ECE 312
Electronic Circuits (A)

Lec. 15: Power Amplifiers

Instructor

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Agenda

- Introduction
- Class A Amplifier
- Class B Amplifier
- Class C Amplifier
- Class D Amplifier

Power Amplifier

- In small-signal amplifiers, the main factors are usually amplification linearity and magnitude of gain.

- Large-signal or power amplifiers, on the other hand, primarily provide sufficient power to an output load to drive a speaker or other power device, typically a few watts to tens of watts.

- The main features of a large-signal amplifier are the circuit's power efficiency, the maximum amount of power that the circuit is capable of handling, and the impedance matching to the output device.

- Amplifier classes represent the amount the output signal varies over one cycle of operation for a full cycle of input signal.

Amplifier Classes

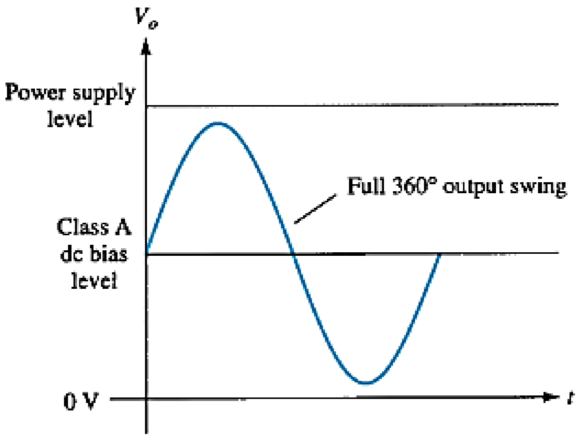
1. **Class A**: The output signal varies for a full 360° of the input signal.

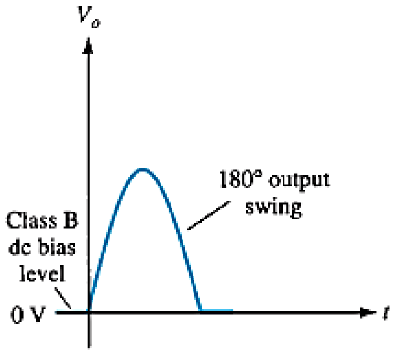
2. **Class B**: provides an output signal varying over one-half the input signal cycle, or for 180° of signal.

3. **Class AB**: An amplifier may be biased at a dc level above the zero-base-current level of class B and above one-half the supply voltage level of class A.

4. **Class C:** The output of a class C amplifier is biased for operation at less than 180° of the cycle and will operate only with a tuned (resonant) circuit, which provides a full cycle of operation for the tuned or resonant frequency.

5. **Class D:** This operating class is a form of amplifier operation using pulse (digital) signals, which are on for a short interval and off for a longer interval.





Amplifier Efficiency

- The **power efficiency** of an amplifier, defined as the ratio of power output to power input, improves (gets higher) going from class A to class D.

TABLE 12.1
Comparison of Amplifier Classes

	Class				
	A	**AB**	**B**	**C**[a]	**D**
Operating cycle	360°	180° to 360°	180°	Less than 180°	Pulse operation
Power efficiency	25% to 50%	Between 25% (50%) and 78.5%	78.5%		Typically over 90%

[a]*Class C is usually not used for delivering large amounts of power, and thus the efficiency is not given here.*

