Chapter 8

Oscillator and Power Amplifier

Outline

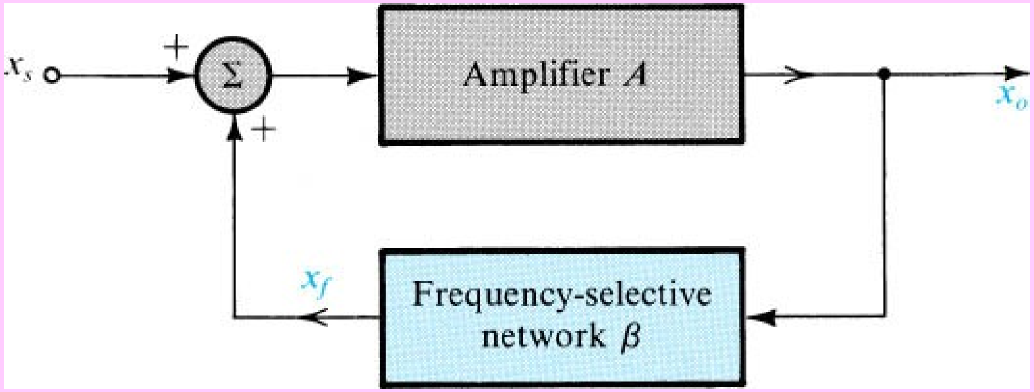
- Oscillator
- Power amplifier

Oscillator

- Basic principles of sinusoidal oscillator.
- The Wien-bridge oscillator
- The phase shift oscillator

Basic Principles of Sinusoidal Oscillator

- The oscillator feedback loop



- The basic structure of a sinusoidal oscillator.
- A positive-feedback loop is formed by an amplifier and a frequency-selective network.

Basic Principles of Sinusoidal Oscillator

- Feedback signal x_f is summed with a positive sign
- The gain-with-feedback is

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

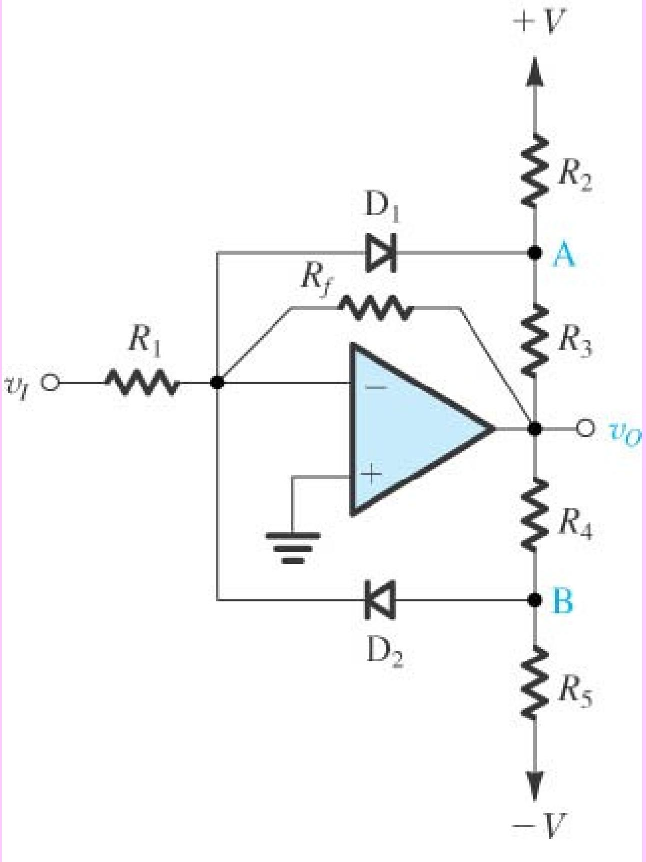
- The oscillation criterion

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

Basic Principles of Sinusoidal Oscillator

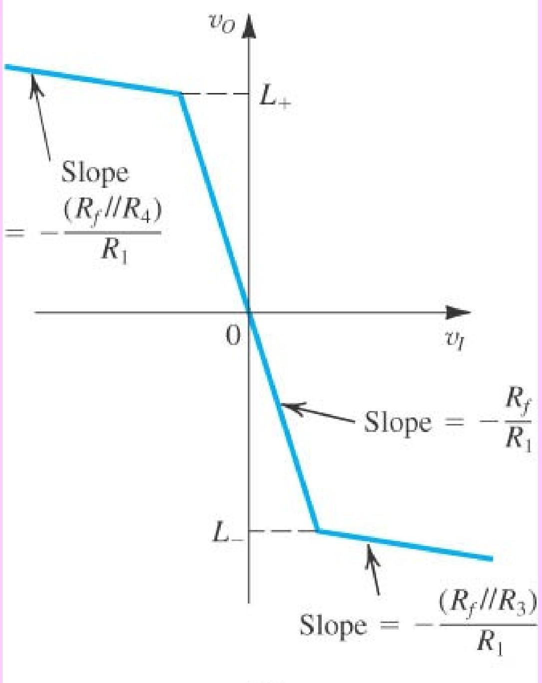
- Nonlinear amplitude control
  - To ensure that oscillations will start, the Aβ is slightly greater than unity.
  - As the power supply is turned on, oscillation will grown in amplitude.
  - When the amplitude reaches the desired level, the nonlinear network comes into action and cause the Aβ to exactly unity.

A Popular Limiter Circuit for Amplitude Control

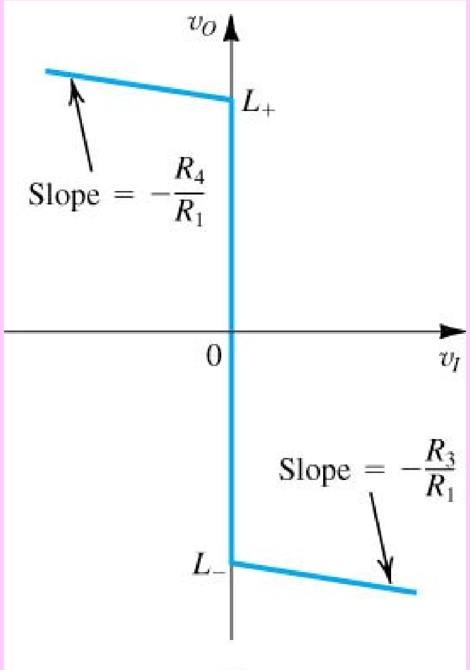


(a)

A Popular Limiter Circuit for Amplitude Control



(b)



