Analog and Digital Signal Processing

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Term Roadmap :

- Introduction to Signal Processing
- Differentiating and Integrating Circuits (OpAmps)
- Clipping and Clamping Circuits
- Design of analog filters
- Sinusoidal Oscillators
- Multivibrators
- Sampling and Quantization techniques of analog signals
- DACs and ADCs
- Data Acquisition Systems
- Introduction to discrete time transform and DSP
- The Z transform
- Design of Digital Filters

Text Books

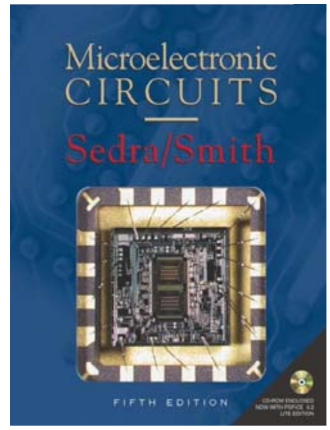
Microelectronic circuits

Adel S. Sedra

Kenneth C. Smith

Sixth Edition, copyright 2011

by Oxford University Press



Analog and Digital Signal Processing

H. Baher

Second Edition, copyright 2001

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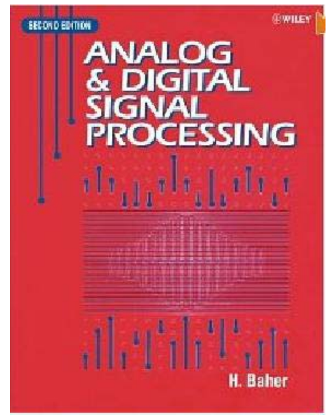


Sinusoidal Oscillators

The use of positive feedback that results in a feedback amplifier having closed-loop gain $|A_f|$ greater than 1 and satisfies the phase conditions will result in operation as an oscillator circuit. An oscillator circuit then provides a varying output signal. If the output signal varies sinusoidally, the circuit is referred to as a *sinusoidal oscillator*. If the output voltage rises quickly to one voltage level and later drops quickly to another voltage level, the circuit is generally referred to as a *pulse* or *square-wave oscillator*.

Structure of Sinusoidal Oscillators

Signal Flow Diagram

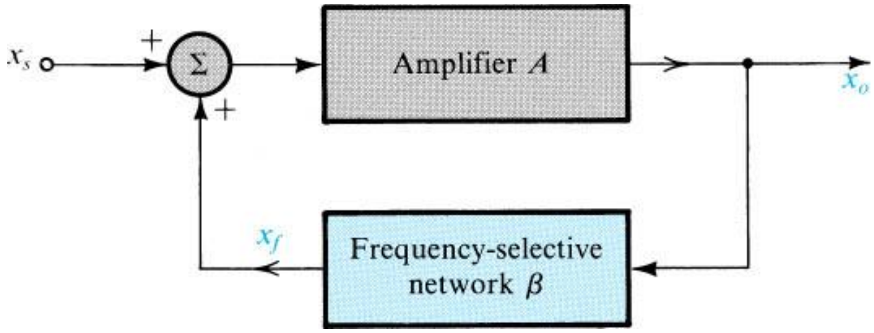


Figure 13.1 basic structure of a sinusoidal oscillator

$$x_f = \beta x_o$$

$$x_i = x_s + x_f$$

$$\therefore A_f(s) \equiv \frac{x_o}{x_s} = \frac{A(s)}{1 - A(s)\beta(s)} = \frac{A(s)}{1 - L(s)}$$

A(s)β(s) .... Loop Gain
A(s) .... Gain of open-loop amplifier
(s)......... Freq.-dep. Feedback β factor

Structure of Sinusoidal Linear Oscillators

$$Charateristic\ Equation:$$

$$1 - L(s) = 0$$

$$L(s) = L(j\omega_o) = A(j\omega_o)\beta(j\omega_o) = 1\angle 0$$

Barhausen Criterion

At a certain frequency f_o, the magnitude of the loop gain is equal to ONE & phase of the loop gain is ZERO (180 degrees for amount of Feedback due to –ve sign), the circuit thus produces an output for NO input (i.e. OSCILLATES at this frequency)

Sinusoidal Linear Oscillators

OP AMP RC Osc.

