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Transistor Tuned Amplifiers

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INTRODUCTION

Most of the audio amplifiers we have discussed in the earlier chapters will also work at radio frequencies *i.e.* above 50 kHz. However, they suffer from two major drawbacks. First, they become less efficient at radio frequency. Secondly, such amplifiers have mostly resistive loads and consequently their gain is independent of signal frequency over a large bandwidth. In other words, an audio amplifier amplifies a wide band of frequencies equally well and does not permit the selection of a particular desired frequency while rejecting all other frequencies.

However, sometimes it is desired that an amplifier should be selective *i.e.* it should select a desired frequency or narrow band of frequencies for amplification. For instance, radio and television transmission are carried on a specific radio frequency assigned to the broadcasting station. The radio receiver is required to pick up and amplify the radio frequency desired while discriminating all others. To achieve this, the simple resistive load is replaced by a parallel tuned circuit whose impedance strongly depends upon frequency. Such a tuned circuit becomes very selective and amplifies very strongly signals of resonant frequency and narrow band on either side. Therefore, the use of tuned circuits in conjunction with a transistor makes possible the selection and efficient amplification of a particular desired radio frequency. Such an amplifier is called a *tuned amplifier*. In this chapter, we shall focus our attention on transistor tuned amplifiers and their increasing applications in high frequency electronic circuits.

15.1 Tuned Amplifiers

Amplifiers which amplify a specific frequency or narrow band of frequencies are called **tuned amplifiers.**

Tuned amplifiers are mostly used for the amplification of high or radio frequencies. It is because radio frequencies are generally single and the tuned circuit permits their selection and efficient amplification. However, such amplifiers are not suitable for the amplification of audio frequencies as they are mixture of frequencies from 20 Hz to 20 kHz and not single. Tuned amplifiers are widely used in radio and television circuits where they are called upon to handle radio frequencies.

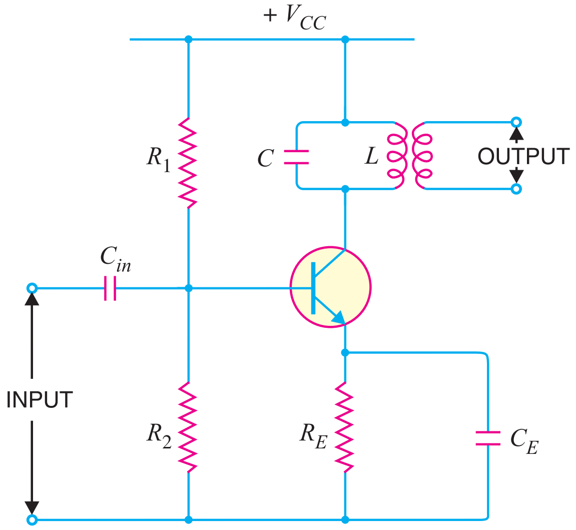

Fig. 15.1

Fig. 15.1 shows the circuit of a simple transistor tuned amplifier. Here, instead of load resistor, we have a parallel tuned circuit in the collector. The impedance of this tuned circuit strongly depends upon frequency. It offers a very high impedance at *resonant frequency* and very small impedance at all other frequencies. If the signal has the same frequency as the resonant frequency of *LC* circuit, large amplification will result due to high impedance of *LC* circuit at this frequency. When signals of many frequencies are present at the input of tuned amplifier, it will select and strongly amplify the signals of resonant frequency while *rejecting all others. Therefore, such amplifiers are very useful in radio receivers to select the signal from one particular broadcasting station when signals of many other frequencies are present at the receiving aerial.

15.2 Distinction between Tuned Amplifiers and other Amplifiers

We have seen that amplifiers (*e.g.*, voltage amplifier, power amplifier *etc.*) provide the constant gain over a limited band of frequencies *i.e.*, from lower cut-off frequency f_1 to upper cut-off frequency f_2. Now bandwidth of the amplifier, $BW = f_2 - f_1$. The reader may wonder, then, what distinguishes a

* For all other frequencies, the impedance of LC circuit will be very small. Consequently, little amplification will occur for these frequencies.

tuned amplifier from other amplifiers? The difference is that tuned amplifiers are designed to have specific, usually narrow bandwidth. This point is illustrated in in Fig. 15.2. Note that BW_S is the bandwidth of standard frequency response while BW_T is the bandwidth of the tuned amplifier. In many applications, the narrower the bandwidth of a tuned amplifier, the better it is.

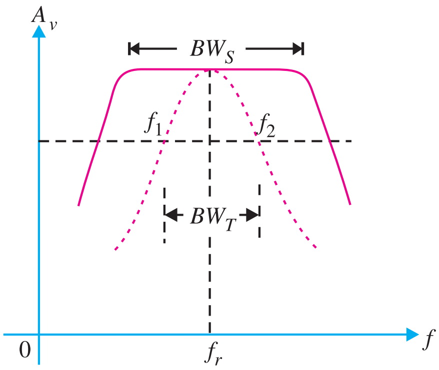

Fig. 15.2

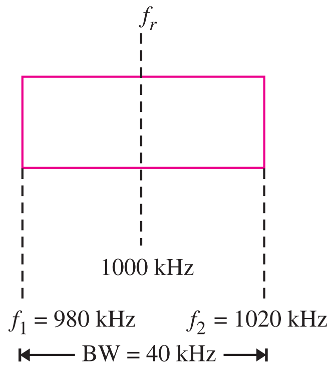

Fig. 15.3

Illustration. Consider a tuned amplifier that is designed to amplify only those frequencies that are within ± 20 kHz of the central frequency of 1000 kHz (*i.e.*, f_r = 1000 kHz). Here [See Fig. 15.3],

f_1 = 980 kHz, f_r = 1000 kHz, f_2 = 1020 kHz, BW = 40 kHz

This means that so long as the input signal is within the range of 980 – 1020 kHz, it will be amplified. If the frequency of input signal goes out of this range, amplification will be drastically reduced.

15.3 Analysis of Parallel Tuned Circuit

A parallel tuned circuit consists of a capacitor C and inductor L in parallel as shown in Fig. 15.4 (*i*). In practice, some resistance R is always present with the coil. If an alternating voltage is applied across this parallel circuit, the frequency of oscillations will be that of the applied voltage. However, if the frequency of applied voltage is equal to the natural or resonant frequency of LC circuit, then *electrical resonance* will occur. Under such conditions, the impedance of the tuned circuit becomes maximum and the line current is minimum. The circuit then draws just enough energy from a.c. supply necessary to overcome the losses in the resistance R.

Parallel resonance. A parallel circuit containing reactive elements (L and C) is *resonant when the circuit power factor is unity *i.e.* applied voltage and the supply current are in phase. The phasor diagram of the parallel circuit is shown in Fig. 15. 4 (*ii*). The coil current I_L has two rectangular components *viz* active component $I_L \cos \phi_L$ and reactive component $I_L \sin \phi_L$. This parallel circuit will resonate when the circuit power factor is unity. This is possible only when the net reactive component of the circuit current is zero *i.e.*

$$I_C - I_L \sin \phi_L = 0$$

or

$$I_C = I_L \sin \phi_L$$

Resonance in parallel circuit can be obtained by changing the supply frequency. At some frequency f_r (called resonant frequency), $I_C = I_L \sin \phi_L$ and resonance occurs.

* Resonance means to be in step with. In an a.c. circuit if applied voltage and supply current are in phase (*i.e.*, in step with), resonance is said to occur. If this happens in a parallel a.c. circuit, it is called parallel resonance.

Resonant frequency. The frequency at which parallel resonance occurs (*i.e.* reactive component of circuit current becomes zero) is called the *resonant frequency* f_r.

