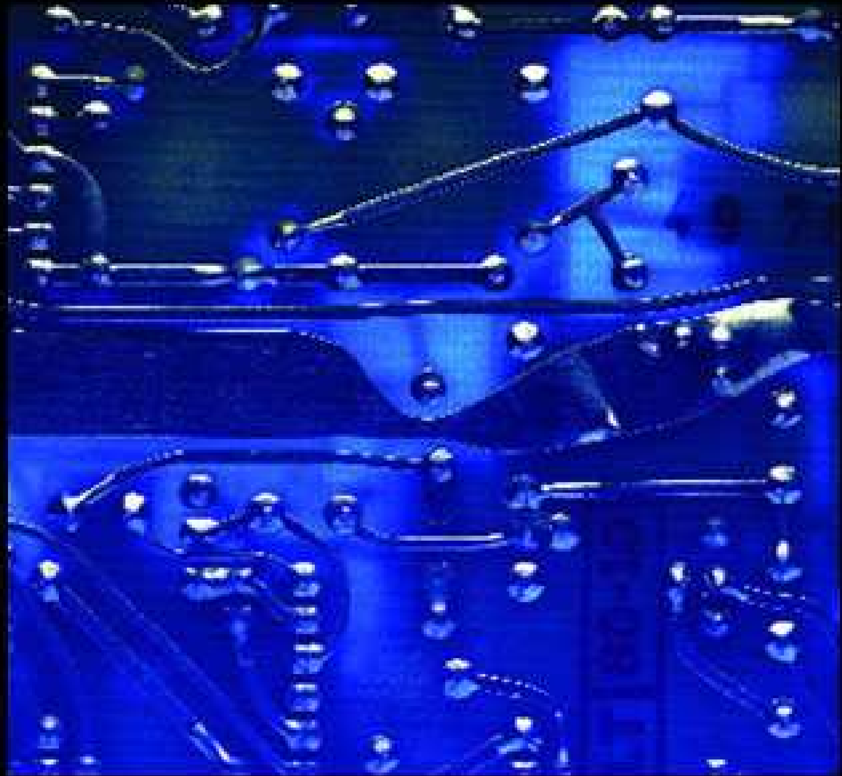
ELECTRONIC DEVICES AND CIRCUIT THEORY

TENTH EDITION



BOYLESTAD

PEARSON

Chapter 14
Feedback and Oscillator Circuits

Feedback Concepts

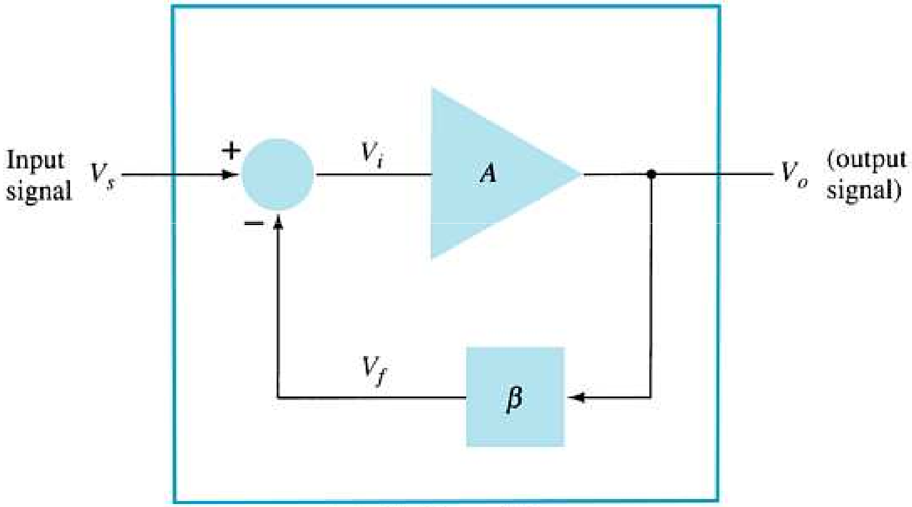
The effects of negative feedback on an amplifier:

Disadvantage

- **Lower gain**

Advantages

- **Higher input impedance**
- **More stable gain**
- **Improved frequency response**
- **Lower output impedance**
- **Reduced noise**
- **More linear operation**



