Introduction

- Oscillator is an electronic circuit that generates a periodic waveform on its output without an external signal source. It is used to convert dc to ac.
- Oscillators are circuits that produce a continuous signal of some type without the need of an input.
- These signals serve a variety of purposes.
- Communications systems, digital systems (including computers), and test equipment make use of oscillators

Oscillators

Oscillation: an effect that repeatedly and regularly fluctuates about the mean value

Oscillator: circuit that produces oscillation

Characteristics: wave-shape, frequency, amplitude, distortion, stability

Application of Oscillators

- **Oscillators are used to generate signals, e.g.**
  - Used as a local oscillator to transform the RF signals to IF signals in a receiver;
  - Used to generate RF carrier in a transmitter
  - Used to generate clocks in digital systems;
  - Used as sweep circuits in TV sets and CRO.

Oscillators

- Oscillators are circuits that generate periodic signals
- An oscillator converts DC power from the power supply into AC signal power spontaneously - without the need for an AC input source

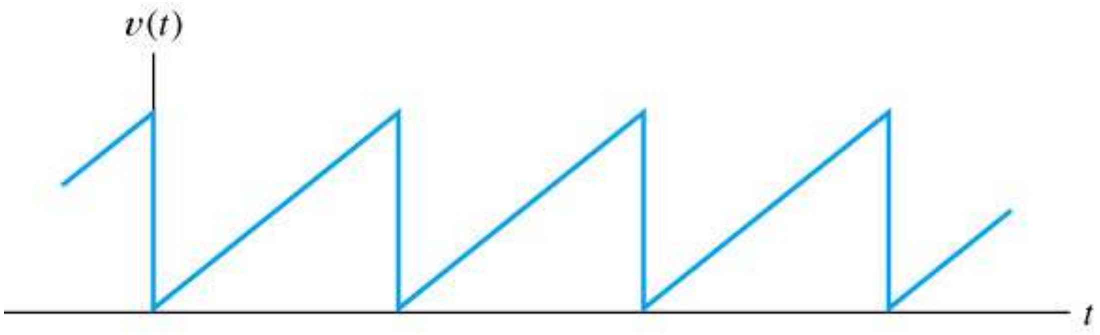
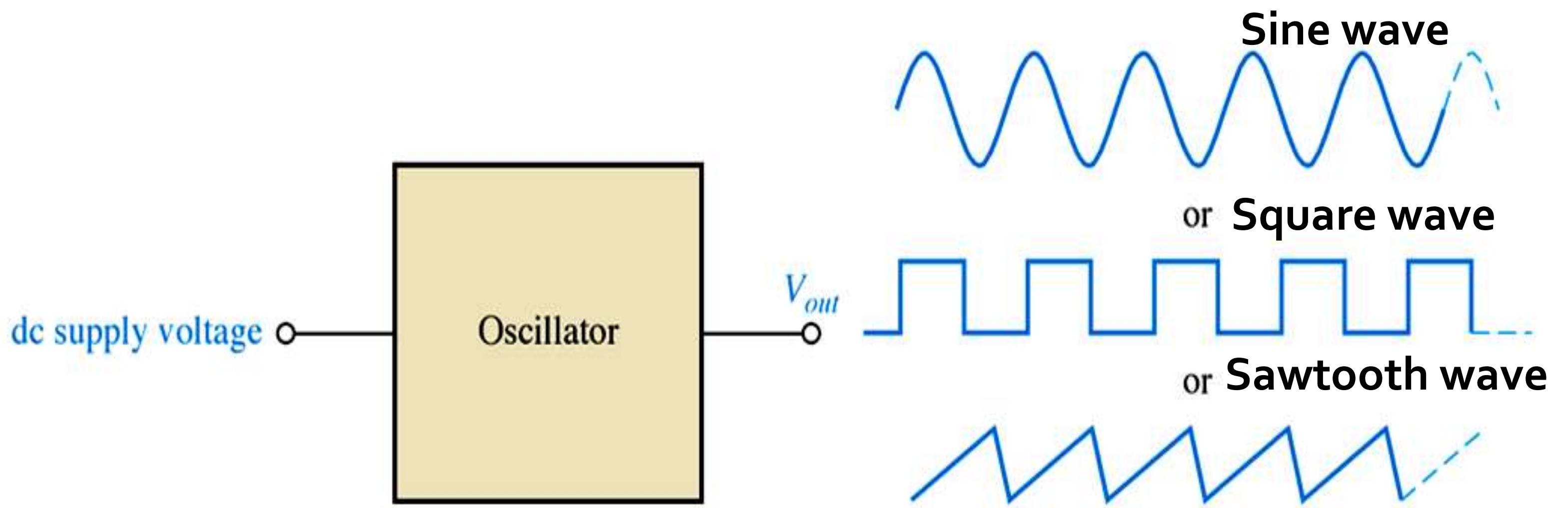


