# Waveform Generators

- In the design of electronic systems, the need for signals having standard waveforms - sinusoidal, square, triangular, or pulse.
- Systems like computer and control systems require standard signals i.e. clock pulses are needed for timing.
- Communication systems where signals of a variety of waveforms are utilized as information carriers.
- Test and measurement systems where signals, a variety of waveforms, are employed for testing and characterizing electronic devices and circuits.

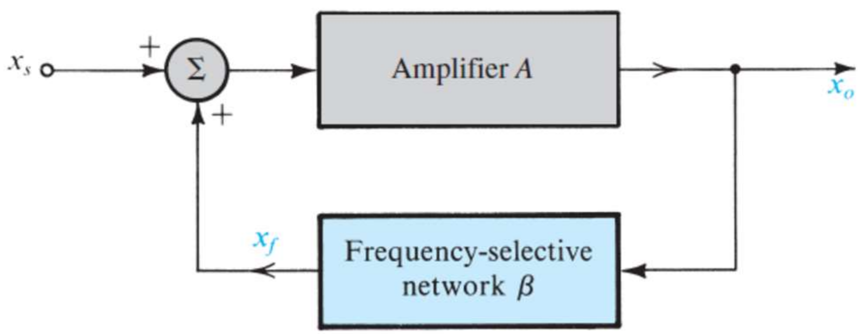
# Waveform Generators

- Sinusoidal Waveform
  - for the generation of sinusoids a **positive-feedback loop** consisting of an amplifier and an RC **frequency-selective network**.

- Generating square, triangular, pulse (etc.) waveforms
  - employ circuit building blocks known as **multivibrators**.
  - They are three types : the **bistable**, the **astable**, and the **monostable**.

# Basic Principles of Sinusoidal Oscillators

- The basic structure of a sinusoidal oscillator consists of an amplifier and a frequency-selective network connected in a **positive-feedback loop**




$$x_o = A\left(x_s + x_f\right) \qquad x_f = \beta x_o$$

$$x_o = A\left(x_s + \beta x_o\right) \qquad x_o\left(1 - A\beta\right) = A x_s$$

$$\frac{x_o}{x_s} = \frac{A}{\left(1 - A\beta\right)} = A_f$$

$$A_f(s) = \frac{A(s)}{1 - A(s)\beta(s)} \qquad L(s) \equiv A(s)\beta(s)$$

# Condition for Oscillation

- The characteristic equation is

$$1 - L(s) = 0$$

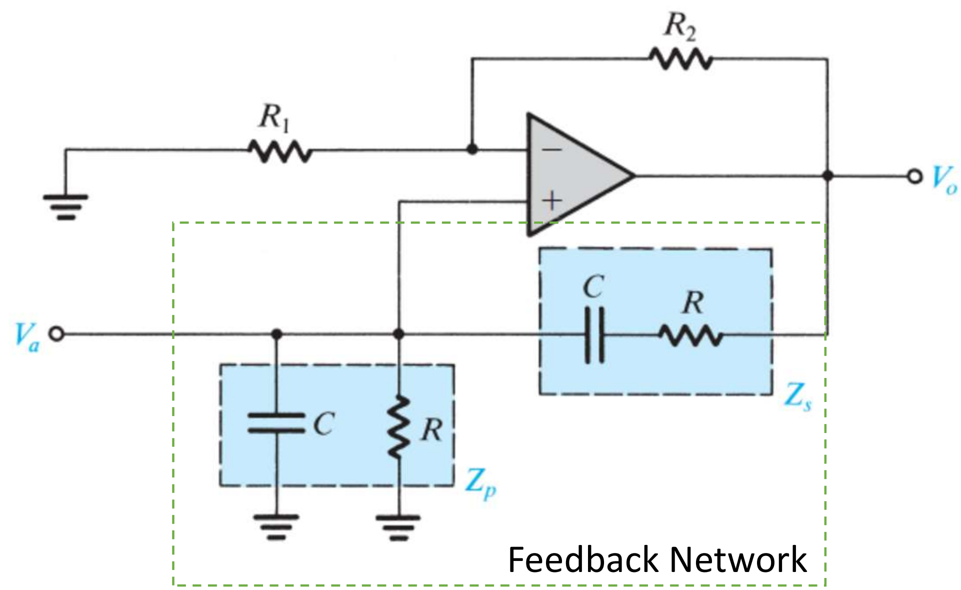
- If at a specific frequency $f_0$ the loop gain L = $A\beta$ is equal to unity, it follows from that $A_f$ will be infinite.
- That is, at this frequency the circuit will have a finite output for zero input signal. Such a circuit is called as “Oscillator”.
- Thus the condition for the feedback loop to provide sinusoidal oscillations of frequency $\omega_0$ is

