UNIT III
TUNED AMPLIFIER

3.1 Introduction

In order to pick up and amplify the desired frequency, the resistive load (R_C) replaced by a tuned circuit. This tuned circuit is capable of selecting a particular frequency and rejecting all the other frequency. An amplifier with this tuned circuit as a load is known as **tuned amplifier**.

Tuned amplifier used for amplifying narrow band of frequency hence it is also known as **Narrow Band Amplifier**.

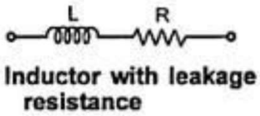
3.2 Need for Tuned Amplifier

In a radio receiver or TV receiver, it is necessary to select a particular channel among the all other channels available.

A tuned circuit generally uses either a variable capacitor or variable inductor for adjusting the resonant frequency at the center of the band of frequency to be amplified.

3.3 Coil Losses

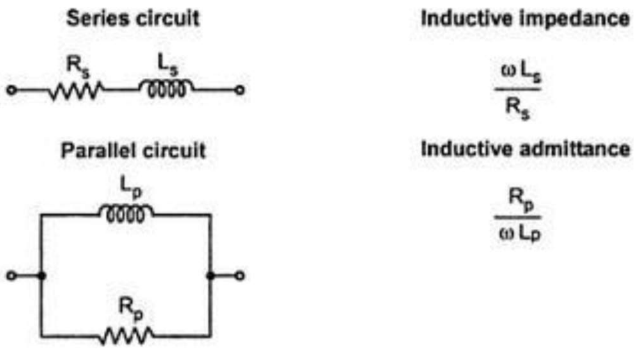
The tuned circuit consists of a coil. Practically, coil is not purely inductive. It consists of few losses and they are represented in the form of leakage resistance in series with the inductor.



The total loss in the coil or inductor is represented by inductance in series with leakage resistance of the coil.

3.4 Q factor

Quality factor is important characteristic of an inductor. It is defined as the measure of efficiency with the inductor can store the energy.



$$Q = \frac{\omega L_S}{R_S} = \frac{R_P}{\omega L_P}$$

3.5Classification of Tuned Amplifier

Tuned Amplifier may be divided into two categories:

1. Small Signal Tuned Amplifier.
2. Large Signal Tuned Amplifier.

3.5.1 Small Signal Tuned Amplifier

Small Signal Tuned Amplifier are operated in class A mode and power involved is small and the distortion is also negligibly small. It can be further classified as

i. **Single Tuned Amplifier**
It uses one parallel tuned circuit as the load in each stage and all these tuned circuit in different stages are tuned to the same frequency.

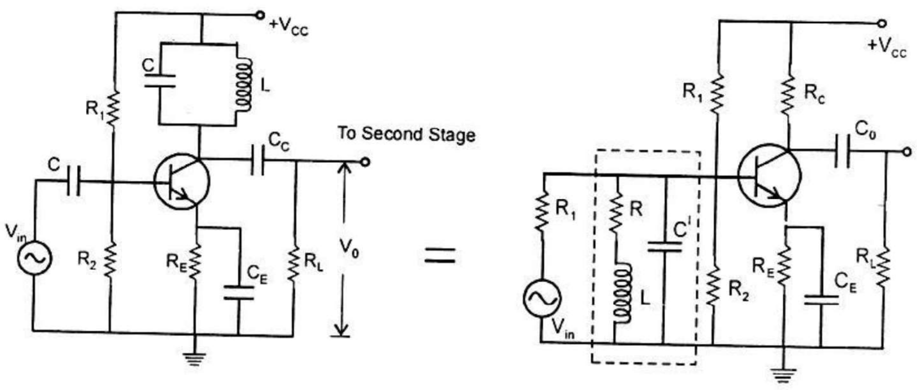
ii. **Double Tuned Amplifier**
It uses two inductively coupled tuned circuits per stage, both tuned circuit being tuned to the same frequency.

iii. **Stagger Tuned Amplifier**
It uses a number of single tuned stages in cascade, the successive tuned circuits being tuned to slightly different frequency.

3.5.2 Large Signal Tuned Amplifier

These amplifiers operated under class B or class C mode. Here distortion gets increased, but the tuned circuit itself eliminates most of the harmonic distortion.

3.6 Signal Tuned Amplifier (Capacitive Coupling)



(i) tuned circuit connected at output side (ii) tuned circuit connected at input side

Figure shows CE single tuned capacitively coupled amplifier in which the output of the first stage is given to the input of second stage.

3.6.1 Construction

The resistor R_1R_2 provides a potential divider bias and R_eC_e provides the thermal stabilization thus it fix up operating point. The tuned circuit may be connected either input or output side.

3.6.2 Working

The signal to be amplified is applied between the inputs. The tank circuit is tuned in such a way that the resonant frequency becomes equal to the frequency of the input signal. At resonance the tuned circuit offers very high impedance and the given input signal is amplified by the amplifier and applas with large value across it and other frequencies will be rejected.

The gain and bandwidth of the single tuned amplifier is derived as follows

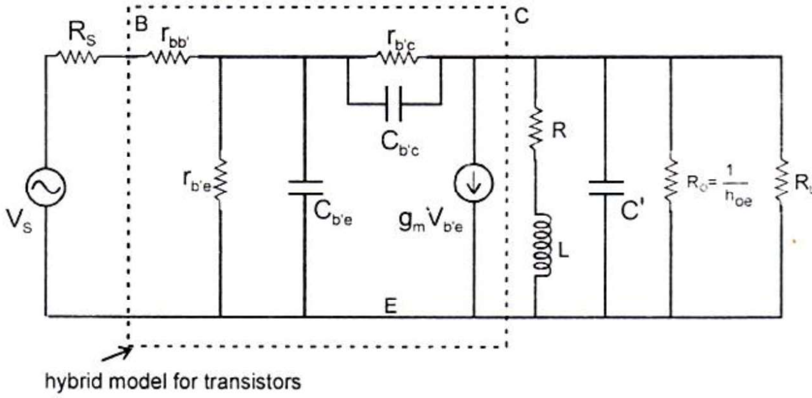


Fig: Hybrid equivalent circuit

Using miller theorem the above circuit is redraw as

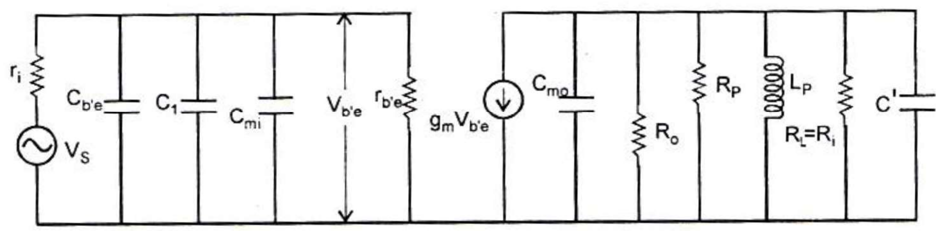


Fig: Miller equivalent circuit

Where

$$C_{mi} = C_{b'c}(1 + g_m R_L) \quad and \quad C_{mo} = C_{b'c}\left(\frac{1 - g_m R_L}{g_m R_L}\right)$$

