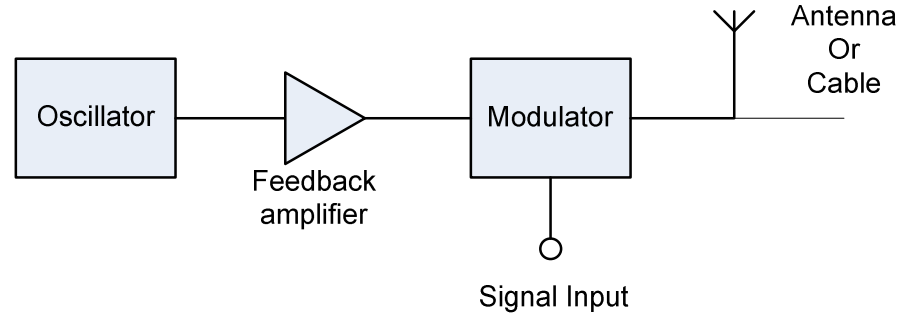


Oscillators (ch:13, Sedra)

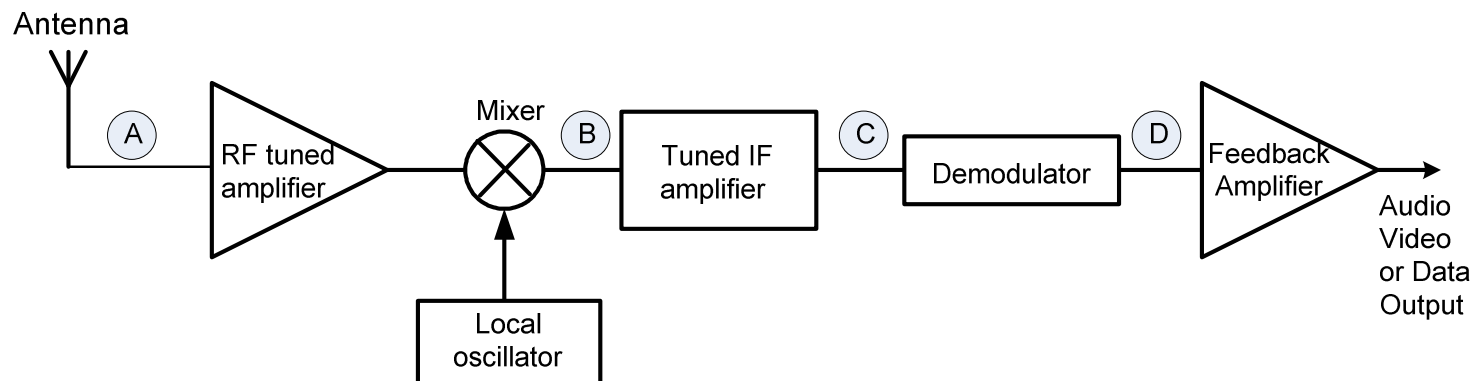
- Basic principles of sinusoidal oscillators
- OP Amp-RC oscillator circuits
 - Wien-Bridge oscillator
 - Phase-shift oscillator
- LC and crystal oscillators
 - LC-tuned oscillators
 - Crystal oscillators

Basic principles of sinusoidal oscillators

- Communication systems require oscillators to generate waveforms for use as information carriers
- *Transmitter*

