Oscillator

- Oscillators are circuits that produce periodic waveforms without any input signal.

- Any signal generator whose output is periodic can be called an oscillator.
  although most frequently the word oscillator is reserved for a sinusoidal source.

Applications:

- Local oscillator for radio receivers, mobile receivers, etc
- As a signal generators in the lab for testing.
- Square wave (Clock input) for analog-digital and digital-analog converters: Clock input for CPU, DSP chips.

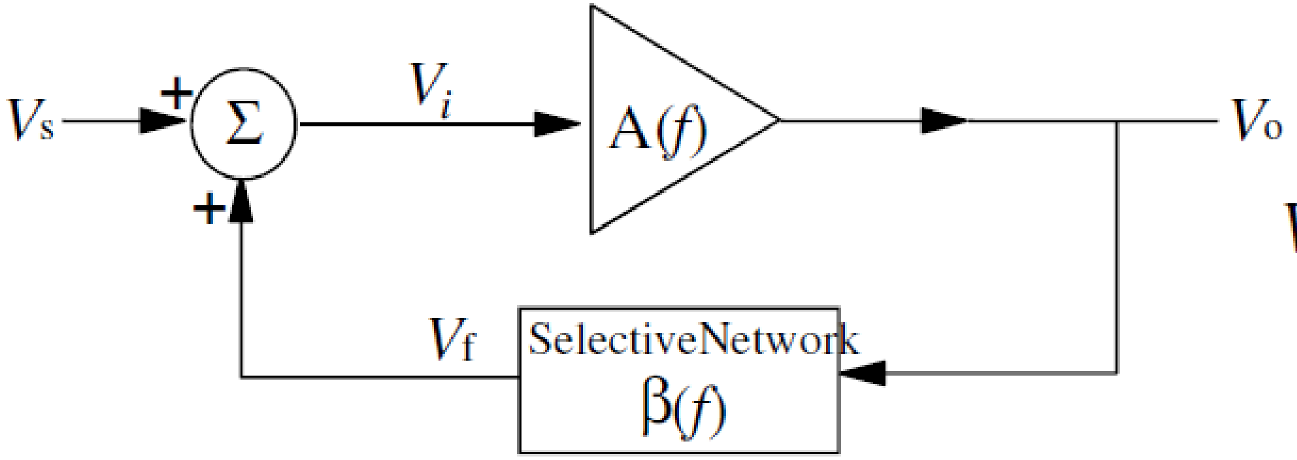
Oscillator Requirement

An oscillator consists of:

- **an amplifier and**
- **a positive feedback network**

1. 'Active device' i.e. Opmp is used as an amplifier.

2. Passive components such as R-C or L-C combinations are used as feedback network.



$$V_o = AV_i = A(V_s + V_f) \quad \text{and} \quad V_f = \beta V_o$$

Gain with feedback

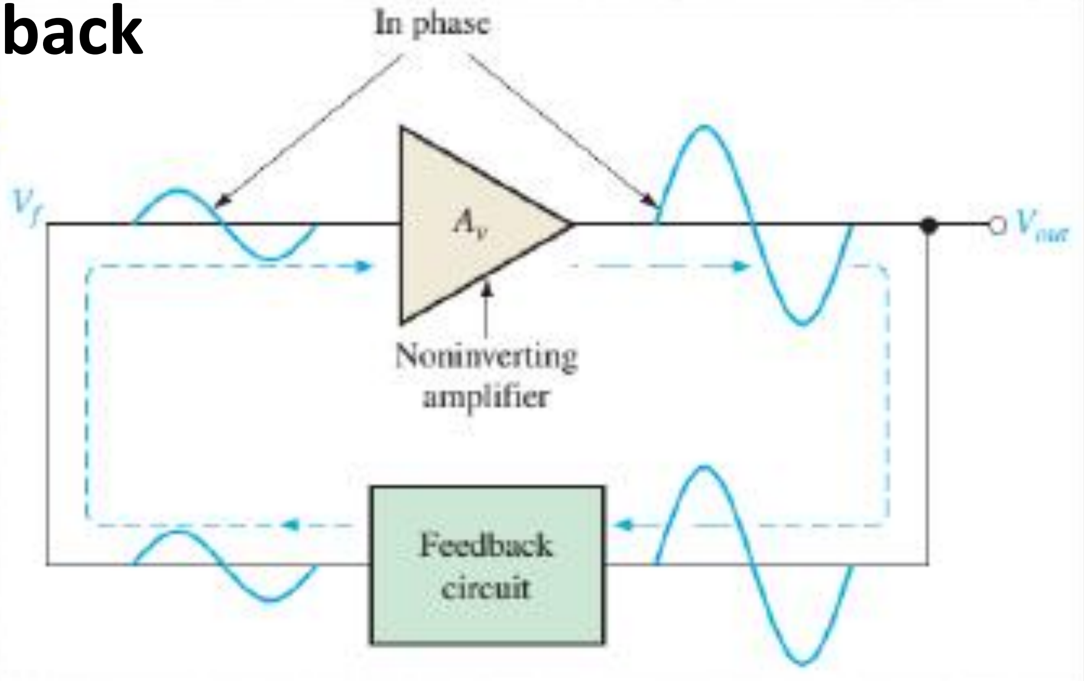
$$A_f = V_o/V_s$$
$$= A / (1 - A\beta)$$

