UNIT 5 OSCILLATORS

Structure

5.1 INTRODUCTION

The important characteristics of an amplifier are its voltage gain, input impedence, output impedance and bandwidth. For a given amplifier these parameters are more or less constant, Quite often, the values of these parameters are required to be changed, This could be done in a number of ways, But the most powerful technique to do this is to introduce feedback in the amplifier circuit. Feedback is defined as taking of a portion of the output of a circuit and coupling or feeding it back into the input. If the portion of the output that is fed back is in phase with respect to the input, then the feedback is termed as positive feedback. With positive fecdback a dircuit can be made to generate an output with no estemal input. In this unit we will use positive feedback in making oscillators.

Any circuit that generates an alternating voltage is called an oscillator, To generate ac voltage, the circuit is supplied energy from a dc source, The oscillators have a variety of applications. In some applications we need voltages of low frequencies; in others of very high frequencies. For example, to test the performance of a stereo amplifier, we need a signal of variable frequency in the audio range,

Generation of high frequencies is essential in all communication systems. For example, in radio and television broadcasting, the transmitter radiates the signal using a carrier of very high frequency say from 550 kHz to 22 MHz in radio broadcasting, and from 47 MHz to few GHz in TV broadcasting. In radio and TV receivers too, there is an oscillator circuit which generates very high frequencies.

Finally, in tlus unit you will learn about few circuits, that produce sinusoidal waveforms of varying frequencies.

In the next unit we will use the concept of negative feedback to improve voltage regulation.

Objectives

After going through this unit you will be able to

- explain different types of feedback in amplifiers,
- explain the advantage of negative fecdback,

- state the conditions under which a feedback amplifier works as an oscillator,
- state the classification of oscillators,
- explain the working of LC and RC oscillators.

5.2 CONCEPT OF FEEDBACK

Feedback simply means transferring a portion of the energy from the output of a device back to its input. In other words, feedback is the process of taking a part of output signal and feeding it back to the input circuit. Look at the block diagram shown in Fig.5.1. Let A be the gain of the amplifier when there is no feedback.

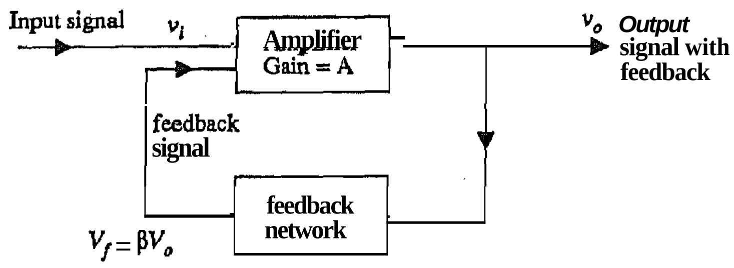

Fig.5.1: Schematic diagram of feedback amplifier.

A portion βV_o where $\beta \leq 1$, is then applied back to the amplifier input. The actual input to the amplifier thus consists of the sum of the signal voltage V_i plus the feedback voltage $V_f = \beta V_o$. We call β as the feedback fraction ($= V_f/V_o$).

So the total input voltage with feedback = $= V_i + \beta V_o$

The output voltage with this input is $V_o = (V_i + \beta V_o) A$

i.e. $V_o = AV_i + A\beta V_o$

as $V_o - A\beta V_o = AV_i$

$V_o(1 - A\beta) = AV_i$

$\therefore$ Gain with feedback, $A_f = \frac{V_o}{V_i} = \frac{A}{1 - A\beta}$ (5.1)

5.3 NEGATIVE FEEDBACK AND ITS EFFECT ON AMPLIFIER PERFORMANCE

In Eq. (5.1) if β is negative, then the feedback signal is out of phase with the applied signal, In such a case, the net input voltage to the amplifiers becomes the difference of the external input voltage and the feedback voltage. Since the net input to the amplifier is reduced the output of the amplifier also decreases. In other words, the gain of the amplifier reduces because of the feedback. Such a feedback is called **negative** or **degenerative feedback**. By putting β as a negative quantity into Eq.(5.1) you will get the gain with negative feedback as

$$A_f = \frac{A}{1 - A(-\beta)} = \frac{A}{1 + A\beta} \quad (5.2)$$

Since you am dividing A by a positive quantity obviously $A_f < A$. Thus negative feedback reduces the gain of the amplifier,

Before moving further solve the following SAQ to see for yourself how the gain is reduced,

SAQ 1

Calculate the gain of a negative-feedback amplifier with an internal gain, A = 100, and feedback factor β = 1/10.

In the last unit we have discussed the frequency response of an amplifier. The difference $(f_2 - f_1)$ is called the bandwidth (BW) of the amplifier. For an amplifier the product of gain and BW, called gain bandwidth product remains the same i.e. $A \times BW$ = constant. Since the gain of the amplifier is decreased with negative feedback, to get the product $A_f \times BW$ same as before, BW has to increase. In other words, the bandwidth of the amplifier increases with negative feedback. Fig.5.2 shows the frequency response of the amplifier both with and without feedback.

In Eq. (5.2) you can see that if $A\beta$ is very large compared to unity in the denominator, then 1 can be neglected in comparision with AB. So Eq. (5.2) reduces to

$$A_f = \frac{A}{A\beta} = \frac{1}{\beta} \tag{5.3}$$

Since β does not depend upon the parameters of the active device that you have used in the amplifier, such as a transistor, the gain with feedback, A_f is almost independent of the actual gain A. On the other hand, A is dependent upon the transistor parameters. Thus by introducing negative feedback one can have the gain to be completely independent of transistor parameters. This is known as stabilization of amplifier gain.

Likewise other effects of negative feedback are, reduction in distortion, reduction in noise, modification of the input and output resistances of the amplifier etc.

Thus, we have seen that the gain of an amplifier is reduced when negative feedback is used. However, the negative feedback improves the performance of the amplifier from so many other points of view. The advantages of negative feedback are listed as follows :

(i) It increases the bandwidth

(ii) It improves the stability of amplifier gain

(iii) It reduces distortion

(iv) It increases the input impedence

(v) It decreases the output impedence.

5.4 POSITIVE FEEDBACK AND OSCILLATIONS

When the feedback voltage is in phase with the input signal, then it adds to the input signal. In this case β is positive and the feedback is termed as **positive** or **regenerative feedback.** You can observe that when β is positive, the gain with feedback is given by

$$A_f = \frac{A}{1 - A\beta} \tag{5.4}$$

Since A is divided by a number less than unity $A_f > A$. So positive feedback increases the gain of an amplifier. This in turn reduces the bandwidth: because you know that the product (Gain x BW) is constant.

