MIU
Misr International University
جامعة مصر الدولية

FACULTY OF ENGINEERING
DEPARTMENT OF ELECTRONICS AND COMMUNICATIONS

GEE336
Electronic Circuits II

Lecture #6
Sinusoidal Oscillators

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Agenda

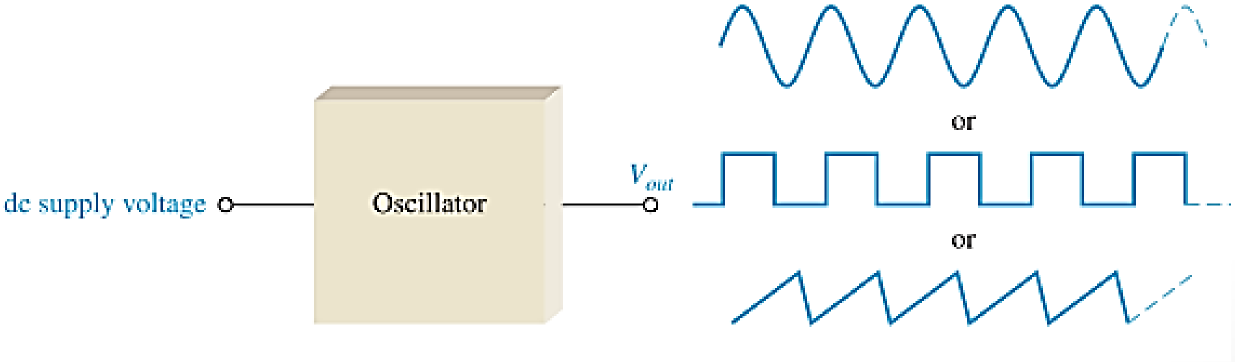
- Introduction
- Feedback Oscillators
- Oscillators with RC Feedback Circuits
  - Wien-bridge & Phase-shift & Quadrature Osc.

INTRODUCTION

Introduction

- An **oscillator** is a circuit that produces a periodic waveform on its output with only the dc supply voltage as an input.
- The output voltage can be either **sinusoidal** or **non sinusoidal**, depending on the type of oscillator.
- Two major classifications for oscillators are **feedback** oscillators and **relaxation** oscillators.

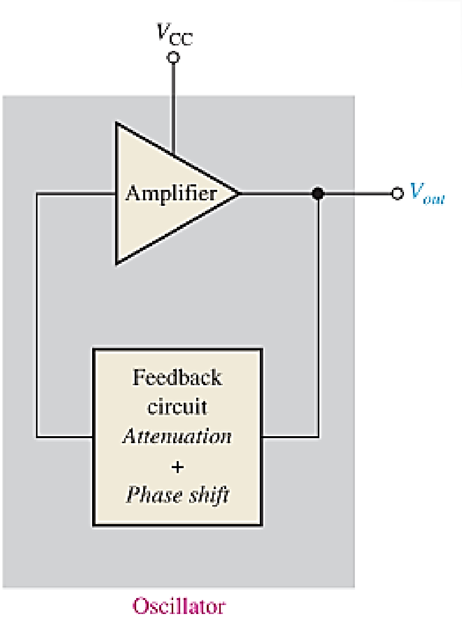
- an oscillator converts electrical energy from the dc power supply to periodic waveforms.