Figure 9.67 Repetitive ramp waveform.

Introduction

- An oscillator is a circuit that produces a repetitive signal from a dc voltage.
- The feedback oscillator **relies on a positive feedback** of the output to **maintain the oscillations**.
- The relaxation oscillator makes use of an RC timing circuit to generate a nonsinusoidal signal such as square wave



Types of oscillators

1. **RC oscillators**
   - Wien Bridge
   - Phase-Shift
2. **LC oscillators**
   - Hartley
   - Colpitts
   - Crystal
3. **Unijunction / relaxation oscillators**

Linear Oscillators

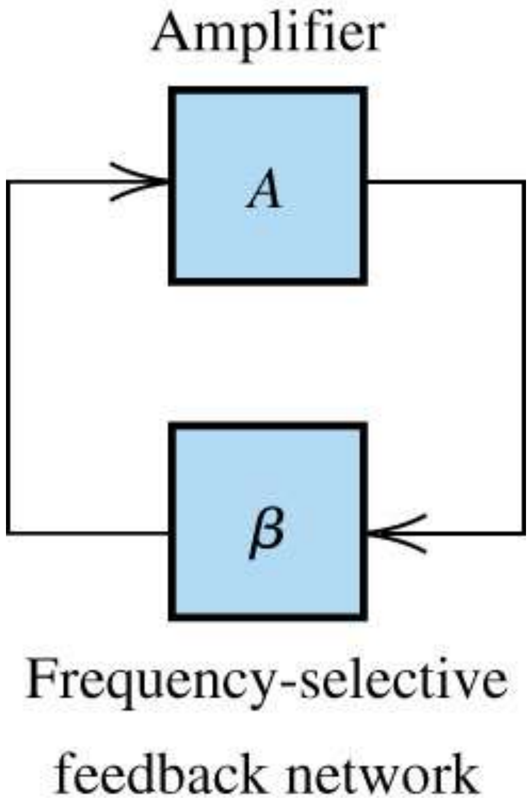
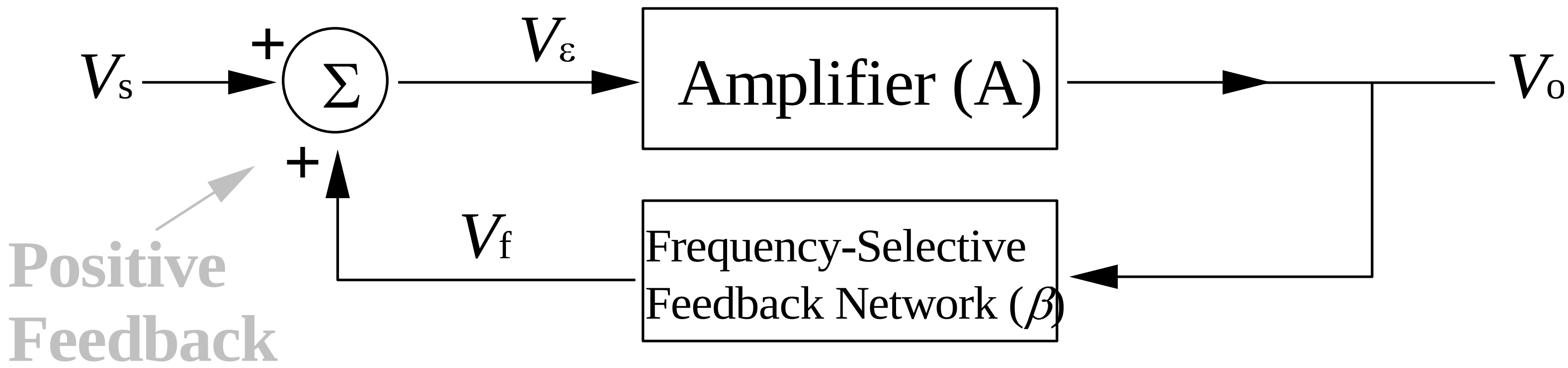