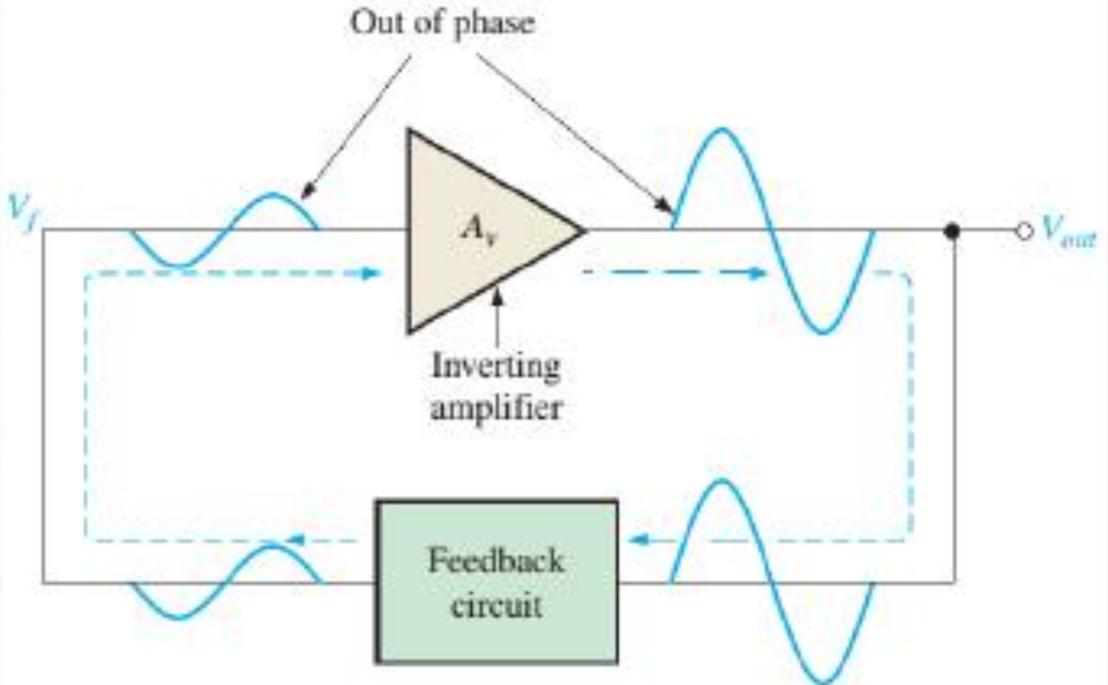
Feedback Ratio $\beta = V_f/V_o$

If $\beta A = 1$ then $V_o = \infty$; Very high output with zero input.

Positive Feedback

- The in-phase feedback voltage is amplified to produce the output voltage, which in turn produces the feedback voltage.
- A loop is created in which the signal maintains itself and a continuous sinusoidal output is produced.
- This phenomenon is called oscillation





BARKHAUSEN CRITERION FOR SUSTAINED OSCILLATIONS

1. Magnitude of the loop gain ($A_v \beta$) = 1,

   where, A_v = Amplifier gain and
   β = Feedback gain.