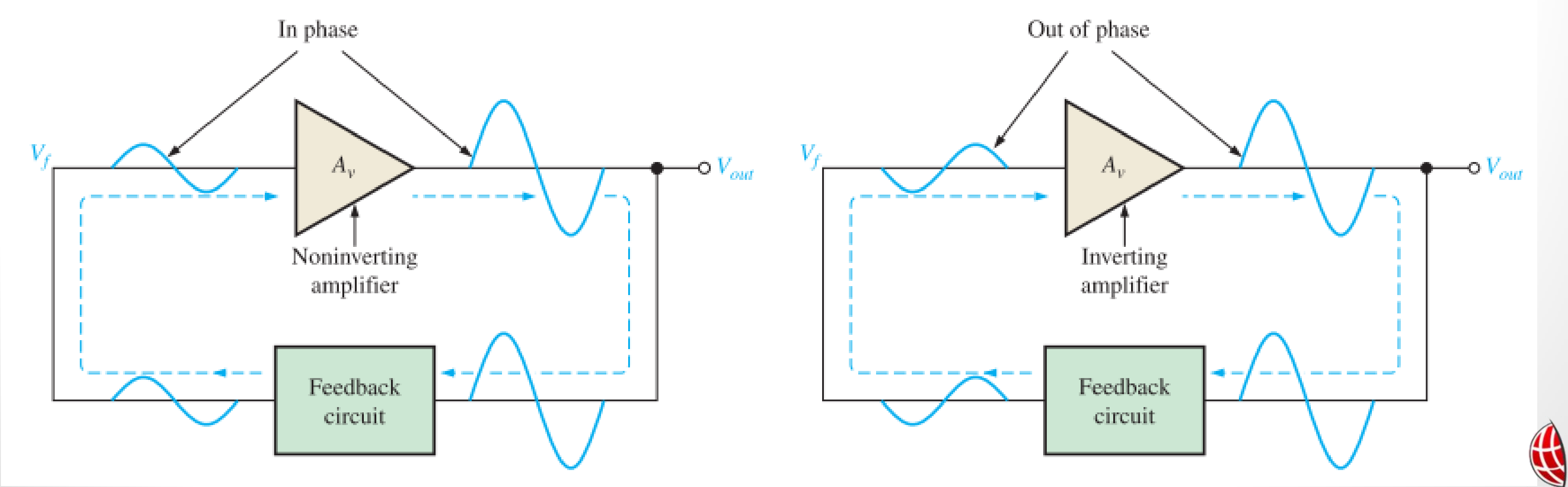
FEEDBACK OSCILLATORS

Positive feedback

- Positive feedback is characterized by the condition wherein a portion of the output voltage of an amplifier is fed back to the input with no net phase shift, resulting in a reinforcement of the output signal.



Basic elements of a feedback oscillator.

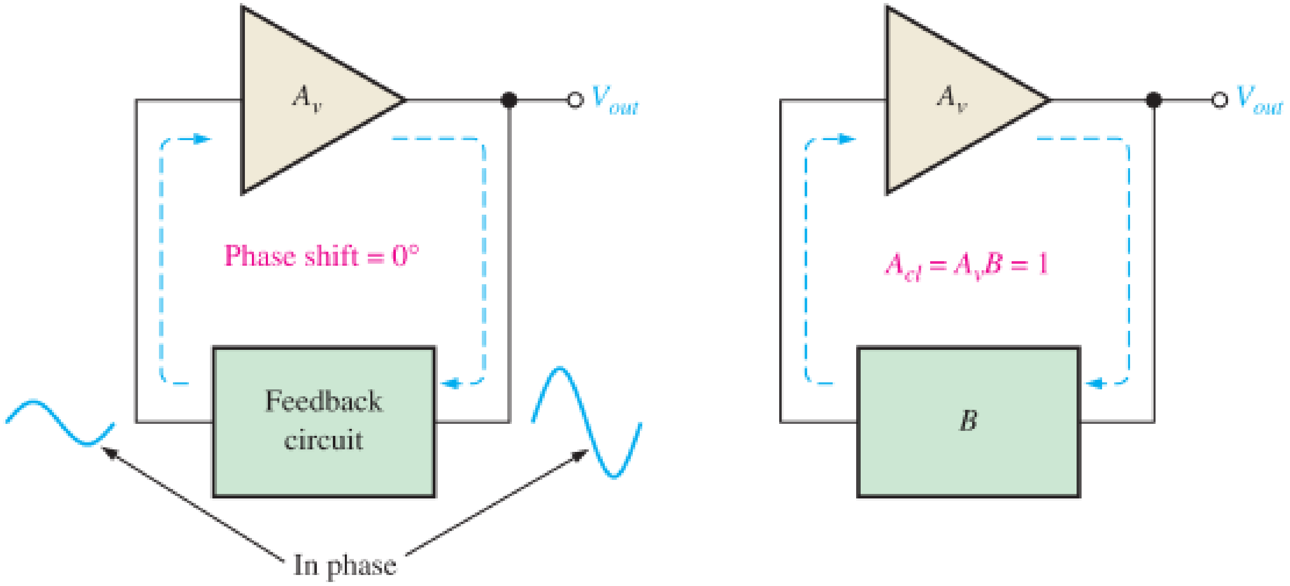


Conditions for Oscillation

- Two conditions:

1. The phase shift around the feedback loop must be effectively 0°.
2. The voltage gain, A_{cl} around the closed feedback loop (loop gain) must equal 1 (unity).