Figure 9.68 A linear oscillator is formed by connecting an amplifier and a feedback network in a loop.

Integrant of Linear Oscillators

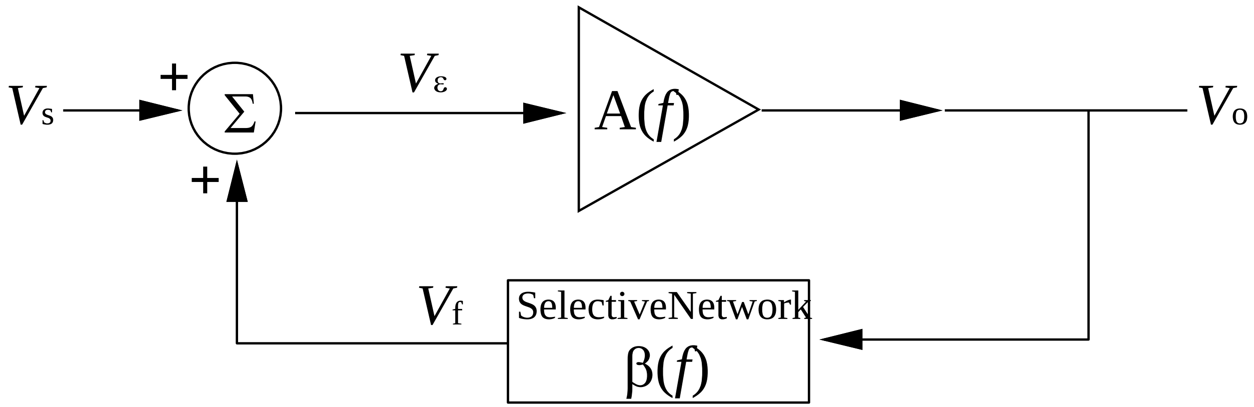


For sinusoidal input is connected
"Linear" because the output is approximately sinusoidal

A linear oscillator contains:

- a frequency selection feedback network
- an amplifier to maintain the loop gain at **unity**

Basic Linear Oscillator



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

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

If $V_s = 0$, the only way that V_o can be nonzero is that loop gain $A\beta=1$ which implies that