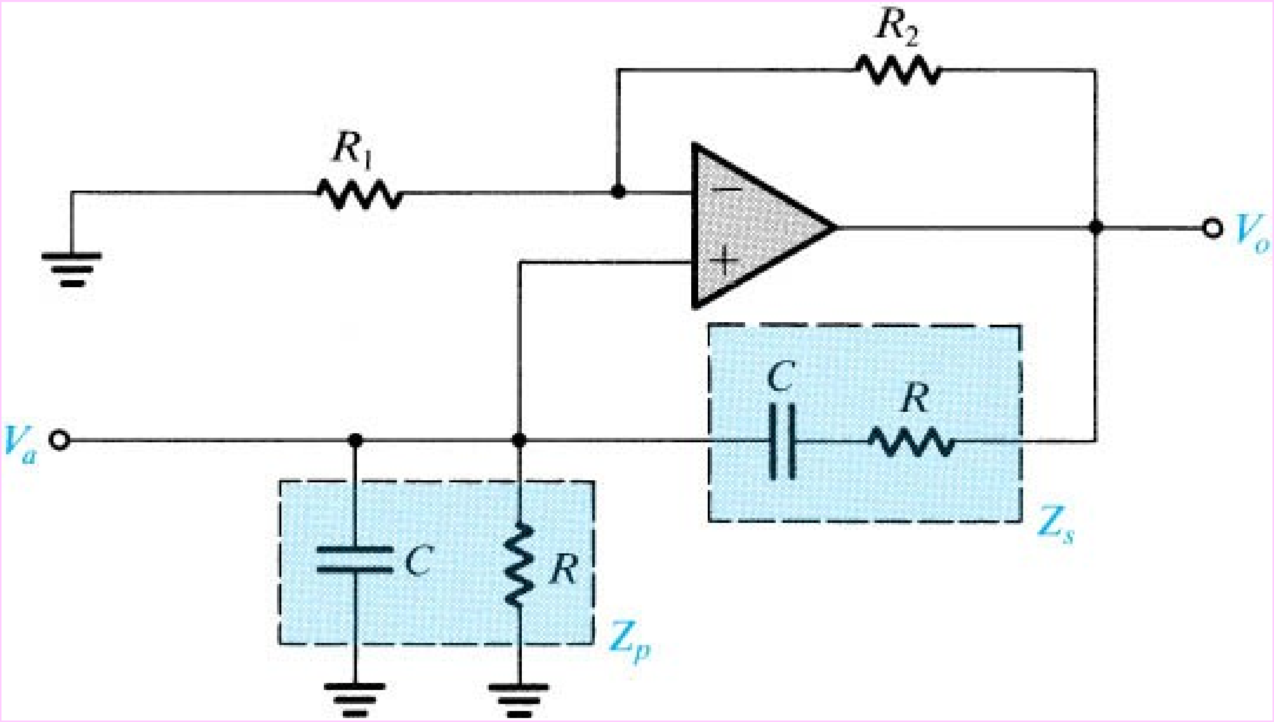
(c)

- Transfer characteristic of the limiter circuit;
- When R_f is removed, the limiter turns into a comparator with the characteristic shown.

Oscillator Circuits

- Op Amp-RC Oscillator Circuits
  - The Wien-Bridge Oscillator
  - The phase-Shift Oscillator
- LC-Tuned Oscillator
  - Colpitts oscillator
  - Hareley oscillator
- Crystal Oscillator

The Wien-Bridge Oscillator



A Wien-bridge oscillator without amplitude stabilization.