The admittance of the series branch inductor is given by,

$$Y = \frac{1}{R + j\omega L} = \frac{R - j\omega L}{R^2 + \omega^2 L^2} = \frac{R}{R^2 + \omega^2 L^2} - \frac{j\omega L}{R^2 + \omega^2 L^2} \ldots\ldots\ldots\ldots\ldots (1)$$

In general, the admittance of the parallel circuit is given by,

$$Y = \frac{1}{R_P} + \frac{1}{j\omega L_P} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Comparing (1) & (2)

$$R_P = \frac{R^2 + \omega^2 L^2}{R} \; \& \; \omega L_P = \frac{R^2 + \omega^2 L^2}{\omega L}$$

At resonant frequency, $\omega L \gg R$

$$R_P = \frac{R^2+\omega^2L^2}{R} \approx \frac{R\left(R+\frac{\omega^2L^2}{R}\right)}{R} \approx \frac{\omega^2L^2}{R} = \omega L Q_0) \;\ldots\ldots\ldots\ldots\ldots..(3)$$

Where $Q_0 = \frac{R_P}{\omega L}$

Similarly

$$L_P = \frac{R^2+\omega^2L^2}{\omega^2L} \approx \frac{R^2}{\omega^2L} + L \approx L$$

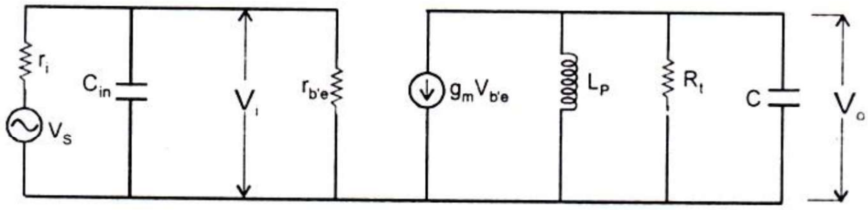


Fig: Simplified equivalent circuit

Where

$C_{in} = C_1 + C_{b'e} + C_{mi}$

$C = C_{mo} + C'$

$C' -$ *External copacitance*

$C_1 -$ *stray capacitance*

The output admittance of the circuit is given by

$$Y = \frac{1}{Z} = \frac{1}{R_t} + \frac{1}{j\omega L} + j\omega C$$

Where

$$\frac{1}{R_t} = \frac{1}{R_0} + \frac{1}{R_P} + \frac{1}{R_L}$$

$$Y = \frac{1}{R_t}\left(1 + \frac{R_t}{j\omega L} + j\omega C R_t\right)$$

$$= \frac{1}{R_t}\left(1 + \frac{R_t}{j\omega L}\frac{\omega_0}{\omega_0} + j\omega C R_t \frac{\omega_0}{\omega_0}\right)$$

$$Y = \frac{1}{R_t}\left(1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)\right)$$

Where

$Q_0 = \frac{R_t}{\omega_0 L} = \omega_0 C R_t$ for parallel resonant circuit,

$$Z = \frac{1}{Y} = \frac{R_t}{1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)}$$

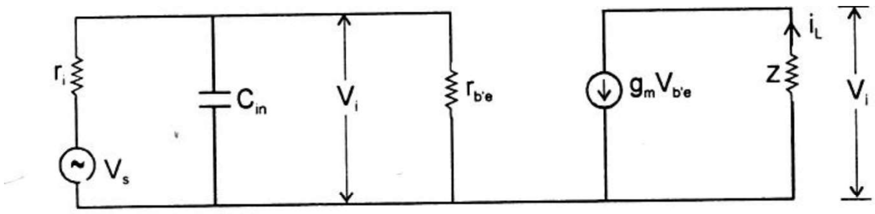
The selectivity is given by

$$\delta = \frac{\omega - \omega_0}{\omega_0} = \frac{\omega}{\omega_0} - 1 \;(OR)\; \frac{\omega}{\omega_0} = 1 + \delta$$

$$Z = \frac{1}{Y} = \frac{R_t}{1 + jQ_0\left(1 + \delta - \frac{1}{1+\delta}\right)}$$

$$= \frac{R_t}{1 + jQ_0\delta\left(\frac{\delta+2}{\delta+1}\right)}$$

$$Z = \frac{R_t}{1 + jQ_0\delta 2\left(\frac{1+\delta/2}{\delta+1}\right)} \approx \frac{R_t}{1 + j2Q_0\delta}$$



At resonance $\delta = 0$ $hence\ z = R_t$

From the equivalent circuit,

$$i_L = -g_m V_{b'e} \text{but } V_{b'e} = V_i \& V_0 = i_L Z$$

$$A_V = \frac{V_0}{V_i} = \frac{= -g_m V_{b'e} Z}{V_i} = -g_m Z \approx -\frac{g_m R_t}{1 + j2Q_0\delta}$$

The gain at mid frequency or resonance $\delta = 0$ &$A_V = A_{Vres}$ is given by,

$$A_{Vres=} - g_m R_t$$

$$A_V = \frac{A_{Vres}}{1 + j2Q_0\delta}(OR)\frac{A_V}{A_{Vres}} = \frac{1}{1 + j2Q_0\delta}$$

$$\left|\frac{A_V}{A_{Vres}}\right| = \frac{1}{\sqrt{1 + (2Q_0\delta)^2}}$$

3 dB cutoff frequency.