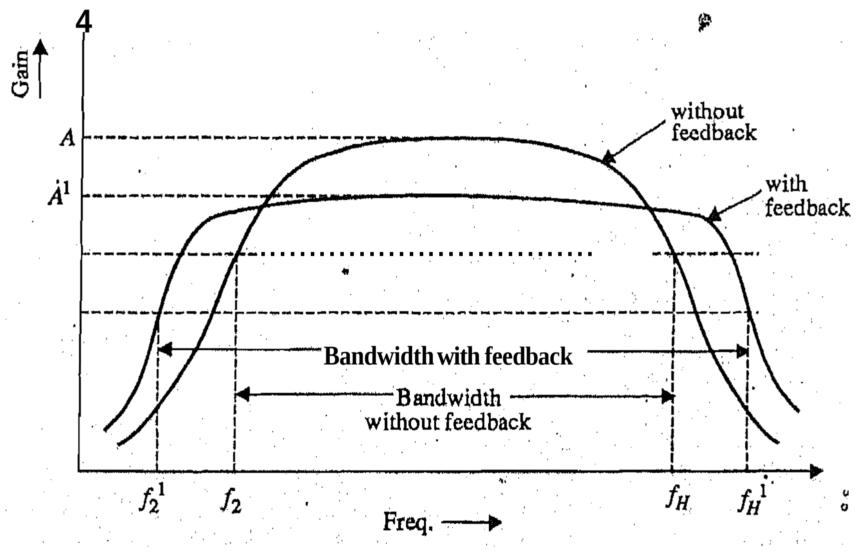

Fig.5.2: Frequency response of feedback amplifier.

In Eq. (5.4) if $A\beta = 1$, then $A_f = \infty$. In other words you have an amplifier which gives an output without an input ! Such a circuit is called as an oscillator. You should not be under the impression that you are getting an output power without any input power. The circuit draws the power from the dc supply connected to the transistor, and converts it into ac power. You are not getting something for nothing! So we can define an oscillator as that circuit which converts dc power into ac power. Fig.5.3 illustrates the difference between an oscillator and an amplifier.

SAQ 2

Fill your response in the space given below :

(i) Negative feedback.......gain and............bandwidth of an amplifier.

(ii) If the feedback fraction is 0.01, the gain with feedback is.......

(iii) Negative feedback..........distortion and noise.

(iv) Another name for negative feedback is..........

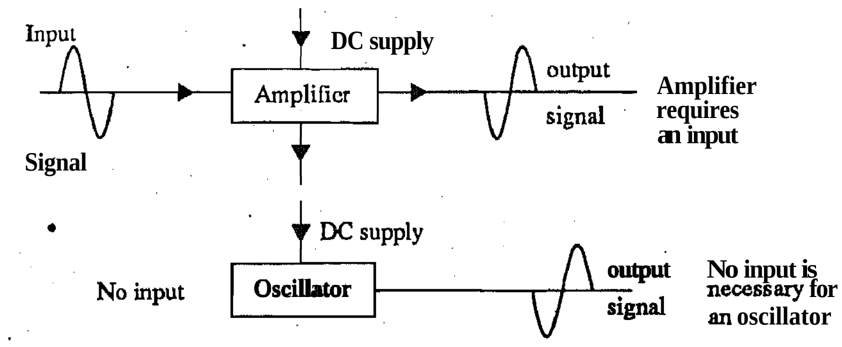

Fig.5.3: Comparison between an amplifier and an oscillator.

For a circuit to work as an oscillator certain conditions have to be satisfied. They are as follows:

1. The feedback should be positive,
2. $A\beta$ should be **unity.** This condition is known as **Barkhausen** criterion of oscillation.
3. The circuit must amplify and the amplification should be sufficient to overcome the losses in the circuit.

The third condition is to be satisfied in order to sustain oscillations otherwise you will get the damped oscillations as shown in Fig.5.4.

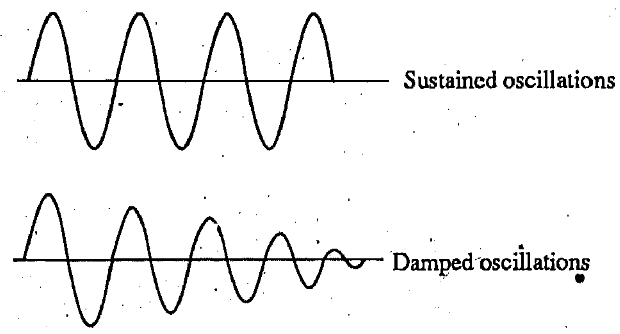

Fig.5.4: Stabilized and damped waveforms.

5.4.1 Classification of Oscillators

Oscillators are mainly divided into two types viz, sinusoidal and relaxation oscillators. Sinusoidal oscillators produce continuously varying signals like sine waves. Whereas relaxation oscillators produce non-sinusoidal signals like square waves, triangular waves etc. In this unit we will study about a few sinusoidal oscillators. Depending upon how oscillations are produced, sinusoidal oscillators are of the following type :

(i) Tuned circuit (LC) oscillators

(ii) RC oscillators.

5.4.2 Principle of Oscillation

An inductor and a capacitor connected in parallel form a tuned or tank circuit. In Fig.5.5a, energy is introduced into this circuit by connecting the capacitor to a dc voltage source. The negative terminal of the battery supplies electrons to the lower plate of the capacitor. Because of the accumulation of electrons, the capacitor gets charged and there is a voltage across it. We say that energy is stored in the capacitor in the form of electric potential energy. When the switch S is thrown to position 2, current starts flowing in the circuit. The capacitor now starts discharging through the inductor. Since the inductor has the property of opposing any change in current, the current builds up slowly. Maximum current flows in the circuit when the capacitor is fully discharged. At this instant, the potential energy of the system is zero, But the electron motion being greatest (maximum current), the magnetic field energy around the coil is maximum. This condition is shown in Fig.5.5b.

