

# Electronic Circuits – EE359A

Bruce McNair

B206

[bmcnair@stevens.edu](mailto:bmcnair@stevens.edu)

201-216-5549

# Filters and Tuned Amplifiers

Second order LCR resonator

Second order Active Filters based on  
Inductor Replacement

## Signal Generators

Oscillators

# Second Order LCR Resonator

- LCR Resonator

$$\frac{V_o}{I} = \frac{1}{Y} = \frac{1}{1/sL + sC + 1/R}$$

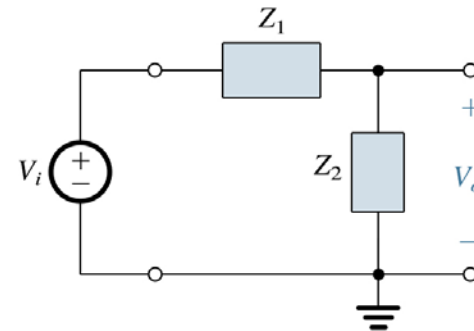
$$= \frac{s/C}{s^2 + s(1/CR) + 1/LC}$$

$$\omega_0^2 = 1/LC$$

$$\omega_0/Q = 1/CR$$

$$\omega_0 = 1/\sqrt{LC}$$

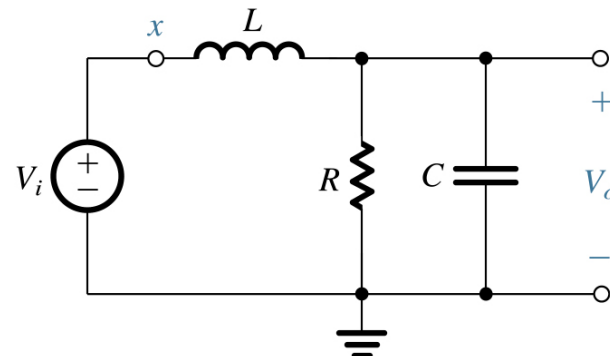
$$Q = \omega_0 CR$$



(a) General structure

- Excite parallel LCR resonator

- Determine natural modes (I.e. poles of response function)



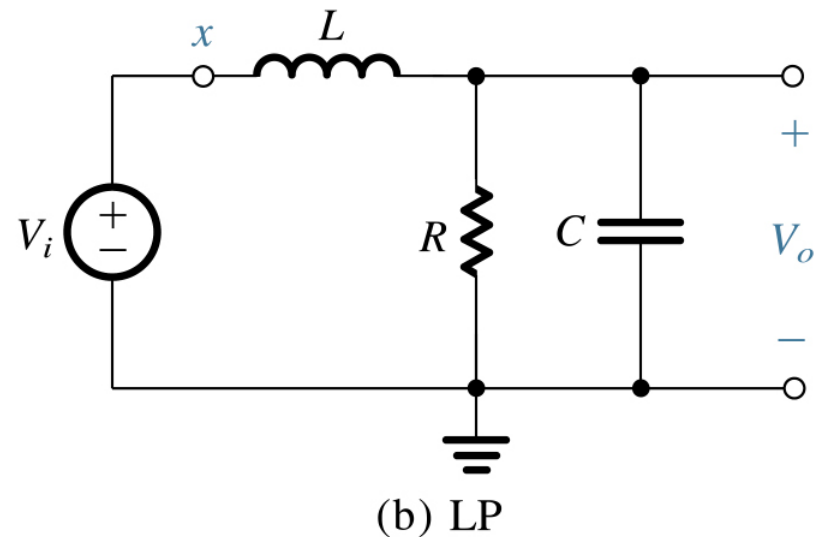
(b) LP

# Transmission Zeros LPF

- Where to inject input signal  $V_i$  ?

$$T(s) = \frac{V_o(s)}{V_i(s)} = \frac{Z_2(s)}{Z_1(s) + Z_2(s)}$$

- Transmission zeros are when  $Z_2(s)$  are zero (if  $Z_1$



# Realization of Low Pass Function

- Transmission zeros are when series impedance becomes infinite.

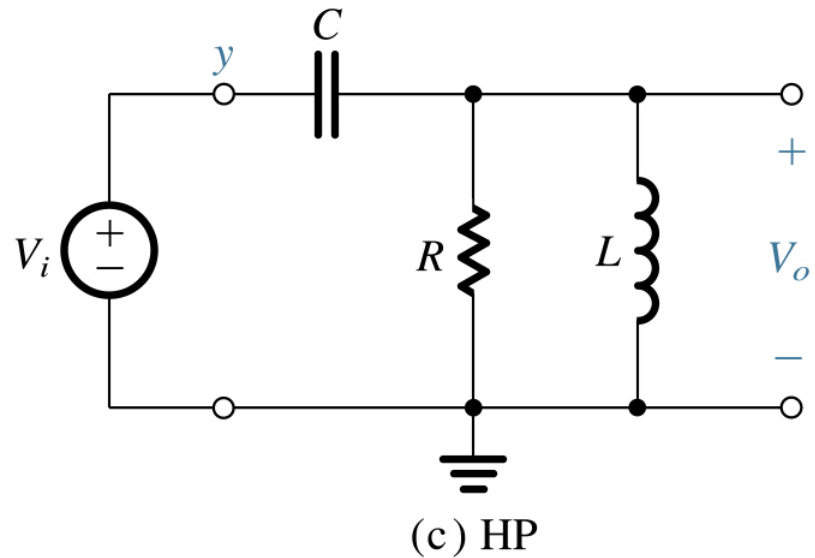
$$sL \rightarrow \infty \Rightarrow s \rightarrow \infty \Rightarrow \frac{1}{sC + 1/R} \rightarrow 0$$

$$T(s) = \frac{V_0}{V_i} = \frac{Z_2}{Z_1 + Z_2} = \frac{Y_1}{Y_1 + Y_2} = \frac{1/sL}{1/sL + sC + 1/R}$$

# High Pass Filter

- Use the series capacitor.  
Transmission zero at  $s=0$  (dc), shunt inductor is a transmission zero at  $s=0$ .

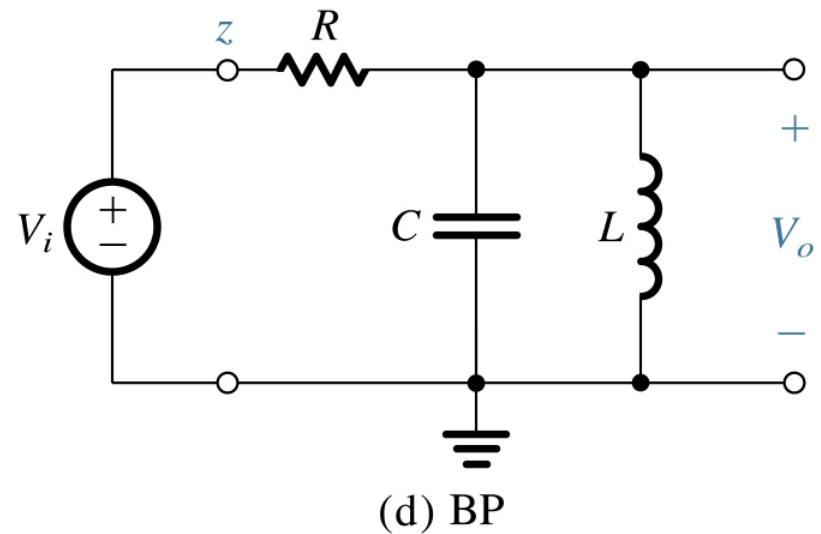
$$T(s) = \frac{V_o}{V_i} = \frac{a_2 s^2}{s^2 + s(\omega_0 / Q) + \omega_0^2}$$



# Bandpass Filter

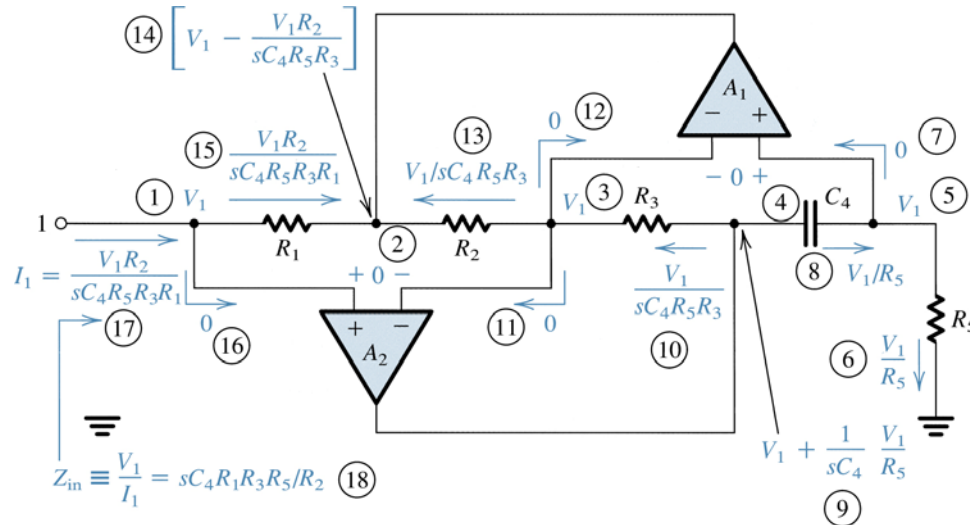
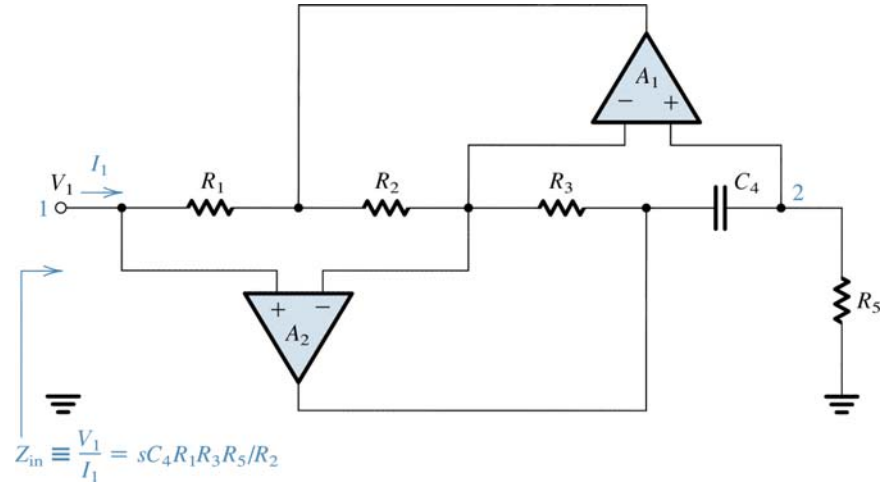
- Zero at  $s=0$  due to shunt inductor,  $s=\infty$  due to shunt capacitor.