$$\left|\frac{A_V}{A_{Vres}}\right| = \frac{1}{\sqrt{1 + (2Q_0\delta)^2}} = \frac{1}{\sqrt{2}}$$

$$\sqrt{1 + (2Q_0\delta)^2} = \sqrt{2}$$

$$1 + (2Q_0\delta)^2 = 2$$

$$1 + 4Q_0^2\delta^2 = 2$$

$$\delta^2 = \frac{1}{4Q_0^2}(OR)\delta = \pm\frac{1}{2Q_0}$$

Lower cutoff frequency

$$\delta = -\frac{1}{2Q_0}$$

$$\frac{\omega - \omega_0}{\omega_0} = -\frac{1}{2Q_0}$$

$$\frac{f-f_0}{f_0}=-\frac{1}{2Q_0}$$

$$f-f_0=-\frac{f_0}{2Q_0}$$

For lower cutoff frequency $f=f_1$

$$f_1-f_0=-\frac{f_0}{2Q_0}$$

Upper cutoff frequency

$$\delta=\frac{1}{2Q_0}$$

$$\frac{\omega-\omega_0}{\omega_0}=\frac{1}{2Q_0}$$

$$\frac{f-f_0}{f_0}=\frac{1}{2Q_0}$$

$$f-f_0=\frac{f_0}{2Q_0}$$

For upper cutoff frequency $f=f_2$

$$f_2-f_0=\frac{f_0}{2Q_0}$$

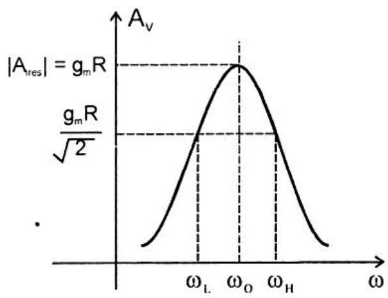
Bandwidth=Upper cutoff frequency-Lower cutoff frequency

$$BW=f_2-f_1=(f_2-f_0)+(f_0-f_1)$$

$$=\frac{f_0}{2Q_0}+\frac{f_0}{2Q_0}=\frac{2f_0}{2Q_0}=\frac{f_0}{Q_0}$$

$$=\frac{\omega_0}{2\pi Q_0}=\frac{1}{2\pi R_t C}$$

3.6.3 Frequency Response of Single Tuned Amplifier



Gain Bandwidth Product = $|A_{Vres}|\times BW$

$$GBW=g_m R_t\times\frac{1}{2\pi R_t C}$$

$$\boldsymbol{GBW=\frac{g_m}{2\pi C}}$$

3.7 Synchronously Tuned Amplifier

Synchronously tuned amplifier can be defined as cascading tuned amplifiers in order to achieve high gain and bandwidth. All amplifier stages are assumed to be identical and to be tuned to the same frequency due to which the amplifier has increased gain and bandwidth.

To illustrate the effect of cascading N synchronously tuned stages, we determine the gain bandwidth of single tuned FET amplifier shown in fig.

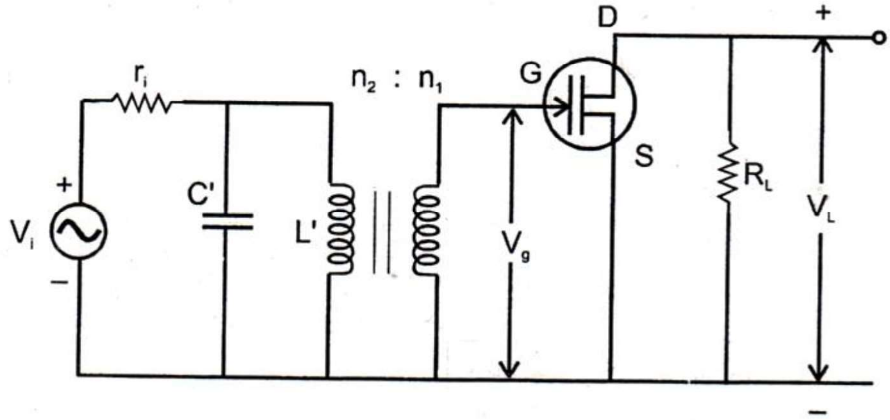


Fig: Synchronously Tuned Amplifier

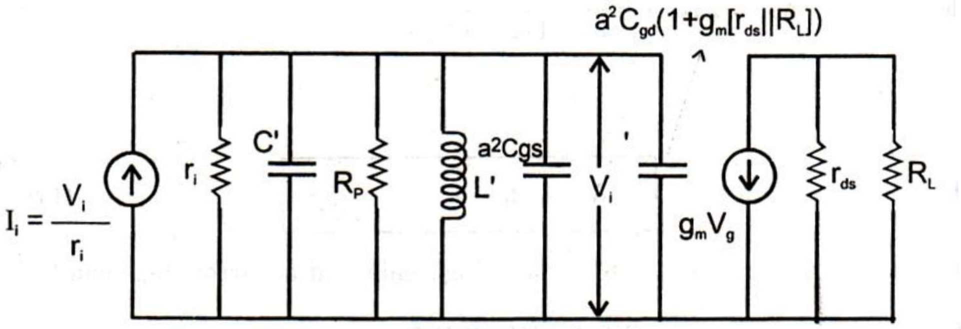


Fig: equivalent circuit for Synchronously Tuned Amplifier

Let

$$C_1 = a^2C_{gs} + a^2C_{gd}[1 + g_m(r_{ds} \parallel R_L)]$$
$$c = C_1 + C' \text{ and } R_L' = R_L \parallel r_{ds} R = r_i \parallel R_P$$

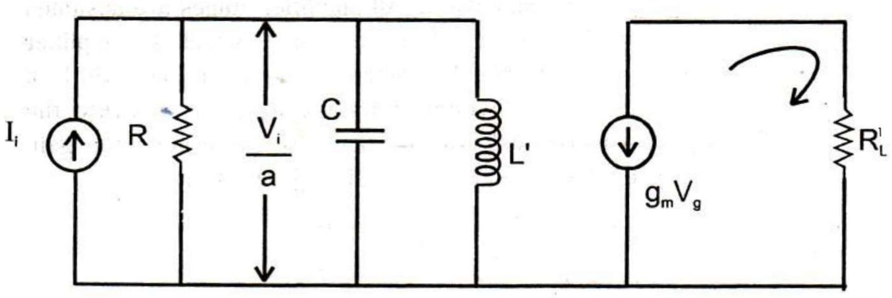


Fig: Simplified equivalent circuit

The admittance of the input circuit is given by,

$$Y = \frac{1}{Z} = \frac{1}{R} + \frac{1}{j\omega L} + j\omega C$$

$$Y = \frac{1}{R}\left(1 + \frac{R}{j\omega L} + j\omega CR\right)$$

$$= \frac{1}{R}\left(1 + \frac{R}{j\omega L}\frac{\omega_0}{\omega_0} + j\omega CR\frac{\omega_0}{\omega_0}\right)$$

$$Y = \frac{1}{R}\left(1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)\right)$$