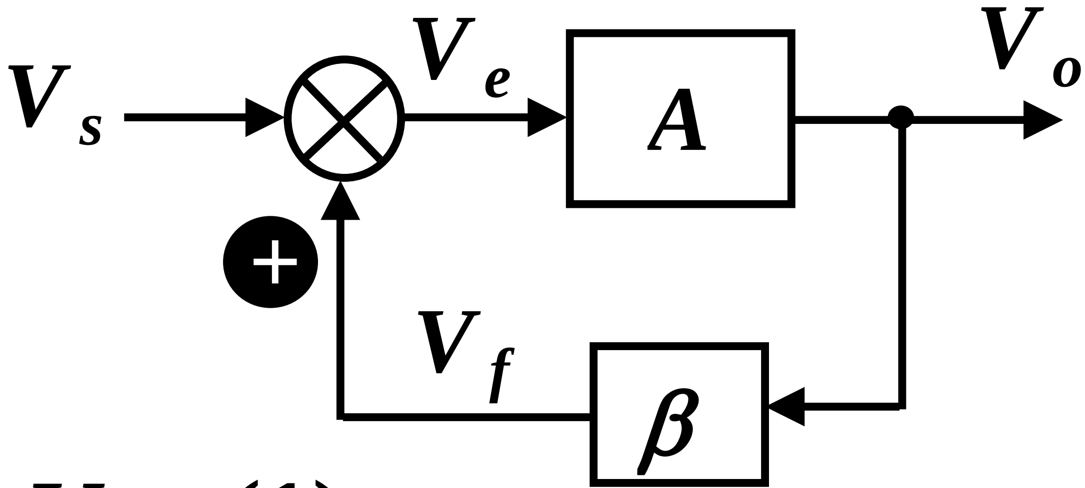
$$|A\beta| = 1$$

(Barkhausen Criterion)

$$\angle A\beta = 0$$

Basic principles for oscillation

- An oscillator is an amplifier with positive feedback.



$$V_e = V_s + V_f \quad (1)$$

$$V_f = \beta V_o \quad (2)$$

$$V_o = AV_e = A(V_s + V_f) = A(V_s + \beta V_o) \quad (3)$$

Basic principles for oscillation

$$\begin{aligned} V_o &= A V_e \\ &= A\left(V_s + V_f\right) = A\left(V_s + \beta V_o\right) \end{aligned}$$

$$V_o = A V_s + A\beta V_o$$

$$\left(1 - A\beta\right) V_o = A V_s$$

- The closed loop gain is:

$$A_f \equiv \frac{V_o}{V_s} = \frac{A}{\left(1 - A\beta\right)}$$

Basic principles for oscillation

- In general A and β are functions of frequency and thus may be written as;

$$A_f(s) = \frac{V_o}{V_s}(s) = \frac{A(s)}{1 - A(s)\beta(s)}$$

$A(s)\beta(s)$ is known as **loop gain**

Basic principles for oscillation

- Writing $T(s) = A(s)\beta(s)$ the loop gain becomes;

$$A_f(s) = \frac{A(s)}{1 - T(s)}$$

- Replacing s with $j\omega$

$$A_f(j\omega) = \frac{A(j\omega)}{1 - T(j\omega)}$$

- and $T(j\omega) = A(j\omega)\beta(j\omega)$

Basic principles for oscillation

- At a specific frequency f_0

$$T(j\omega_0) = A(j\omega_0)\beta(j\omega_0) = 1$$

- At this frequency, the closed loop gain;

$$A_f(j\omega_0) = \frac{A(j\omega_0)}{1 - A(j\omega_0)\beta(j\omega_0)}$$

will be infinite, i.e. the circuit will have finite output for zero input signal - oscillation

Basic principles for oscillation

- Thus, the condition for sinusoidal oscillation of frequency f_0 is;

$$\boldsymbol{A(j\omega_0)\beta(j\omega_0) = 1}$$

- This is known as **Barkhausen criterion**.
- The frequency of oscillation is solely determined by the phase characteristic of the feedback loop – the loop oscillates at the frequency for which the phase is zero.