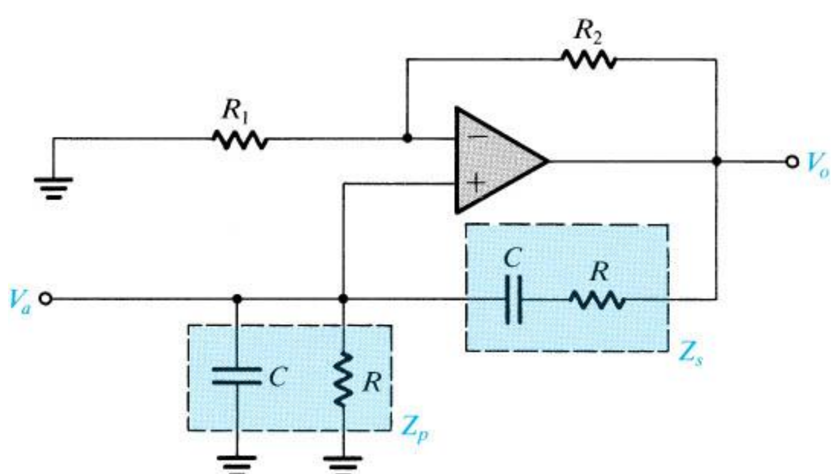
1. Wien-Bridge Oscillator
2. Phase-Shift Oscillator
3. Quadrature Oscillator

LC & Crystal Osc.

1. Colpitts Oscillator
2. Hartley Oscillator
3. Crystal Oscillator

I. OP AMP RC Osc.

1- Wien-Bridge Oscillator



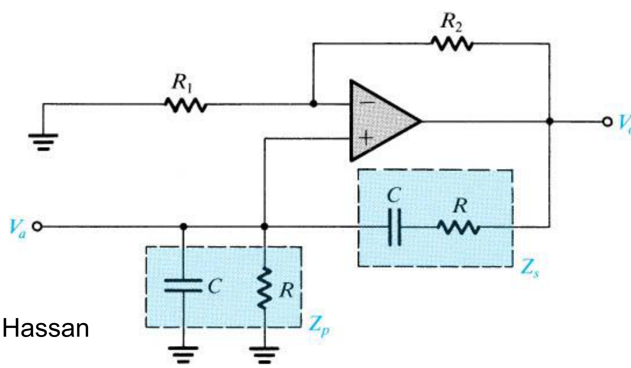
1. Wien-Bridge Oscillator

$$L(s)=\left[1+\frac{R_2}{R_1}\right]\frac{Z_p}{Z_p+Z_s}$$

$$where\quad Z_p=\frac{R}{1+sRC},\; Z_s=R+\frac{1}{sC}=\frac{1+sRC}{sC}$$

$$\therefore L(s)=\left[1+\frac{R_2}{R_1}\right]\frac{\frac{R}{1+sRC}}{\frac{R}{1+sRC}+\frac{1+sRC}{sC}}=\frac{\left[1+\frac{R_2}{R_1}\right]}{\frac{1+sRC}{R}\left[\frac{R}{1+sRC}+\frac{1+sRC}{sC}\right]}=$$

$$=\frac{\left[1+\frac{R_2}{R_1}\right]}{1+\left[\frac{1}{sRC}+2+sRC\right]}=\frac{1+\frac{R_2}{R_1}}{3+sRC+\frac{1}{sRC}}$$



$$\therefore L(j\omega)=\frac{1+\frac{R_2}{R_1}}{3+j(\omega RC-\frac{1}{\omega RC})}\qquad \text{i.e. } \omega_o=\frac{1}{\text{RC}}$$

