Analog Electronics

Course No: AE-2

Lec: Oscillator

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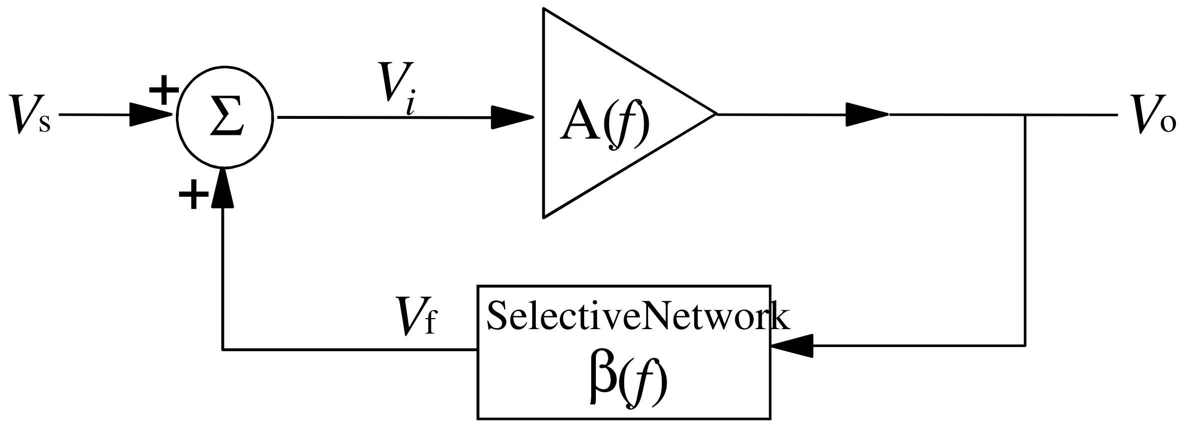
Positive Feedback

- When input and feedback signal both are in same phase, It is called a positive feedback.

- Positive feedback is used in analog and digital systems.

- A primary use of +ve feedback is in the production of oscillators.



$V_o = AV_i = A(V_s + V_f)$ and $V_f = \beta V_o$

$$\boxed{\frac{V_o}{V_s} = \frac{A}{1 - A\beta}}$$

Barkhausen Criterion: for oscillator βA=1 and +ve feedback

Oscillator Circuit

- **Oscillator is an electronic circuit which converts dc signal into ac signal.**

- **Oscillator is basically a positive feedback amplifier with unity loop gain.**

- **For an inverting amplifier- feedback network provides a phase shift of 180° while for non-inverting amplifier- feedback network provides a phase shift of 0° to get positive feedback .**

$$\boxed{\frac{V_o}{V_s} = \frac{A}{1 - A\beta}}$$

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

Use positive feedback through frequency-selective feedback network to ensure sustained oscillation at ω_0

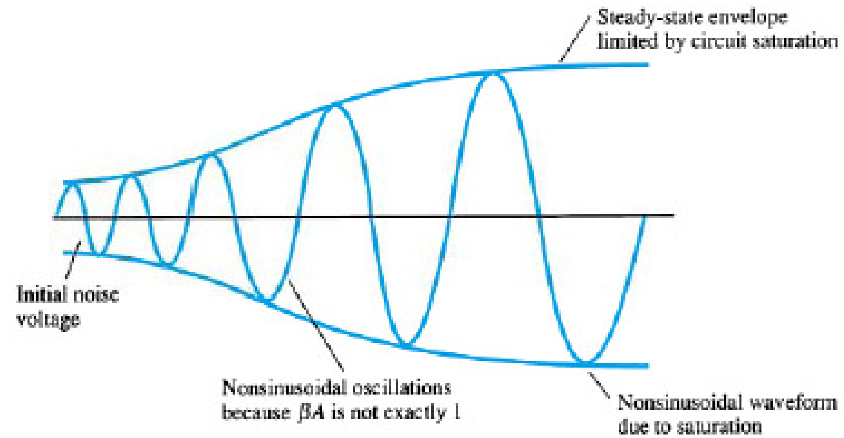
Use of Oscillator Circuits

- Clock input for CPU, DSP chips …
- Local oscillator for radio receivers, mobile receivers, etc
- As a signal generators in the lab
- Clock input for analog-digital and digital-analog converters

Oscillators

- If the feedback signal is not positive and gain is less than unity, oscillations dampen out.