Barkhausen Criterion – another way

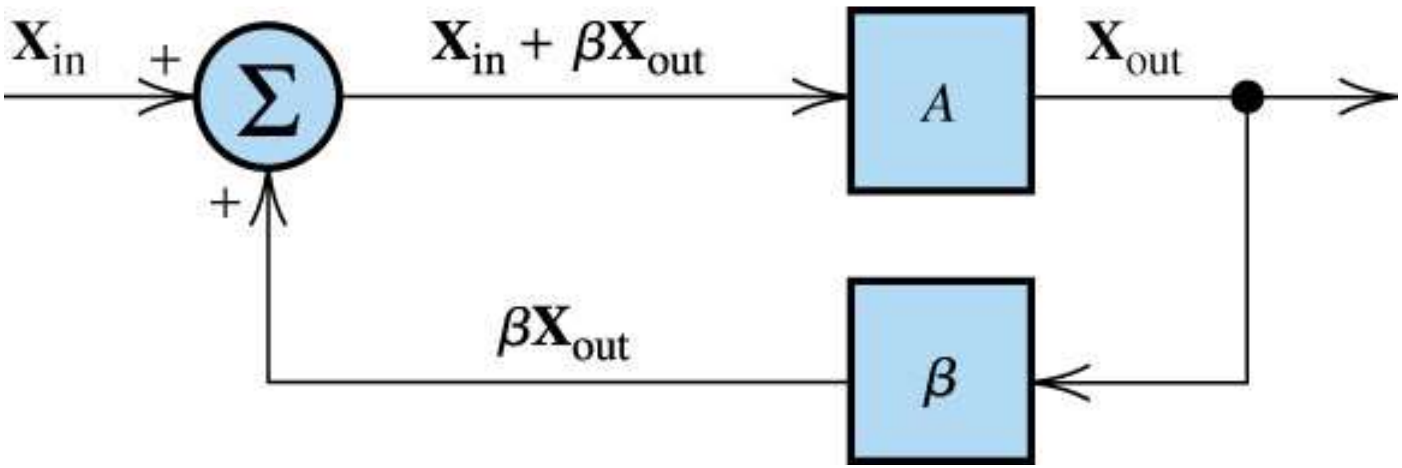


Figure 9.69 Linear oscillator with external signal X_{in} injected.

Barkhausen Criterion

How does the oscillation get started?

- Noise signals and the transients associated with the circuit turning on provide the initial source signal that initiate the oscillation