Feedback amplifier

Feedback Connection Types

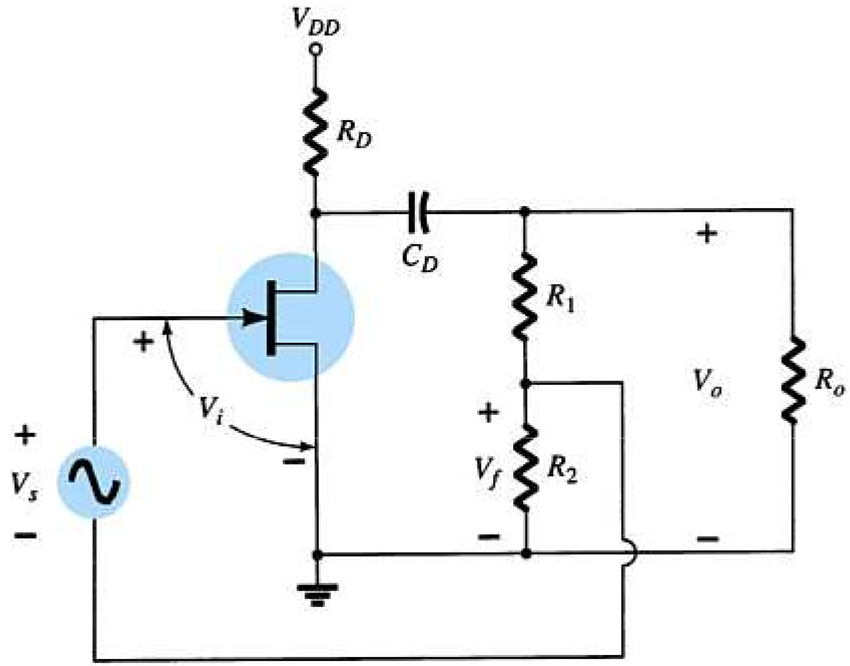
- **Voltage-series feedback**
- **Voltage-shunt feedback**
- **Current-series feedback**
- **Current-shunt feedback**

Voltage-Series Feedback

For voltage-series feedback, the output voltage is fed back in series to the input.

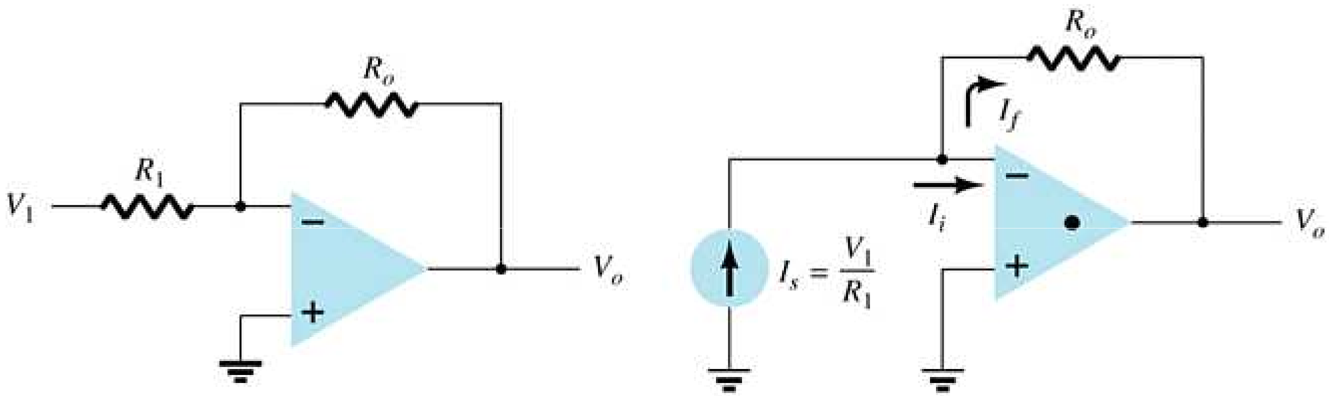
The feedback gain is given by:

$$A_f \cong \frac{1}{\beta} = \frac{R_1 + R_2}{R_2}$$



Voltage-Shunt Feedback

For a voltage-shunt feedback amplifier, the output voltage is fed back in parallel with the input.

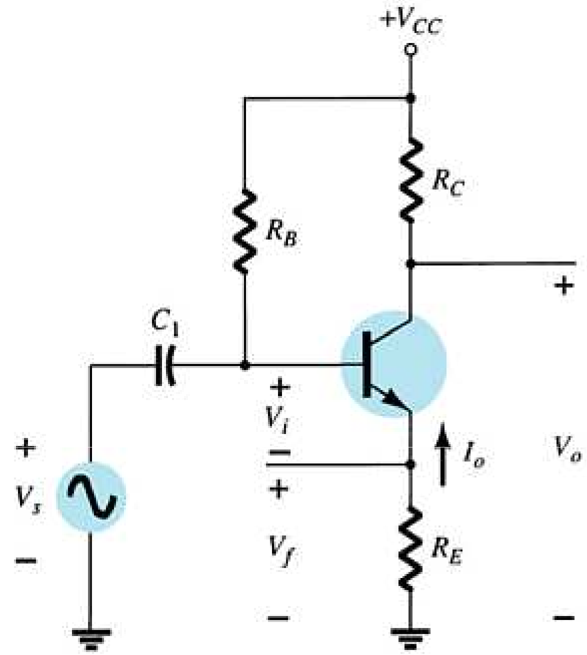


The feedback gain is given by

$$A_f = -\frac{R_o}{R_i}$$

Current-Series Feedback

For a current-series feedback amplifier, a portion of the output current is fed back in series with the input.