We know,

$$i_L = -g_m V_g \quad and \quad V_L = i_L R_L$$

Using transformer theory we get $V_g = aV_i$

$$V_i = I_i Z = \frac{I_i}{Y} = \frac{I_i R}{1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)}$$

$$V_g = \frac{aI_i R}{1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)}$$

$$i_L = -g_m V_g = \frac{-g_m a I_i R}{1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)}$$

Current gain is given by,

$$A_i = \frac{I_L}{I_i} = \frac{-g_m a R}{1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)}$$

The voltage gain is given by,

$$A_v = A_i \times \frac{R'_L}{r_i} = \frac{-g_m a R}{1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)} \times \frac{R'_L}{r_i}$$

Substitute R'_L&R in above equation,

$$A_v = \frac{-g_m a(r_i \parallel R_P)}{1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)} \times \frac{R_L \parallel r_{ds}}{r_i}$$

At center frequency when $\omega = \omega_0 \& A_v = A_{vres}$

$$A_{vres} = \frac{-g_m a(R_P)R_L \parallel r_{ds}}{r_i + R_P}$$

The 3dB bandwidth is given by

$$BW = \frac{1}{2\pi RC} = \frac{1}{2\pi(r_i \parallel R_P)(C_1 + C')}$$

$$GBW = \frac{a g_m \frac{R_L'}{r_i}}{2\pi C}$$

If two identical stages are connected in cascade and tuned to same frequency with same bandwidth then, voltage gain of amplifier is given by,

$$A_v = \frac{V_L}{V_i} = \frac{(g_m a R)^2 \left(\frac{R_L'}{r_i}\right)^2}{\left(1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)\right)^2}$$

The center frequency when $\omega = \omega_0 \& A_v = A_{vres}$

$$A_{vres} = (g_m a R)^2 \left(\frac{R_L'}{r_i}\right)^2$$

$$A_v = \frac{A_{vres}}{\left(1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)\right)^2}$$

$$\frac{A_v}{A_{vres}} = \frac{1}{\left(1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)\right)^2}$$

$$\left|\frac{A_v}{A_{vres}}\right| = \left|\frac{1}{\left(1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)\right)^2}\right| = \frac{1}{\sqrt{\left(1 + Q_0^2\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)^2\right)^2}}$$

3 dB cutoff frequency.

$$\left|\frac{A_v}{A_{vres}}\right| = \frac{1}{\sqrt{\left(1 + Q_0^2\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)^2\right)^2}} = \frac{1}{\sqrt{2}}$$

$$\sqrt{\left(1 + Q_0^2\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)^2\right)^2} = \sqrt{2}$$

$$\left(1+Q_0^2\left(\frac{\omega}{\omega_0}-\frac{\omega_0}{\omega}\right)^2\right)^2=2$$

The selectivity is given by

$$\delta=\frac{\omega-\omega_0}{\omega_0}=\frac{\omega}{\omega_0}-1\ (OR)\frac{\omega}{\omega_0}=1+\delta$$

$$\left(1+Q_0^2\left(1+\delta-\frac{1}{1+\delta}\right)^2\right)^2=2$$

$$\left(1+Q_0^2\delta^2\left(\frac{\delta+2}{\delta+1}\right)^2\right)^2=2$$

$$\left(1+Q_0^2\delta^2 4\left(\frac{1+\delta/2}{\delta+1}\right)^2\right)^2=2$$

$$(1+4Q_0^2\delta^2)^2=2$$

$$1+4Q_0^2\delta^2=2^{1/2}$$

$$4Q_0^2\delta^2=2^{1/2}-1$$

$$4Q_0^2\delta^2=2^{1/2}-1$$

$$\delta^2=\frac{1}{4Q_0^2}\times 2^{1/2}-1$$

$$\delta=\pm\frac{1}{2Q_0}\sqrt{2^{1/2}-1}$$

$$f-f_0=\pm\frac{f_0}{2Q_0}\sqrt{2^{1/2}-1}$$

$$Bandwidth=\frac{f_0}{Q_0}\sqrt{2^{1/2}-1}(OR)\frac{\omega_0}{2\pi Q_0}\sqrt{2^{1/2}-1}$$

$$BW=\frac{0.693f_0}{Q_0}=\frac{0.693}{2\pi RC}$$

For n stages $\boldsymbol{Bandwidth=\frac{\omega_0}{2\pi Q_0}\sqrt{2^{1/n}-1}}$

The result of cascading two synchronously tuned stages is to increase the voltage gain and decrease bandwidth.

3.8 Double Tuned Amplifier

An amplifier that uses a pair of mutually inductively coupled coils where both primary and secondary are tuned, such a tuned circuit is known as **double tuned amplifier**.

These amplifiers are mainly used as amplifier in radio and television receivers.