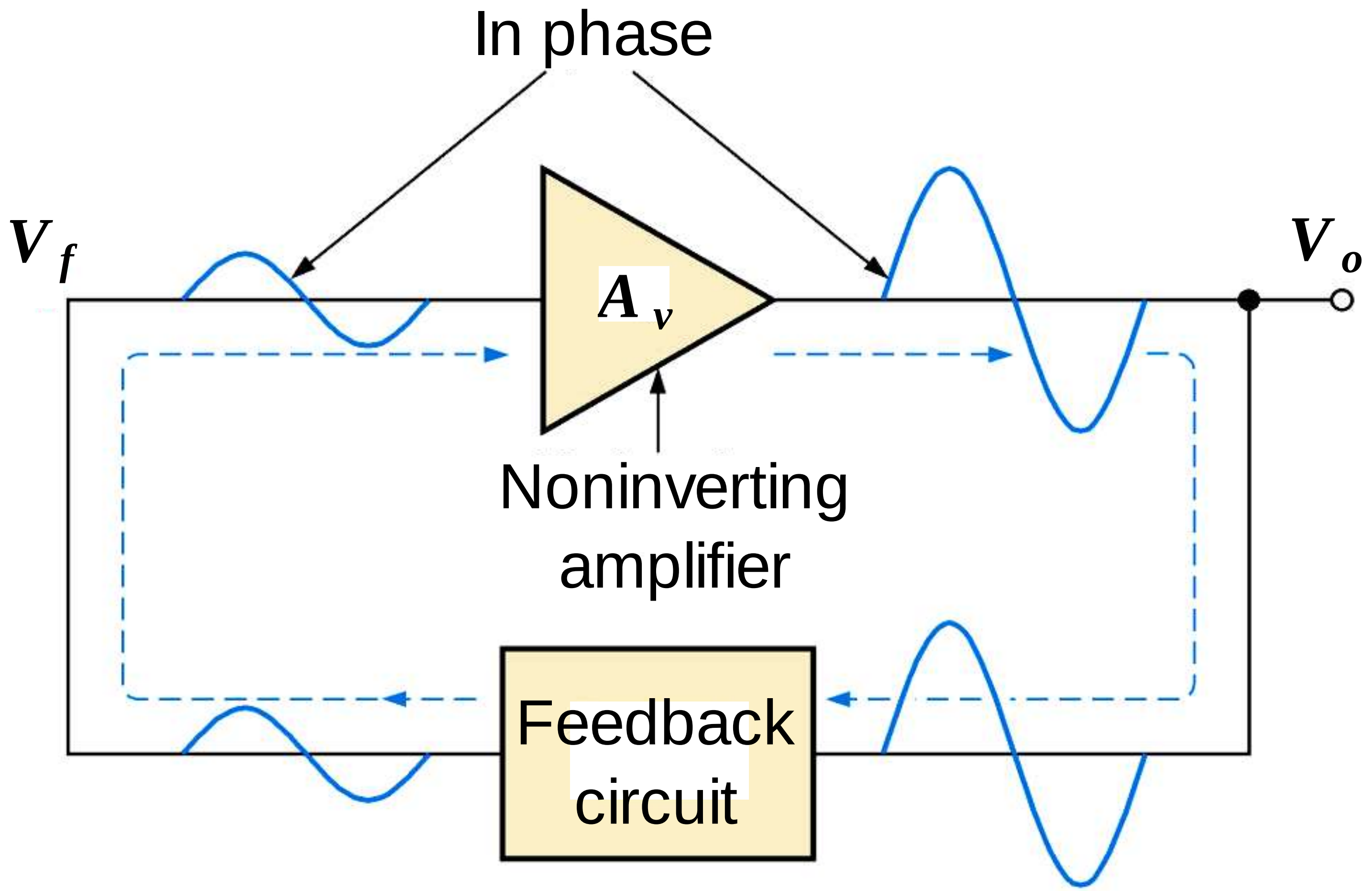
Practical Design Considerations

- Usually, oscillators are designed so that the loop gain magnitude is slightly higher than unity at the desired frequency of oscillation
- This is done because if we designed for unity loop gain magnitude a slight reduction in gain would result in oscillations that die to zero
- The drawback is that the oscillation will be slightly distorted (the higher gain results in oscillation that grows up to the point that will be clipped)

Basic principles for oscillation

- The feedback oscillator is widely used for generation of sine wave signals.
- The positive (in phase) feedback arrangement maintains the oscillations.
- The feedback gain must be kept to unity to keep the output from distorting.