- If the gain is higher than unity then oscillation saturates.



Type of Oscillators

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

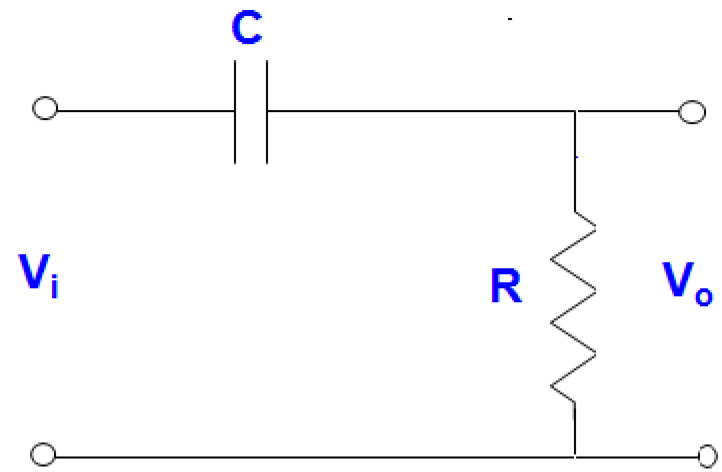
- RC Oscillators: Phase shift and Wien Bridge Oscillators

- LC Oscillators: Colpitt and Hartley Oscillators

- Crystal Oscillators

RC Oscillators

$$V_o = (\frac{R}{R - jX_c})V_{in} \quad \text{and} \quad \phi = \tan^{-1}(\frac{X_C}{R})$$



- **Φ =0° if X_c=0 and Φ =90° if R=0**

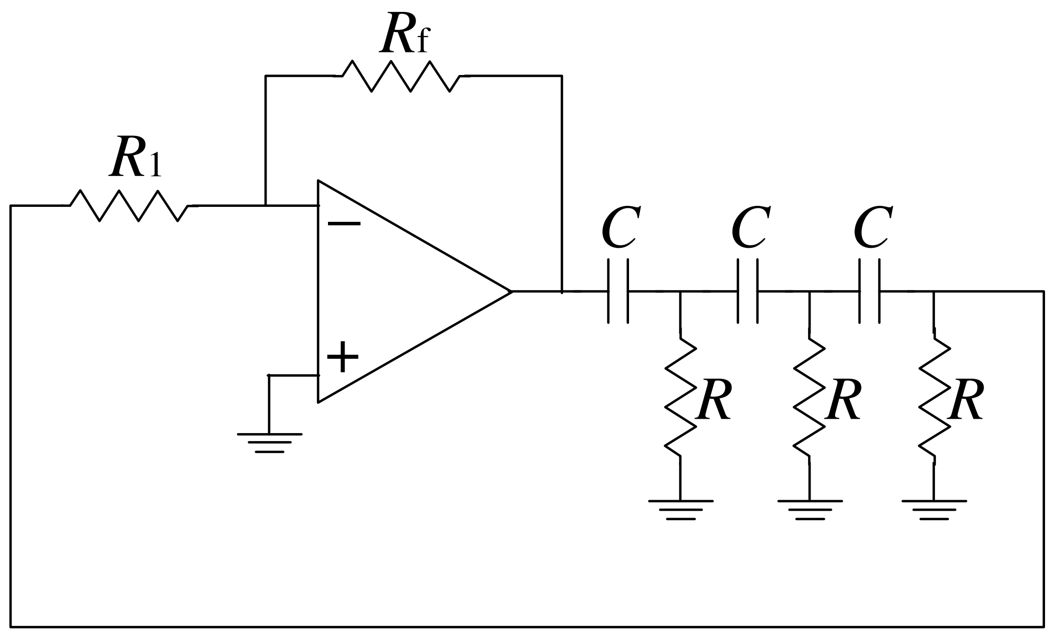
- **However adjusting R to zero is impractical because it would lead to no voltage across R, thus in a RC circuit, phase shift is always ≤ 90° and it is a function of frequency.**