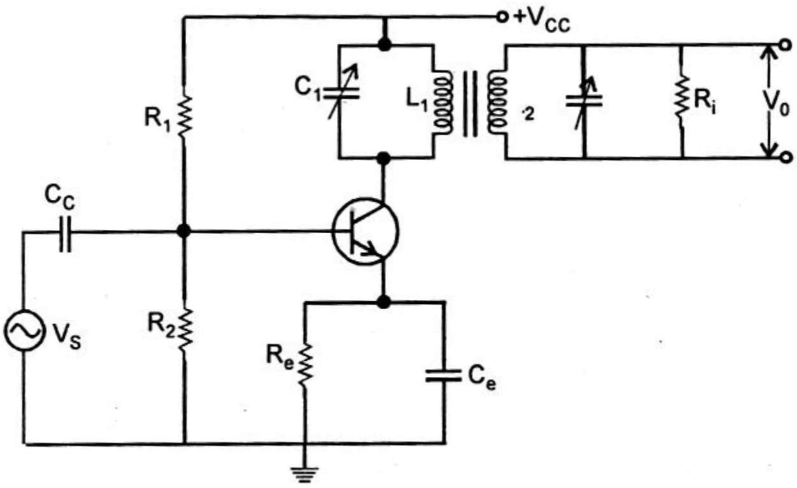


Fig: Double Tuned Amplifier

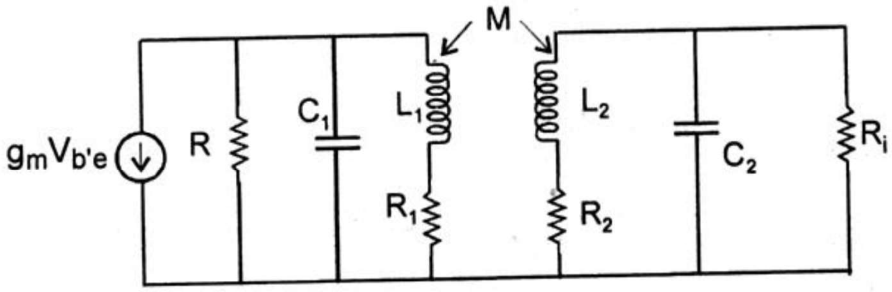


Fig: equivalent circuit of output side

From figure 2 the impedance R is parallel with inductance L_1

$$z = R \parallel j\omega L_1 = \frac{R \times j\omega L_1}{R + j\omega L_1}$$

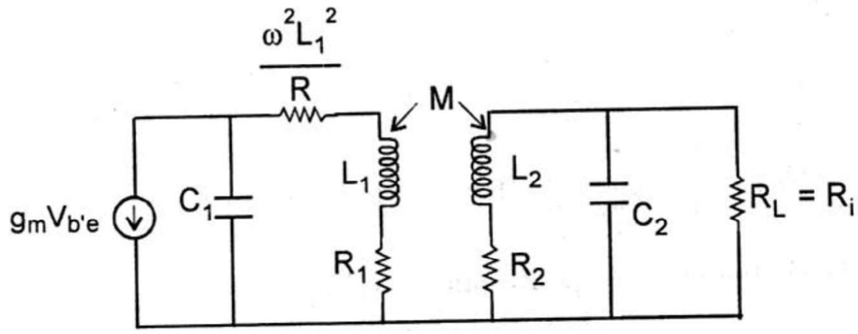
$$Z = \frac{R \times j\omega L_1}{R + j\omega L_1} \times \frac{R - j\omega L_1}{R - j\omega L_1} = \frac{Rj\omega L_1(R - j\omega L_1)}{R^2 + \omega^2 L_1^2}$$

$$Z = \frac{\omega^2 L_1^2 R + j\omega L_1 R^2}{R^2 + \omega^2 L_1^2}$$

If $R \gg \omega L_1$ then

$$Z = \frac{\omega^2 L_1^2}{R} + j\omega L_1 \dots\dots\dots\dots (1)$$

Equation (1) defines the resistance R and L_1 parallel can approximated by a series circuit in figure 3.



The current source in parallel with C is converted in to an equivalent voltage source in series with the capacitance shown in figure 4. In this case, mutual inductance is take in to account

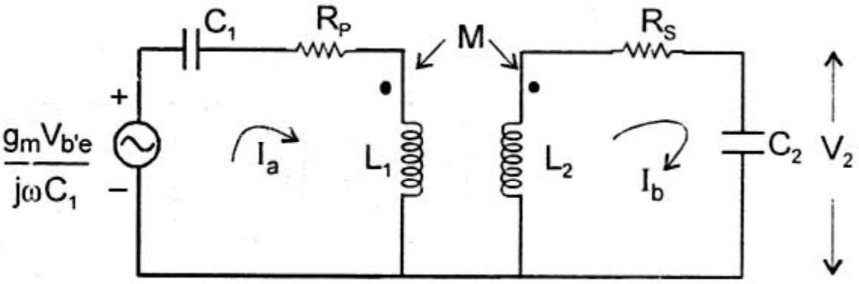


Fig: Approximate equivalent circuit

Apply KVL to the input and output circuit of figure 4

$$\frac{-g_m V_{b'e}}{j\omega C_1} = Z_P I_a + j\omega M I_b \dots\dots\dots\dots (2)$$

$$0 = j\omega M I_a + Z_S I_b \dots\dots\dots\dots (3)$$

Where,

$$Z_P = R_P + \frac{1}{j\omega C_1} + j\omega L_1 = R_P\left[1 + \frac{j\omega L_1}{R_P} + \frac{1}{j\omega C_1 R_P}\right]$$

$$= R_P\left[1 + \frac{j\omega L_1}{R_P}\frac{\omega_0}{\omega_0} + \frac{1}{j\omega C_1 R_P}\frac{\omega_0}{\omega_0}\right]$$

$$= R_P\left[1 + jQ_1\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)\right]$$

Where the quality factor for series tuning is given by,

$$Q_1 = \frac{\omega_{0L_1}}{R_P} = \frac{1}{\omega_0 C_1 R_P}$$

The selectivity is given by

$$\delta = \frac{\omega - \omega_0}{\omega_0} = \frac{\omega}{\omega_0} - 1\ (OR)\ \frac{\omega}{\omega_0} = 1 + \delta$$

Substitute the value of $\frac{\omega}{\omega_0}$ in Z_P

$$Z_P = R_P\left[1 + jQ_1\delta\left(\frac{\delta+2}{\delta+1}\right)\right] \approx R_P(1 + j2Q_1\delta)$$

$$\boldsymbol{Z_P = R_P(1 + j2Q_1\delta)}$$

Similarly for output side

$$Z_S = R_S + \frac{1}{j\omega C_{12}} + j\omega L_2$$

Simplify we get,

$$\boldsymbol{Z_S = R_S(1 + j2Q_2\delta)}$$

From equation (2)

$$j\omega M I_a = -Z_S I_b$$

$$I_a = -\frac{Z_S I_b}{j\omega M} \dots\dots\dots\dots (3)$$

Substitute (3) in (1)

$$\frac{-g_m V_{b'e}}{j\omega C_1} = -Z_P\frac{Z_S I_b}{j\omega M} + j\omega M I_b$$

$$\frac{-g_m V_{b'e}}{j\omega C_1} = I_b\left(j\omega M - \frac{Z_P Z_S}{j\omega M}\right)$$

$$I_b = \frac{\frac{-g_m V_{b'e}}{j\omega C_1}}{j\omega M - \frac{Z_P Z_S}{j\omega M}}$$

Substitute $Z_P \& Z_S$ in above equation,

$$I_b = \frac{\frac{-g_m V_{b'e}}{j\omega C_1}}{j\omega M - \frac{Z_P Z_S}{j\omega M}} = \frac{\frac{-g_m V_{b'e}}{j\omega C_1}}{-\left(\frac{R_P R_S(1+j2Q_1\delta)(1+j2Q_2\delta)}{j\omega M} - j\omega M\right)}$$

$$= \frac{g_m V_{b'e} M}{C_1\{R_P R_S(1 + j2Q_1\delta)(1 + j2Q_2\delta) + \omega^2 M^2\}}$$

$$I_b = \frac{g_m V_{b'e} M}{C_1\{R_P R_S\left(1 - 4\delta^2 Q_1 Q_2 + j2\delta(Q_1 + Q_2)\right) + \omega^2 M^2\}}$$