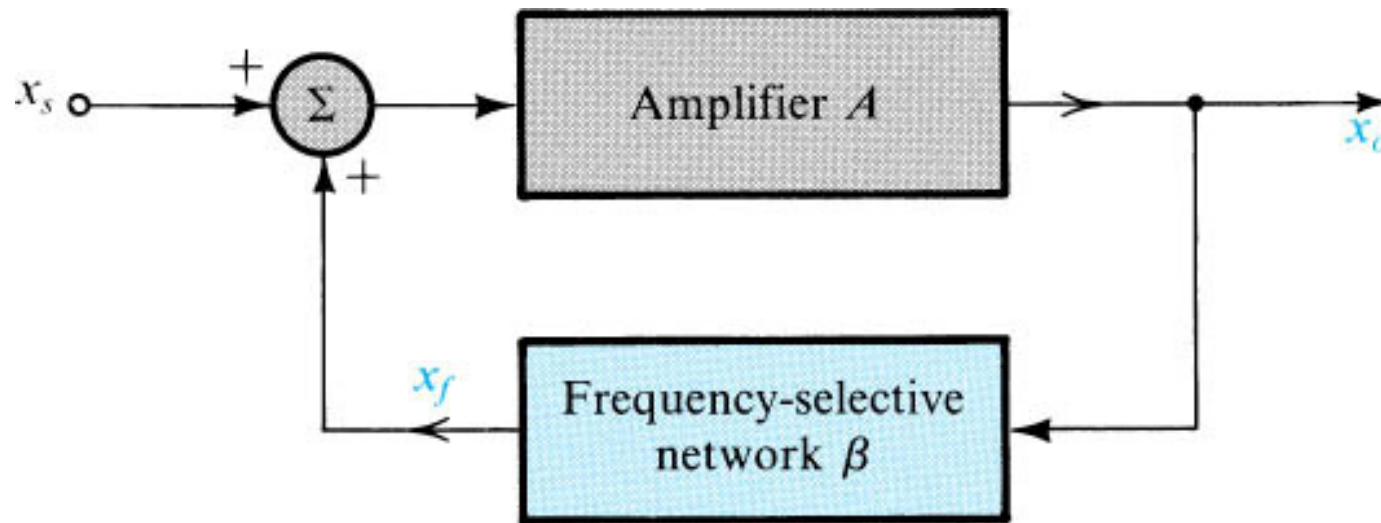


- *Receiver*



Basic principles of sinusoidal oscillators

- Sinusoidal oscillator
 - Positive feedback loop comprising an amplifier and frequency selective network



The basic structure of a sinusoidal oscillator. A positive-feedback loop is formed by an amplifier and a frequency-selective network. In an actual oscillator circuit, no input signal will be present; here an input signal x_s is employed to help explain the principle of operation.

Basic principles of sinusoidal oscillators

- The gain-with-feedback

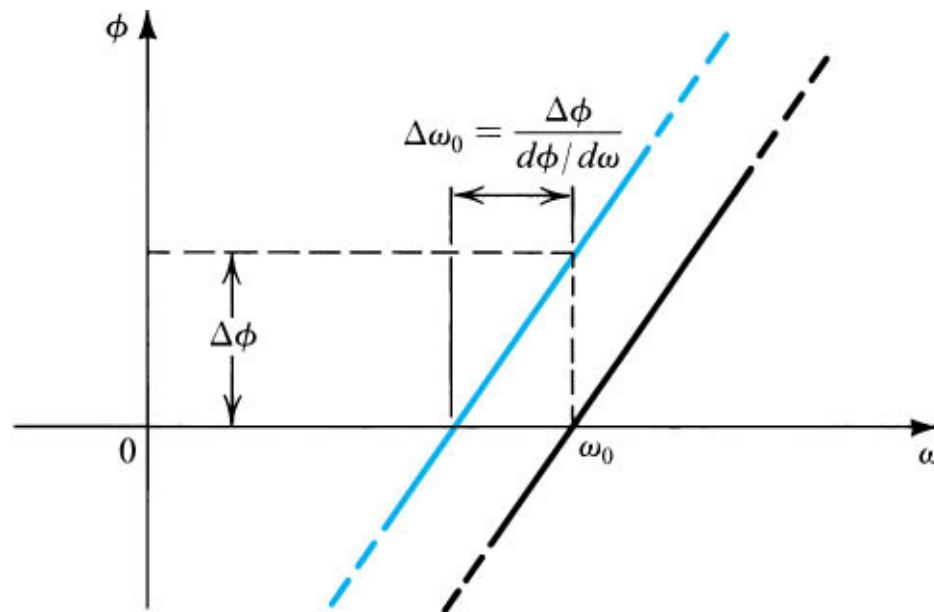
$$A_f(s) = \frac{A(s)}{1 - A(s)\beta(s)}$$

