Chapter 26

Optoelectric Devices

Objectives

- After completing this chapter, you will be able to:
  - Identify the three categories of semiconductor devices that react to light
  - Classify the major frequency ranges of light
  - Identify major light-sensitive devices and describe their operation and applications

Objectives (cont'd.)

- Identify major light-emitting devices and describe their operation and applications
- Draw and label the schematic symbols associated with optoelectric devices
- Identify packages used for optoelectric devices

Basic Principles of Light

- Light
  - Electromagnetic radiation visible to human eye
  - Frequency range
    - 300 to 300,000,000 gigahertz
  - Visible region
    - 400,000 to 750,000 gigahertz

Light-Sensitive Devices

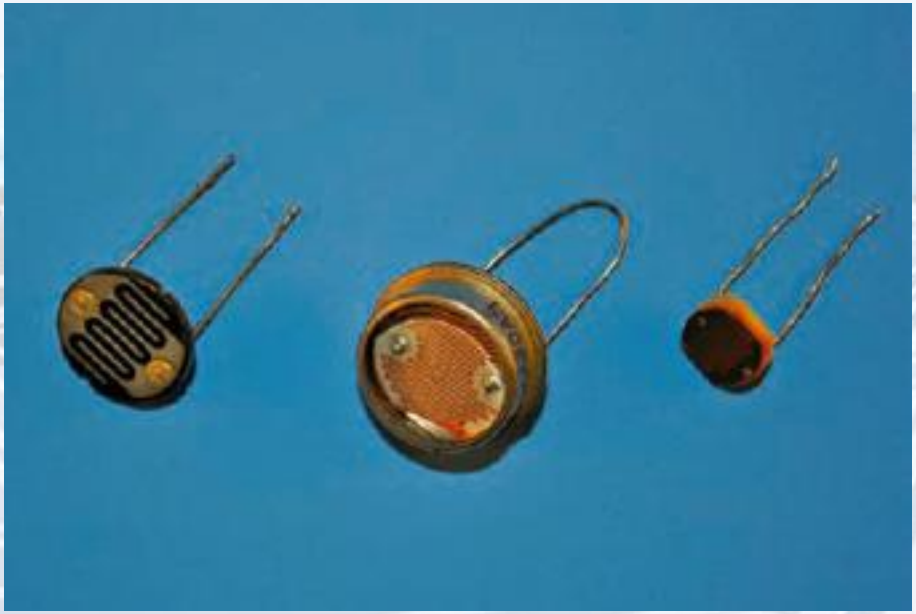
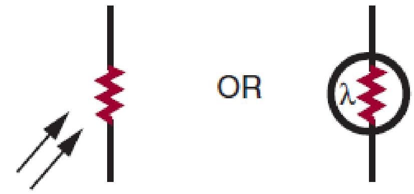


Figure 26-1. Photo cell.

FIGURE 26–2

Schematic symbols for a photo cell.



Light-Sensitive Devices (cont'd.)

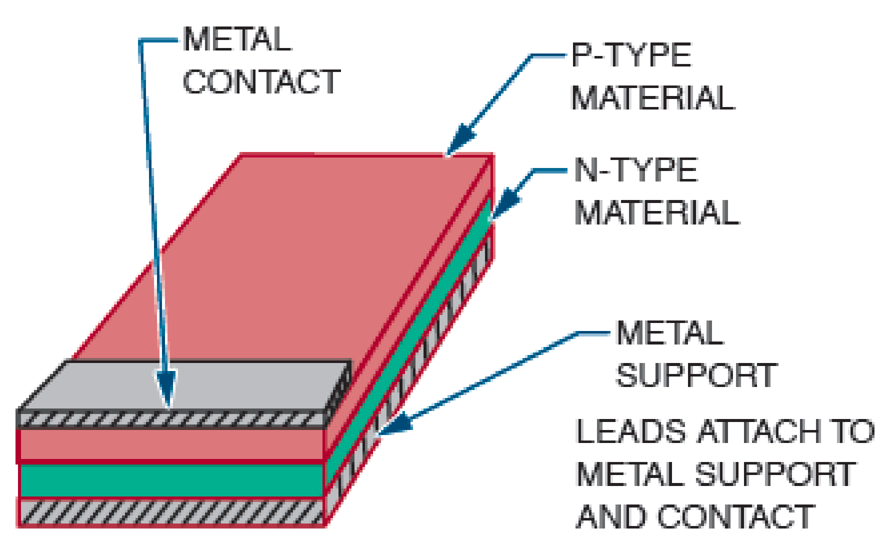


Figure 26-3. Construction of a solar cell.

Light-Sensitive Devices (cont'd.)

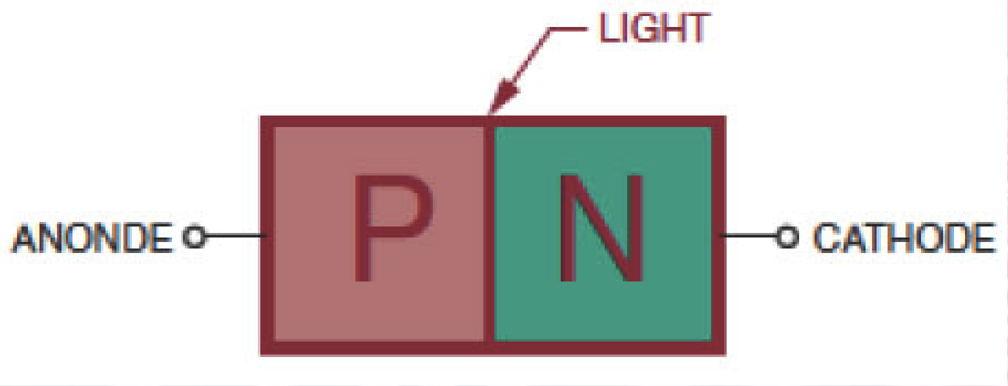


Figure 26-5. PN junction photodiode.

Light-Sensitive Devices (cont'd.)

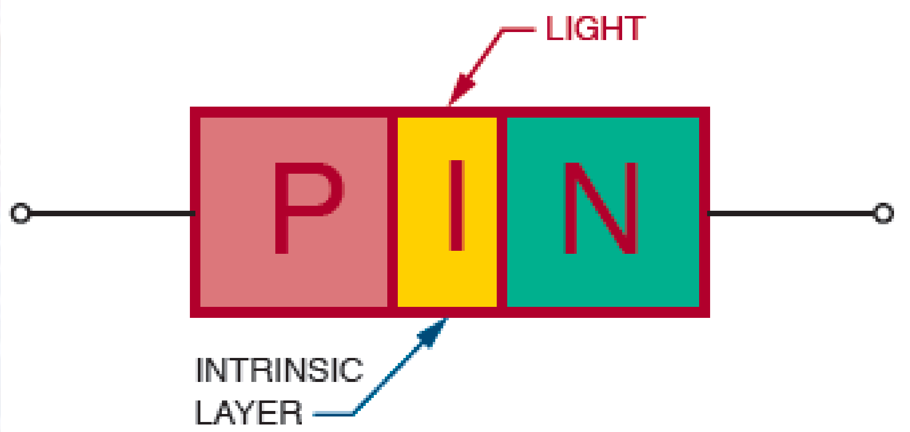


Figure 26-6. PIN junction photodiode.

Light-Sensitive Devices (cont'd.)

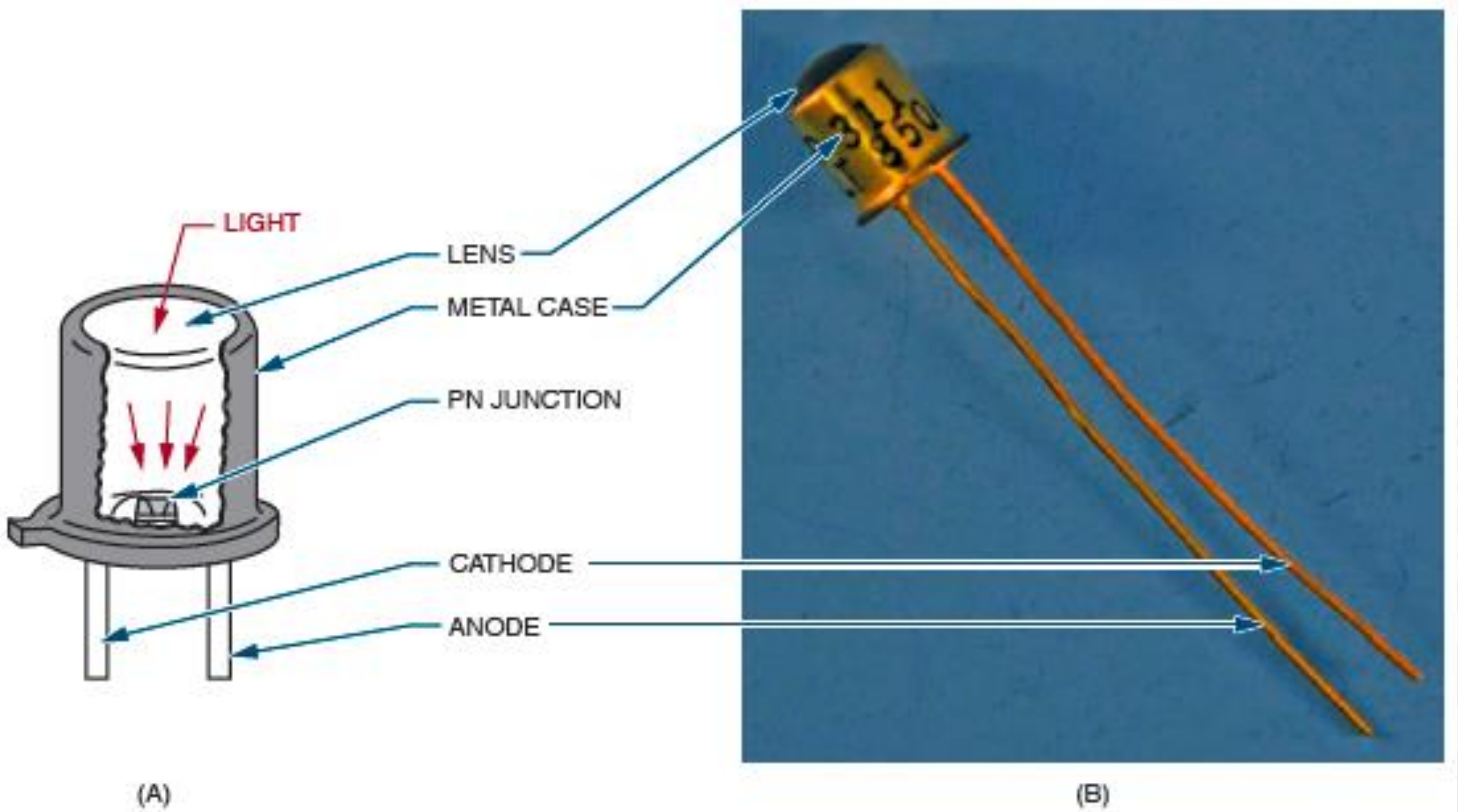


Figure 26-7. Photodiode package.

Light-Sensitive Devices (cont'd.)

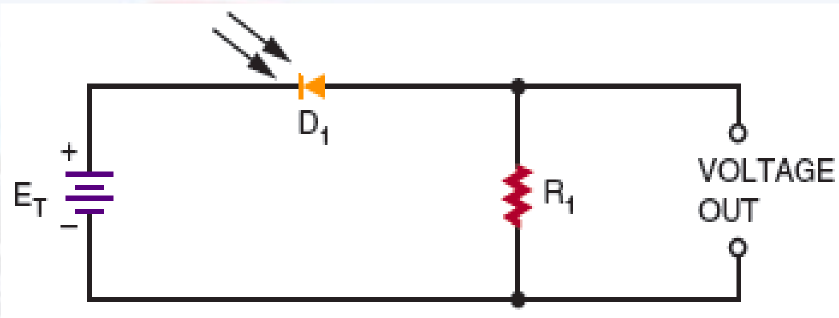
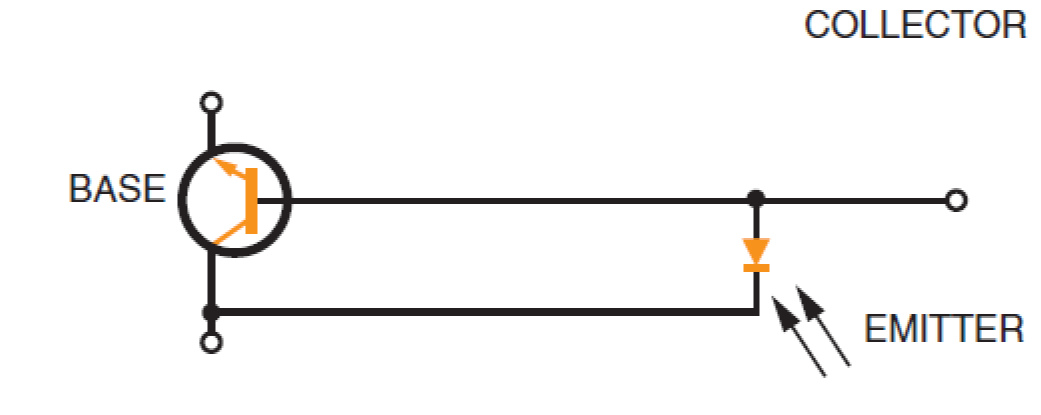


Figure 26-9. Voltage divider using a photodiode.

- The PIN photodiode has a lower internal capacitance because of the intrinsic layer, resulting in faster response to changes in light intensity.
- More linear change in reverse current with light intensity is produced.
- The disadvantage is a low output compared to other photosensitive devices.

Equivalent circuit for a phototransistor



- **Phototransistor** is constructed like other transistors with two PN junctions and resembles a standard NPN transistor.
- It is used like a photodiode and packaged like a photodiode, except that it has three leads (emitter, base, and collector)
- Transistor conduction depends on the conduction of the photodiode.

Light-Sensitive Devices (cont'd.)

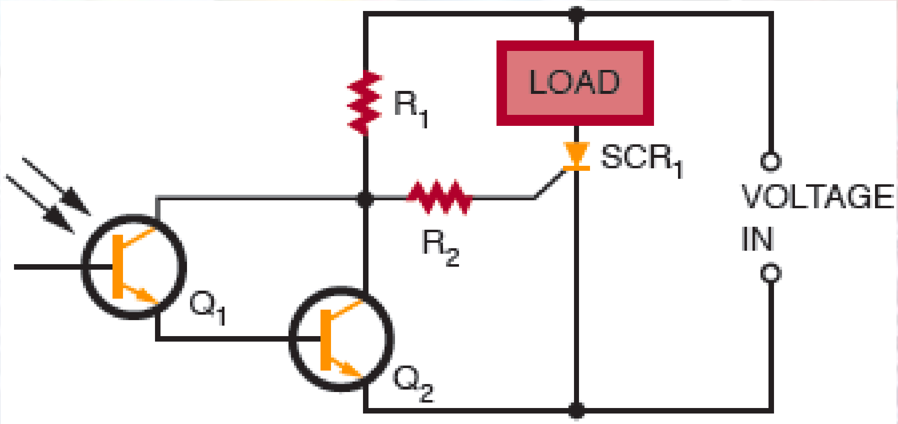


Figure 26-12. Darkness-on DC switch.

Light-Emitting Devices

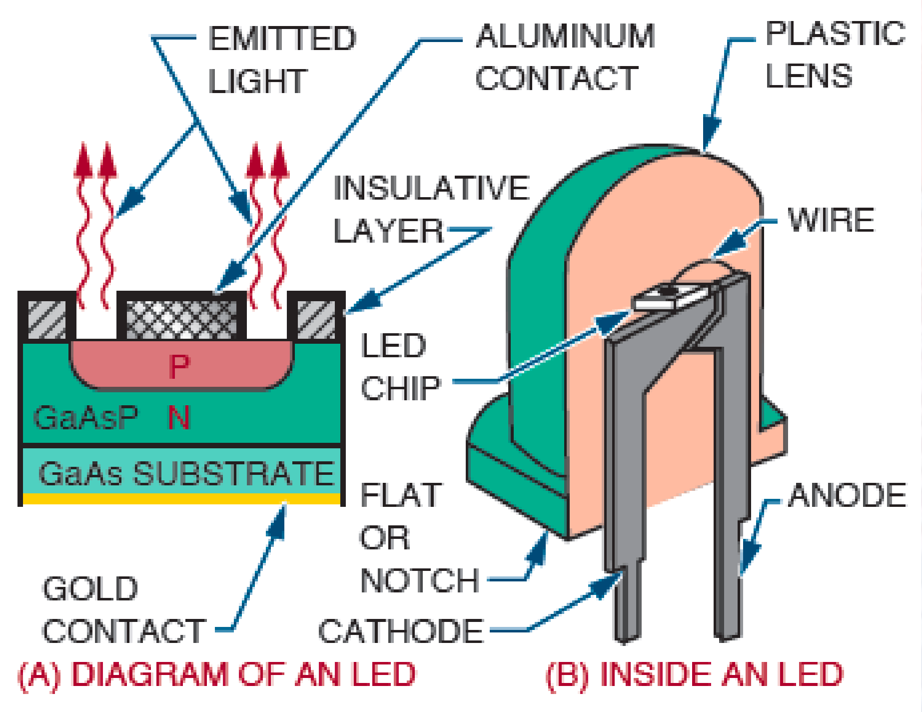


Figure 26-13. LED construction.

Light-Emitting Devices (cont'd.)

