Applied Electronics

Instructor:

Dr. Ahmad El-Banna

DAY#3
SUMMER 2016

Agenda

- Amplifier Basics
- Amplifier Frequency Response
- Power Amplifier
- Tuned Amplifier
- Differential Amplifier
- Troubleshooting
- Practical Applications

Amplification in ac domain

$\eta = P_o/P_i$ cannot be greater than 1.

In fact, a *conversion efficiency* is defined by $\eta = P_{o(ac)}/P_{i(dc)}$, where $P_{o(ac)}$ is the ac power to the load and $P_{i(dc)}$ is the dc power supplied.

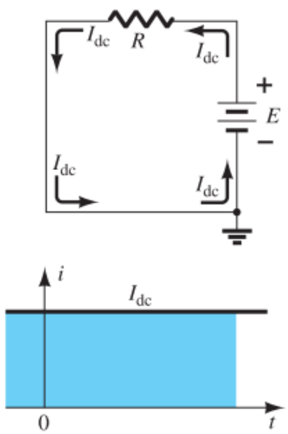


FIG. 5.1
Steady current established by a dc supply.

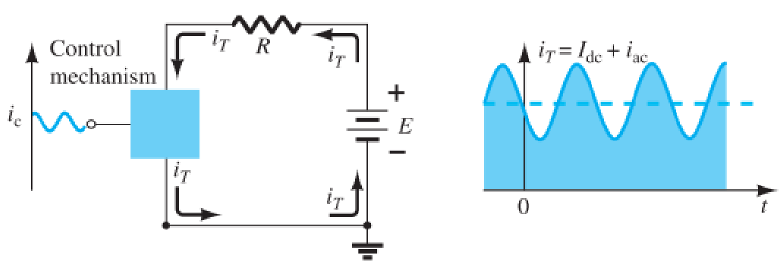
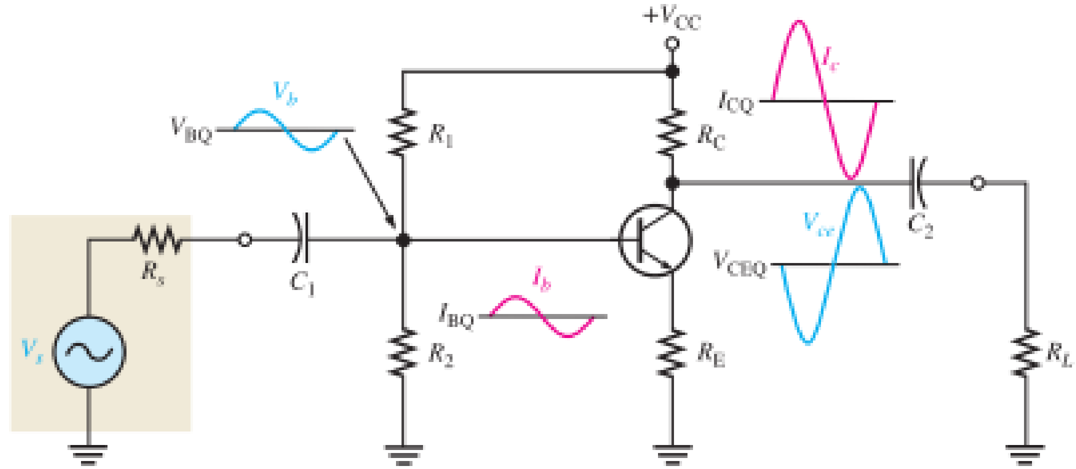


FIG. 5.2
Effect of a control element on the steady-state flow of the electrical system of Fig. 5.1.

- The superposition theorem is applicable for the analysis and design of the dc and ac components of a BJT network, permitting the separation of the analysis of the dc and ac responses of the system.

Linear Amplifier

- A linear amplifier provides amplification of a signal without any distortion so that the output signal is an exact amplified replica of the input signal.