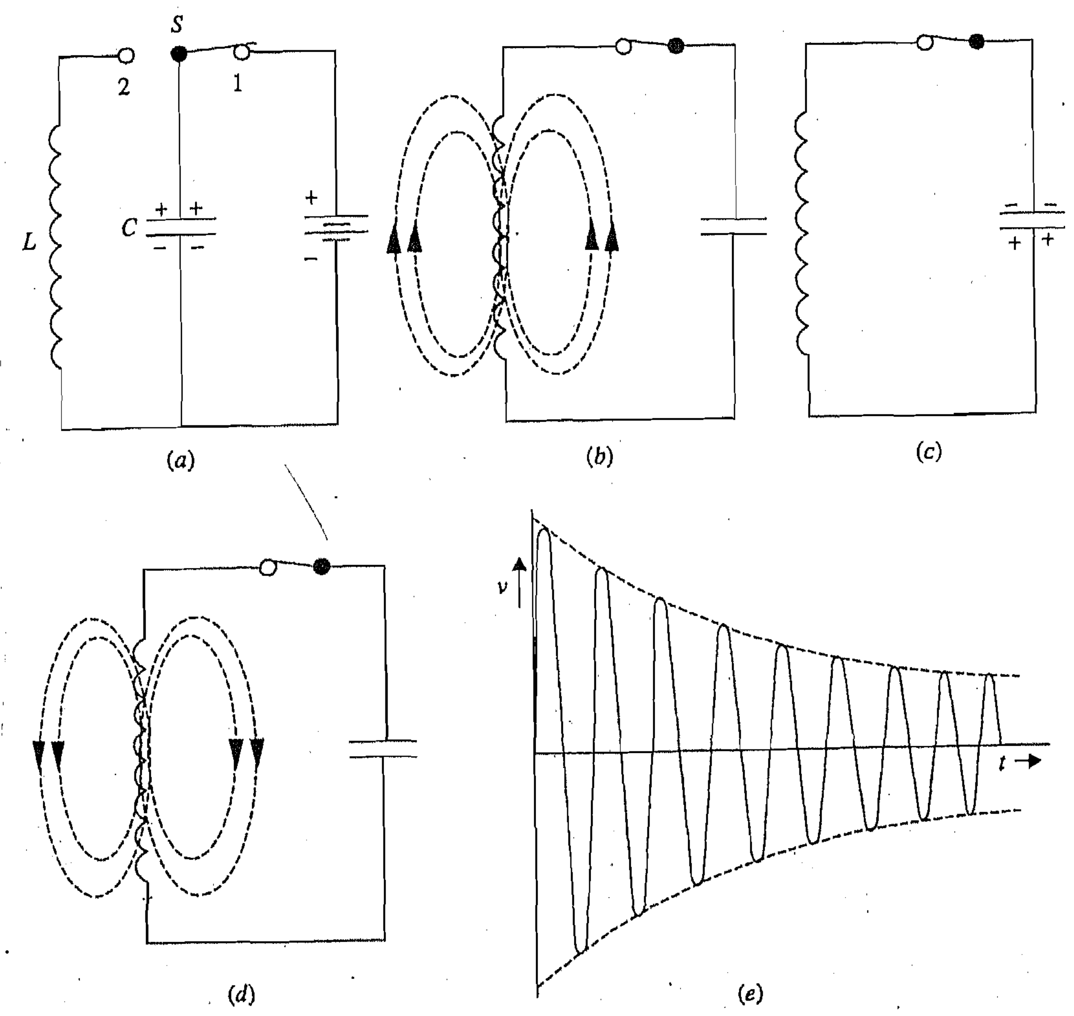

Fig.5.5: Damped oscillation in an LC circuit.

Once the capacitor is fully discharged, the magnetic field begins to collapse, The back emf in the inductor keeps the current flowing in the same direction. The capacitor starts charging, but with opposite polarity this time, as shown in Fig.5.5c. As the charge builds up across the capacitor, the current decreases and the magnetic field decreases. When the magnetic field energy drops to zero, the capacitor charges to the value it had in condition (a). Once again all the energy is in the form of potential energy. The capacitor now begins to discharge again, This time current flows in the opposition direction. Fig.5.5d shows the capacitor fully discharged. and also shows maximum current flowing in the circuit. Again, all the energy is in the magnetic field. The interchange or "oscillation" of energy between L and C is repeated again and again. This situation is similar to an oscillating pendulum, in which the energy keeps on interchanging between potential energy and kinetic energy. In a practical pendulum, because of the friction at the pivot and the air resistance, some energy is lost during each swing. The amplitude of each half-cycle goes on decreasing. Ultimately, the pendulum comes to rest, though it may like a long time. The oscillations of the pendulum are said to be damped.

A practical LC circuit deviates from the ideal one. The inductor coil will have some resistance, and the dielectric material of the capacitor will have some resistance, and the dielectric material of the capacitor will have some leakage. Because of these factors, some energy loss takes place during each cycle of the oscillation. As a result of this loss, the amplitude of oscillation decreases continuously and ultimately the oscillations die down. Thus, we find that a tank circuit by itself is capable of producing oscillations, but they are damped as shown in Fig.5.5e.

Frequency of Oscillations in an LC Circuit

In LC circuit, the constants of the system are the inductance and capacitance values. The frequency of oscillation is the same as the resonant frequency of the tank circuit. It is given by

$$f_o = \frac{1}{2\pi\sqrt{LC}} \qquad (5.4)$$

Sustained Oscillations

The oscillations of a pendulum can be maintained at a constant level, if we supply additional energy to it from time to time, to overcome the effect of the losses.

The oscillations of an LC circuit can also be maintained at a constant level in a similar way For this, we have to supply a spurt of pulse of energy at the right time in each cycle. The resulting "undamped oscillations" are called sustained oscillations, as shown in Fig.5.6. Such sustained oscillations (or continuous waves) are generated by the electronic oscillator circuits.

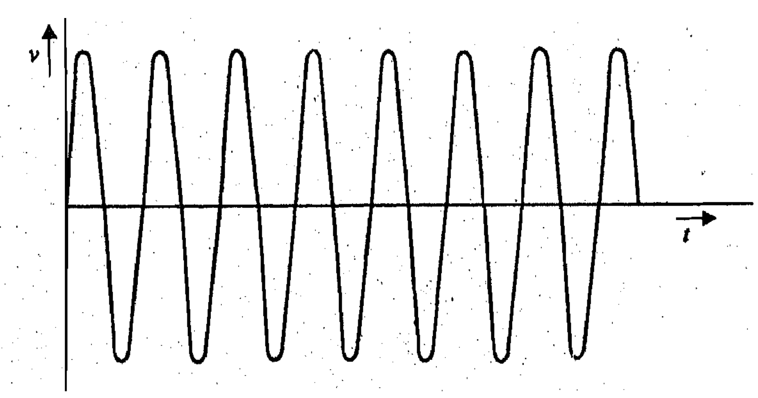

Fig.5.6: Sustained oscillations.

There are many varieties of LC-oscillator circuits. All of them have following three features in common :

(i) They must contain an active device (transistor or tube) that works as an amplifier.

(ii) There must be positive feedback in the amplifier.

(iii) The amount of feedback must be sufficient to overcome the losses.

5.4.3 Pbsitive Feedback Amplifier as an Oscillator

The main application of positive feedback is in oscillators. An oscillator generates ac output signal without any input ac signal. A part of the output is fed back to the input; and this feedback signal is the only input to the internal amplifier.