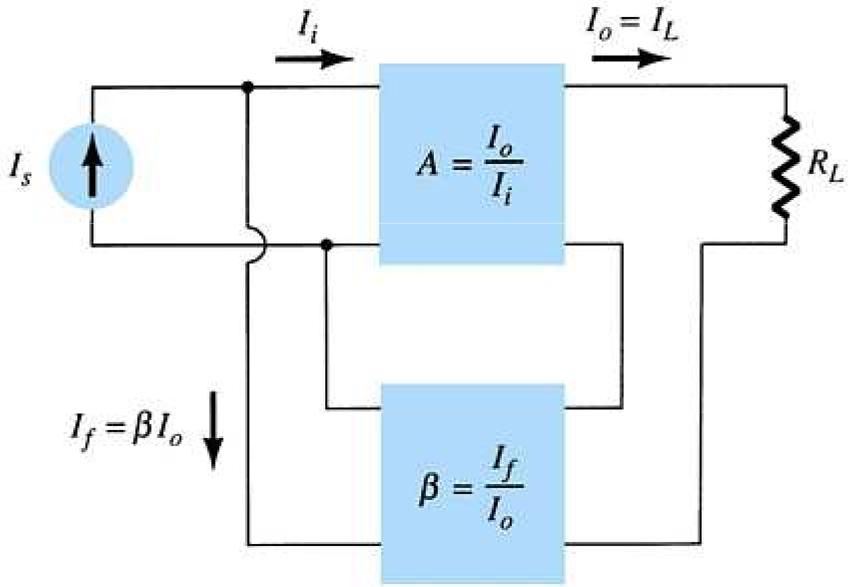


To determine the feedback gain:

$$A_f = \frac{I_o}{V_s} = \frac{A}{1+\beta A} = \frac{-h_{fe}/h_{ie}}{1+(-R_E)\left(\dfrac{-h_{fe}}{h_{ie}+R_E}\right)} \cong \frac{-h_{fe}}{h_{ie}+h_{fe}R_E}$$

Current-Shunt Feedback

For a current-shunt feedback amplifier, a portion of the output current is directed back in parallel with the input.



The feedback gain is given by:

$$A_f = \frac{I_o}{I_s}$$

Summary of Feedback Effects

Summary of Gain, Feedback, and Gain with Feedback

		Voltage-Series	*Voltage-Shunt*	*Current-Series*	*Current*
Shunt					
Gain without feedback	A	$\frac{V_o}{V_i}$	$\frac{V_o}{I_i}$	$\frac{I_o}{V_i}$	$\frac{I_o}{I_i}$
Feedback	b	$\frac{V_f}{V_o}$	$\frac{I_f}{V_o}$	$\frac{V_f}{I_o}$	$\frac{I_f}{I_o}$
	A_f	$\frac{V_o}{V_s}$	$\frac{V_o}{I_s}$	$\frac{I_o}{V_s}$	$\frac{I_o}{I_s}$

Effect of Feedback Connection on Input and Output Impedance

	Voltage-Series	*Current-Series*	*Voltage-Shunt*	*Current-Shunt*
Z_{if}	$Z_i\,(1+\beta A)$ (increased)	$Z_i\,(1+\beta A)$ (increased)	$\frac{Z_i}{1+\beta A}$ (decreased)	$\frac{Z_i}{1+\beta A}$ (decreased)
Z_{of}	$\frac{Z_o}{1+\beta A}$ (decreased)	$Z_o\,(1+\beta A)$ (increased)	$\frac{Z_o}{1+\beta A}$ (decreased)	$Z_o\,(1+\beta A)$ (increased)

Frequency Distortion with Feedback

- **If the feedback network is purely resistive, then the gain with feedback will be less dependent on frequency variations. In some cases the resistive feedback removes all dependence on frequency variations.**

- **If the feedback includes frequency dependent components (capacitors and inductors), then the frequency response of the amplifier will be affected.**