SERIES-FED CLASS A AMPLIFIER

- DC Bias Operation

$$I_B = \frac{V_{CC} - 0.7\text{ V}}{R_B}$$

$$I_C = \beta I_B$$

$$V_{CE} = V_{CC} - I_C R_C$$

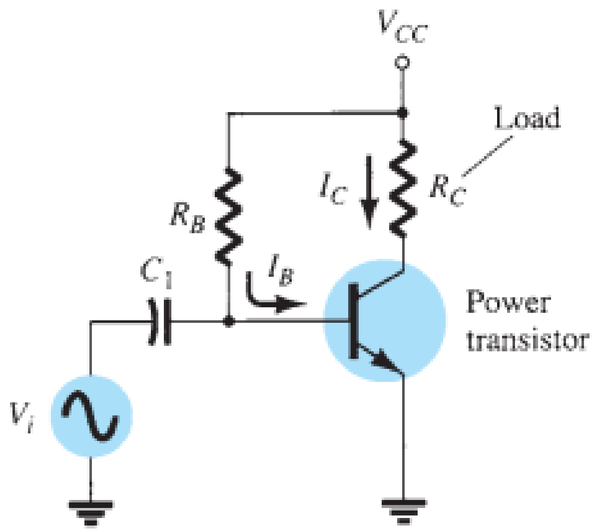
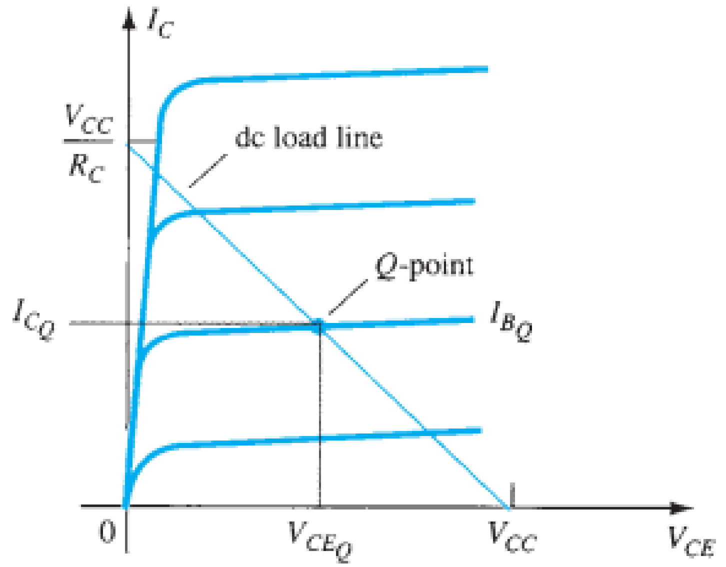


FIG. 12.2
Series-fed class A large-signal amplifier.