The output voltage,

$$V_2 = I_b\left(\frac{1}{j\omega C_2}\right)$$

$$V_2 = \frac{g_m V_{b'e} M}{C_1\{R_P R_S\left(1 - 4\delta^2 Q_1 Q_2 + j2\delta(Q_1 + Q_2)\right) + \omega^2 M^2\}}\left(\frac{1}{j\omega C_2}\right)$$

Where $V_{b'e} = V_i$ then

$$V_2 = \frac{g_m V_i M}{j\omega C_2 C_1\{R_P R_S\left(1 - 4\delta^2 Q_1 Q_2 + j2\delta(Q_1 + Q_2)\right) + \omega^2 M^2\}}$$

Voltage gain is given by,

$$A_v = \frac{V_2}{V_i} = \frac{g_m M / j\omega C_2 C_1 R_P R_S}{\left\{\left(1 - 4\delta^2 Q_1 Q_2 + j2\delta(Q_1 + Q_2)\right) + \frac{\omega^2 M^2}{R_P R_S}\right\}}$$

At resonance when $\omega = \omega_0 \;\; \delta = 0 \quad then \;\; A_v = A_{vres}$

$$A_{vres} = \frac{g_m M / j\omega_0 C_1 C_2 R_P R_S}{1 + \frac{\omega_0{}^2 M^2}{R_P R_S}}$$

$$A_v = \frac{A_{vres}}{\left\{1 - \left(\frac{1 - 4\delta^2 Q_1 Q_2 + j2\delta(Q_1 + Q_2)}{1 + \frac{\omega_0{}^2 M^2}{R_P R_S}}\right)\right\}}$$

$$\left|\frac{A_v}{A_{vres}}\right| = \left|\frac{1}{\left\{1 - \left(\frac{1 - 4\delta^2 Q_1 Q_2 + j2\delta(Q_1 + Q_2)}{1 + \frac{\omega_0{}^2 M^2}{R_P R_S}}\right)\right\}}\right|$$

Let

$$b = \frac{\omega_0 M}{\sqrt{R_P R_S}}$$

$$\text{Gain Bandwidth Product} = |A_{Vres}| \times BW$$

$$= |A_{Vres}| \times \left(\frac{1}{2\pi RC}\right) = \frac{g_m M / j\omega_0 C_2 C_1 R_P R_S}{1 + \frac{\omega_0{}^2 M^2}{R_P R_S}} \times \left(\frac{1}{2\pi RC}\right)$$

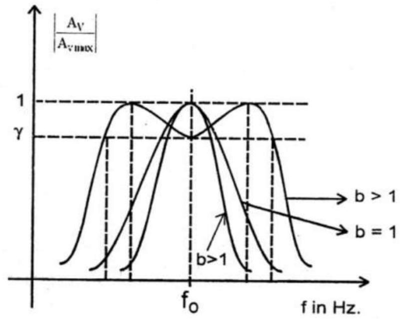
$$= \frac{g_m M}{j\omega_0 C_1 C_2 R_P R_S \left(1 + \frac{\omega_0{}^2 M^2}{R_P R_S}\right)} \times \left(\frac{1}{2\pi RC}\right) \times \frac{b}{b}$$

.

$$= \frac{g_m M}{j\omega_0 C_1 C_2 R_P R_S (1 + b^2)} \times \left(\frac{1}{2\pi RC}\right) \times \frac{b}{\frac{\omega_0 M}{\sqrt{R_P R_S}}}$$

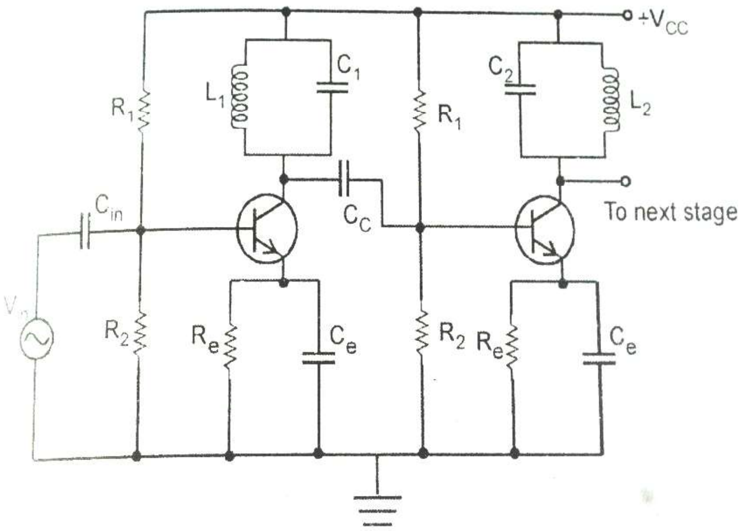
$$\boldsymbol{GBW = \frac{g_m}{j\omega_0^2 C_1 C_2 2\pi RC \sqrt{R_P R_S}} \left(\frac{b}{1 + b^2}\right)}$$

3.8.1 Frequency Response of double tuned amplifier

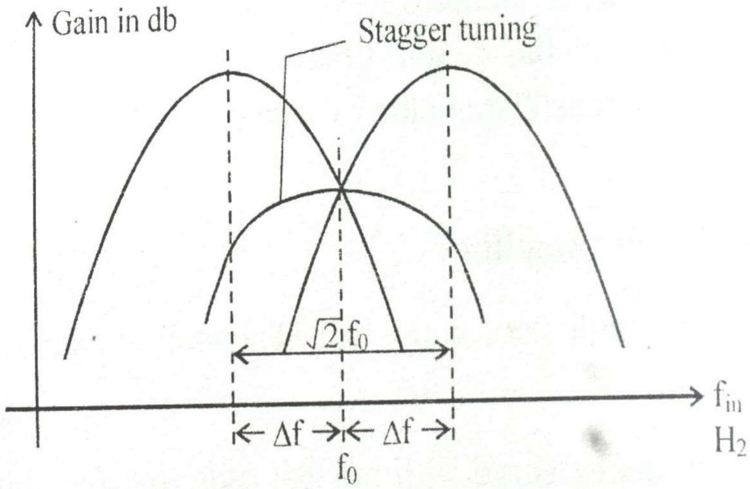


Staggered Tuned Amplifier

If two tuned circuits are cascade and tuned to the same frequency, thus the overall bandwidth decreases. It is known as "Synchronous tuning". The double tuned amplifier gives wider bandwidth with steeper sides and flat top, but alignment of double tuned amplifier is difficult. To overcome this problem stagger tuned amplifier has been developed. In this case two more tuned circuits are connected in cascade as shown in figure.