- Oscillation (Barkhausen) criterion

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

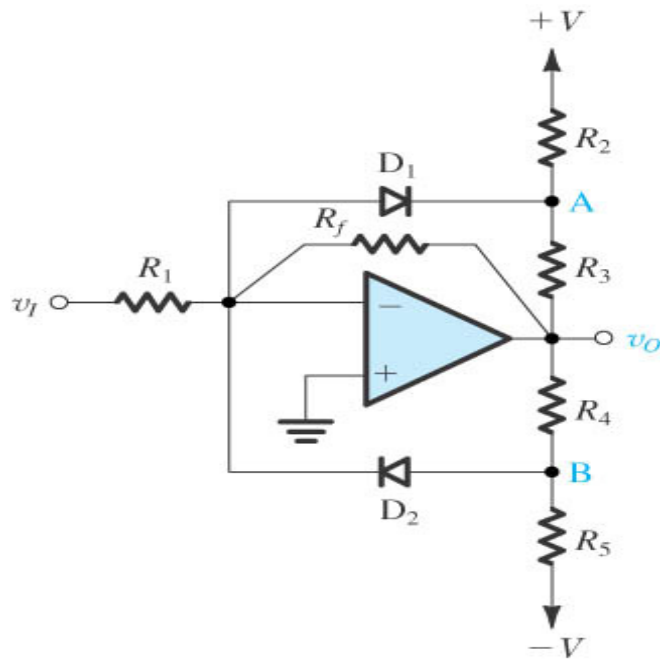
Basic principles of sinusoidal oscillators

- Frequency of oscillation
 - Frequency stability depends on how phase of the feedback loop varies with frequency
 - Steep phase response with frequency gives better oscillator frequency stability for a given phase change

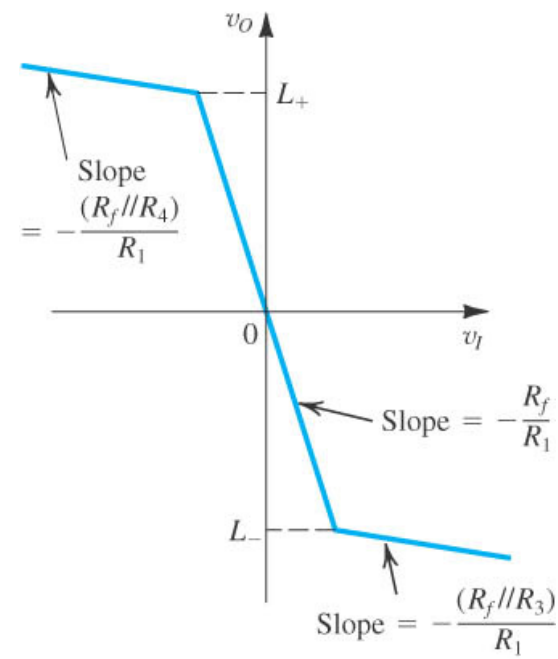


Basic principles of sinusoidal oscillators

- Nonlinear amplitude control



Limiter circuit



Transfer characteristic

Basic principles of sinusoidal oscillators

- Negative limiting level:

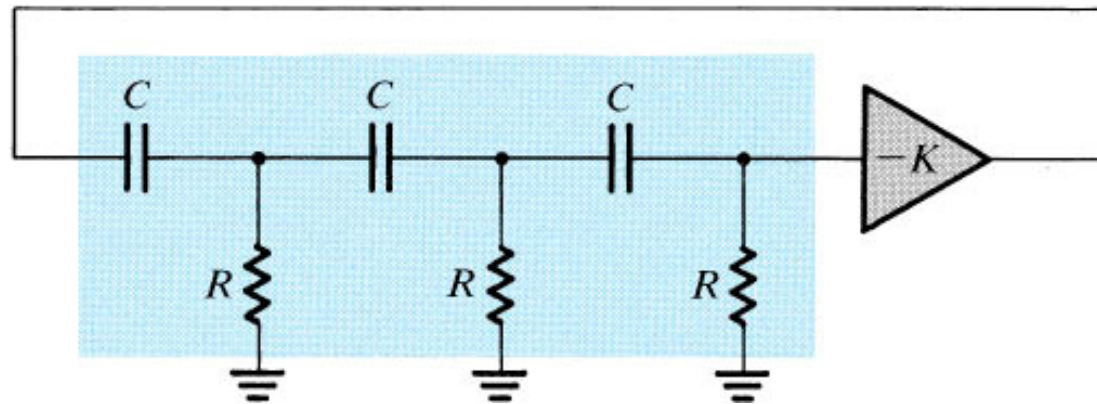
$$L_- = -V \frac{R_3}{R_2} - V_D \left(1 + \frac{R_3}{R_2}\right)$$

