II YEAR II SEMESTER

Electronic Circuits – Analysis and Design

UNIT - IV

Feedback Amplifiers and Oscillators

By

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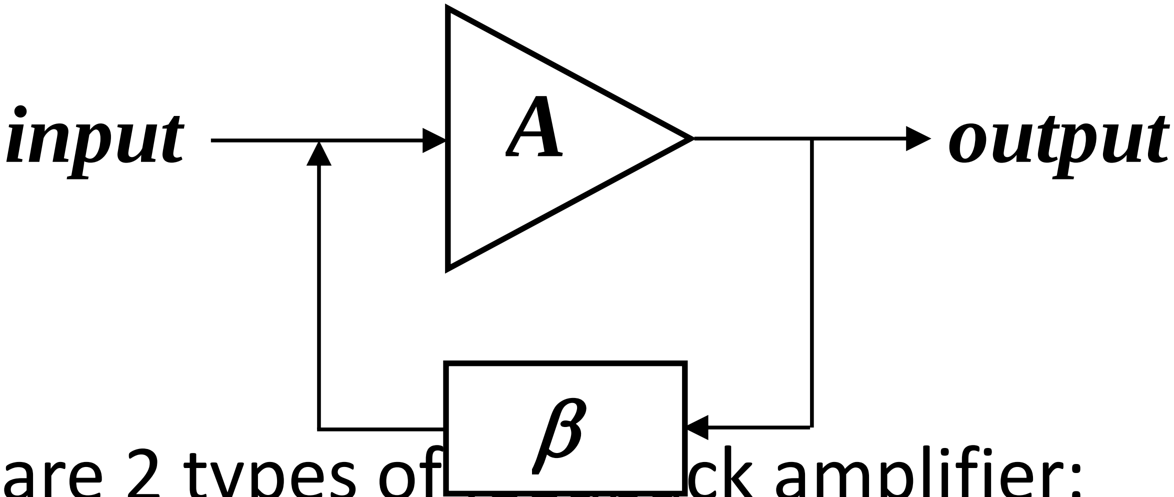
Introduction to Feedback

- Feedback is used in virtually all amplifier system.
- Invented in 1928 by Harold Black – engineer in Western Electric Company
  - methods to stabilize the gain of amplifier for use in telephone repeaters.
- In feedback system, a signal that is proportional to the output is fed back to the input and combined with the input signal to produce a desired system response.
- However, unintentional and undesired system response may be produced.

Feedback Amplifier

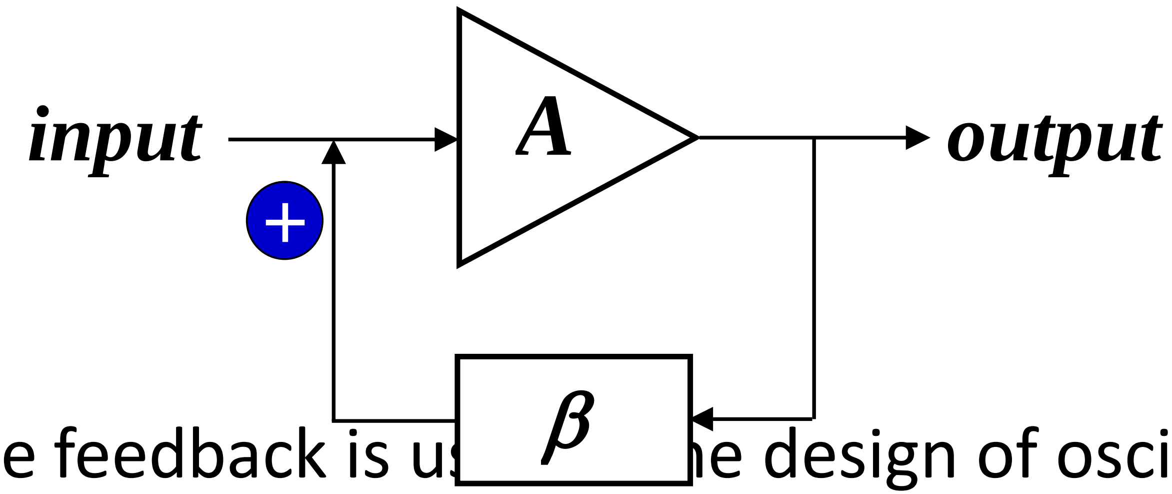
- *Feedback* is a technique where a proportion of the output of a system (amplifier) is fed back and recombined with input



- There are 2 types of feedback amplifier:
  - Positive feedback
  - Negative feedback

Positive Feedback

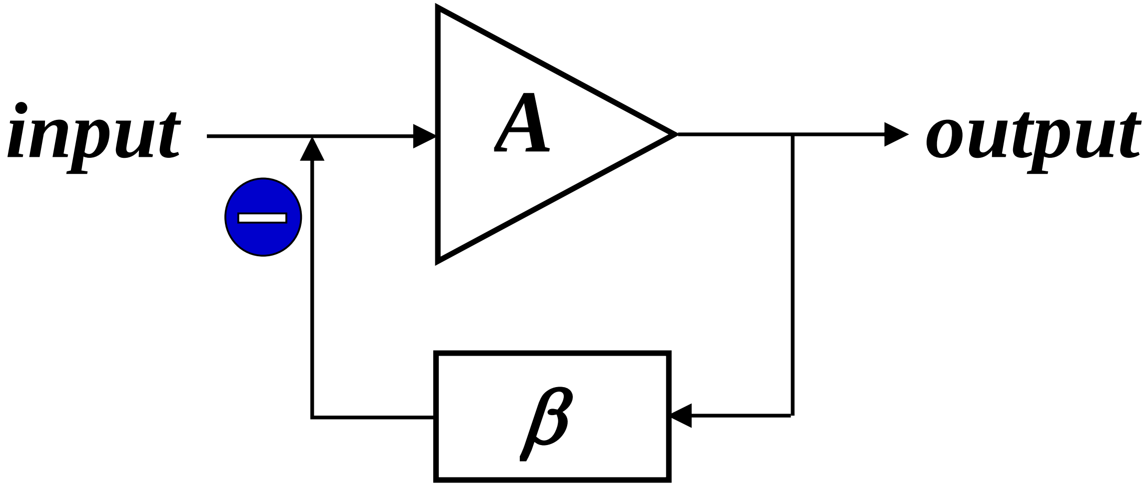
- Positive feedback is the process when the output is *added* to the input, amplified again, and this process continues.



- Positive feedback is us he design of oscillator and other application.