To understand haw an oscillator produces an output signal without an external input signal, let us consider Fig.5.7a. The voltage source v drives the input terminals YZ of the internal amplifier (with voltage gain A). The amplified signal AV drives the feedback network to produce feedback voltage $A\beta$. This voltage returns to the point X. If the phase shift due to the amplifier and feedback network is coirect, the signal at point X will be exactly in phase with the signal driving the input terminals YZ of the terminal amplifier.

The action of an oscillator is explained a little later. For the time being, assume that we connect points X and Y, and remove voltage source v. The feedback signal now drives the input terminals YZ of the amplifier (see Fig.5.7b). If $A\beta$ is less than unity, $A\beta v$ is less than v, and the output signal will die out as shown in Fig.5.7c. This happens because enough voltage is not returned to the input of the amplifier. On the other hand, if $A\beta$ is greater than unity, $A\beta v$ is greater than v, and the output voltage builds up as shown in Fig.5.7d. Such oscillations are called growing oscillations. Finally, if $A\beta$ equals unity, no change occurs in the output; we get an output whose amplitude remains constant, as shown in Fig.5.7e.

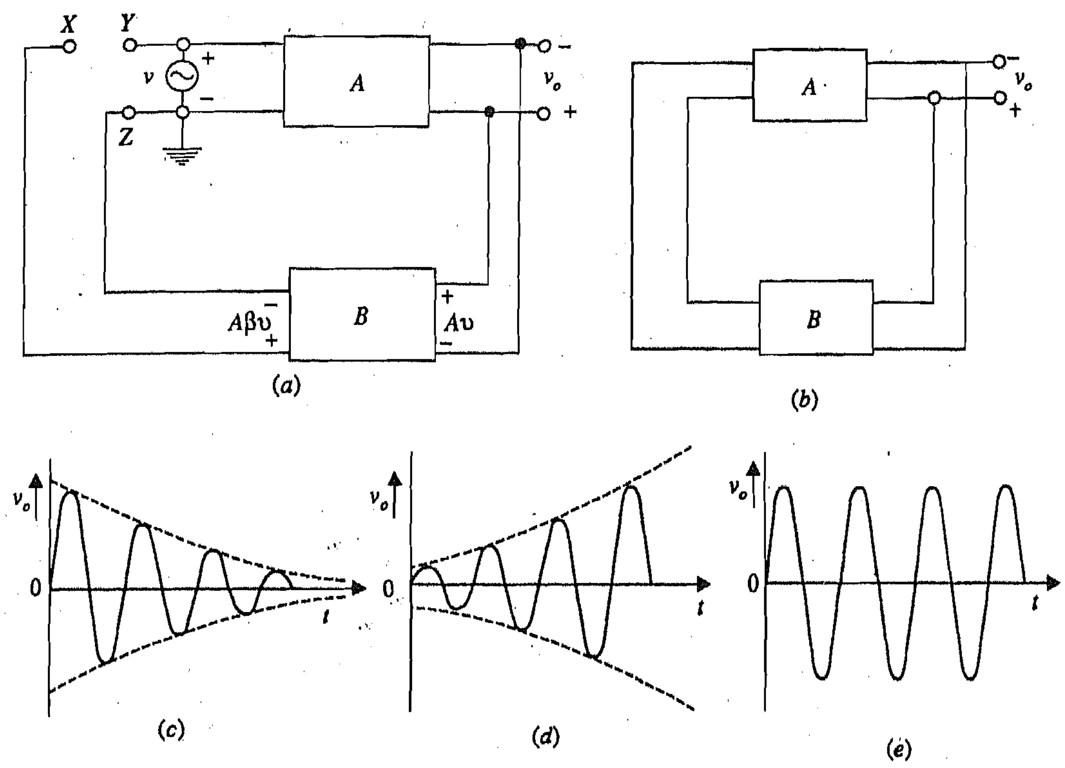

Fig.5.7: Proper positive feedback in an amplifier makes it an oscillator.

To find the necessary condition for the sustained oscillations, refer to Eq. (5.4) for the overall gain of the amplifier when the feedback is positive,

$$A_f = \frac{A}{1 - A\beta} \qquad (5.5)$$

It can now be seen that if $A\beta = 1$ $A_f = \infty$. The gain becoming infinity means that there is output without any input. In other words, the amplifier becomes an oscillator, The condition,

$$A\beta = 1, \qquad (5.6)$$

known as Barkhausen criterion of oscillation, is the necessary condition.

5.5 LC OSCILLATORS

LC oscillators or resonant-circuit oscillators are widely used for generating high frequencies. With practical values of inductors and capacitors, it is possible to produce frequencies as high as 500 MHz. The oscillators used in rf generators, radio and TV receivers, high,-frequency heating, etc, are LC oscillators. Such an oscillator has an amplifier, an LC resonant circuit and a feedback arrangement. There is a large variety of *LC*-oscillator circuits. Here, we shall discuss only a few important ones,

5.5.1 Tuned-collector Oscillator

Fig.5.8 shows a basic *LC*-oscillator circuit, It is called tuned-collector oscillator, because the tuned circuit is connected to the collector. We have used a transformer here. The primary of the transformer and the capacitor form the tuned circuit (or tank circuit) which decides the frequency of the oscillation. The secondary winding is connected to the base. Since a phase difference of 180° is provided by the transistor amplifier, and an additional 180° by the transformer, the type of feedback is positive. The transistor amplifier provides sufficient gain for oscillator action to take place.

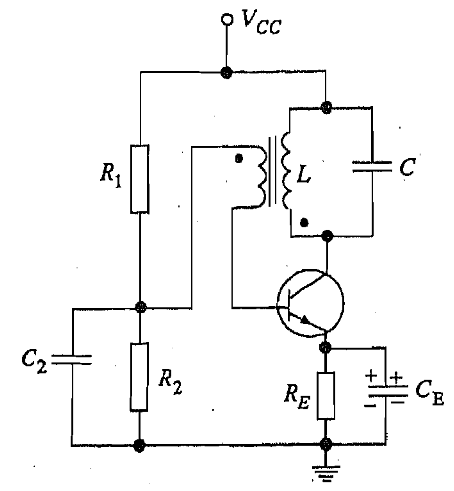

Fig.5.8: Tuned-collector oedllntor.

Resistors R_1 R_2 and R_E provide dc bias to the transistor. The capacitors C_E and C_2 bypass resistors R_E and R_2, respectively. It is for this reason, the resistors R_E and R_2 have no effect on the ac operation of the circuit. The dc bias voltage set by the potential divider R_1 and R_2 is connected to the base through the low-resistance secondary winding of the transformer. At the same time, the secondary of the transformer provides ac feedback voltage. This voltage appears across the base-emitter junction, since the junction point of R_1 and R_2 is at ac ground (due to bypass capacitor C_2). Notice that if capacitor C_2 was not connected across resistor R_2, the feedback voltage induced in the secondary of the transformer would not be directly going to the input of the transistor; some of this voltage will drop across R_2.