$$A_{cl} = A_v B$$

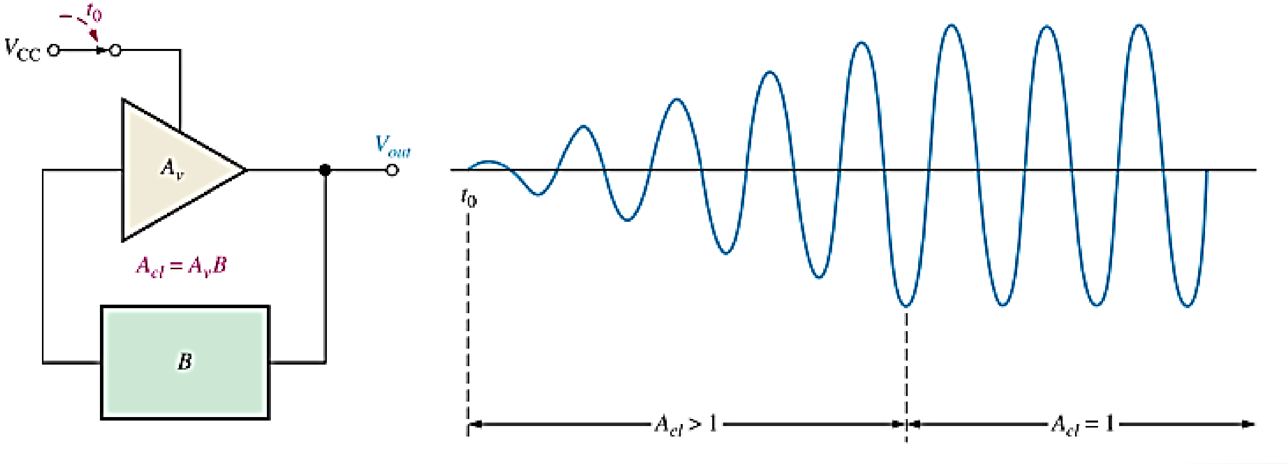


(a) The phase shift around the loop is 0°.

(b) The closed loop gain is 1.

Start-Up Conditions

- For oscillation to begin, the voltage gain around the positive feedback loop must be greater than 1 so that the amplitude of the output can build up to a desired level.
- The gain must then decrease to 1 so that the output stays at the desired level and oscillation is sustained.
- Initially, a small positive feedback voltage develops from thermally produced broad-band noise in the resistors or other components or from power supply turn-on transients.



Wien-bridge oscillator

Phase-shift oscillator

Quadrature oscillator

OSCILLATORS WITH RC FEEDBACK CIRCUITS

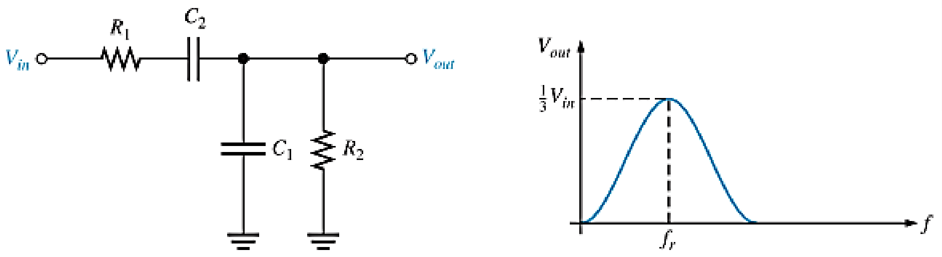
The Wien-Bridge Oscillator

- Generally, RC feedback oscillators are used for frequencies up to about 1 MHz.
- The Wien-bridge is by far the most widely used type of RC feedback oscillator for this range of frequencies.