- **Hence to get 180° phase shift from the feedback network, we need 3 RC circuits.**

- **RC oscillators build by using inverting amplifier and 3 RC circuits is known as phase shift oscillator.**

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.



A phase shift of 180° is obtained at a frequency f, given by

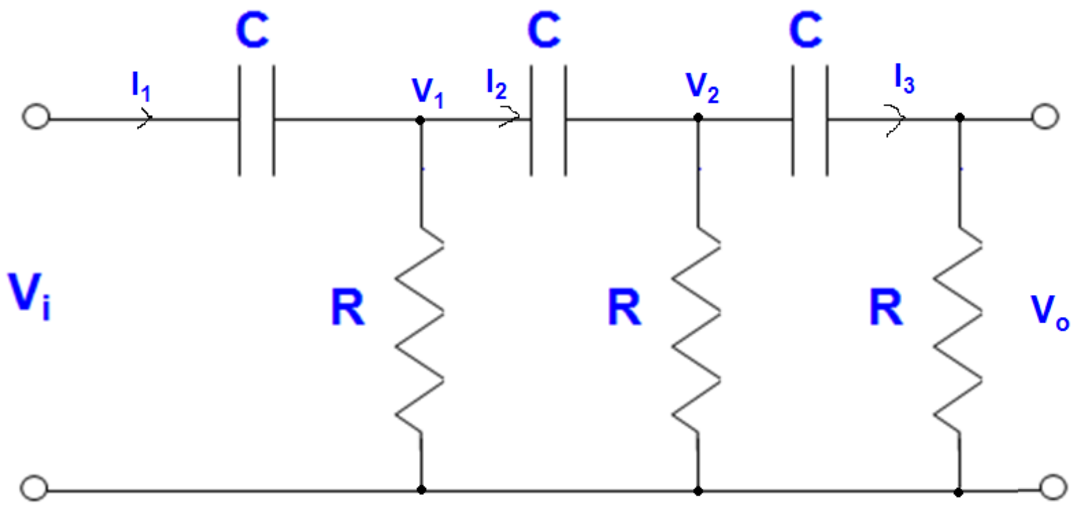
$$f = \frac{1}{2\pi CR\sqrt{6}}$$

At this frequency the gain of the network is $$\frac{v_o}{v_i} = -\frac{1}{29}$$

RC Oscillators: Phase shift Oscillator

At node V_2

$$V_2 = V_o + I_3 X_c = V_o + \frac{I_3}{jwC}$$



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