The moment we switch on the supply, the current starts building up. This induces a varying voltage in the secondary of the transformer. An amplified voltage again appears in the tank circuit, which responds most to its resonant frequency. Because of the sufficient gain provided by the transistor, and the proper amount of feedback in the correct phase, the oscillations grow till a certain level is reached. Thus, sustained oscillations are obtained.

To obtain the expression of (i) frequency of oscillafion and (ii) condition of oscillation we have to consider the equivalent circuit of tuned collector oscillator. Fig.5.9 shows the equivalent circuit of this oscillator using CE hybrid model.

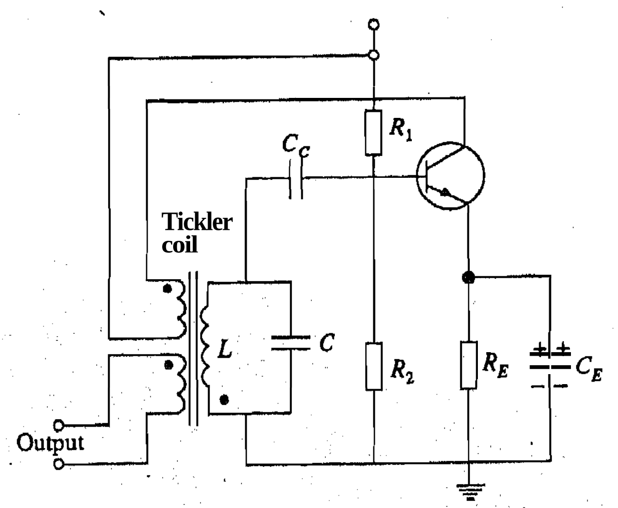

Fig.5.9: Equivalent circuit of tuned collector oscillator ueing CE hybrid model.

Here, the transformer winding resistances have been neglected. It is also assumed that $h_{re} = 0$. R is the resistance of the secondary reflected in the primary

The feedback voltage V_f is given by

$$V_f = -i\,\omega\, M I_L \tag{5.7}$$

The voltage V_2 across the tuned circuit is given by

$$V_2 = -(R + j\omega L_1)\, I_L = -\frac{1}{j\omega}\frac{I_c}{c_1} \tag{5.8}$$

Hence for feedback network,

$$\beta = \frac{V_f}{V_2} = \frac{-j\omega M I_L}{-(R + j\omega L_1) I_L} = \frac{j\omega M}{R + j\omega L_1} \tag{5.9}$$

Further

$$V_s = V_f \tag{5.10}$$

The current I is given

$$I = h_{fe} I_b + h_{oe} V_2 \tag{5.11}$$

The transfer impedence Z_T is given by

$$Z_T = \frac{V_f}{I} = \frac{-j\omega M I_L}{I_L + I_c} = \frac{-j\omega M I_L}{I_t + I_L (R + j\omega L_1) j\omega C_1} \tag{5.12}$$

[∵ from Eq. (5.8), $I_c = I_L (R + j\omega L_1) j\omega C_1$]

Also

$$I_b = \frac{V_s}{h_{ie}} \tag{5.13}$$

Eq. (5.11) may be written as

$$-\frac{V_s}{Z_T} = h_{fe} \cdot \frac{V_s}{h_{ie}} + h_{oe} V_2$$

or

$$V_2 = -\frac{V_s}{Z_T h_{oe}} - \frac{h_{fe} V_s}{h_{ie} h_{oe}}$$

Hence the gain of the amplifier is

$$A = \frac{V_2}{V_s} = \left[\frac{h_{fe}}{h_{oe} h_{oe}} + \frac{1}{Z_T h_{oe}}\right] \tag{5.14}$$

For sustained oscillation, according to Barkhausen criterion - $A\,\beta$ must equal one.

Heme from Eqs. (5.9) and (5.14) we get

$$\frac{j\omega M}{(R + j\omega L_1)}\left[\frac{h_{fe}}{h_{ie} h_{oe}} + \frac{1}{Z_T h_{oe}}\right] = 1$$

Substituting the value of Z_T from Eq. (5.12), we have

$$\frac{j\omega M}{(R + j\omega L_1)}\left[\frac{h_{fe}}{h_{ie} h_{oe}} + \frac{1}{h_{oe}\left(\frac{-j\omega M}{1 + (R + j\omega L_1) j\omega C_1}\right)}\right]$$

or

$$\frac{j\omega M}{(R + j\omega L_1)}\left[\frac{h_{fe}}{h_{ie} h_{oe}} - \frac{(1 + (R + j\omega L_1) j\omega C_1)}{h_{oe} j\omega M}\right] = 1$$

or

$$\frac{j\omega M\, h_{fe}}{h_{ie}\; h_{oe}} - \frac{1}{h_{oe}} - \frac{R\, j\omega C_1}{h_{oe}} - \frac{j\omega L_1 \times j\omega C_1}{h_{oe}} = R + j\omega L_1$$

Multiplying any quantity by j is equivalent to a rotation of $+90^\circ = \frac{\pi}{2}$ radian. If a sinusoidally varying quantity, such as voltage or current, is multiplied by the operator the angle variable is increased by 90°.

The applied peak e.m.f. across the resistance and inductance in series is

$E_o = I_o R + j\omega L\, I_o$

The multiplication of the potential difference $\omega L I_o$ across inductance by j is due to the fact that it is 90° ahead of the current which is in phase with the potential difference across the resistance.

Similarly, the peak e.m.f. equation in case of circuit containing resistance. and capacitance in series is

$E_o = I_o R - j\frac{I_o}{\omega c}$ the factor is there because the potential difference across capacitance is behind the current by 90° which is in phase with the peak potential difference across the resistance.