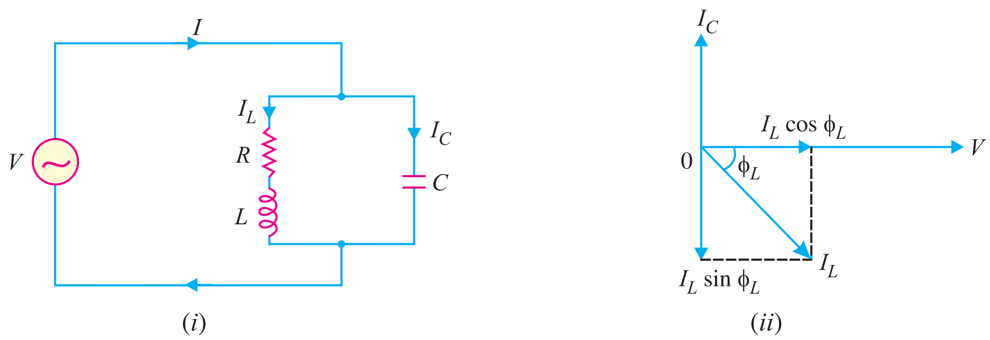

Fig. 15.4

At parallel resonance, we have, $I_C = I_L \sin \phi_L$

Now $I_L = V/Z_L$; $\sin \phi_L = X_L/Z_L$ and $I_C = V/X_C$

$$\therefore \quad \frac{V}{X_C} = \frac{V}{Z_L} \times \frac{X_L}{Z_L}$$

$$\text{or} \quad X_L X_C = Z_L^2$$

$$\text{or} \quad \frac{\omega L}{\omega C} = Z_L^2 = R^2 + X_L^2 \qquad \text{...(i)}$$

$$\text{or} \quad \frac{L}{C} = R^2 + (2 \pi f_r L)^2$$

$$\text{or} \quad (2 \pi f_r L)^2 = \frac{L}{C} - R^2$$

$$\text{or} \quad 2\pi f_r L = \sqrt{\frac{L}{C} - R^2}$$

$$\text{or} \quad f_r = \frac{1}{2 \pi L}\sqrt{\frac{L}{C} - R^2}$$

$$\therefore \quad \text{Resonant frequency, } f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} \qquad \text{...(ii)}$$

If coil resistance R is small (as is generally the case), then,

$$f_r = \frac{1}{2\pi\sqrt{L\,C}} \qquad \text{...(iii)}$$

The resonant frequency will be in Hz if R, L and C are in ohms, henry and farad respectively.

Note. If in the problem, the value of R is given, then eq. (*ii*) should be used to find f_r. However, if R is not given, then eq. (*iii*) may be used to find f_r.

15.4 Characteristics of Parallel Resonant Circuit

It is now desirable to discuss some important characteristics of parallel resonant circuit.

(*i*) Impedance of tuned circuit. The impedance offered by the parallel LC circuit is given by the supply voltage divided by the line current *i.e.*, V/I. Since at resonance, line current is minimum, therefore, impedance is maximum at resonant frequency. This fact is shown by the impedance-frequency curve of Fig 15.5. It is clear from impedance-frequency curve that impedance rises to a steep peak at resonant frequency f_r. However, the impedance of the circuit decreases rapidly when the frequency is changed above or below the resonant frequency. This characteristic of parallel tuned circuit provides it the selective properties *i.e.* to select the resonant frequency and reject all others.

Line current, $I = I_L \cos \phi_L$

or $$\frac{V}{Z_r} = \frac{V}{Z_L} \times \frac{R}{Z_L}$$

or $$\frac{1}{Z_r} = \frac{R}{Z_L^2}$$

or $$\frac{1}{Z_r} = \frac{R}{L/C} = \frac{CR}{L}$$

$$\left[\because Z_L^2 = \frac{L}{C} \text{ from eq. } (i)\right]$$

$\therefore$ Circuit impedance, $$Z_r = \frac{L}{CR}$$

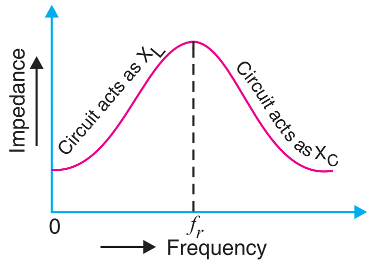

Fig. 15.5

Thus at parallel resonance, the circuit impedance is equal to **L*/*CR*. It may be noted that Z_r will be in ohms if *R*, *L* and *C* are measured in ohms, henry and farad respectively.

***(ii)* Circuit Current.** At parallel resonance, the circuit or line current *I* is given by the applied voltage divided by the circuit impedance Z_r *i.e.*,

Line current, $I = \dfrac{V}{Z_r}$ where $Z_r = \dfrac{L}{CR}$

Because Z_r is very high, the line current *I* will be very small.

***(iii)* Quality factor Q.** It is desired that resonance curve of a parallel tuned circuit should be as sharp as possible in order to provide selectivity. The sharp resonance curve means that impedance falls rapidly as the frequency is varied from the resonant frequency. The smaller the resistance of coil, the more sharp is the resonance curve. This is due to the fact that a small resistance consumes less power and draws a relatively small line current. The ratio of inductive reactance and resistance of the coil at resonance, therefore, becomes a measure of the quality of the tuned circuit. This is called *quality factor* and may be defined as under :

The ratio of inductive reactance of the coil at resonance to its resistance is known as ****quality factor Q** *i.e.*,

$$Q = \frac{X_L}{R} = \frac{2\pi f_r L}{R}$$

The quality factor *Q* of a parallel tuned circuit is very important because the sharpness of resonance curve and hence selectivity of the circuit depends upon it. The higher the value of *Q*, the more selective is the tuned circuit. Fig. 15.6 shows the effect of resistance *R* of the coil on the sharpness of

* Two things are worth noting. First, Z_r (= L/CR) is a pure resistance because there is no frequency term present. Secondly, the value of Z_r is very high because the ratio L/C is very large at parallel resonance.

** Strictly speaking, the *Q* of a tank circuit is defined as the ratio of the energy stored in the circuit to the energy lost in the circuit *i.e.*,

$$Q = \frac{\text{Energy stored}}{\text{Energy lost}} = \frac{\text{Reactive Power}}{\text{Resistive Power}} = \frac{I_L^2 X_L}{I_L^2 R} \quad \text{or} \quad Q = \frac{X_L}{R}$$

the resonance curve. It is clear that when the resistance is small, the resonance curve is very sharp. However, if the coil has large resistance, the resonance curve is less sharp. It may be emphasised that where high selectivity is desired, the value of Q should be very large.

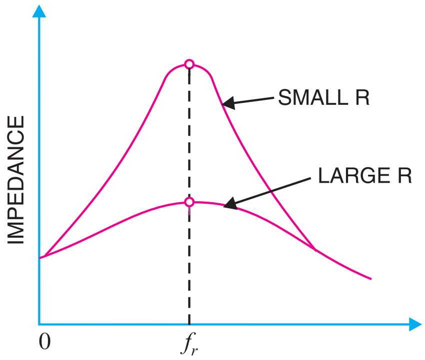

Fig. 15.6

Example 15.1. *A parallel resonant circuit has a capacitor of 250pF in one branch and inductance of 1.25mH plus a resistance of 10Ω in the parallel branch. Find (i) resonant frequency (ii) impedance of the circuit at resonance (iii) Q-factor of the circuit.*

Solution.

$R = 10\Omega\,;\, L = 1.25 \times 10^{-3}\text{H};\ C = 250 \times 10^{-12}\text{ F}$

(*i*) Resonant frequency of the circuit is

$$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{10^{12}}{1.25 \times 10^{-3} \times 250} - \frac{10^2}{(1.25 \times 10^{-3})^2}}\ \text{Hz}$$

$$= 284.7 \times 10^3\ \text{Hz} = \mathbf{284.7\ kHz}$$

(*ii*) Impedance of the circuit at resonance is

$$Z_r = \frac{L}{C\,R} = \frac{1.25 \times 10^{-3}}{250 \times 10^{-12} \times 10} = 500 \times 10^3\ \Omega$$

$$= \mathbf{500\ k\Omega}$$

(*iii*) Quality factor of the circuit is

$$Q = \frac{2\pi f_r L}{R} = \frac{2\pi\,(284.7 \times 10^3) \times 1.25 \times 10^{-3}}{10} = \mathbf{223.6}$$

Example 15.2. *A parallel resonant circuit has a capacitor of 100 pF in one branch and inductance of 100 μH plus a resistance of 10 Ω in parallel branch. If the supply voltage is 10 V, calculate (i) resonant frequency (ii) impedance of the circuit and line current at resonance.*

Solution.

$R = 10\ \Omega\,,\ L = 100 \times 10^{-6}\text{ H}\,;\ C = 100 \times 10^{-12}\text{ F}$

(*i*) Resonant frequency of the circuit is

$$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{10^{12}}{100 \times 10^{-6} \times 100} - \frac{10^2}{(100 \times 10^{-6})^2}}\ \text{Hz}$$

$$= 1592.28 \times 10^3\ \text{Hz} = \mathbf{1592.28\ kHz}$$

(*ii*) Impedance of the circuit at resonance is

$$Z_r = \frac{L}{C\,R} = \frac{L}{C} \times \frac{1}{R} = \frac{100 \times 10^{-6}}{100 \times 10^{-12}} \times \frac{1}{R}$$

$$= 10^6 \times \frac{1}{R} = 10^6 \times \frac{1}{10} = 10^5\ \Omega = \mathbf{0.1\ M\Omega}$$

Note that the circuit impedance Z_r is very high at resonance. It is because the ratio L/C is very large at resonance.

Line current at resonance is

$$I = \frac{V}{Z_r} = \frac{10\text{ V}}{10^5\ \Omega} = \mathbf{100\ \mu A}$$

Example 15.3. *The *dynamic impedance of a parallel resonant circuit is 500 kΩ. The circuit consists of a 250 pF capacitor in parallel with a coil of resistance 10Ω. Calculate (i) the coil inductance (ii) the resonant frequency and (iii) Q-factor of the circuit.*

Solution.