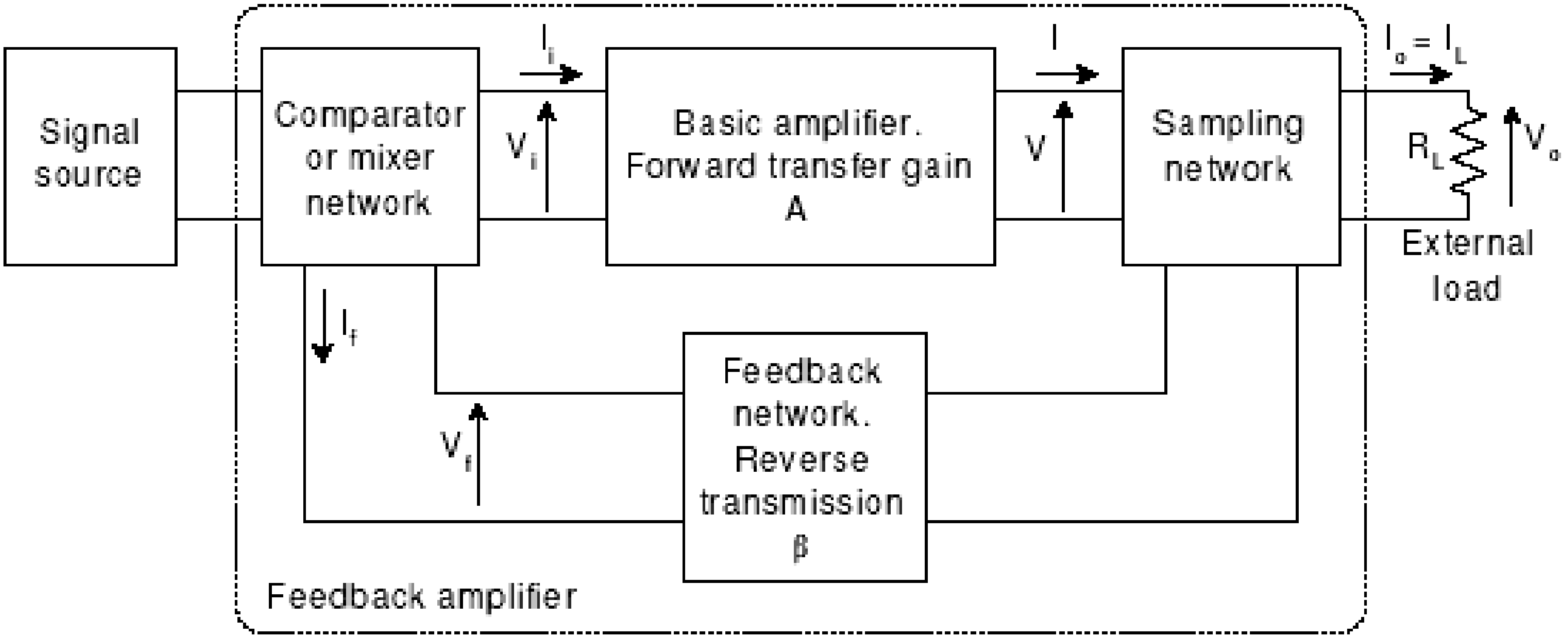
Negative Feedback

- Negative feedback is when the output is subtracted from the input.



- The use of negative feedback reduces the gain. Part of the output signal is taken back to the input with a negative sign.

Feedback Amplifier - Concept



Basic structure of a single - loop feedback amplifier

Advantages of Negative Feedback

1. Gain Sensitivity – variations in gain is reduced.
2. Bandwidth Extension – larger than that of basic amplified.
3. Noise Sensitivity – may increase S-N ratio.
4. Reduction of Nonlinear Distortion
5. Control of Impedance Levels – input and output impedances can be increased or decreased.

Feedback Topologies:

1. The Four Basic Feedback Topologies

   12.2.1 Series - Shunt Feedback or Voltage Amplifiers

   2. shunt-series feedback or Current Amplifiers
   3. Series-Series Feedback or Transconductance Amplifiers
   4. Shunt - Shunt Feedback or Transresistance Amplifiers
   5. Summary of Feedback Topologies

3. Negative Feedback Voltage Amplifiers

   1. Gain Calculation
   2. Bandwidth Extension
   3. Input and output Impedance
   4. Noise Reduction
   5. Advantages and Disadvantages of negative feedback

The Four Basic Feedback Topologies

1. Series-Shunt Feedback (Voltage amplifiers)

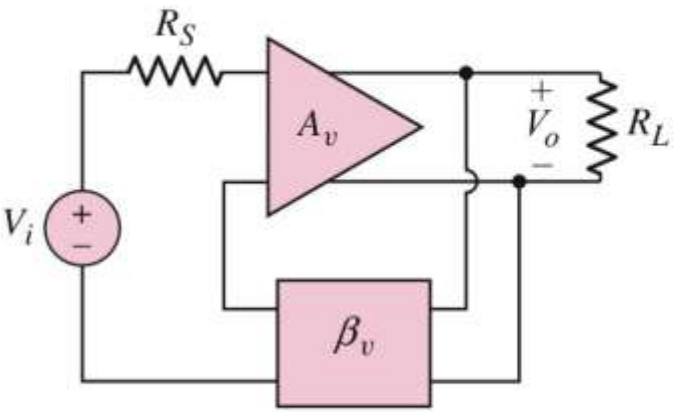
   i/p mixing   o/p sampling

2. Shunt- Series Feedback (Current amplifiers)

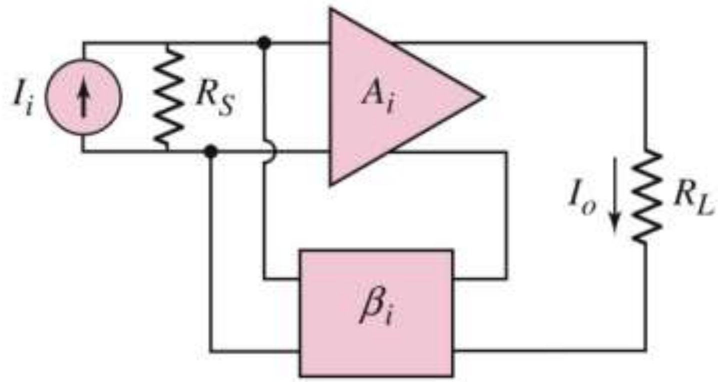
3. Series-Series Feedback (Transconductance amplifiers)

4. Shunt-Shunt Feedback (Transresistance amplifiers)

Feedback Configuration

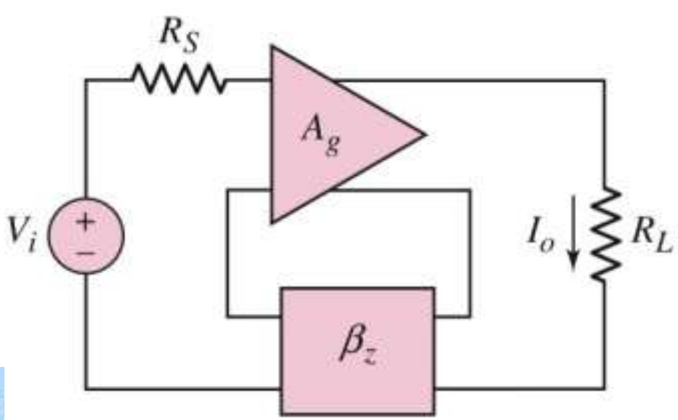


(a) Series–shunt

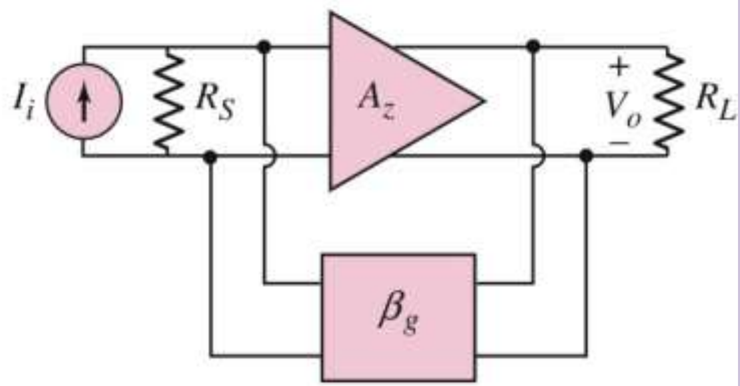


(b) Shunt–series

Series: connecting the feedback signal in series with the input signal voltage.