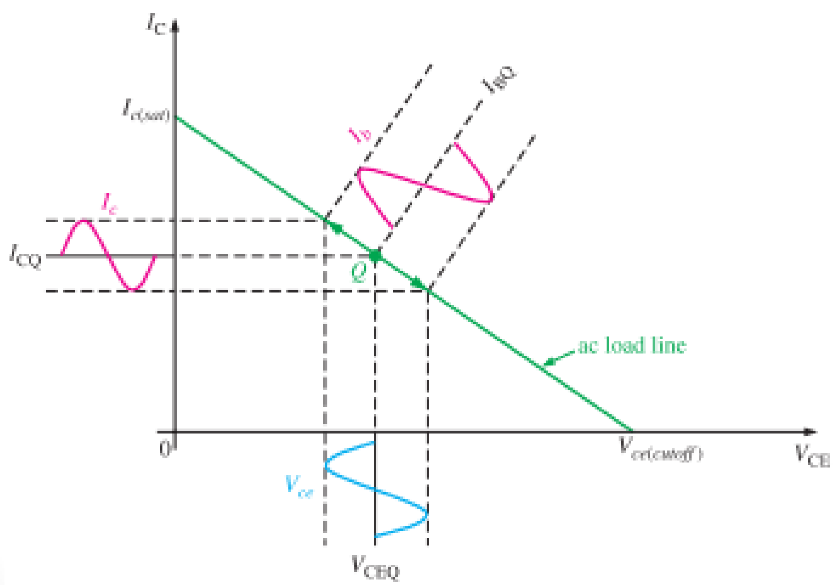
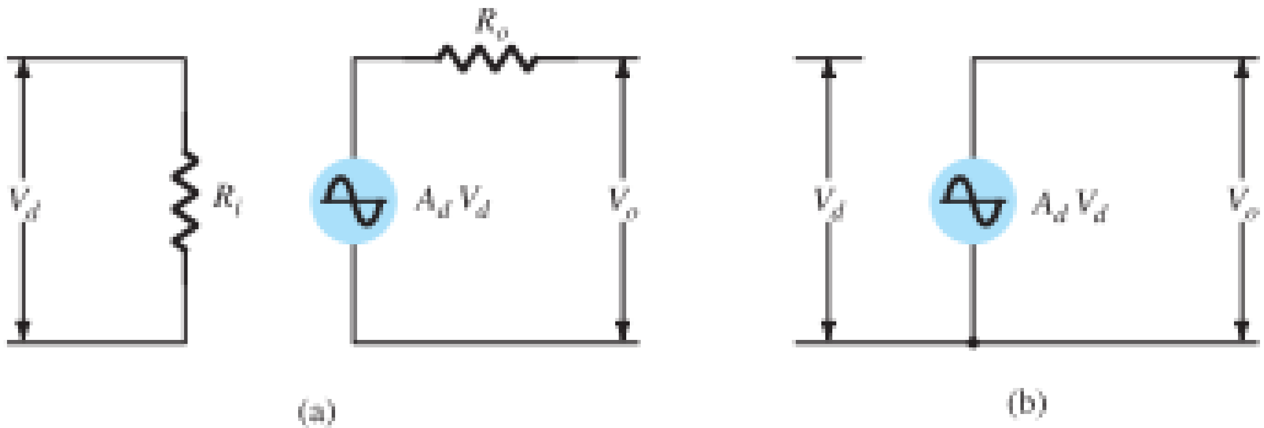


FIGURE 6–3

Graphical ac load line operation of the amplifier showing the variation of the base current, collector current, and collector-to-emitter voltage about their dc Q-point values. I_b and I_c are on different scales.

Amplifier block diagram



practical

Ideal

Amplifier Important parameters

- Input Impedance
- Output impedance
- Gain

Frequency response

- We will now investigate the frequency effects introduced by the larger capacitive elements of the network at low frequencies and the smaller capacitive elements of the active device at high frequencies.
- Different coupling used in amplifier stages are:
  - Direct coupling
  - Capacitive coupling
  - Transformer coupking