SERIES-FED CLASS A AMPLIFIER

- AC Operation

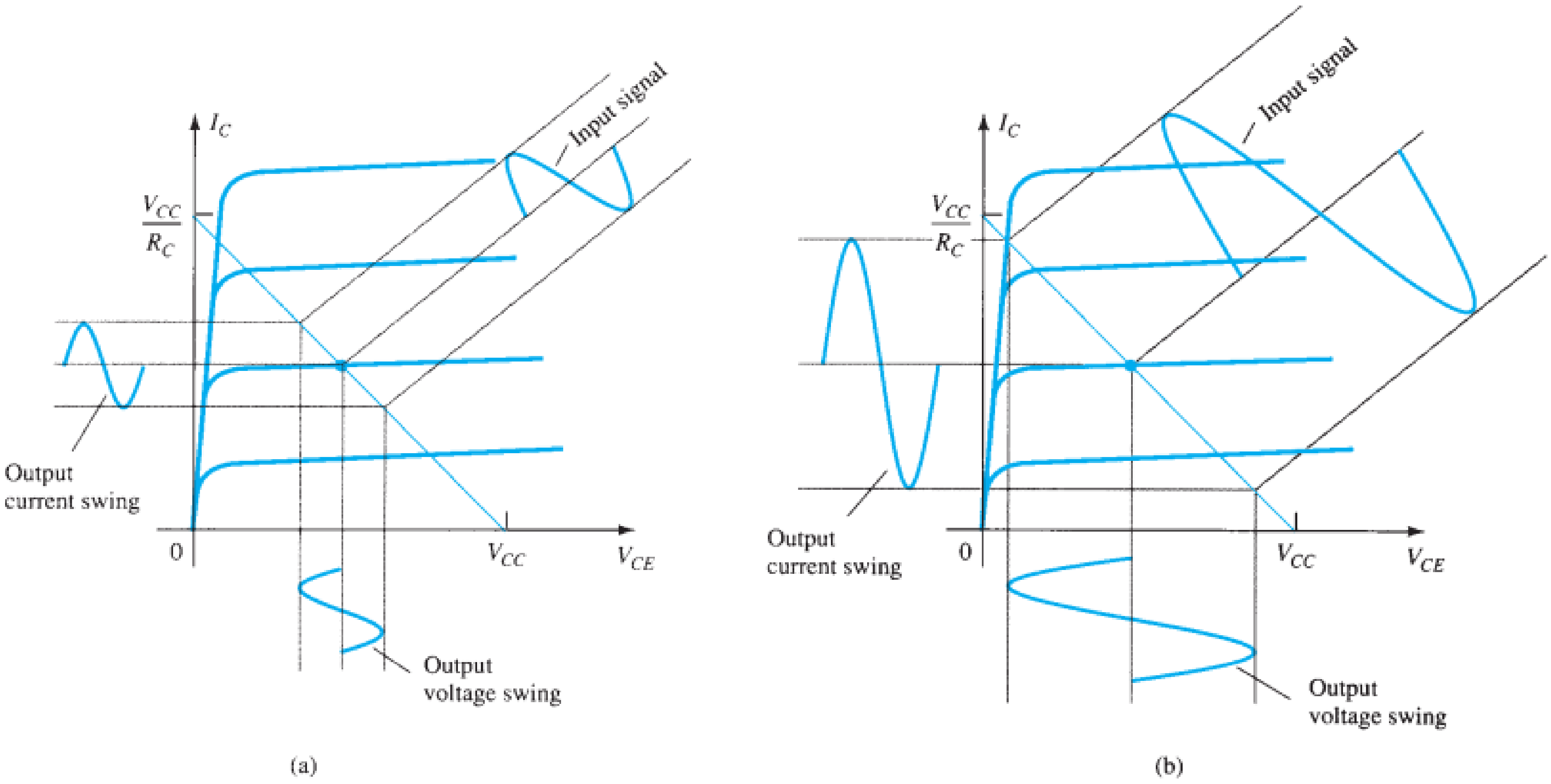


FIG. 12.4
Amplifier input and output signal variation.

Power Considerations

- The power drawn from the supply is

$$P_i(\text{dc}) = V_{CC} I_{C_Q}$$

- Output Power

$$P_o(\text{ac}) = V_{CE}(\text{rms}) I_C(\text{rms})$$

$$P_o(\text{ac}) = I_C^2(\text{rms}) R_C$$

$$P_o(\text{ac}) = \frac{V_C^2(\text{rms})}{R_C}$$

- Efficiency

$$\% \eta = \frac{P_o(\text{ac})}{P_i(\text{dc})} \times 100\%$$

- Maximum Efficiency

$$\text{maximum } V_{CE}(\text{p-p}) = V_{CC}$$

$$\text{maximum } I_C(\text{p-p}) = \frac{V_{CC}}{R_C}$$

$$\text{maximum } P_o(\text{ac}) = \frac{V_{CC}(V_{CC}/R_C)}{8} = \frac{V_{CC}^2}{8R_C}$$

$$\text{maximum } P_i(\text{dc}) = V_{CC}(\text{maximum } I_C) = V_{CC}\frac{V_{CC}/R_C}{2} = \frac{V_{CC}^2}{2R_C}$$

$$\text{maximum } \% \eta = \frac{\text{maximum } P_o(\text{ac})}{\text{maximum } P_i(\text{dc})} \times 100\% = \frac{V_{CC}^2/8R_C}{V_{CC}^2/2R_C} \times 100\% = 25\%$$

N.B.:

$$V_{\text{RMS}} = \frac{V_{\text{P}}}{\sqrt{2}}$$

EXAMPLE 12.1 Calculate the input power, output power, and efficiency of the amplifier circuit in Fig. 12.5 for an input voltage that results in a base current of 10 mA peak.

Solution: Using Eqs. (12.1) through (12.3), we can determine the Q-point to be

$$I_{B_Q} = \frac{V_{CC} - 0.7\text{ V}}{R_B} = \frac{20\text{ V} - 0.7\text{ V}}{1\text{ k}\Omega} = 19.3\text{ mA}$$

$$I_{C_Q} = \beta I_B = 25(19.3\text{ mA}) = 482.5\text{ mA} \cong 0.48\text{ A}$$

$$V_{CE_Q} = V_{CC} - I_C R_C = 20\text{ V} - (0.48\ \Omega)(20\ \Omega) = 10.4\text{ V}$$

This bias point is marked on the transistor collector characteristic of Fig. 12.5b. The ac variation of the output signal can be obtained graphically using the dc load line drawn on Fig. 12.5b by connecting $V_{CE} = V_{CC} = 20$ V with $I_C = V_{CC}/R_C = 1000$ mA $= 1$ A, as shown. When the input ac base current increases from its dc bias level, the collector current rises by

$$I_C(\text{p}) = \beta I_B(\text{p}) = 25(10\text{ mA peak}) = 250\text{ mA peak}$$