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

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

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

At node V_1

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

RC Oscillators: Phase shift Oscillator

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

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

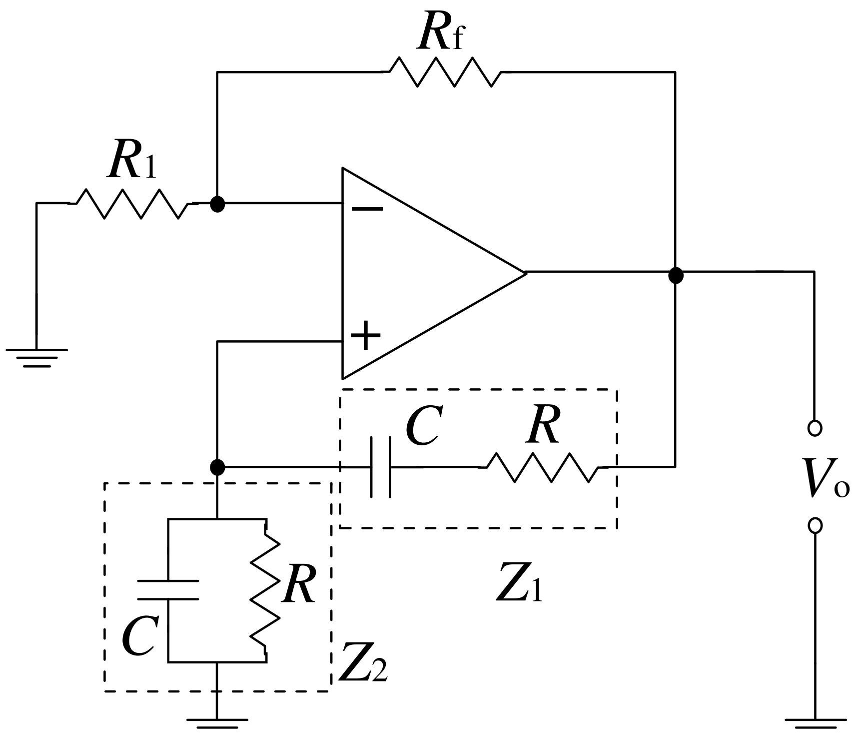
$$\boxed{V_i = V_1 + \frac{I_1}{j\omega C} = V_o(1 + \frac{6}{j\omega cR} - \frac{5}{\omega^2 C^2 R^2} - \frac{1}{j\omega^3 C^3 R^3})}$$

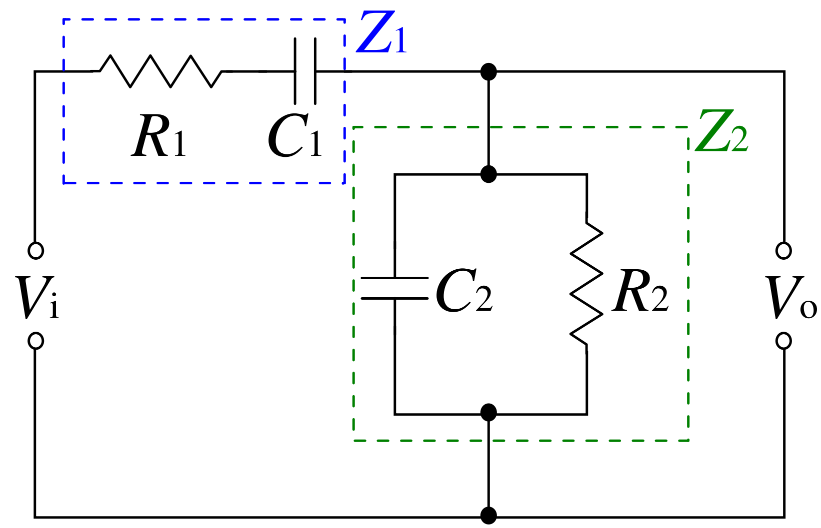
Output voltage should be real hence imaginary part equal to zero.