If these cascade tuned circuit are tuned to different frequencies, it is possible to obtain increased bandwidth with steep sides. This technique is called 'Stagger tuning'. The figure shows two Stagger tuned amplifier. The Stagger tuning is achieved by resonating the tuned circuits L_1C_1 and L_2C_2 to slightly different frequencies.



The fig shows the frequency response of stagger tuned amplifier. The resultant staggered tuned pair will have a bandwidth of $\sqrt{2}$ times that of each of the individual single tuned circuit. The gain of the single tuned amplifier is given by,

$$\frac{A_V}{A_{Vres}} = \frac{1}{1+2jQ_0\delta} = \frac{1}{1+jX}$$

where$X = 2Q_0\delta$

$$\left(\frac{A_V}{A_{Vres}}\right)_1 = \frac{1}{1+j(X-1)} \; and \; \left(\frac{A_V}{A_{Vres}}\right)_2 = \frac{1}{1+j(X+1)}$$

By multiplying the relative gains of the two amplifiers, the overall gain function becomes,

$$\left(\frac{A_V}{A_{Vres}}\right)_{Pair} = \left(\frac{A_V}{A_{Vres}}\right)_1 \left(\frac{A_V}{A_{Vres}}\right)_2 = \frac{1}{1+j(X-1)}\frac{1}{1+j(X+1)} = \frac{1}{2-X^2+2jX}$$

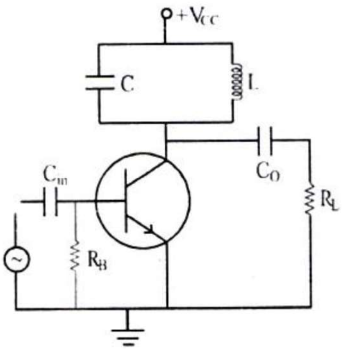
$$\left|\frac{A_V}{A_{Vres}}\right|_{Pair} = \frac{1}{\sqrt{(2-X^2)^2+(2X)^2}}$$

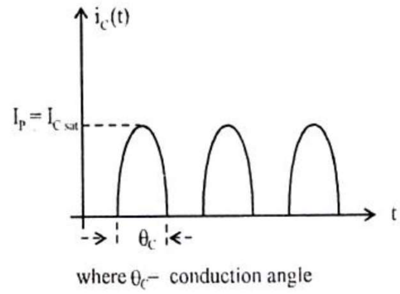
$$\left|\frac{A_V}{A_{Vres}}\right|_{Pair} = \frac{1}{\sqrt{4+X^4}} = \frac{1}{\sqrt{4+(2Q_0\delta)^4}}$$

3.9 Large Signal Tuned Amplifier

Class C Tuned Amplifier

Class C operation means, collector current flow for less than 180^0 of the ac input cycle. It implies that the collector current of a class C amplifier is highly non-sinusoidal because of current flows in pulse, thus the tank circuit is used as a load in an amplifier results in a sinusoidal output voltage, thus this amplifier is known as class C tuned amplifier.





3.9.1 Circuit Operation

When no bais is applied then $V_{BB} = 0$ ie) input junction is unbiased results in which no collector current will flow. When an ac input signal is applied there is collector current until voltage across the base emitter junction reaches 0.7V. this means that the conduction of transistor is occurs only for a short period during the positive peaks of the input signal, thus result is pulsed output. The conduction angle

$$\theta_C = 2\cos^{-1}\left(\frac{V_C}{V_p}\right)$$

When this pulse output is fed to tuned circuit and it is tuned to resonant frequency, result in which the capacitor is changed to a maximum voltage and it will discharge through a coil and load resistor and setting up oscillation consequently sinusoidal output is obtained.

Let r_1 be the ratio of the peak value of the fundamental component to peak value of the class C wave form.

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

Let r_0 be the ratio of the dc value of the class C waveform to its peak value.

$$r_0 = \frac{dc\ value}{peak\ value} = \frac{\theta_C}{\pi(180^0)}$$

Output power

$$P_0 = \frac{V_{CC}}{\sqrt{2}} \cdot \frac{r_1 I_P}{\sqrt{2}} = \frac{r_1 I_P V_{CC}}{2}$$

Where I_P Peak output power.

The input power is given by,

$$P_i = V_{CC}(r_0 I_P)$$

Efficiency is give by

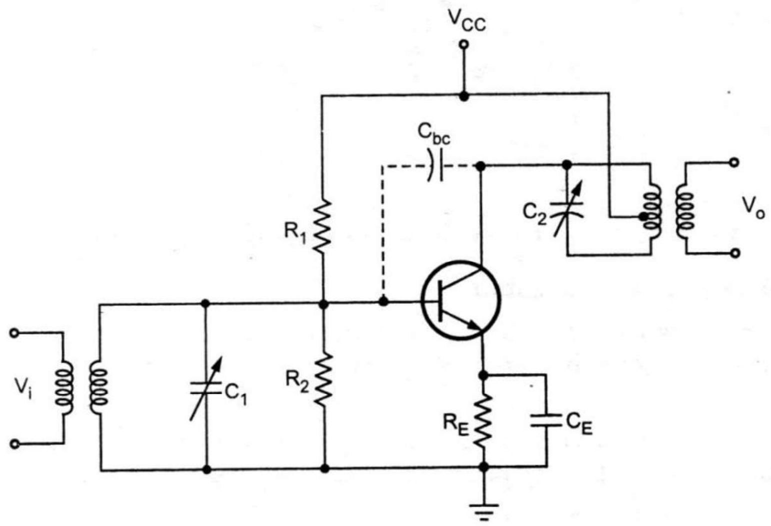
$$\%\eta = \frac{P_0}{P_i} = \frac{\frac{r_1 I_P V_{CC}}{2}}{V_{CC}(r_0 I_P)} = \frac{r_1}{2r_0}$$

3.9.2 Application of class C tuned amplifier

1. It is used as tuned circuit in radio/TV communication systems.
2. It is used as modulator in AM/FM transmitter circuit because of its efficiency.

