Feedback and Oscillators

Lesson #16

Oscillators

Section 9.11-12

Oscillator Principles

- Types of Oscillators
  - Sinusoidal: Used in AM/FM/Video Circuits to support selection of channels
  - Squares Wave: Clocking/Timing Circuits
  - Triangular Wave: TV/Video Timing Circuits
  - Rectangular Pulse Waves: Clocking/Timing in Computers
- Linear Oscillators
  - Positive Feedback amplifier circuits which feed back the proper amplitude and phase to sustain an unlimited output

The Barkhausen Criterion

- The requirements for oscillation using a feedback circuit:

$$\mathbf{X}_{out} = A(f)[\mathbf{X}_{in} + \beta(f)\mathbf{X}_{out}]$$

$$\mathbf{X}_{out} = \frac{A(f)}{1-\beta(f)A(f)}\mathbf{X}_{in}$$

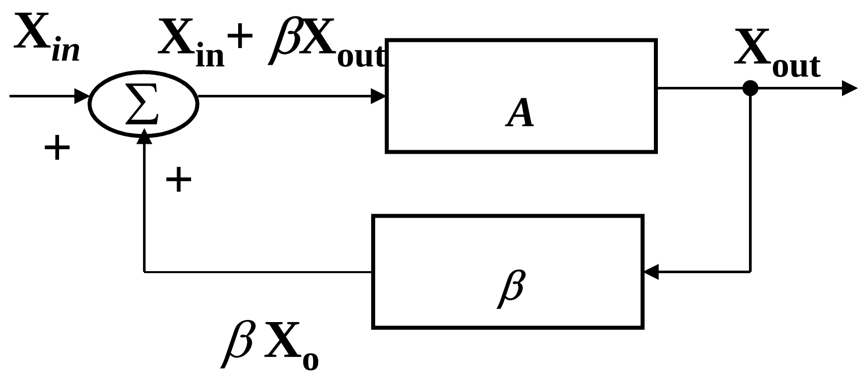
For $\mathbf{X}_{in} = 0$ and $\mathbf{X}_{out}$ to be nonzero, $\beta(f)A(f) = 1$ where the frequency of oscillation is f.

More percisely, $\beta(f)A(f) = 1\angle 0^{\circ}$

OR

$\mathrm{Re}[\beta(f)A(f)] = 1$

$\mathrm{Im}[\beta(f)A(f)] = 0$



Practically, we make *β(f)A(f)* slightly > *1* ($\mathbf{X}_{out}$ grows) at the frequency of oscillation. (Otherwise, the signal will decay to zero.) This causes clipping eventually but ultimately, a constant amplitude results. (This method enables some wave shaping to yield waveforms other than a sinusoid.)

Analysis of an Oscillator

$$\beta = \frac{(R \parallel C)_{parallel}}{(R \parallel C)_{parallel} + (R + C)_{series}}$$

$$(R \parallel C)_{parallel} = \frac{1}{\frac{1}{R} + j\omega C} = \frac{R}{1 + j\omega RC}$$

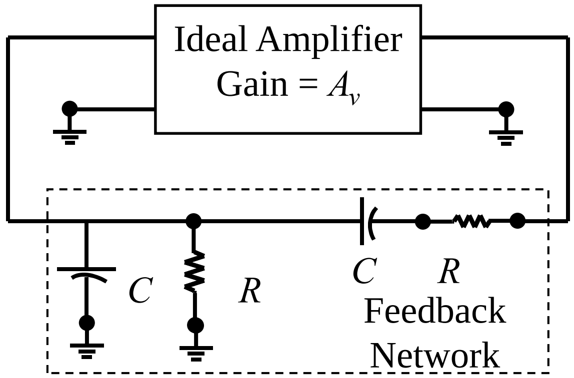
$$(R + C)_{series} = R + \frac{1}{j\omega C} = \frac{j\omega RC + 1}{j\omega C}$$

$$\beta(j\omega) = \frac{\frac{R}{1 + j\omega RC}}{\frac{R}{1 + j\omega RC} + \frac{j\omega RC + 1}{j\omega C}}$$

$$= \frac{\frac{R}{1 + j\omega RC}}{\frac{j\omega CR}{(1 + j\omega RC)j\omega C} + \frac{(j\omega RC + 1)^2}{(1 + j\omega RC)j\omega C}}$$

$$= \frac{j\omega CR}{1 - (\omega RC)^2 + 3j\omega CR}$$

$$= \frac{\omega CR}{j[(\omega RC)^2 - 1] + 3\omega CR}$$



Barkhausen Criterion:

$$A_v \beta(j\omega) = 1$$

$$\frac{A_v \omega CR}{j[(\omega RC)^2 - 1] + 3\omega CR} = 1$$

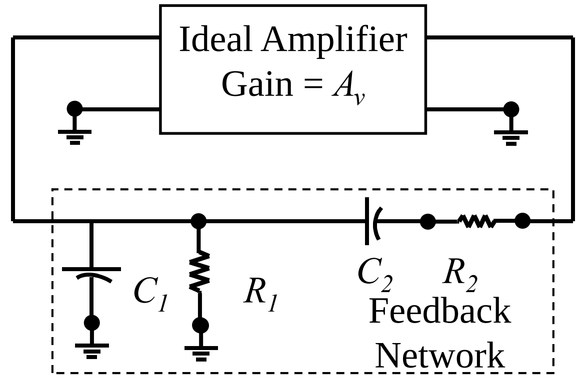
$$3\omega CR - A_v \omega CR + j[(\omega RC)^2 - 1] = 0$$