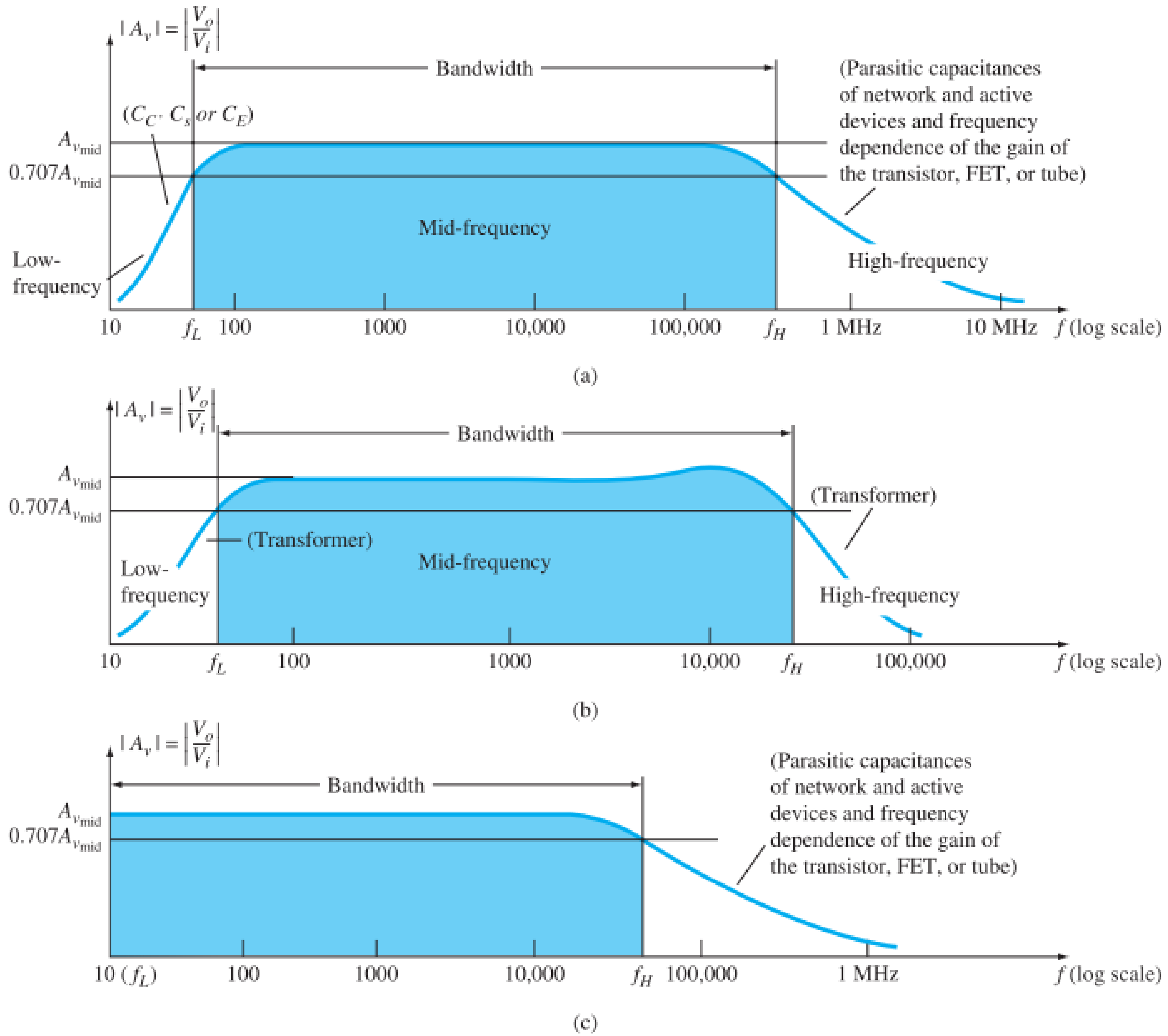


FIG. 9.8

Gain versus frequency: (a) RC-coupled amplifiers; (b) transformer-coupled amplifiers; (c) direct-coupled amplifiers.

- Normalized plot

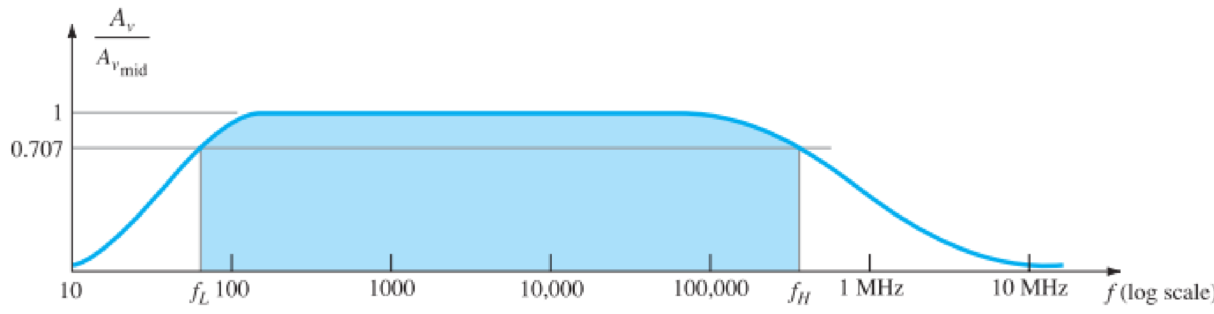


FIG. 9.9
Normalized gain versus frequency plot.

- Decibel plot

$$\left.\frac{A_v}{A_{v_{mid}}}\right|_{dB} = 20 \log_{10} \frac{A_v}{A_{v_{mid}}}$$

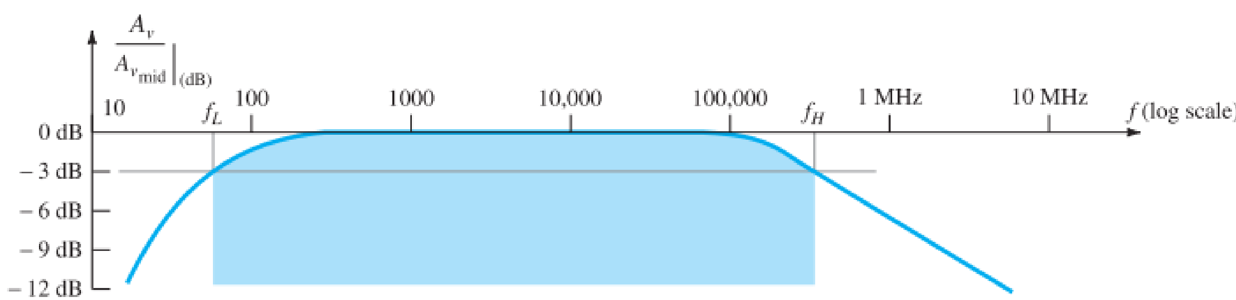


FIG. 9.12
Decibel plot of the normalized gain versus frequency plot of Fig. 9.9.