The Wien-Bridge Oscillator

- The loop gain transfer function

$$L(s) = \frac{1 + R_2/R1}{3 + sCR + 1/sCR}$$

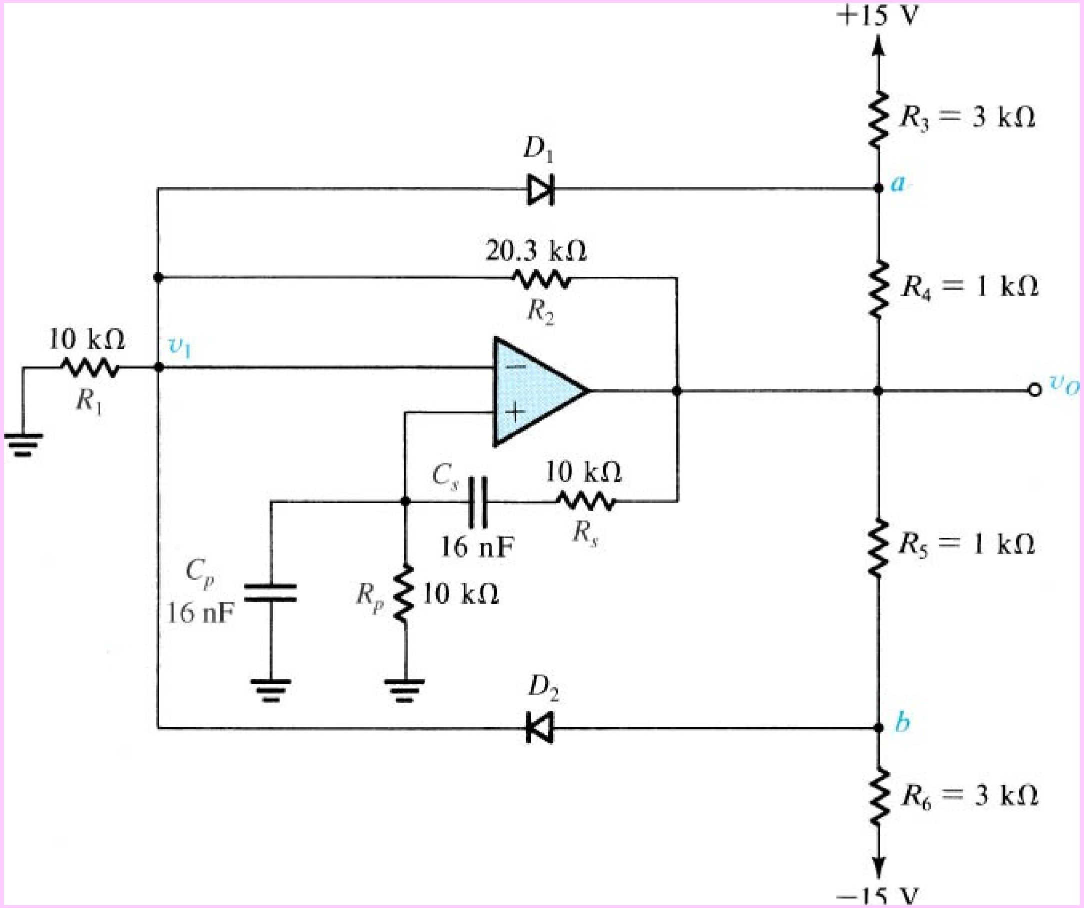
- Oscillating frequency

$$\omega_0 = 1/RC$$

- To obtain sustained oscillation

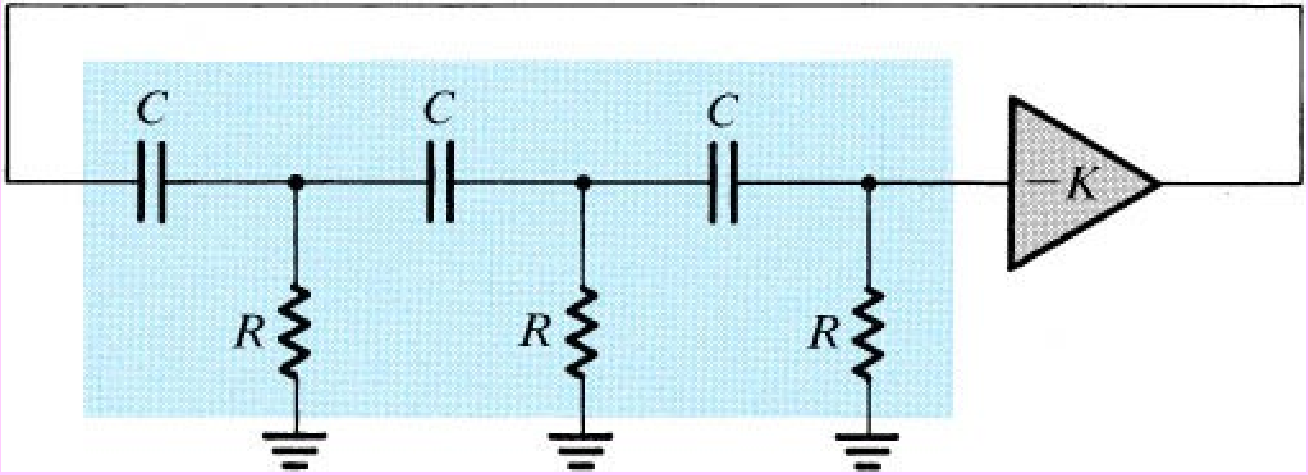
$$R_2/R_1 = 2$$

The Wien-Bridge Oscillator



A Wien-bridge oscillator with a limiter used for amplitude control.

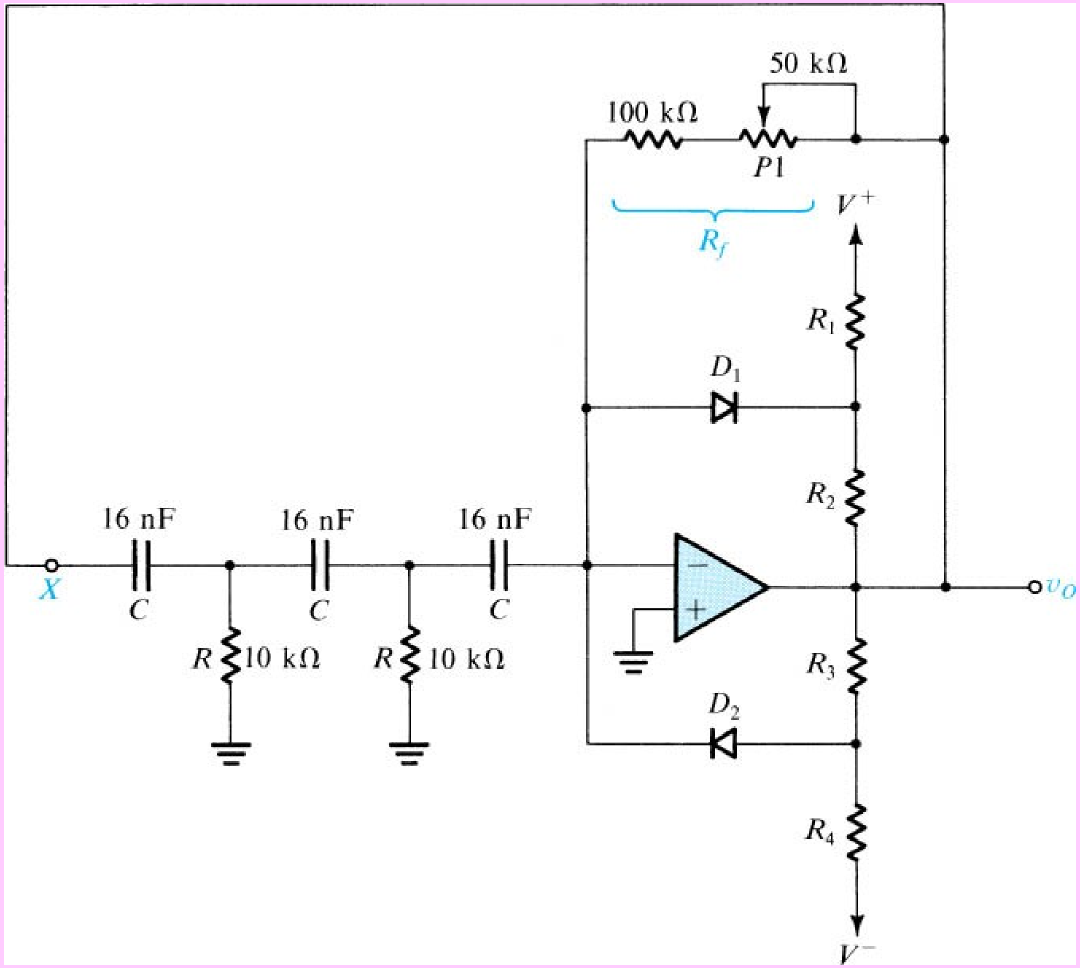
The Phase-Shift Oscillator



The circuit consists of a negative-gain amplifier and three-section RC ladder network.