Using Eq. (12.6) yields

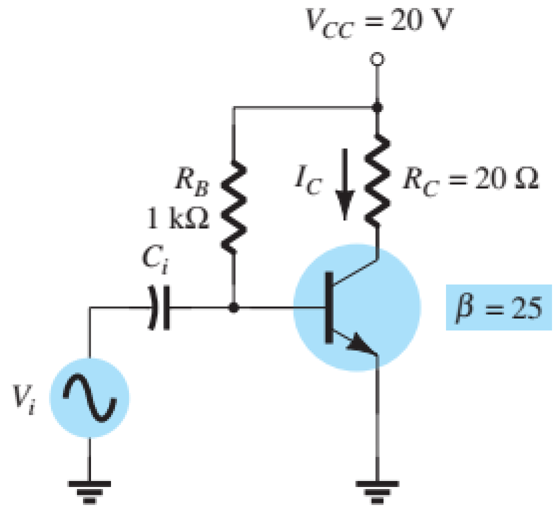
$$P_o(\text{ac}) = I_C^2(rms)R_C = \frac{I_C^2(\text{p})}{2}R_C = \frac{(250 \times 10^{-3}\text{ A})^2}{2}(20\ \Omega) = \mathbf{0.625\ W}$$

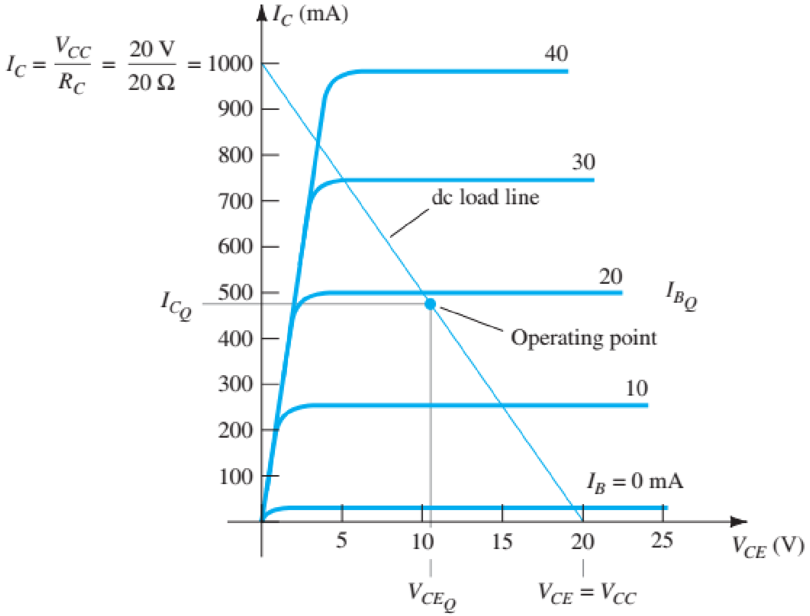
Using Eq. (12.4) results in

$$P_i(\text{dc}) = V_{CC}I_{C_Q} = (20\text{ V})(0.48\text{ A}) = \mathbf{9.6\ W}$$

The amplifier's power efficiency can then be calculated using Eq. (12.8):

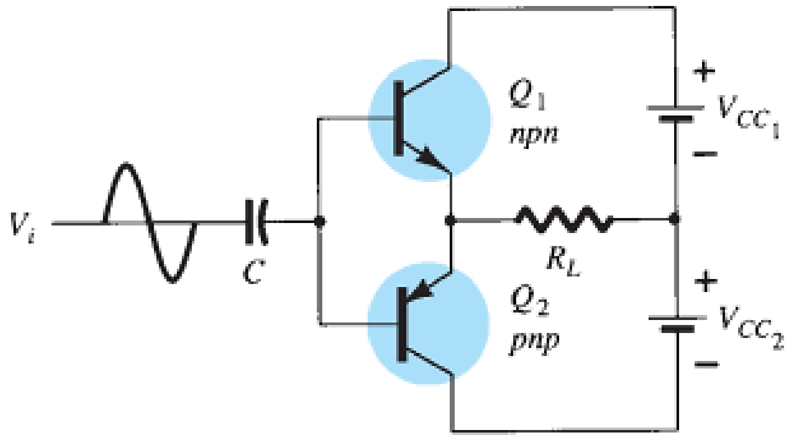
$$\%\ \eta = \frac{P_o(\text{ac})}{P_i(\text{dc})} \times 100\% = \frac{0.625\text{ W}}{9.6\text{ W}} \times 100\% = \mathbf{6.5\%}$$