- Positive limiting level:

$$L_+ = V \frac{R_4}{R_5} + V_D \left(1 + \frac{R_4}{R_5}\right)$$

OP Amp-RC oscillator circuits

- Wien-Bridge oscillator (*section 13.2.1*)
- Phase-shift oscillator

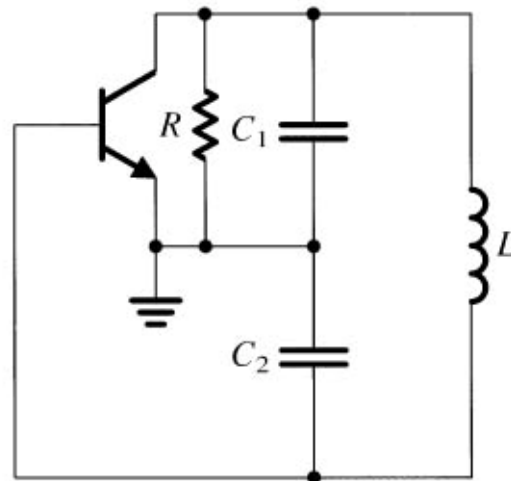


OP Amp-RC oscillator circuits

- Negative gain (inverting) amplifier
- Three section RC ladder network (each RC section provides 1/3 of the total required 180° phase shift.)
- Three section RC network is used because this is the minimum number of sections that can produce 180° phase shift at a finite frequency.

LC Tuned Oscillators

- Application for 100KHz to hundreds of MHz oscillators.
- Transistor (FET, BJT) provides gain, and LC tuned circuit used as feedback element.
- Higher than RC oscillators, but difficult to tune over wide ranges.
- Colpitts oscillator
 - Parallel LC circuit connected between collector and base
 - Feedback is achieved using capacitive divider



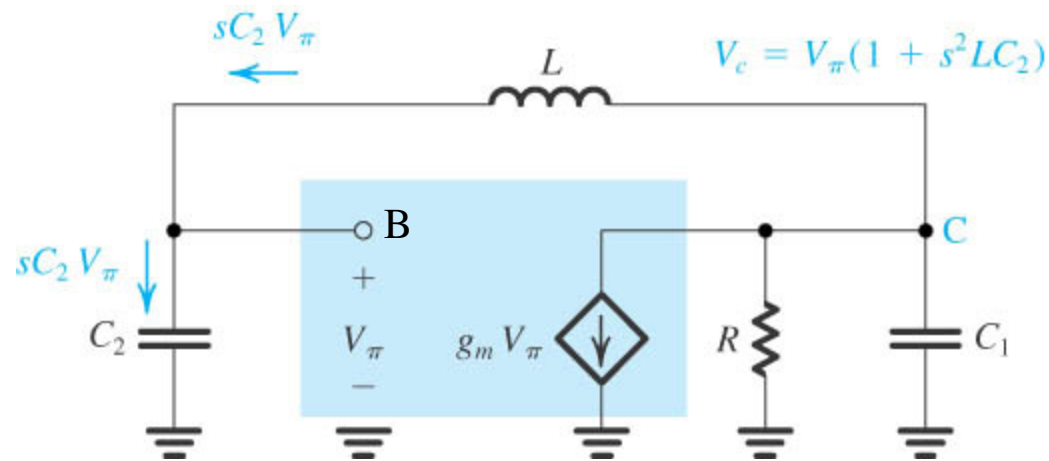
Colpitts oscillator

Colpitts oscillator

- Equivalent circuit

Assumes:

- Negligible transistor capacitance
- Very high input resistance
- R includes output resistance of transistor