2. Phase-Shift Oscillator

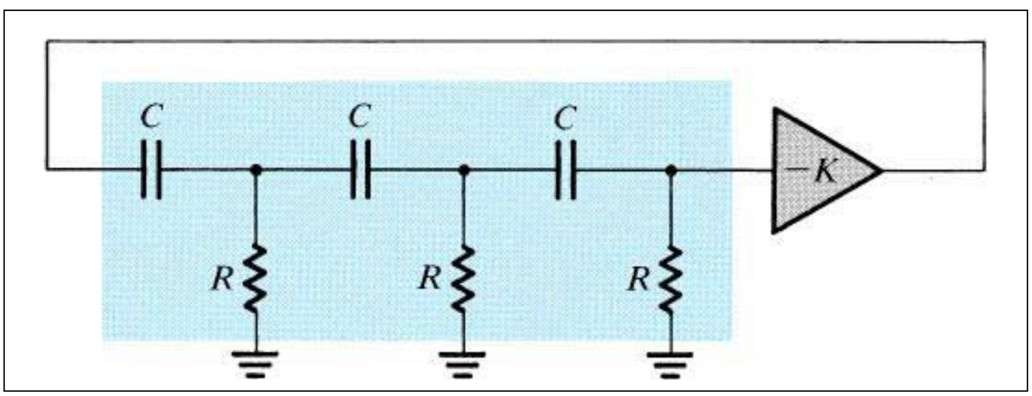
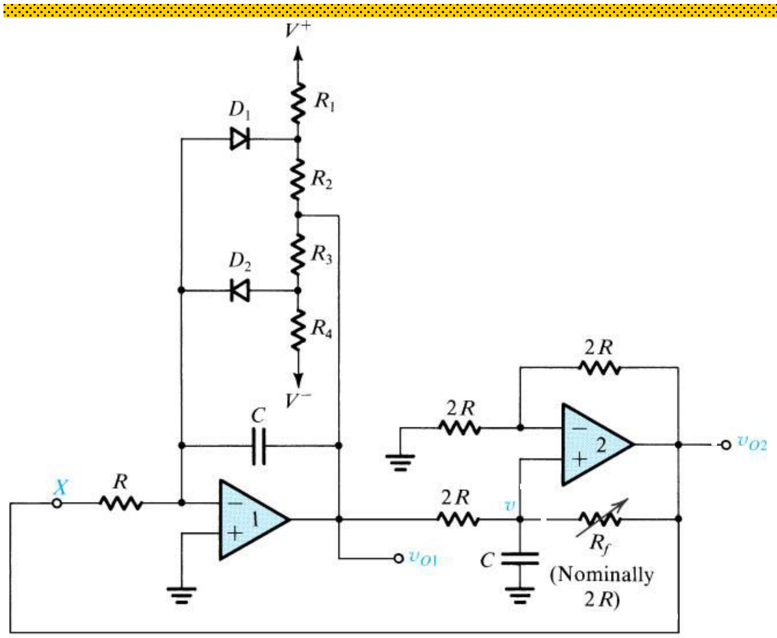


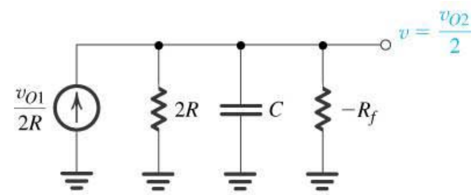
Figure 13.7 A phase-shift oscillator

$$L(j\omega)=\frac{\omega^2C^2RR_f}{4+j(3\omega CR-1/\omega CR)}\Rightarrow \omega_o=\frac{1}{\sqrt{3}RC}$$

3. Quadrature Oscillator



(a)



(b)

