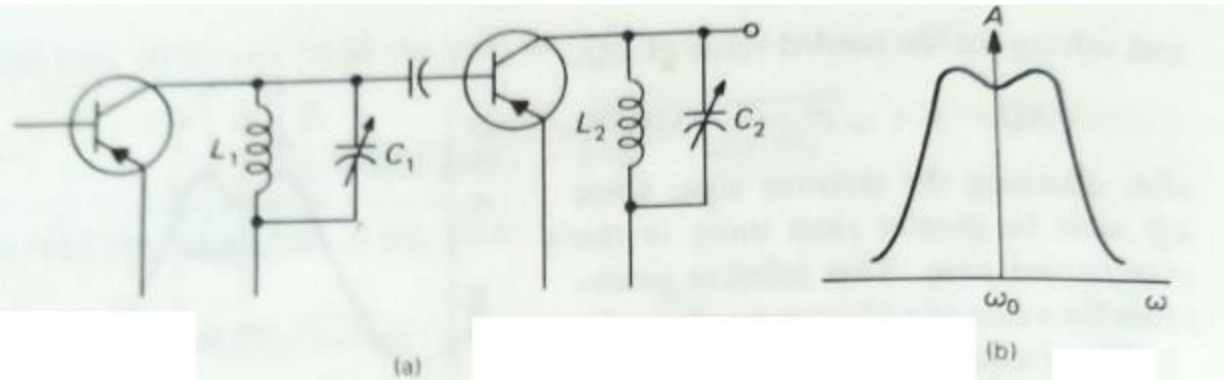
The amplifiers of the figure have gains

$$A_1(s) = -g_m Z_1(s)$$

where the impedance of the resonant circuit is

$$Z_1(s) = \frac{1}{C_1} \frac{s}{(s + s_1)(s + s_1^*)}$$

where s_1^* indicates the usual conjugate root. Each stage has a similar function



(a) (b)

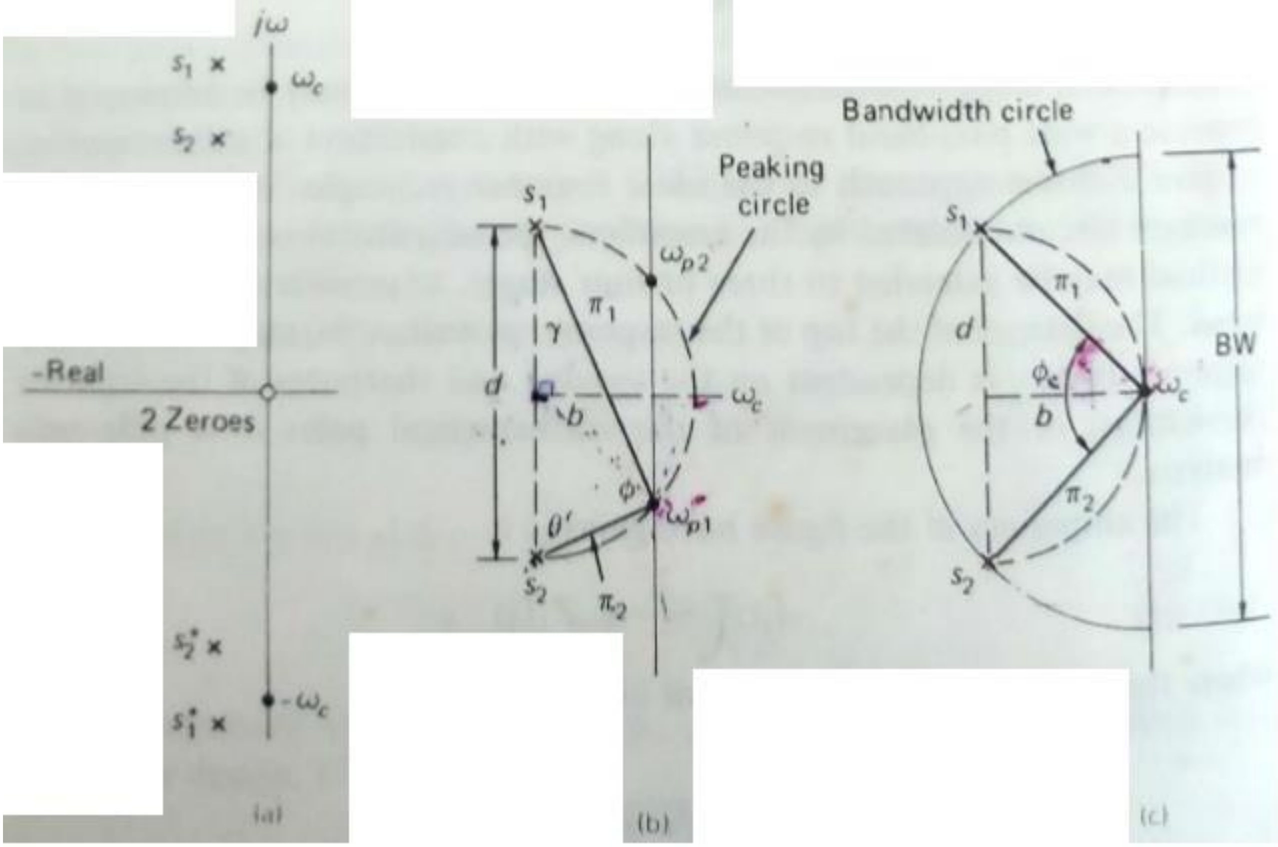
Stagger-tuned pair.