$R_1 = R_2$ and $X_{C1} = X_{C2}$

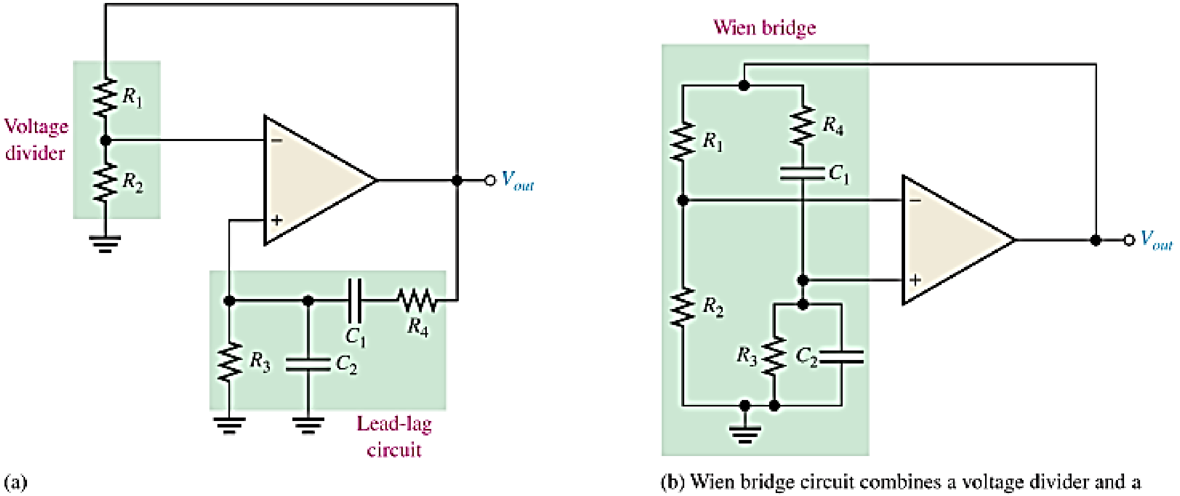
$$\frac{V_{out}}{V_{in}} = \frac{1}{3}$$

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



Lead-lag circuit and its response curve

- **Basic Circuit**



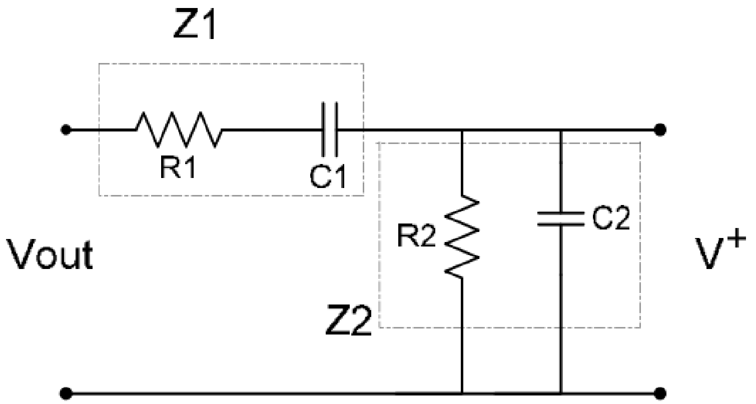
(a)

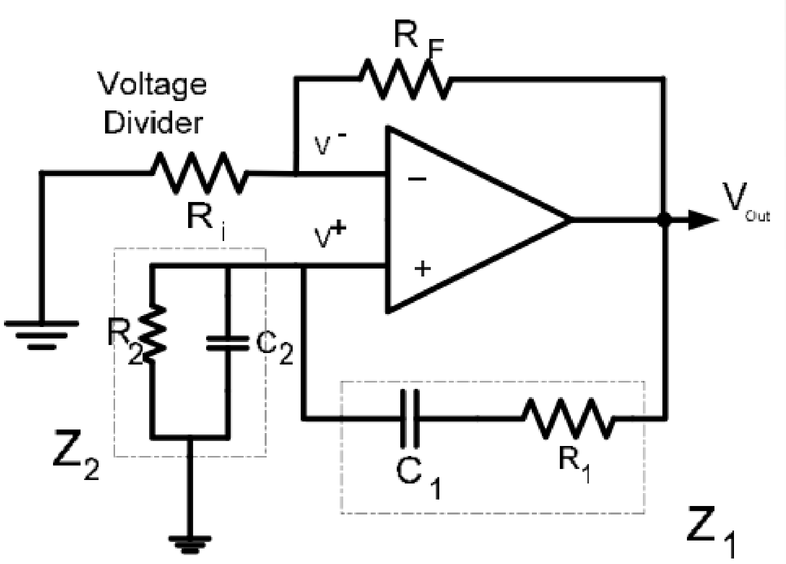
(b) Wien bridge circuit combines a voltage divider and a lead-lag circuit.

▲ FIGURE 16–7

The Wien-bridge oscillator schematic drawn in two different but equivalent ways.