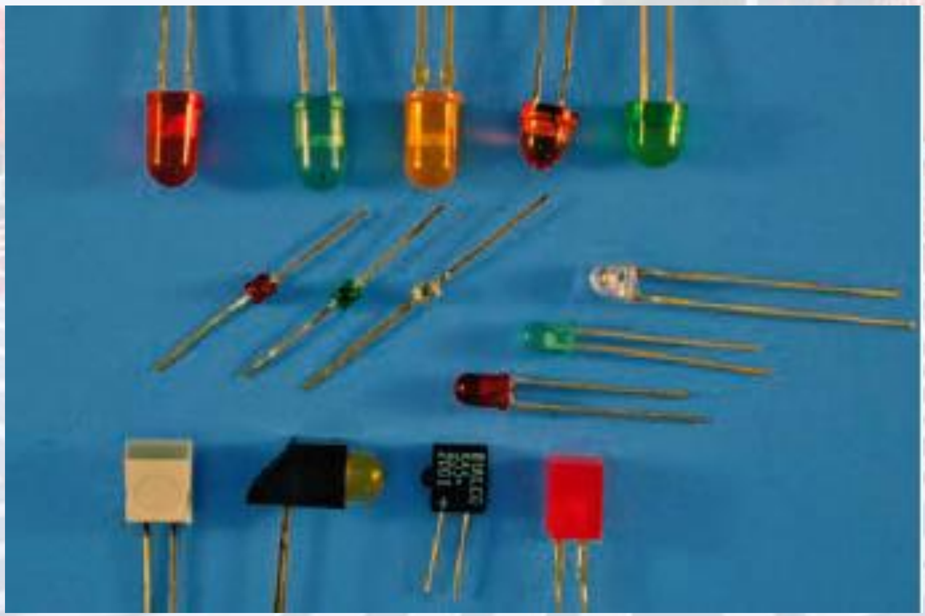


Figure 26-14. Common LED packages.

Light-Emitting Devices (cont'd.)

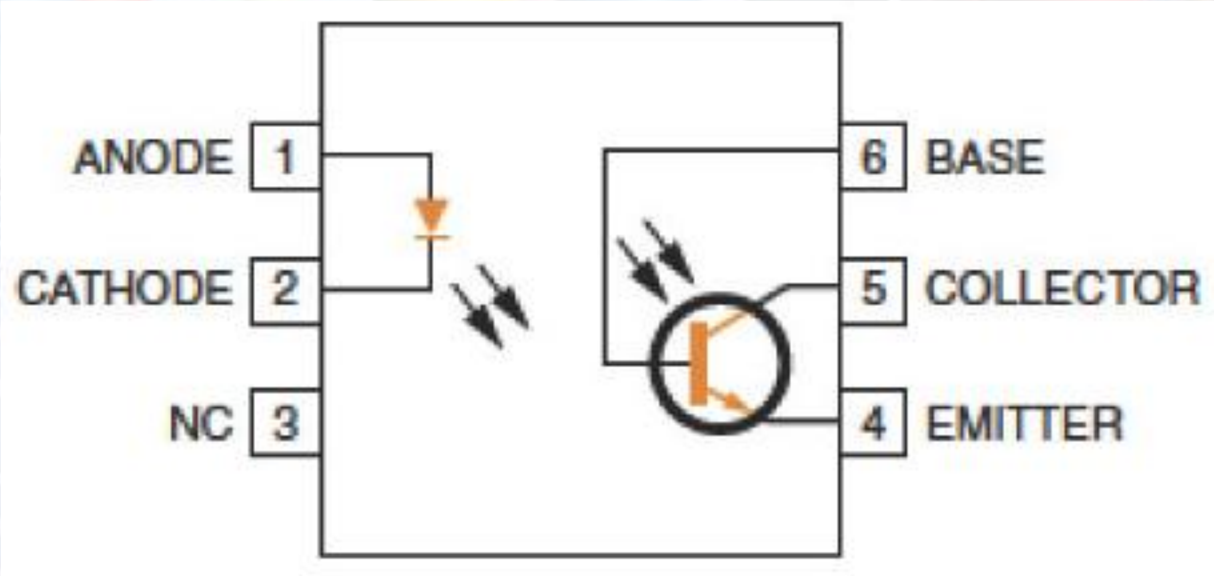


Figure 26-19. Commercial optical coupler.

Summary

- Semiconductor devices that interact with light
  - Light-detection devices
  - Light-conversion devices
  - Light-emitting devices
- Light is electromagnetic radiation that is visible to the human eye

Summary (cont'd.)

- Light-sensitive devices include photo cells, solar cells, photodiodes, and phototransistors
- Light-emitting devices include the LED (light-emitting diode)
- An optical coupler combines a light-sensitive device with a light-emitting device

Chapter 27

Power Supplies

Objectives

- After completing this chapter, you will be able to:
  - Explain the purpose of a power supply
  - Draw a block diagram of the circuits and parts of a power supply
  - Describe the three different rectifier configurations
  - Explain the function of a filter

Objectives (cont'd.)

- Describe the two basic types of voltage regulators and how they operate
- Explain the function of a voltage multiplier
- Identify over-voltage and over-current protection devices

Transformers

- Transformers
  - Used in power supplies for isolation
  - Used to step up or step down the voltage
- Primary power ratings
  - 110 to 120 volts
  - 220 to 240 volts

Rectifier Circuits

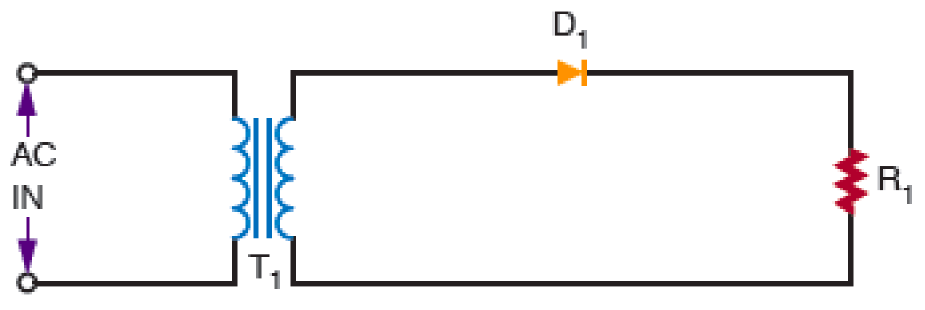


Figure 27-1. Basic half-wave rectifier.

FIGURE 27–2
Half-wave rectifier during positive alternation.

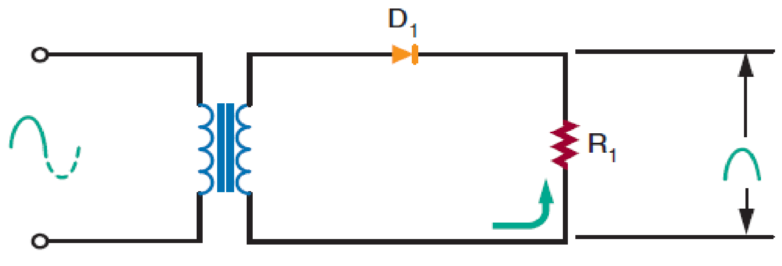
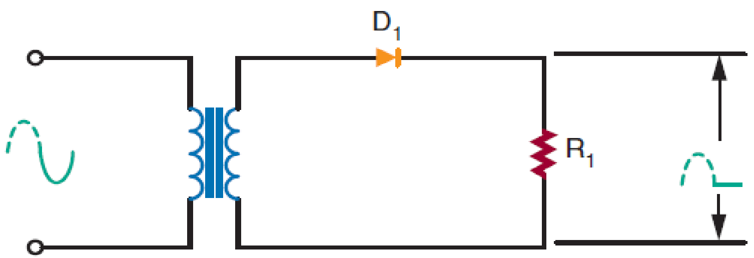


FIGURE 27–3
Half-wave rectifier during negative alternation.



- The half-wave rectifier operates during only one-half of the input cycle.
- The output is a series of positive or negative pulses, depending on how the diode is connected in the circuit

Rectifier Circuits (cont'd.)

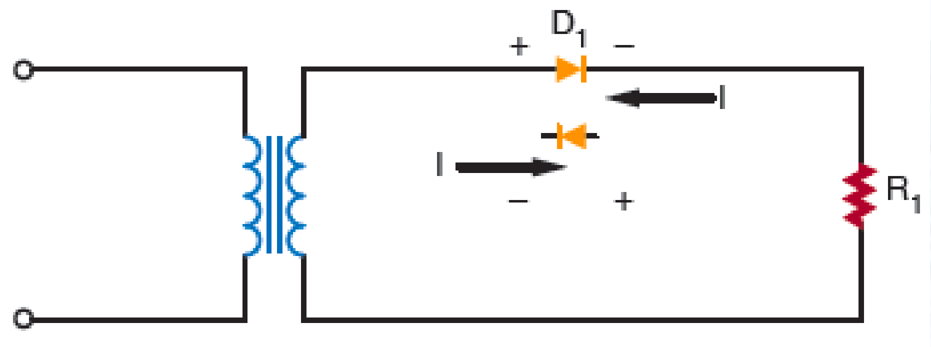


Figure 27-4. The diode determines the direction of current flow.

- There is a serious disadvantage with the halfwave rectifier because current flows during only half of each cycle.
- To overcome this disadvantage, a full-wave rectifier can be used.

Rectifier Circuits (cont'd.)

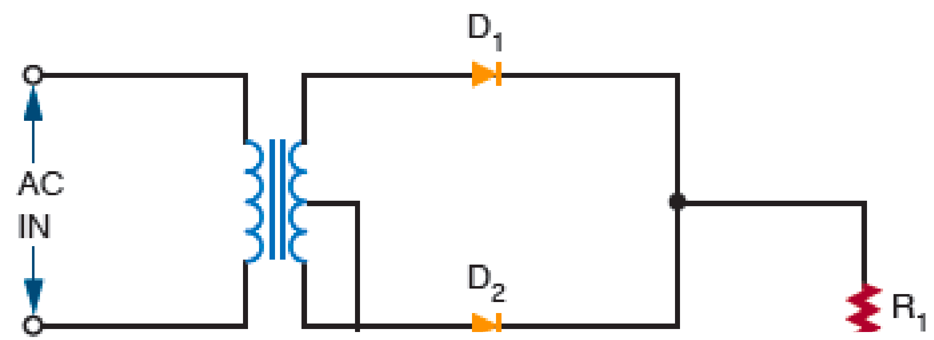
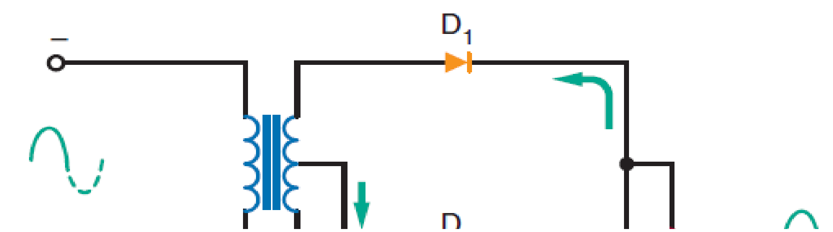


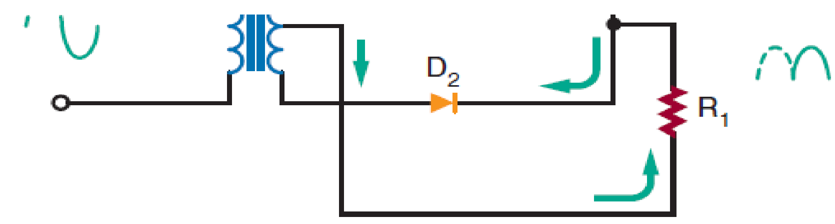
FIGURE 27–6
Full-wave rectifier during positive alternation.



There is a disadvantage with the full-wave rectifier because the output voltage is half that of a half-wave rectifier for the same transformer. This disadvantage can be overcome by the use of
a bridge rectifier circuit.

Figur

- W
cycles. This means that the ripple frequency is twice the input frequency.



Rectifier Circuits (cont'd.)

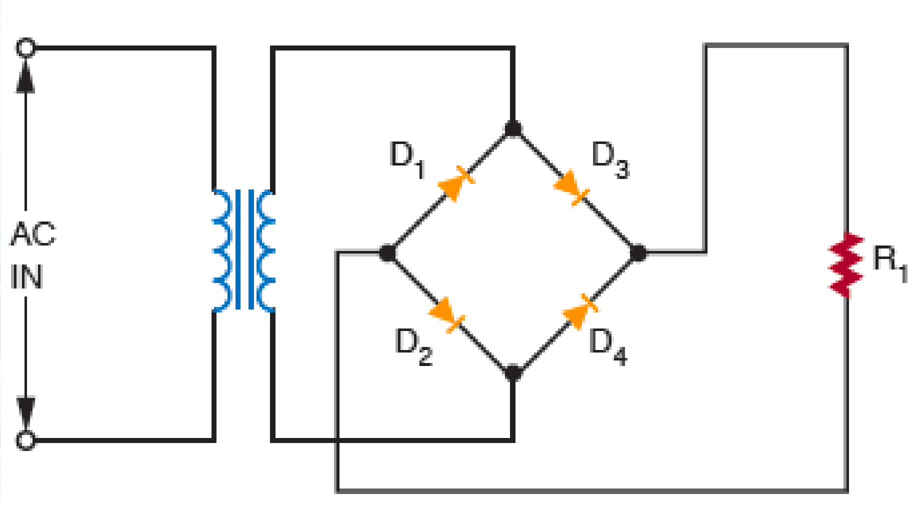


Figure 27-8. Bridge rectifier circuit.

FIGURE 27–9

Bridge rectifier during positive alternation.

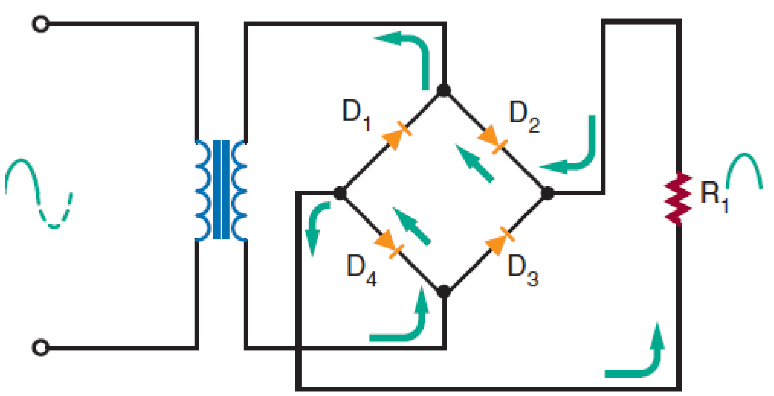
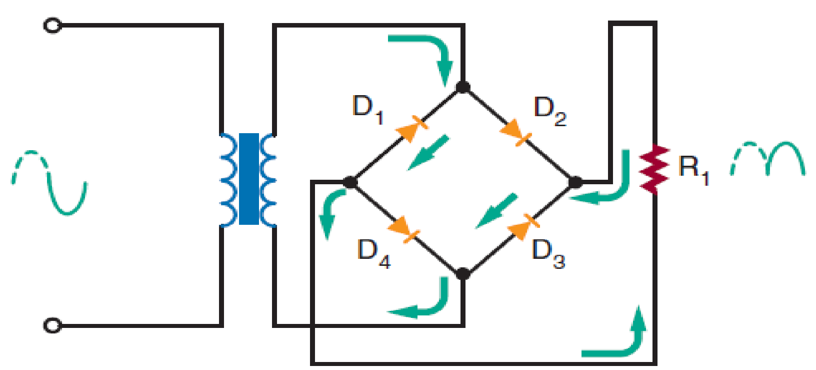


FIGURE 27–10

Bridge rectifier during negative alternation.



A bridge rectifier is a type of full-wave rectifier because it operates on both half-cycles of the input sine wave. The advantage of the bridge rectifier is that the circuit does not require a centertapped secondary. This circuit does not require a transformer to operate.

Filter Circuits

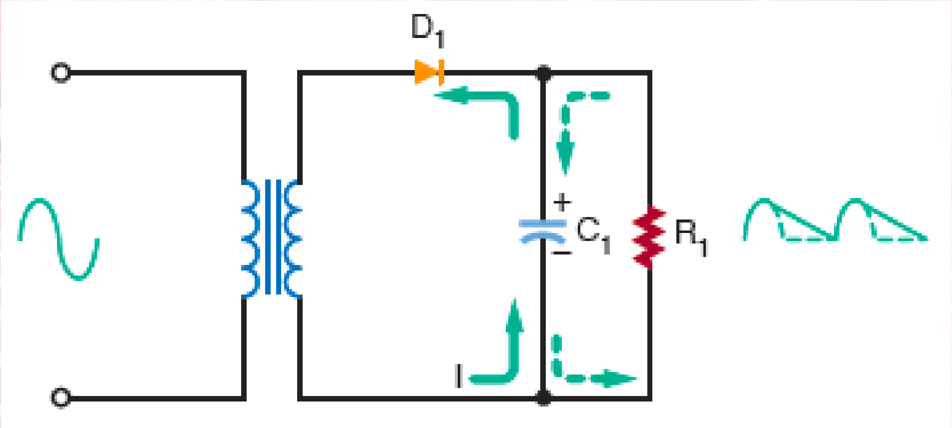


Figure 27-11. Half-wave rectifier with capacitor filter.

Filter Circuits (cont'd.)

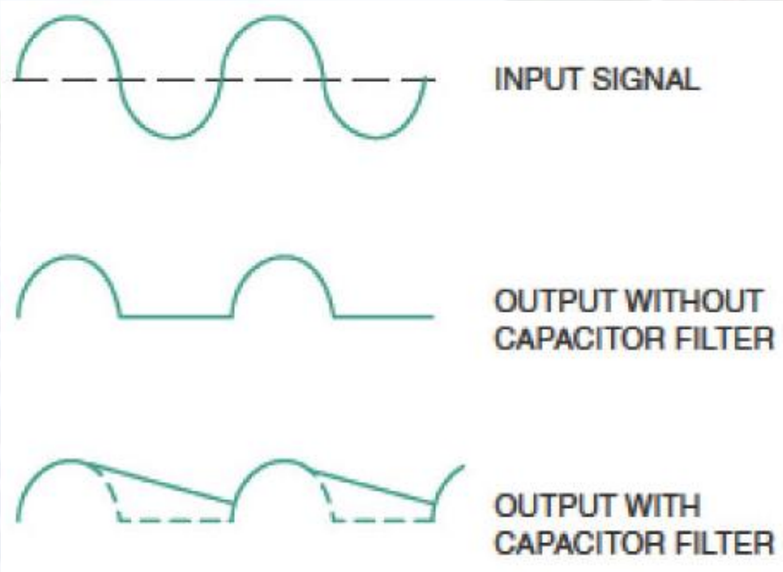


Figure 27-12. Output of a half-wave rectifier without and with a filter capacitor.