$$T(s) = \frac{V_o}{V_i} = \frac{s(1/CR)}{s^2 + s(1/CR) + 1/LC}$$



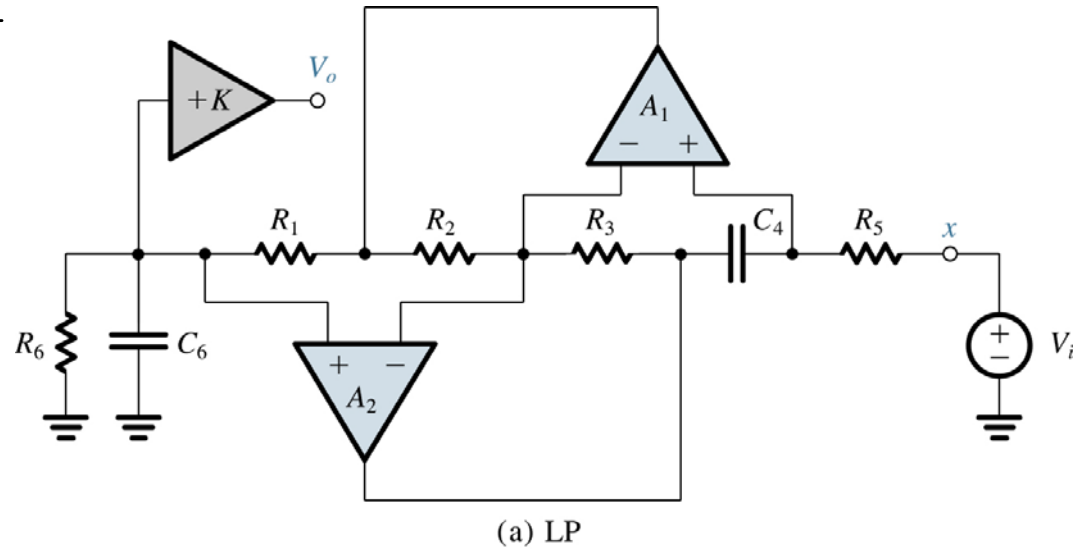
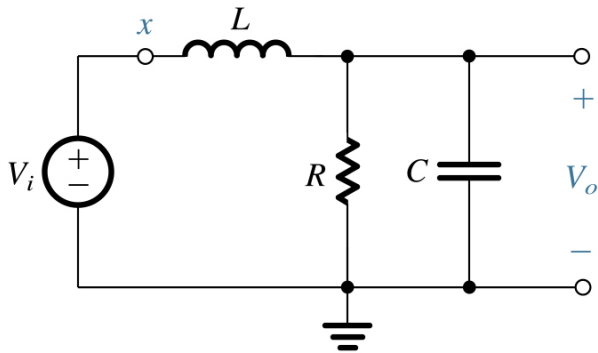
# Inductance Simulation

- Use opamps instead of inductor!



# Low Pass Filter

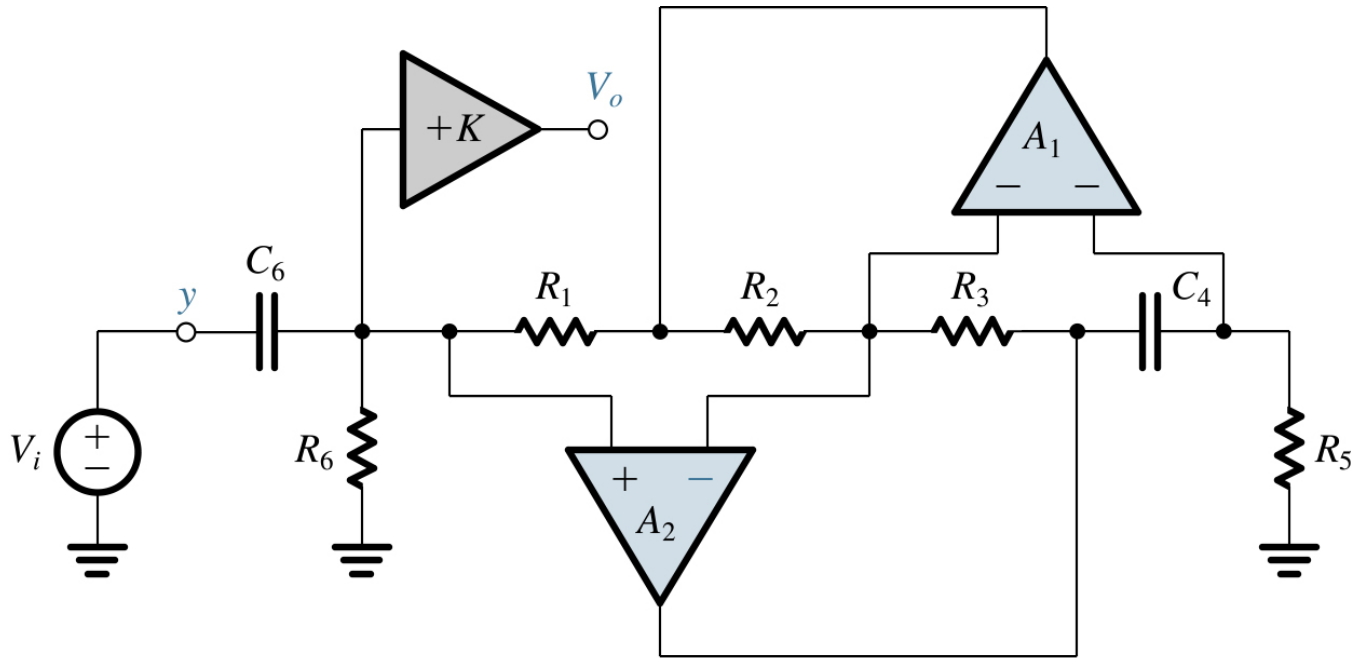
$$T(s) = \frac{V_o(s)}{V_i(s)} = \frac{Z_2(s)}{Z_1(s) + Z_2(s)}$$



$$T(s) = \frac{V_o}{V_i} = \frac{Z_2}{Z_1 + Z_2} = \frac{Y_1}{Y_1 + Y_2} = \frac{1/sL}{1/sL + sC + 1/R}$$

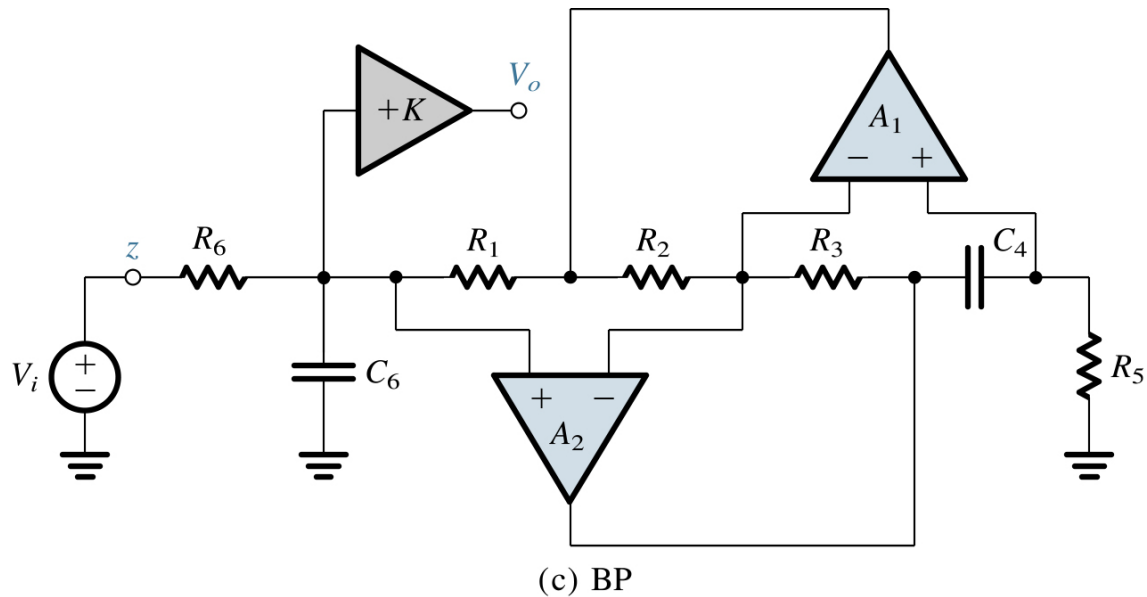
# High Pass Filter

- $$T(s) = \frac{V_o}{V_i} = \frac{a_2 s^2}{s^2 + s(\omega_0 / Q) + \omega_0^2}$$