$$L(s) = \frac{V_{o2}}{V_x} =$$

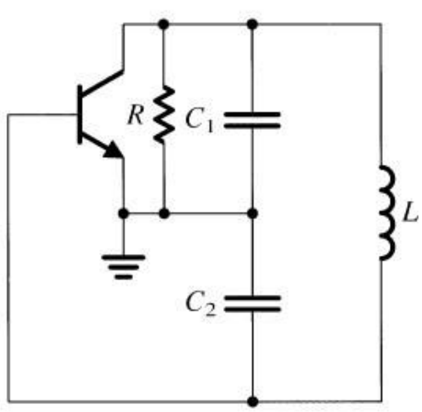
$$= -\frac{1}{sC^2R^2} \Rightarrow$$

$$\omega_o = \frac{1}{RC}$$

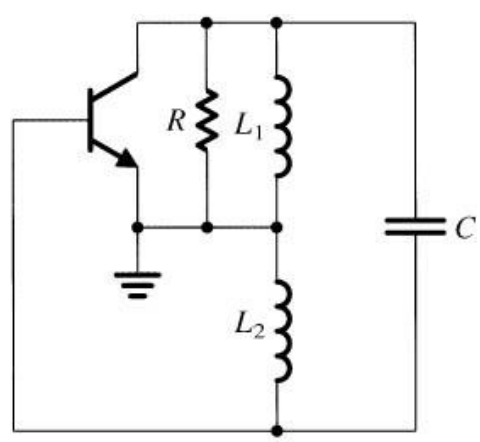
Figure 13.9 (a) A quadrature-oscillator circuit. (b) Equivalent circuit at the input of op amp 2.

II. LC Oscillators

1- Used in frequency ranges from 100 KHz to hundreds of MHz
2. Higher Q than RC type oscillators



(a)

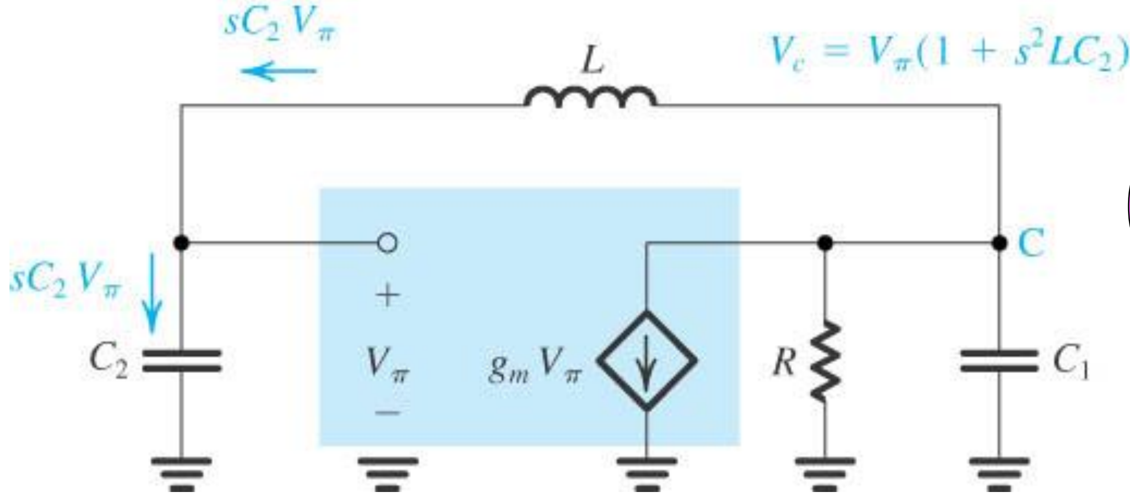


(b)

Figure 13.12 Two commonly used configurations of LC-tuned oscillators:

(a) Colpitts (b) Hartley.

II. 1 Colpitts Oscillator



C

Figure 13.13 Equivalent circuit of the Colpitts oscillator of Fig. 13.12(a).

To simplify analysis, C_μ and r_π are neglected.

C_π to be part of C_2,

r_o is included in R (inductor losses).

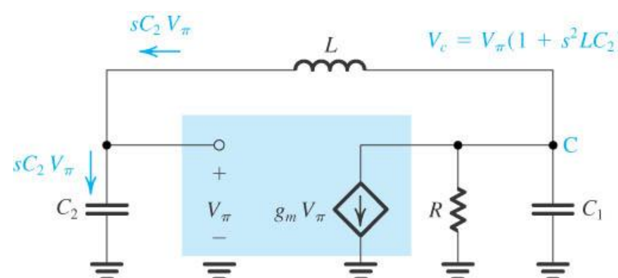
II. 1 Colpitts Oscillator (cntd)

$$I_L + I_{transistor} + I_{R//C_1} = 0$$

$$\frac{V_\pi}{Z_{C_2}} + g_m V_\pi + \frac{V_C}{R // C_1} = 0$$

$$sC_2 V_\pi + g_m V_\pi + \left(\frac{1}{R} + sC_1\right)\left(1 + s^2 LC_2\right)V_\pi = 0$$

$$\left(g_m + \frac{1}{R} - \frac{\omega^2 LC_2}{R}\right) + j\left(\omega(C_2 + C_2) - \omega^3 LC_1C_2\right) = 0$$