The Wien-Bridge Oscillator..





$$Z_1 = R_1 - \frac{j}{\omega c_1} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$Z_2 = R_2 \backslash\backslash -\frac{j}{\omega c_2} = \frac{R_2 \times \frac{-j}{\omega c_2}}{R_2 - \frac{j}{\omega c_2}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2) \qquad \div\left(\frac{-j}{\omega c_2}\right)$$

$$\therefore Z_2 = \frac{R_2}{j\omega R_2 C_2 + 1} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The Wien-Bridge Oscillator...

$$\beta = \frac{V^{+}}{V_{Out}} = \frac{Z_2}{Z_1 + Z_2} = \frac{(\frac{R_2}{j\omega R_2 C_2 + 1})}{(R_1 - \frac{j}{\omega C_1}) + (\frac{R_2}{j\omega R_2 C_2 + 1})} \qquad \ldots\ldots\ldots\ldots\ldots(4)$$

$$\beta = \frac{V^{+}}{V_{Out}} = \frac{(\frac{R_2}{j\omega R_2 C_2 + 1})}{(\frac{R_1 + j\omega R_1 R_2 C_2 + \frac{R_2 C_2}{C_1} - \frac{j}{\omega C_1} + R_2}{j\omega R_2 C_2 + 1})} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$\beta = \frac{V^{+}}{V_{Out}} = \frac{R_2}{(R_1 + R_2 + R_2 \times \frac{C_2}{C_1}) + j(\omega R_1 R_2 C_2 - \frac{1}{\omega C_1})} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

The Wien-Bridge Oscillator….

In order for V^+ to have the same phase as V_{Out}, this ratio must be a purely real number. Therefore, the imaginary part in Equation (6) must be zero. Setting the imaginary part equal to zero and solving for ω`gives us the oscillation frequency:

$$\omega_o R_1 R_2 C_2 - \frac{1}{\omega_o C_1} = 0 \Rightarrow \omega_o R_1 R_2 C_2 = \frac{1}{\omega_o C_1} \Rightarrow \omega_o{}^2 = \frac{1}{R_1 R_2 C_1 C_2} \quad \ldots(7)$$

$$\omega_o = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

$$f = f_0 = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

$R_1 = R_2 = R$ and $C_1 = C_2 = C$.

$$f = f_o = \frac{1}{2\pi RC} \quad \ldots\ldots\ldots\ldots\ldots(10)$$

The Wien-Bridge Oscillator…..

When $R_1 = R_2 = R$ and $C_1 = C_2 = C$, the feedback ratio at the oscillation frequency is:

$$\beta = \frac{R}{R+R+R\times\frac{C}{C}+j0} = \frac{R}{3R} = \frac{1}{3} \qquad \ldots\ldots\ldots\ldots\ldots(11)$$

Therefore, the amplifier must provide a gain of 3 to make the magnitude of the loop gain unity and sustain oscillation.

$$A = \frac{1}{\beta} = 3 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots....(12)$$

For non-inverting amplifier:

$$A = 1+\frac{R_F}{R_i} = 3 \Rightarrow \frac{R_F}{R_i} = 2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(13)$$