$$L(j\omega_0) \equiv A(j\omega_0)\beta(j\omega_0) = 1$$

# Wien-Bridge Oscillator

- The circuit consists of an op amp connected in the noninverting configuration, with a closed-loop gain of A = 1+$R_2/R_1$.
- In the feedback path, RC network is connected
- Feedback factor β is given by,

$$\beta = \frac{V_a}{V_o} = \frac{Z_p}{Z_p + Z_p}$$



# Analysis

- Impedance of the RC parallel combination

$$Z_p = \frac{1}{Y_p} = \frac{1}{\frac{1}{R} + j\omega c} = \frac{R}{1 + j\omega RC}$$

- Impedance of the RC series combination

$$Z_s = \frac{1}{j\omega c} + R = \frac{1 + j\omega RC}{j\omega C}$$

- Hence the feedback factor is

$$\beta = \frac{Z_p}{Z_p + Z_s} = \frac{j\omega RC}{1 - (\omega RC)^2 + j3\omega RC}$$

$$Z_p + Z_s = \frac{1 - (\omega RC)^2 + j3\omega RC}{j\omega C(1 + j\omega RC)}$$

# Analysis

- For the circuit to have oscillations,

$$A\beta = 1$$

- Since A is a real quantity, β must also be a real quantity, hence

$$1-(\omega RC)^2 = 0$$

- Thus the frequency of oscillation is, $f = \dfrac{1}{2\pi RC}$

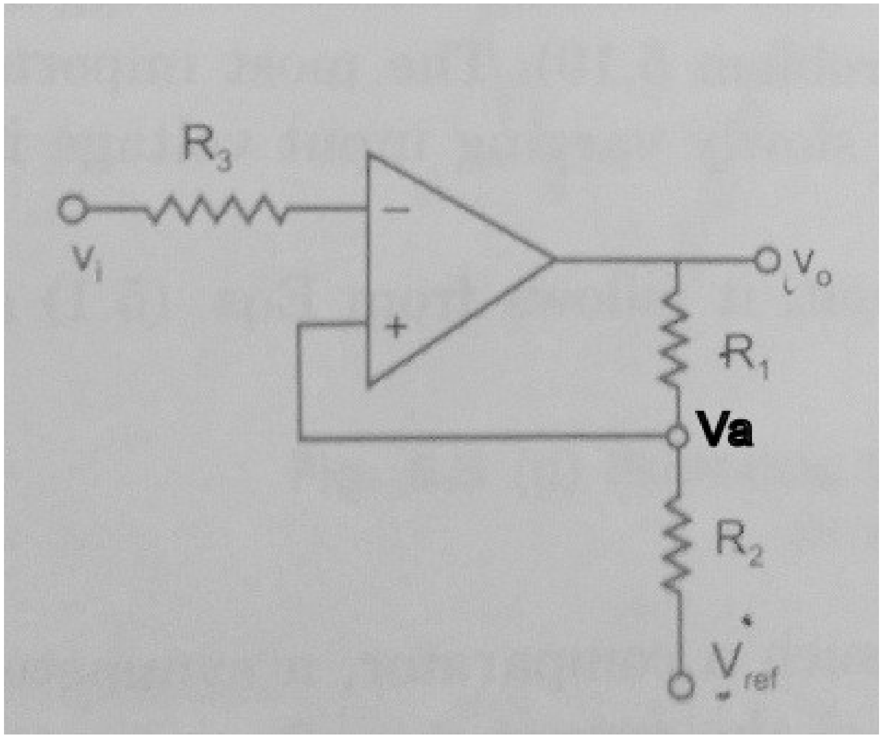
- Then β = 1/3, leading to A = 3, (since $A = 1+R_2/R_1$), $R_2 = 2R_1$.

# Example:

- Determine the maximum and minimum frequency of oscillations of a **Wien Bridge Oscillator** circuit having a resistor of 10kΩ and a variable capacitor of 1nF to 1000nF.