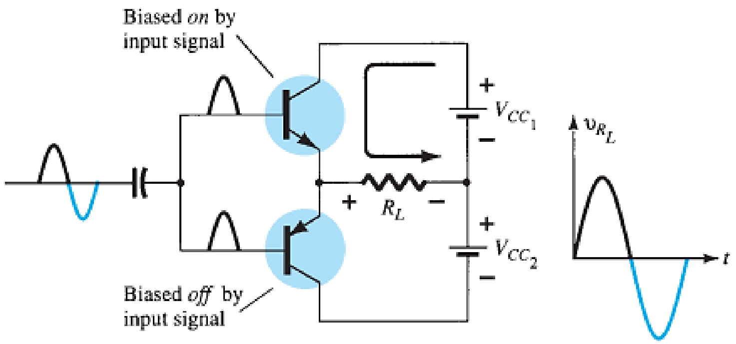


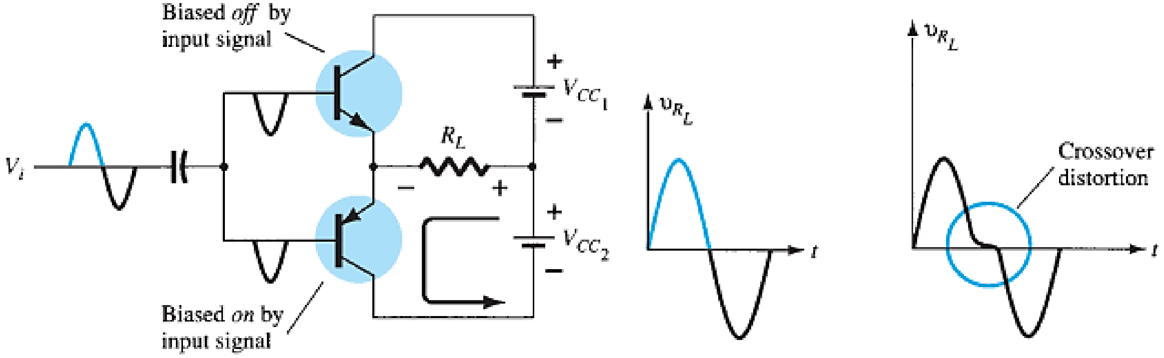


Class B Amplifier

- Class B operation is provided when the dc bias leaves the transistor biased just off, the transistor turning on when the ac signal is applied.
- To obtain output for the full cycle of signal, it is necessary to use two transistors and have each conduct on opposite half-cycles, the combined operation providing a full cycle of output signal. (push–pull operation)







Biasing the transistors in class AB improves this operation

Class C Amplifier

- Class C amplifiers, although not used as audio amplifiers, do find use in tuned circuits as in communications.

- The tuned circuit in the output, however, will provide a full cycle of output signal for the fundamental or resonant frequency of the tuned circuit (L and C tank circuit) of the output.

- This type of operation is therefore limited to use at one fixed frequency, as occurs in a communications circuit

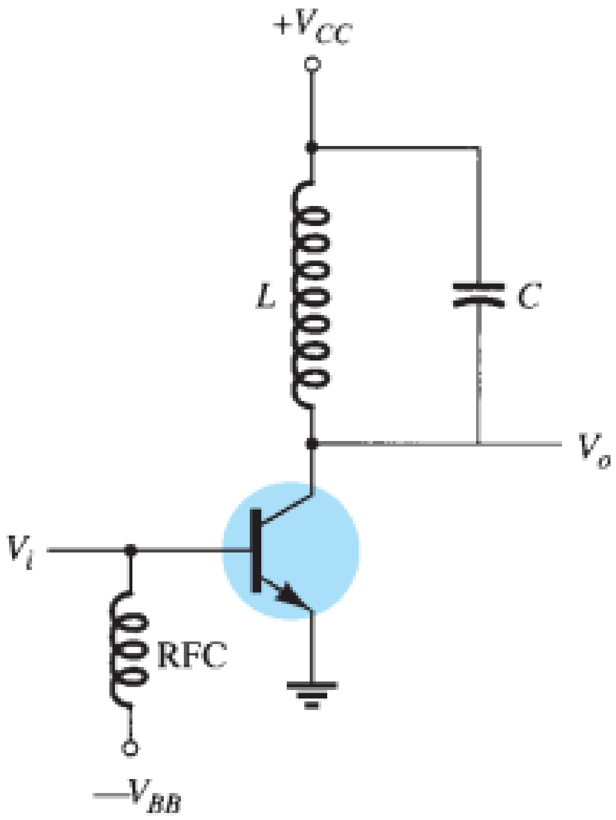


FIG. 12.25
Class C amplifier circuit.