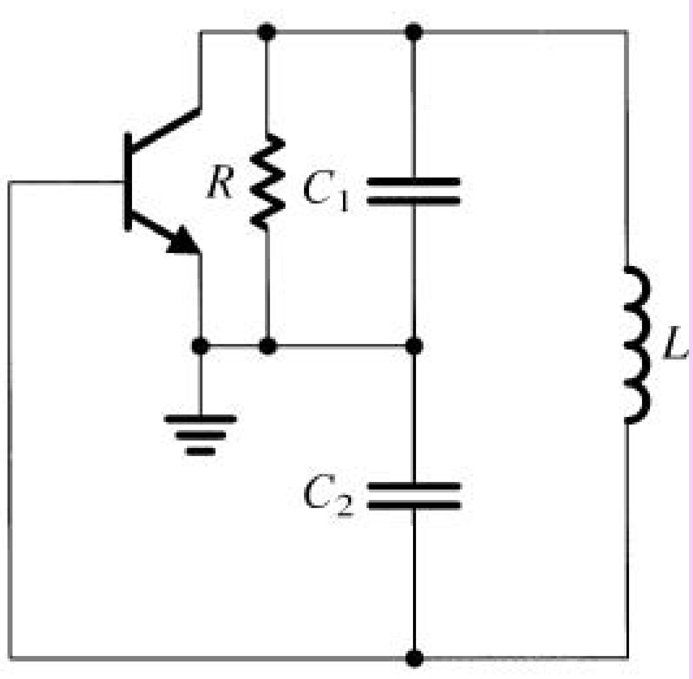
Oscillating frequency is the one that the phase shift of the RC network is 180^0

The Phase-Shift Oscillator



A practical phase-shift oscillator with a limiter for amplitude stabilization.

The LC-Tuned oscillator

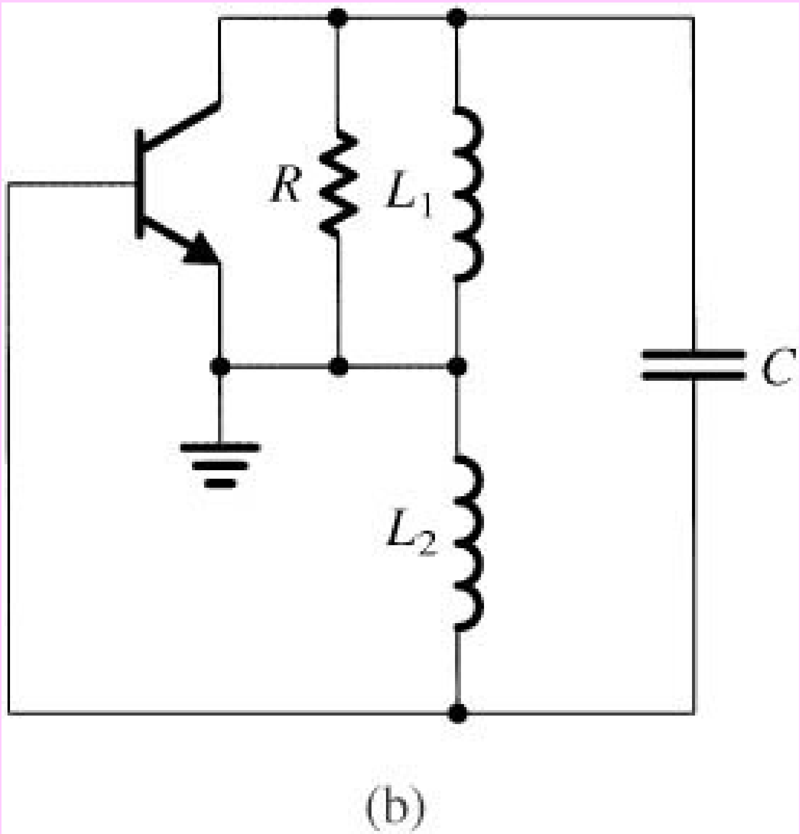


(a)

- Colpitts Oscillator
- A parallel LC resonator connected between collector and base.
- Feedback is achieved by way of a capacitive divider
- Oscillating frequency is determined by the resonance frequency.

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

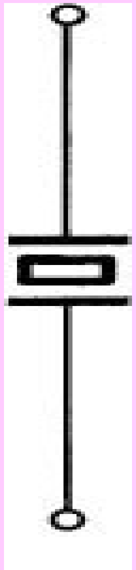
The LC-Tuned oscillator



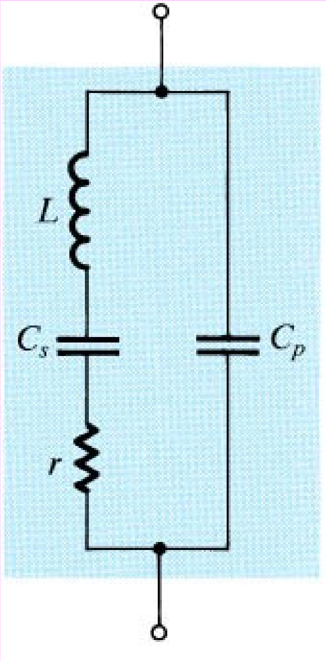
- Hartley Oscillator
- A parallel LC resonator connected between collector and base.
- Feedback is achieved by way of an inductive divider.
- Oscillating frequency is determined by the resonance frequency.

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

Crystal Oscillators



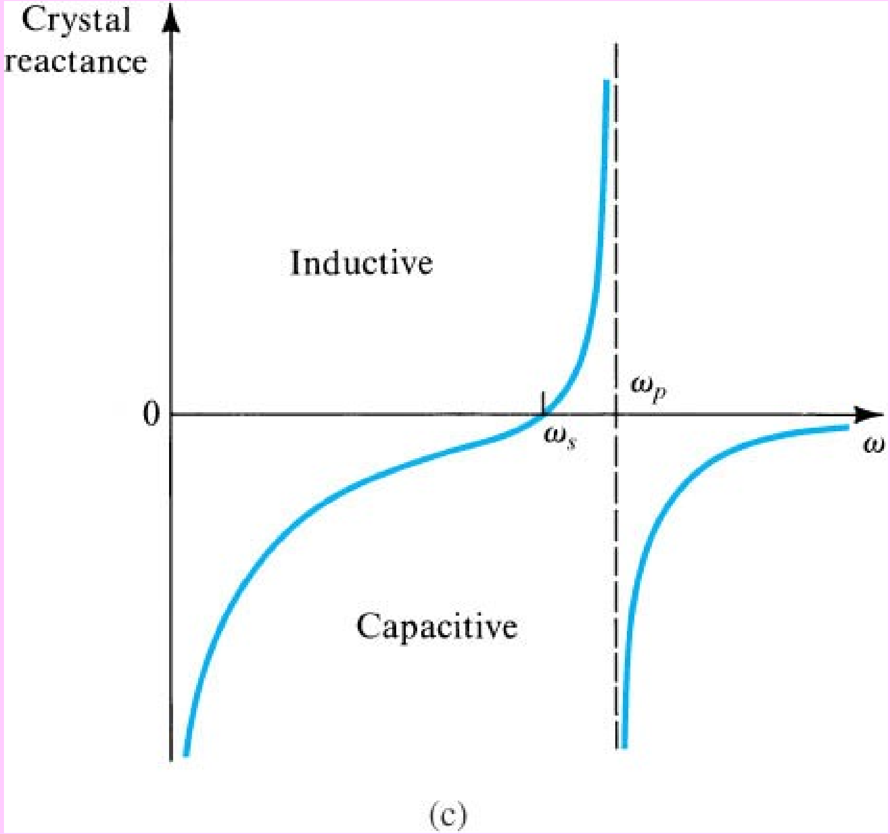
(a)