Filter Circuits (cont'd.)

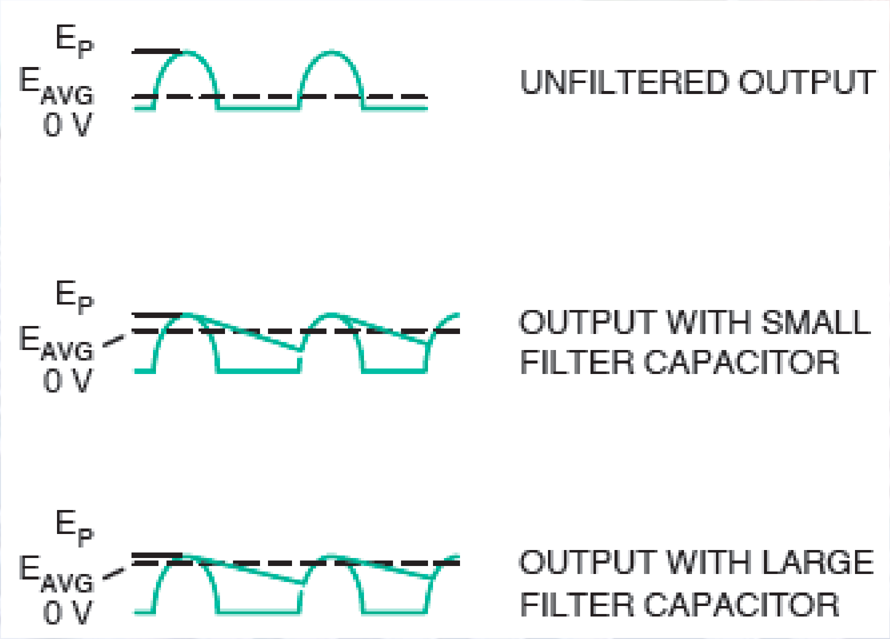
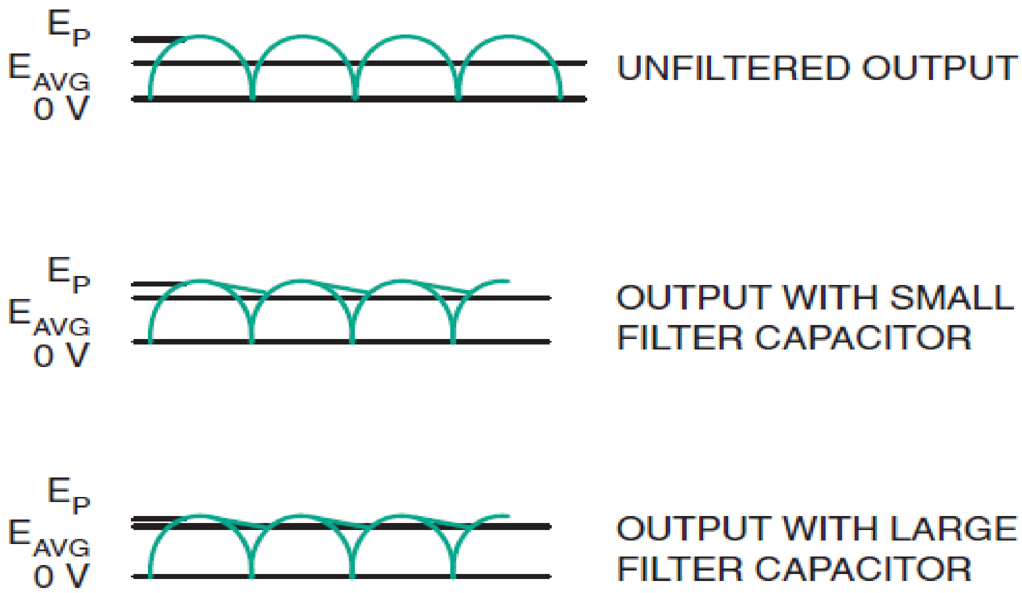


Figure 27-13. Effects of different filter capacitors on output of half-wave rectifier.

FIGURE 27–14

Effects of different filter capacitors on output of full-wave or bridge rectifier.



Voltage Regulators

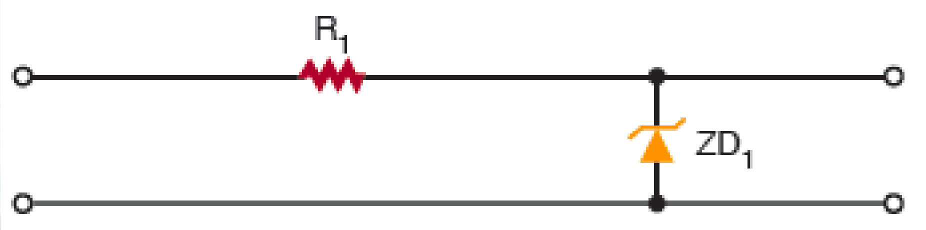


Figure 27-17. Basic zener diode regulator circuit.

- There are two basic types of voltage regulators: **shunt regulators** and **series regulators**
- shunt regulator is connected in parallel with the load.
- Series regulator is connected in series with the load

Voltage Regulators (cont'd.)

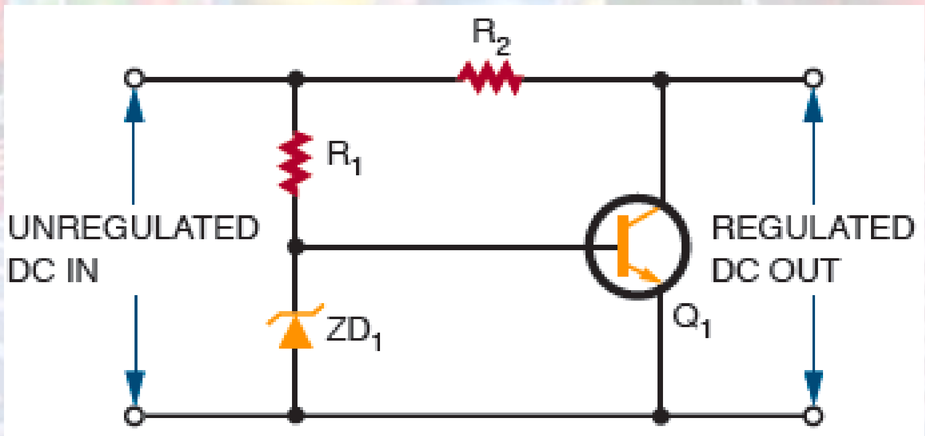


Figure 27-18. Shunt regulator using a transistor.

Voltage Regulators (cont'd.)

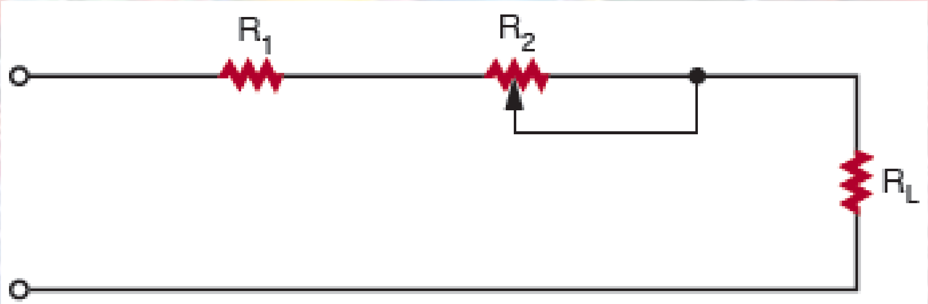


Figure 27-19. Series regulator using a variable resistor.

Voltage Regulators (cont'd.)

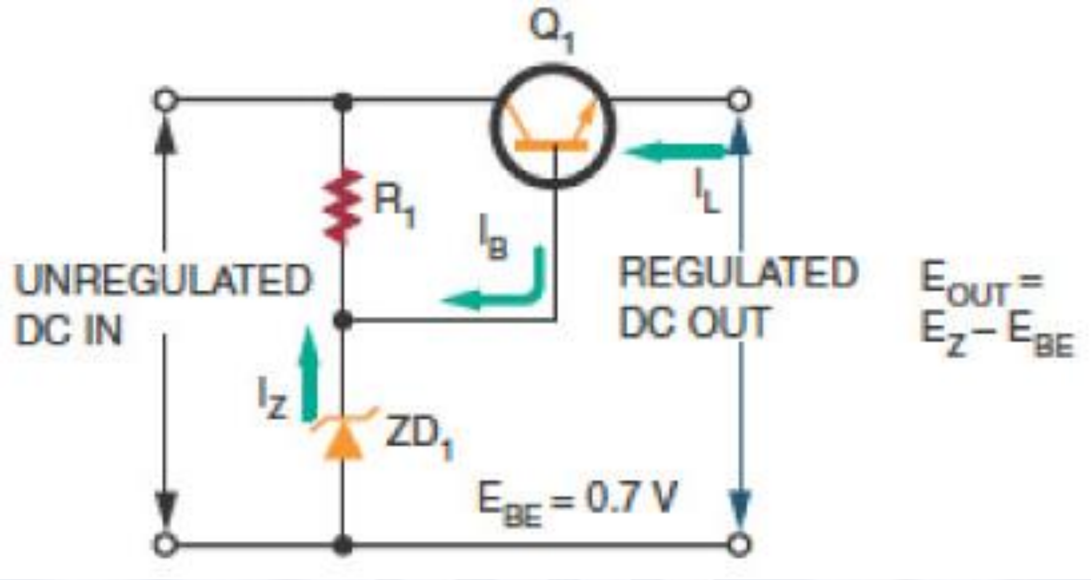


Figure 27-22. A series regulator.

Voltage Multipliers

- Voltage multipliers
  - Provide higher DC voltage than the input without the aid of a transformer
- Voltage doubler
- Voltage tripler

Circuit Protection Devices

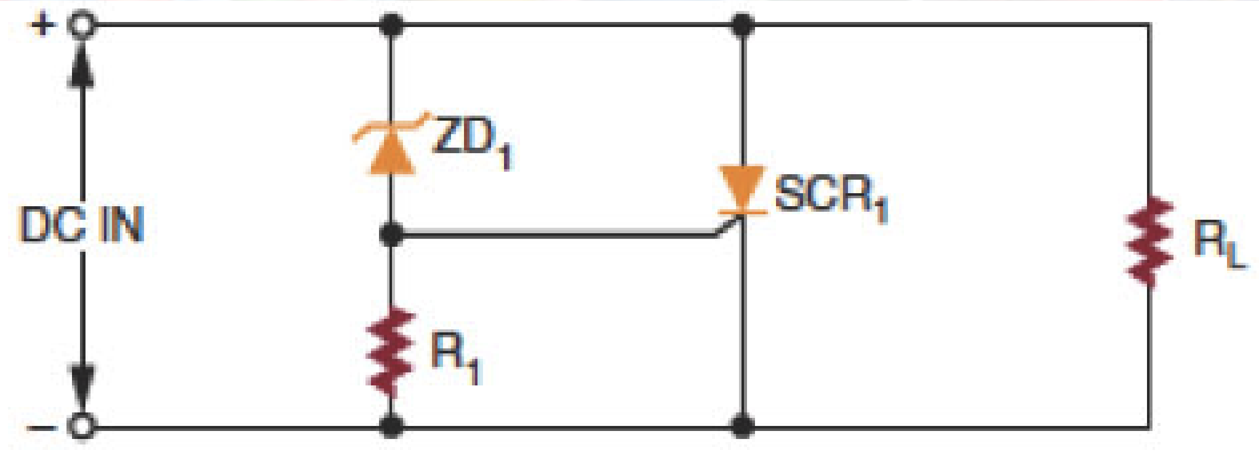


Figure 27-37. Crowbar overprotection circuit.

Circuit Protection Devices (cont'd.)

Figure 27-38. Fuses used for protection of electronic circuits.

Circuit Protection Devices (cont'd.)

Figure 27-39. Circuit breakers used for protection of electronic circuits.

Summary

- The primary purpose of a power supply is to convert AC to DC
- The basic rectifier circuits are half-wave, full-wave, and bridge
- To convert pulsating DC voltage to a smooth DC voltage, a filter must follow the rectifier in the circuit

Summary (cont'd.)

- The two basic types of regulator are the shunt regulator and the series regulator
- Voltage multipliers are circuits capable of providing higher DC voltages than the input without the aid of a transformer
- A crowbar is a circuit designed for over-voltage protection
- A fuse protects a circuit from a current

Chapter 28

Amplifier Basics

Objectives

- After completing this chapter, you will be able to:
  - Describe the purpose of an amplifier
  - Identify the three basic configurations of transistor amplifier circuits
  - Identify the classes of amplifiers

Objectives (cont'd.)

- Describe the operation of direct coupled amplifiers, audio amplifiers, video amplifiers, RF amplifiers, IF amplifiers, and operational amplifiers
- Draw and label schematic diagrams for the different types of amplifier circuits

Amplifier Configurations

Three circuit configurations are:
Common-base circuit,
Common-emitter circuit,
Common-collector circuit.

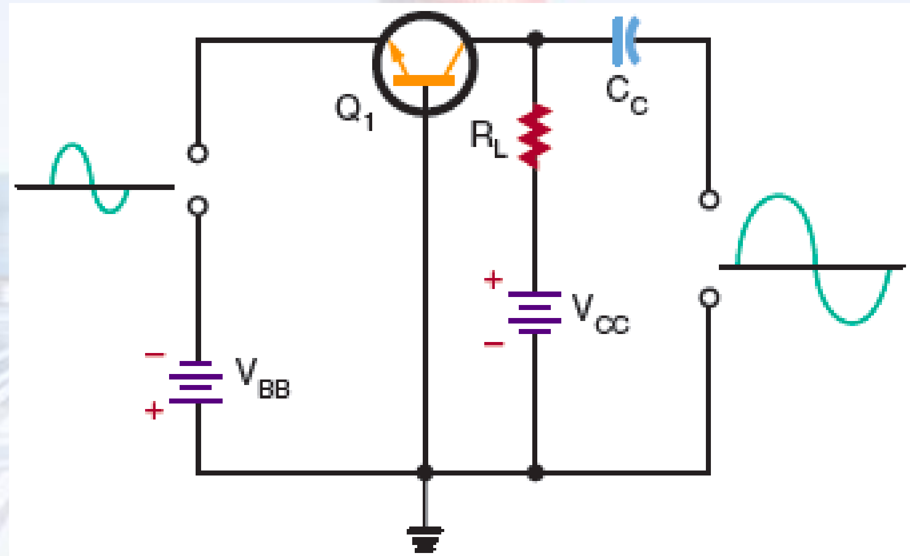


Figure 28-1. Common-base amplifier circuit.

- Base is the element common to both the input and output circuits

Amplifier Configurations (cont'd.)

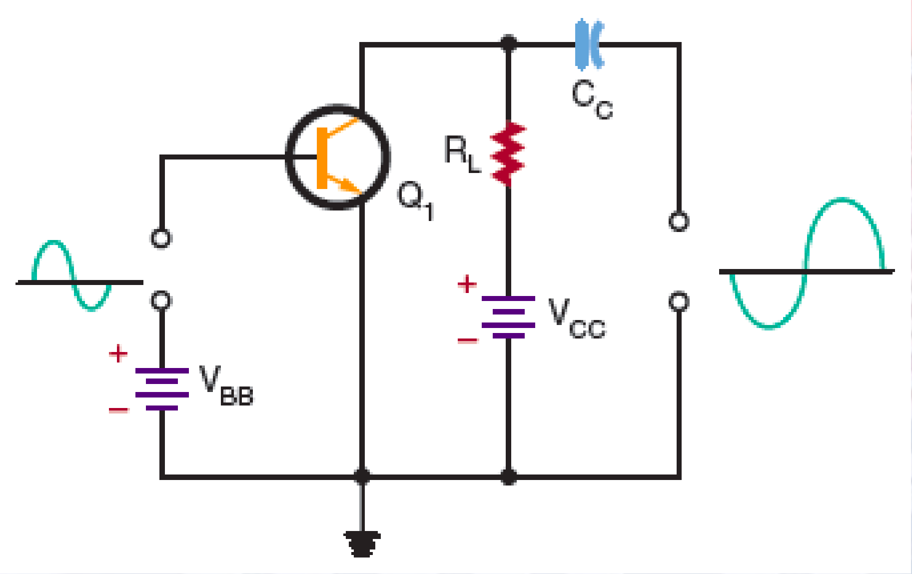


Figure 28-2. Common-emitter amplifier circuit.

Amplifier Configurations (cont'd.)

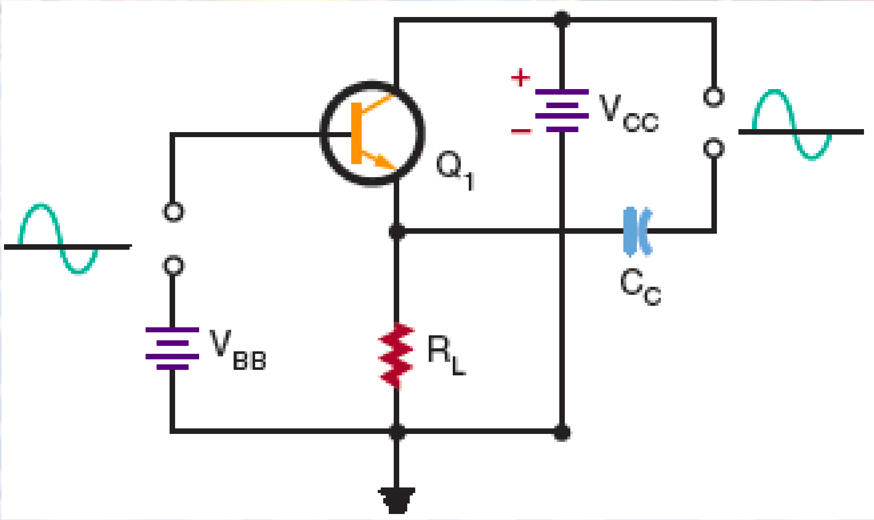


Figure 28-3. Common-collector amplifier circuit.