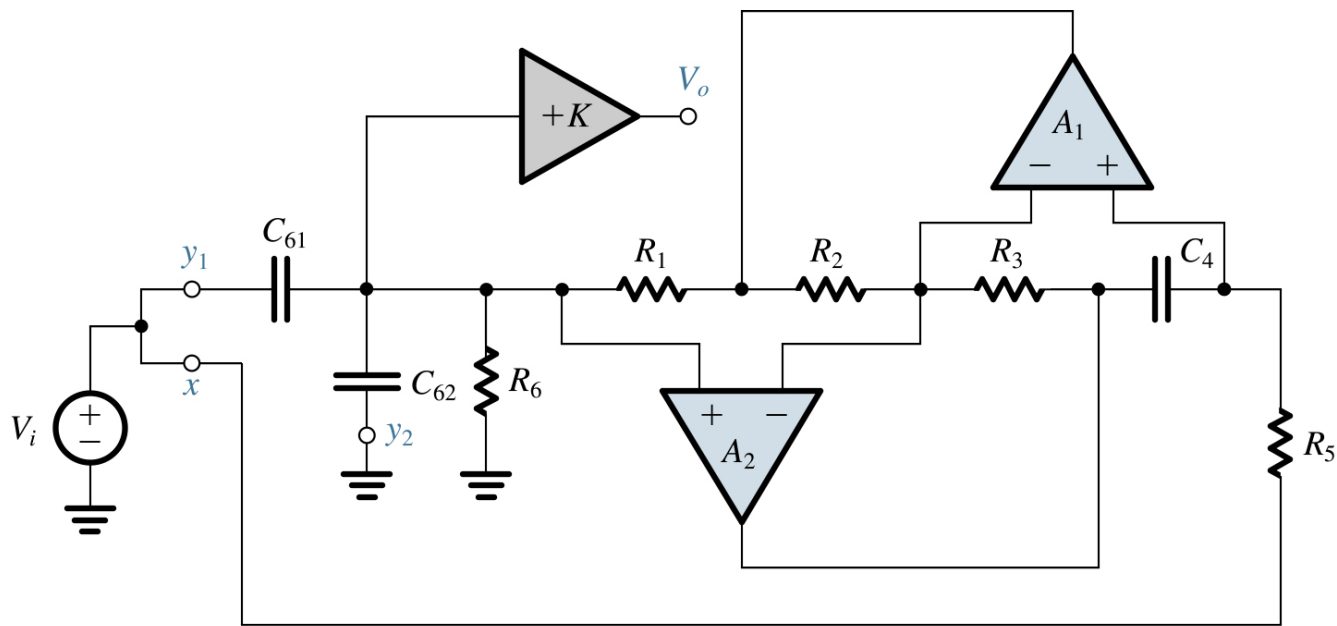
(b) HP

# Bandpass Filter



$$T(s) = \frac{V_o}{V_i} = \frac{s(1/CR)}{s^2 + s(1/CR) + 1/LC}$$

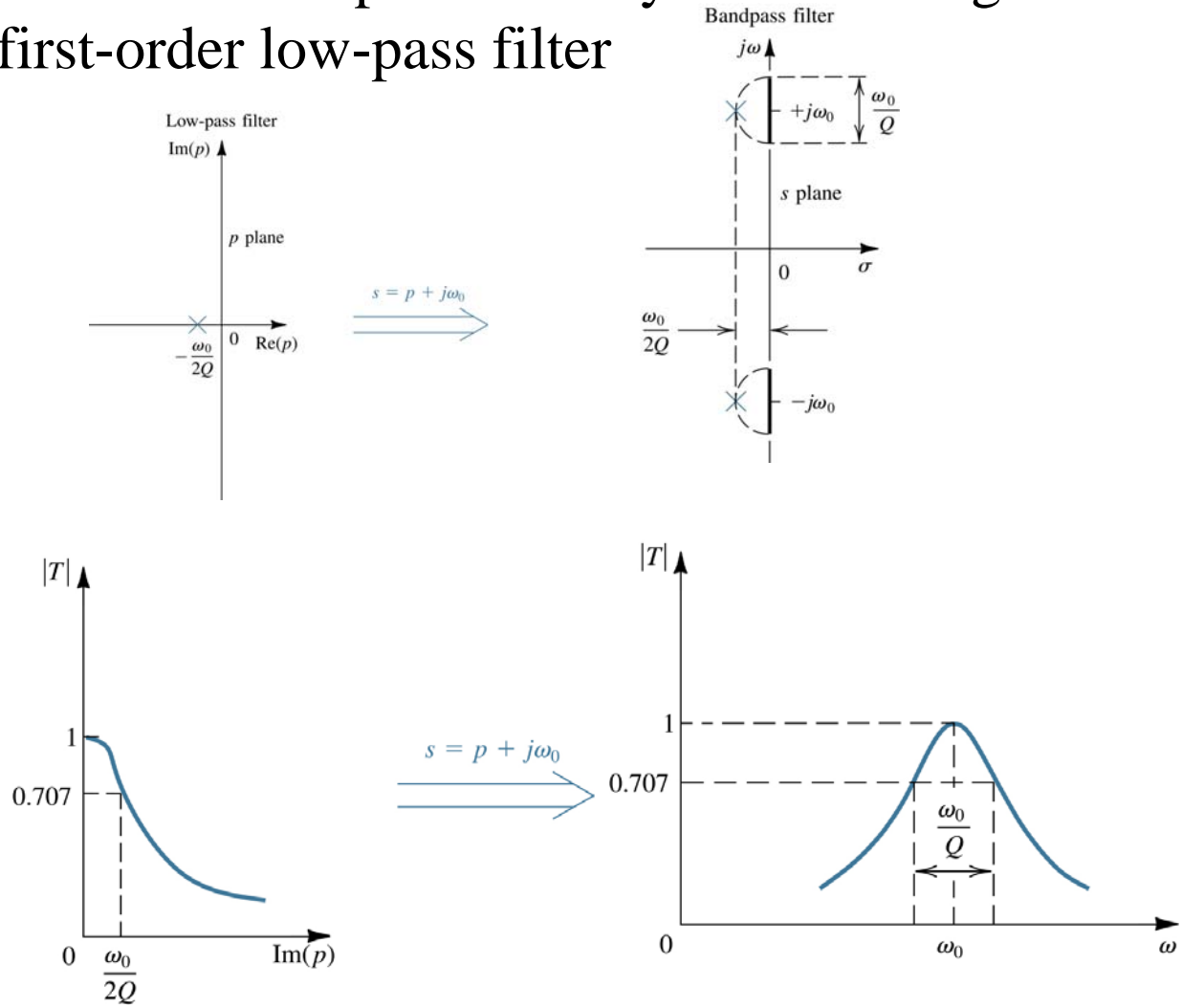
# Low Pass Notch filter



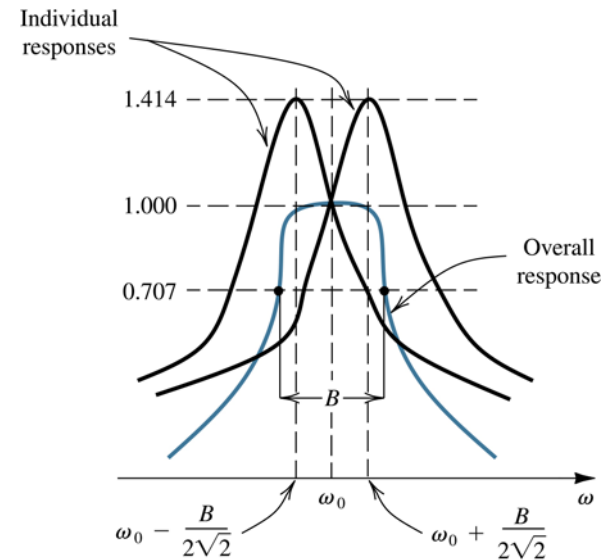
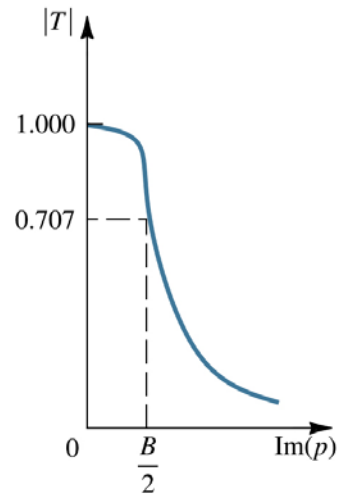
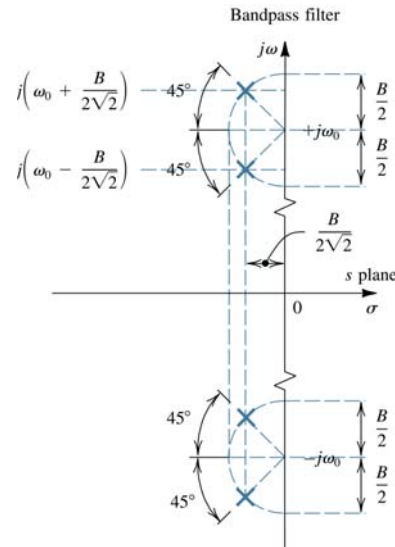
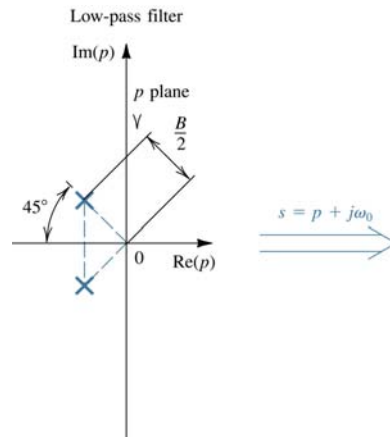
(e) LPN,  $\omega_n \geq \omega_0$

# Second-order narrow-band bandpass filter by transforming a first-order low-pass filter

Second-order narrow-band bandpass filter by transforming a first-order low-pass filter. (a) Pole of the first-order filter in the  $s$ -plane. (b) Applying the transformation  $s = p + j\omega_0$  and adding a complex conjugate pole results in the poles of the second-order bandpass filter. (c) Magnitude response of the first-order low-pass filter. (d) Magnitude response of the second-order bandpass filter.