(b)

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

Crystal Oscillators



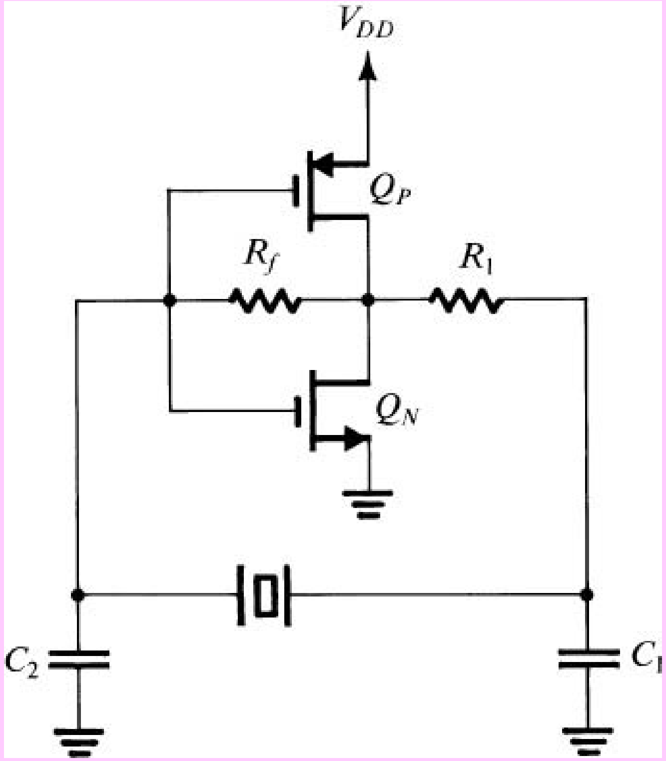
- Crystal reactance versus frequency (neglecting the small resistance *r*,).
- A series resonance at

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

- A parallel resonance at

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

Crystal Oscillators



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

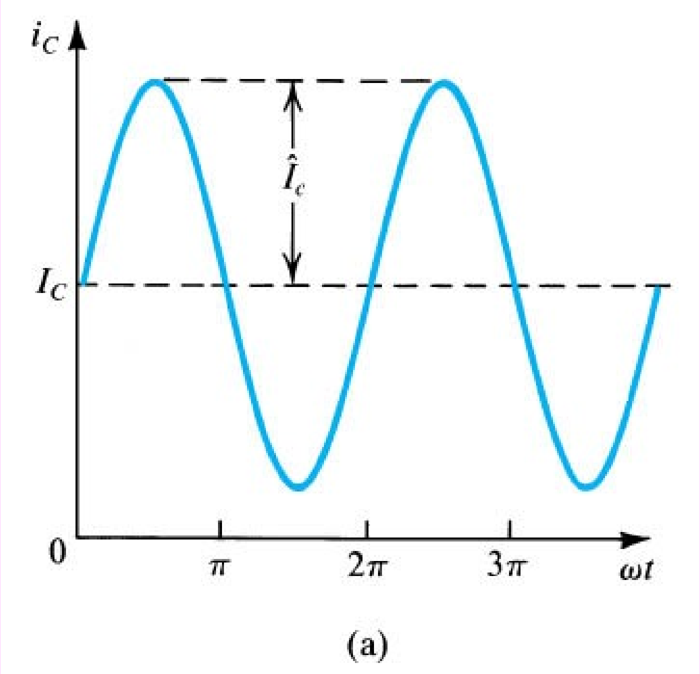
Power Amplifier

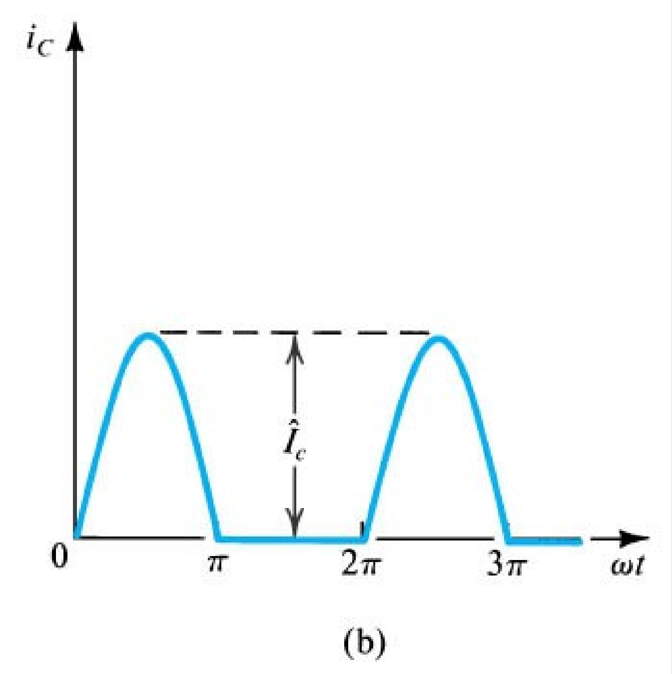
- Small-signal approximation and models either are not applicable or must be used with care.
- Deliver the power to the load in *efficient* manner.
- Power dissipation is as low as possible.

Classification of Power Amplifier

- Power amplifiers are classified according to the collector current waveform that results when an input signal is applied.
- Conducting angle.