- Phase plot

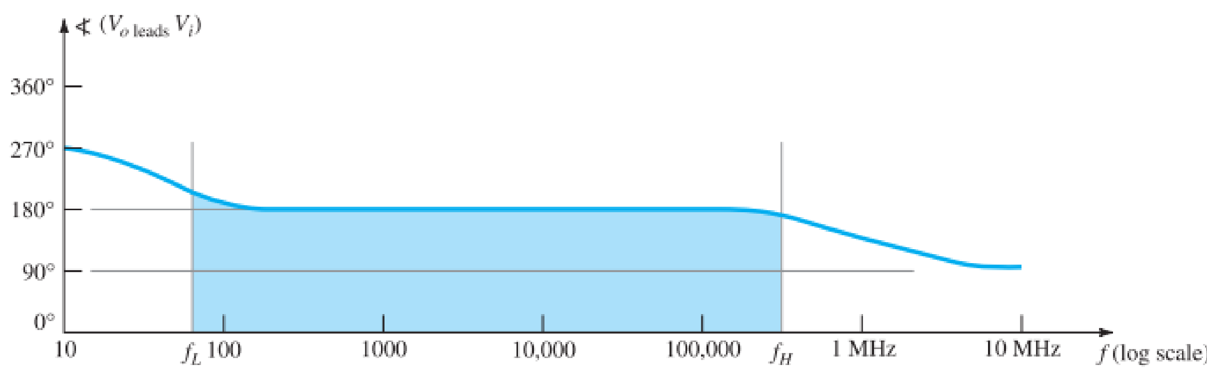


FIG. 9.13
Phase plot for an RC-coupled amplifier system.

POWER AMPLIFIERS

Amplifier Classes

- 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.

Power Amplifier Classes:

1. **Class A**: The output signal varies for a full 360° of the input signal.
   - Bias at the half of the supply

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

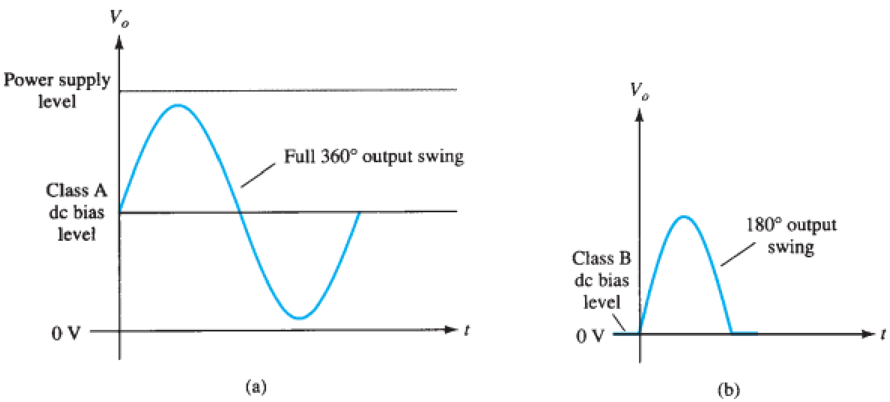


FIG. 12.1
Amplifier operating classes.

Amplifier Efficiency

Power Amplifier Classes …

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.

- 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.*

CLASS A AMPLIFIER Types

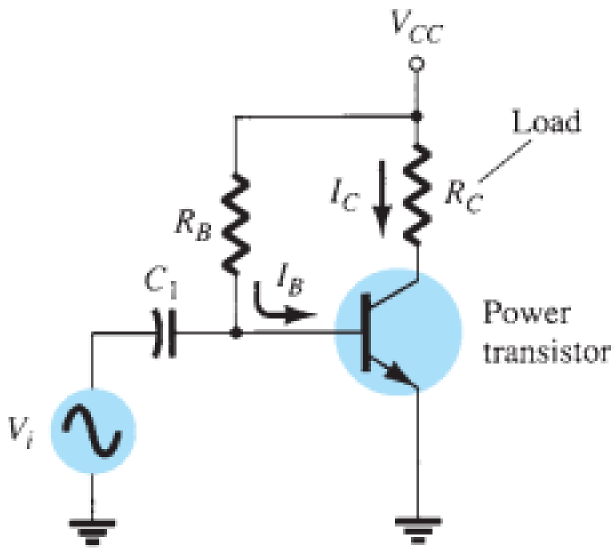


FIG. 12.2
Series-fed class A large-signal amplifier.