2. Phase shift around the loop must be 360° or 0°.

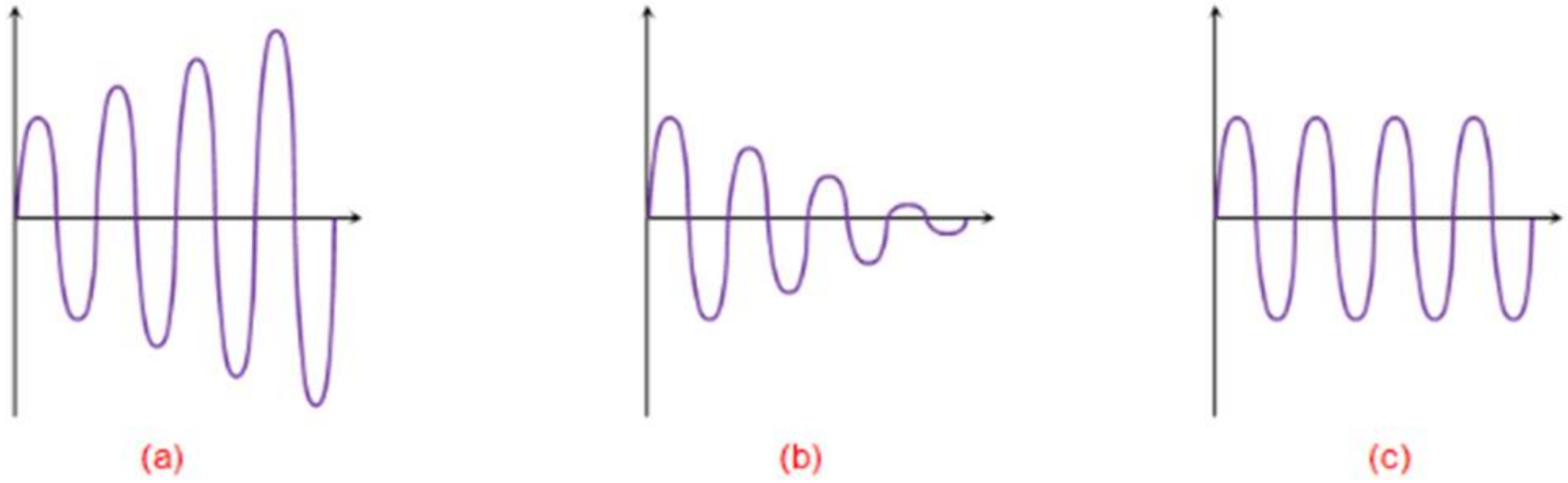


Figure (a) Increasing Oscillations (b) Decaying Oscillations (c) Constant-Amplitude Oscillations

$A\beta > 1$ $\qquad$ $A\beta < 1$ $\qquad$ $A\beta = 1$

Type of Oscillators

Oscillators can be categorized according to the types of feedback network used:

- RC Oscillators: Phase shift and Wien Bridge Oscillators
- LC Oscillators: Colpitt and Hartley Oscillators
- Crystal Oscillators

This course is limited to RC phase shift Oscillator only.