(*i*) Dynamic impedance, $Z_r = \frac{L}{CR}$

∴ Inductance of coil, $L = Z_r\, CR = (500 \times 10^3) \times (250 \times 10^{-12}) \times 10$

$= 1.25 \times 10^{-3}$ H $=$ **1.25 mH**

(*ii*) Resonant frequency, $f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$

$$= \frac{1}{2\pi}\sqrt{\frac{10^{12}}{1.25 \times 10^{-3} \times 250} - \frac{10^2}{(1.25 \times 10^{-3})^2}}$$

$= 284.7 \times 10^3$ Hz $=$ **284.7 kHz**

(*iii*) Q-factor of the circuit $= \frac{2\pi f_r L}{R} = \frac{2\pi \times (284.7 \times 10^3) \times (1.25 \times 10^{-3})}{10} =$ **223.6**

15.5 Advantages of Tuned Amplifiers

In high frequency applications, it is generally required to amplify a single frequency, rejecting all other frequencies present. For such purposes, tuned amplifiers are used. These amplifiers use tuned parallel circuit as the collector load and offer the following advantages :

(*i*) Small power loss. A tuned parallel circuit employs reactive components L and C. Consequently, the power loss in such a circuit is quite low. On the other hand, if a resistive load is used in the collector circuit, there will be considerable loss of power. Therefore, tuned amplifiers are highly efficient.

(*ii*) High selectivity. A tuned circuit has the property of selectivity *i.e.* it can select the desired frequency for amplification out of a large number of frequencies simultaneously impressed upon it. For instance, if a mixture of frequencies including f_r is fed to the input of a tuned amplifier, then maximum amplification occurs for f_r. For all other frequencies, the tuned circuit offers very low impedance and hence these are amplified to a little extent and may be thought as rejected by the circuit. On the other hand, if we use resistive load in the collector, all the frequencies will be amplified equally well *i.e.* the circuit will not have the ability to select the desired frequency.

(*iii*) Smaller collector supply voltage. Because of little resistance in the parallel tuned circuit, it requires small collector supply voltage V_{CC}. On the other hand, if a high load resistance is used in the collector for amplifying even one frequency, it would mean large voltage drop across it due to zero signal collector current. Consequently, a higher collector supply will be needed.

* Impedance of parallel resonant circuit at ressonance is called dynamic impedance.

15.6 Why not Tuned Circuits for Low Frequency Amplification ?

The tuned amplifiers are used to select and amplify a specific high frequency or narrow band of frequencies. The reader may be inclined to think as to why tuned circuits are not used to amplify low frequencies. This is due to the following reasons :

(*i*) *Low frequencies are never single.* A tuned amplifier selects and amplifies a single frequency. However, the low frequencies found in practice are the audio frequencies which are a mixture of frequencies from 20 Hz to 20 kHz and are not single. It is desired that all these frequencies should be equally amplified for proper reproduction of the signal. Consequently, tuned amplifiers cannot be used for the purpose.

(*ii*) *High values of L and C.* The resonant frequency of a parallel tuned circuit is given by;

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

For low frequency amplification, we require large values of *L* and *C*. This will make the tuned circuit bulky and expensive. It is worthwhile to mention here that *R-C* and transformer coupled amplifiers, which are comparatively cheap, can be conveniently used for low frequency applications.

15.7 Frequency Response of Tuned Amplifier

The voltage gain of an amplifier depends upon β, input impedance and effective collector load. In a tuned amplifier, tuned circuit is used in the collector. Therefore, voltage gain of such an amplifier is given by :

$$\text{Voltage gain} = \frac{\beta Z_C}{Z_{in}}$$

where Z_C = effective collector load

Z_{in} = input impedance of the amplifier

The value of Z_C and hence gain strongly depends upon frequency in the tuned amplifier. As Z_C is maximum at resonant frequency, therefore, voltage gain will be maximum at this frequency. The value of Z_C and gain decrease as the frequency is varied above and below the resonant frequency. Fig. 15.7 shows the frequency response of a tuned amplifier. It is clear that voltage gain is maximum at resonant frequency and falls off as the frequency is varied in either direction from resonance.

Bandwidth. The range of frequencies at which the voltage gain of the tuned amplifier falls to 70.7 % of the maximum gain is called its *bandwidth*. Referring to Fig. 15.7, the bandwidth of tuned amplifier is $f_1 - f_2$. The amplifier will amplify nicely any signal in this frequency range. The bandwidth of tuned amplifier depends upon the value of *Q* of *LC* circuit *i.e.* upon the sharpness of the frequency response. The greater the value of *Q* of tuned circuit, the lesser is the bandwidth of the amplifier and *vice-versa*. In practice, the value of *Q* of *LC* circuit is made such so as to permit the amplification of desired narrow band of high frequencies.

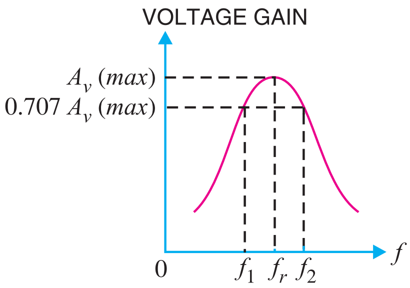

Fig. 15.7

The practical importance of bandwidth of tuned amplifiers is found in communication system. In radio and TV transmission, a very high frequency wave, called *carrier wave* is used to carry the audio or picture signal. In radio transmission, the audio signal has a frequency range of 10 kHz. If the carrier wave frequency is 710 kHz, then the resultant radio wave has a frequency range *between (710 –5) kHz and (710 +5) kHz. Consequently, the tuned amplifier must have a bandwidth of 705 kHz to 715 kHz (*i.e.* 10 kHz). The *Q* of the tuned circuit should be such that bandwidth of the amplifier lies in this range.

15.8 Relation between *Q* and Bandwidth

The quality factor *Q* of a tuned amplifier is equal to the ratio of resonant frequency (f_r) to bandwidth (*BW*) *i.e.*,

$$Q = \frac{f_r}{BW}$$

The *Q* of an amplifier is determined by the circuit component values. It may be noted here that *Q* of a tuned amplifier is generally greater than 10. When this condition is met, the resonant frequency at parallel resonance is approximately given by:

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

Example 15.4. *The Q of a tuned amplifier is 60. If the resonant frequency for the amplifier is 1200 kHz, find (i) bandwidth and (ii) cut-off frequencies.*

Solution.

(*i*)
$$BW = \frac{f_r}{Q} = \frac{1200\text{ kHz}}{60} = \mathbf{20\text{ kHz}}$$

(*ii*) Lower cut-off frequency, $f_1 = 1200 - 10 = \mathbf{1190\text{ kHz}}$

Upper cut-off frequency, $f_2 = 1200 + 10 = \mathbf{1210\text{ kHz}}$

Example 15.5. *A tuned amplifier has maximum voltage gain at a frequency of 2 MHz and the bandwidth is 50 kHz. Find the Q factor.*

Solution. The maximum voltage gain occurs at the resonant frequency. Therefore, f_r = 2 MHz = 2×10^6 Hz and BW = 50 kHz = 50×10^3 Hz.

Now
$$BW = \frac{f_r}{Q}$$

∴
$$Q = \frac{f_r}{BW} = \frac{2 \times 10^6}{50 \times 10^3} = \mathbf{40}$$

Example 15.6. *Draw the frequency response of an ideal tuned amplifier and discuss its characteristics.*

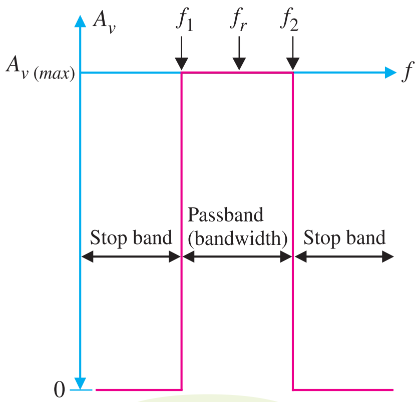

Fig. 15.8

* See chapter on modulation and demodulation.

Solution. Fig. 15.8 shows the frequency response of an ideal tuned amplifier. The ideal tuned amplifier has zero gain for all frequencies from 0 Hz up to the lower cut-off frequency f_1. At this point, the gain *instantly* jumps to the maximum value [$A_{v\,(max)}$]. The gain stays at the maximum value until f_2 is reached. At this time, the gain *instantly* drops back to zero. Thus all the frequencies within the bandwidth (f_1 to f_2) of the amplifier would be *passed* by the circuit while all others would be effectively stopped. This is where the terms *pass band* and *stop band* come from. The pass band is the range of frequencies that is passed (amplified) by a tuned amplifier. On the other hand, the stop band is the range of frequencies that is outside the amplifier's pass band.