Amplifier circuit characteristics.

CIRCUIT TYPE	INPUT RESISTANCE	OUTPUT RESISTANCE	VOLTAGE GAIN	CURRENT GAIN	POWER GAIN
COMMON BASE	Low	High	High	Less than 1	Medium
COMMON EMITTER	Medium	Medium	Medium	Medium	High
COMMON COLLECTOR	High	Low	Less than 1	Medium	Medium

Amplifier circuit input-output phase relationships.

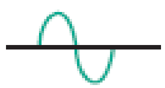
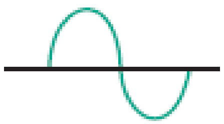
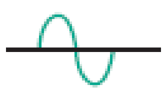
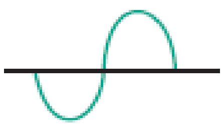
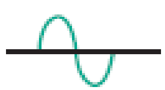
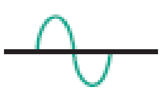
AMPLIFIER TYPE	INPUT WAVEFORM	OUTPUT WAVEFORM
COMMON BASE		
COMMON EMITTER		
COMMON COLLECTOR		

FIGURE 28–6

Common-emitter amplifier with single voltage source.

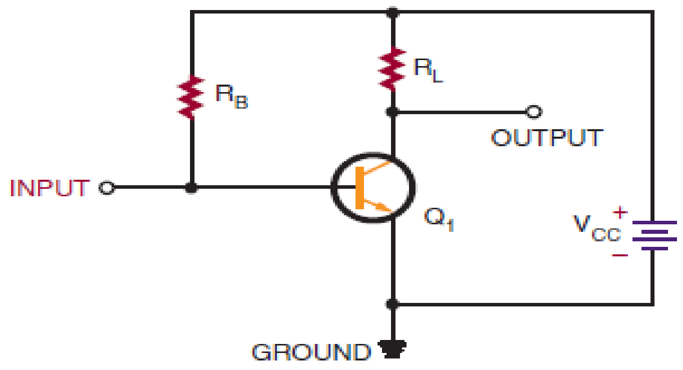


FIGURE 28–7

Schematic representation of common-emitter amplifier with single voltage source.

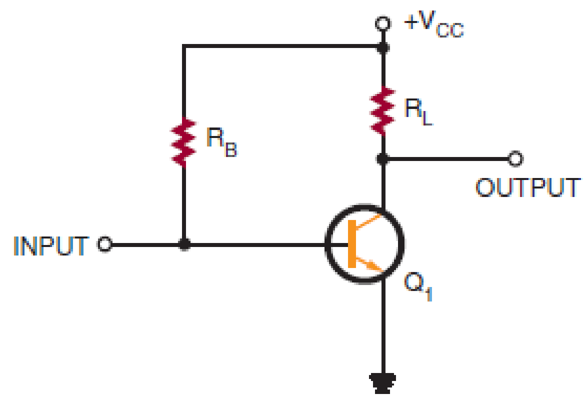


FIGURE 28–8

Common-emitter amplifier with collector feedback.

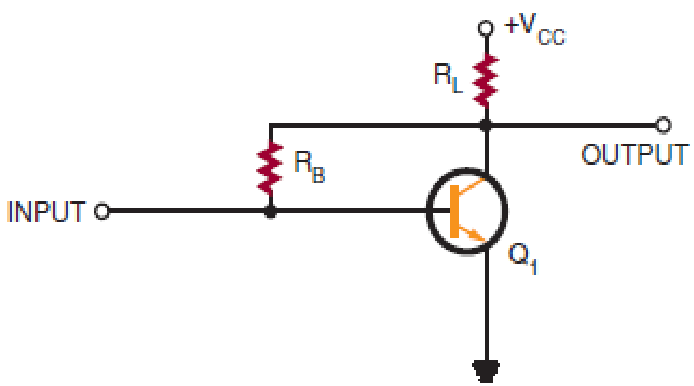
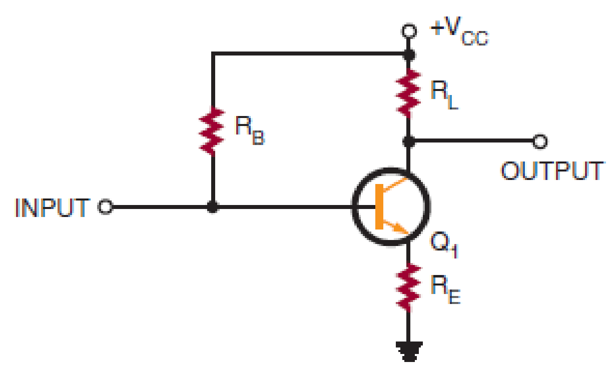


FIGURE 28–9

Common-emitter amplifier with emitter feedback.



Amplifier Biasing

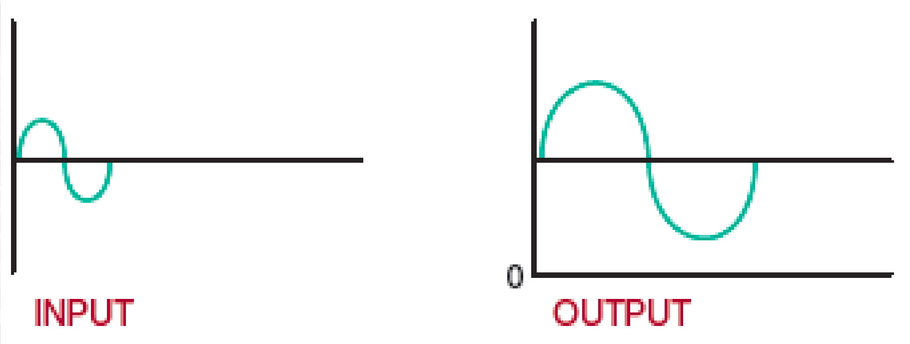


Figure 28-12. Class A amplifier output.

- An amplifier that is biased so that the current flows throughout the entire cycle is operating as a **class A amplifier**

Amplifier Biasing (cont'd.)

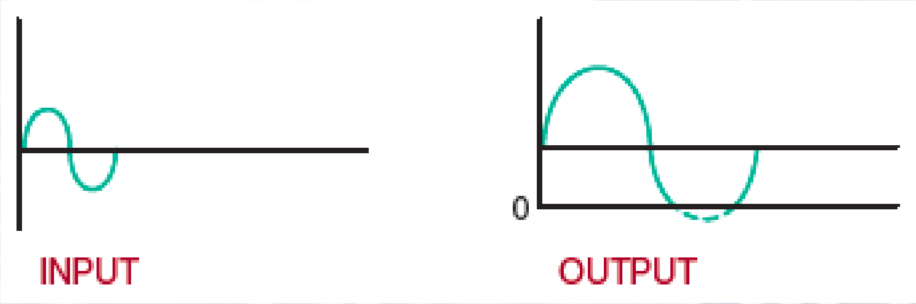


Figure 28-13. Class AB amplifier output.

- An amplifier that is biased so that the output current flows for less than a full cycle but more than a half cycle is operating as a **class AB amplifier**

Amplifier Biasing (cont'd.)

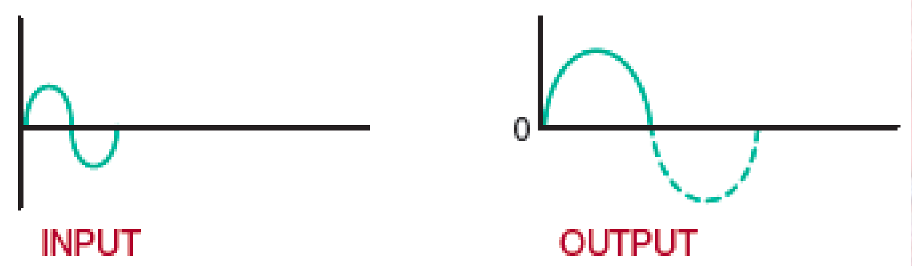


Figure 28-14. Class B amplifier output.

- An amplifier that is biased so that the output current flows for only half of the input cycle is operating as a **class B amplifier.**

Amplifier Biasing (cont'd.)

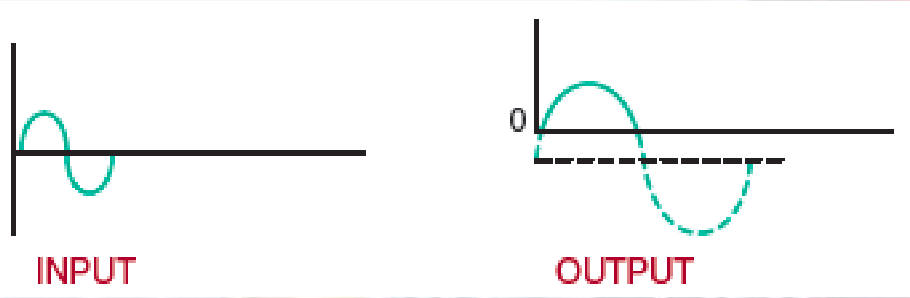


Figure 28-15. Class C amplifier output.

- An amplifier that is biased so that the output current flows for less than half of the AC input cycle is operating as a **class C amplifier.**

Amplifier Coupling

To prevent one amplifier's bias voltage from affecting the operation of the second amplifier, a **coupling** technique must be used. The coupling method used must not disrupt the operation of either circuit.

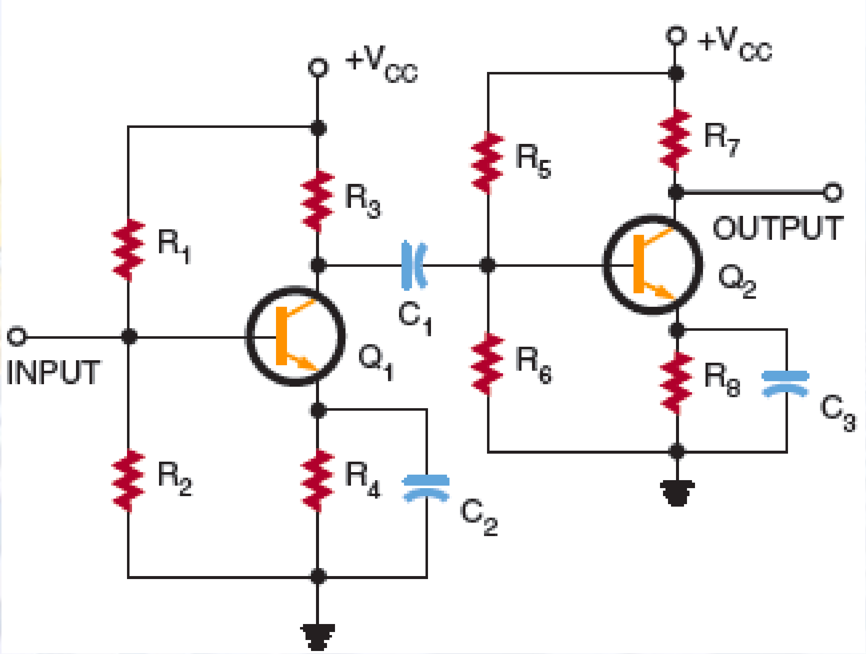


Figure 28-17. RC coupling.

FIGURE 28–18

Impedance coupling.

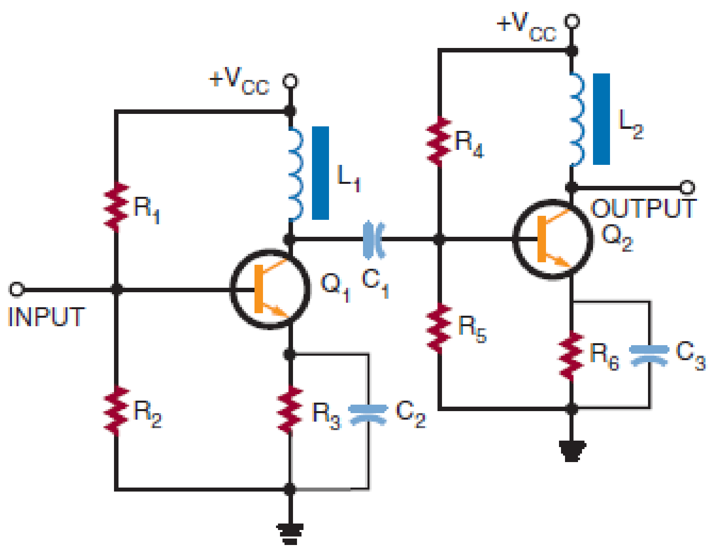
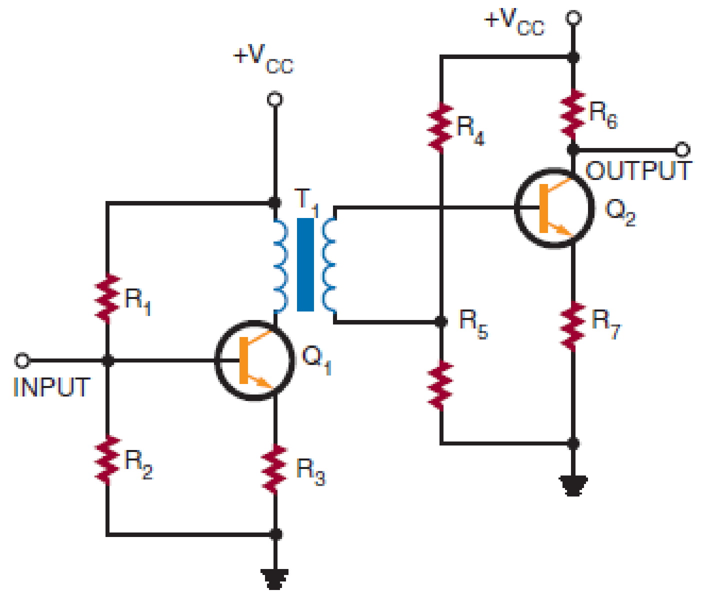


FIGURE 28–19

Transformer coupling.



Amplifier Coupling (cont'd.)

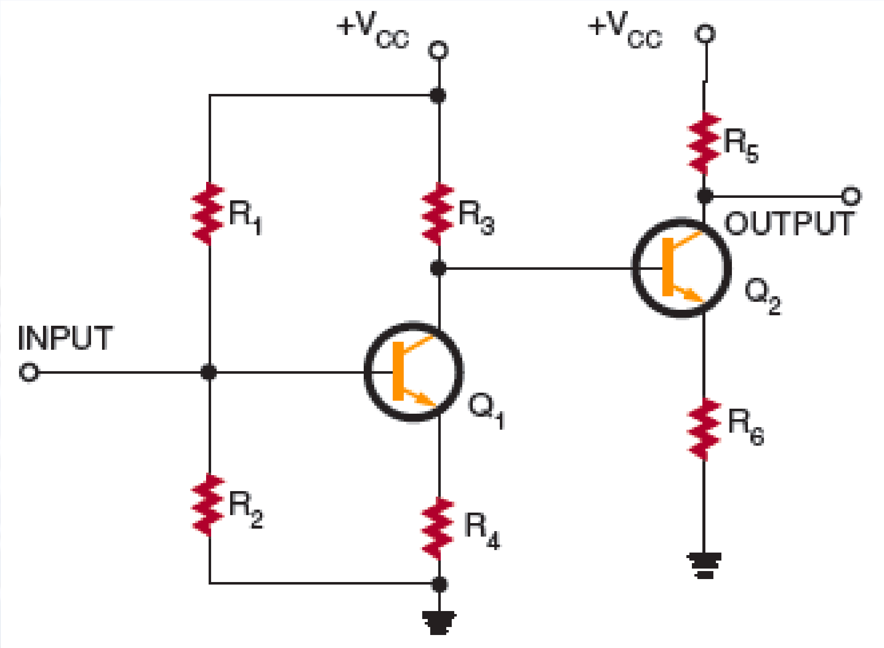


Figure 28-20. Direct coupling.

- Direct-coupled amplifiers provide a uniform current or voltage gain over a wide range of frequencies. This type of amplifier can amplify frequencies from zero (DC) hertz to many thousands of hertz.
- A drawback of direct-coupled amplifiers is that they are not stable

Summary

- Amplifiers are electronic circuits used to increase the amplitude of an electronic signal
- The transistor is used primarily as an amplifying device
- Three transistor amplifier configurations
  - Common base, common collector, and common emitter

Summary (cont'd.)

- Coupling methods used to connect one transistor to another
  - Resistance-capacitance coupling, impedance coupling, transformer coupling, and direct coupling
- Direct-coupled amplifiers are used for high gain at low frequencies or amplification of a DC signal

Chapter 29

Amplifier Applications

Objectives

- After completing this chapter, you will be able to:
  - Describe the operation of:
    - —direct coupled amplifiers
    - —audio amplifiers
    - —video amplifiers

Objectives (cont'd.)