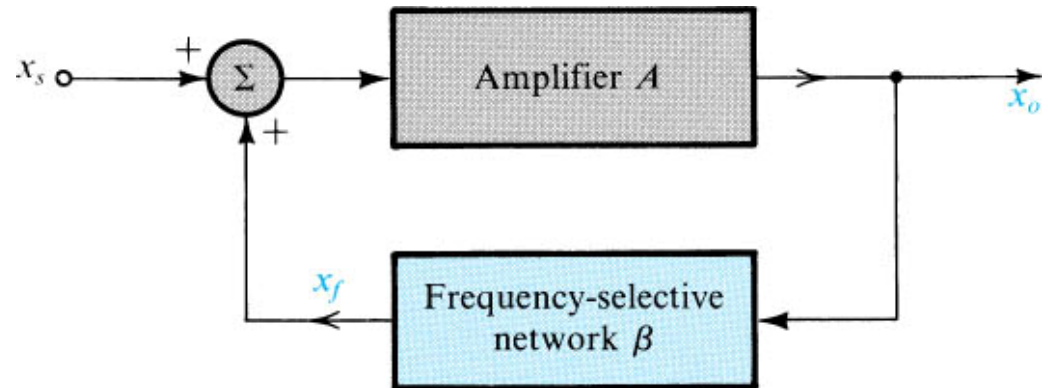


Poles and the frequency response of a fourth-order stagger-tuned narrow-band bandpass amplifier by transforming a second-order low-pass .



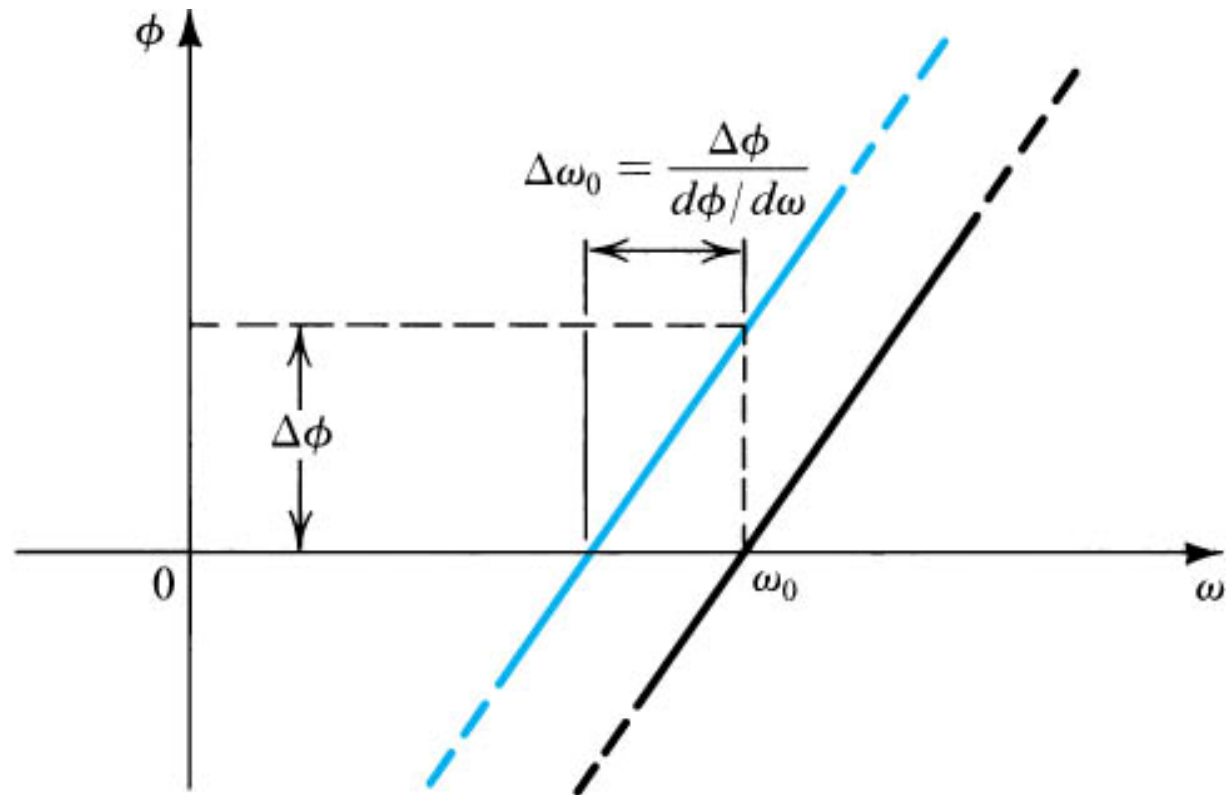
# SIGNAL GENERATORS /OSCILLATORS

A positive-feedback loop is formed by an amplifier and a frequency-selective network

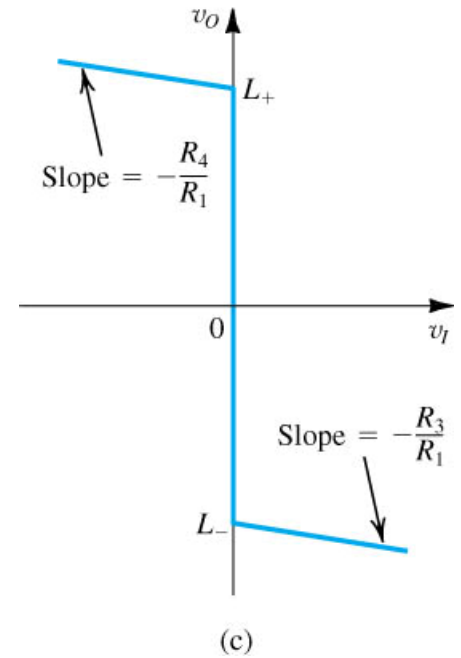
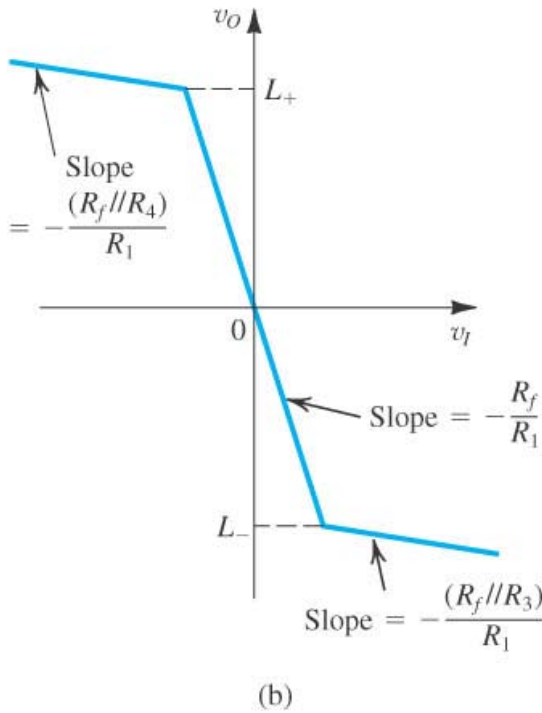
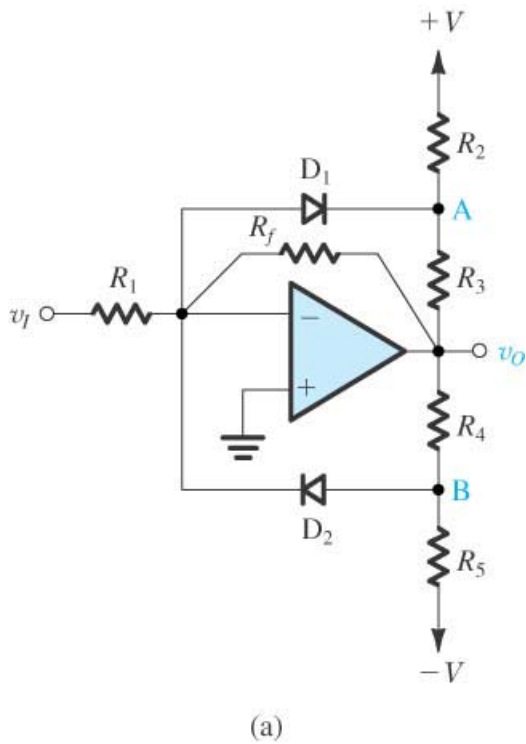