Class D Amplifier

- Class D amplifier is designed to operate with digital or pulse-type signals.
- An efficiency of over 90% is achieved, making it desirable in power amplifiers.
- It is necessary to convert any input signal into a pulse-type waveform before using it to drive a large power load and to convert the signal back into a sinusoidal-type signal to recover the original signal.

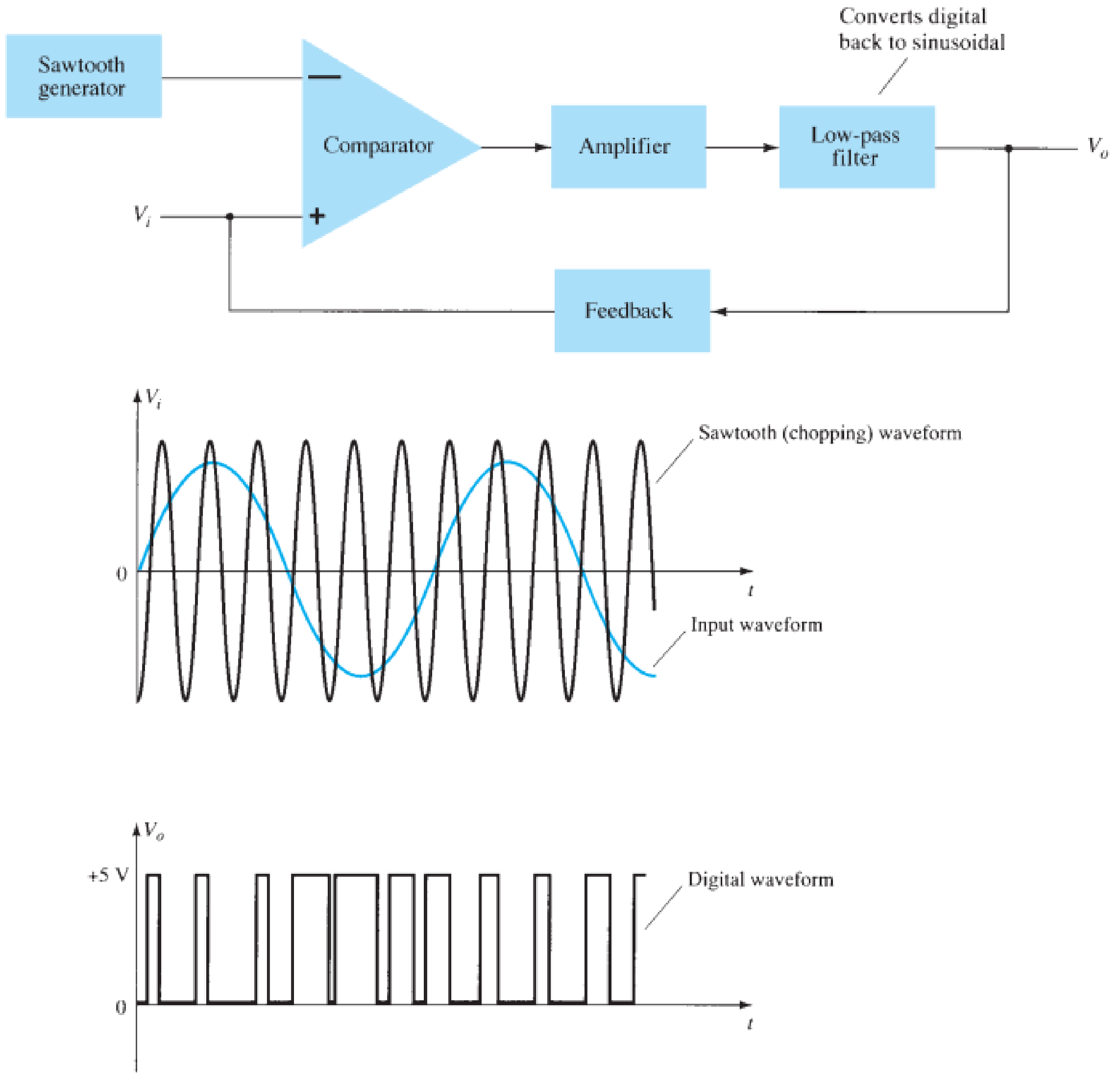


FIG. 12.26
Chopping of a sinusoidal waveform to produce a digital waveform.


Thank You!