Multiplying by $\frac{h_{oe}}{j\omega C_1}$ on both sides, we have

$$\frac{h_{fe}}{h_{ie}} \times \frac{M}{C_1} - \frac{1}{j\omega C_1} - R - j\omega L_1 = \frac{(R + j\omega L_1)\, h_{oe}}{j\omega C_1}$$

or

$$\frac{h_{fe}}{h_{ie}} \times \frac{M}{C_1} = R + j\left(\omega L_1 - \frac{1}{\omega C_1}\right) + \left[\frac{-j h_{oe} R}{\omega C_1} + \frac{L_1 h_{oe}}{C_1}\right] \tag{5.15}$$

Equating the real parts in Eq. (5.15), we get

$$\frac{h_{fe}}{h_{ie}} - \frac{M}{C_1} = R + \frac{L_1 h_{oe}}{C_1}$$

or

$$\boxed{\frac{h_{fe}}{h_{ie}} = \frac{R C_1 + h_{oe} L_1}{M}} \tag{5.16}$$

Eq. (5.16) gives the condition for sustained oscillation, Equating the imaginary part in Eq. (5.15),

we get

$$\omega L_1 - \frac{1}{\omega C_1} - \frac{h_{oe} R}{\omega C_1} = 0$$

or

$$\omega^2 = \frac{1}{L_1 C_1}\left[1 + h_{oe} R\right]$$

or

$$\boxed{\omega^2 = \omega_0^2 (1 + h_{oe} R)} \tag{5.17}$$

$\left[\text{where } \omega_0^2 = \frac{1}{L_1 C_1}\right]$

Eq. (5.17) gives the frequency of oscillation. Thus equation shows that the frequency of oscillation exceeds the frequency of resonance of the tuned circuit.

5.5.2 Hartley Oscillator

The Hartley oscillator is one of the simplest types of oscillator circuits. In this circuit only one coil is used, which is tapped such that a portion L_1 of the coil is in the collector circuit, while L_2 is in the base circuit, The amplified energy in the collector section is fed back to

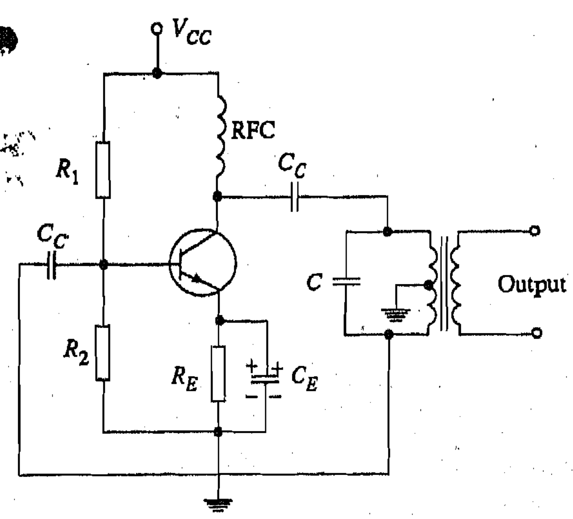

Fig: 5.10: Hartley Oscillator.

the base by means of inductive coupling and amount of coupling will depend upon the number of turns in L_1 and L_2. Fig.5.10 shows a Hartley oscillator circuit.

An *RFC* (radio frequency choke) permits an easy flow of dc current. At the same time, it offers very high impedence to high frequency currents. In other words, an *RFC* ideally looks like a dc short and an ac open. The presence of the coupling capacitor C_c in the output circuit of the Hartley oscillator does not permit the dc currents to go to the tank circuit. The radio-frequency energy developed across the *RFC* is capacitively coupled to the tank circuit through the capacitor C_c.

The frequency of oscillation can be calculated in a manner similar to the one described in case of tuned collector oscillator. It is given by

$$\omega = \omega_0 \sqrt{1 - \frac{X_1 X_2}{1 - h_{ie} h_{oe}}}$$

Where $\omega L_1 = X_1$ and $\omega L_2 = X_2$.

5.5.3 Colpitts Oscillator

The Colpitts oscillator in Fig.5.11 is a superb circuit. It is widely used in commercial signal generators above 1 MHz. The oscillator is similar to the Hartley oscillator given in Fig.5.10. The only difference is that the Colpitts oscillator uses a split-tank capacitor instead of a split-tank inductor. The *RFC* has the same function as in the Hartley oscillator. The voltage developed across the capacitor C_2 provides the regenerative feedback required for the sustained oscillations. The values of L, C_1 and C_2 determine the frequency of oscillation. The frequency of oscillation is given by

$$f = \frac{1}{2\pi\sqrt{LC}} \quad (5.18)$$

where,

$$C = \frac{C_1 C_2}{C_1 + C_2} \quad (5.19)$$

since C_1 and C_2 are in series.

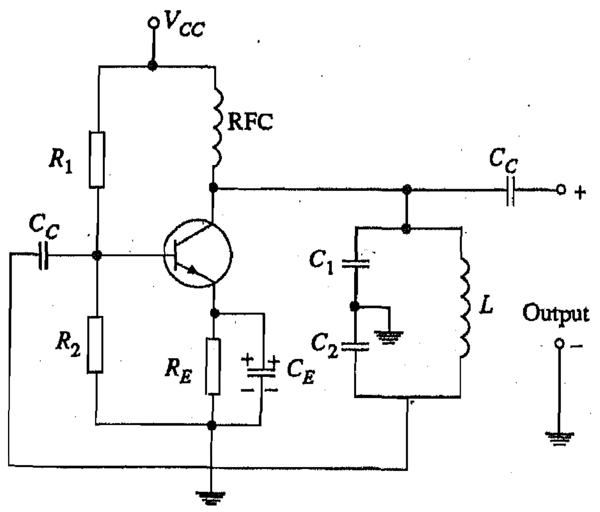

Fig.5.11: Colpitts oscillator using a transistor.

5.6 *RC* OSCILLATORS

Till now we have discussed only those oscillators which use an LC-tuned circuit. These tuned circuit oscillators are good for generating high frequencies, But for low frequencies (say, audio frequencies), the LC circuit becomes impracticable. RC oscillators are more suitable. There are many types of RC oscillators, but following two are most important:

(i) Phase-shift oscillator

(ii) Wein bridge oscillator

Basic Principles of RC Oscillators

We know that a single stage of an amplifier not only amplifies the input signal but also shifts its phase by 180°. If we take a part of the output and feed it back to the input, a negative feedback takes place. The net output voltage then decreases. But for producing oscillations we must have positive feedback (of sufficient amount). Positive feedback occurs only when the feedback voltage is in phase with the original input signal. This condition can be achieved in two ways. We can take a part of the output of a single stage amplifier (giving a phase shift of 180°) and then pass it through a phase-shift network giving an additional phase shift of 180°. Thus a total phase shift of 180° +180° = 360° (which is equivalent to a phase shift of 0°) occurs, as the signal passes through the amplifier and the phase-shift network. This is the principal of a phase-shift oscillator.

Another way of getting a phase shift of 360° is to use two stages of amplifiers each giving a phase shift of 180°. A part of this output is fed back to the input through a feedback network without producing any further phase shift. This is the principle of a wein bridge oscillator.

5.6.1 Phase-Shift Oscillator

Fig.5.12 shows a phase-shift oscillator.