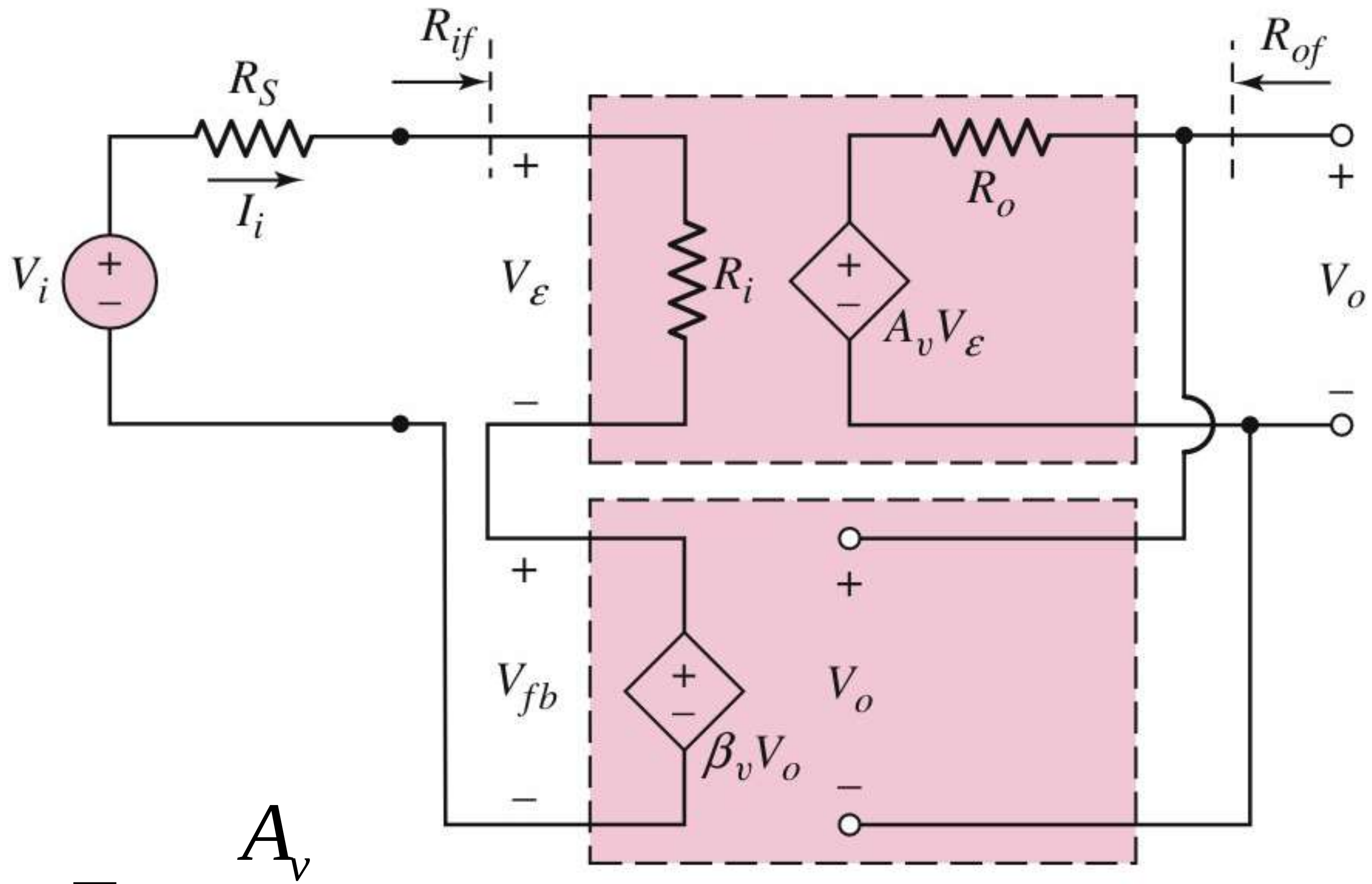
(c) Series–series



(d) Shunt–shunt

Shunt: connecting the feedback signal in shunt (parallel) with an input current source

Series - Shunt Configuration



$$A_{vf} = \frac{A_v}{1+\beta_v A_v}$$

Series - Shunt Configuration

if $R_o << R_L$

then the output of feedback network is an open circuit;

Output voltage is:

$$V_o = A_v V_\varepsilon$$

feedback voltage is:

$$V_{fb} = \beta_v V_o$$

where ßv is closed-loop voltage transfer function

By neglecting R_s due to $R_i >> R_s$ error voltage is:

$$V_\varepsilon = V_i - V_{fb}$$

$$\therefore A_{vf} = \frac{V_o}{V_i} = \frac{A_v}{1+\beta_v A_v}$$

Series - Shunt Configuration

Input Resistance, R_{if}

$$V_i = V_\varepsilon + V_{fb} = V_\varepsilon + \beta_v (A_v V_\varepsilon)$$

$$V_\varepsilon = \frac{V_i}{(1+\beta_v A_v)}$$

- Inp

$$I_i = \frac{V_\varepsilon}{R_i} = \frac{V_i}{R_i(1+\beta_v A_v)}$$

- R_{if} with feedback

$$R_{if} = \frac{V_i}{I_i} = R_i(1+\beta_v A_v)$$

Output Resistance, R_{of}

Assume Vi=0 and Vx applied to output terminal.

$$V_\varepsilon + V_{fb} = V_\varepsilon + \beta_v V_x = 0$$

Or

$$V_\varepsilon = -\beta_v V_x$$

- Inp

$$I_i = \frac{V_x - A_v V_\varepsilon}{R_o} = \frac{V_x(1+\beta_v A_v)}{R_o}$$

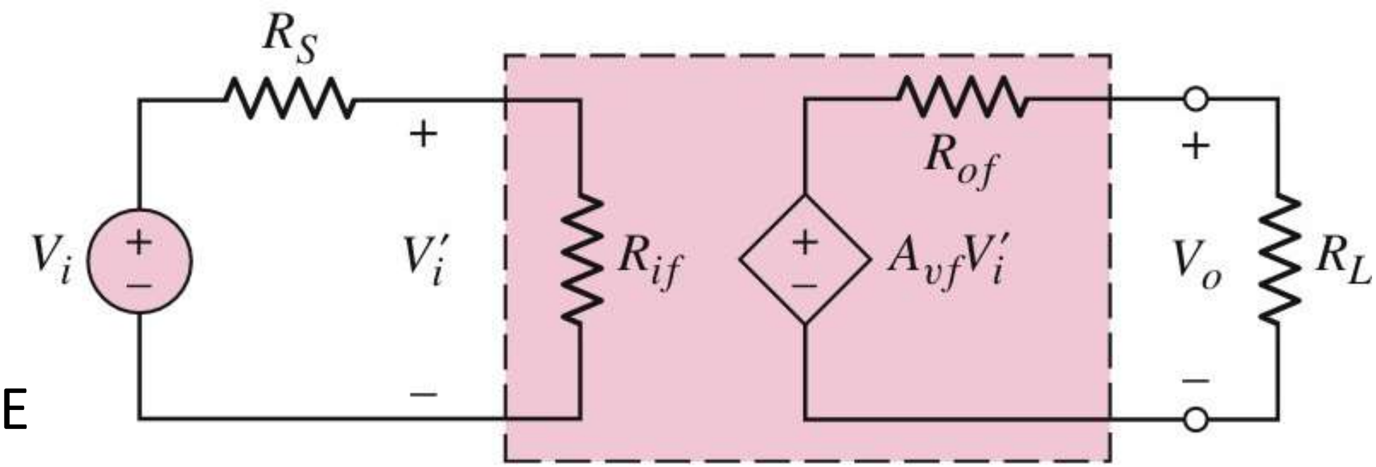
- R

$$R_{of} = \frac{V_x}{I_x} = \frac{R_o}{(1+\beta_v A_v)}$$

Series - Shunt Configuration

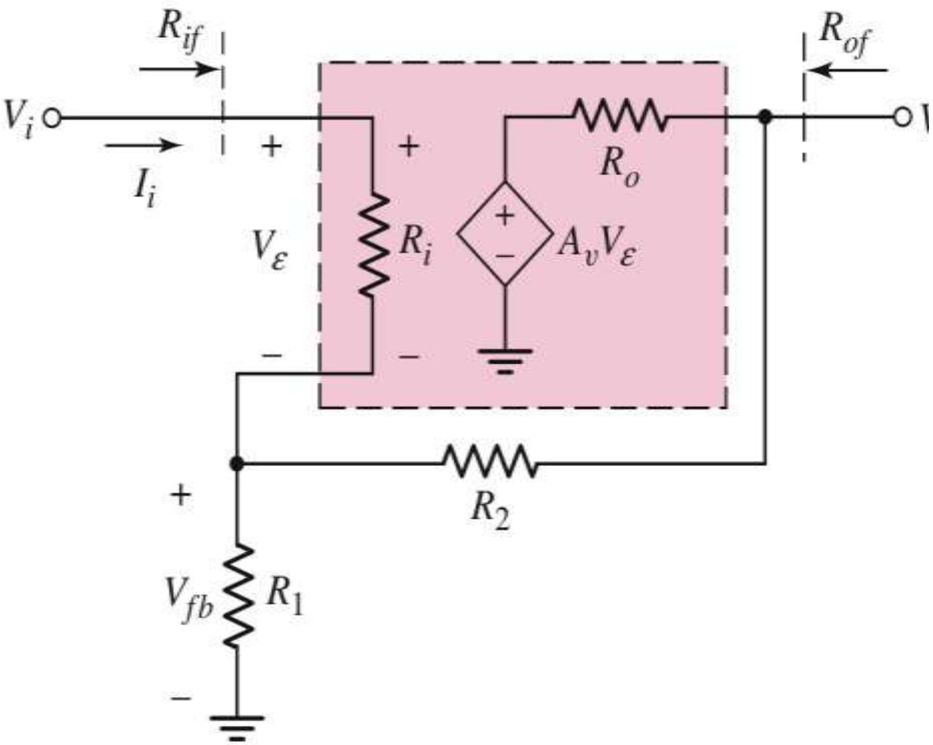
- Series input connection increase input resistance – avoid loading effects on the input signal source.
- Shunt output connection decrease the output resistance - avoid loading effects on the output signal when output load is connected.