Colpitts oscillator

Analysis:

- To obtain loop gain, break loop at B, find the return voltage at B at the input voltage V_π
- Node equation at C

$$sC_2V_\pi + g_mV_\pi + (1/R + sC_1)(1 + s^2LC_2)V_\pi = 0$$

- If oscillations are present $V_\pi \neq 0$ and it can be eliminated

$$s^3LC_1C_2 + s^2(LC_2/R) + s(C_1 + C_2) + (g_m + 1/R) = 0$$

- Let $s=j\omega$

$$(g_m + 1/R - \omega^2LC_2/R) + j[\omega(C_1 + C_2) - \omega^3LC_1C_2] = 0$$

- For oscillations to start, both real and imaginary parts must be zero.

Colpitts oscillator

- Equating imaginary part to zero

Oscillation frequency

$$\omega_0 = 1 / \sqrt{L \left(\frac{C_1 C_2}{C_1 + C_2} \right)}$$

- Equating real part to zero

$$g_m R = C_2 / C_1$$

- For steady state oscillation, gain must equal inverse of the voltage ratio provided by the capacitive divider.
- LC tuned oscillator rely on the nonlinear I_c - V_{BE} curve of the transistor for amplitude control.

Crystal Oscillator

- Piezoelectric crystals (e.g. quartz) has mechanical movement when voltage is applied across its electrodes, and produces a voltage if mechanical pressure is applied.
- It also exhibits mechanical resonance if excited by an alternating voltage of the correct frequency.
- Resonant frequency depends on size and shape of crystal, which can be cut to precisely control the resonant frequency.