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

At this frequency: V_i =-29 V_o therefore, A_v = -29

RC Oscillators: Wien Bridge Oscillator

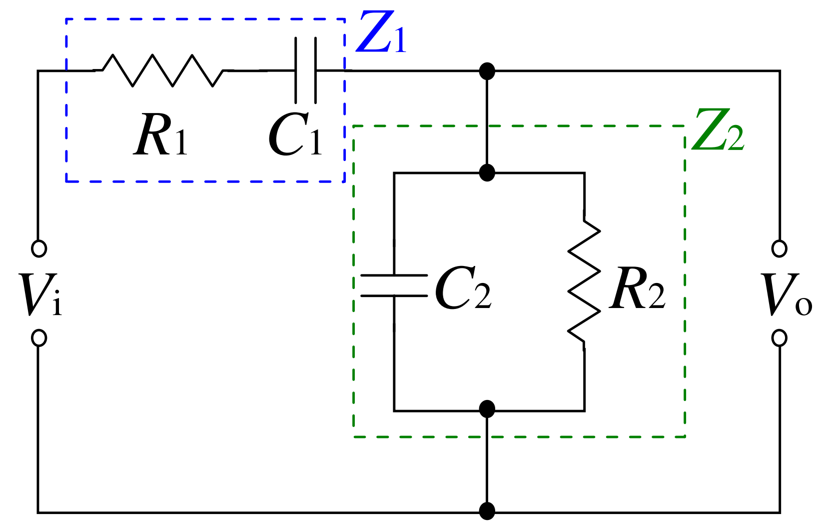




Feedback Network

- **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,

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

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

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

RC Oscillators: Wien Bridge Oscillator

For ***Barkhausen Criterion***, imaginary part = 0, $R_1 R_2 - X_{C1} X_{C2} = 0$

$$R_1 R_2 = \frac{1}{\omega C_1} \frac{1}{\omega C_2}$$

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

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

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

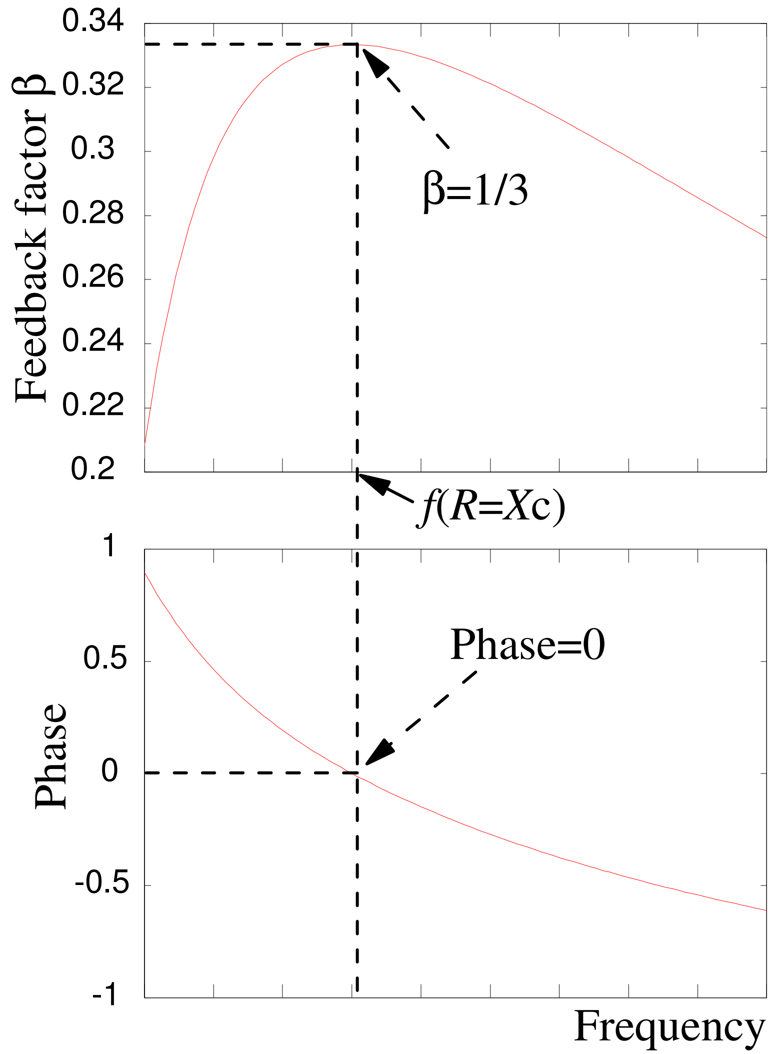
At this frequency: β = 1 / 3 and phase shift = 0°