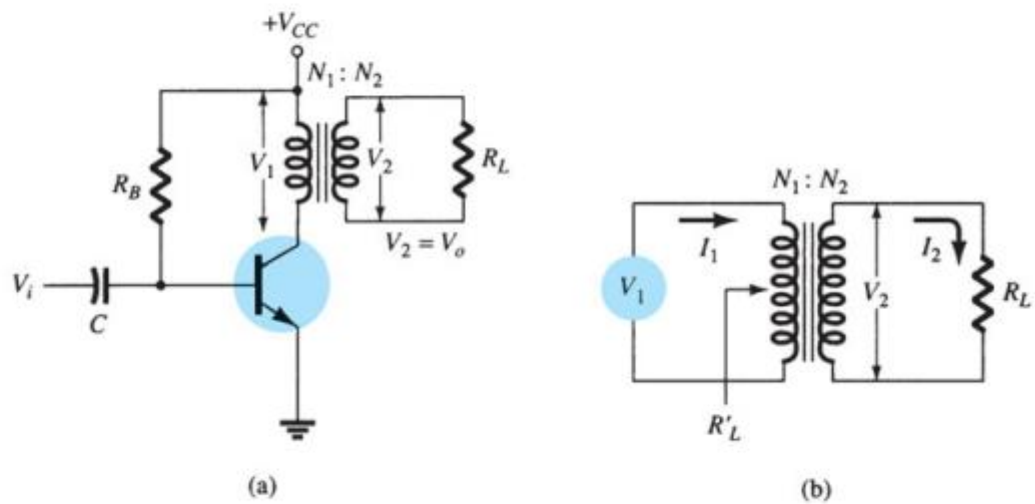


FIG. 12.6
Transformer-coupled audio power amplifier.

SERIES-FED

Transformer Coupled

Push–Pull 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.
- This is essentially no bias, and the transistor conducts current for only one-half of the signal cycle.

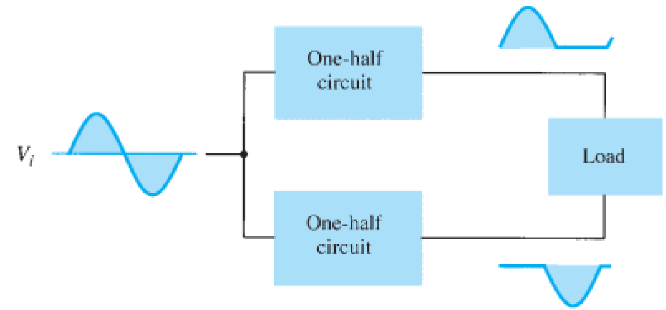


FIG. 12.12
Block representation of push–pull operation.

- Connection of push–pull amplifier to load

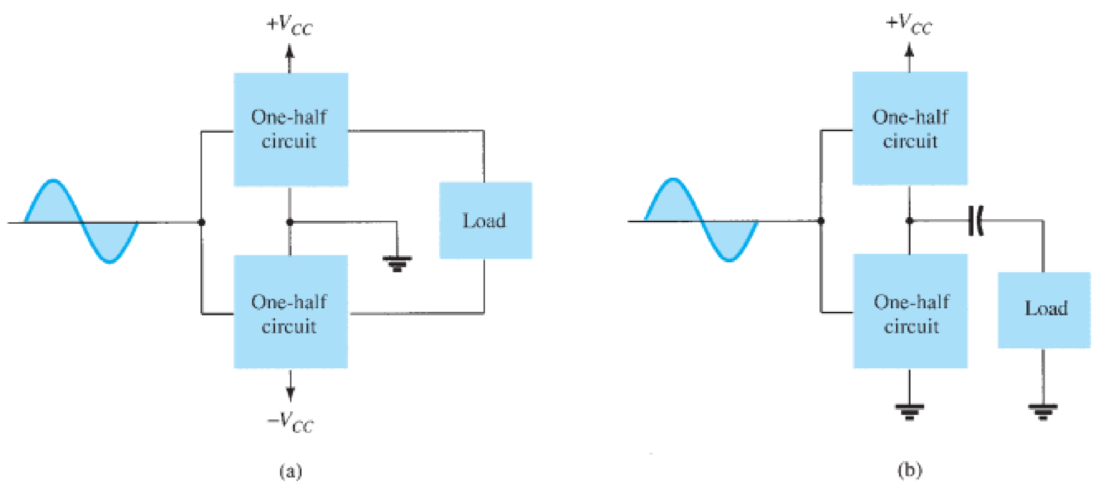
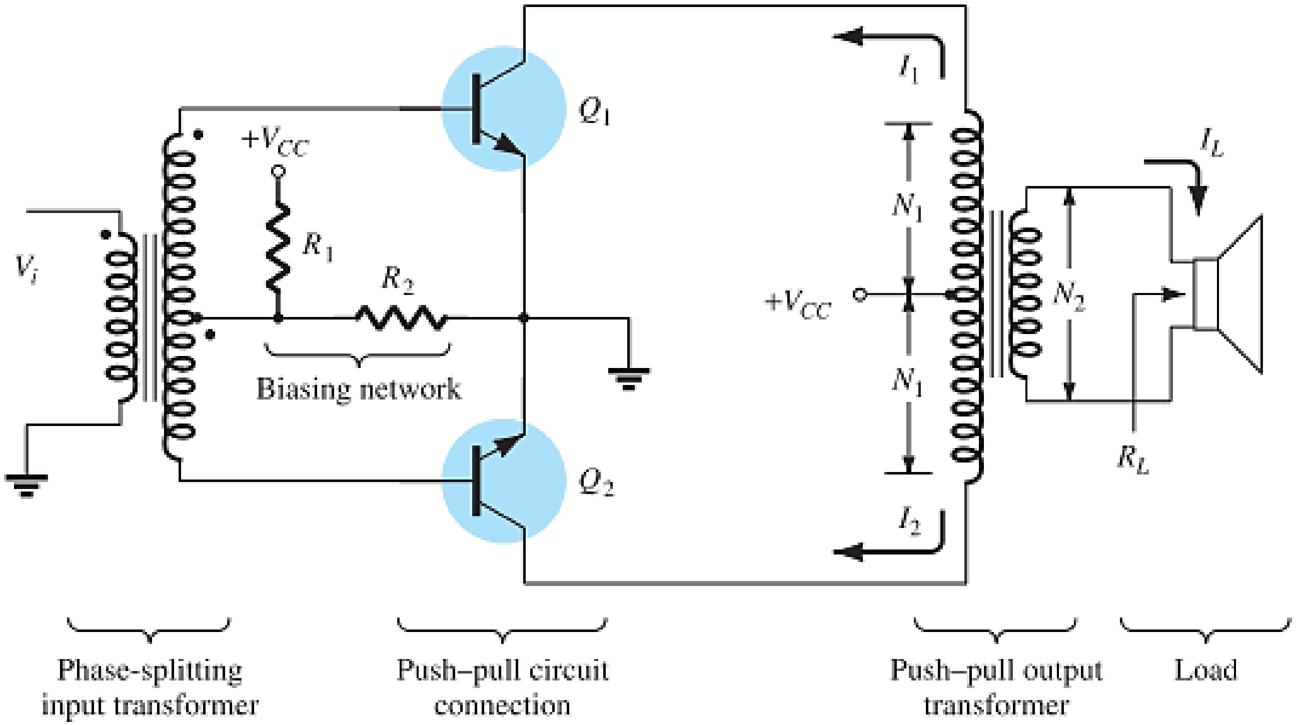