Basic principles for oscillation



Design Criteria for Oscillators

1. The magnitude of the loop gain must be unity or slightly larger

   $$|A\beta| = 1$$ – Barkhaussen criterion

2. Total phase shift, ϕ of the loop gain mus t be Nx360° where N=0, 1, 2, …

RC Oscillators

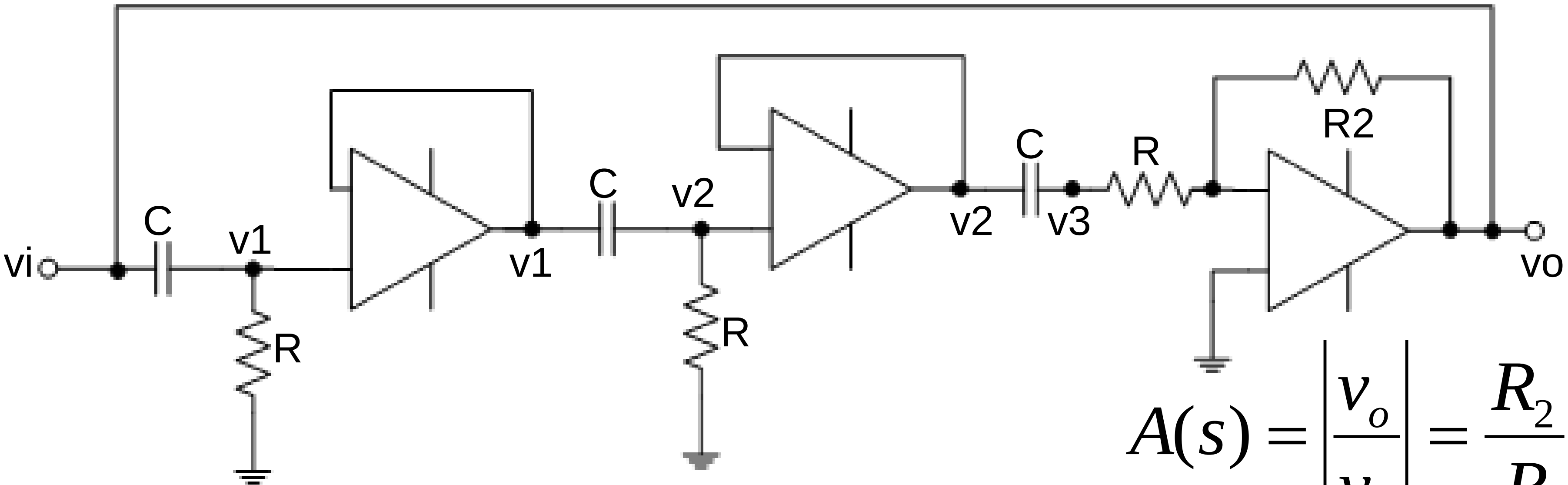
- RC feedback oscillators are generally limited to frequencies of 1 MHz or less.
- The types of RC oscillators that we will discuss are the **Wien-bridge** and the **phase-shift**

Phase-Shift Oscillator

- The phase shift oscillator utilizes **three RC circuits to provide 180° phase shift** that when coupled with the 180° of the op-amp itself provides the necessary feedback to sustain oscillations.
- The **gain must be at least 29** to maintain the oscillations.
- The frequency of resonance for the this type is similar to any RC circuit oscillator:

$$f_r = \frac{1}{2\pi\sqrt{6}RC}$$

Phase-Shift Oscillator



$$A(s) = \left|\frac{v_o}{v_3}\right| = \frac{R_2}{R}$$

$$v_1 = \left(\frac{sRC}{1+sRC}\right) v_i \qquad v_3 = \left(\frac{sRC}{1+sRC}\right)^3 v_i$$

$$v_2 = \left(\frac{sRC}{1+sRC}\right)^2 v_i \qquad \frac{v_3}{v_i} = \beta(s) = \left(\frac{sRC}{1+sRC}\right)^3$$

Phase-Shift Oscillator

- Loop gain, T(s):

$$T(s) = A(s)\beta(s) = \left(\frac{R_2}{R}\right)\left(\frac{sRC}{1+sRC}\right)^3$$

- Set s=jw

$$T(j\omega) = \left(\frac{R_2}{R}\right)\left(\frac{j\omega RC}{1+j\omega RC}\right)^3$$

$$T(j\omega) = -\left(\frac{R_2}{R}\right)\frac{(j\omega RC)(\omega RC)^2}{\left[1-3\omega^2R^2C^2\right]+j\omega RC\left[3-\omega^2R^2C^2\right]}$$

Phase-Shift Oscillator

- To satisfy condition $T(jw_o)=1$, real component must be zero since the numerator is purely imaginary.

$$1-3\omega^2R^2C^2=0$$

- the oscillation frequency: $$\omega_0=\frac{1}{\sqrt{3}RC}$$

- Apply w_o in equation:

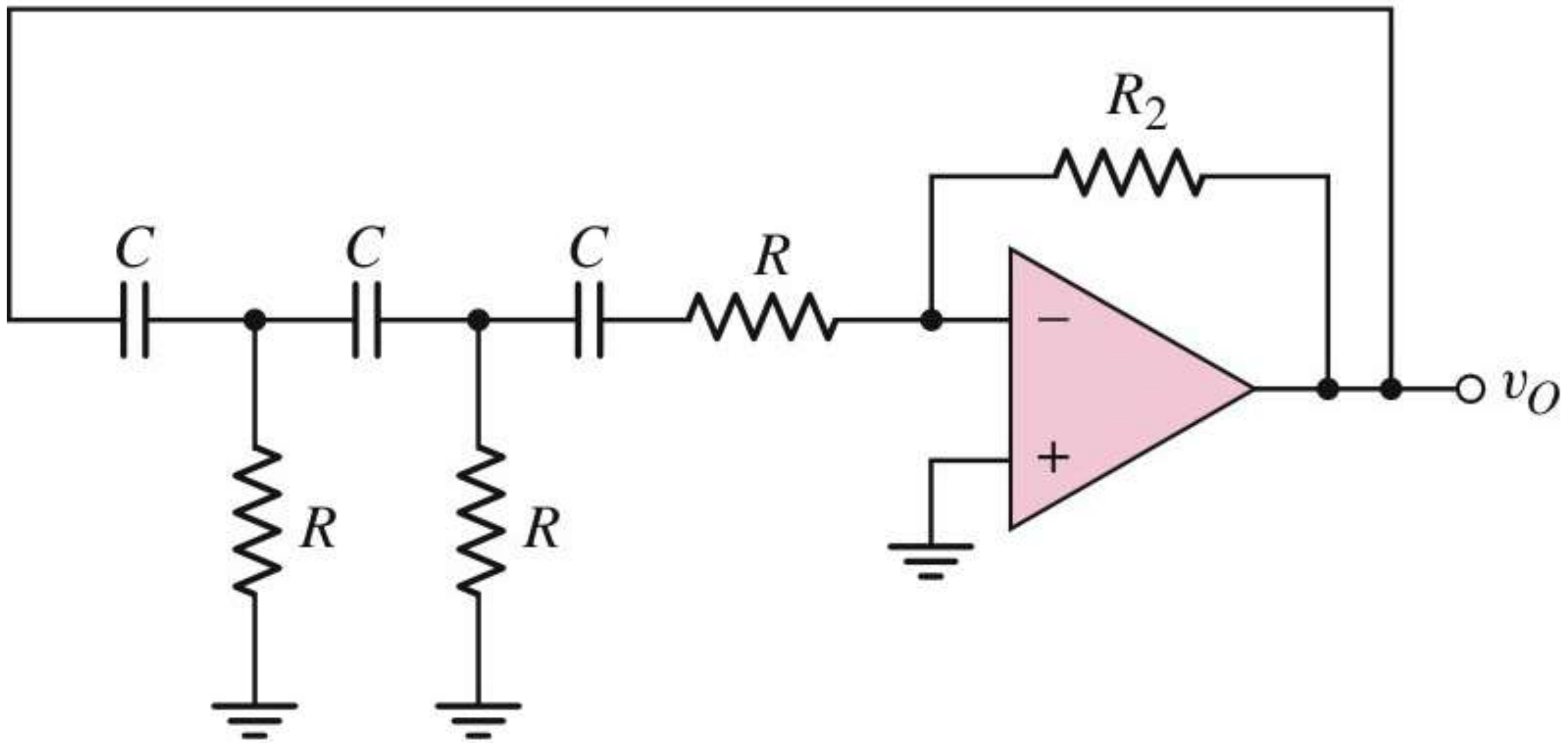
$$T(j\omega_o)=-\left(\frac{R_2}{R}\right)\frac{(j/\sqrt{3})(1/3)}{0+(j/\sqrt{3})\left[3-(1/3)\right]}=-\left(\frac{R_2}{R}\right)\left(\frac{1}{8}\right)$$

- To satisfy condition $T(jw_o)=1$

$$\frac{R_2}{R}=8$$

The gain greater than 8, the circuit will spontaneously begin oscillating & sustain oscillations

Phase-Shift Oscillator



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

$$\frac{R_2}{R} = 29$$

The gain must be at least 29 to maintain the oscillations