In an actual oscillator circuit, no input signal will be present

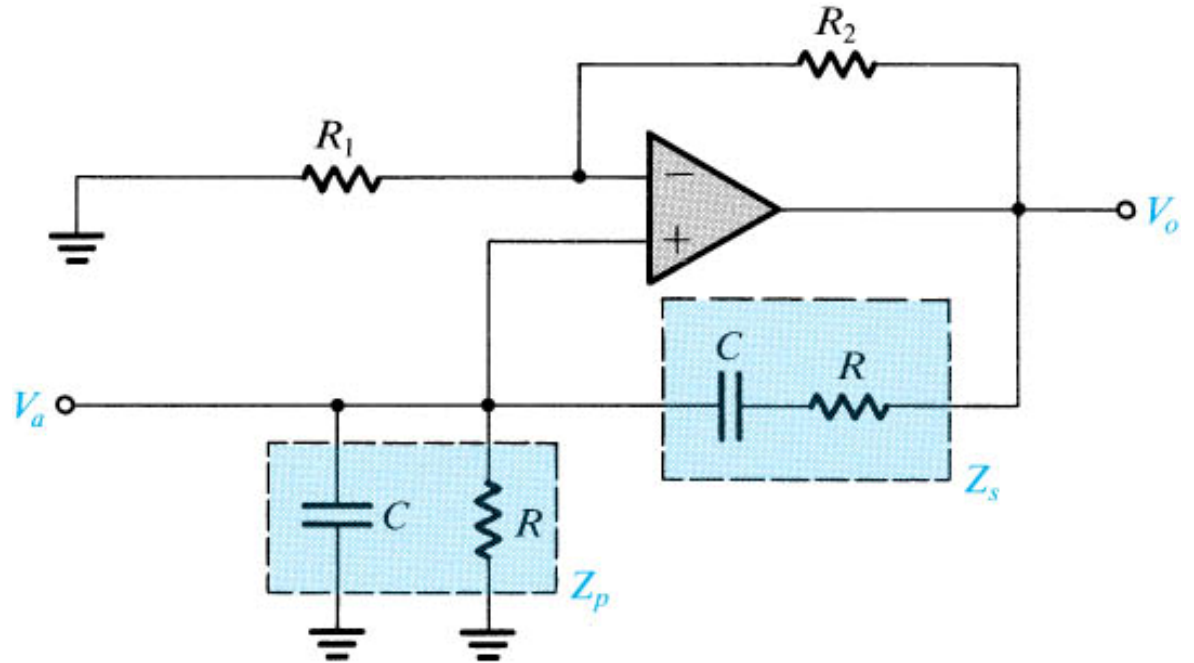
# Oscillator-frequency stability



# Limiter Ckt $\rightarrow$ Comparator



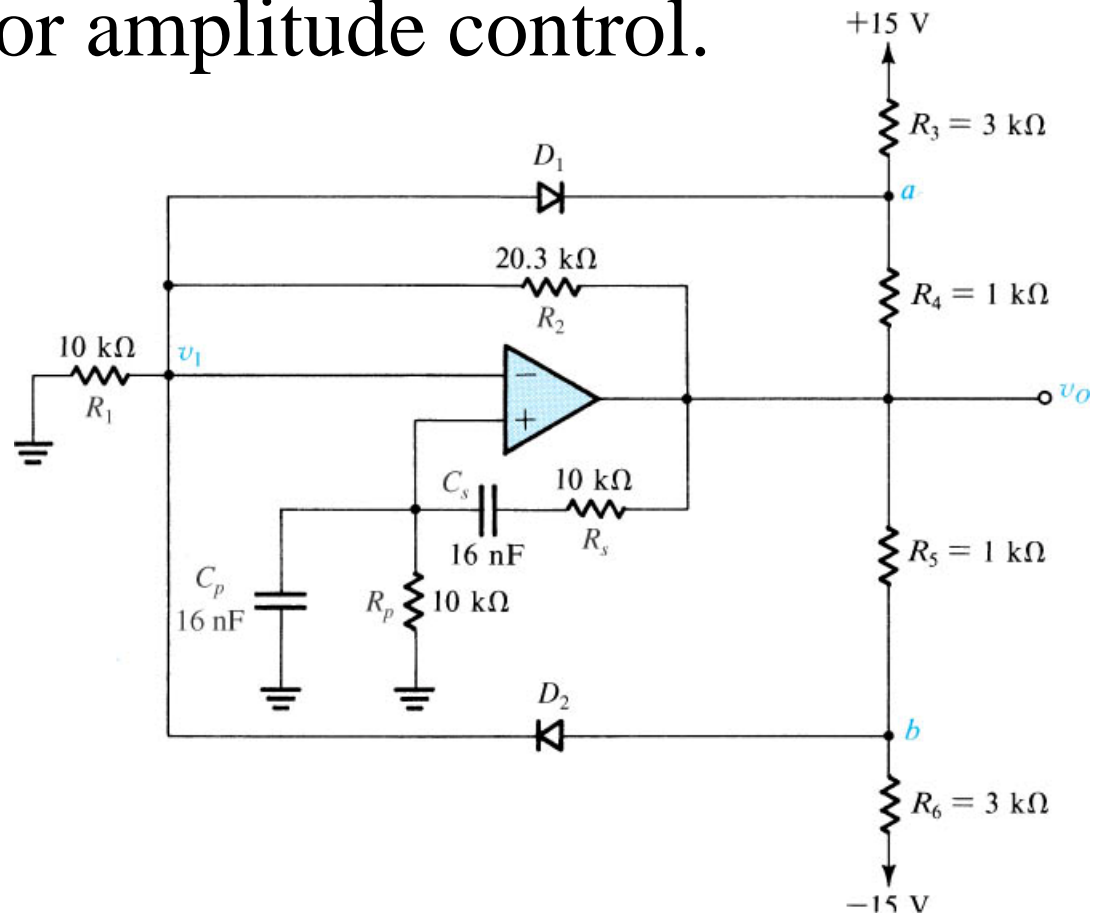
# Wien-bridge oscillator



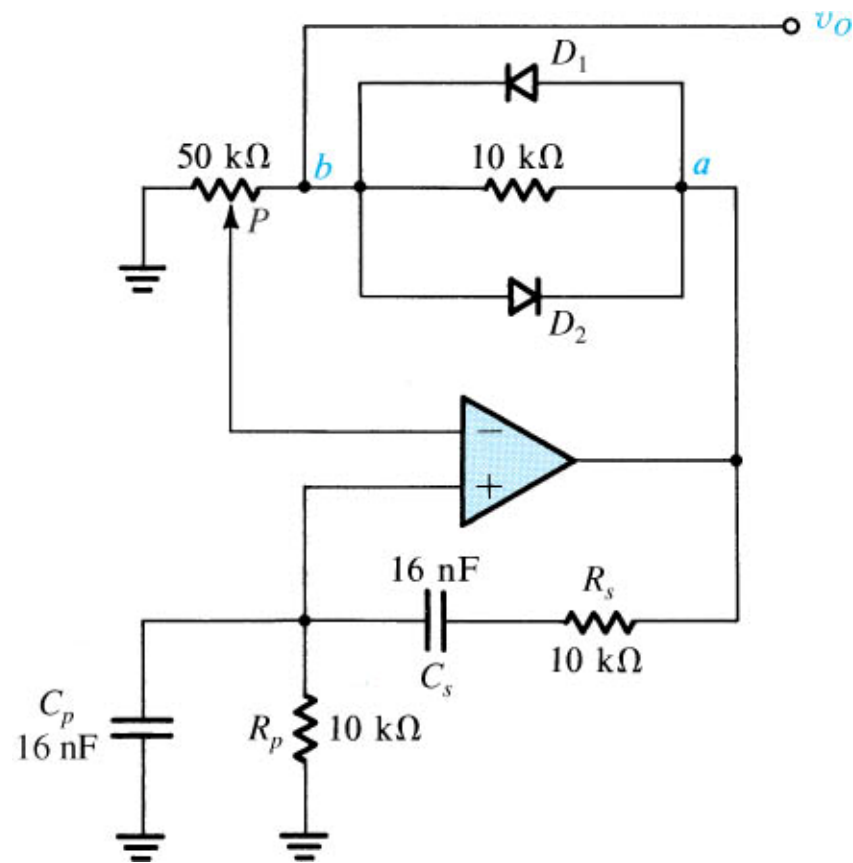
without amplitude  
stabilization.

# Wien bridge w/ Amp. Stabil.

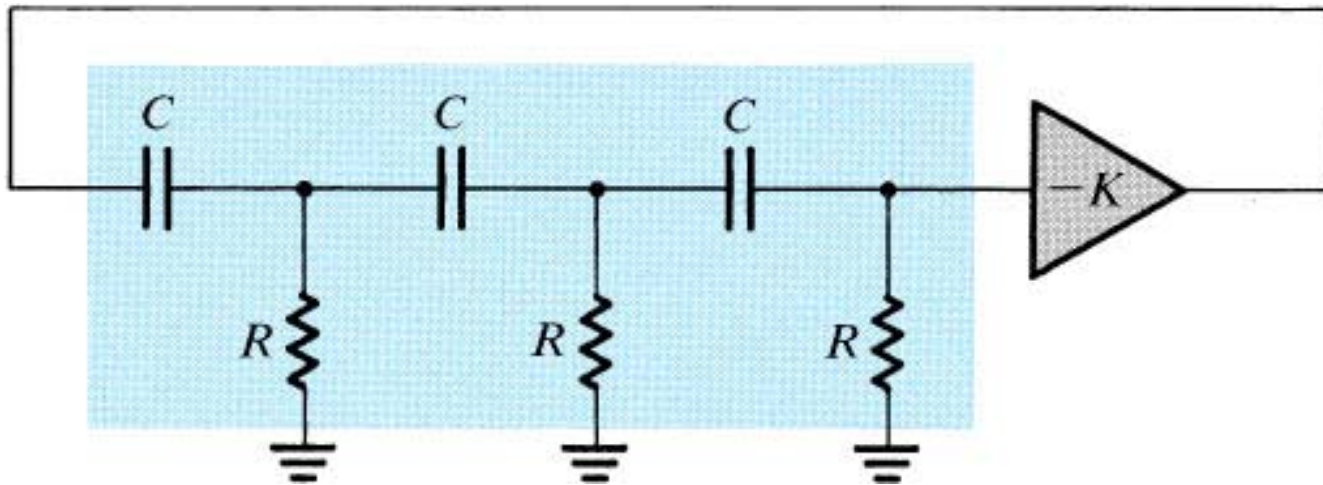
limiter used for amplitude control.