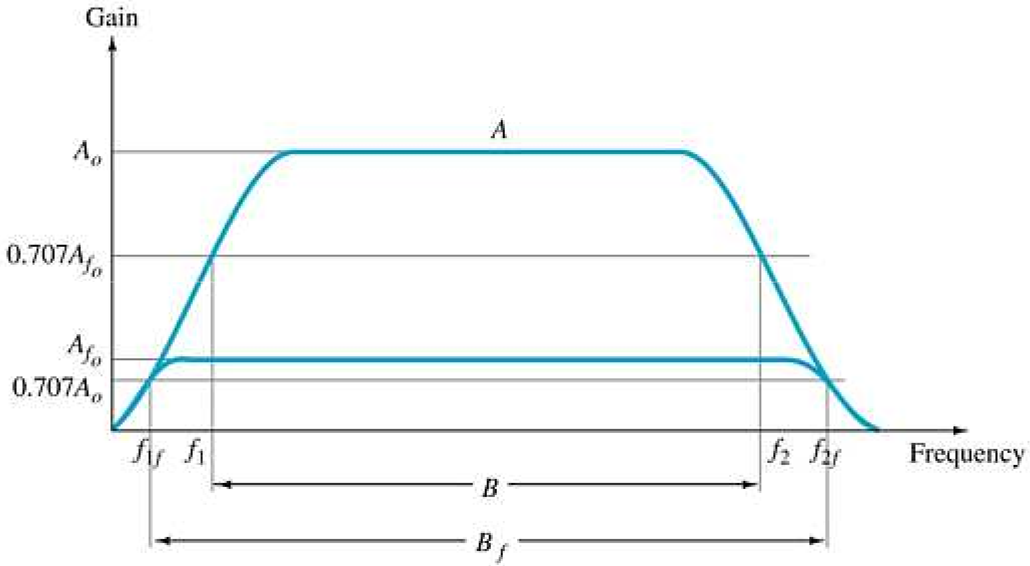
Noise and Nonlinear Distortion

- **The feedback network reduces noise by cancellation. The phase of the feedback signal is often opposite the phase of the input signal.**

- **Nonlinear distortion is also reduced simply because the gain is reduced. The amplifier is operating in midrange and not at the extremes.**

Bandwidth with Feedback

Feedback increases the bandwidth of an amplifier.



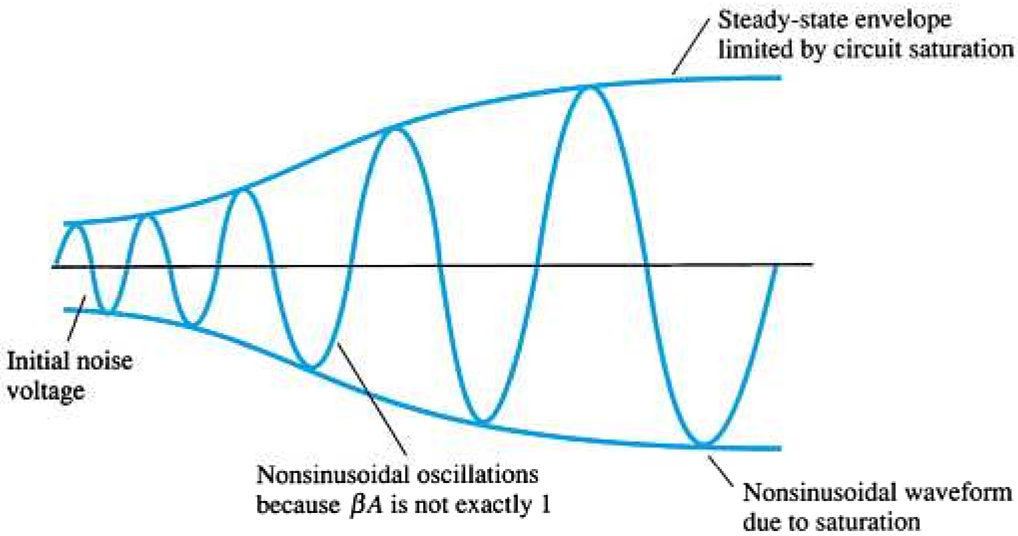
Gain Stability with Feedback

Gain calculations with feedback are often based on external resistive elements in the circuit. By removing gain calculations from internal variations of β and g_m, the gain becomes more stable.

Phase and Frequency Considerations

At higher frequencies the feedback signal may no longer be out of phase with the input. The feedback is thus positive and the amplifier, itself, becomes unstable and begins to

Oscillator Operation



The feedback signal must be positive.

If the feedback signal is not positive or the gain is less than one, the oscillations dampens out.

The overall gain must equal one (unity gain).

If the overall gain is greater than one, the oscillator eventually saturates.