E



voltage amplifier

Series - Shunt Configuration



$$\boldsymbol{V_o = A_v V_\varepsilon}$$

$$\boldsymbol{V_\varepsilon} = V_i - V_{fb}$$

$$V_{fb} \cong \left(\frac{R_1}{R_1 + R_2}\right) V_o$$

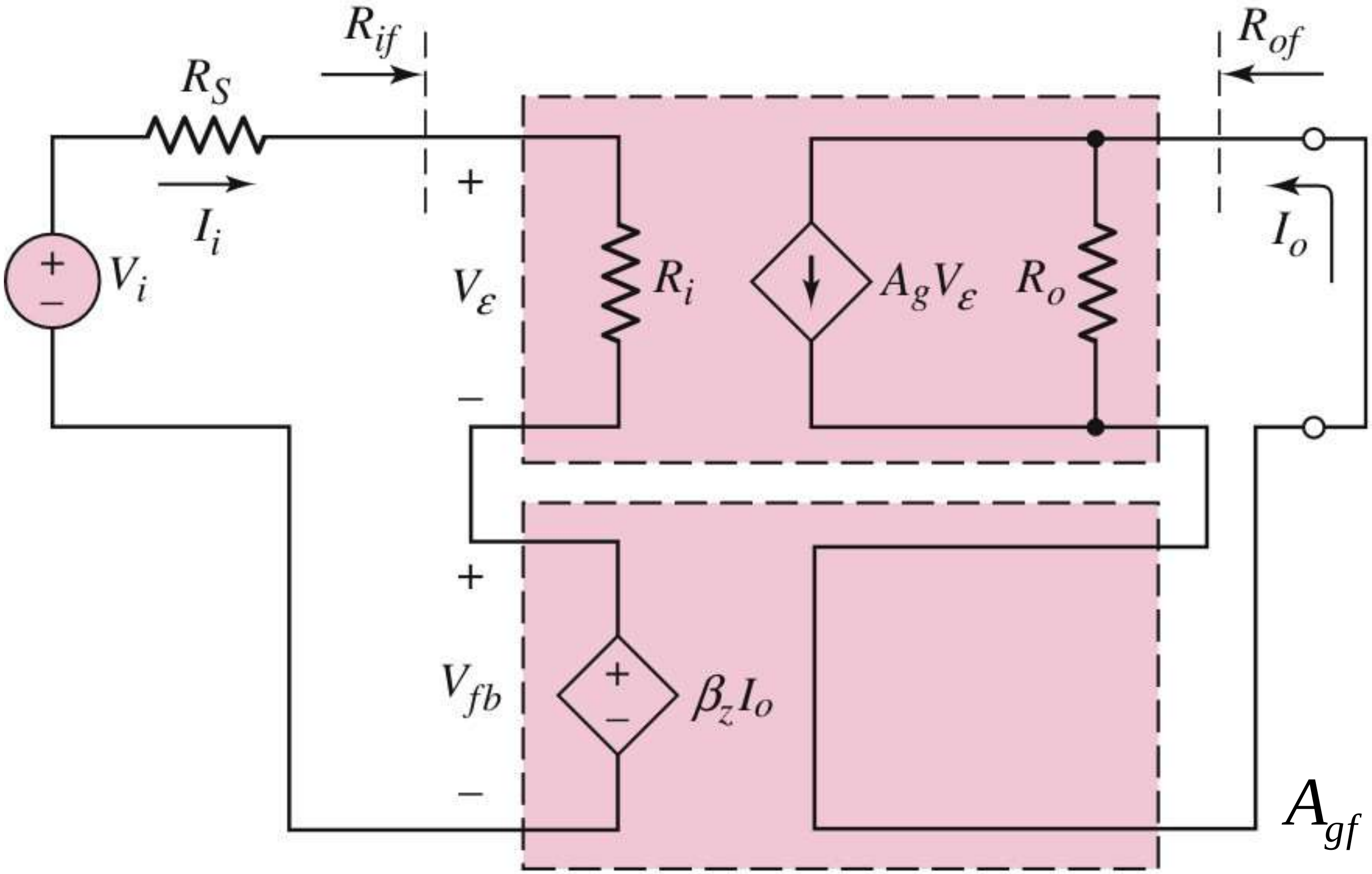
$$A_{vf} = \frac{V_o}{V_i} = \frac{A_v}{1 + \dfrac{A_v}{\left(\dfrac{R_1}{R_1 + R_2}\right)}} = \frac{A_v}{1 + \beta A_v}$$

$$V_i = V_\varepsilon + \left(\frac{R_1}{R_1 + R_2}\right) V_o = V_\varepsilon + \frac{A_v V_\varepsilon}{\left(1 + \dfrac{R_2}{R_1}\right)}$$

$$R_{if} = \frac{V_i}{I_i} = \frac{V_i}{V_\varepsilon / R_i} = R_i (1 + \beta A_v)$$

Equivalent circuit

Series – Series Configuration



$$A_{gf} = \frac{A_g}{1+\beta_g A_g}$$

Series – Series Configuration

- The feedback samples a portion of the output current and converts it to a voltage – voltage-to-current amplifier.
- The circuit consist of a basic amplifier that converts the error voltage to an output current with a gain factor, A_g and that has an input resistance, R_i.
- The feedback circuit samples the output current and produces a feedback voltage, V_{fb}, which is in series with the input voltage, V_i.

Series – Series Configuration

Assume the output is a short circuit, the output current:

$$I_o = A_g V_\varepsilon$$

feedback voltage is:

$$V_{fb} = \beta_z I_o$$

where ßz is a resistance feedback transfer function

Input signal voltage (neglect Rs=∞):

$$V_i = V_\varepsilon + V_{fb}$$

$$\therefore A_{gf} = \frac{I_o}{V_i} = \frac{A_g}{1+\beta_z A_g}$$

Series – Series Configuration

Input Resistance, R_{if}

$$V_i = V_\varepsilon + V_{fb} = V_\varepsilon + \beta_z (A_g V_\varepsilon)$$

Or

$$V_\varepsilon = \frac{V_i}{(1+\beta_z A_g)}$$

- Input current

$$I_i = \frac{V_\varepsilon}{R_i} = \frac{V_i}{R_i(1+\beta_z A_g)}$$

- R_{if} with feedback

$$R_{if} = \frac{V_i}{I_i} = R_i(1+\beta_z A_g)$$

Output Resistance, R_{of}

Assume I_i=0 and I_x applied to output terminal.

$$I_\varepsilon + I_{fb} = I_\varepsilon + \beta_z I_x = 0$$

$$I_\varepsilon = -\beta_z I_x$$

$$V_x = (I_x - A_g I_\varepsilon) R_o$$

$$V_x = \left[I_x - A_g(-\beta_z I_x)\right] R_o$$

$$V_x = I_x(1+\beta_z A_g) R_o$$

- R_{of} with feedback

$$R_{of} = \frac{V_x}{I_x} = R_o\left(1+\beta_z A_g\right)$$

COMPARISON OF FEEDBACK AMPLIFIERS:

Parameter	Voltage Series	Current Shunt	Current Shunt	Voltage Shunt
Gain with feedback	$A_{vf} = \frac{A_v}{1+\beta A_v}$ Decreases	$G_{mf} = \frac{G_m}{1+\beta G_m}$ decreases	$A_{if} = \frac{A_i}{1+\beta A_i}$ decreases	$R_{mf} = \frac{R_m}{1+\beta R_m}$ decreases
Stability	Improve	Improve	Improve	Improve
Frequency response	Improve	Improve	Improve	Improve
Frequency distortion	Reduces	Reduces	Reduces	Reduces
Input resistance	$R_{if} = R_i(1+\beta A_v)$ increase	$R_{if} = R_i(1+\beta G_m)$ increase	$R_{if} = \frac{R_i}{1+\beta A_i}$ decreases	$R_{if} = \frac{R_i}{1+\beta R_m}$ decreases
Output resistance	$R_{of} = \frac{R_o}{1+\beta A_v}$ decreases	$R_{of} = R_o(1+\beta G_m)$ increases	$R_{of} = (1+\beta A_i)$ increases	$R_{of} = \frac{R_o}{1+\beta R_m}$ decreases

Oscillators:

- In this chapter we will explore the working principle of the oscillator. Generally speaking, the oscillator produces sinusoidal and other waveforms.
- Beginning with a detailed circuit analysis of the oscillator, we will proceed to discuss the conditions and frequency of oscillation.
- Following this, the different types of *oscillators—Tuned oscillator, Hartley oscillator, Colpitts oscillator, Clapp oscillator, Phase-shift oscillator, Crystal oscillator and Wien-bridge oscillator*—will be examined with detailed mathematical analysis and illustrations.
- The chapter ends with an overview of the applications of the oscillator.