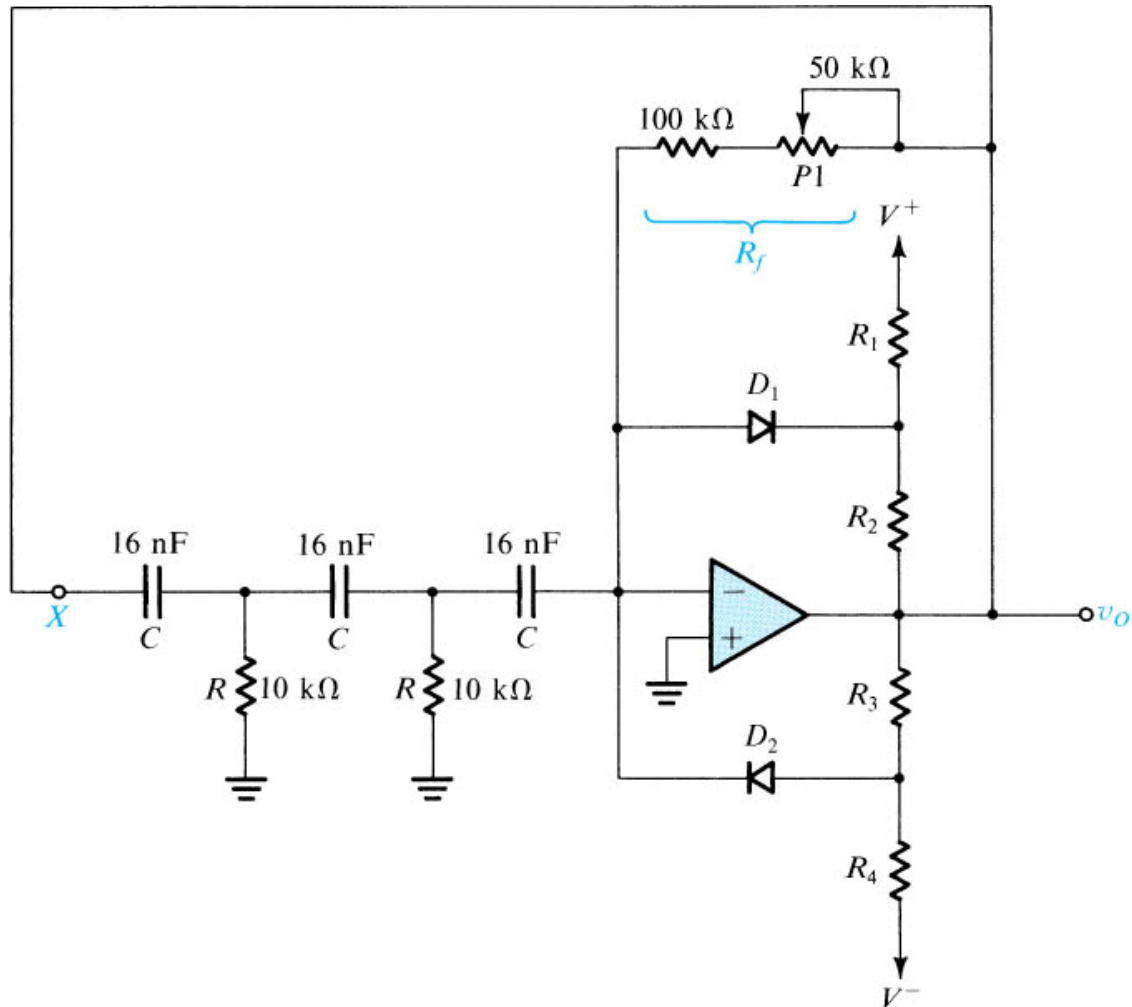
# Alternate Wien bridge stabil.



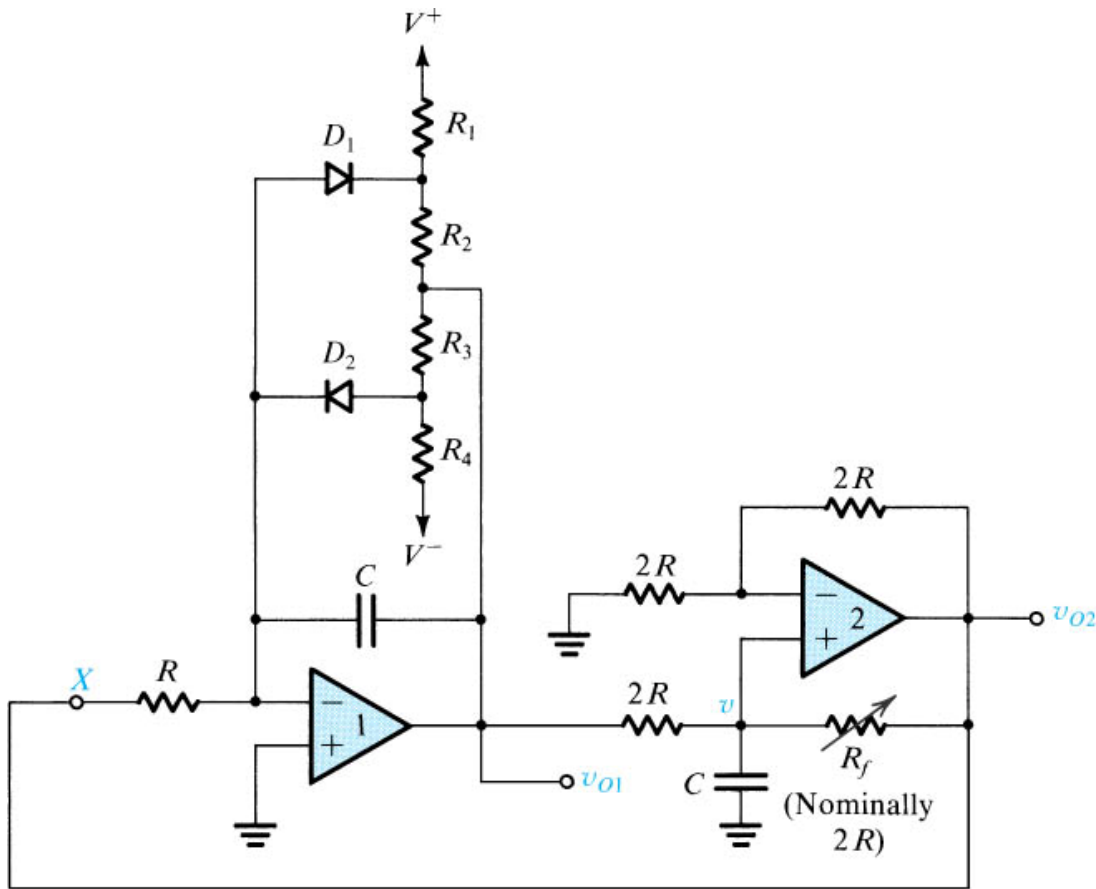
# Phase Shift Oscillator



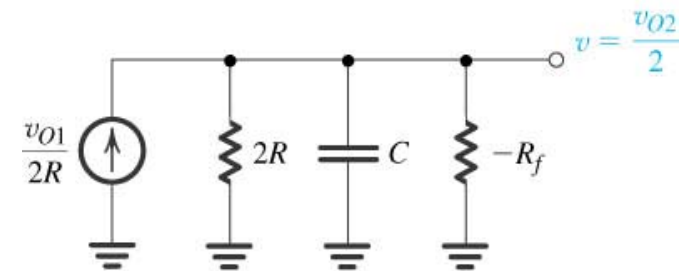
# Phase Shift. Osc. W/ Stabil.