Types of Oscillator Circuits

Phase-shift oscillator
Wien bridge oscillator
Tuned oscillator circuits
Crystal oscillators
Unijunction oscillator

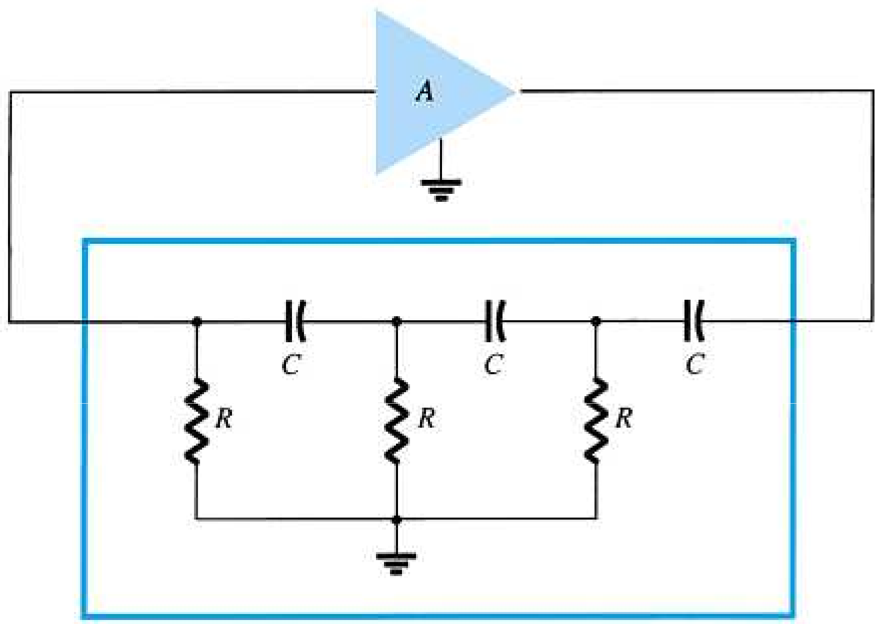
Phase-Shift Oscillator

The amplifier must supply enough gain to compensate for losses. The overall gain must be unity.

The RC networks provide the necessary phase shift for a positive feedback.

The values of the RC components also determine the frequency of oscillation:

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



Feedback network

more…

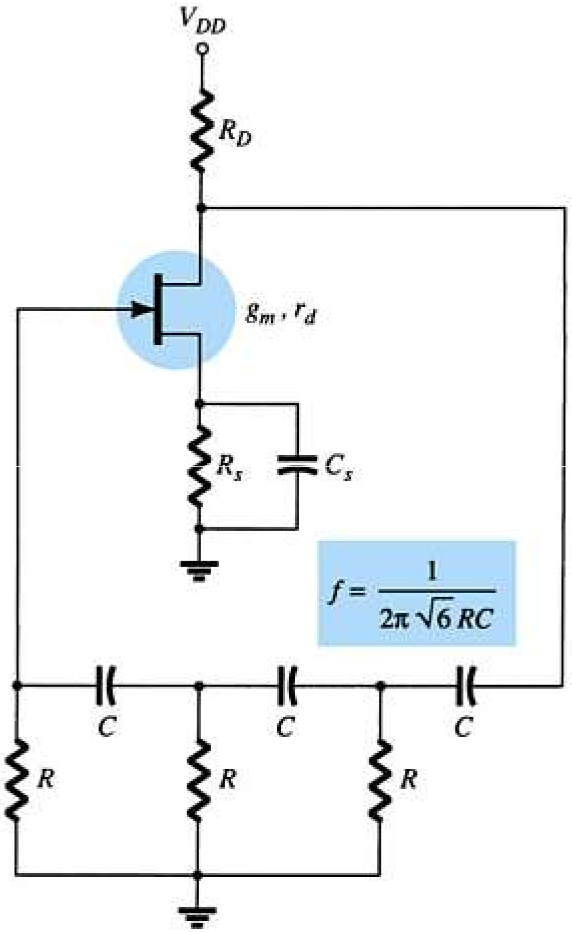
Phase-Shift Oscillator

The amplifier must supply enough gain to compensate for losses. The overall gain must be unity.

The RC networks provide the necessary phase shift for a positive feedback.

The values of the RC components also determine the frequency of oscillation:

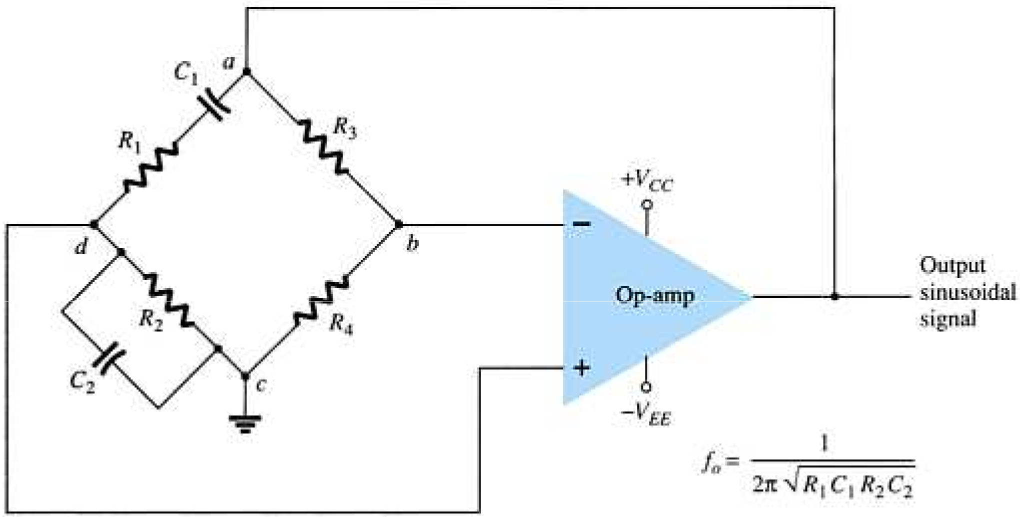
$$f = \frac{1}{2\pi\sqrt{6}RC}$$



Wien Bridge Oscillator

The amplifier must supply enough gain to compensate for losses. The overall gain must be unity.

- **The feedback resistors are R_3 and R_4.**
- **The phase-shift components are R_1, C_1 and R_2, C_2.**



Tuned Oscillator Circuits

Tuned oscillators use a parallel LC resonant circuit (LC tank) to provide the oscillations.

There are two common types:

> **Colpitts—The resonant circuit is an inductor and two capacitors.**
>
> **Hartley—The resonant circuit is a tapped inductor or two inductors and one capacitor.**

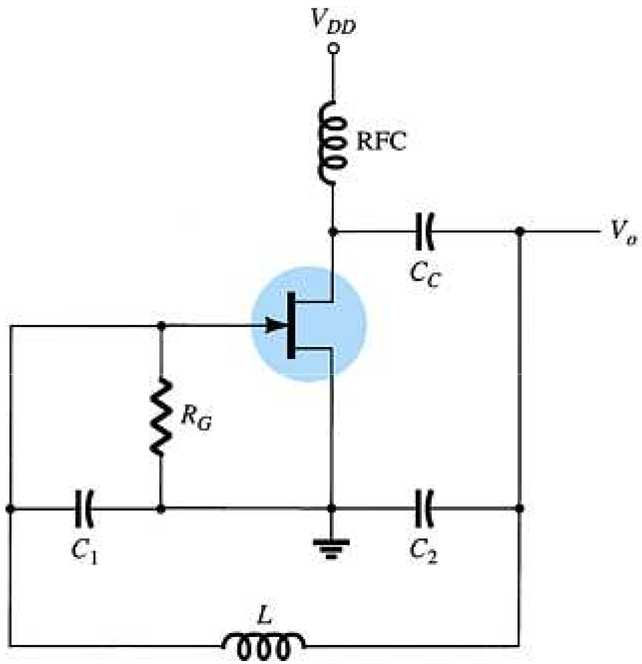
Colpitts Oscillator Circuit

The frequency of oscillation is determined by:

$$f_o = \frac{1}{2\pi\sqrt{LC_{eq}}}$$

where:

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$



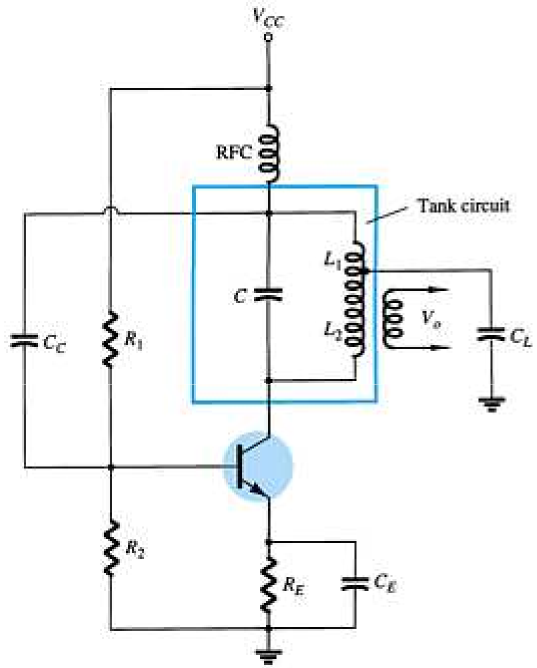
Hartley Oscillator Circuit

The frequency of oscillation is determined by:

$$f_o = \frac{1}{2\pi\sqrt{L_{eq}C}}$$

where:

$$L_{eq} = L_1 + L_2 + 2M$$



Crystal Oscillators

The crystal appears as a resonant circuit.