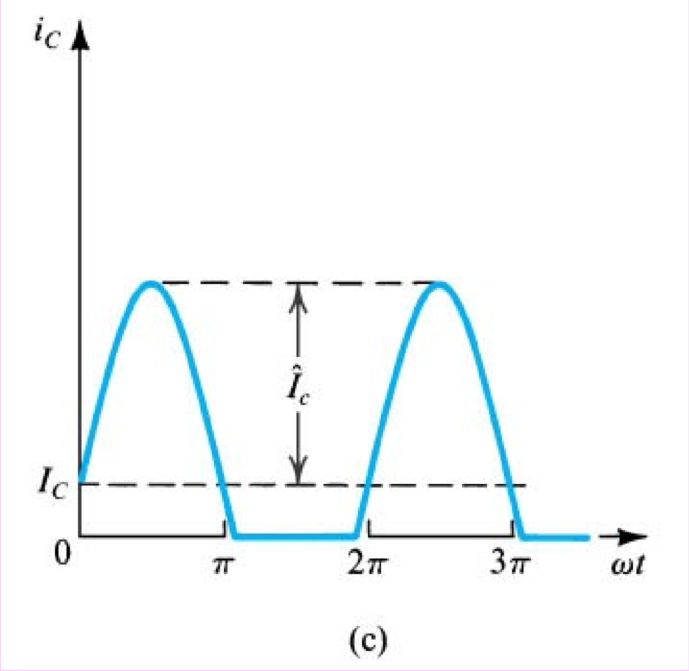
Classification of Power Amplifier

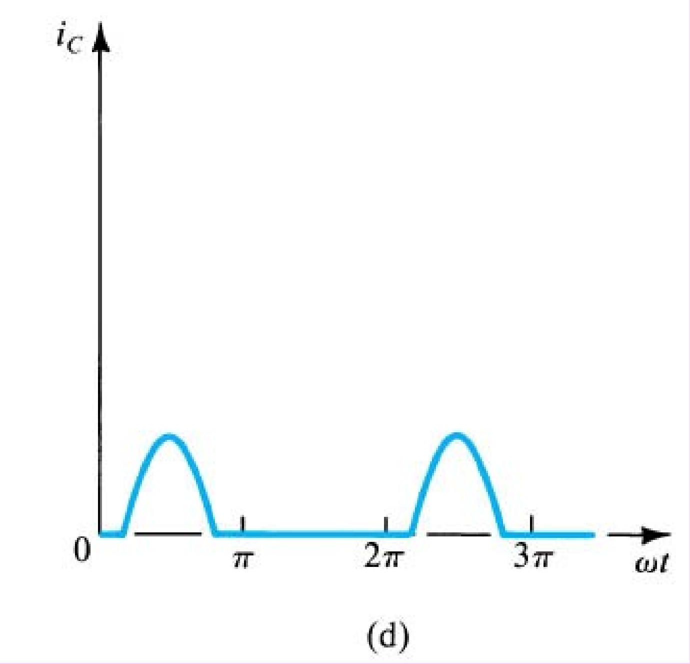




Collector current waveforms for transistors operating in **(a)** class A, **(b)** class B