# Quad Osc. Circuit

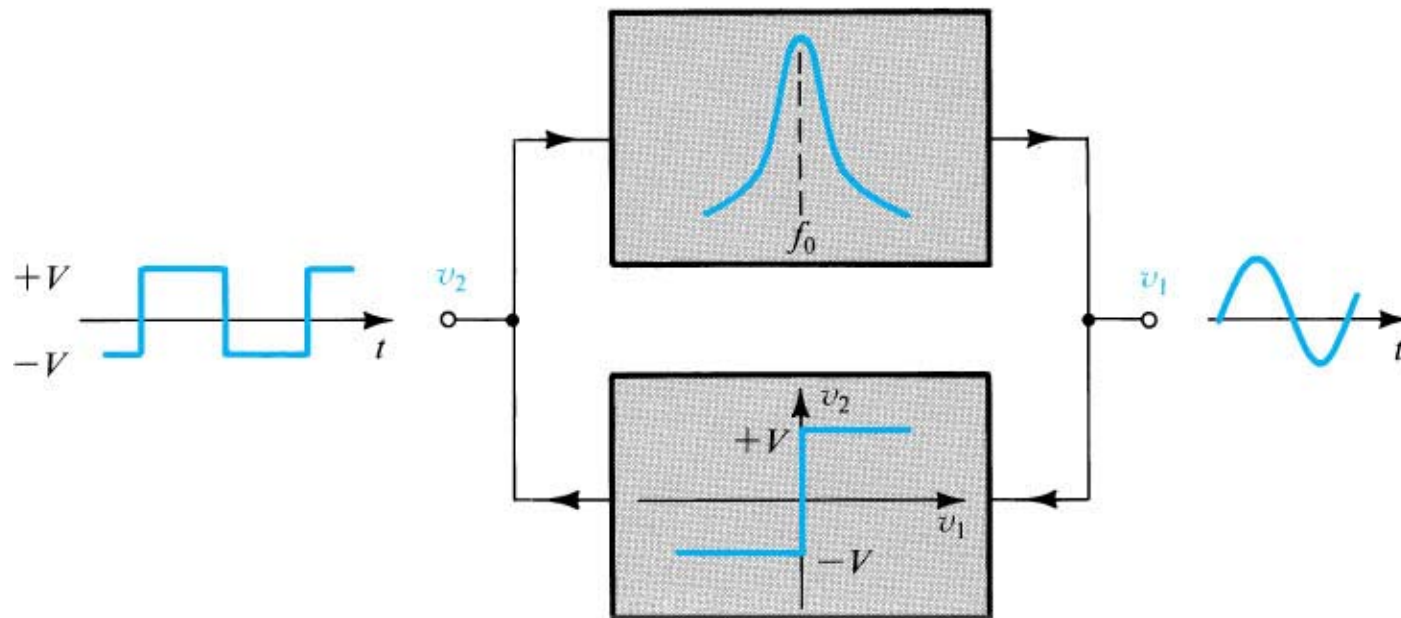


(a)

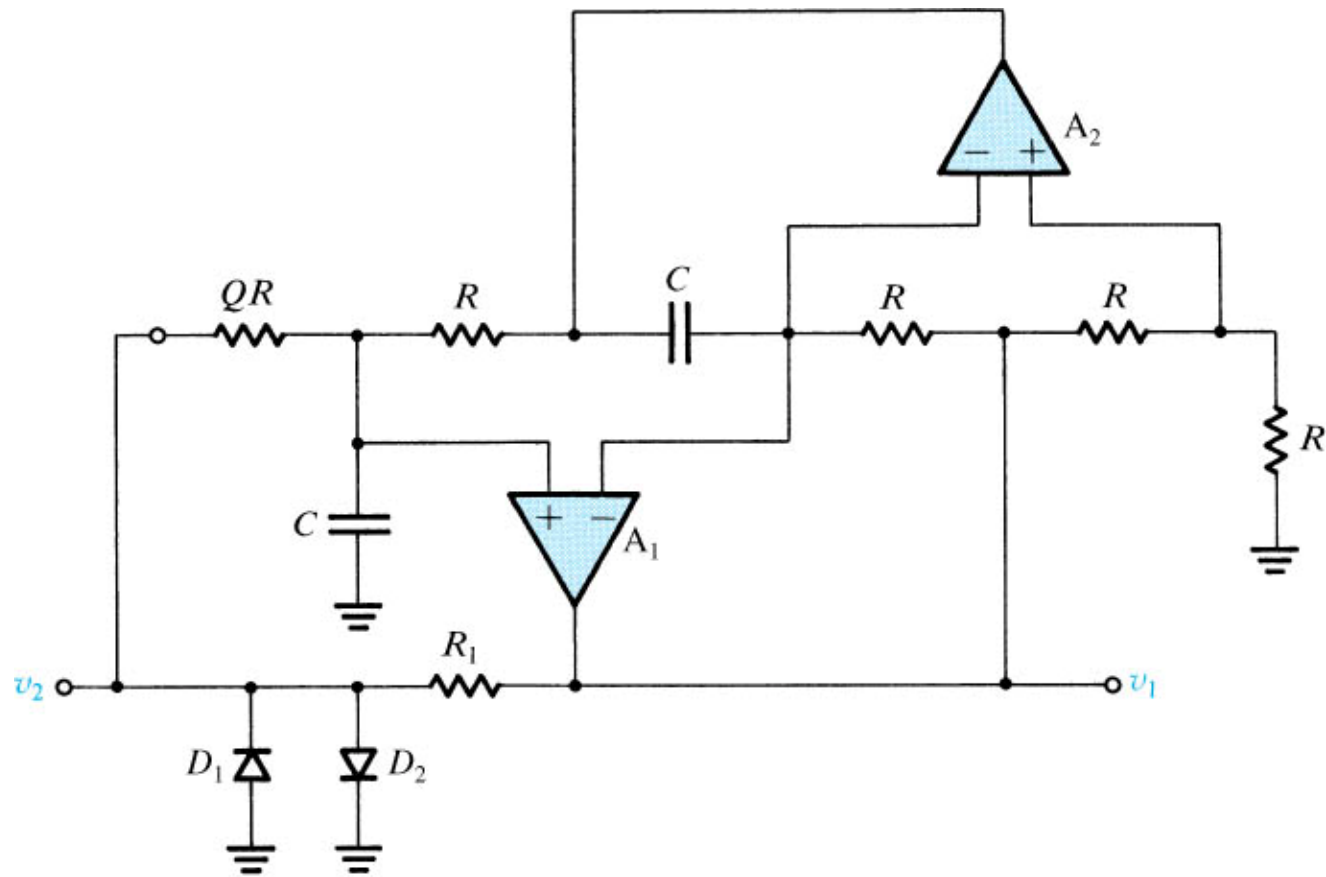


(b)

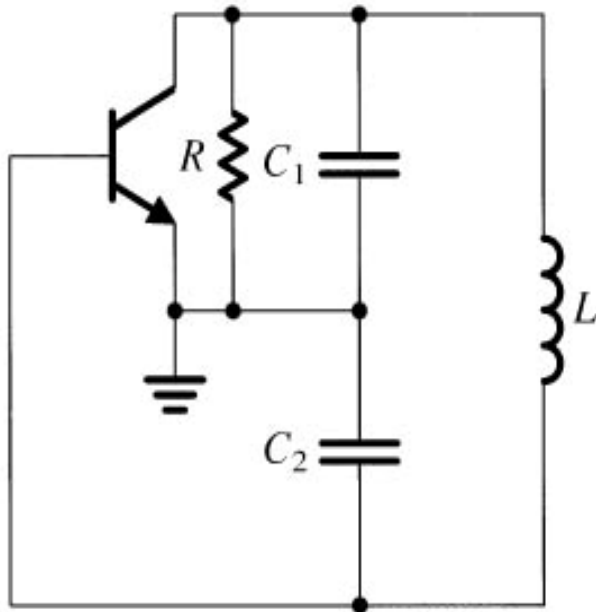
# Active Tuned Osc.



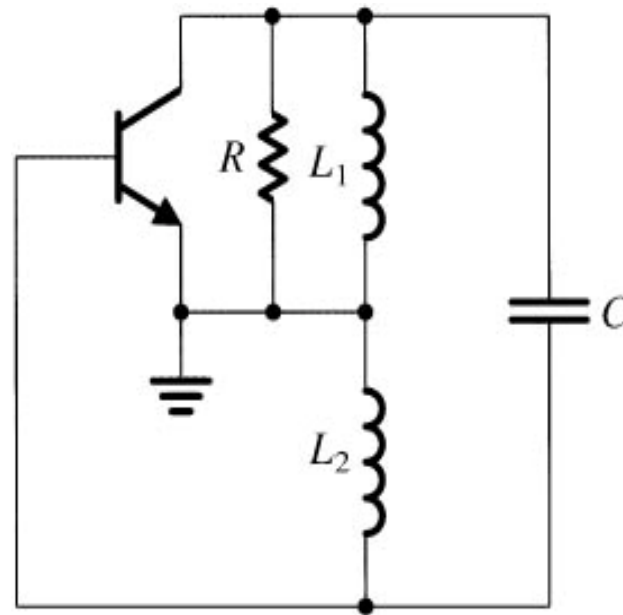
# OPAMP based Tuned Amp. Osc.



# Colpitts and Hartley Oscillators



(a)