—RF amplifiers

—IF amplifiers

—operational amplifiers

– Identify schematic diagrams for the different types of amplifier circuits

Direct-Coupled Amplifiers

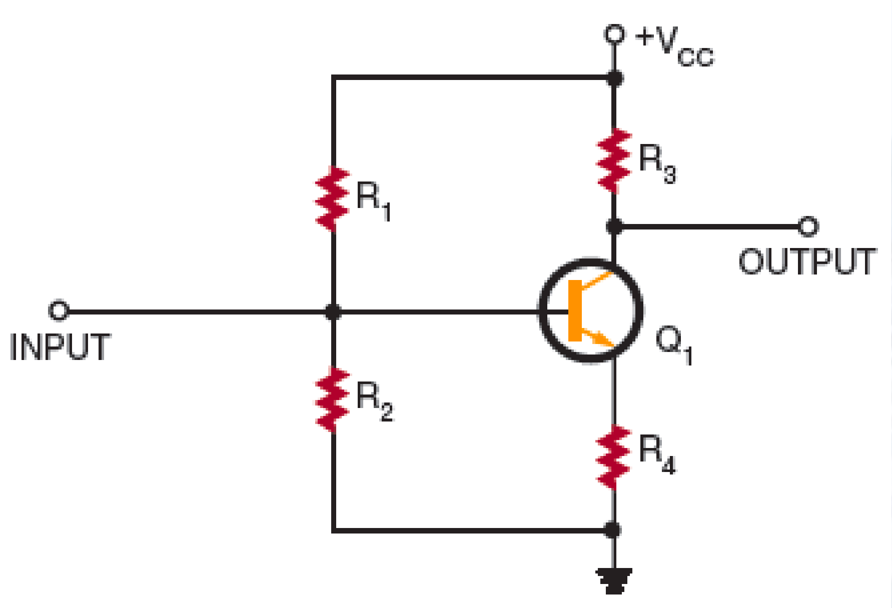


Figure 29-1. Simple DC amplifier.

- Common-emitter amplifier is the one most frequently used.
- DC amplifier can provide both voltage and current gain.

Direct-Coupled Amplifiers (cont'd.)

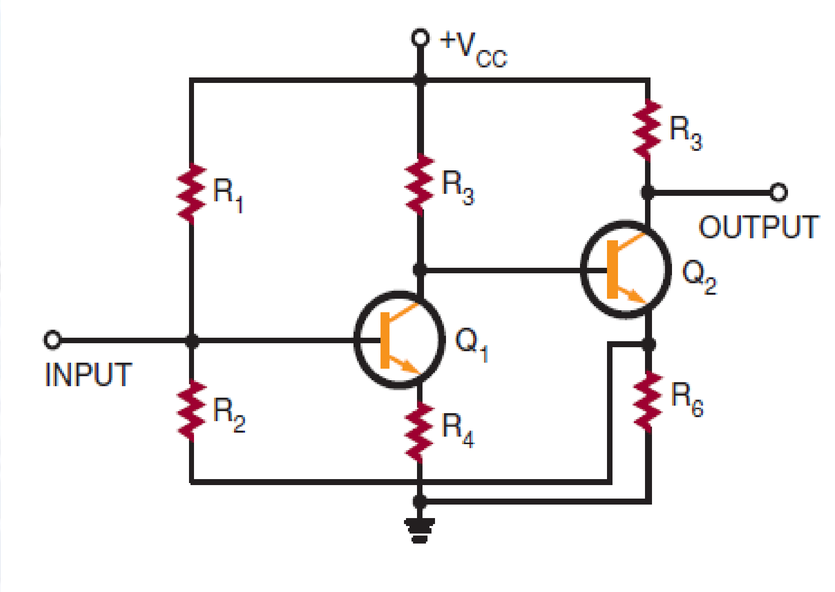
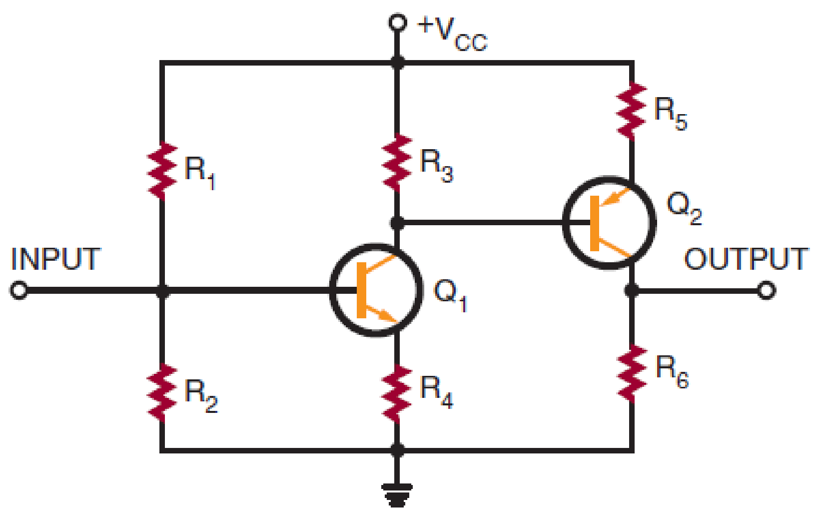


Figure 29-2. Two-stage DC amplifier.

- The input signal is amplified by the first stage.
- The amplified signal is then applied to the base of the transistor in the second stage.

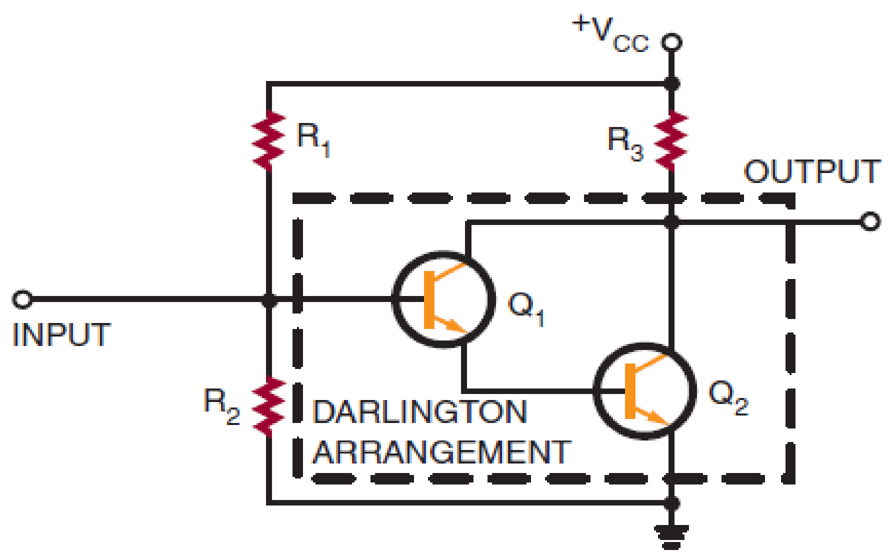
FIGURE 29–3

Complementary DC amplifier.



- Both an NPN and a PNP transistor are used.
- The difference is that the second-stage transistor is a PNP transistor.

FIGURE 29–4
Darlington arrangement.



Darlington arrangement

- Transistor Q_1 is used to control the conduction of transistor Q_2.
- The input signal applied to the base of transistor Q_1 controls the base of transistor Q_2.

The darlington arrangement may be a single package with three leads: emitter (E), base (B), and collector (C). It is used as a simple DC amplifier but offers a very high voltage gain.

Direct-Coupled Amplifiers (cont'd.)

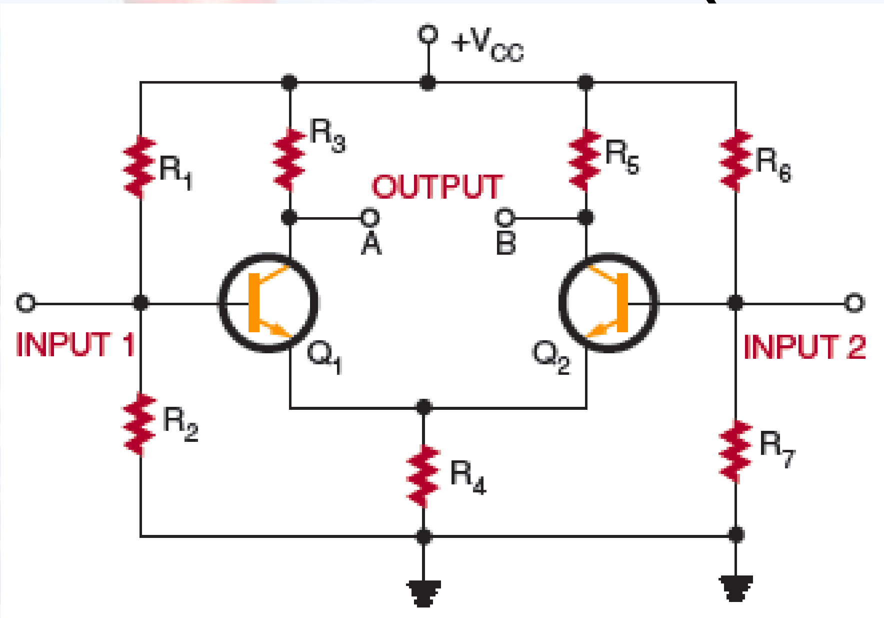


Figure 29-5. Differential amplifier.

- Both high gain and temperature stability are required, another type of amplifier is necessary. This type is called a **differential amplifier**

Audio Amplifiers

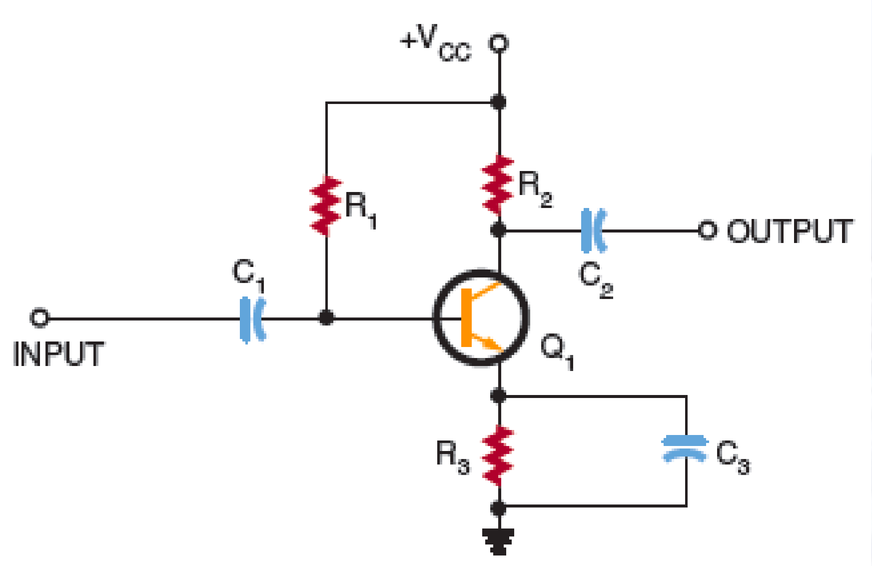


Figure 29-6. Voltage amplifier.

- **Audio amplifiers** amplify AC signals in the frequency range of approximately 20 to 20,000 hertz.
- Audio amplifiers are divided into two categories: **voltage amplifiers and power amplifiers**.

- Power amplifier is used to drive the load and can typically a load vary from 4 to 16 ohms.

Audio Amplifiers (cont'd.)

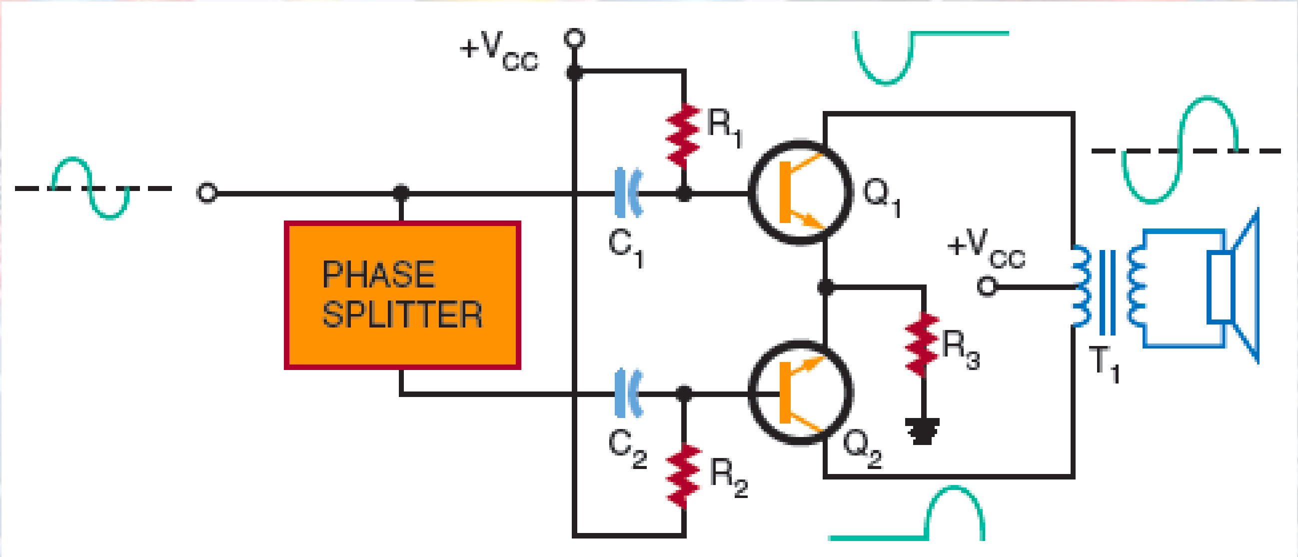


Figure 29-7. Push-pull power amplifier.

Audio Amplifiers (cont'd.)

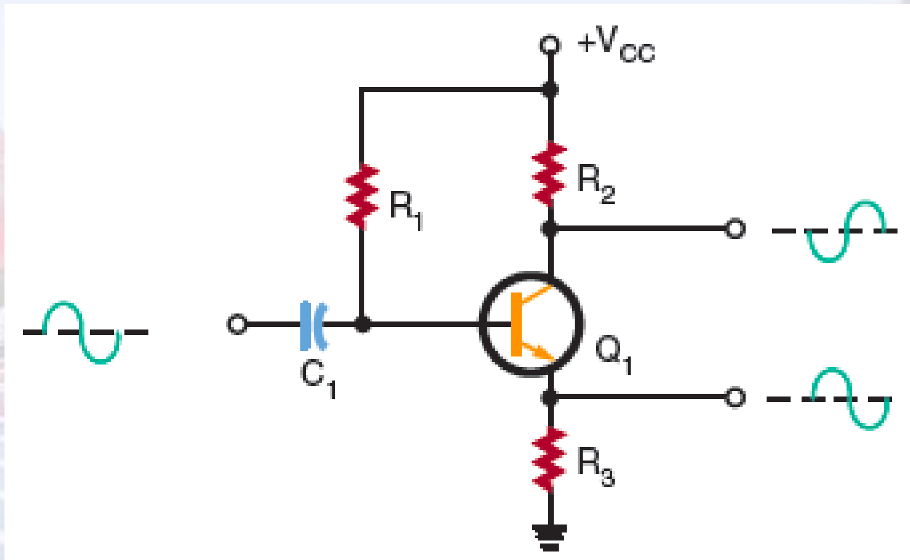


Figure 29-8. Phase splitter.

The phase splitter is operated as a class A amplifier to provide minimum distortion

FIGURE 29–9

Complementary push-pull power amplifier.

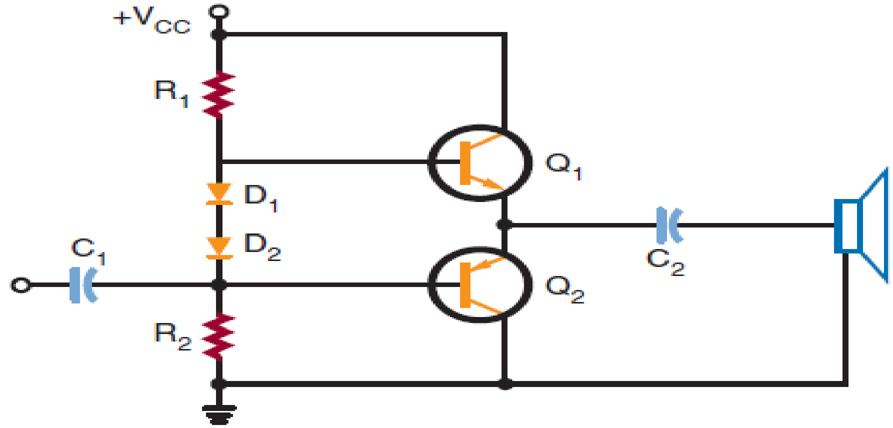
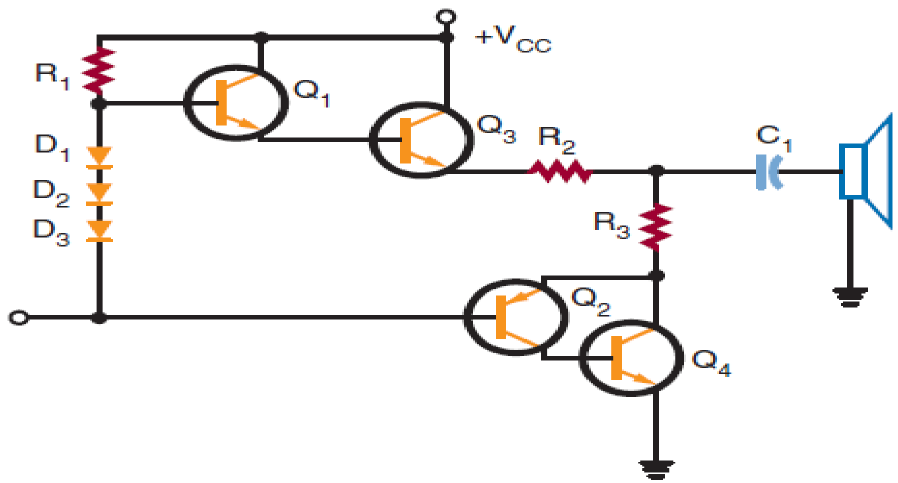


FIGURE 29–10

Quasi-complementary power amplifier.



Video Amplifiers

FIGURE 29–12
Shunt peaking.