with differing resonant frequencies and poles, and an amplifier has, in general, a gain function as

$$A(s) = \frac{g_{m1} g_{m2} \cdots g_{mn}}{C_1 C_2 \cdots C_n} \frac{s^n}{(s + s_1)(s + s_1^*)(s + s_2)(s + s_2^*) \cdots (s + s_n)(s + s_n^*)}$$

A two-circuit example will parallel the results of Section 10.12. The region around the frequency $+\omega_c$ and encompassing the positive frequency poles can be expanded as in Fig. 10.18(b). The pole coordinate on the real axis is

$$b = -\frac{\omega_o}{2Q_1}$$



(a) Pole locations for $n = 2$; (b) at peak gain; (c) for maximal flatness.

The frequency ω_c is the center frequency of the two poles, with the poles separated by the distance d on the diagram. The gain $A(s)$ varies as

$$A(s) = H\frac{1}{\pi_1\pi_2} \qquad (1\quad)$$

The triangle formed by π_1, π_2, and d can be studied by use of the law of sines:

$$\frac{\pi_1}{\sin\theta} = \frac{\pi_2}{\sin\gamma} = \frac{d}{\sin\Phi}$$

From Fig. 10.18(b),

$$\sin\theta = \frac{b}{\pi_2} \qquad \text{and} \qquad \sin\gamma = \frac{b}{\pi_1}$$

so

$$\pi_1\pi_2 = \frac{bd}{\sin\Phi}$$

thus resolving the gain, Eq. 1 into a function of one variable, $\sin\Phi$. Then

$$A(s) = H\frac{\sin\Phi}{bd}$$

As ω increases toward ω_{p1}, the angle Φ increases and the gain
At $\omega = \omega_{p1}$, the angle $\Phi = 90^\circ$ and the gain is at a maximum. As ω m
up from ω_{p1} toward ω_c, the angle $\Phi > 90^\circ$ and the gain falls. The conditi
$\Phi = 90^\circ$ requires that π_1 and π_2 intersect on the *peaking circle* of diar
d. But this intersection must also occur on the j axis, and so there are
frequencies of maximum gain, ω_{p1} and ω_{p2}. With $d/2$ as the radius o
peaking circle, the geometry of the triangle leads to

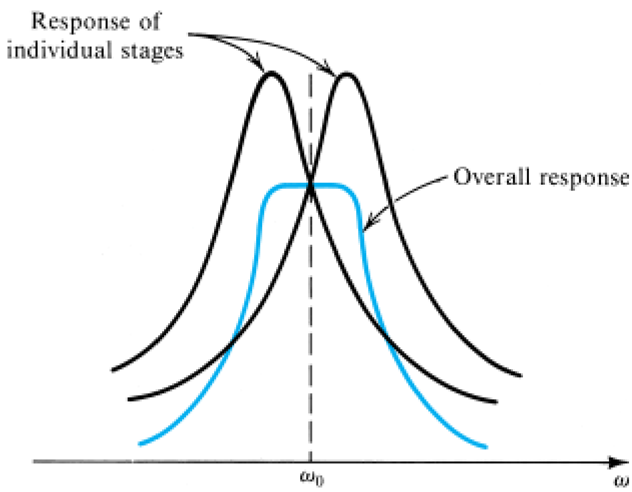
$$\omega_p - \omega_c = \sqrt{\left(\frac{d}{2}\right)^2 - b^2}$$

When the pole separation is $d = 2b$, the peaking circle is located
Fig. 10.18(c), just tangent to the $j\omega$ axis. The value of $\Phi = 90^\circ$ occu
$\omega = \omega_c$, and only one peak is obtained.