In practice, the ideal characteristics of the tuned amplifier cannot be achieved. In a practical frequency response (refer back to Fig. 15.7), the gain falls gradually from maximum value as the frequency goes outside the f_1 or f_2 limits. However, the closer the frequency response of a tuned amplifier to that of the ideal, the better.

15.9 Single Tuned Amplifier

A single tuned amplifier consists of a transistor amplifier containing a parallel tuned circuit as the collector load. The values of capacitance and inductance of the tuned circuit are so selected that its resonant frequency is equal to the frequency to be amplified. The output from a single tuned amplifier can be obtained either (*a*) by a coupling capacitor C_C as shown in Fig. 15.9 (*i*) or (*b*) by a secondary coil as shown in Fig. 15.9 (*ii*).

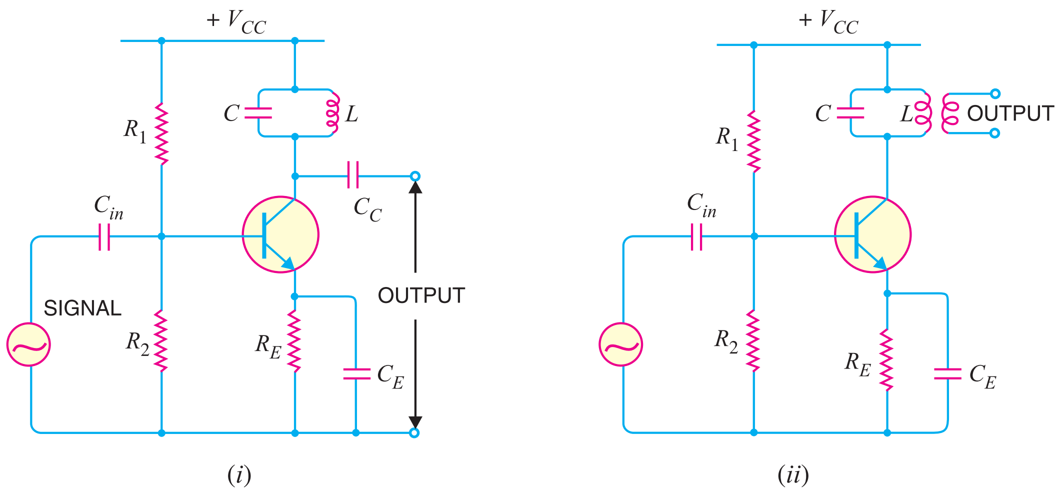

Fig. 15.9

Operation. The high frequency signal to be amplified is given to the input of the amplifier. The resonant frequency of parallel tuned circuit is made equal to the frequency of the signal by changing the value of *C*. Under such conditions, the tuned circuit will offer very high impedance to the signal frequency. Hence a large output appears across the tuned circuit. In case the input signal is complex containing many frequencies, only that frequency which corresponds to the resonant frequency of the tuned circuit will be amplified. All other frequencies will be rejected by the tuned circuit. In this way, a tuned amplifier selects and amplifies the desired frequency.

Note. The fundamental difference between *AF* and tuned (*RF*) amplifiers is the bandwidth they are expected to amplify. The *AF* amplifiers amplify a major portion of *AF* specturm (20 Hz to 20 kHz) equally well throughout. The tuned amplifiers amplify a relatively narrow portion of *RF* spectrum, rejecting all other frequencies.

15.10 Analysis of Tuned Amplifier

Fig. 15.10 (*i*) shows a single tuned amplifier. Note the presence of the parallel *LC* circuit in the collector circuit of the transistor. When the circuit has a high *Q*, the parallel resonance occurs at a frequency f_r given by:

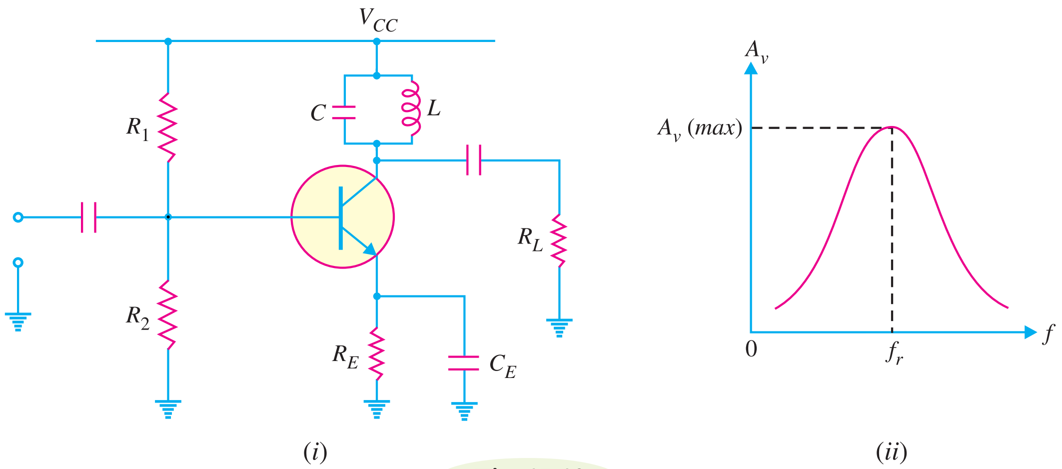

Fig. 15.10

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

At the resonant frequency, the impedance of the parallel resonant circuit is very high and is purely resistive. Therefore, when the circuit is tuned to resonant frequency, the voltage across R_L is maximum. In other words, the voltage gain is maximum at f_r. However, above and below the resonant frequency, the voltage gain decreases rapidly. The higher the *Q* of the circuit, the faster the gain drops off on either side of resonance [See Fig. 15.10 (*ii*)].

15.11 A.C. Equivalent Circuit of Tuned Amplifier

Fig. 15.11 (*i*) shows the *ac* equivalent circuit of the tuned amplifier. Note the tank circuit components are not shorted. In order to completely understand the operation of this circuit, we shall see its behaviour at three frequency conditions *viz.*,

(*i*) $f_{in} = f_r$ **(*ii*)** $f_{in} < f_r$ **(*iii*)** $f_{in} > f_r$

(*i*) When input frequency equals f_r (*i.e.*, $f_{in} = f_r$). When the frequency of the input signal is equal to f_r, the parallel *LC* circuit offers a very high impedance *i.e.*, it acts as an open. Since R_L represents the only path to ground in the collector circuit, all the ac collector current flows through R_L. Therefore, voltage across R_L is maximum *i.e.*, the voltage gain is maximum as shown in Fig. 15.11 (*ii*).

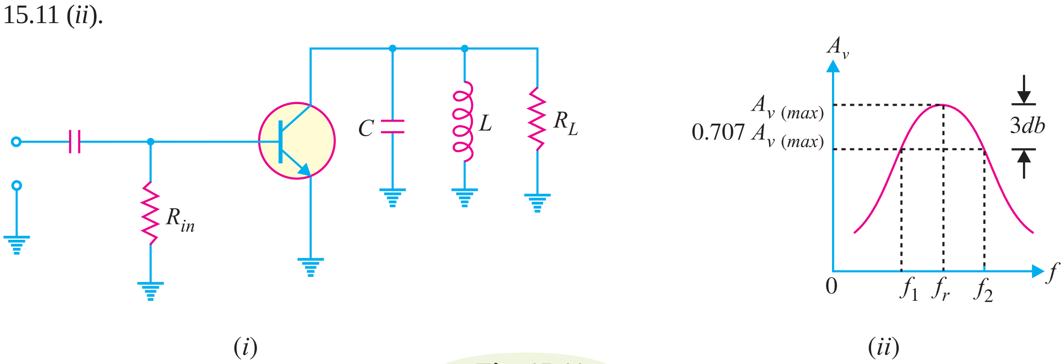

Fig. 15.11

(*ii*) When input frequency is less than f_r (*i.e.*, $f_{in} < f_r$). When the input signal frequency is less than f_r, the circuit is effectively* inductive. As the frequency decreases from f_r, a point is reached when $X_C - X_L = R_L$. When this happens, the voltage gain of the amplifier falls by 3 *db*. In other words, the lower cut-off frequency f_1 for the circuit occurs when $X_C - X_L = R_L$.

(*iii*) When input frequency is greater than f_r (*i.e.*, $f_{in} > f_r$). When the input signal frequency is greater than f_r, the circuit is effectively capacitive. As f_{in} is increased beyond f_r, a point is reached when $X_L - X_C = R_L$. When this happens, the voltage gain of the amplifier will again fall by 3*db*. In other words, the upper cut-off frequency for the circuit will occur when $X_L - X_C = R_L$.