FIG. 12.13
Connection of push–pull amplifier to load: (a) using two voltage supplies; (b) using one voltage supply.

Class B Amplifier Circuits

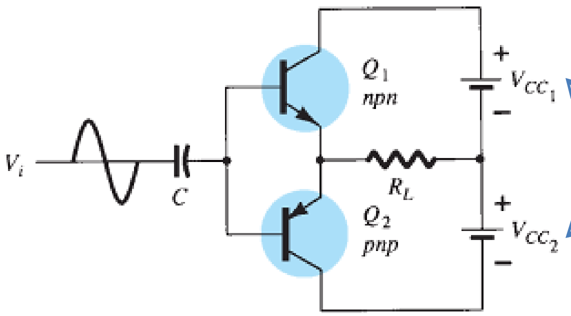
- Transformer-Coupled Push–Pull Circuits



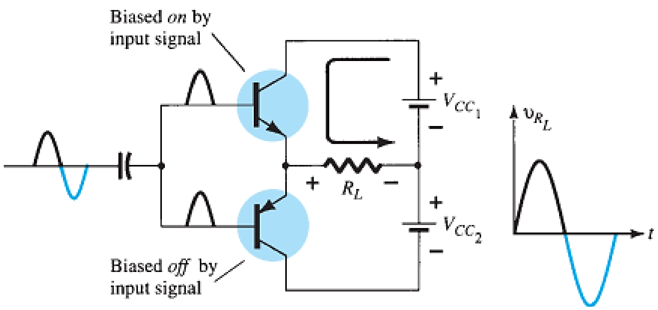
Transformers are bulky !

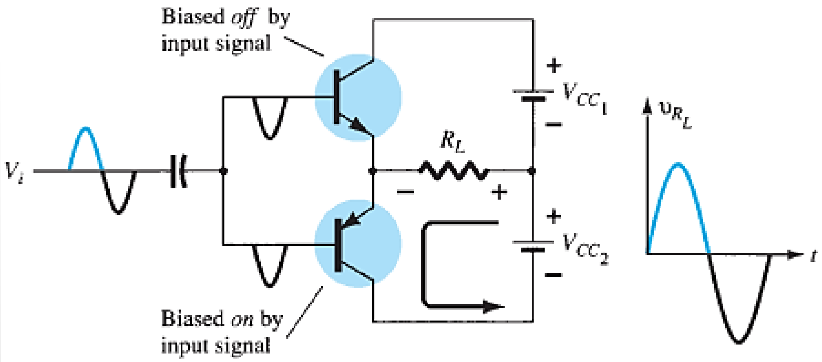
Class B Amplifier Circuits..

- Complementary-Symmetry Circuits

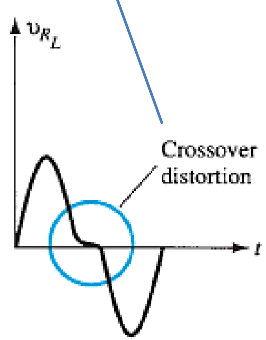


Needs two separate voltage supplies!