The crystal has two resonant frequencies:

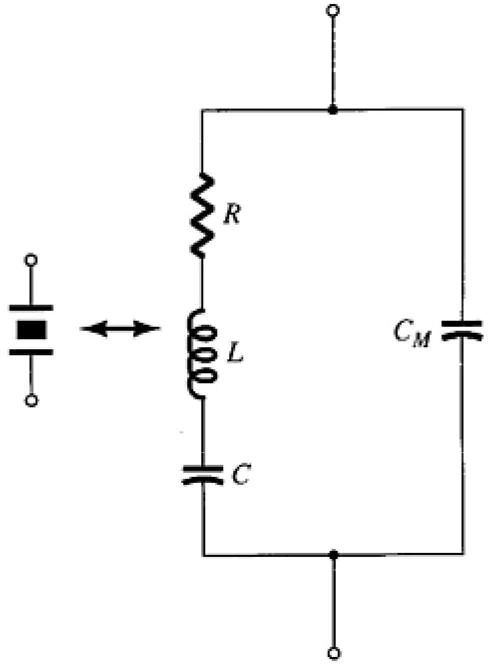
Series resonant condition

- RLC determine the resonant frequency
- The crystal has a low impedance

Parallel resonant condition

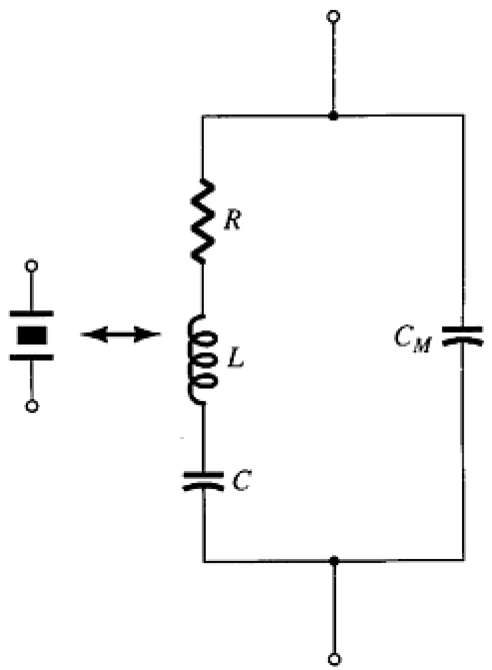
- RL and C_M determine the resonant frequency
- The crystal has a high impedance

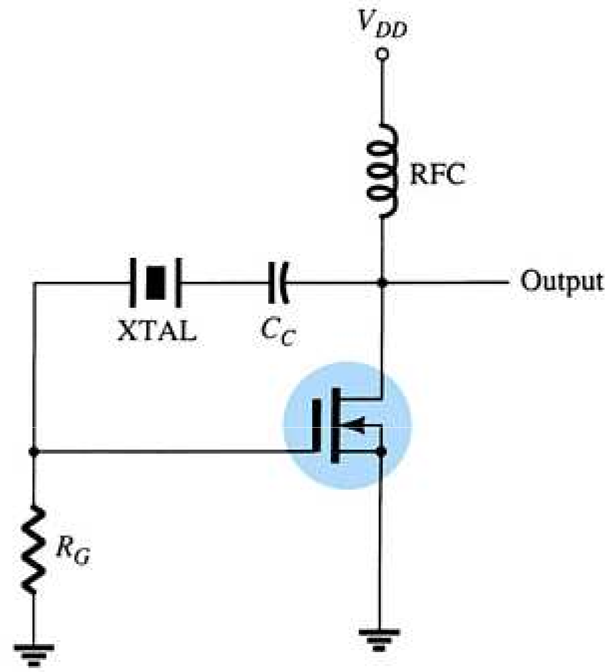
The series and parallel resonant frequencies are very close, within 1% of each other.



Series Resonant Crystal Oscillator

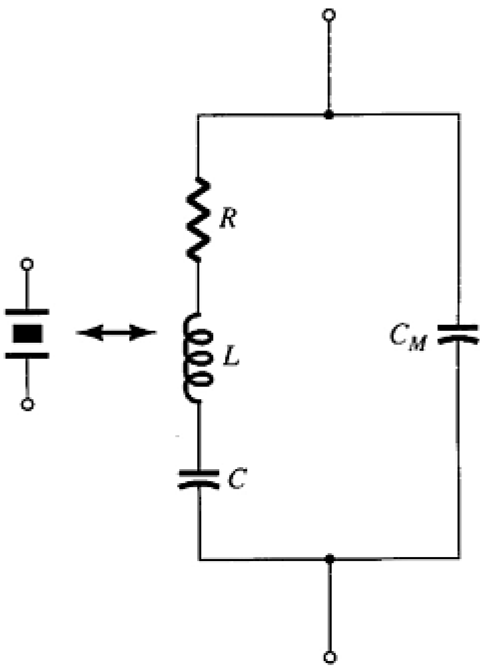
- **RLC determine the resonant frequency**
- **The crystal has a low impedance**