Crystal Oscillator

- Series resonant frequency

$$\omega_s = 1/\sqrt{LC_s}$$

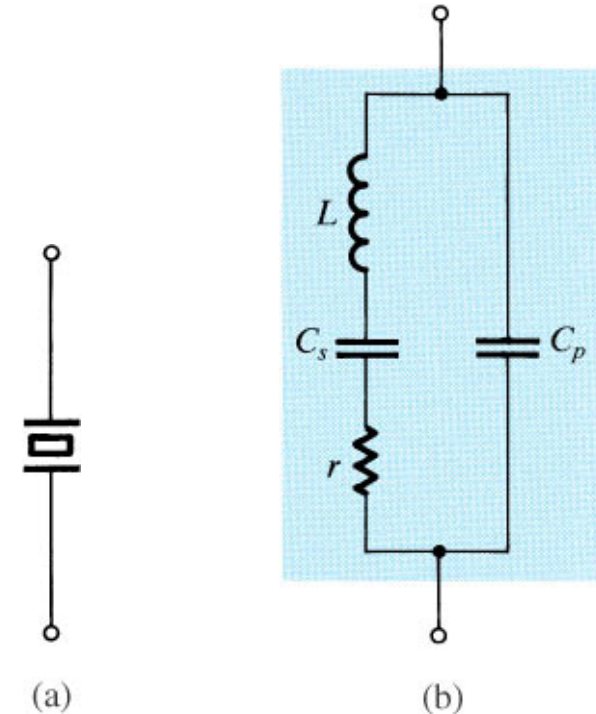
- Parallel resonant frequency

$$\omega_p = 1/\sqrt{L\left(\frac{C_s C_p}{C_s + C_p}\right)}$$

- Impedance

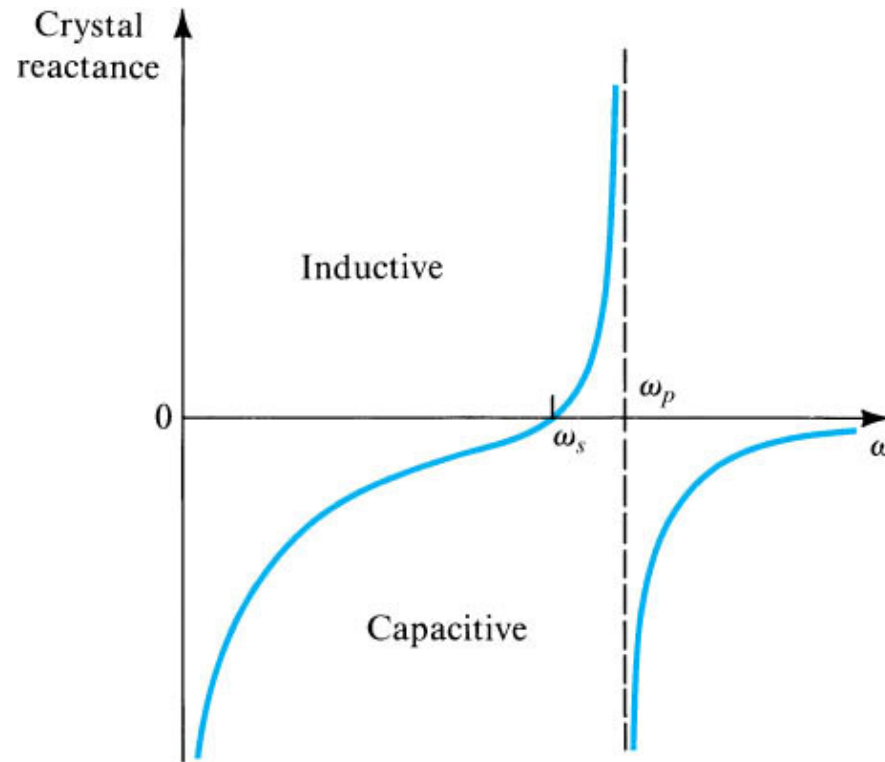
$$Z_s = 1/\left[sC_p + \frac{1}{sL + 1/sC_s}\right]$$

- $C_p \gg C_s$, the two resonant frequencies are very close.



A piezoelectric crystal. (a) Circuit symbol.
(b) Equivalent circuit.

Crystal Oscillator



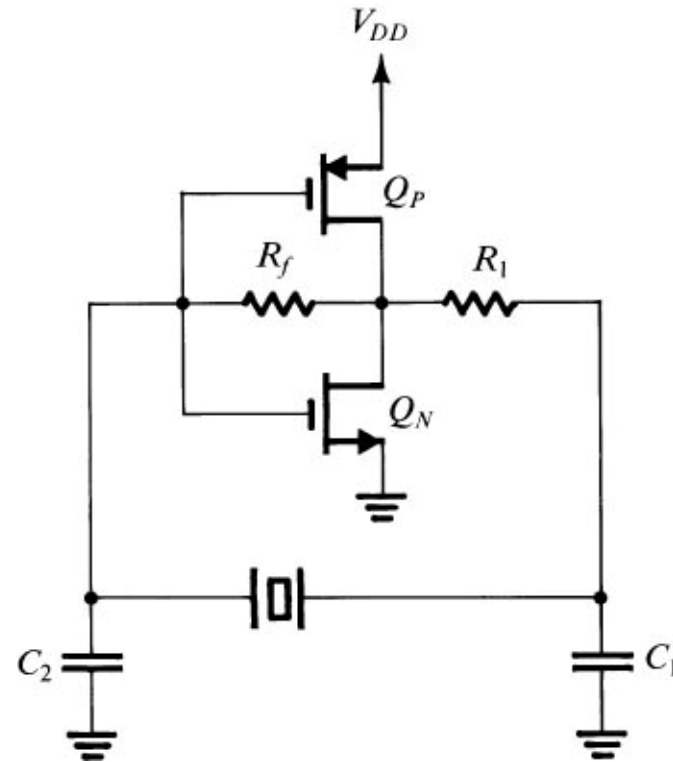
(c)

- Note: crystal resonance is inductive over the very narrow frequency range between ω_s and ω_p . This is very well defined. Hence can use crystal to replace the inductor of Colpitts oscillator to give very accurate and stable oscillator.

Crystal Oscillator

- Oscillation frequency is resonance of L with series equivalent of C_s and $(C_p + C_1 C_2 / (C_1 + C_2))$.
- Since $C_s \ll C_p, C_1, C_2$

$$\omega_0 = 1 / \sqrt{L C_s} = \omega_s$$



A Pierce crystal oscillator utilizing a CMOS inverter as an amplifier.