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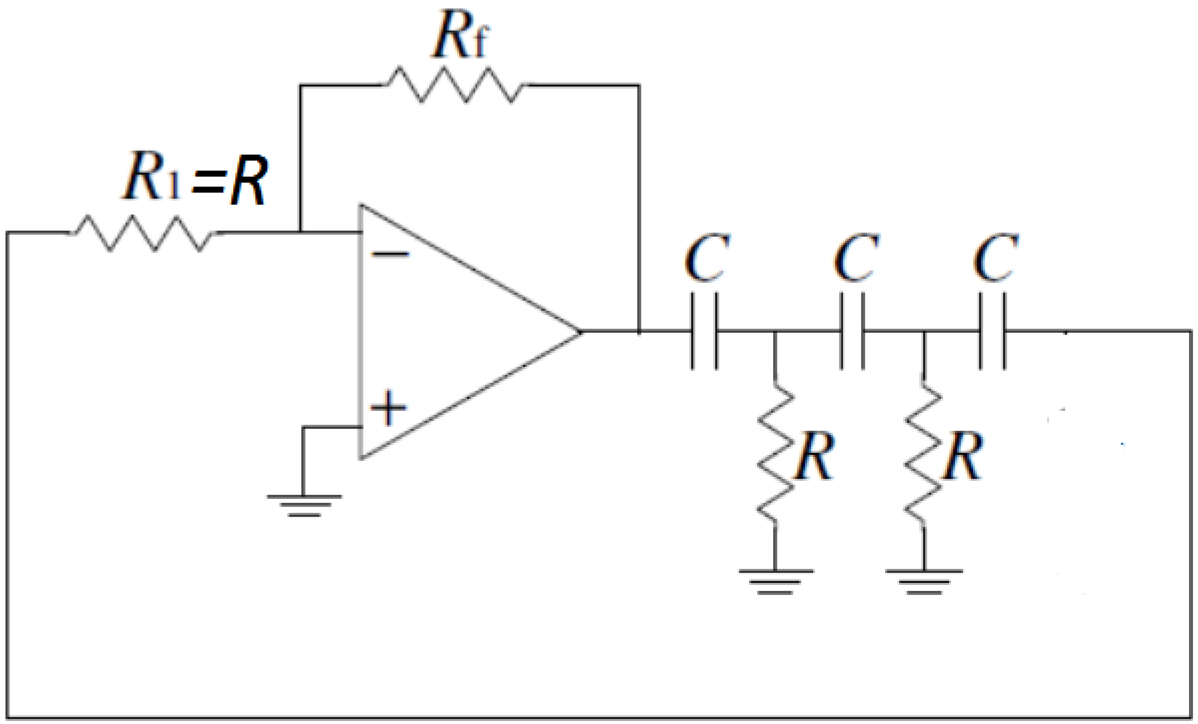
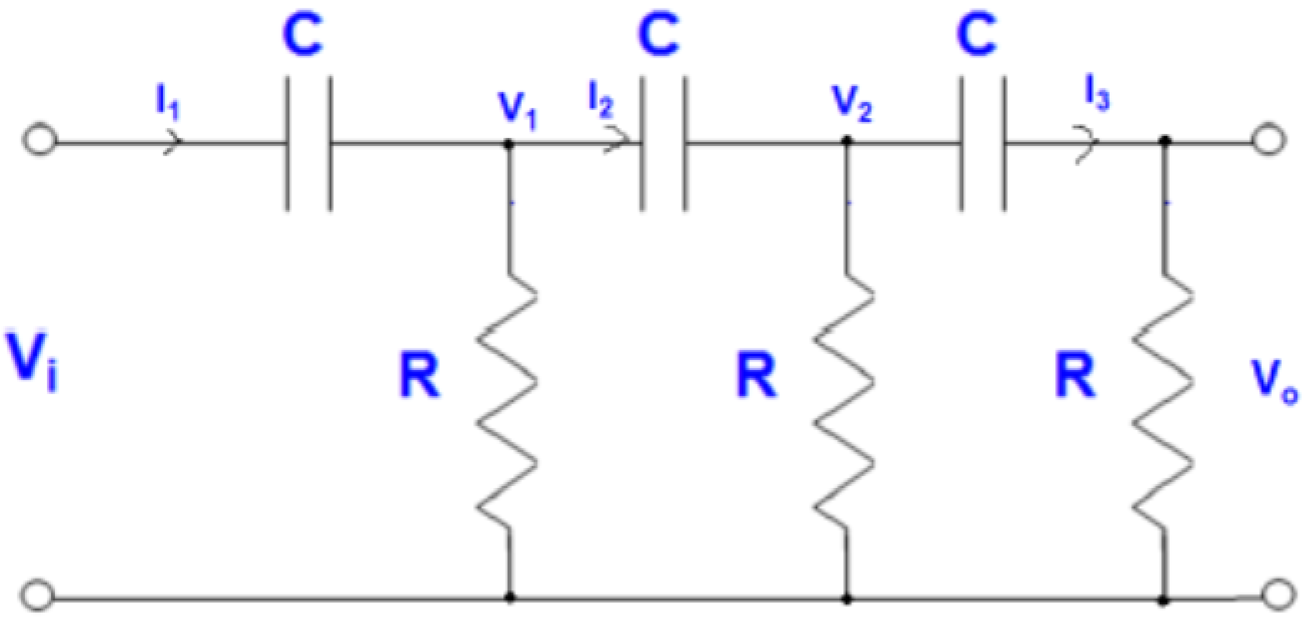
RC Oscillators: Phase shift Oscillator

- Use of an inverting amplifier.
- The additional 180º phase shift is provided by an RC ladder network.
- It can be used for very low frequencies and provides good frequency stability.



RC Oscillators: Phase shift Oscillator

As inverting is virtual ground. RC phase shift circuit can be considered as follows