A *bandwidth circle* may be drawn through the poles, with its cent
ω_c. The diameter is $\sqrt{2}\,d$ or $\sqrt{2}(f_2 - f_1)$. Therefore, the diameter i
bandwidth of the double-peaked circuit, and

$$d = \frac{BW}{\sqrt{2}} \quad (1$$

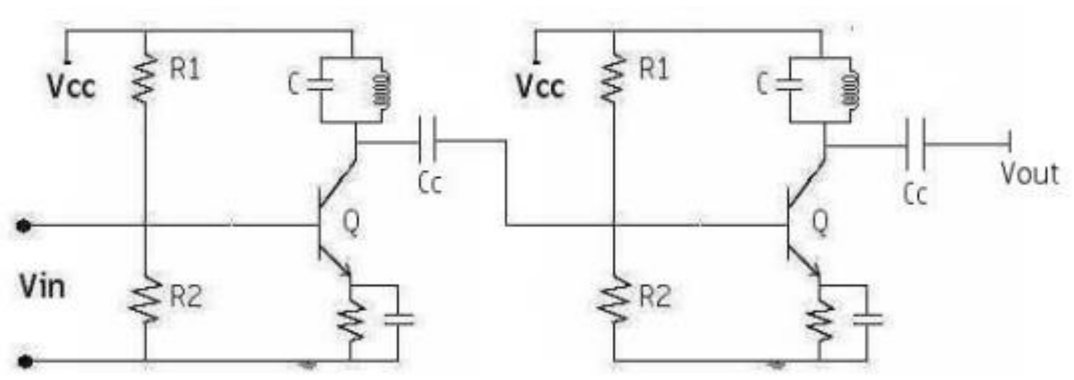
is useful in design. This is the condition of *maximally flat response*.



OR

Double tuned amplifier gives greater 3 dB bandwidth having steeper sides and flat top. But alignment of double tuned amplifier is difficult. To overcome this problem two single tuned cascaded amplifiers having certain bandwidth are taken and their resonant frequencies are so 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 staggered tuned amplifiers. If it is desired to build a wide band high gain amplifier, one procedure is to use either single tuned or double tuned circuits which have been heavily loaded so as to increase the bandwidth. The gain per stage is correspondingly reduced, by virtue of the constant gain-bandwidth product. The use of a cascaded chain of stages will provide for the desired gain. Generally, for a specified gain and bandwidth the double tuned cascaded amplifier is preferred, since fewer tubes are often possible, and also since the pass-band characteristics of the double tuned cascaded chain are more favourable, falling more sensitive to variations in tube capacitance and coil inductance than the single tuned circuits.

Circuit diagram:



Stagger Tuned Amplifiers are used to improve the overall frequency response of tuned Amplifiers. Stagger tuned Amplifiers are usually designed so that the overall response exhibits maximal flatness around the centre frequency. It needs a number of tuned circuits operating in union. The overall frequency response of a Stagger tuned amplifier is obtained by adding the individual response together. Since the resonant Frequencies of different tuned circuits are displaced or staggered, they are referred as STAGGER TUNED AMPLIFIER. The main advantage of stagger tuned amplifier is increased bandwidth. Its Drawback is Reduced Selectivity and critical tuning of many tank circuits. They are used in RF amplifier stage in Radio Receivers. Analysis: Gain of the single tuned amplifier:

$$\frac{A_v}{A_v\ (\text{at resonance})_1} = \frac{1}{1+j(X+1)}$$

$$\frac{A_v}{A_v\ (\text{at resonance})_2} = \frac{1}{1+j(X-1)}$$

where $X = 2\,Q_{eff}\,\delta$

Gain of the cascaded amplifier:

$$\frac{A_v}{A_v\ (\text{at resonance})_{cascaded}} = \frac{A_v}{A_v\ (\text{at resonance})_1} \times \frac{A_v}{A_v\ (\text{at resonance})_2}$$

$$\left|\frac{A_v}{A_v\ (\text{at resonance})}\right|_{cascaded} = \frac{1}{\sqrt{4+(2Q_{eff}\,\delta)^4}} = \frac{1}{\sqrt{4+16\,Q_{eff}^4\,\delta^4}}$$

$$= \frac{1}{2\sqrt{1+4\,Q_{eff}^4\,\delta^4}}$$