Example 15.7. *For the tuned amplifier shown in Fig. 15.12, determine (i) the resonant frequency (ii) the Q of tank circuit and (iii) bandwidth of the amplifier.*

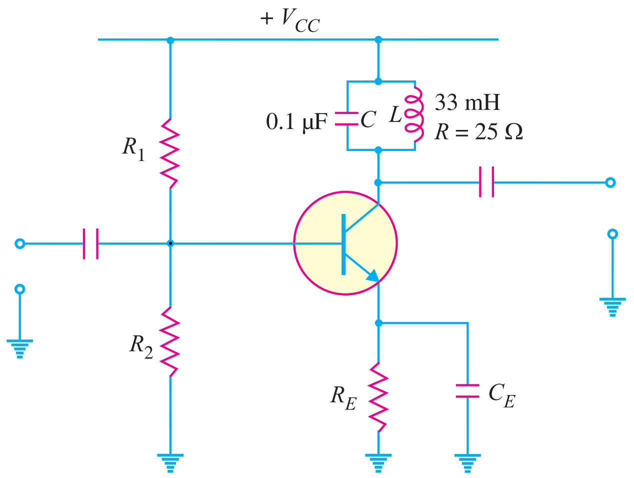

Fig. 15.12

Solution.

(*i*) Resonant frequency, $f_r = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{33 \times 10^{-3} \times 0.1 \times 10^{-6}}}$

$$= 2.77 \times 10^3 \text{ Hz} = \textbf{2.77 kHz}$$

(*ii*) $X_L = 2\pi f_r L = 2\pi \times (2.77 \times 10^3) \times 33 \times 10^{-3} = 574\ \Omega$

$$\therefore \quad Q = \frac{X_L}{R} = \frac{574}{25} = \mathbf{23}$$

(*iii*) $$BW = \frac{f_r}{Q} = \frac{2.77 \text{ kHz}}{23} = \textbf{120 Hz}$$

15.12 Double Tuned Amplifier

Fig. 15.13 shows the circuit of a double tuned amplifier. It consists of a transistor amplifier containing two tuned circuits ; one (L_1C_1) in the collector and the other (L_2C_2) in the output as shown. The high frequency signal to be amplified is applied to the input terminals of the amplifier. The resonant frequency of tuned circuit L_1C_1 is made equal to the signal frequency. Under such conditions, the

* At frequencies below f_r, $X_C > X_L$ or $I_L > I_C$. Therefore, the circuit will be inductive.

tuned circuit offers very high impedance to the signal frequency. Consequently, large output appears across the tuned circuit L_1C_1. The output from this tuned circuit is transferred to the second tuned circuit L_2C_2 through mutual induction. Double tuned circuits are extensively used for coupling the various circuits of radio and television receivers.

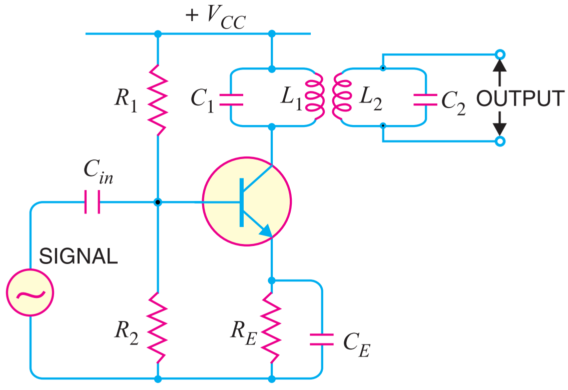

Fig. 15.13

Frequency response. The frequency response of a double tuned circuit depends upon the degree of coupling *i.e.* upon the amount of mutual inductance between the two tuned circuits. When coil L_2 is coupled to coil L_1 [See Fig. 15.14 (*i*)], a portion of load resistance is coupled into the primary tank circuit L_1C_1 and affects the primary circuit in exactly the same manner as though a resistor had been added in series with the primary coil L_1.

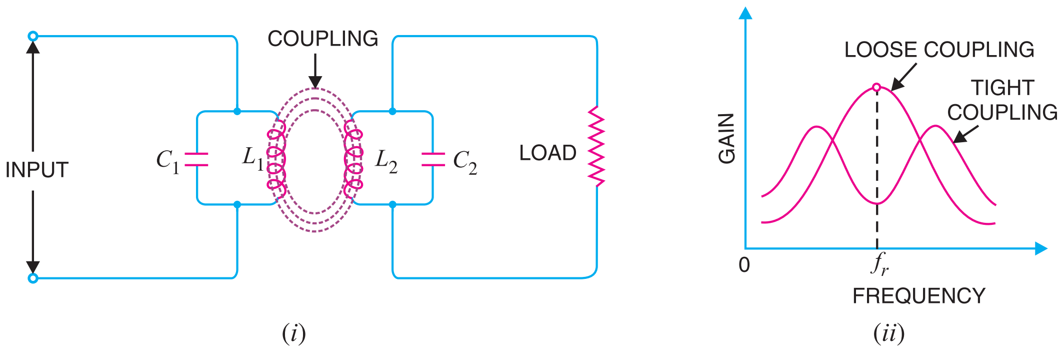

Fig.15.14

When the coils are spaced apart, all the primary coil L_1 flux will not link the secondary coil L_2. The coils are said to have *loose coupling*. Under such conditions, the resistance reflected from the load (*i.e.* secondary circuit) is small. The resonance curve will be sharp and the circuit Q is high as shown in Fig. 15.14 (*ii*). When the primary and secondary coils are very close together, they are said to have *tight coupling*. Under such conditions, the reflected resistance will be large and the circuit Q is lower. Two positions of gain maxima, one above and the other below the resonant frequency, are obtained.

15.13 Bandwidth of Double–Tuned Circuit

If you refer to the frequency response of double-tuned circuit shown in Fig. 15.14 (*ii*), it is clear that bandwidth increases with the degree of coupling. Obviously, the determining factor in a double-tuned circuit is not Q but the coupling. For a given frequency, the tighter the coupling, the greater is the bandwidth.

$$BW_{dt} = k\,f_r$$

The subscript *dt* is used to indicate double-tuned circuit. Here *k* is coefficient of coupling.

Example 15.8. *It is desired to obtain a bandwidth of 200 kHz at an operating frequency of 10 MHz using a double tuned circuit. What value of co-efficient of coupling should be used ?*

Solution.

$$BW_{dt} = k\,f_r$$

∴ Co-efficient of coupling, $k = \frac{BW_{dt}}{f_r} = \frac{200 \text{ kHz}}{10 \times 10^3 \text{ kHz}} = \mathbf{0.02}$

15.14 Practical Application of Double Tuned Amplifier

Double tuned amplifiers are used for amplifying radio-frequency (*RF*) signals. One such application is in the radio receiver as shown in Fig. 15.15. This is the IF stage using double tuned resonant circuits. Each resonant circuit is tuned to *455 kHz. The critical coupling occurs when the coefficient of coupling is

$$k_{cirtical} = \frac{1}{\sqrt{Q_1 Q_2}}$$

where Q_1 = quality factor of primary resonant circuit ($L_1 C_1$)

Q_2 = quality factor of secondary resonant circuit ($L_2 C_2$)

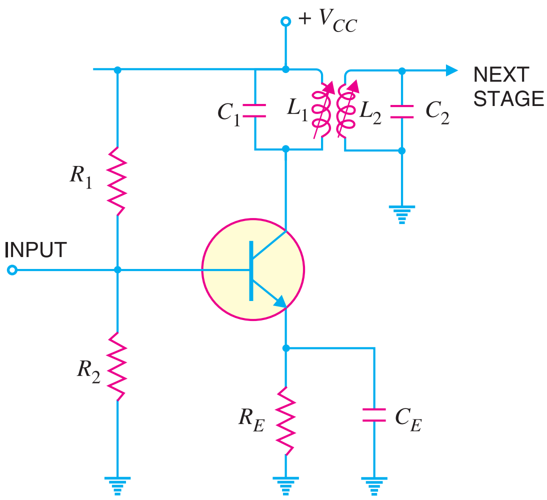

Fig. 15.15

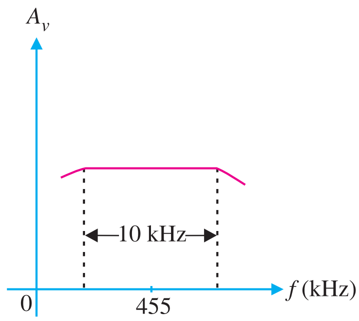

Fig. 15.16

When two resonant circuits are critically coupled, the frequency response becomes flat over a considerable range of frequencies as shown in Fig. 15.16. In other words, the double tuned circuit has better frequency response as compared to that of a single tuned circuit. The use of double tuned circuit offers the following advantages :

(*i*) Bandwidth is increased.

(*ii*) Sensitivity (*i.e.* ability to receive weak signals) is increased.

(*iii*) Selectivity (*i.e.* ability to discriminate against signals in adjacent bands) is increased.