At node V_2

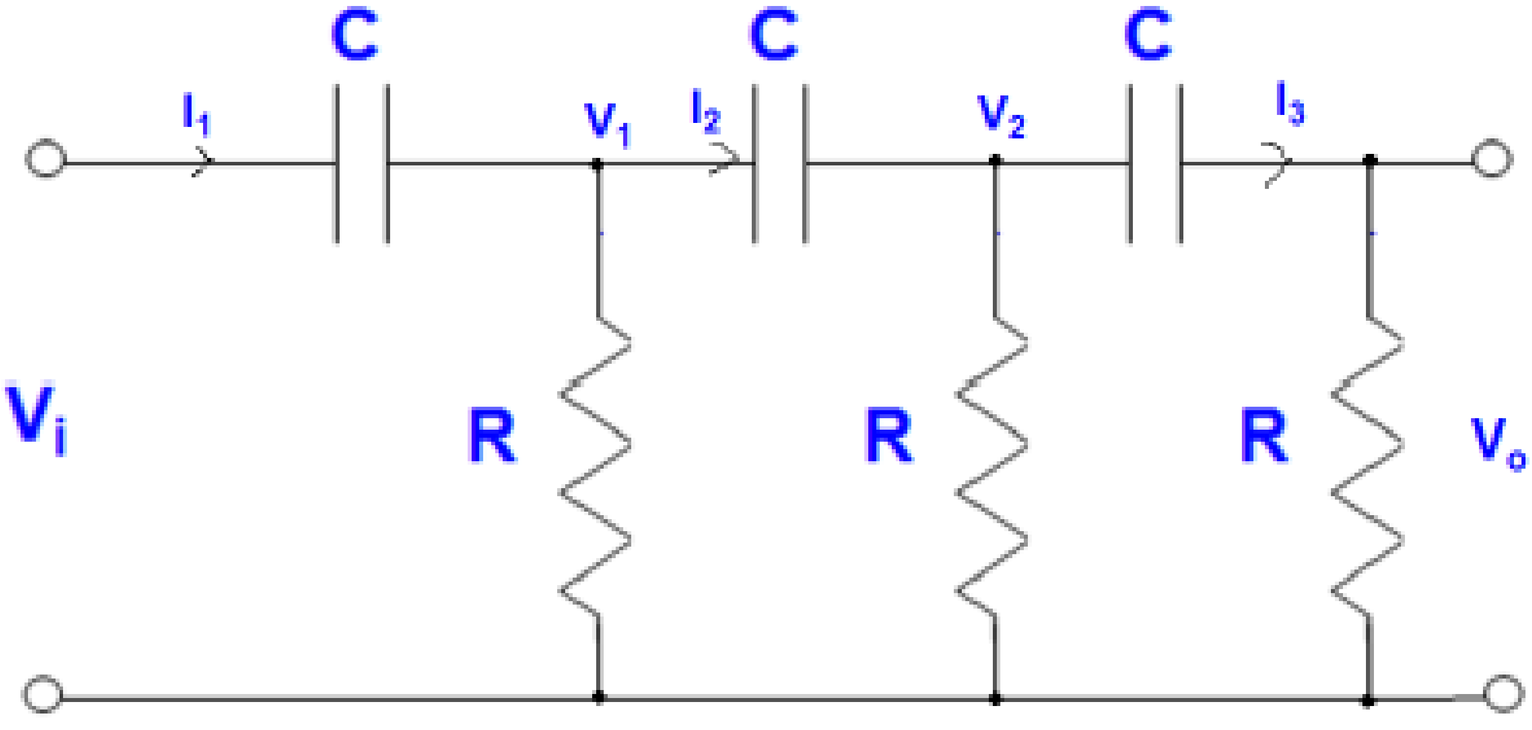
$$V_2 = V_o + I_3 Z_c = V_o + \frac{I_3}{j\omega C}$$

But $I_3 = \frac{V_o}{R}$

$$\boxed{V_2 = V_o\left(1 + \frac{1}{j\omega CR}\right)}$$

$$I_2 = I_3 + \frac{V_2}{R} = \frac{V_o}{R} + \frac{V_o}{R}\left(1 + \frac{1}{j\omega CR}\right)$$