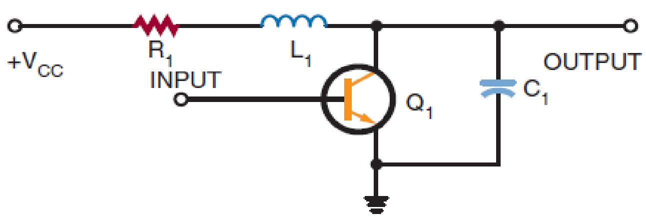
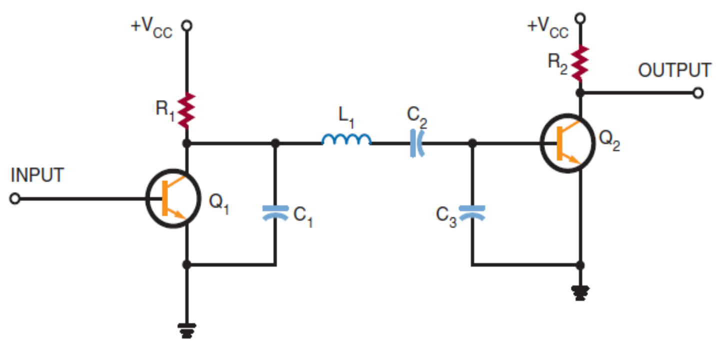


FIGURE 29–13
Series peaking.



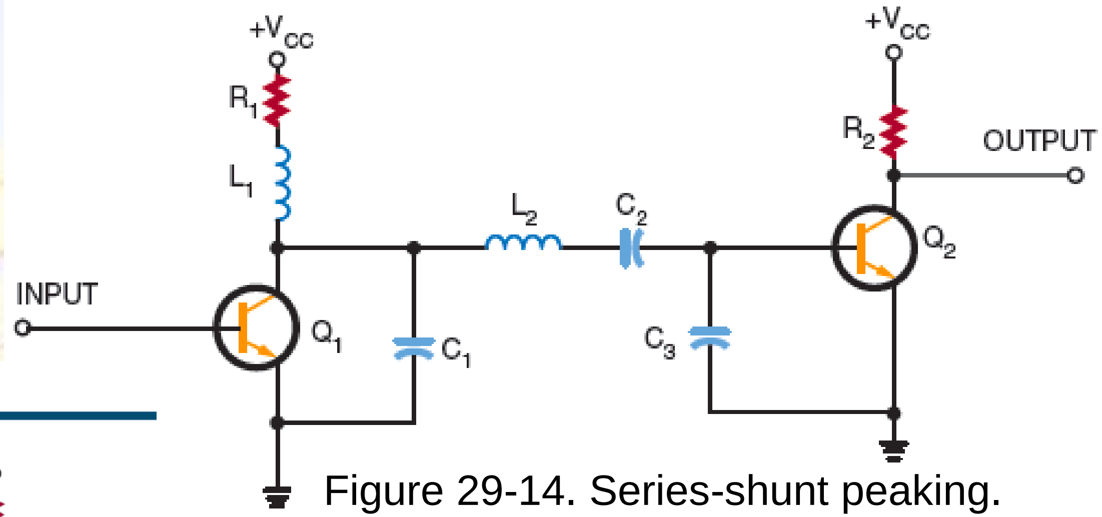


Figure 29-14. Series-shunt peaking.

Video amplifiers are wideband amplifiers used to amplify video (picture) information. The frequency range for video amplifier few hertz to 5 or 6 megahertz.

Video Amplifiers (cont'd.)

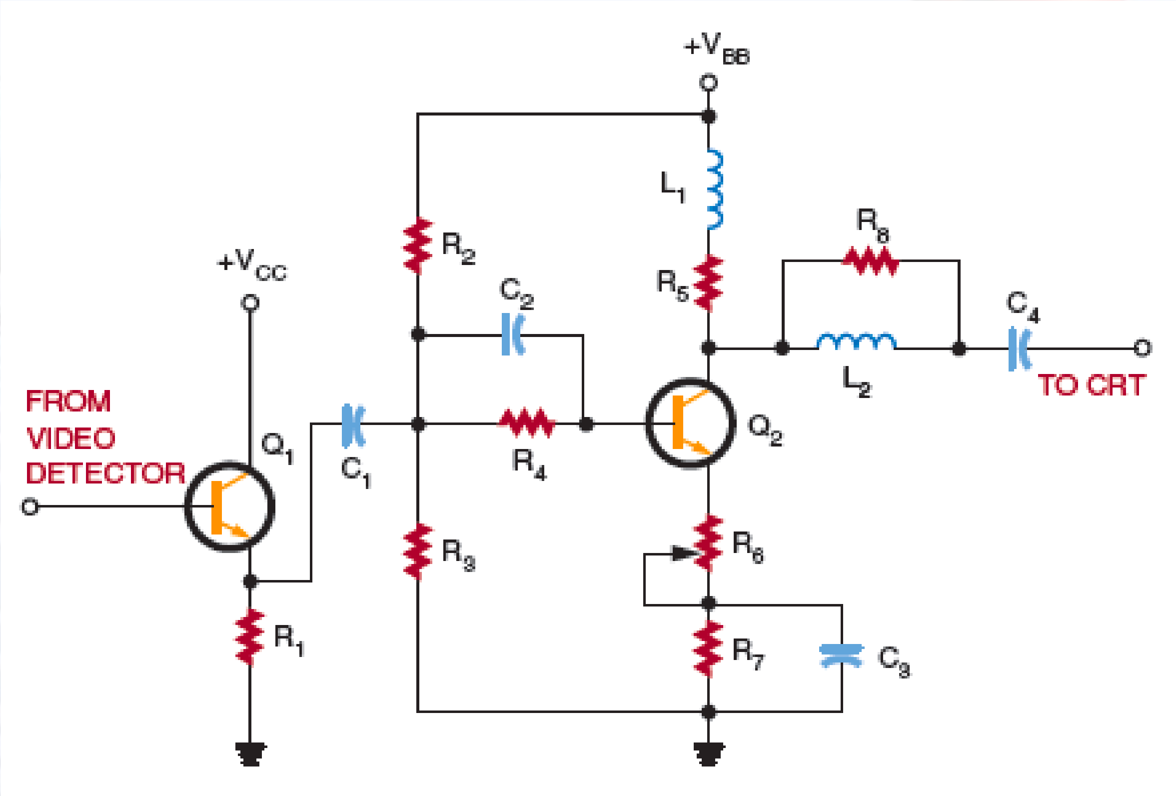


Figure 29-15. Video amplifier in a television receiver.

- **RF (radio-frequency) amplifiers** usually are the first stage in an AM, FM, or TV receivers and are similar to other amplifiers.
- Frequency spectrum over which they operate, ranging from 10,000 to 30,000 megahertz

RF and IF Amplifiers

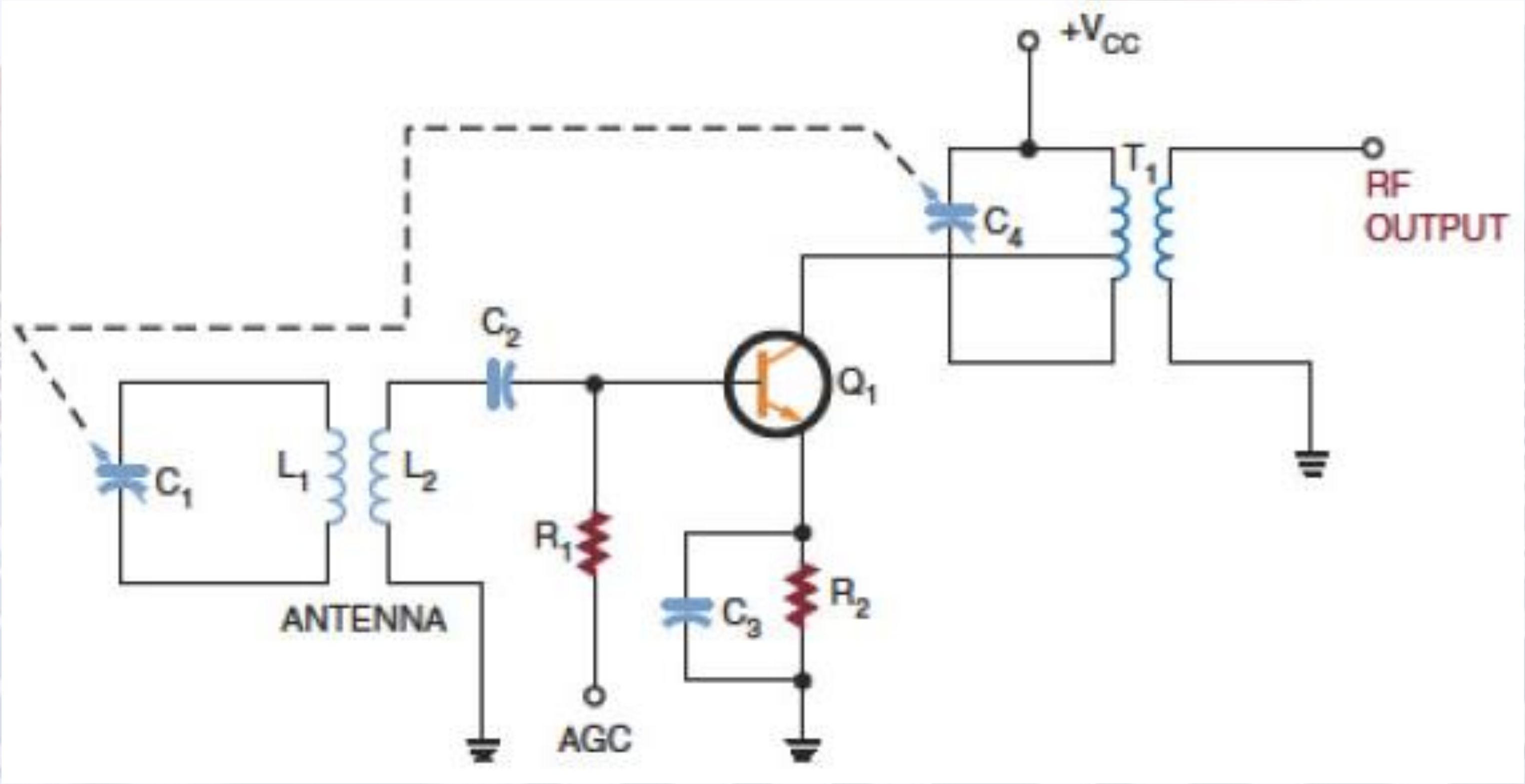


Figure 29-16. RF amplifier in an AM radio.

RF and IF Amplifiers (cont'd.)

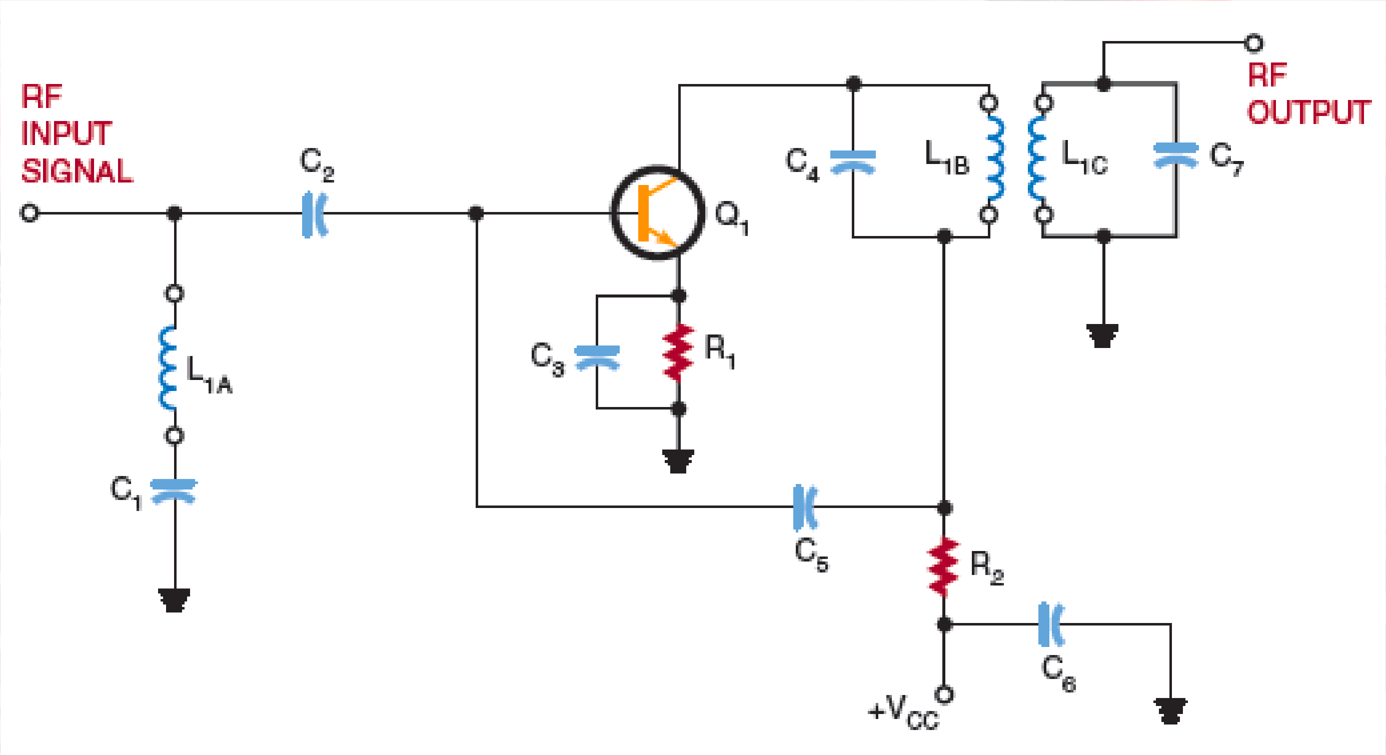


Figure 29-17. RF amplifier in a television VHF tuner.

RF and IF Amplifiers (cont'd.)

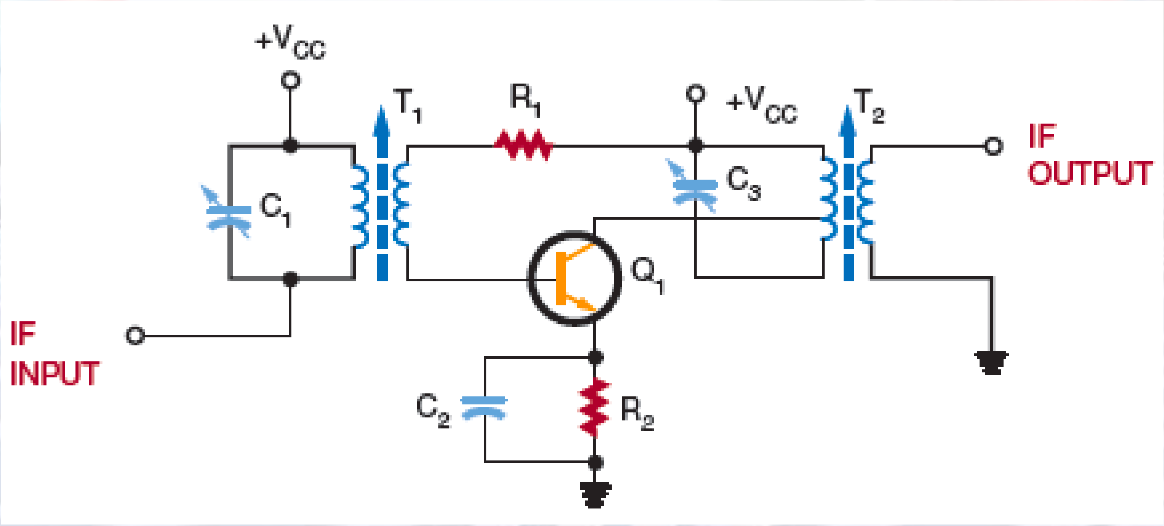


Figure 29-18. IF amplifier in an AM radio.

IF frequency is 455,000 hertz

RF and IF Amplifiers (cont'd.)

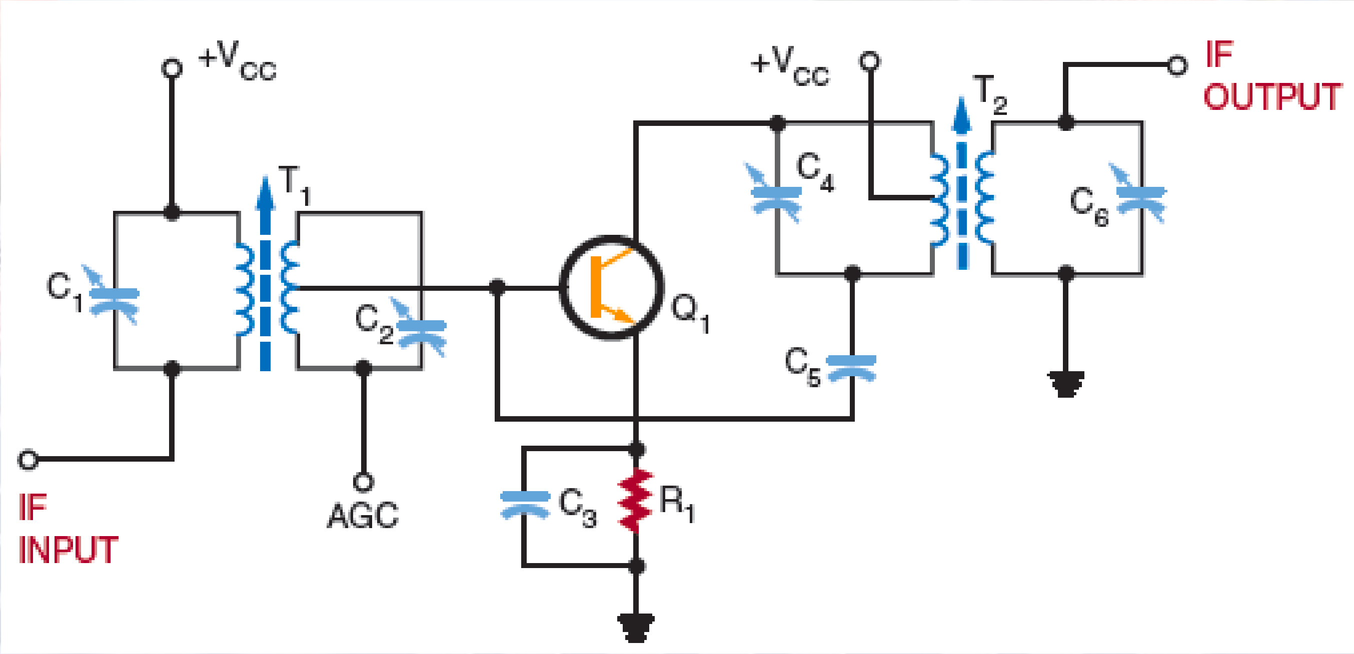


Figure 29-19. IF amplifier in a television receiver.