15.15 Tuned Class C Amplifier

So far we have confined our attention to tuned class *A* amplifiers. Such amplifiers are used where *RF* signal has low power level *e.g.* in radio receivers, small signal applications in transmitters. However, owing to low efficiency of class *A* operation, these amplifiers are not employed where large *RF* (radio frequency) power is involved *e.g.* to excite transmitting antenna. In such situations, tuned class *C* power amplifiers are used. Since a class *C* amplifier has a very high efficiency, it can deliver more load power than a class *A* amplifier.

* In a radio receiver, the *IF* (intermediate frequency) of 455 kHz is obtained from the mixer circuit regardless of radio station to which the receiver is tuned (See Chapter 16).

Class *C* operation means that collector current flows for less than 180º. In a practical tuned class *C* amplifier, the collector current flows for much less than 180º ; the current looks like narrow pulses as shown in Fig. 15.17. As we shall see later, when narrow current pulses like these drive a high-*Q* resonant (*i.e.* *LC*) circuit, the voltage across the circuit is almost a perfect sine wave. One very important advantage of class *C* operation is its *high efficiency. Thus 10 W supplied to a class *A* amplifier may produce only about 3.5 W of a.c. output (35 % efficiency). The same transistor biased to class *C* may be able to produce 7 W output (70 % efficiency). Class *C* power amplifiers normally use *RF* power transistors. The power ratings of such transistors range from 1 W to over 100 W.

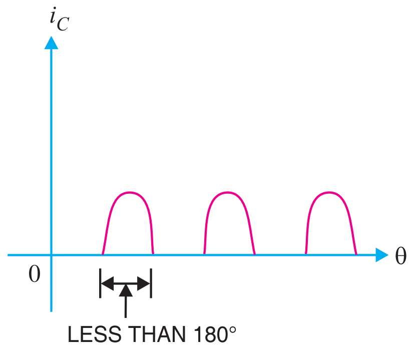

Fig. 15.17

15.16 Class C Operation

Fig. 15.18 (*i*) shows the circuit of tuned class *C* amplifier. The circuit action is as under:

(*i*) When no a.c. input signal is applied, no collector current flows because the emitter diode (*i.e.* base-emitter junction) is unbiased.

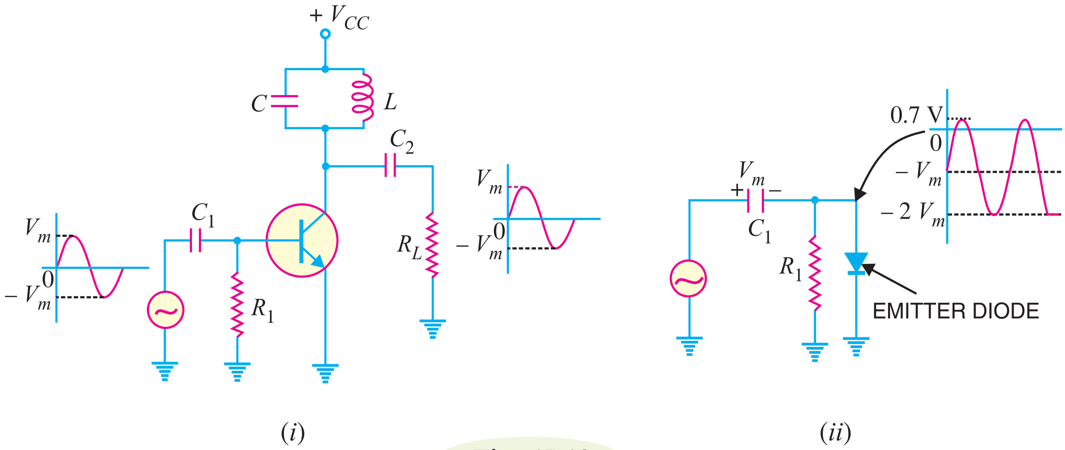

Fig. 15.18

(*ii*) When an a.c. signal is applied, *clamping action* takes place as shown in Fig. 15.18 (*ii*). The voltage across the emitter diode varies between + 0.7 V (during positive peaks of input signal) to about $-2V_m$ (during negative peaks of input signal). This means that conduction of the transistor occurs only for a short period during positive peaks of the signal. This results in the pulsed output *i.e.* collector current waveform is a train of narrow pulses (Refer back to Fig. 15.17).

(*iii*) When this pulsed output is fed to the *LC* circuit, **sine-wave output is obtained. This can be easily explained. Since the pulse is narrow, inductor looks like high impedance and the capacitor like a low impedance. Consequently, most of the current charges the capacitor as shown in Fig. 15.19.

* Class *C* amplifier has a relatively long duration between the pulses, allowing the transistor to rest for a major portion of each input cycle. In other words, very little power is dissipated by the transistor. For this reason, class *C* amplifier has high efficiency.

** There is another explanation for it. The pulsed output is actually the sum of an infinite number of sine waves at frequencies in multiples of the input frequency. If the LC tank circuit is set up to resonate at the input frequency, it will result in sine-wave output of just the input frequency.

When the capacitor is fully charged, it will discharge through the coil and the load resistor, setting up oscillations just as an oscillatory circuit does. Consequently, sine-wave output is obtained.

(iv) If only a single current pulse drives the *LC* circuit, we will get damped sine-wave output. However, if a train of narrow pulses drive the *LC* circuit, we shall get undamped sine-wave output.

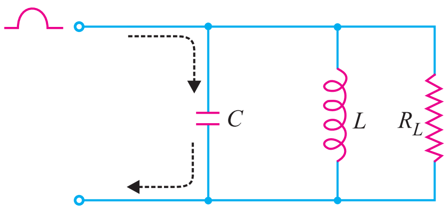

Fig. 15.19

15.17 D.C. and A.C. Loads

Fig. 15.20 shows the circuit of tuned class *C* amplifier. We shall determine the d.c. and a.c. load of the circuit.

(i) The d.c. load of the circuit is just the d.c. resistance *R* of the inductor because the capacitor looks like an open to d.c.

$\therefore$ D.C. load, R_{dc} = d.c. resistance of the inductor = R

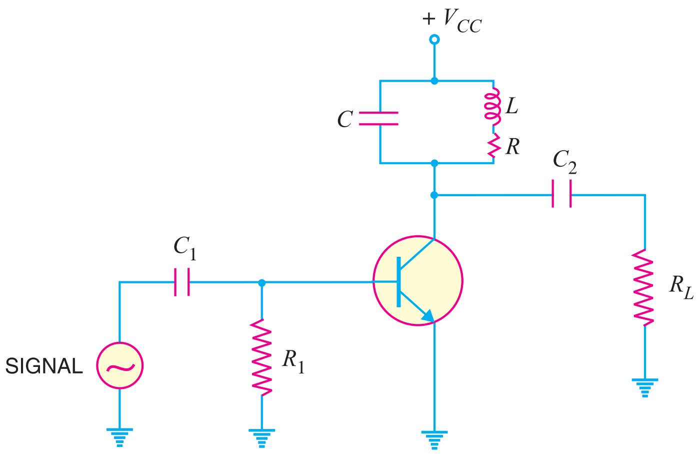

Fig. 15.20

(ii) The a.c. load is a parallel combination of capacitor, coil and load resistance R_L as shown in Fig. 15.21 (*i*). The series resistance *R* of the inductor can be replaced by its equivalent parallel resistance R_P as shown in Fig. 15.21 (*ii*) where

$$R_P = Q_{coil} \times X_L$$

The a.c. load resistance R_{AC} is the equivalent resistance of the parallel combination of R_P and R_L *i.e.*

$$R_{AC} = R_P \,||\, R_L = \frac{R_P \times R_L}{R_P + R_L}$$

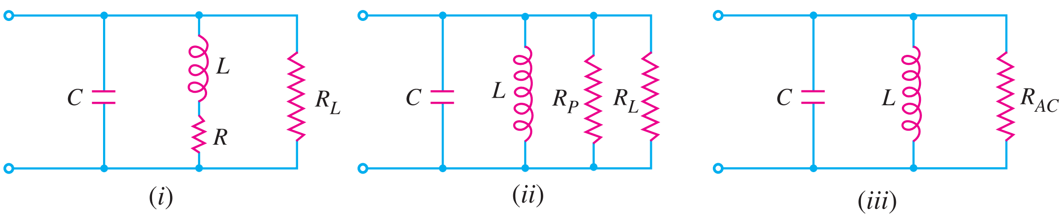

Fig. 15.21

Example 15.9. *In the circuit shown in Fig.15.20, C = 500 pF and the coil has L = 50.7 µH and R = 10Ω and R_L = 1 MΩ. Find (i) the resonant frequency (ii) d.c. load and a.c. load.*

Solution.