Classification of Power Amplifier

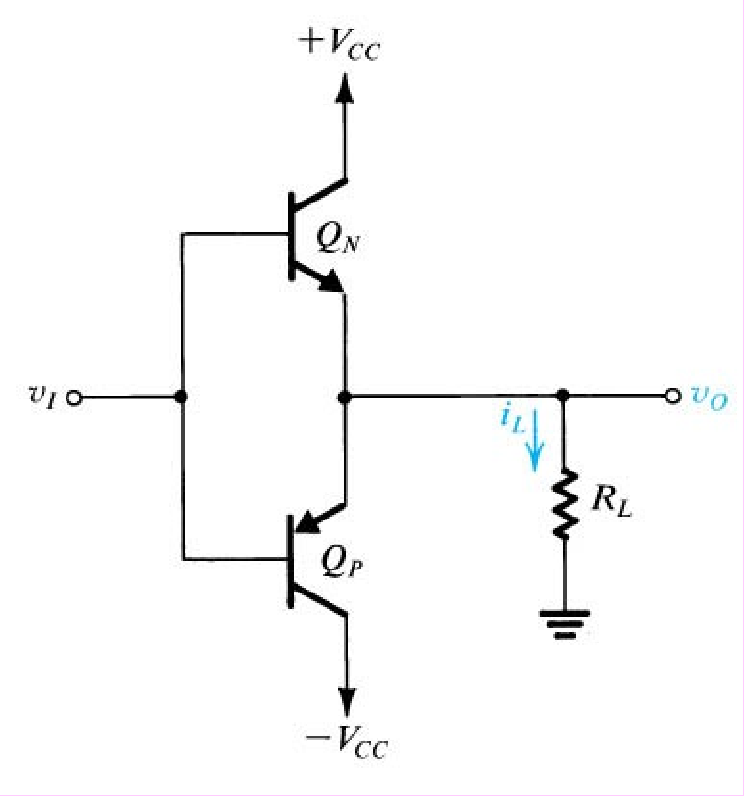




class AB

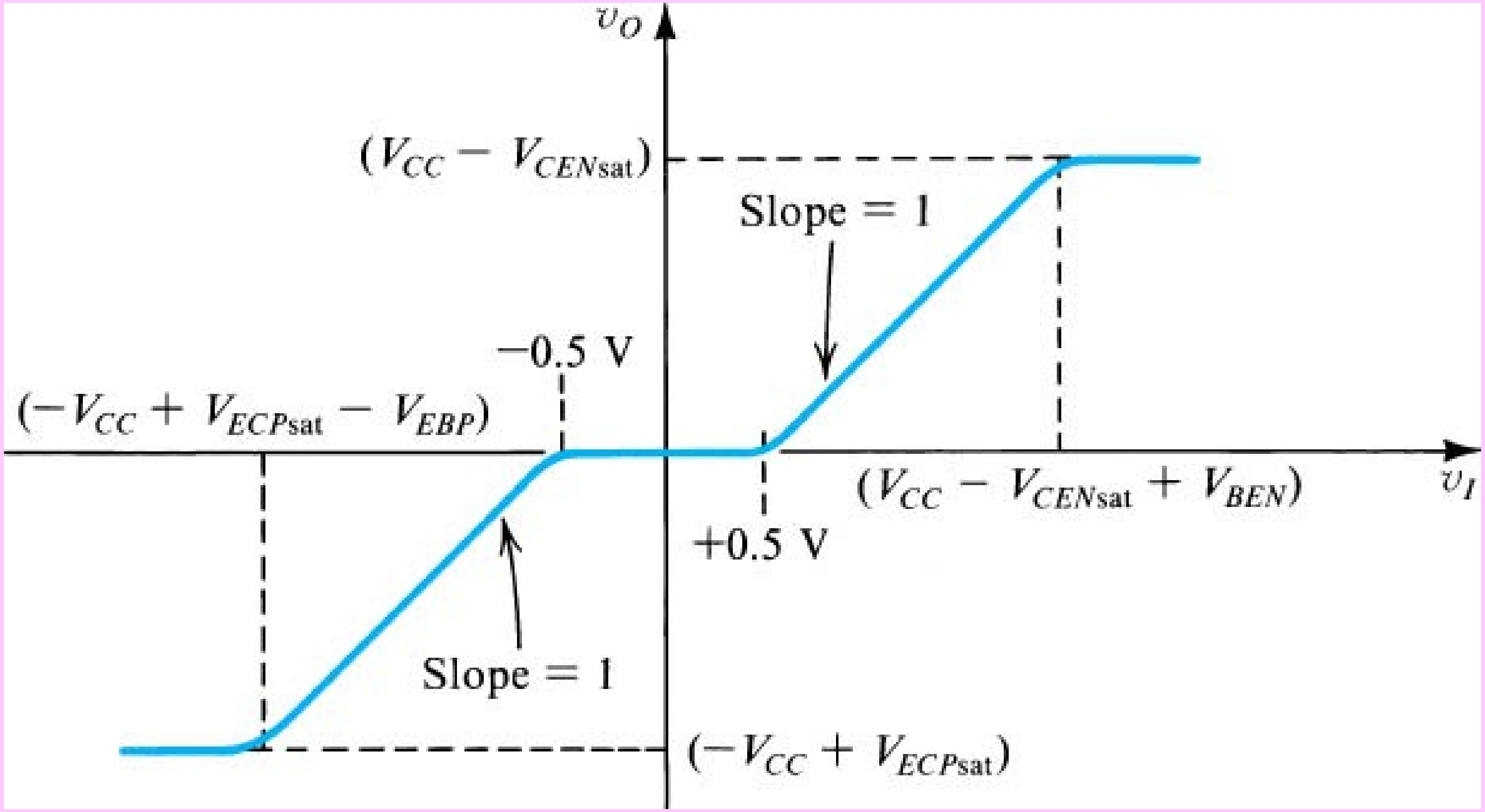
class C

Class B Output Stage

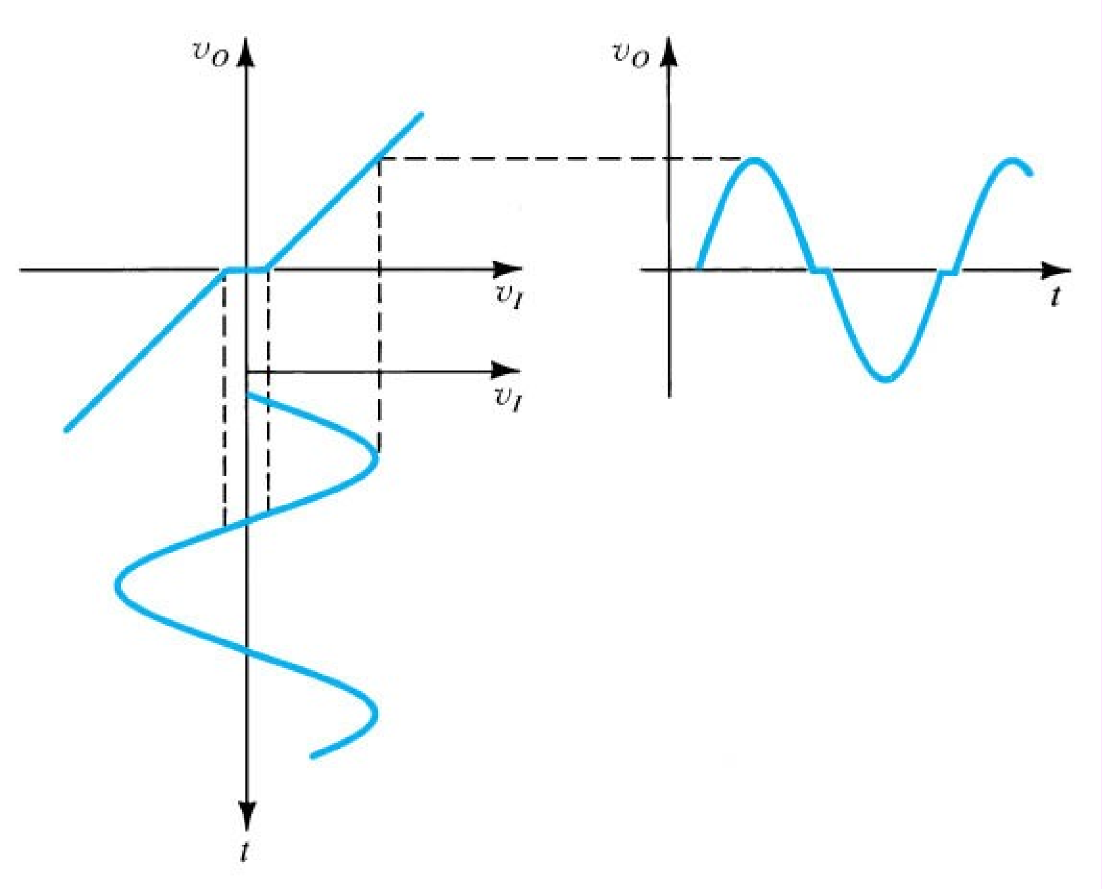


- A class B output stage.
- Complementary circuits.
- Push-pull operation
- Maximum power-conversion efficiency is 78.5%

Transfer Characteristic



Crossover Distortion



Power Dissipation

- The load power

$$P_L = \frac{1}{2}\frac{\hat{V}_o^{\,2}}{R_L}$$

- Maximum load power

$$P_{L\max} = \frac{1}{2}\frac{\hat{V}_o^{\,2}}{R_L}\bigg|_{\hat{V}_o = V_{CC}} = \frac{V_{CC}^{\,2}}{2R_L}$$

Power Dissipation

- Total supply power

$$P_s = \frac{2}{\pi}\frac{\hat{V}_o}{R_L}V_{CC}$$

- Maximum total supply power

$$P_{s\max} = \frac{2}{\pi}\frac{\hat{V}_o}{R_L}V_{CC}\Bigg|_{\hat{V}_o = V_{CC}} = \frac{2}{\pi}\frac{V_{CC}{}^2}{R_L}$$