$$\boxed{I_2 = \frac{V_o}{R}\left(2 + \frac{1}{j\omega CR}\right)}$$



$$\boxed{V_2 = V_o\left(1 + \frac{1}{j\omega CR}\right)}$$

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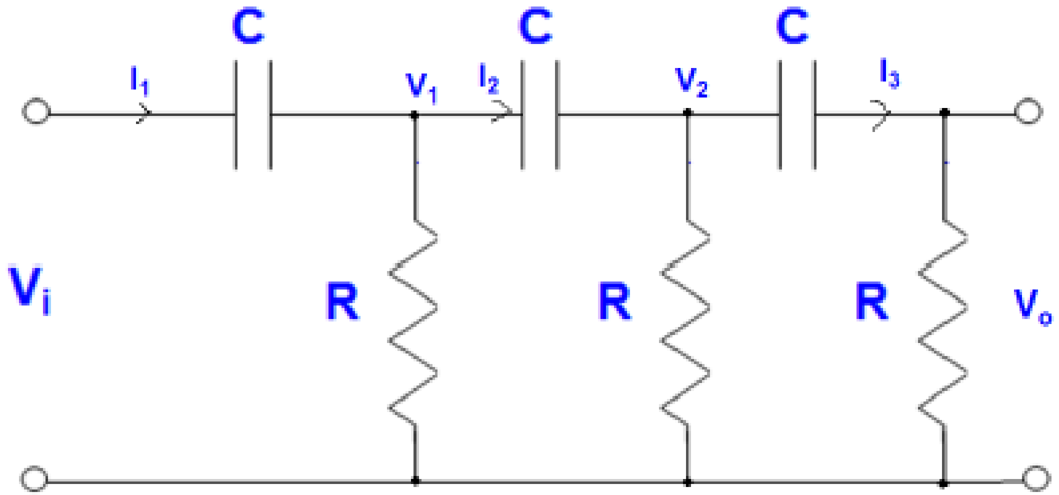
$$\boxed{I_2 = \frac{V_o}{R}\left(2 + \frac{1}{j\omega CR}\right)}$$

At node V_1

$$\boxed{V_1 = V_2 + \frac{I_2}{j\omega C} = V_o\left(1 + \frac{3}{j\omega cR} - \frac{1}{\omega^2 C^2 R^2}\right)}$$

$$\boxed{V_1 = V_2 + \frac{I_2}{j\omega C} = V_o(1 + \frac{3}{j\omega cR} - \frac{1}{\omega^2 C^2 R^2})}$$



$$\boxed{I_1 = I_2 + \frac{V_1}{R} = \frac{V_0}{R}(3 + \frac{4}{j\omega cR} - \frac{1}{\omega^2 C^2 R^2})}$$

$$\boxed{V_i = V_1 + \frac{I_1}{j\omega C} = V_o(1 + \frac{6}{j\omega cR} - \frac{5}{\omega^2 C^2 R^2} - \frac{1}{j\omega^3 C^3 R^3})} \quad \text{.............(A)}$$

Output voltage should be real hence imaginary part equal to zero.

$$\frac{6}{j\omega cR} - \frac{1}{j\omega^3 C^3 R^3} = 0 \qquad \boxed{6\omega^2 C^2 R^2 = 1} \qquad \boxed{\omega = \frac{1}{RC\sqrt{6}}}$$

From Eq. A, at this frequency $\beta = V_o/V_i = -1/29$,

and Therefore from Barkhausen Criterion $A_v.\beta = 1 \Rightarrow A_v = -29 = -R_f/R_1$

Example: Design a phase-shift oscillator for a frequency of 800 Hz. The capacitors are to be 10 nF.

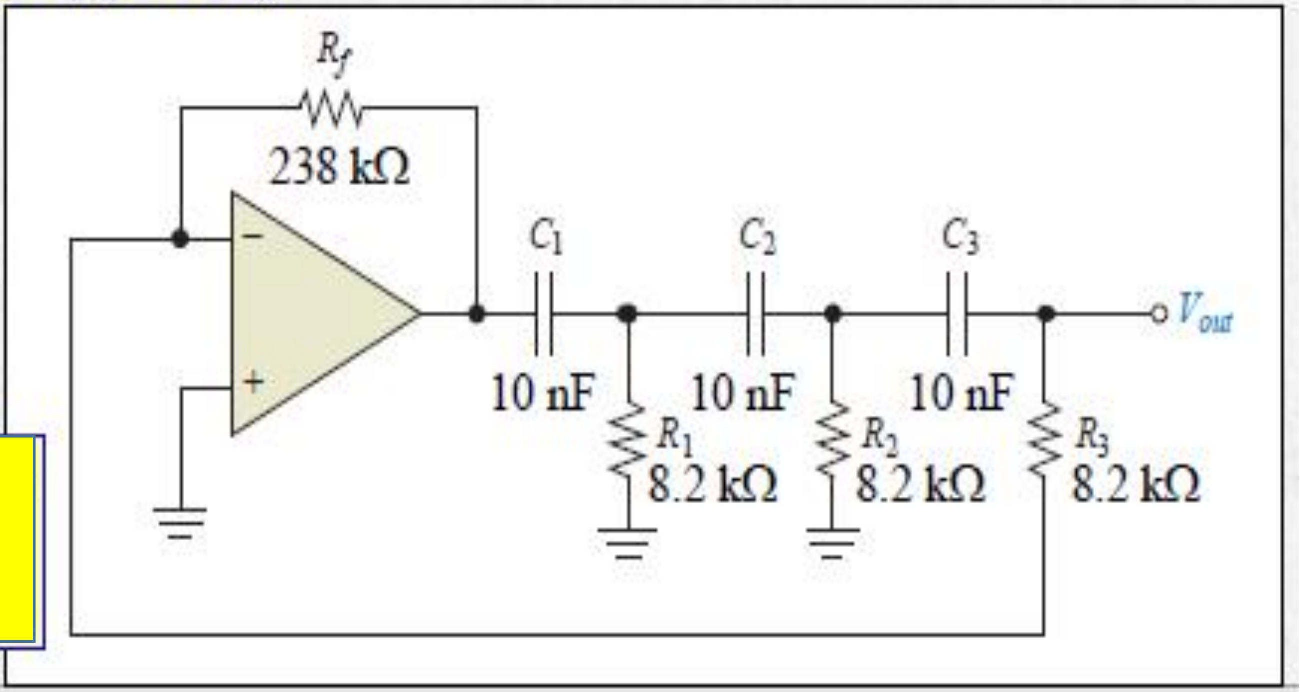
Solution:

Start by solving for the resistors needed in the feedback circuit:

$$R = \frac{1}{2\pi\sqrt{6} f_r C} = \frac{1}{2\pi\sqrt{6}(800\ \text{Hz})(10\ \text{nF})} = 8.12\ \text{k}\Omega \quad \text{(Use 8.2 k}\Omega\text{.)}$$

Calculate the feedback resistor needed:

$R_f = 29R = 238\ \text{k}\Omega$.



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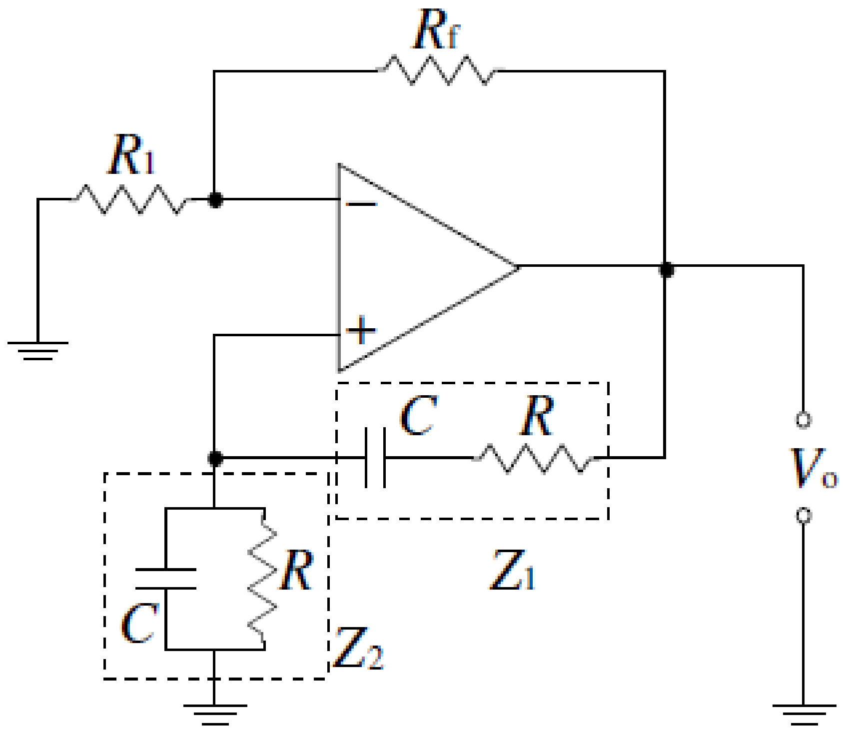
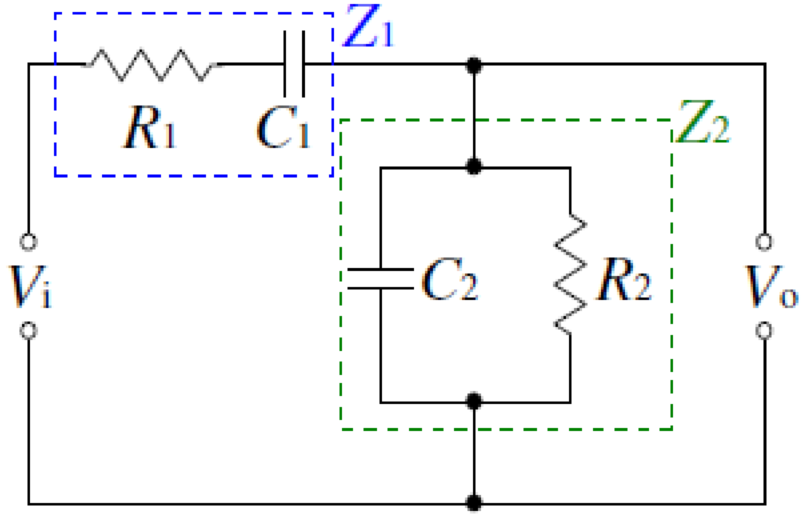
RC Oscillators: Wien Bridge Oscillator