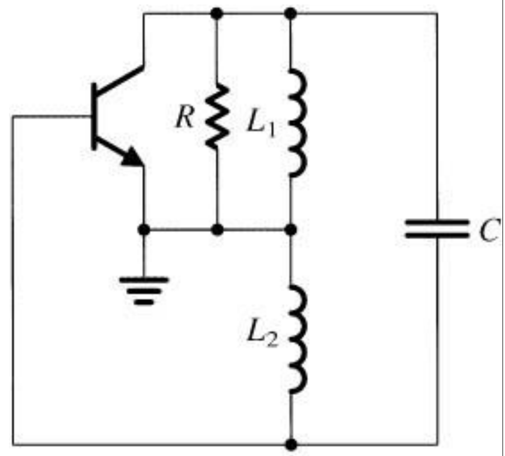
$$\text{Im}aginary = 0 \Rightarrow \omega_o = \frac{1}{\sqrt{L\left(\frac{C_1C_2}{C_1 + C_2}\right)}}$$

$$\text{Re}alPart = 0 \Rightarrow \frac{C_2}{C_1} = g_m R$$

II. 2 Hartley Oscillator

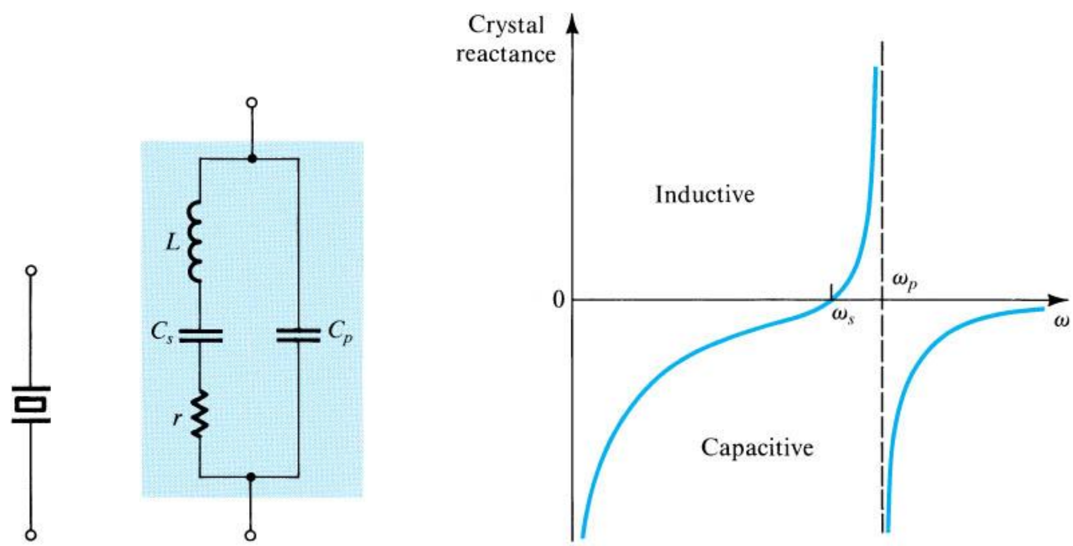
$$\text{Im}\,aginary = 0 \Rightarrow \omega_o = \frac{1}{\sqrt{(L_1 + L_2)C}}$$

$$\text{Re}\,alPart = 0 \Rightarrow \frac{L_2}{L_1} = g_m R$$



(b)

III. Crystal Oscillators



(a) (b) (c)

Figure 13.15 A piezoelectric crystal. (a) Circuit symbol. (b) Equivalent circuit. (c) Crystal reactance versus frequency [note that, neglecting the small resistance r, Zcrystal = jX(w)].

Thank you