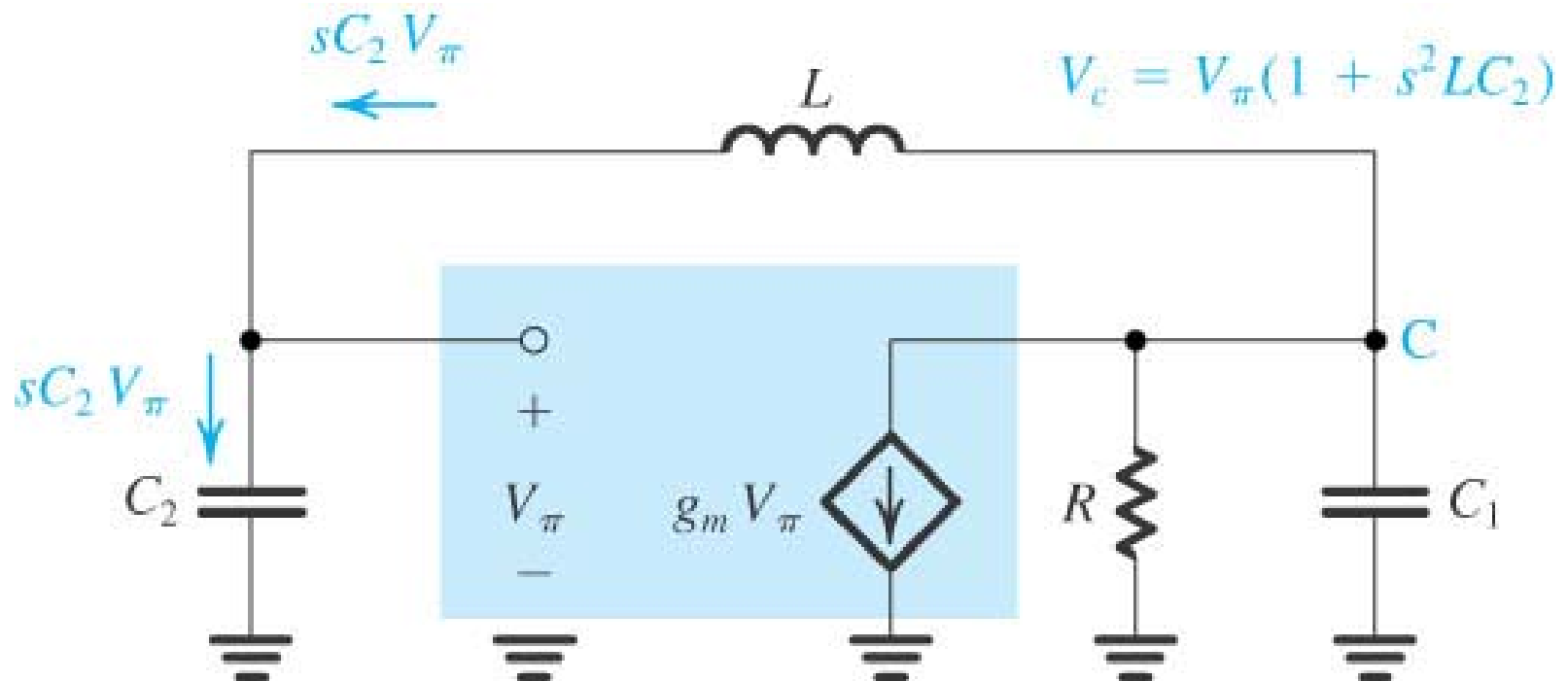


(b)

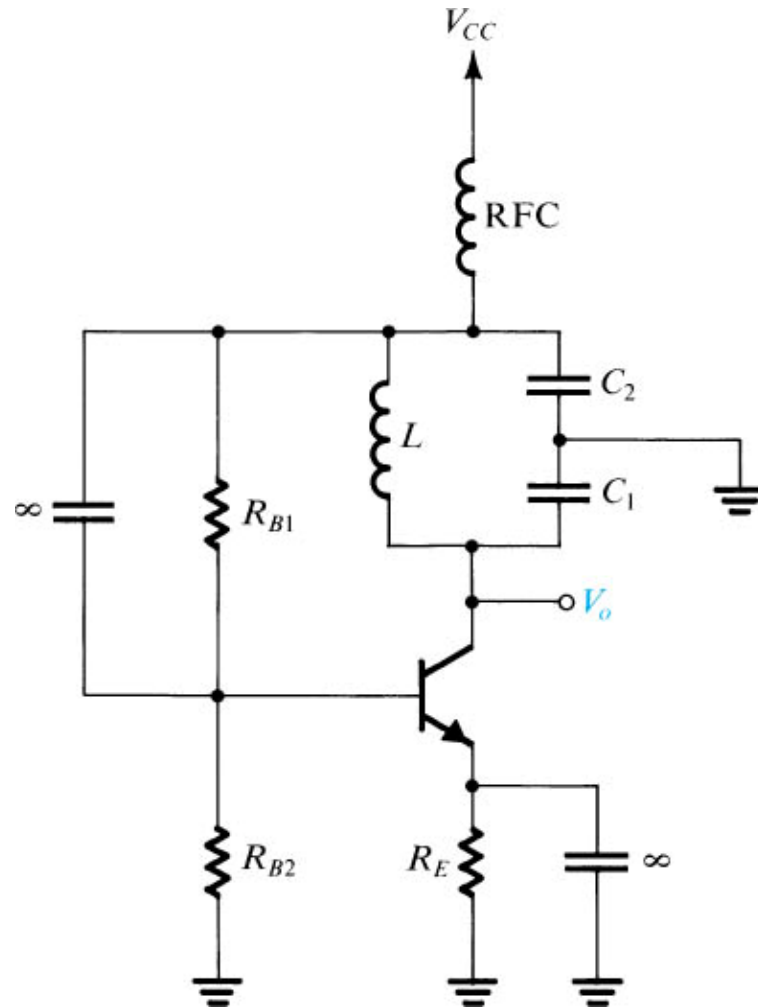
# Equiv. Ckt

To simplify the analysis, neglect  $C_m$  and  $r_p$

Consider  $C_p$  to be part of  $C_2$ , and include  $r_o$  in  $R$ .



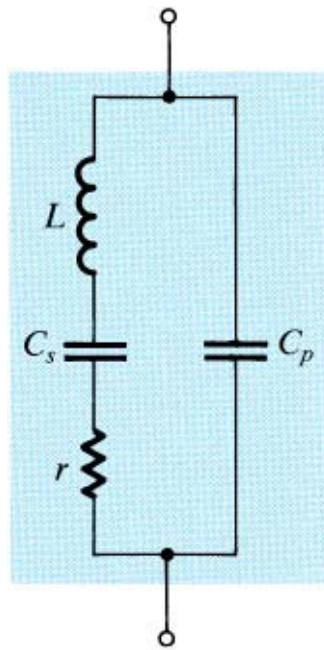
# Collpits Oscillator



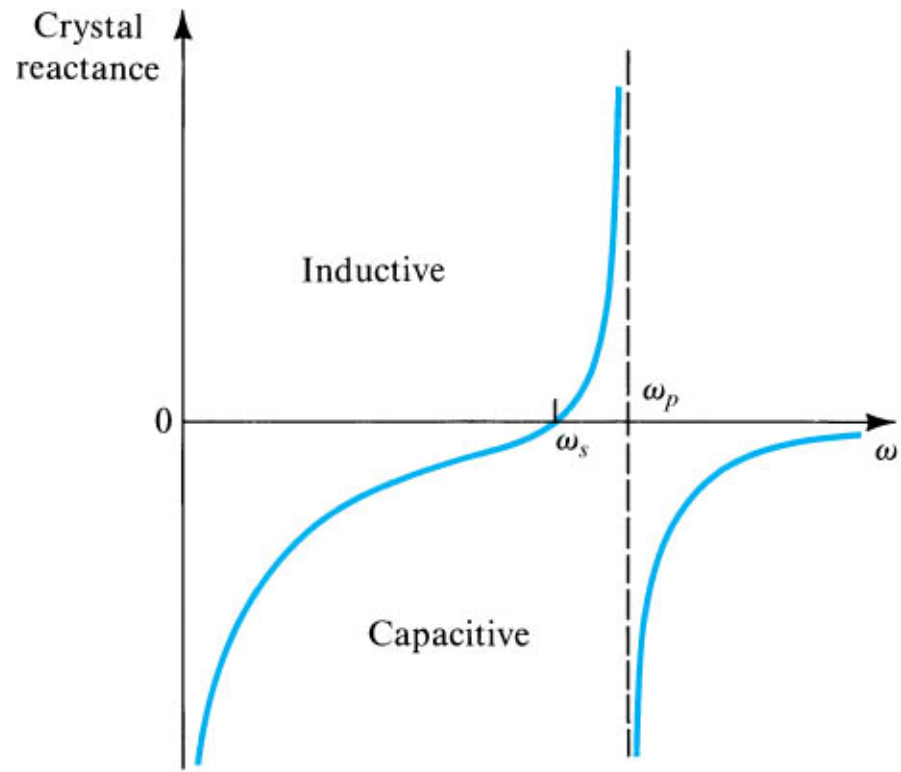
# Piezoelectric Crystal



(a)



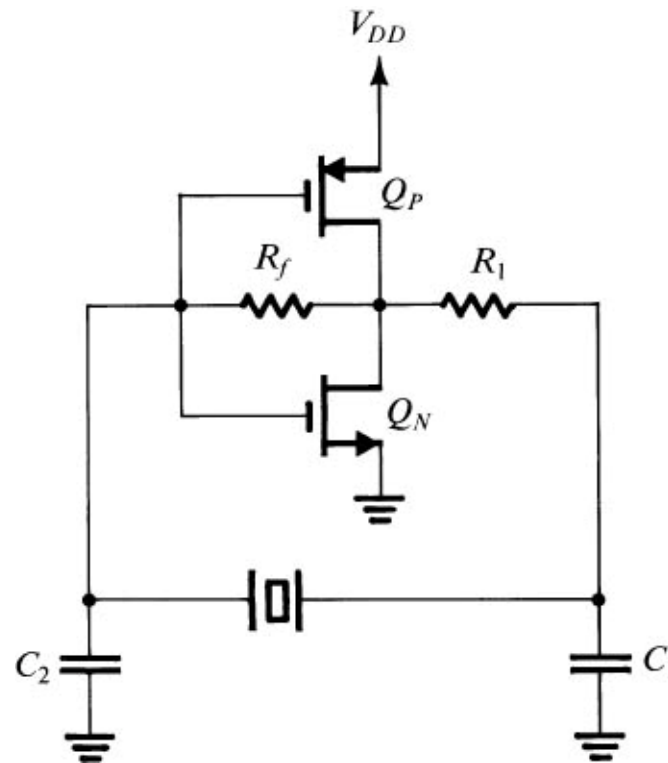
(b)



(c)

# Pierce Oscillator

CMOS inverter as an amplifier.



# Bistable Operation