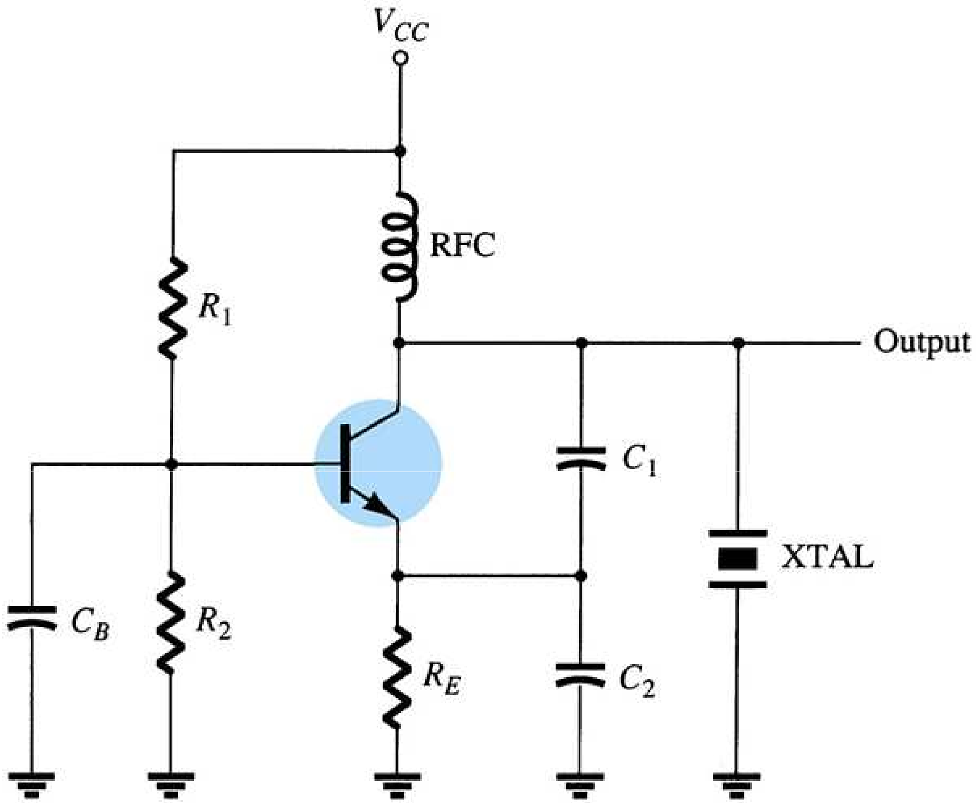




Parallel Resonant Crystal Oscillator

- R_L and C_M determine the resonant frequency
- The crystal has a high impedance



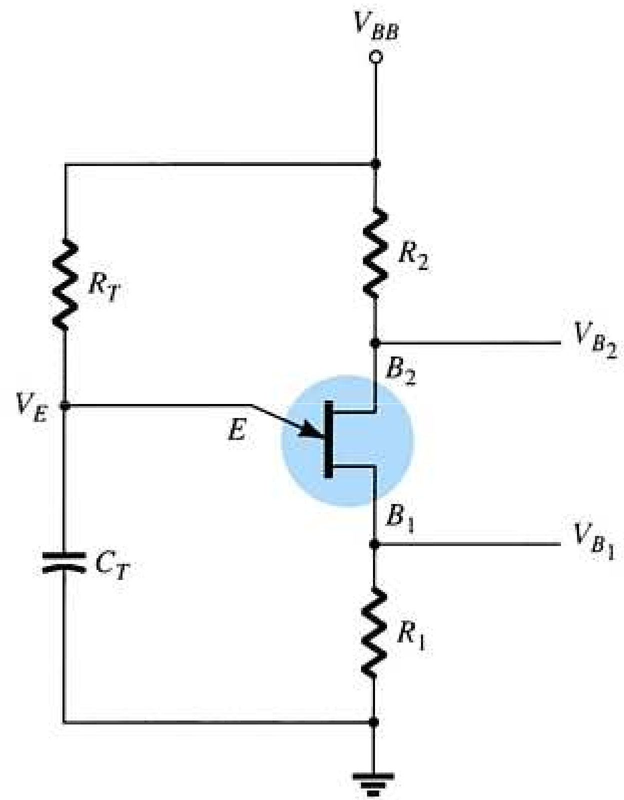


Unijunction Oscillator

The output frequency is determined by:

$$f_o = \frac{1}{R_T C_T \ln\left[1/(1-\eta)\right]}$$

Where η is a rating of the unijunction transistor with values between 0.4 and 0.6.



Unijunction Oscillator Waveforms

The unijunction oscillator (or relaxation oscillator) produces a sawtooth waveform.