Comparison of radio and television frequencies

TYPE	RECEIVED RF	COMMON IF	BANDWIDTH
AM Radio	535-1605 kHz	455 kHz	10 kHz
FM Radio	88-108 MHz	10.7 MHz	150 kHz
Television			
Channels 2-6	54-88 MHz		
Channels 7-13	174-216 MHz	41-47 MHz	6 MHz
Channels 14-83	470-890 MHz		

Operational Amplifiers

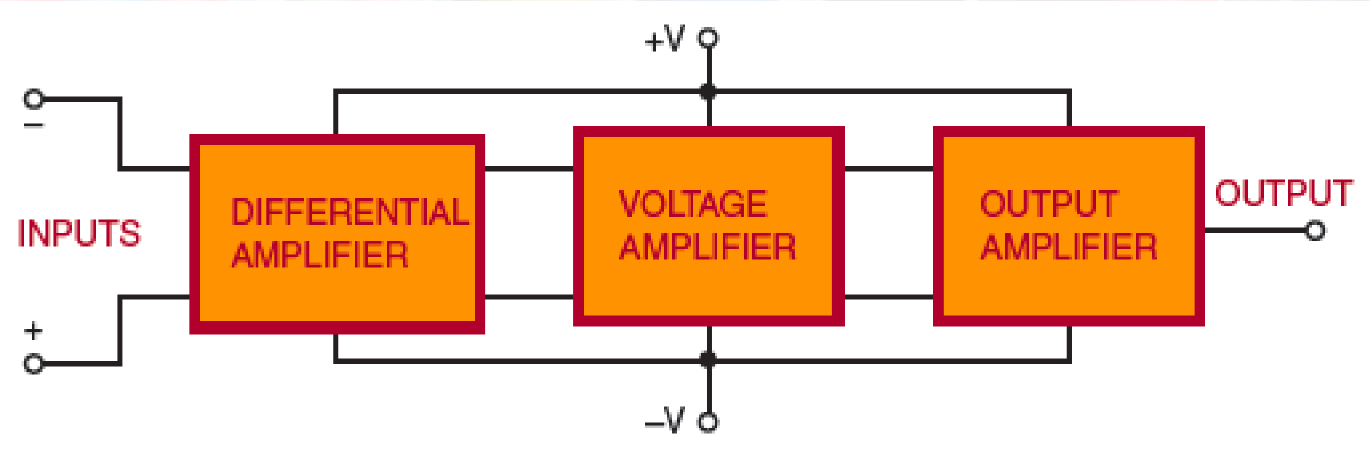


Figure 29-22. Block diagram of an op-amp.

Operational Amplifiers (cont'd.)

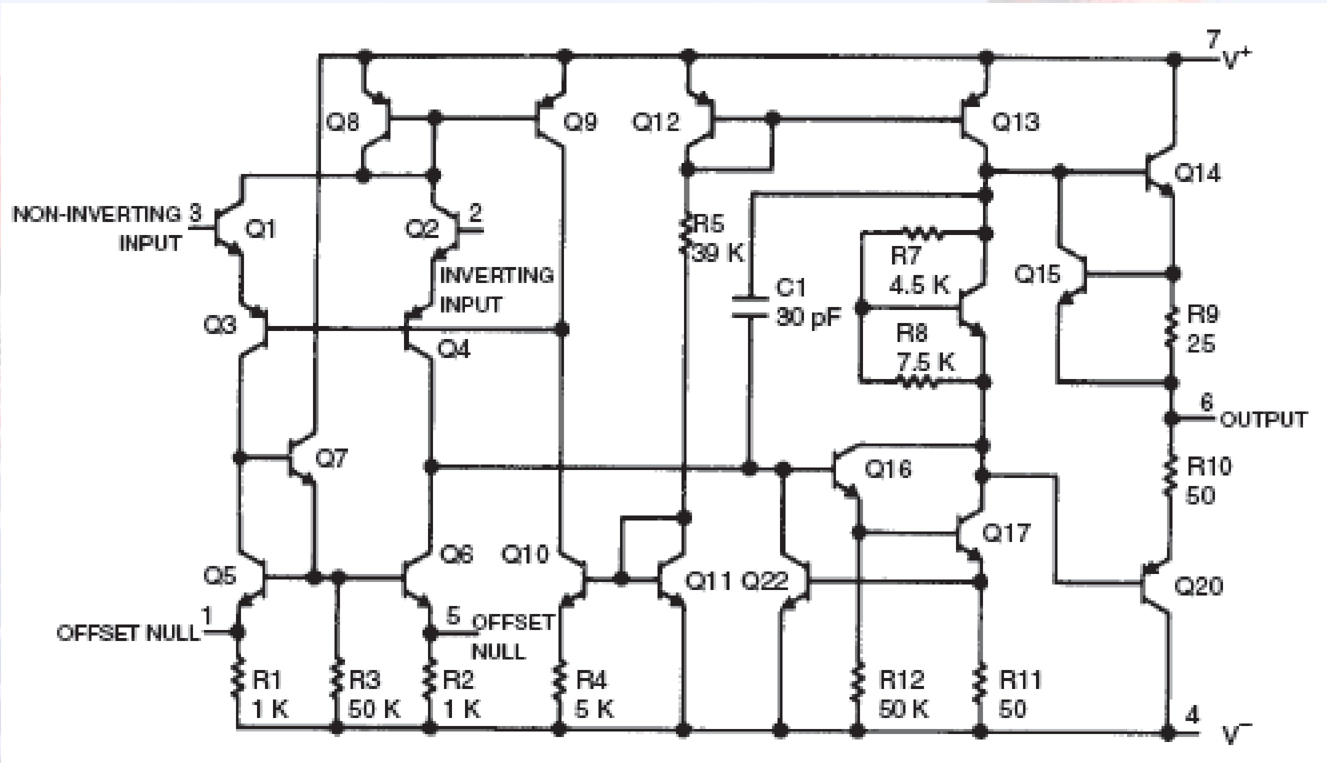


Figure 29-23. Schematic diagram of an op-amp.
(Courtesy of National Semiconductor Corporation.)

Operational Amplifiers (cont'd.)

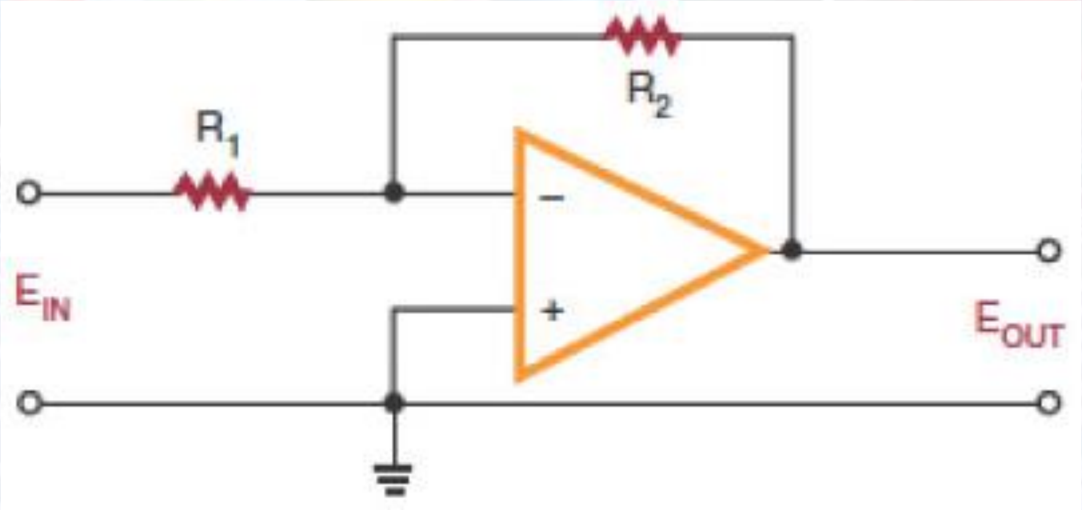


Figure 29-24. Op-amp connected as an inverting amplifier.

Operational Amplifiers (cont'd.)

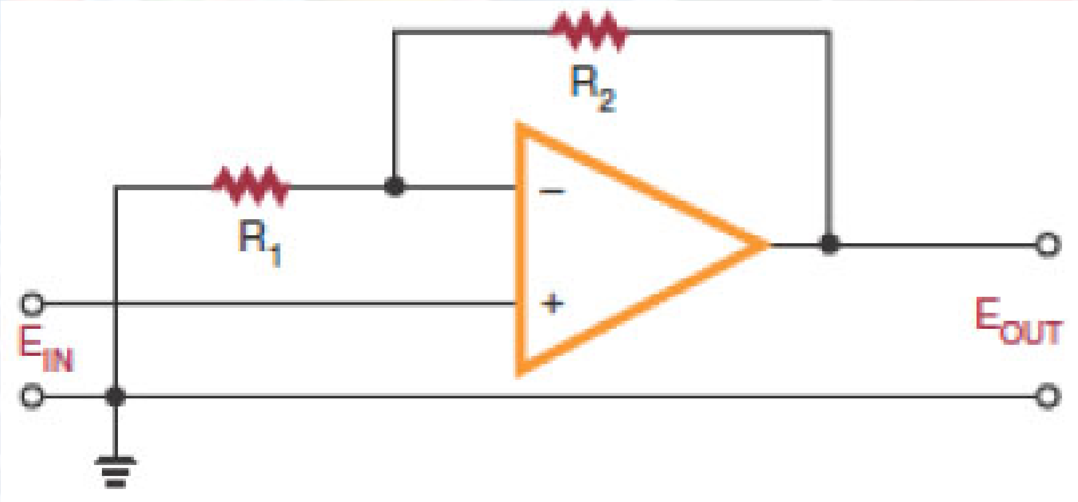


Figure 29-25. Op-amp connected as a noninverting amplifier.

Summary

- Direct-coupled amplifiers are used primarily as voltage amplifiers
- Audio amplifiers amplify AC signals in the audio range of 20 to 20,000 hertz
- Two types of audio amplifiers
  - Voltage amplifiers and power amplifiers
- RF amplifiers operate from 10,000 to 30,000 megahertz

Summary (cont'd.)

- Two types of RF amplifiers
  - Tuned and untuned
- Op-amps may provide output gains of 20,000 to 1,000,000 times the input
- Two basic closed-loop modes
  - Inverting configuration and noninverting configuration

Chapter 30

Oscillators

Objectives

- After completing this chapter, you will be able to:
  - Describe an oscillator and its purpose
  - Identify the main requirements of an oscillator
  - Explain how a tank circuit operates and describe its relationship to an oscillator
  - Draw a block diagram of an oscillator

Objectives (cont'd.)

- – Identify LC, crystal, and RC sinusoidal oscillator circuits
- – Identify nonsinusoidal relaxation oscillator circuits
- – Draw examples of sinusoidal and nonsinusoidal oscillators

Fundamentals of Oscillators

- Oscillator
  - A circuit that generates a repetitive AC signal
  - Output may be sinusoidal, rectangular, or sawtooth waveforms
- Main requirement
  - Output must not vary in frequency or amplitude

Fundamentals of Oscillators (cont'd.)

- Tank circuit
  - Formed when an inductor and capacitor are connected in parallel
  - Oscillates when excited by external DC source
  - Oscillation dampened by resistance of circuit
  - Oscillation maintained by positive feedback

Fundamentals of Oscillators (cont'd.)

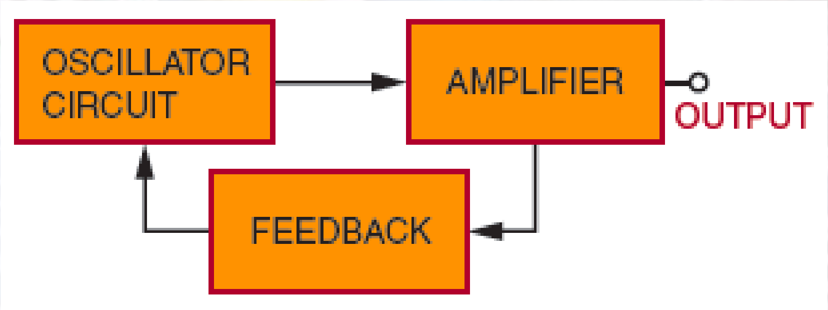


Figure 30-1. Block diagram of an oscillator.

Sinusoidal Oscillators

- Sinusoidal oscillators
  - Produce a sine-wave output
- Three basic types
  - LC oscillators
  - Crystal oscillators
  - RC oscillators

Sinusoidal Oscillators (cont'd.)

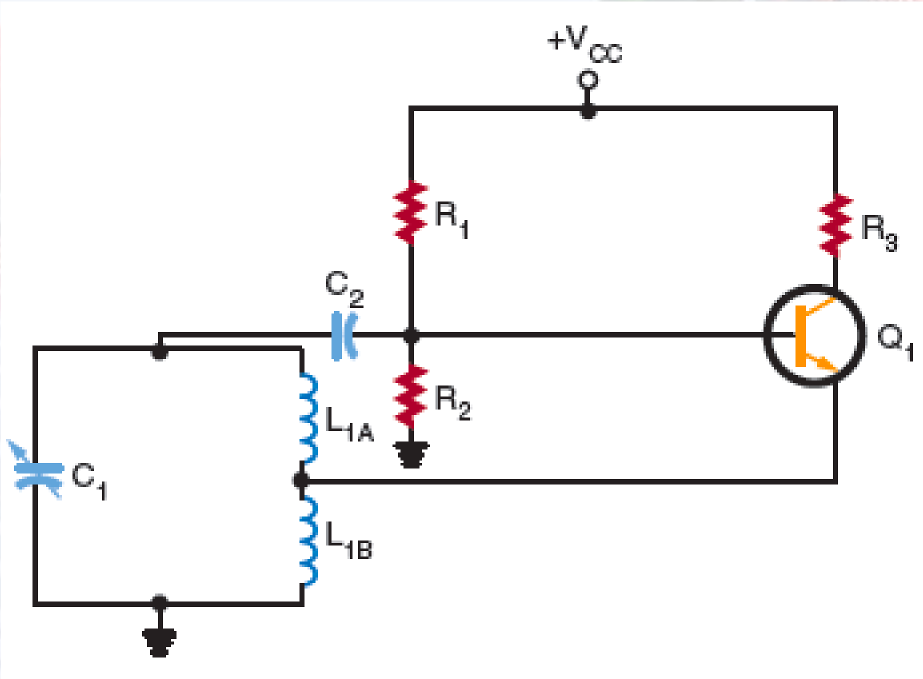


Figure 30-2. Series-fed Hartley oscillator.

Sinusoidal Oscillators (cont'd.)

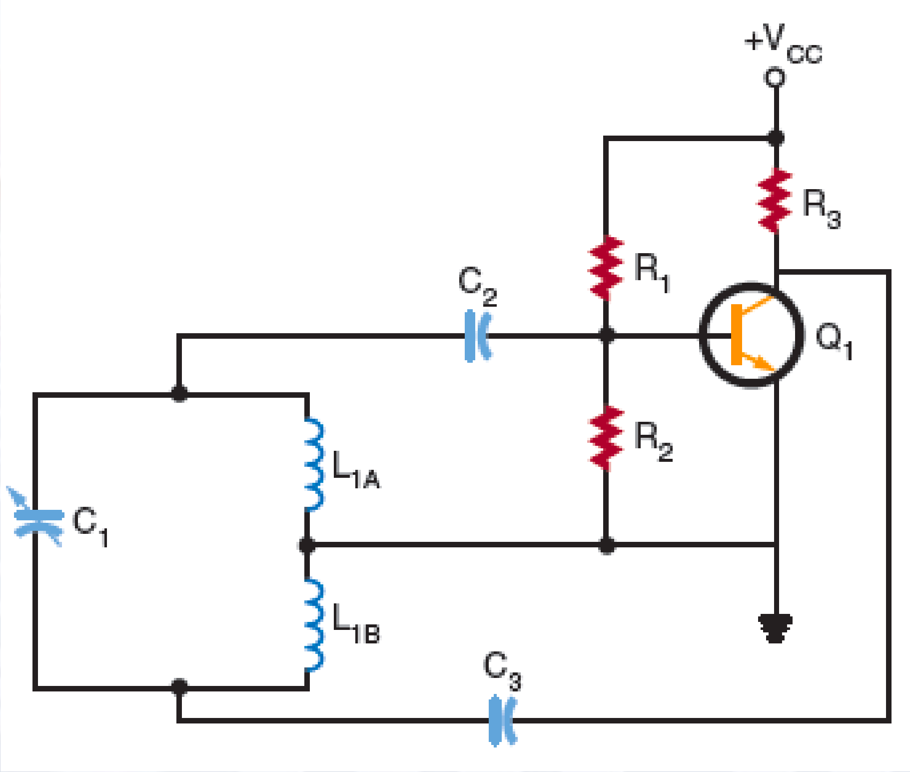


Figure 30-3. Shunt-fed Hartley oscillator.

Sinusoidal Oscillators (cont'd.)