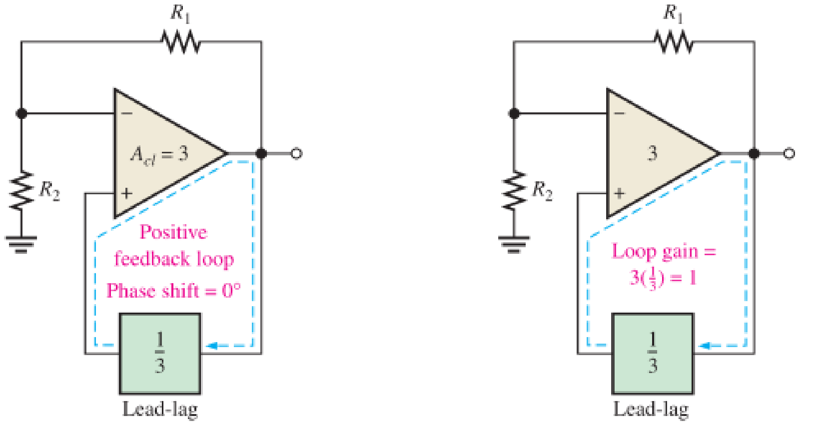
The Wien-Bridge Oscillator……

- Positive Feedback Conditions for Oscillation

$A_{cl} = 3 \longrightarrow$ $A_{cl} = 1 + (R_1/R_2)$

choose $R_1 = 2R_2$

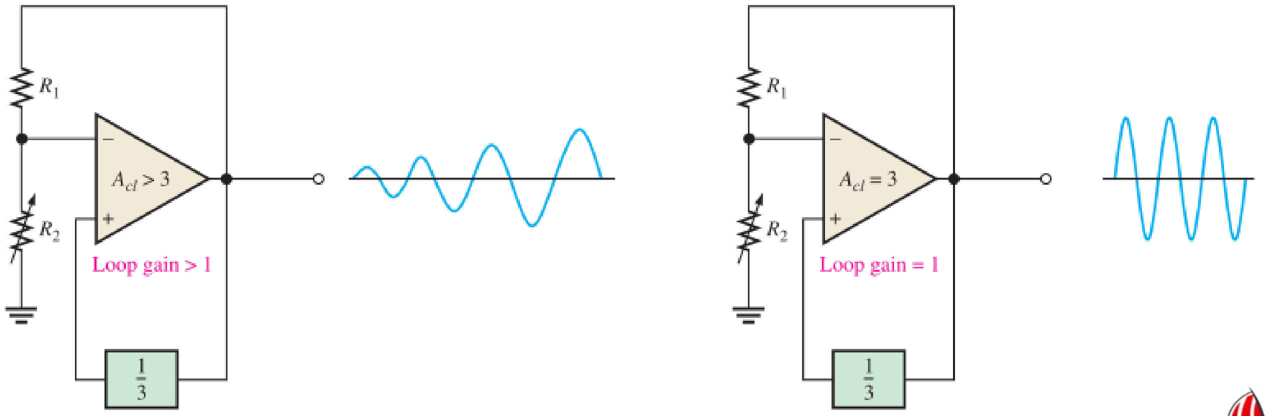
$$A_{cl} = \frac{R_1 + R_2}{R_2} = \frac{2R_2 + R_2}{R_2} = \frac{3R_2}{R_2} = 3$$



(a) The phase shift around the loop is 0°. (b) The voltage gain around the loop is 1.

- Start-Up Conditions

$(A_{cl} > 3)$



(a) Loop gain greater than 1 causes output to build up. (b) Loop gain of 1 causes a sustained constant output.

Self-starting Wien-bridge oscillator

Using a form of automatic gain control (AGC)

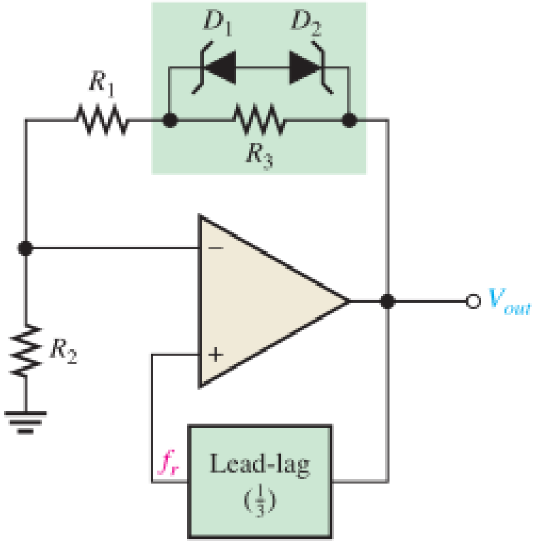


FIGURE 16–10

Self-starting Wien-bridge oscillator using back-to-back zener diodes.

1- When dc power is first applied, both zener diodes appear as opens.