3.10 Stability of Tuned Amplifier

In tuned RF amplifier, transistors are used at the frequencies nearer to their unity gain bandwidths, to amplify a narrow band of frequencies centered on a radio frequency. At this frequency inter junction capacitance between base and collector, C_{bc} of the transistor becomes dominant. In CE configuration capacitance C_{bc} come across input and output circuits of the amplifier, it reactance of C_{bc} at RF is low enough it provides feedback path from collector to base with this circuit condition if some feedback signal manages to reach input from output in appositive manner with proper phase shift then there is possibility of circuit converted to an unusable one generating its own oscillations and can stop working as an amplifier.

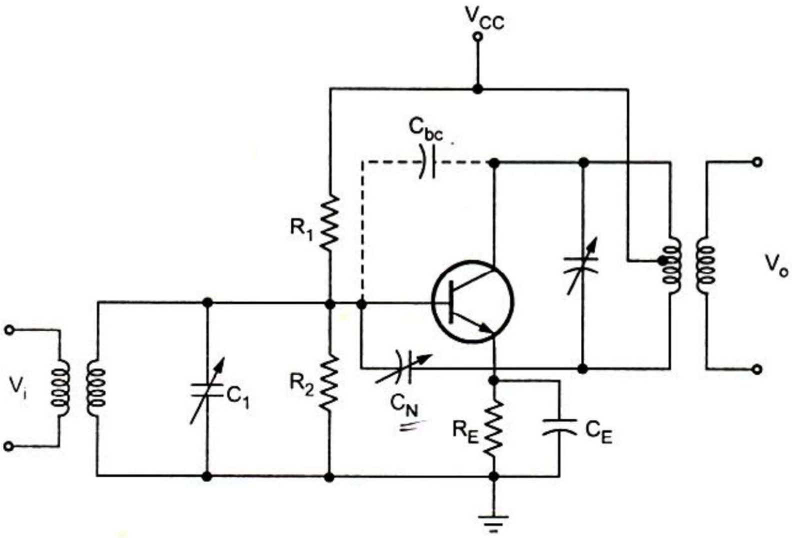


In order to prevent oscillation in the tuned RF amplifiers it was necessary to reduce the stage gain to a level that ensured circuit stability. This could be accomplished in several ways such as lowering the Q of the tune circuits, stagger tuning, and loose coupling between the stages. While all these methods reduced gain, detuning and Q reduction had detrimental effects on selectivity.

Instead of losing the circuit performance to achieve stability, the professor L.A. Hazeltine introduced a circuit in which the troublesome effect of the collector to base capacitance of the transistor was neutralized by introducing a signal which cancels the signal coupled through collector to base capacitance. He proved that the neutralization can be achieved by deliberately feeding back a portion of the output signal to the input in such a way that it has the same amplitude as the unwanted feedback but opposite phase.

3.10.1 Hazeltine Neutralization

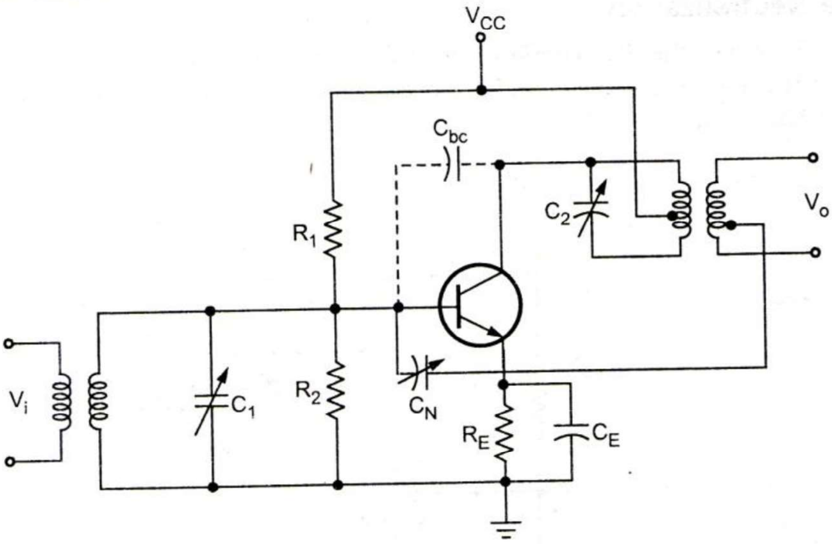
In this circuit a small value of variable capacitance C_N is connected from the bottom of coil, point B, to the base. Therefore the internal capacitanceC_{bc} shown dotted, feeds from top end of the coil, point A, to the transistor base and the C_N feeds a signal of equal magnitude but opposite polarity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



3.10.2 Neutrodyne Neutralization

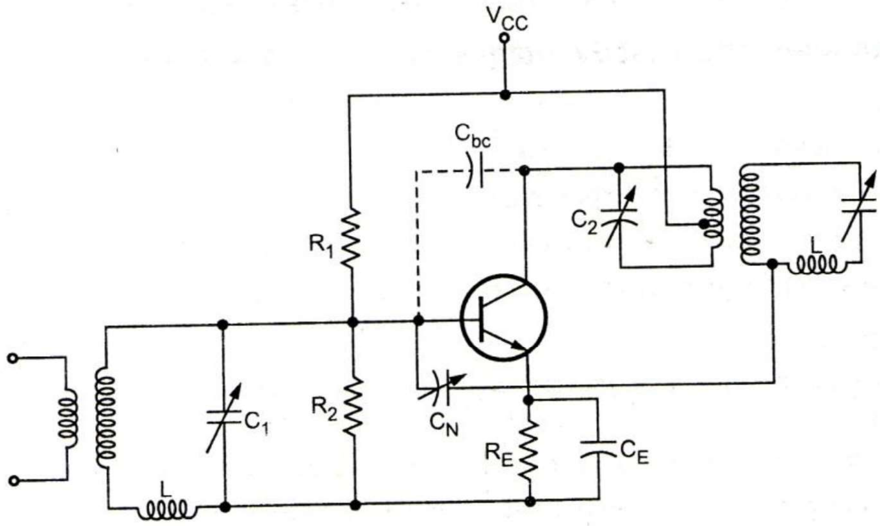
In this circuit the neutralization capacitor is connected from the lower end of the base coil of the next stage to the base of the transistor.

This circuit functions in the same manner as the hazeltine neutralization circuit with the advantages that the neutralizing capacitor does not have the supply voltage across it.



3.10.3 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 is mounted at right angle to the coupled windings. If the windings are properly polarized the voltage across L due to the circulating current in the base circuit will have the proper phase to cancel the signal coupled through the base to collector C_{bc} capacitance.



3.10.4 Rice Neutralization

It uses a centre tapped coil in the base circuit. With this arrangement the signal voltages at the tuned base coil are equal and out off phase.