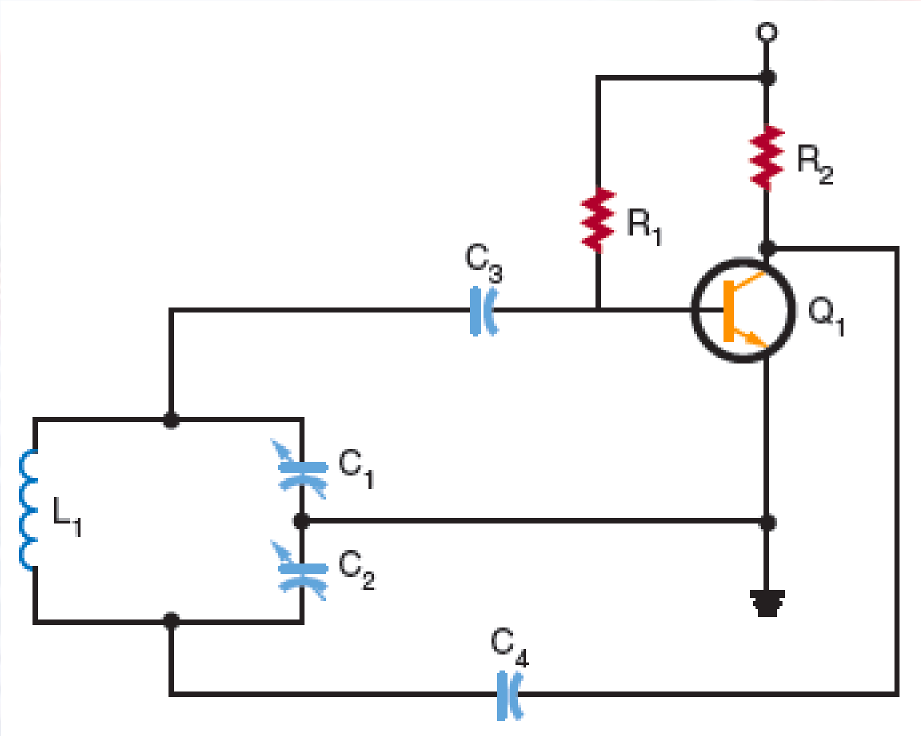


Figure 30-4. Colpitts oscillator.

Sinusoidal Oscillators (cont'd.)

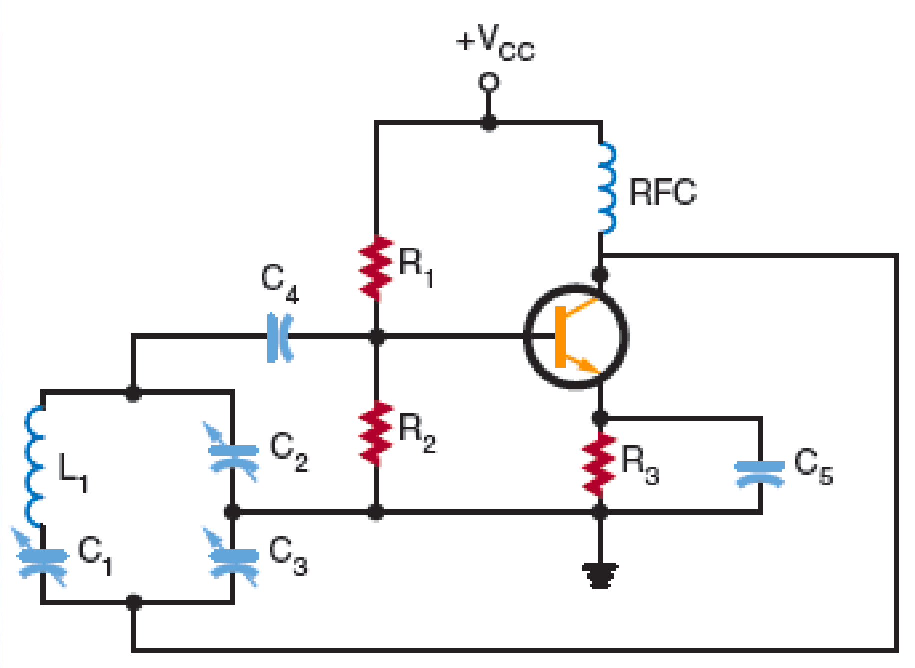


Figure 30-5. Clapp oscillator.

Sinusoidal Oscillators (cont'd.)

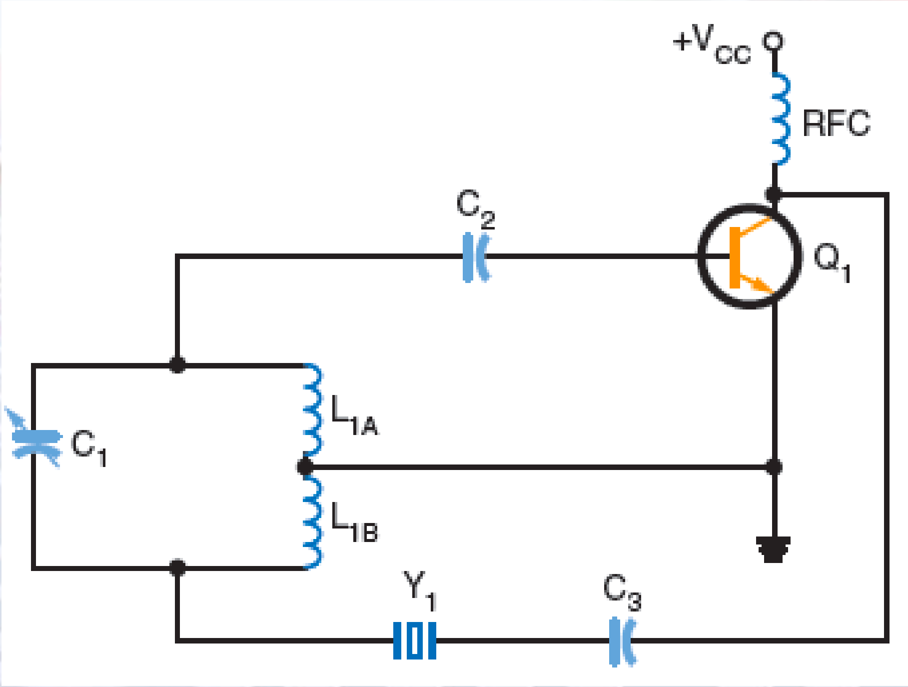


Figure 30-7. Crystal shunt-fed Hartley oscillator.

Sinusoidal Oscillators (cont'd.)

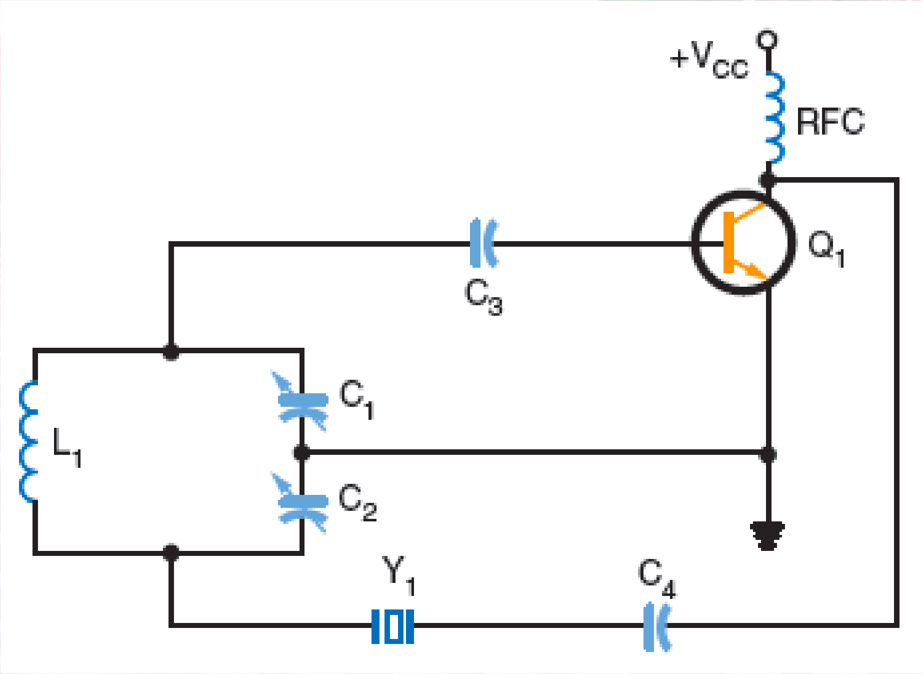


Figure 30-8. Colpitts crystal oscillator.

Sinusoidal Oscillators (cont'd.)

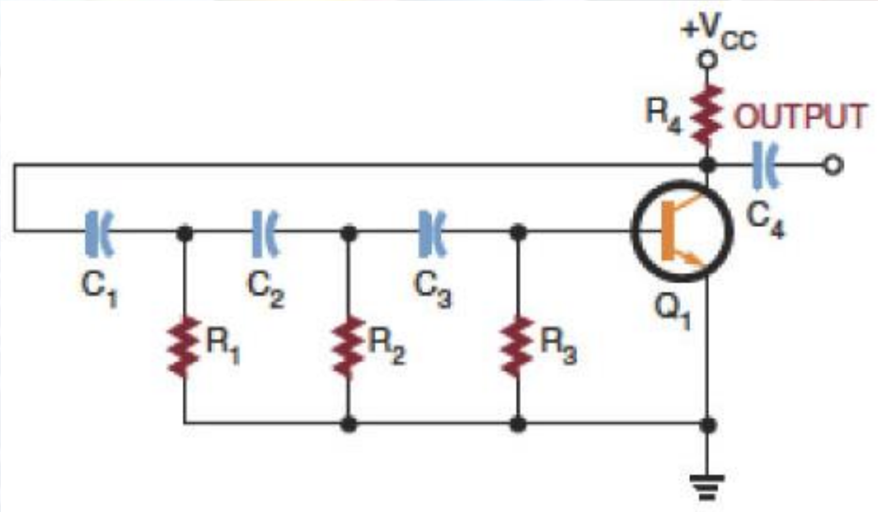


Figure 30-11. Phase-shift oscillator.

Sinusoidal Oscillators (cont'd.)

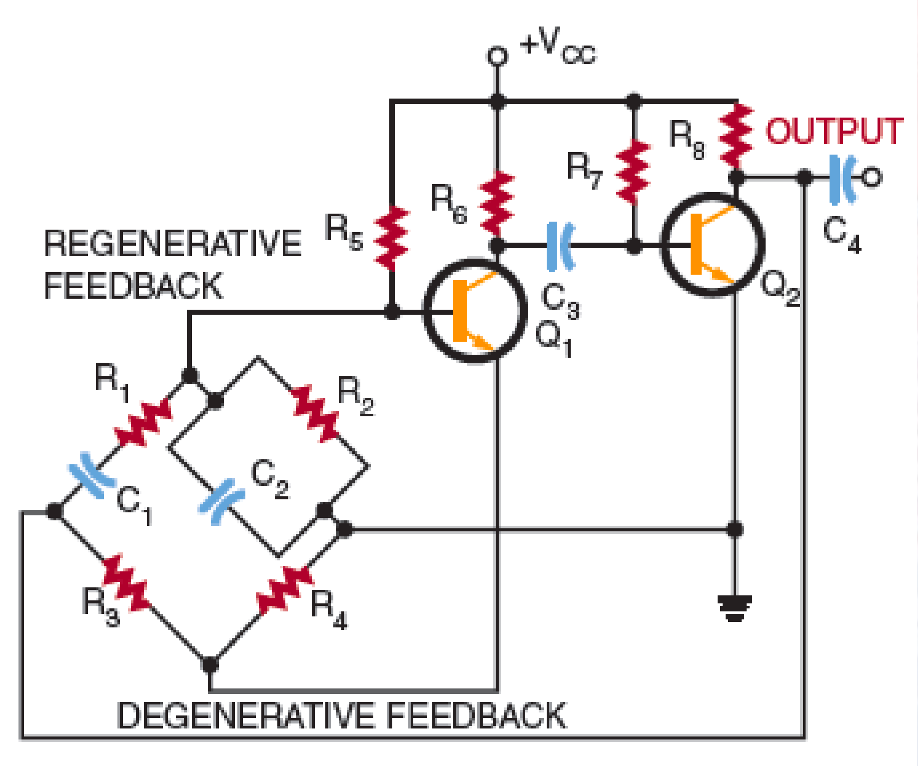


Figure 30-12. Wien-bridge oscillator.

Nonsinusoidal Oscillators

- Nonsinusoidal oscillators
  - Do not produce a sine-wave output
  - Outputs include square, sawtooth, rectangular, or triangular waveforms, or a combination of two waveforms
  - Form of relaxation oscillator

Nonsinusoidal Oscillators (cont'd.)

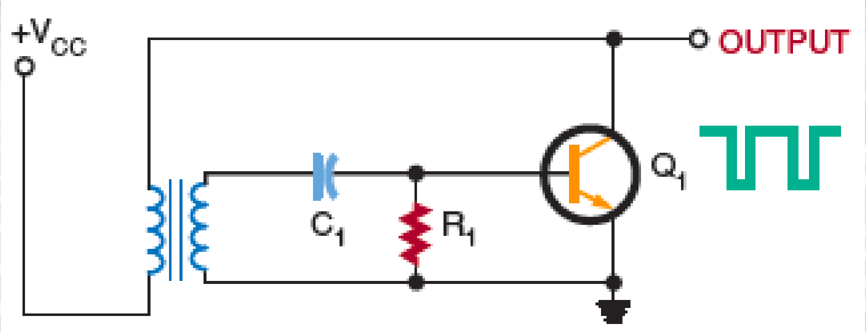


Figure 30-14. Blocking oscillator.

Nonsinusoidal Oscillators (cont'd.)

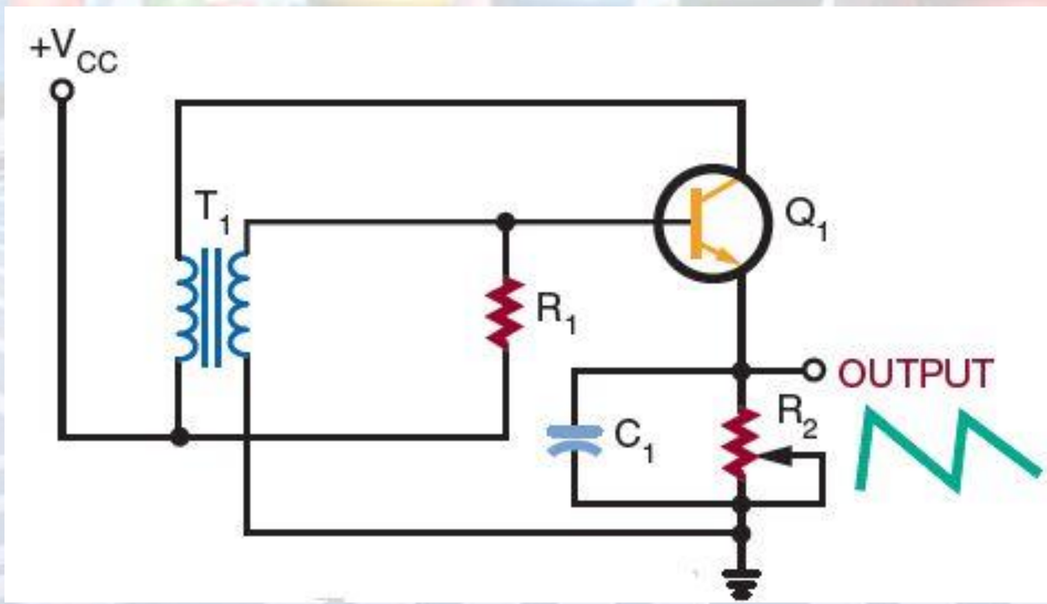


Figure 30-15. Sawtooth waveform generated by a blocking oscillator.

Nonsinusoidal Oscillators (cont'd.)

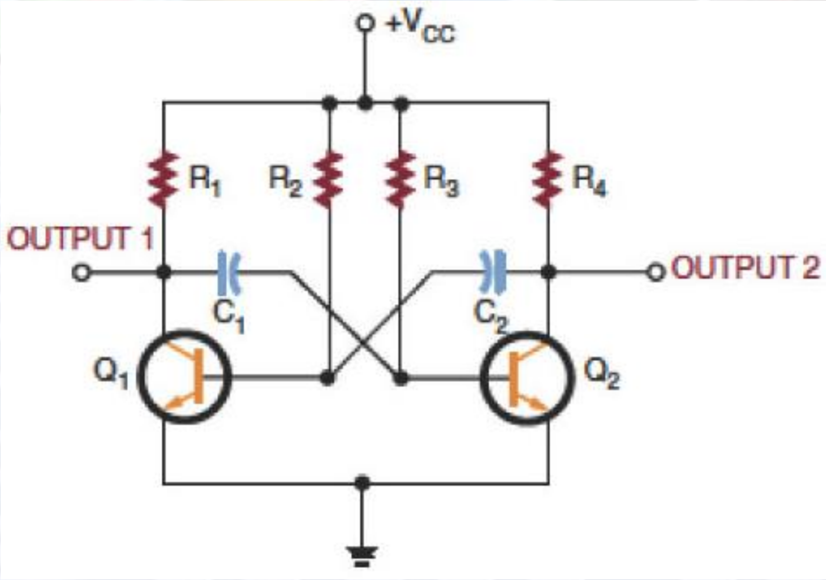


Figure 30-16. Free-running multivibrator.

Summary

- An oscillator is a nonrotating device for producing alternating current
- Main requirement of an oscillator
  - That output be uniform and not vary in frequency or amplitude
- A tank circuit oscillates when an external voltage source is applied

Summary (cont'd.)

- The three basic types of sinusoidal oscillators
  - LC oscillators, crystal oscillators, and RC oscillators
- Nonsinusoidal oscillators do not produce a sine-wave output
- A relaxation oscillator is the basis of all nonsinusoidal oscillators

Homework

1. What is the function of the rectifier in a power supply?
2. Draw schematic diagrams of the three basic configurations of transistor amplifier circuits