As shown in the figure, the phase of the signal at the input gets reversed when it is amplified by the amplifier. The output of the amplifier goes to a feedback network. The

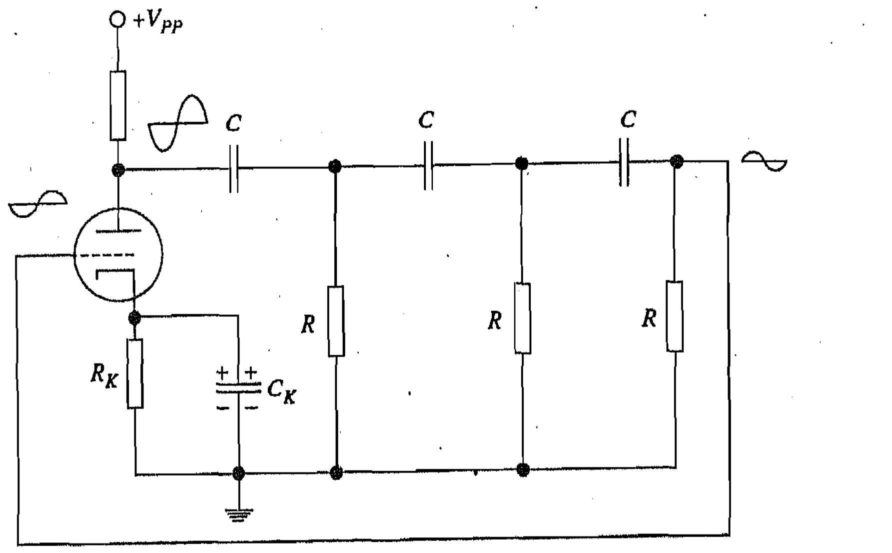

Fig.5.12 : Phase-shift oscillator.

feedback network consists of three identical RC sections. Each *RC* section provides a phase shift of 60°. Thus a total of 60° x 3 = 180° phase shift is provided by the feedback network. The output of this network is now in the same phase as the originally assumed input to the amplifier, as shown in figure. If the condition $A\beta = 1$ is satisfied, oscillations will be maintained.

It may be shown by a straightforward (but a little complicated) analysis that the frequency at which the RC network provides exactly 180° phase-shift is given by

$$f = \frac{1}{2\pi R C\sqrt{6}} \tag{5.20}$$

This must then be the frequency of oscillation.

SAQ 3

A transistor phase-shift oscillator uses three identical RC sections in the feedback network. The values of the components are R = 100 k and C = 0.01 μ F. Calculate the frequency of oscillation.

5.6.2 Wein Bridge Oscillator

The Wein bridge oscillator is a standard circuit for generating low frequencies in the range of 10 Hz to about 1 MHz. It is used in all commercial audio generators. Basically, this oscillator consists of two stages of RC-coupled amplifier and a feedback network, The block diagram of Fig.5.13 explains the principles of working of this oscillator.

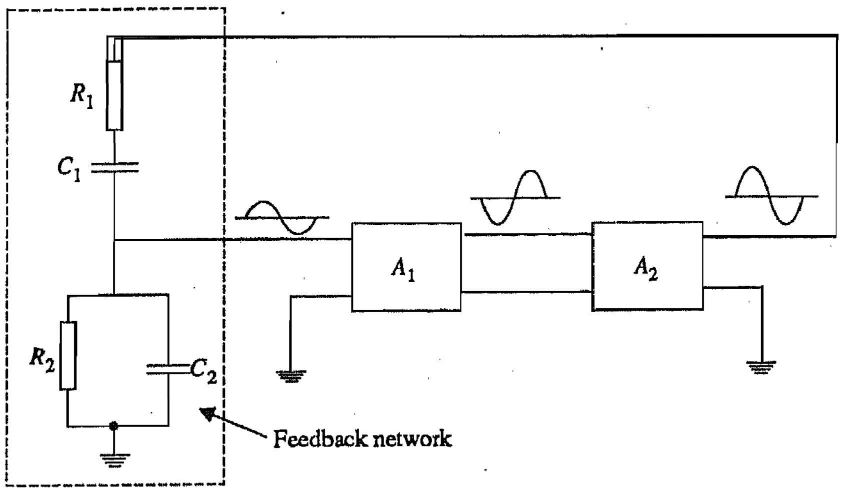

Fig.5.13: Block diagram of a basic Wein bridge oscillator.

Here, the blocks A_1 and A_2 represent two amplifier stages. The output of the second stage goes to the feedback network. The voltage across the parallel combination C_2 R_2 is fed to the input of the first stage. The net phase shift through the two amplifiers is zero. Therefore, it is evident that for the oscillation to be maintained, the phase shift through the coupling network must be zero. It can be shown that this condition occurs at a frequency given by

$$f_o = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}} \qquad (5.21)$$

To have a gain we add some amount of negative feedback, The addition of negative feedback modifies the circuit in Fig.5.13 to that shown in Fig.5.14. The same circuit is redrawn as in Fig.5.15.

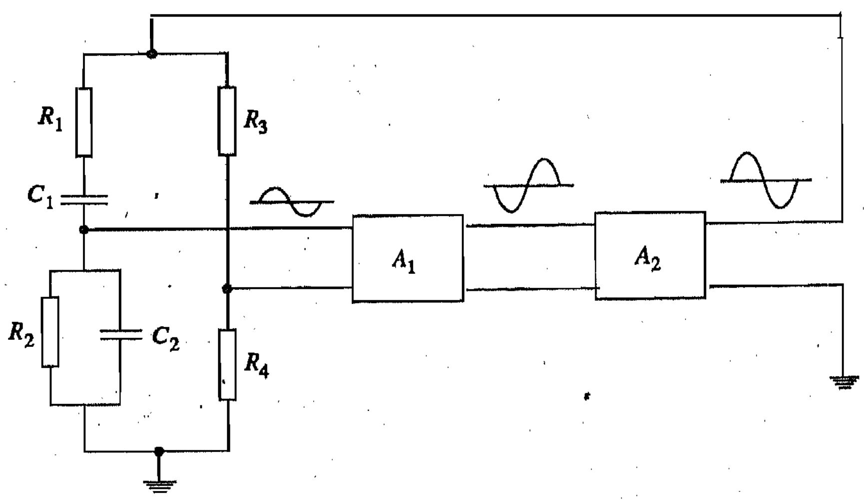

Fig.5.14: Circuit in Fig. 5.13 modified to include negative feedback.

You may now see why this circuit is called a bridge oscillator. In this circuit, the resistors' R_3 and R_4 provide the desired negative feedback. The two blocks in Fig.5.14 representing the two stages of the amplifier are replaced by a single block in Fig.5.15.