Feedback Network (in general)

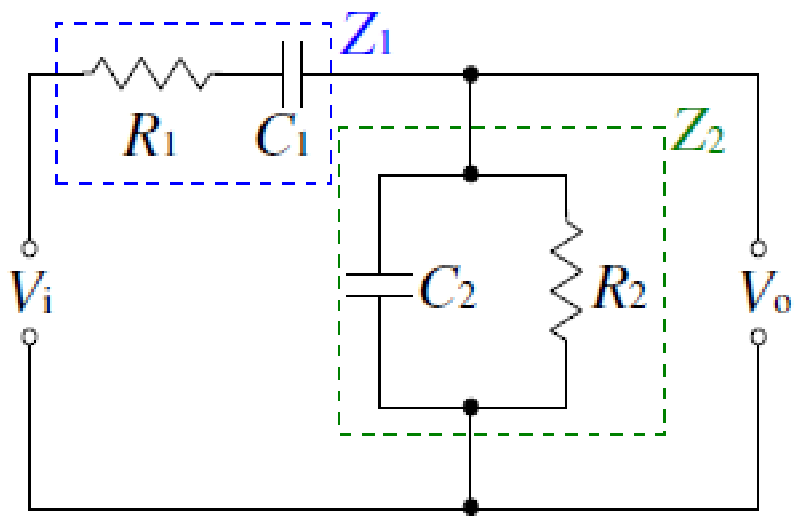
➢ Feedback network is a lead-lag circuit where R_1, C_1 form the lag portion and R_2, C_2 form the lead portion. Thus feedback network provides 0^o phase shift.

RC Oscillators: Wien Bridge Oscillator

Let $X_{C1} = \dfrac{1}{\omega C_1}$ $X_{C2} = \dfrac{1}{\omega C_2}$ and

$$Z_1 = R_1 - jX_{C1}$$

$$Z_2 = \left[\frac{1}{R_2} + \frac{1}{-jX_{C2}} \right]^{-1} = \frac{-jR_2 X_{C2}}{R_2 - jX_{C2}}$$



Therefore, the feedback factor,

$$\beta = \frac{V_o}{V_i} = \frac{Z_2}{Z_1 + Z_2} = \frac{(-jR_2 X_{C2} / R_2 - jX_{C2})}{(R_1 - jX_{C1}) + (-jR_2 X_{C2} / R_2 - jX_{C2})}$$

$$\beta = \frac{-jR_2 X_{C2}}{(R_1 - jX_{C1})(R_2 - jX_{C2}) - jR_2 X_{C2}}$$

$$\beta = \frac{R_2 X_{C2}}{R_1 X_{C2} + R_2 X_{C1} + R_2 X_{C2} + j(R_1 R_2 - X_{C1} X_{C2})}$$

$$\beta = \frac{R_2 X_{C2}}{R_1 X_{C2} + R_2 X_{C1} + R_2 X_{C2} + j(R_1 R_2 - X_{C1} X_{C2})}$$

For ***Barkhausen Criterion***, imaginary part = 0,

$$R_1 R_2 - X_{C1} X_{C2} = 0$$

$$R_1 R_2 = \frac{1}{\omega C_1} \frac{1}{\omega C_2} \qquad \boxed{\omega = 1/\sqrt{R_1 R_2 C_1 C_2}}$$

Supposing, $R_1 = R_2 = \mathrm{R}$ and $X_{C1} = X_{C2} = X_C$,

$$\beta = \frac{R X_C}{3 R X_C + j(R^2 - X_C^2)}$$

At this frequency: β = 1 / 3 and phase shift = 0º

Due to ***Barkhausen Criterion***, gain $A_v \beta = 1$

Where A_v : Gain of the amplifier

$$A_v \beta = 1 \Rightarrow A_v = 3 = 1 + \frac{R_f}{R_1} \qquad \boxed{\frac{R_f}{R_1} = 2}$$

Thanks