(*i*) Resonant frequency, $f_r \simeq \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{10^9}{2\pi\sqrt{50.7 \times 500}}$ = **106 Hz**

(*ii*) D.C. load, $R_{dc} = R =$ **10 Ω**

$$X_L = 2\,\pi\, f_r L = 2\,\pi \times (10^6) \times (50.7 \times 10^{-6}) = 318\ \Omega$$

$$Q_{coil} = \frac{X_L}{R} = \frac{318}{10} = 31.8$$

The series resistance R (= 10 Ω) of the inductor can be replaced by its equivalent parallel resistance R_P where,

$$R_P = Q_{coil} \times X_L = 31.8 \times 318 = 10^4\ \Omega = 10\ k\Omega$$

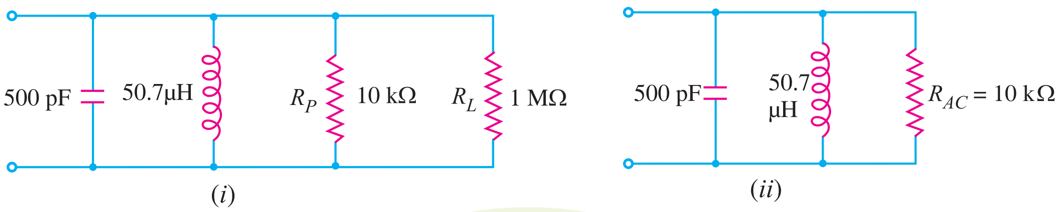

Fig. 15.22

The equivalent circuit is shown in Fig. 15.22 (*i*). This further reduces to the circuit shown in Fig. 15.22 (*ii*).

$$\therefore \quad R_{AC} = R_P \,||\, R_L = 10\ k\Omega \,||\, 1\ M\Omega \simeq \mathbf{10\ k\Omega}$$

15.18 Maximum A.C. Output Power

Fig. 15.23 (*i*) shows tuned class *C* amplifier. When no signal is applied, the collector-emitter voltage is *V_{CC} *i.e.*

$$v_{CE} = V_{CC}$$

When signal is applied, it causes the total collector-emitter voltage to swing above and below this voltage. The collector-emitter voltage can have a maximum value of $2V_{CC}$ and minimum value 0 (ideally) as shown in Fig. 15.23 (*ii*).

Referring to Fig. 15.23 (*ii*), output voltage has a peak value of V_{CC}. Therefore, the maximum a.c. output power is :

$$P_{o(max)} = \frac{V_{r.m.s.}^2}{R_{AC}} = \frac{\left(V_{CC}/\sqrt{2}\right)^2}{R_{AC}} = \frac{V_{CC}^2}{2\,R_{AC}}$$

where R_{AC} = a.c. load

Maximum efficiency. The d.c. input power (P_{dc}) from the supply is :

$$P_{dc} = P_{o(max)} + P_D$$

where P_D = power dissipation of the transistor

$$\therefore \quad \text{Max. collector } \eta = \frac{P_{o(max)}}{P_{o(max)} + P_D}$$

* Because the drop in *L* due to d.c. component is negligible.

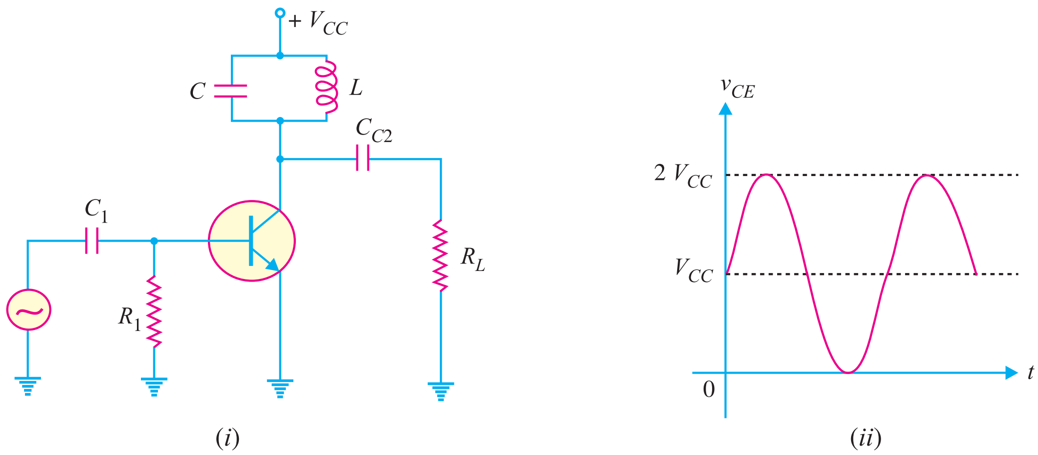

Fig. 15.23

As discussed earlier, P_D in class *C* operation is very small because the transistor remains biased off during most of the input signal cycle. Consequently, P_D may be neglected as compared to $P_{o(max)}$.

$$\therefore \qquad \text{Maximum } \eta \simeq \frac{P_{o(max)}}{P_{o(max)}} \simeq 100\ \%$$

It is worthwhile to give a passing reference about the maximum efficiencies of class *A*, class *B* and class *C* amplifiers. *A* class *A* amplifier (transformer-coupled) has a maximum efficiency of 50%, class *B* of 78.5% and class *C* nearly 100%. It is emphasised here that class *C* operation is suitable only for *resonant *RF* applications.

Example 15.10. *Calculate (i) a.c. load (ii) maximum load power in the circuit shown in Fig. 15.24.*

Solution.

(*i*) A.C. load, R_{AC} = Reflected load resistance seen by the collector

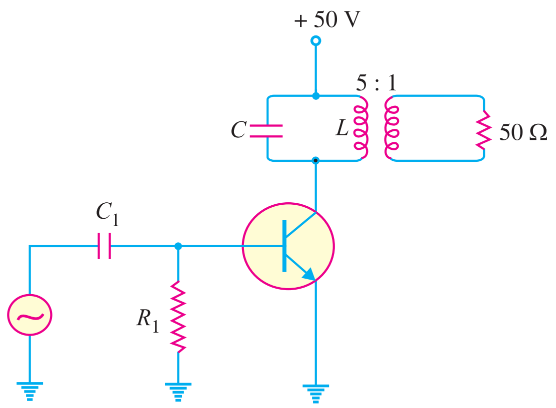

Fig. 15.24

* Because power losses are very small (less than 1 %) in high - *Q* resonant circuits. An extremely narrow pulse will compensate the losses.

$$= (N_p/N_s)^2 \times 50 = (5/1)^2 \times 50 = \mathbf{1250\ \Omega}$$

(*ii*) Max. load power, $P_{o(max)} = \dfrac{V_{CC}^2}{2R_{AC}} = \dfrac{(50)^2}{2\times 1250} = \mathbf{1\ W}$

Example 15.11. *In the above example, if power dissipation of the transistor is 4 mW, find the maximum collector efficiency.*

Solution.

$$P_{o\,(max)} = 1\text{W};\ P_D = 4\text{mW} = 4 \times 10^{-3}\ \text{W}$$

$$\therefore \quad \text{Max. collector } \eta = \frac{P_{o\,(\max)}}{P_{o(\max)} + P_D} \times 100$$

$$= \frac{1}{1 + 4 \times 10^{-3}} \times 100 = \mathbf{99.6\%}$$

Note that maximum collector efficiency is very close to the ideal case of 100% efficiency. Therefore, we can neglect P_D in circuit calculations with reasonable accuracy.

MULTIPLE-CHOICE QUESTIONS

1. A tuned amplifier uses .... load.
(*i*) resistive (*ii*) capacitive
(*iii*) LC tank (*iv*) inductive

2. A tuned amplifier is generally operated in .... operation.
(*i*) class A (*ii*) class C
(*iii*) class B (*iv*) none of the above

3. A tuned amplifier is used in .... applications.
(*i*) radio frequency
(*ii*) low frequency
(*iii*) audio frequency
(*iv*) none of the above

4. Frequencies above .... kHz are called radio frequencies.
(*i*) 2 (*ii*) 10
(*iii*) 50 (*iv*) 200

5. At series or parallel resonance, the circuit power factor is ....
(*i*) 0 (*ii*) 0.5
(*iii*) 1 (*iv*) 0.8

6. The voltage gain of a tuned amplifier is .... at resonant frequency.
(*i*) minimum (*ii*) maximum
(*iii*) half-way between maximum and minimum
(*iv*) zero

7. At parallel resonance, the line current is ....
(*i*) minimum (*ii*) maximum
(*iii*) quite large (*iv*) none of the above

8. At series resonance, the circuit offers .... impedance.
(*i*) zero (*ii*) maximum
(*iii*) minimum (*iv*) none of the above

9. A resonant circuit contains .... elements.
(*i*) *R* and *L* only (*ii*) *R* and *C* only
(*iii*) only *R* (*iv*) *L* and *C*