We can have a continuous variation of frequency in the oscillator by varying the two capacitors C_1 and C_2 simultaneously. These capacitors are variable air-gang capacitors. We can change the frequency range of the oscillator by switching into the circuit different values of resistors R_1 and R_2.

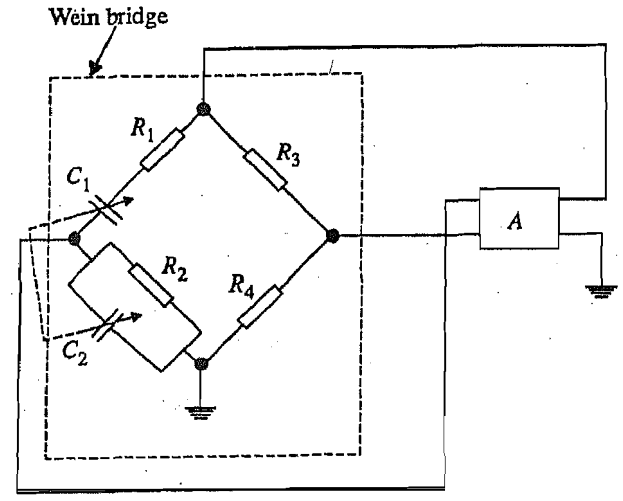

Fig.5.15: Circuit in Fig. 5.14 is redrawn to show the presence of a "bridge" in Wein bridge oscillator.

SAQ 4

The *RC* network of a Wein bridge oscillator consists of resistors and capacitors of values $R_1 = R_2 = 220$ K and $C_1 = C_2 = 250$ pF. Calculate the frequency of Oscillations.

5.7 SUMMARY

(1) An amplifier in which a portion of the output voltage or current is fed back to the input is called a feedback amplifier.

(2) If the feedback signal is in phase with the applied signal and aids it, positive or regenerative feedback takes place.

(3) If the feedback signal is opposed to the applied signal (i.e. out of phase), negative or degenerative feedback takes places.

(4) Gain increases with positive feedback, which may lead to oscillations.

(5) Negative feedback decreases the gain, and also distortion.

(6) An oscillator acts as energy converter which changes direct current energy into alternating current energy.

(7) Essential parts of an oscillator are (i) the frequency determining network (ii) source of dc energy and (iii) a feedback.circuit to provide positive feedback.

(8) Hartley oscillator uses a tapped coil'in the feedback circuit.

(9) Colpitt's oscillator uses a tapped capacitance network in the feedback circuit, It has better frequency stability than Hartley oscillator.

(10) A Wein bridge oscillator is an *RC* oscillator whose frequency of oscillation can be varied over a wide range.

5.8, TERMINAL QUESTIONS

(1) Gain of an amplifier without feedback is 10^3. If the gain with negative Feedback is 10^2, what is the feedback ratio ?

(2) An amplifier withnegative feedback has a voltage gain of 100. It is found that without feedback, an input signal of 50 mV is required to produce a given output; whereas with feedback, the input signal must be 0.6 V for the same output. Calculate the value of A and β.

(3) What is meant by stabilization of gain? How is it achieved with negative feedback ?

(4) What is meant by loop gain 7

(5) A Wien bridge oscillators uses 10 k resistors and 4.70 nF capacitors in its bridge circuit. What is the frequency of oscillation7

5.9 SOLUTIONS/ANSWERS

SAQ's

1. The gain of the feedback amplifier is given by

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

Here, A = 100; β = 1/10 = 0.1. Hence

$$A_f = \frac{100}{1 + 100 \times 0.1} = \frac{100}{1 + 10} = \frac{100}{11}$$

$$= 9.09$$

2. (i) Decreases, Increases

(ii) $\frac{1}{\beta} = \frac{1}{0.01} = 100$

(iii) Reduces

(iv) Degenerative feedback.'

3, The frequency of oscillation of a phase-shift oscillator is given as

$$f_o = \frac{1}{2\pi R C \sqrt{6}}$$

Here, R = 100 k = 10^5 ; $C = 0.01\ \mu F = 10^{-8}$ F.

Therefore,

$$f_o = \frac{1}{2 \times 3.141 \times 10^5 \times 10^{-8} \times 2.45} = 64.97 \text{ Hz}$$

4. For a Wein bridge oscillator, the frequency of oscillation is given as

$$f_o = \frac{1}{2\pi \sqrt{R_1 R_2 C_1 C_2}} = \frac{1}{2\pi RC}$$

where $R_1 = R_2 = R$, and $C_1 = C_2 = C$.

Here, R = 220 K = 2.2×10^5 ; C = 250 pF = 2.5×10^{-10} F.

Therefore,

$$f_o = \frac{1}{2 \times 3.141 \times 2.2 \times 10^5 \times 2.5 \times 10^{-10}}$$

$$= 2893.7 \text{ Hz}$$

$$= 2.89 \text{ kHz}.$$

TQ's

1. $A' = \frac{A}{1 + A\beta}$ $A' = 100, A = 1000$

$$100 = \frac{1000}{1 + A\beta}$$

$$1 + 1000\ \beta = \frac{1000}{100} = 10$$

$$1000\ \beta = 10 - 1 = 9$$

$$\beta = \frac{9}{1000} = .009$$

$$\beta = .009 \times 100 = 0.9\%.$$

2. The **gain** A_f of the feedback amplifier is 100. The input voltage required to produce the same output voltage as for the **amplifier without** feedback. if 0.6 V. Thus, the output will be

$$V_o = A_f V_i = 100 \times 0.6 \times = 60V$$

If no feedback is employed, the required input to produce 60V output is 50 mV = 0.05V. Hence, the internal gain of the amplifier is

$$A = \frac{V_o}{V_i} = \frac{60}{0.05} = 1200$$

Now using Eq. 5.2, we have

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

or

$$V + 1200 \times \beta = \frac{1200}{100}$$

or

$$\beta = \frac{12-1}{1200} = \frac{11}{1200} = \frac{11}{12}\ \%.$$

3. Making the gain independent device parameter is known as gain stabilization In the limit $A\beta >> 1$, negative feedback reduces the **gain** to $\frac{1}{\beta}$, **which** is independent of **device** parameters.

4. **The** product $A\beta$ is known as loop gain. The input signal is multiplied By A times in passing through the amplifier of β times before it arrives at the input. Hence the name **loop** gain

5. $$f = \frac{1}{2\pi RC}\ R = 10K\ \Omega = 10 \times 10^3\ \Omega$$

$$C = 4.7\ nF = 4700\ pF.$$

$$f = \frac{1}{2 \times 3.142 \times 10 \times 10^3 \times 4700 \times 10^{-12}}$$

$$= 3386\ Hz.$$