INTRODUCTION:

- An oscillator is an electronic system.
- It comprises active and passive circuit elements and sinusoidal produces repetitive waveforms at the output without the application of a *direct external input signal to the circuit.*
- *It* converts the dc power from the source to ac power in the load. A rectifier circuit converts ac to dc power, but an oscillator converts dc noise signal/power to its ac equivalent.
- The general form of a harmonic oscillator is an electronic amplifier with the output attached to a narrow-band electronic filter, and the output of the filter attached to the input of the amplifier.
- In this chapter, the oscillator analysis is done in two methods—first by a general analysis, considering all other circuits are the special form of a common generalized circuit and second, using the individual circuit KVL analysis.

Difference between an amplifier and an oscillator:

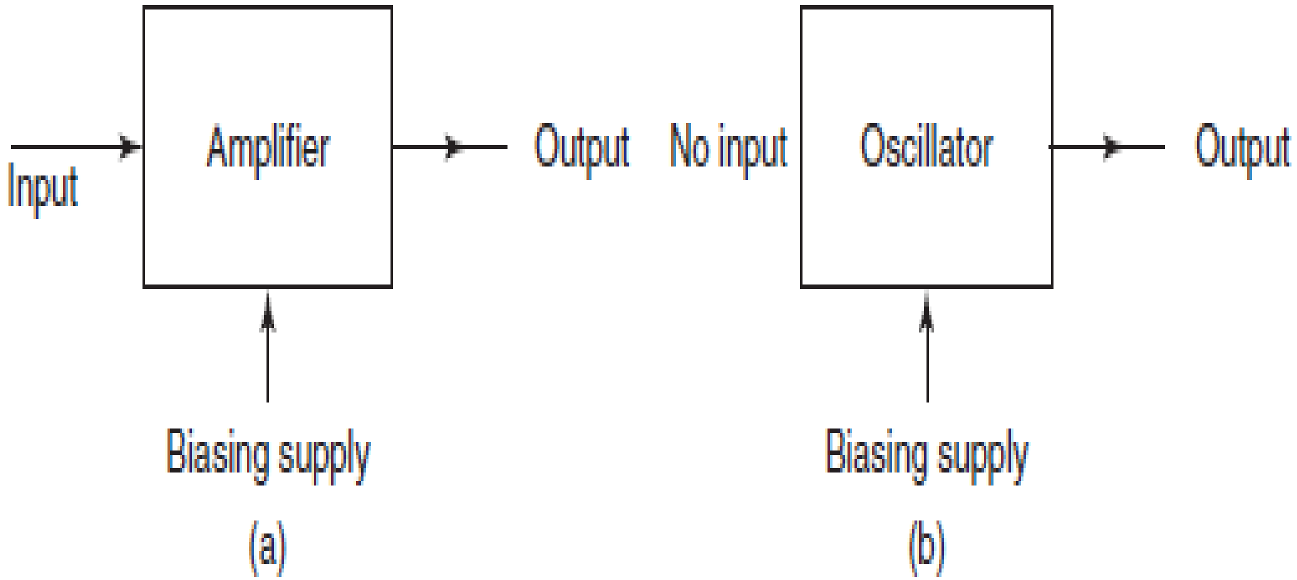


Figure 12-1 Schematic block diagrams showing the difference between an amplifier and an oscillator

CLASSIFICATION:

- Oscillators are classified based on the type of the output waveform.
- If the generated waveform is *sinusoidal or close to sinusoidal* (with a certain frequency) then the oscillator is said to be a *Sinusoidal Oscillator*.

  If the output waveform is *non-sinusoidal*, which refers to square/saw-tooth waveforms, the oscillator is said to be a

  Relaxation Oscillator.
- An oscillator has a positive feedback with the loop gain infinite. Feedback-type sinusoidal oscillators can be classified as *LC (inductor-capacitor) and RC (resistor-capacitor) oscillators.*

Different types of oscillators and their frequency ranges

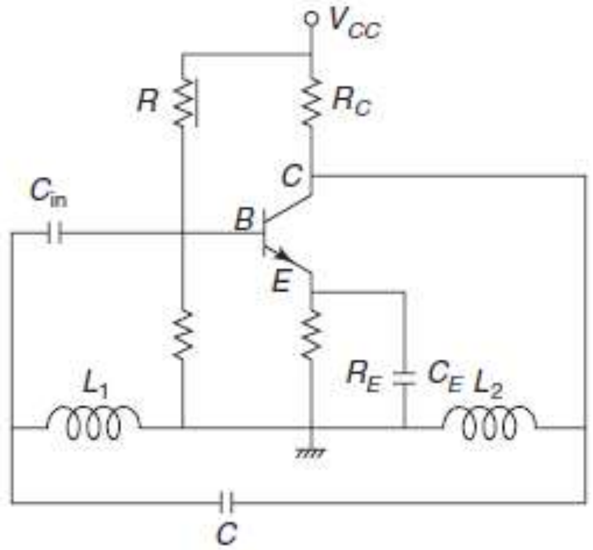
Type of Oscillator	*Frequency Range Used*
1. Audio-frequency oscillator	20 Hz – 20 kHz
2. Radio-frequency oscillator	20 kHz – 30 MHz
3. Very-high-frequency oscillator	30 MHz –300 MHz
4. Ultra-high-frequency oscillator	300 MHz – 3 GHz
5. Microwave oscillator	3 GHz – 30 GHz
6. Millimeter wave oscillator	30 GHz – 300 GHz

Hartley Oscillator:

Hartley oscillator contains two inductors and one capacitor, as shown in Fig. 12-3 where, x_1 and x_2 are inductances, and x_3 is a capacitance, i.e., $x_1 = \omega L_1, x_2 = \omega L_2, x_3 = -1/\omega C$.

Substituting the values in Eq. (12-23) we get the condition for oscillation, considering R is small.

$$h_f = \frac{\omega L_1}{\omega L_2} + \frac{R \cdot h_i}{\omega^2 L_1 L_2}$$



Hartley Oscillator:

Substituting the values in Eq. (12-23) we get the condition for oscillation, considering R is small.

$$h_f = \frac{\omega L_1}{\omega L_2} + \frac{R \cdot h_i}{\omega^2 L_1 L_2}$$

$$\therefore \quad h_f = \frac{L_1}{L_2}$$

$$h_f = \frac{L_1}{L_2} + \frac{RCh_i}{L_{11}} \tag{12-24}$$

Where

$$L_{11} = \frac{L_1 L_2}{L_1} + L_2$$

$$L_{11} = L_1 L_2 / L_1 + L_2$$

$$L_{11}(L_1 + L_2) = L_1 L_2$$

$$L_{11} \times \frac{1}{\omega 2C} = L_1 L_2$$

$$\Theta\ x_1 + x_2 = -x_3$$

$$\omega L_1 + \omega L_2 = -\left(\frac{-1}{\omega C}\right)$$

$$L_1 + L_2 = -\frac{1}{\omega^2 C}$$

$$\therefore \quad \frac{L_1}{L_2} + \frac{Rh_i}{\omega^2 L_1 L_2} = \frac{L_1}{L_2} + \frac{Rh_i}{\omega^2 L_1 L_2} = \frac{L_1}{L_2} + \frac{Rh_i C}{L_{11}}$$

Colpitts Oscillator:

Colpitt oscillator contains two capacitors and one inductor, as shown in Fig. 12-4. X_1 and X_2 are capacitances, X_3 is inductance, Z_1 and Z_2 are capacitors, C_1 and C_2 are capacitances, and Z_3 is an inductor of inductance L.

$$X_1 = -\frac{1}{\omega C_1}$$

$$X_2 = -\frac{1}{\omega C_2}$$

$$X_3 = \omega L$$

$$X_1 + X_2 + X_3 = 0$$

$$-\frac{1}{\omega C_1} - \frac{1}{\omega C_2} + \omega L = 0$$

$$\frac{1}{\omega}\left(\frac{1}{C_1} + \frac{1}{C_2}\right) = \omega L$$

Colpitts Oscillator:

$$\frac{1}{L}\left(\frac{1}{C_1}+\frac{1}{C_2}\right)=\omega^2,\ \omega=\sqrt{\frac{1}{L}\left(\frac{1}{C_1}+\frac{1}{C_2}\right)}$$