# Regenerative Comparator

- $V_i$ applied at (-) input terminal and feedback voltage to the (+) input terminal.
- $V_i$ triggers the output Vo every time it exceeds the certain voltage level.
- The voltage levels are called upper (lower) threshold voltage $V_{UT}$ ($V_{LT}$).
- $V_{UT}$ - $V_{LT}$ is referred as hysteresis width



# Computing Upper Threshold voltages ($V_{UT}$)

- Let Vo = +Vsat: to determine 'Va' i.e. $V_{UT}$, use superposition
- Case 1: Assuimg $V_{ref}$ = 0, voltage across "$R_2$" will be Va,

$$V_a = V_{UT} = \frac{R_2}{R_1 + R_2} V_{sat}$$

- Case 2: By considering $V_o$ = 0, then voltage across $R_1$ will be Va

$$V_a = \frac{R_1}{R_1 + R_2} V_{ref}$$

- By combining the above two cases,

$$V_{UT} = \frac{R_1}{R_1 + R_2} V_{ref} + \frac{R_2}{R_1 + R_2} V_{sat}$$

# Computing Lower Threshold voltage ($V_{LT}$)

- Let Vo = -Vsat: to determine '$V_a$' i.e. $V_{LT}$, again use superposition
- Case 1: Assuimg $V_{ref}$ = 0, voltage across "$R_2$" will be,

$$V_a = -\frac{R_2}{R_1 + R_2} V_{sat}$$

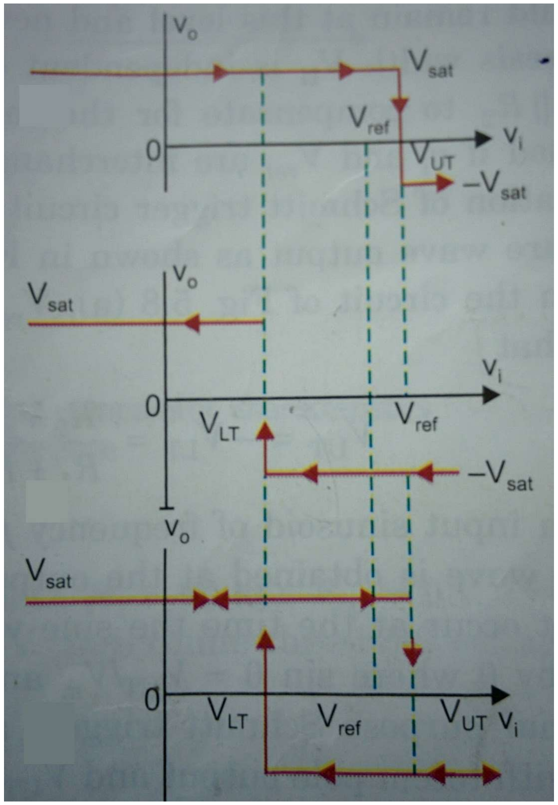
- Case 2: By considering $V_o$ = 0, then voltage across $R_1$ will be,