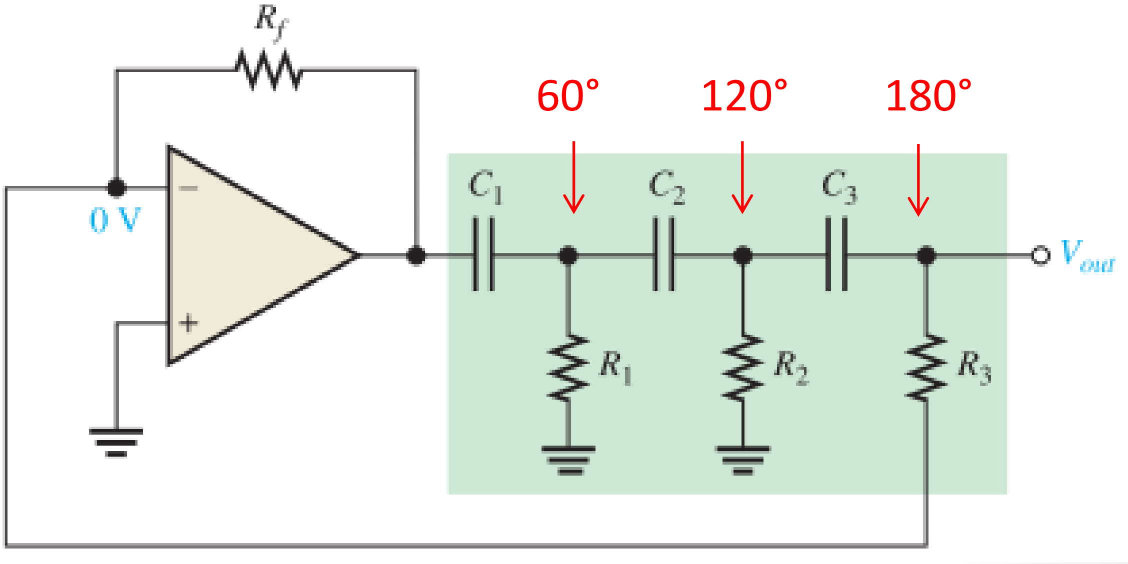
$$A_{cl} = \frac{R_1 + R_2 + R_3}{R_2} = \frac{3R_2 + R_3}{R_2} = 3 + \frac{R_3}{R_2}$$

2- When the zeners conduct, they short out R_3 and $A_{cl} = 3$

- The zener feedback is simple, it suffers from the nonlinearity of the zener diodes that occurs in order to control gain.
- A better method to control the gain uses a JFET as a voltage-controlled resistor in a negative feedback path.

The Phase-Shift Oscillator

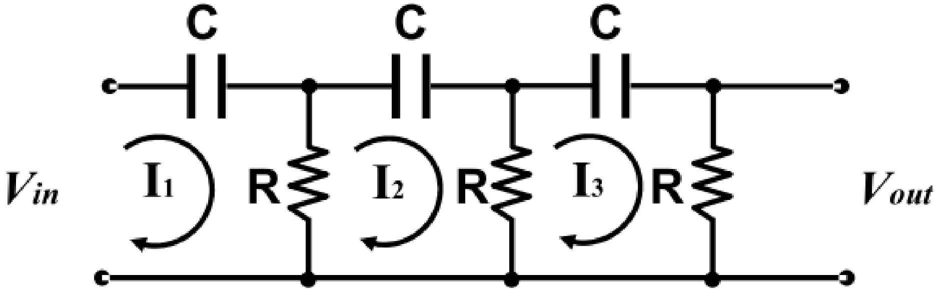
- Each of the three RC circuits in the feedback loop can provide a maximum phase shift approaching 90°.
- Oscillation occurs at the frequency where the total phase shift through the three RC circuits is 180°.
- The inversion of the op-amp itself provides the additional 180° to meet the requirement for oscillation of a 360° (or 0°) phase shift around the feedback loop.



$$B = \frac{1}{29} \qquad \text{where } B = R_3/R_f.$$

$$R_1 = R_2 = R_3 = R \text{ and } C_1 = C_2 = C_3 = C. \qquad f_r = \frac{1}{2\pi\sqrt{6}RC}$$

The Phase-Shift Oscillator..



$$(R - \frac{j}{2\pi fC})I_1 - RI_2 + 0I_3 = V_{in} \qquad \text{...(1)}$$

$$-RI_1 + (2R - \frac{j}{2\pi fC})I_2 - RI_3 = 0 \qquad \text{...(2)}$$

$$0I_1 - RI_2 + (2R - \frac{j}{2\pi fC})I_3 = 0 \qquad \text{....(3)}$$

In order to get V_{out}, we must solve for I_3 using ***determinates***.

$$\beta = \frac{V_{out}}{V_{in}} = \frac{RI_3}{V_{in}} = \frac{1}{(1 - \frac{j}{2\pi fRC})(2 - \frac{j}{2\pi fRC})^2 - (3 - \frac{2j}{2\pi fRC})} \quad \text{...(4)}$$

The Phase-Shift Oscillator...