Frequency of oscillation:

$$2\pi f=\frac{1}{\sqrt{LC}}\Rightarrow f=\frac{1}{2\pi\sqrt{LC}} \tag{12-26}$$

Where,

$$\frac{1}{C'}=\frac{1}{C_1}+\frac{1}{C_2}$$

$$h_f=\frac{X_1}{X_2}+\frac{Rh_i}{X_1X_2} \tag{12-27}$$

Therefore, condition for oscillation:

$$h_f=\frac{C_2}{C_1}+Rh_i\,\omega^2C_1C_2 \tag{12-28}$$

$$=\frac{C_2}{C_1}+R_{hi}\,\omega^2C_1C_2$$

R = Resistance of the coil 2

$$R=\frac{C_2}{C_1}+Rh_i\frac{1}{L}\cdot\frac{C_1+C_2}{C_1\cdot C_2}\cdot C_1\,C_2\left[\because \omega^2=\frac{1}{L}\left(\frac{1}{C_1}+\frac{1}{C_2}\right)\right]$$

Colpitts Oscillator:

$$R = \frac{C_2}{C_1} + Rh_i \frac{1}{L}(C_1 + C_2)\, Rh_i \qquad (12\text{-}29)$$

$$R = \frac{C_2}{C_1}\left[\text{neglecting}\, \frac{Rh_i}{L}(C_1 + C_2)\right]$$

The circuit diagram of Colpitts oscillator is shown in Fig. 12-4.

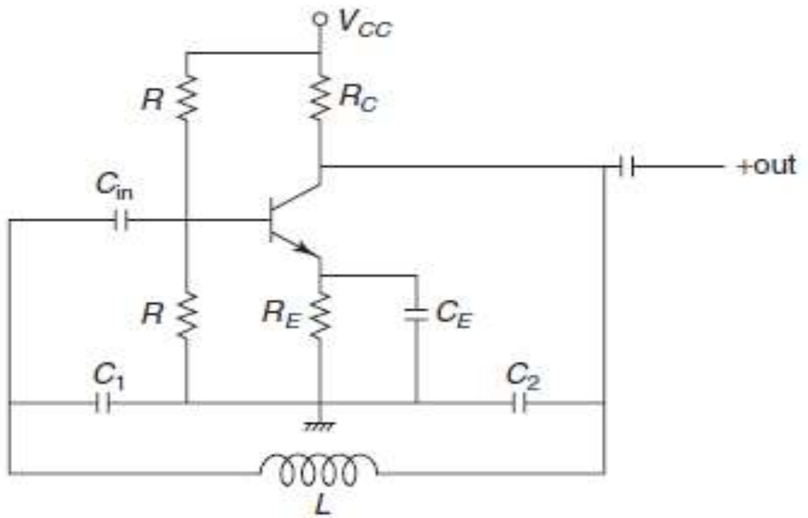


Figure 12-4 Colpitts oscillator

Phase-Shift Oscillator:

The circuit diagram of a phase-shift oscillator with three pairs of RC combination is shown in Fig. 12-5(a).

The equivalent circuit representation of phase-shift oscillator is shown in Fig. 12-5(b). By applying KVL in the circuit in Fig. 12-5(b) we have the mesh ABCHIJ at loop (2).

$$(i + h_f i_1) R + (i - i^1) R + \frac{i}{jwc} = 0$$

$$\left(2R + \frac{1}{jwc}\right) i + R h_f i_1 - R i^1 = 0$$

$$(2R + jx_c)\, i + R h_f i_1 - R i^1 = 0 \qquad (12\text{-}30)$$

At mesh CDGH [at loop (3)]:

$$(i^1 - i) R + \frac{1}{j\omega c} i^1 + (i^1 - i_1) R = 0$$

$$(2R + jx_c) i^1 - Ri - Ri_1 = 0 \qquad (12\text{-}31)$$

At mesh CDEFGH [at loop (4)]:

$$(i_1 - i^1) R + jx_c i_1 + R i_1 = 0$$

$$(2R + jx_c)\, i_1 - R i^1 = 0 \qquad (12\text{-}32)$$

Phase-Shift Oscillator:

Eliminating i_1, i, i^1, Order wise Eqs. (12-30), (12-31) and (12-32) will be:

$$\begin{vmatrix} i_1 & i & i^1 \\ (2R + jx_c) & 0 & -R \\ Rh_f & (2R + jx_c) & -R \\ -R & -R & (2R + jx_c) \end{vmatrix}$$

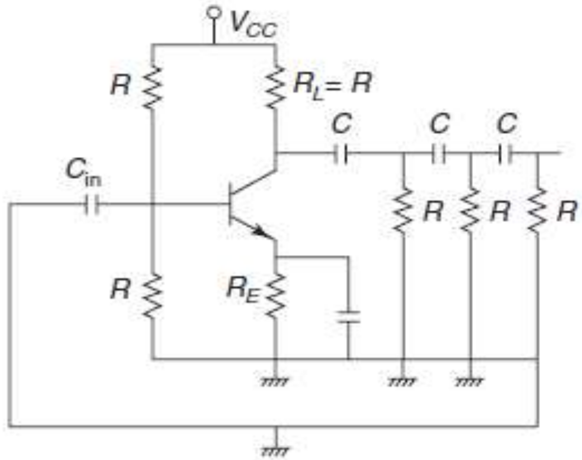


Figure 12-5(a) Phase-shift oscillator: equivalent circuit using the approximate equivalent circuit of the transistor

Phase-Shift Oscillator:

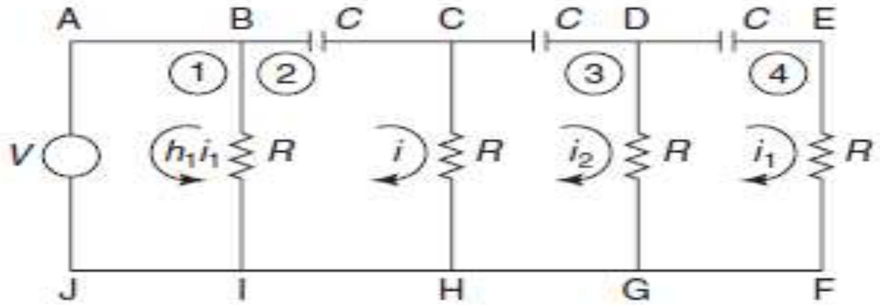


Figure 12-5(b) Equivalent circuit representation of a phase-shift oscillator

Dividing each element of the determinant by R:

$$\therefore \quad \frac{1}{R}\begin{vmatrix} R(2 + jx_c/R) & 0 & -R \\ R_{hf} & R(2 + jx_c/R) & -R \\ -R & -R & R(2 + jx_c/R) \end{vmatrix} = 0$$

Let
$$\frac{X_C}{R} = a$$

$$\therefore \quad \begin{vmatrix} (2 + ja) & 0 & -1 \\ h_f & (2 + ja) & -1 \\ -1 & -1 & (2 + ja) \end{vmatrix} = 0$$

Phase-Shift Oscillator:

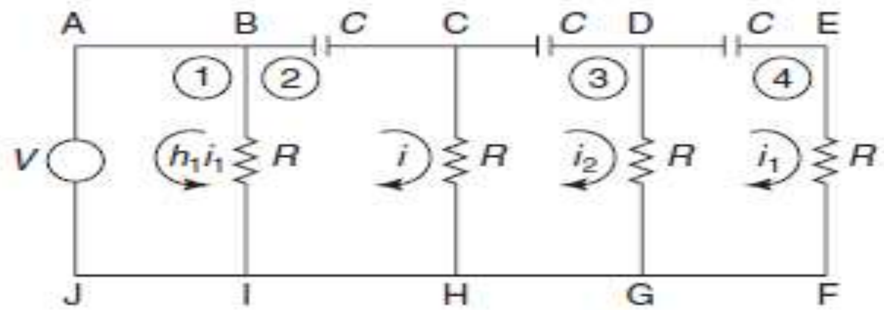


Figure 12-5(b) Equivalent circuit representation of a phase-shift oscillator

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Phase-Shift Oscillator:

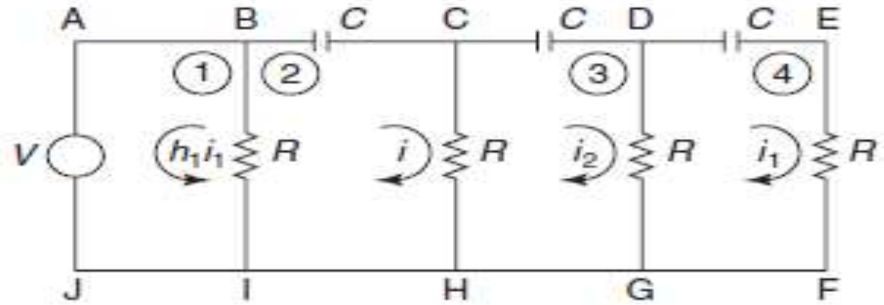

Figure 12-5(b) Equivalent circuit representation of a phase-shift oscillator

Dividing each element of the determinant by R:

$$\therefore \quad \frac{1}{\mathrm{R}}\begin{vmatrix} R(2+jx_c/R) & 0 & -R \\ R_{hf} & R(2+jx_c/R) & -R \\ -R & -R & R(2+jx_c/R) \end{vmatrix} = 0$$

Let

$$\frac{X_C}{R} = a$$

$$\therefore \quad \begin{vmatrix} (2+ja) & 0 & -1 \\ h_f & (2+ja) & -1 \\ -1 & -1 & (2+ja) \end{vmatrix} = 0$$

Phase-Shift Oscillator:

Let $$\frac{X_C}{R} = a$$

$\therefore$ $$\begin{vmatrix} (2 + ja) & 0 & -1 \\ h_f & (2 + ja) & -1 \\ -1 & -1 & (2 + ja) \end{vmatrix} = 0$$

$$(2 + ja)\,[(2 + ja)^2 - 1] + 0 + (-1)\,[-h_f + 2 + ja] = 0$$

$$(2 + ja)\,[4 + 4ja - a^2 - 1] + h_f - 2 - ja = 0$$

$$8 + 8ja - 2a^2 - 2 + 4ja - 4a^2 - ja^3 - ja + h_f - 2 - ja = 0$$

$$-ja^3 + 8 + 12ja - 6a^2 - 4 - 2ja + h_f = 0$$

$\therefore$ Equating the imaginary parts:

$$j\,(-a^3 - 2a + 12a) = 0$$

$$a\,(10 - a^2) = 0$$

$$a^2 - 10 = 0$$

$\therefore$ $$a = \sqrt{10}$$

Phase-Shift Oscillator:

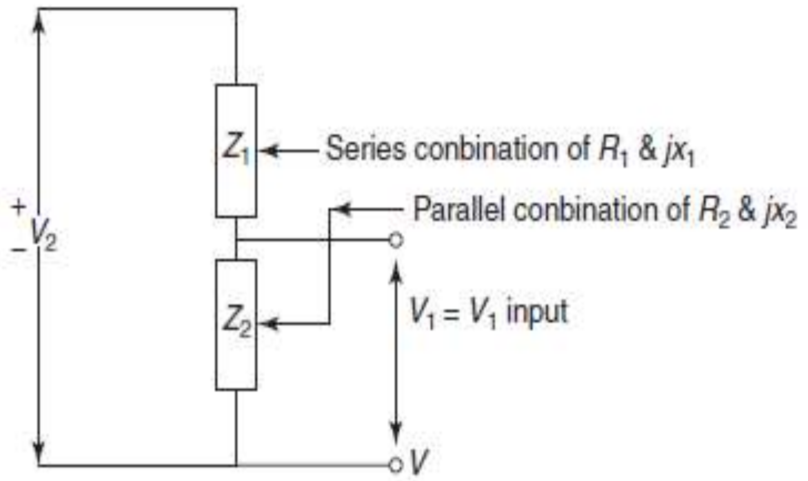

Figure 12-6 Equivalent diagram of a phase-shift oscillator

$$\frac{XC}{R} = \sqrt{10}$$

$$\frac{X_c^2}{R^2} = 10$$

$$\frac{1}{\omega^2 C^2 R^2} = 10$$

or

$$\omega^2 = \frac{1}{10C^2R^2}$$

or

$$\omega = \frac{1}{\sqrt{10}\,CR}$$

Phase-Shift Oscillator:

∴ Frequency of oscillation is:

$$f = \frac{1}{2\pi\sqrt{10}\,CR} \tag{12-33}$$

Equating the real parts we get:

$$8 - 6a^2 - 4 + h_{fe} = 0$$

$$h_{fe} = 4 + 6a^2 - 8 = 4 + 6.10 - 8$$

$$= 4 + 60 - 8$$

$$= 56$$

For sustained oscillations, h_{fe} of 56 for $R = R_L$
The equivalent diagram of a phase-shift oscillator is shown in Fig. 12-6.

Wien-Bridge Oscillator:

Wein-bridge oscillator is the series and parallel combination of a resistance R and a capacitor C. According to Barkhausen criteria, $A_v\beta = 1$.

Since $\quad A_v\beta = 1,$

$$\beta = \frac{1}{A_v} = \frac{v_f}{v_0} = \frac{v_{zi}}{(z_1 + z_2)i}$$

$$A_v = \frac{1}{\beta} = \frac{z_1 + z_2}{z_2} = 1 + \frac{z_1}{z_2} \qquad (12\text{-}34)$$

$$z_1 = R + jx_1 \text{ [series combination]}$$

$$\frac{1}{z_2} = \frac{1}{R_2} + \frac{1}{jx_2} \quad \text{[parallel combination]}$$

$$A = 1 + (R_1 + jx_1)\left(\frac{1}{R_2} + \frac{1}{jx_2}\right)$$

$$= 1 + \left(\frac{R_1}{R_2} + \frac{x_1}{x_2}\right) + j\left(\frac{x_1}{R_2} - \frac{R_1}{x_2}\right) \qquad (12\text{-}35)$$

Wien-Bridge Oscillator:

The two-stage *RC* coupled amplifier can be used by equating real and imaginary parts. Considering only the real parts, we get:

$$A = 1 + \frac{R_1}{R_2} + \frac{x_1}{x_2} \tag{12-36}$$

Considering only the imaginary parts, we get:

$$\frac{x_1}{R_2} - \frac{R_1}{X_2} = 0 \tag{12-37}$$

$X_1 X_2 = R_1 R_2$ (frequency of oscillation)

$$R_1 R_2 = \frac{1}{w^2 c_1 c^2}$$

$$w^2 = \frac{1}{C_1 C_2 R_1 R_2} \tag{12-38}$$

Wien-Bridge Oscillator:

If $R_1 = R_2 = R$ & $C_1 = C_2 = C$

$$A = 1 + 1 + 1 = 3$$

And,

$$w^2 = \frac{1}{C^2R^2} \Rightarrow w = \frac{1}{CR} \quad (12\text{-}39)$$

$$f = \frac{1}{2\pi CR} \quad (12\text{-}40)$$

At balance condition:

$$\frac{R_3}{R_4} = \frac{Z_1}{Z_2} \text{ (for oscillation)}$$

Circuit Diagram of Wien-Bridge Oscillator:

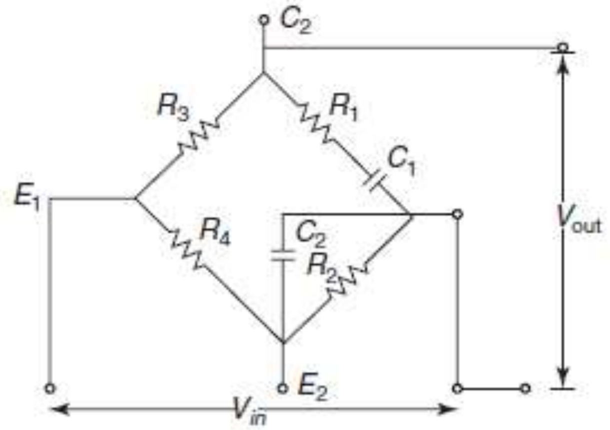

Figure 12-7 Wien-Bridge oscillator

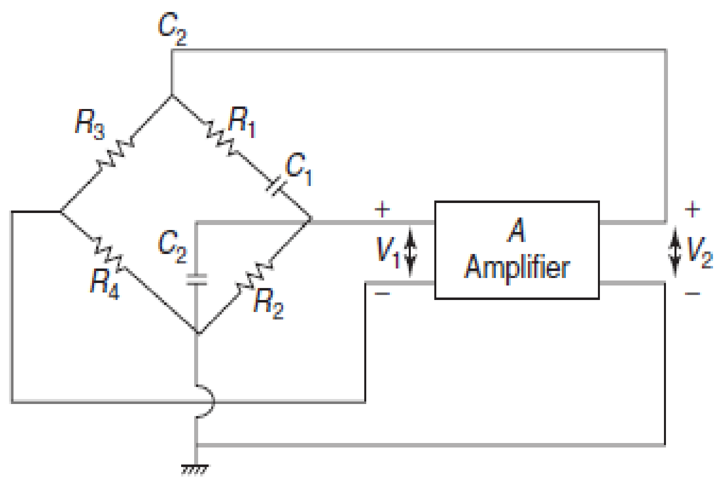

Figure 12-8 Wien-bridge oscillator with an amplifier

Wien-Bridge Oscillator:

From the circuit diagram of the wien-bridge oscillator, as given in Fig. 12-7, we get:

$$\frac{R_3}{R_4} = \left(R_1 + \frac{1}{jwc_1}\right)\left(\frac{1}{R_2} + jwc_2\right)$$

$$= \left(\frac{R_1}{R_2} + \frac{C_2}{C_1}\right) + j\left(\omega C_2 R_1 - \frac{1}{\omega C_1 R_2}\right)$$

Equating imaginary parts we get:

$$\omega c_2 R_1 = \frac{1}{\omega C_1 R_2}$$

$$\omega^2 = \frac{1}{C^2 R^2}$$

$\because R_1 = R_2 = R$ and $C_1 = C_2 = \mathrm{C}$

$\therefore$

$$\frac{R_3}{R_4} = \frac{R_1}{R_2} + \frac{C_2}{C_1}$$

$$\frac{R_3}{R_4} = \frac{R}{R} + \frac{C}{C} = 1 + 1 = 2$$

Wien-Bridge Oscillator:

- **Advantages of Wien-Bridge Oscillator:**
- 1. The frequency of oscillation can be easily varied just by changing *RC network*
- 2. High gain due to two-stage amplifier
- 3. Stability is high

- **Disadvantages of Wien-Bridge Oscillator**
- The main disadvantage of the Wien-bridge oscillator is that a high frequency of oscillation cannot be generated.

CRYSTAL OSCILLATOR:

- Crystal oscillator is most commonly used oscillator with high-frequency stability. They are used for laboratory experiments, communication circuits and biomedical instruments. They are usually, fixed frequency oscillators where stability and accuracy are the primary considerations.
- In order to design a stable and accurate LC oscillator for the upper HF and higher frequencies it is absolutely necessary to have a crystal control; hence, the reason for crystal oscillators.
- Crystal oscillators are oscillators where the primary frequency determining element is a quartz crystal. Because of the inherent characteristics of the quartz crystal the crystal oscillator may be held to extreme accuracy of frequency stability. Temperature
- compensation may be applied to crystal oscillators to improve thermal stability of the crystal oscillator.

- The crystal size and cut determine the values of *L, C, R and C'. The resistance R is the friction of* the vibrating crystal, capacitance *C is the compliance, and inductance L is the equivalent mass. The capacitance C' is the electrostatic capacitance between the mounted pair of electrodes with the crystal as the dielectric.*

Circuit Diagram of CRYSTAL OSCILLATOR:

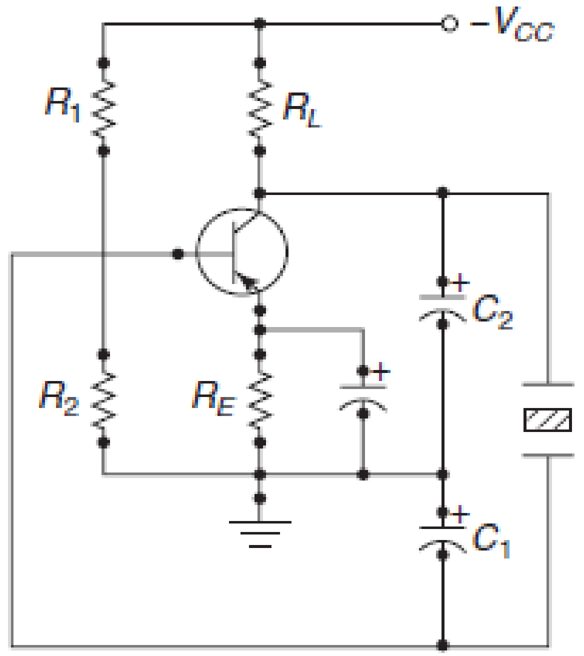

Figure 12-13 Circuit of a crystal oscillator

Circuit Diagram of CRYSTAL OSCILLATOR:

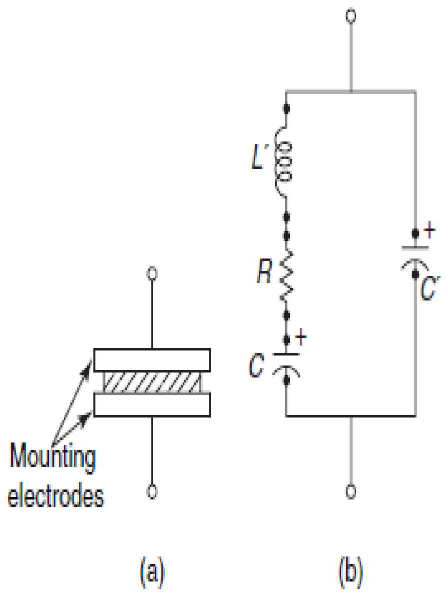

Figure 12-11(a) Symbol of a vibrating piezoelectric crystal (b) Its equivalent electrical circuit

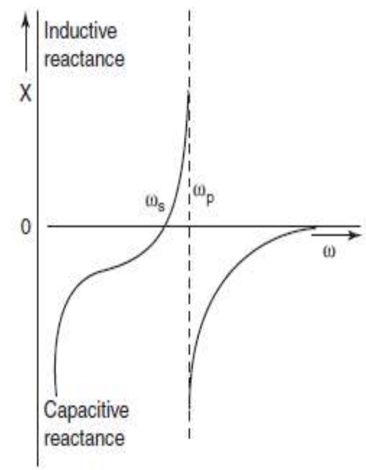

Figure 12-12 Reactance vs. frequency graph

Circuit Analysis of CRYSTAL OSCILLATOR:

The circuit of Fig. 12-11(b) has two resonant frequencies. At the series resonant frequency f_s the reactance of the series LC arm is zero, that is:

$$\omega_s L - \frac{1}{\omega_s C} = 0$$

or

$$\omega_s = \frac{1}{\sqrt{LC}} \qquad (12\text{-}94)$$

ω_p is the parallel resonant frequency of the circuit greater than ω_s where:

$$\left(\omega_p L - \frac{1}{\omega_p C}\right) = \frac{1}{\omega_p C'}$$

or

$$\omega_p^2 = \frac{1}{2}\left(\frac{1}{C} + \frac{1}{C'}\right)$$

or

$$\omega_p = \sqrt{\frac{1}{2}\left(\frac{1}{C} + \frac{1}{C'}\right)} \qquad (12\text{-}95)$$

Therefore, ω_p and ω_s are as shown in Fig. 12-12. At the parallel, resonant frequency, the impedance offered by the crystal to the internal circuit is very high.

The resonant frequencies of a crystal vary inversely as the thickness of the cut.

$$f = \frac{1}{t}$$

APPLICATIONS OF OSCILLATORS:

- Oscillators are a common element of almost all electronic circuits. They are used in various applications, and their use makes it possible for circuits and subsystems to perform numerous useful functions.
- In oscillator circuits, oscillation usually builds up from zero when power is first applied under linear circuit operation.
- The oscillator's amplitude is kept from building up by limiting the amplifier saturation and various non-linear effects.
- Oscillator design and simulation is a complicated process. It is also extremely important and crucial to design a good and stable oscillator.
- Oscillators are commonly used in communication circuits. All the communication circuits for different modulation techniques—AM, FM, PM—the use of an oscillator is must.
- Oscillators are used as stable frequency sources in a variety of electronic applications.
- Oscillator circuits are used in computer peripherals, counters, timers, calculators, phase-locked loops, digital multi-metres, oscilloscopes, and numerous other applications.