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

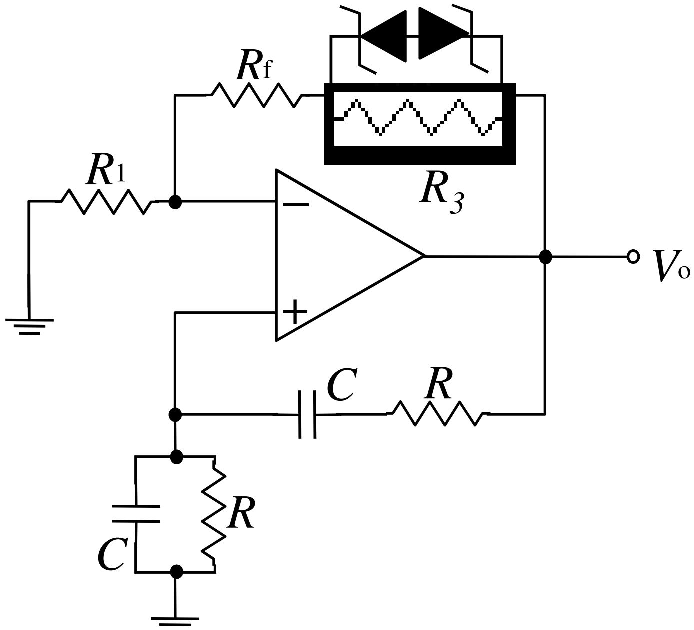
Where A_v : Gain of the amplifier

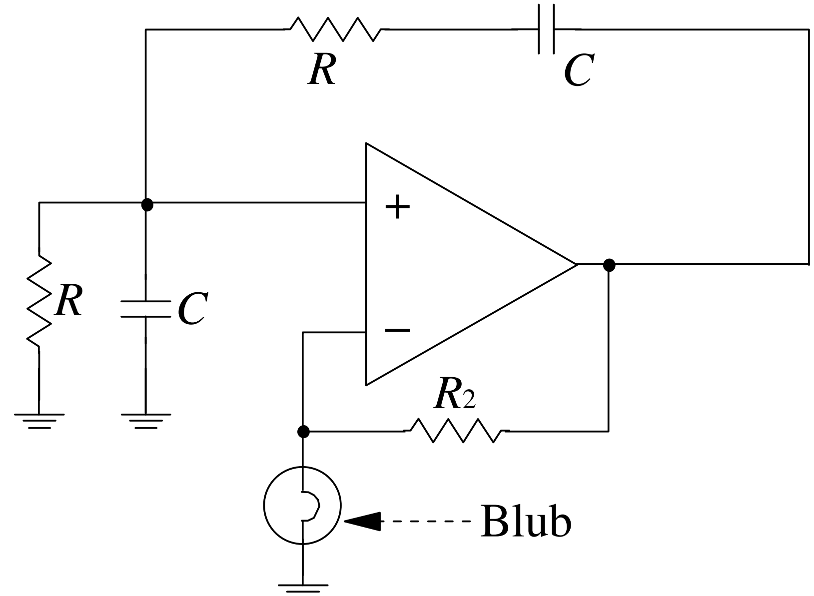
$$A_v\beta = 1 \Rightarrow A_v = 3 = 1 + \frac{R_f}{R_1}$$

$$\boxed{\frac{R_f}{R_1} = 2}$$



Stabilization method for Wien Bridge Oscillator





When dc power is first applied, both zener diode is off.

$$A_v = 1 + \frac{R_f + R_3}{R_1} = 3 + \frac{R_3}{R_1} \quad \text{Because} \quad \frac{R_f}{R_1} = 2$$

Initially, a small +ve feedback signal develops from noise or turn-on transients. This feedback signal is amplified and continually reinforced , resulting in a buildup of the output voltage. When the output voltage reaches the zener breakdown voltage , zener diode conducts and effective short out R3 and thus lowers the close loop voltage gain to 3.