Combining the real terms and the imaginary terms separately.

$$\beta = \frac{V_{out}}{V_{in}} = \frac{1}{\left(1 - \frac{5}{(2\pi f)^2 R^2 C^2}\right) - j\left(\frac{6}{2\pi fRC} - \frac{1}{(2\pi f)^3 R^3 C^3}\right)} \quad \text{........(5)}$$

In order to have a 180° phase shift through the network, the first term must be a negative number and the value of imaginary term must be equal ***zero*** at the frequency of oscillation f_o.

$$\therefore \frac{6}{2\pi f_o RC} - \frac{1}{(2\pi f_o)^3 R^3 C^3} = 0 \quad \text{.....(6)}$$

Solving for f_o.

$$\boxed{f_o = \frac{1}{2\pi\sqrt{6}RC}} \quad \text{..........(7)}$$

The Phase-Shift Oscillator….

Since the imaginary terms is zero.

$$\frac{V_{out}}{V_{in}} = \frac{1}{(1 - \frac{5}{\left(2\pi f_o\right)^2 R^2 C^2})} = \frac{-1}{29} = \beta \quad \text{……..(8)}$$

Thus the gain for the feedback network, β = $\frac{-1}{29}$

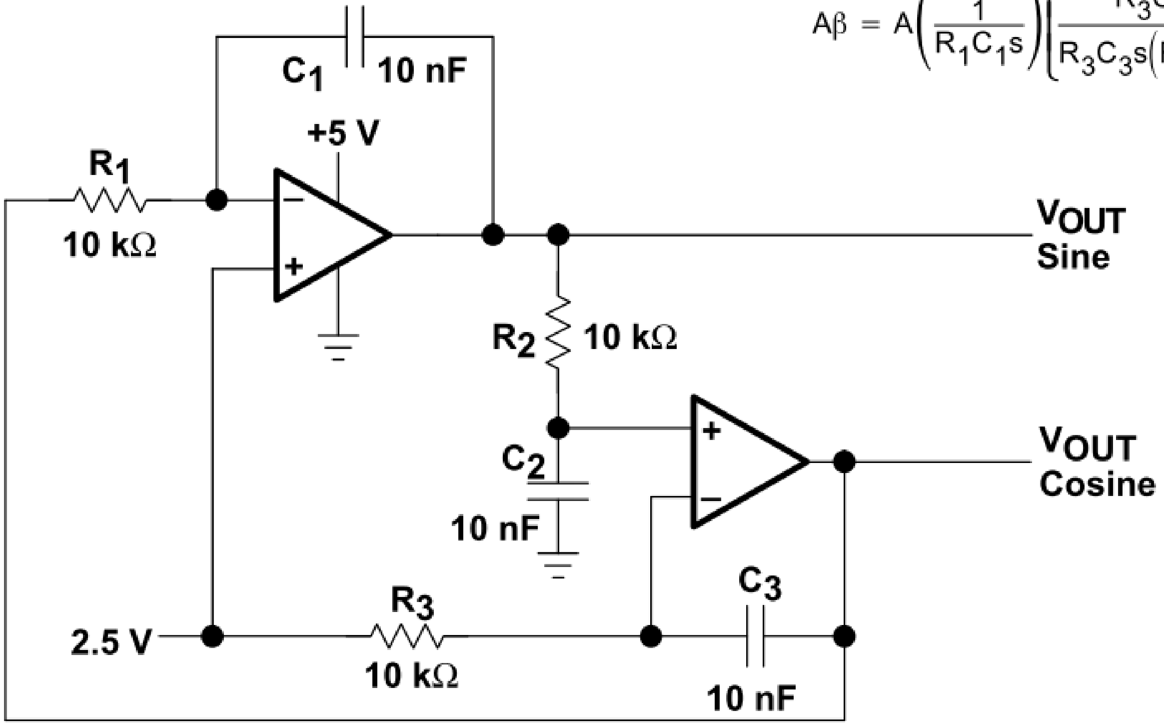
$\therefore$ The closed-loop gain of op.amp must be (≥ -29)

i.e. A≥-29 and Aβ=1.

Quadrature Oscillator

- type of phase-shift oscillator, but the three RC sections are configured so each section contributes 90° of phase shift.
- This provides both sine and cosine waveform outputs (the outputs are quadrature, or 90° apart), which is a distinct advantage over other phase-shift oscillators.

$$A\beta = A\left(\frac{1}{R_1C_1s}\right)\left[\frac{R_3C_3s + 1}{R_3C_3s\left(R_2C_2s + 1\right)}\right]$$



- For more details, refer to:
  - Chapter 16 at T. Floyd, **Electronic Devices**,9th edition.
  - http://www.electronics-tutorials.ws/oscillator/rc_oscillator.html
  - http://www.electronics-tutorials.ws/oscillator/oscillators.html
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