Power Dissipation

- Power-conversion efficiency

$$\eta = \frac{\pi}{4}\frac{\hat{V}_o}{V_{CC}}$$

- Maximum power-conversion efficiency

$$\eta_{\max} = \frac{\pi}{4}\frac{\hat{V}_o}{V_{CC}}\bigg|_{\hat{V}_o = V_{CC}} = 78.5\%$$

Power Dissipation

- Power dissipation

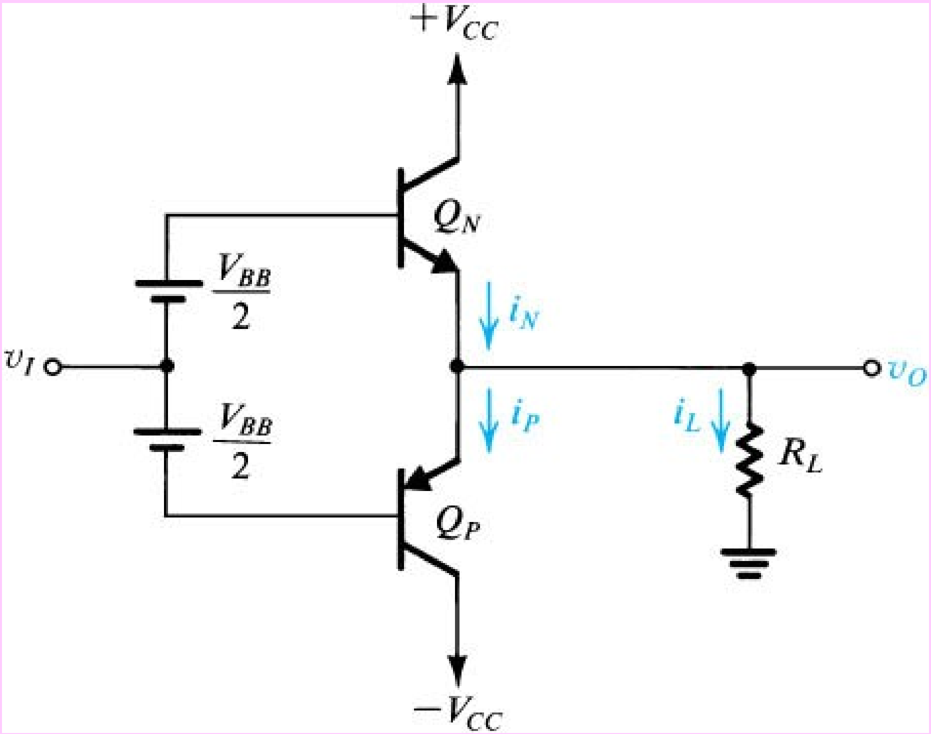
$$P_D = \frac{2}{\pi}\frac{\hat{V}_o}{R_L}V_{CC} - \frac{1}{2}\frac{\hat{V}_o^{\,2}}{R_L}$$

- Maximum Power dissipation

$$P_{DN\max} = P_{DP\max} = \left.\frac{2}{\pi}\frac{\hat{V}_o}{R_L}V_{CC} - \frac{1}{2}\frac{\hat{V}_o^{\,2}}{R_L}\right|_{\hat{V}_o=\frac{2}{\pi}V_{CC}}$$

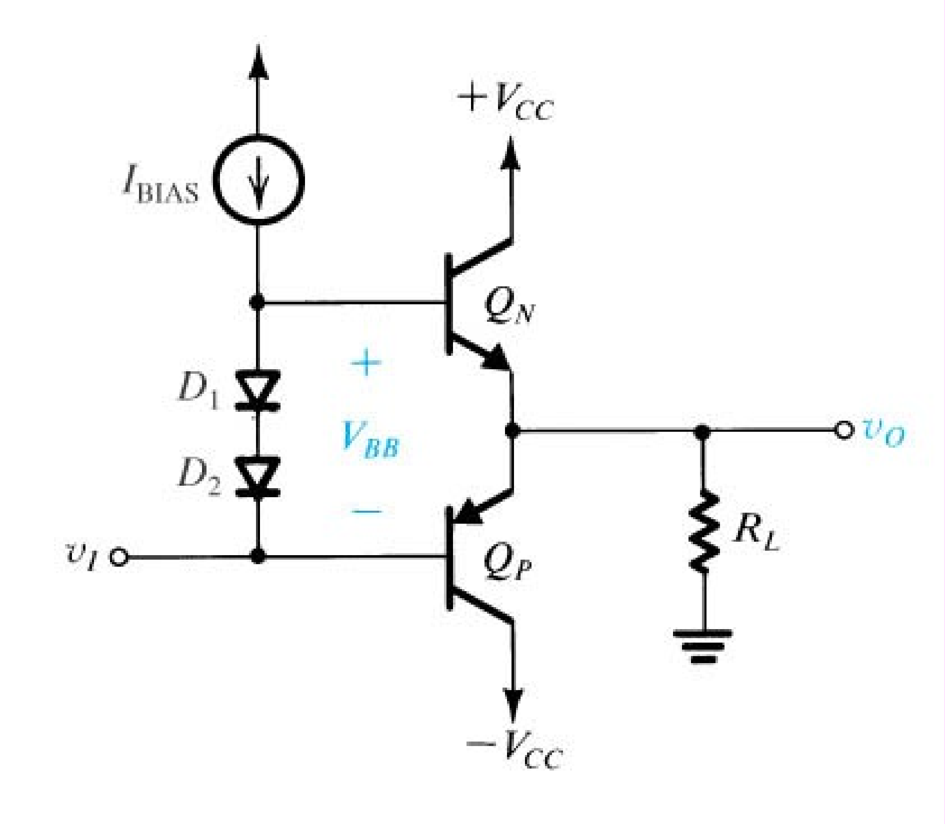
$$= \frac{2V_{CC}^{\,2}}{\pi^2 R_L} = 0.2P_{L\max}$$

Class AB Output Stage



A bias voltage V_{BB} is applied between the bases of Q_N and Q_P, giving rise to a bias current I_Q . Thus, for small v_I, both transistors conduct and crossover distortion is almost completely eliminated.

A Class AB Output Stage Utilizing Diodes for Biasing



A Class AB Output Stage Utilizing A V_{BE} Multiplier for Biasing