This yields:

$$A_{v\min} = 3$$

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

Analysis of an Oscillator



$$\beta = \frac{(R_1 \parallel C_1)_{parallel}}{(R_1 \parallel C_1)_{parallel} + (R_2 + C_2)_{series}}$$

$$(R_1 \parallel C_1)_{parallel} = \frac{1}{\frac{1}{R_1} + j\omega C_1} = \frac{R_1}{1 + j\omega R_1 C_1}$$

$$(R_2 + C_2)_{series} = R_2 + \frac{1}{j\omega C_2} = \frac{j\omega R_2 C_2 + 1}{j\omega C_2}$$

$$\beta(j\omega) = \frac{\frac{R_1}{1 + j\omega R_1 C_1}}{\frac{R_1}{1 + j\omega R_1 C_1} + \frac{j\omega R_2 C_2 + 1}{j\omega C_2}}$$

$$= \frac{\frac{R_1}{1 + j\omega R_1 C_1}(1 + j\omega R_1 C)(j\omega C_2)}{R_1 j\omega C_2 + (1 + j\omega R_2 C_2)(1 + j\omega R_1 C_1)}$$

$$= \frac{j\omega C_2 R_1}{(1 - \omega^2 R_2 C_2 R_1 C_1) + j\omega(C_2 R_1 + R_2 C_2 + R_1 C_1)}$$

Barkhausen Criterion:

$$A_v \beta(j\omega) = 1$$

$$\frac{A_v j\omega C_2 R_1}{(1 - \omega^2 R_2 C_2 R_1 C_1) + j\omega(C_2 R_1 + R_2 C_2 + R_1 C_1)} = 1$$

$$A_v j\omega C_2 R_1 = (1 - \omega^2 R_2 C_2 R_1 C_1) + j\omega(C_2 R_1 + R_2 C_2 + R_1 C_1)$$

$$0 = (1 - \omega^2 R_2 C_2 R_1 C_1) + j\omega[A_v C_2 R_1 - (C_2 R_1 + R_2 C_2 + R_1 C_1)]$$

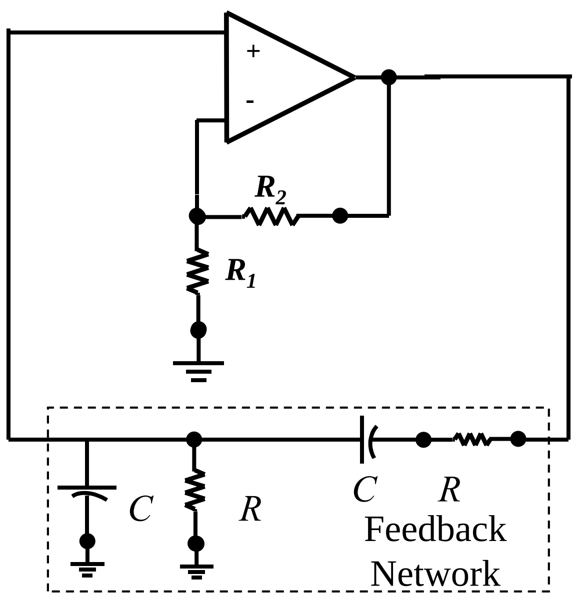
This yields:

$$A_{v\min} = \frac{C_2 R_1 + R_2 C_2 + R_1 C_1}{C_2 R_1}$$

$$f = \frac{1}{2\pi\sqrt{R_2 C_2 R_1 C_1}}$$

Wien Bridge Oscillator

- A non-inverting Amplifier with gain determined by R_1 and R_2 and the RC feedback network



For the non - inverting amplifier

$$v_{in} = v_f = \frac{R_1}{R_1 + R_2} v_o$$

$$\therefore A_{noninverting} = \frac{R_1 + R_2}{R_1} = 1 + \frac{R_2}{R_1}$$

$$A_{v\min} = 3 = 1 + \frac{R_2}{R_1}$$

$R_2 \geq 2R_1$ for Oscillations

If $R_2 > 2R_1$ then the amplitude of the oscillations will increase and clipping will occur.

Homework

- Oscillator Principles
  - Problems: 9.83-89
- Wien Bridge Oscillator
  - Problems: 9.91