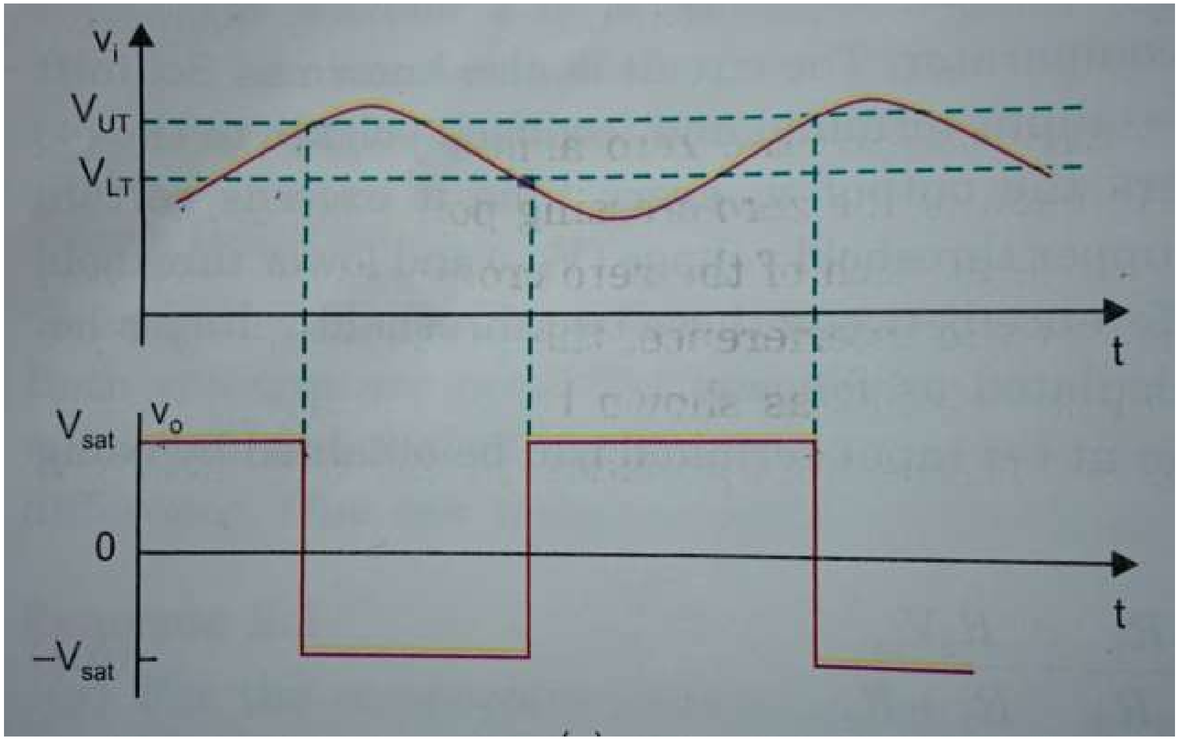
$$V_a = \frac{R_1}{R_1 + R_2} V_{ref}$$

- By combining the above two cases,

$$V_{LT} = \frac{R_1}{R_1 + R_2} V_{ref} - \frac{R_2}{R_1 + R_2} V_{sat}$$

# Asymmetric Square wave

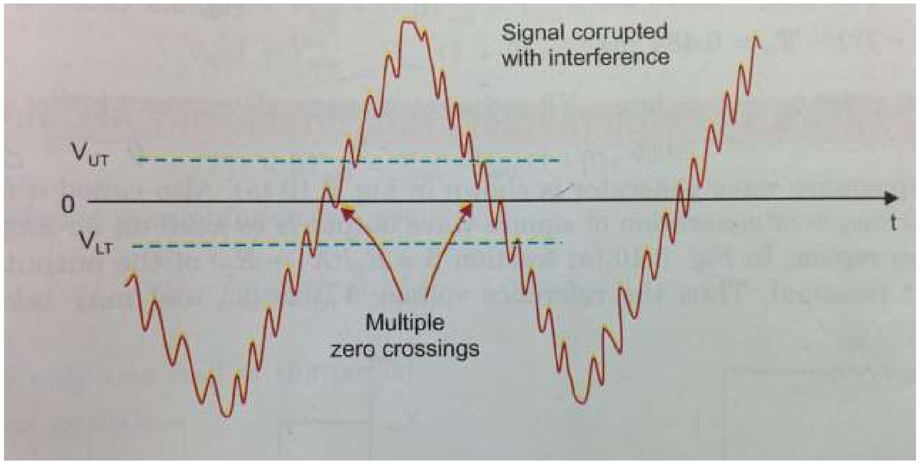


- Hysteresis width is

$$V_H = \frac{2R_2}{R_1 + R_2} V_{sat}$$

- Further, if the ref voltage is zero, then symmetric square wave can be obtained.
- Application:
  - slow varying input can be converted in square wave output.
  - Superior to simple zero crossing detector circuit.



# Example:

- In the given circuit of Schmitt trigger, $R_2$ = 100 Ω, $R_1$ = 50 KΩ, $V_{ref}$ = 0 V, Vi = 1 Vpp sine wave and saturation voltage = +/- 14 V . Determine the threshold voltages $V_{UT}$, $V_{LT}$ and $V_H$.

$$V_{UT} = +\frac{R_2}{R_1 + R_2} V_{sat} = 28mV$$

$$V_H = \frac{2R_2}{R_1 + R_2} V_{sat} = 56mV$$

$$V_{LT} = -\frac{R_2}{R_1 + R_2} V_{sat} = -28mV$$