10. At series or parallel resonance, the circuit behaves as a .... load.
(*i*) capacitive (*ii*) resistive
(*iii*) inductive (*iv*) none of the above

11. At series resonance, voltage across *L* is .... voltage across *C*.
(*i*) equal to but opposite in phase to
(*ii*) equal to but in phase with
(*iii*) greater than but in phase with
(*iv*) less than but in phase with

12. When either *L* or *C* is increased, the resonant frequency of *LC* circuit ....
(*i*) remains the same
(*ii*) increases (*iii*) decreases
(*iv*) insufficient data

13. At parallel resonance, the net reactive component of circuit current is ....
(*i*) capacitive (*ii*) zero
(*iii*) inductive (*iv*) none of the above

14. At parallel resonance, the circuit impedance is ....
(*i*) $\frac{C}{LR}$ (*ii*) $\frac{R}{LC}$
(*iii*) $\frac{CR}{L}$ (*iv*) $\frac{L}{CR}$

15. In a parallel *LC* circuit, if the input signal frequency is increased above resonant frequency, then ....
(*i*) X_L increases and X_C decreases
(*ii*) X_L decreases and X_C increases
(*iii*) both X_L and X_C increase
(*iv*) both X_L and X_C decrease

16. The *Q* of an *LC* circuit is given by ....
(*i*) $2\pi f_r \times R$ (*ii*) $\frac{R}{2\pi f_r L}$
(*iii*) $\frac{2\pi f_r L}{R}$ (*iv*) $\frac{R^2}{2\pi f_r L}$

17. If *Q* of an *LC* circuit increases, then bandwidth ....
(*i*) increases (*ii*) decreases
(*iii*) remains the same
(*iv*) insufficient data

18. At series resonance, the net reactive component of circuit current is ....
(*i*) zero (*ii*) inductive
(*iii*) capacitive (*iv*) none of the above

19. The dimensions of *L*/*CR* are that of ....
(*i*) farad (*ii*) henry
(*iii*) ohm (*iv*) none of the above

20. If *L*/*C* ratio of a parallel *LC* circuit is increased, the *Q* of the circuit ....
(*i*) is decreased (*ii*) is increased
(*iii*) remains the same
(*iv*) none of the above

21. At series resonance, the phase angle between applied voltage and circuit current is ....
(*i*) 90° (*ii*) 180°
(*iii*) 0° (*iv*) none of the above

22. At parallel resonance, the ratio *L*/*C* is ....
(*i*) very large (*ii*) zero
(*iii*) small (*iv*) none of the above

23. If the resistance of a tuned circuit is increased, the *Q* of the circuit ....
(*i*) is increased (*ii*) is decreased
(*iii*) remains the same
(*iv*) none of the above

24. The *Q* of a tuned circuit refers to the property of ....
(*i*) sensitivity (*ii*) fidelity
(*iii*) selectivity (*iv*) none of the above

25. At parallel resonance, the phase angle between the applied voltage and circuit current is ....
(*i*) 90° (*ii*) 180°
(*iii*) 0° (*iv*) none of the above

26. In a parallel *LC* circuit, if the signal frequency is decreased below the resonant frequency, then ....
(*i*) X_L decreases and X_C increases
(*ii*) X_L increases and X_C decreases
(*iii*) line current becomes minimum
(*iv*) none of the above

27. In series resonance, there is ....
(*i*) voltage amplification
(*ii*) current amplification
(*iii*) both voltage and current amplification
(*iv*) none of the above

28. The *Q* of a tuned amplifier is generally ....
(*i*) less than 5 (*ii*) less than 10
(*iii*) more than 10 (*iv*) none of the above

29. The *Q* of a tuned amplifier is 50. If the resonant frequency for the amplifier is 1000 kHz, then bandwidth is ....
(*i*) 10 kHz (*ii*) 40 kHz
(*iii*) 30 kHz (*iv*) 20 kHz

30. In the above question, what are the values of cut-off frequencies ?
(*i*) 140 kHz, 60 kHz
(*ii*) 1020 kHz, 980 kHz
(*iii*) 1030 kHz, 970 kHz
(*iv*) none of the above

31. For frequencies above the resonant frequency, a parallel *LC* circuit behaves as a .... load.
(*i*) capacitive
(*ii*) resistive
(*iii*) inductive
(*iv*) none of the above

32. In parallel resonance, there is ....
(*i*) both voltage and current amplification
(*ii*) voltage amplification
(*iii*) current amplification
(*iv*) none of the above

33. For frequencies below resonant frequency, a series *LC* circuit behaves as a .... load.
(*i*) resistive (*ii*) capacitive
(*iii*) inductive (*iv*) none of the above

34. If a high degree of selectivity is desired, then double-tuned circuit should have .... coupling.
(*i*) loose (*ii*) tight
(*iii*) critical (*iv*) none of the above

35. In the double tuned circuit, if the mutual inductance between the two tuned circuits is decreased, the level of resonance curve ....
(*i*) remains the same
(*ii*) is lowered
(*iii*) is raised
(*iv*) none of the above

36. For frequencies above the resonant frequency, a series *LC* circuit behaves as a .... load.
(*i*) resistive (*ii*) inductive
(*iii*) capacitive (*iv*) none of the above

37. Double tuned circuits are used in .... stages of a radio receiver
(*i*) IF (*ii*) audio
(*iii*) output (*iv*) none of the above

38. A class C amplifier always drives .... load.
(*i*) a pure resistive (*ii*) a pure inductive
(*iii*) a pure capacitive
(*iv*) a resonant tank

39. Tuned class C amplifiers are used for RF signals of ....
(*i*) low power
(*ii*) high power
(*iii*) very low power
(*iv*) none of the above

40. For frequencies below the resonant frequency, a parallel LC circuit behaves as a .... load.
(*i*) inductive (*ii*) resistive
(*iii*) capacitive (*iv*) none of the above

Answers to Multiple-Choice Questions

1. (*iii*)	**2.** (*ii*)	**3.** (*i*)	**4.** (*iv*)	**5.** (*iii*)
6. (*ii*)	**7.** (*i*)	**8.** (*iii*)	**9.** (*iv*)	**10.** (*ii*)
11. (*i*)	**12.** (*iii*)	**13.** (*ii*)	**14.** (*iv*)	**15.** (*i*)
16. (*iii*)	**17.** (*ii*)	**18.** (*i*)	**19.** (*iii*)	**20.** (*ii*)
21. (*iii*)	**22.** (*i*)	**23.** (*ii*)	**24.** (*iii*)	**25.** (*iii*)
26. (*i*)	**27.** (*i*)	**28.** (*iii*)	**29.** (*iv*)	**30.** (*ii*)
31. (*i*)	**32.** (*iii*)	**33.** (*ii*)	**34.** (*i*)	**35.** (*iii*)
36. (*ii*)	**37.** (*i*)	**38.** (*iv*)	**39.** (*iv*)	**40.** (*i*)

Chapter Review Topics

1. What are tuned amplifiers and where are they used ?
2. Discuss parallel tuned circuit with special reference to resonant frequency, circuit impedance and frequency response.
3. What do you understand by quality factor *Q* of parallel tuned circuit ?
4. Discuss the advantages of tuned amplifiers.
5. Discuss the circuit operation of a single tuned amplifier.
6. Write short notes on the following :
(*i*) Double tuned amplifier (*ii*) Bandwidth of tuned amplifier

Problems

1. A parallel circuit has a capacitor of 100 pF in one branch and an inductance of 100 µH plus a resistance of 10 Ω in the second branch. The line voltage is 100V. Find (*i*) resonant frequency (*ii*) circuit impedance at resonance and (*iii*) line current at resonance. **[(*i*) 1590 kHz (*ii*) 100 kΩ (*iii*) 100 mA]**
2. A tuned amplifier is designed to have a resonant frequency of 1000 kHz and a bandwidth of 40 kHz. What is the *Q* of this amplifier ? **[25]**
3. The *Q* of a tuned amplifier is 25. If the resonant frequency of the circuit is 1400 kHz, what is its bandwidth? **[56 kHz]**
4. A tuned amplifier has parallel *LC* circuit. One branch of this parallel circuit has a capacitor of 100 pF and the other branch has an inductance of 1mH plus a resistance of 25 Ω. Determine (*i*) the resonant frequency and (*ii*) *Q* of the tank circuit. **[(*i*) 503.3 kHz (*ii*) 126.5]**
5. It is desired to obtain a bandwidth of 12 kHz at an operating frequency of 800 kHz, using a double-tuned circuit. What value of co-efficient of coupling should be used ? **[0.015]**

Discussion Questions

1. Why are tuned circuits not used for low frequency applications ?
2. Why is tuned amplifier operated in class *C* operation ?
3. How does coupling affect the gain of tuned amplifiers ?
4. What is the effect of *Q* on the resonance curve ?
5. What are the practical applications of tuned amplifiers ?

Top