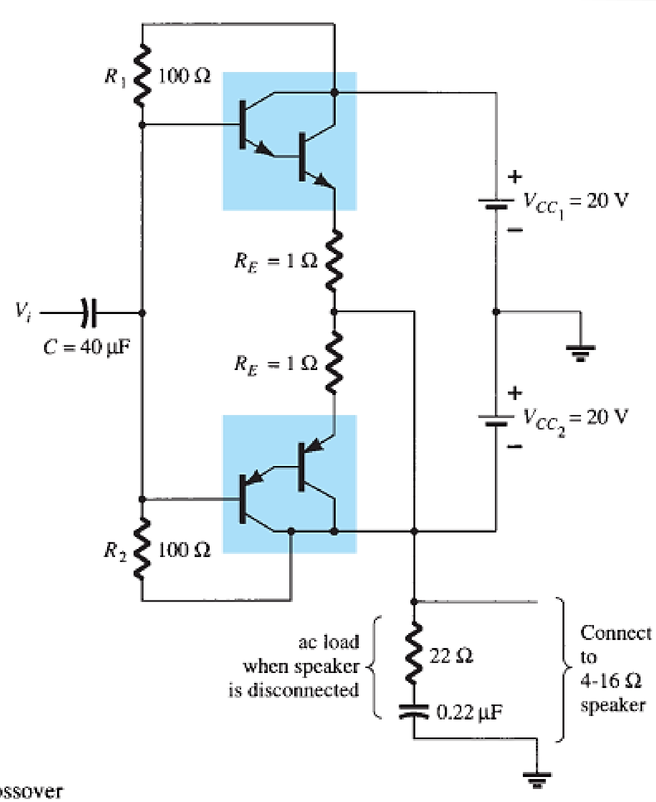




Biasing the transistors in class AB improves this operation



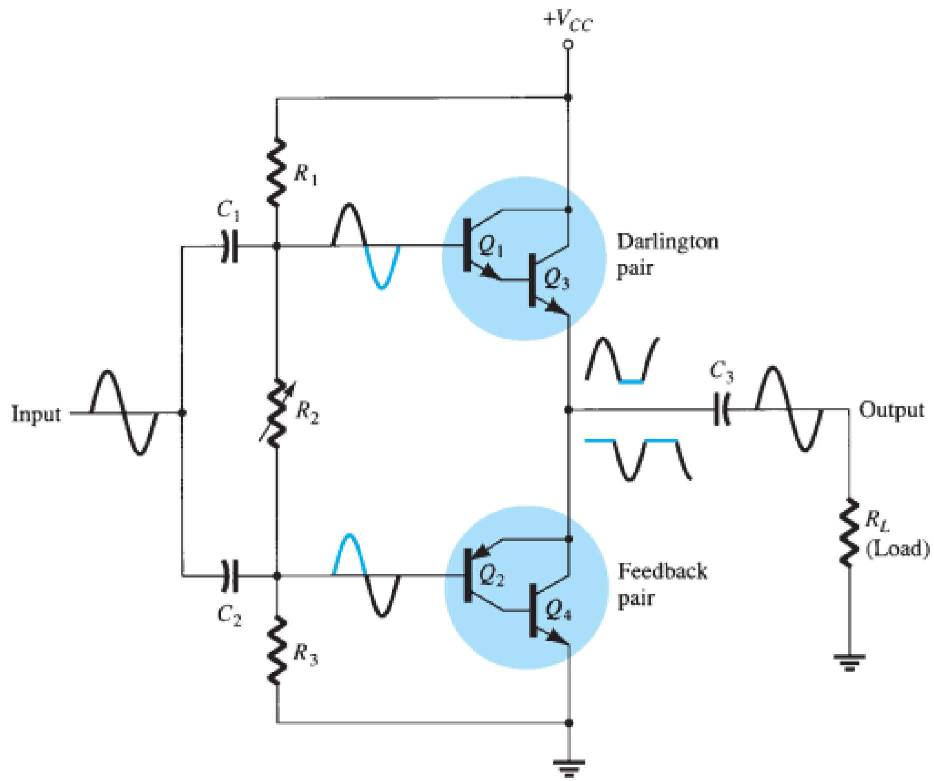
- Complementary-symmetry push–pull circuit using Darlington transistors.



- higher output current
- lower output resistance.

Class B Amplifier Circuits…

- Quasi-Complementary Push–Pull Amplifier



- In practical power amplifier circuits, it is preferable to use npn transistors for both high-current-output devices.
- The push–pull operation is achieved by using complementary transistors (Q_1 and Q_2) before the matched npn output transistors (Q_3 and Q_4).
- R_2 can be adjusted to minimize crossover distortion.
- It is the most popular form of power amplifier

- Quasi-complementary push–pull transformerless power amplifier.

TUNED AMPLIFIER

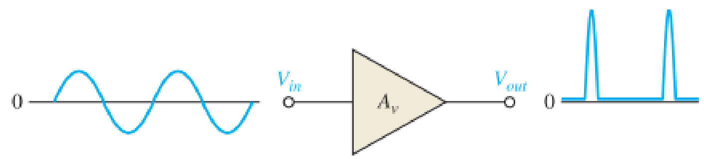
Introduction

- Class C amplifiers are biased so that conduction occurs for much less than 180°.
- Class C amplifiers are more efficient than either class A or push-pull class B and class AB, which means that more output power can be obtained from class C operation.
- The output amplitude is a nonlinear function of the input, so class C amplifiers are not used for linear amplification.
- They are generally used in radio frequency (RF) applications, including circuits, such as
  - oscillators, that have a constant output amplitude
  - modulators, where a high-frequency signal is controlled by a low-frequency signal.

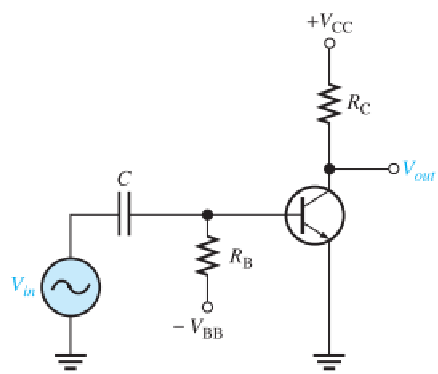
- Therefore, <u>Class C amplifiers are also called Tuned Amplifiers.</u>

- An amplifier which amplifies a specific frequency (or a narrow band of frequencies) is called a *tuned voltage amplifier*.
- It has two purposes:
  - Selection of a desired radio frequency signal.
  - Amplification of the selected signal to a suitable voltage level.

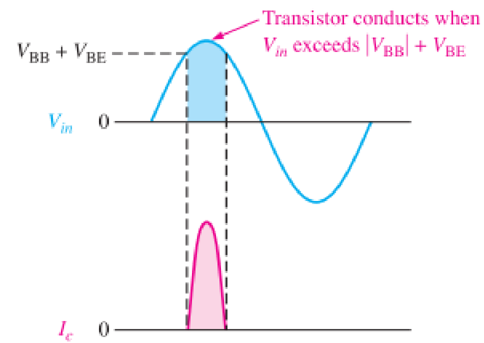
Class C operation



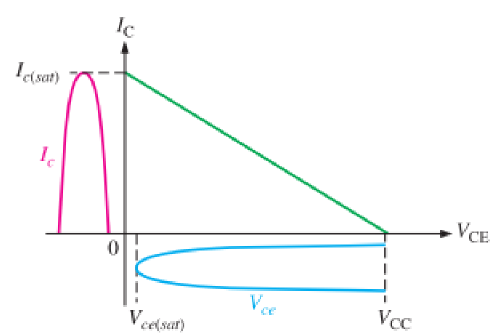
- It is biased below cutoff with the negative V_{BB} supply.
- A class C amplifier is normally operated with a resonant circuit load, so the resistive load is used only for the purpose of illustrating the concept.



(a) Basic class C amplifier circuit



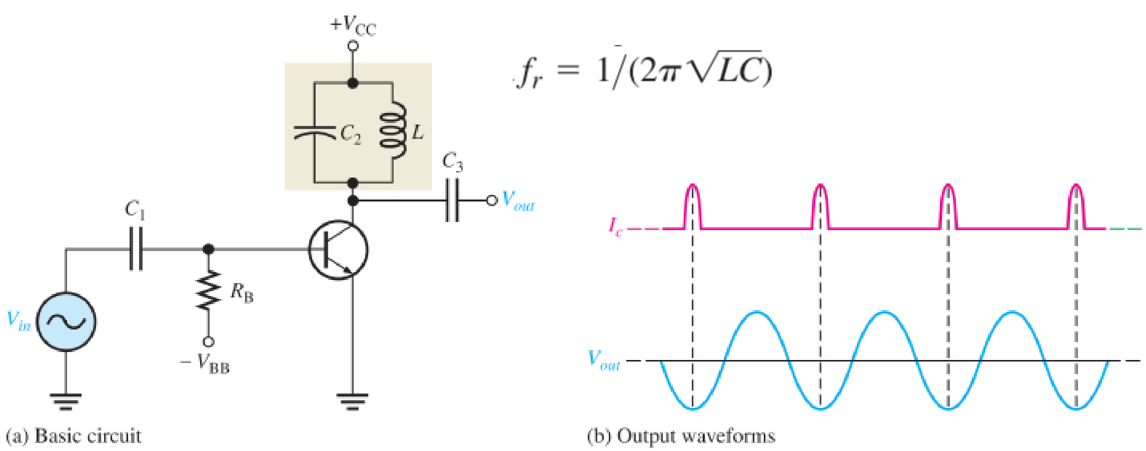
(b) Input voltage and output current waveforms



(c) Load line operation

Usage of Parallel Resonance Circuit

- Because the collector voltage (output) is not a replica of the input, the resistively loaded class C amplifier alone is of no value in linear applications.
- It is therefore necessary to use a class C amplifier with a parallel resonant circuit (tank).
- The short pulse of collector current on each cycle of the input initiates and sustains the oscillation of the tank circuit so that an output sinusoidal voltage is produced.
- The tank circuit has high impedance only near the resonant frequency, so the gain is large only at this frequency.

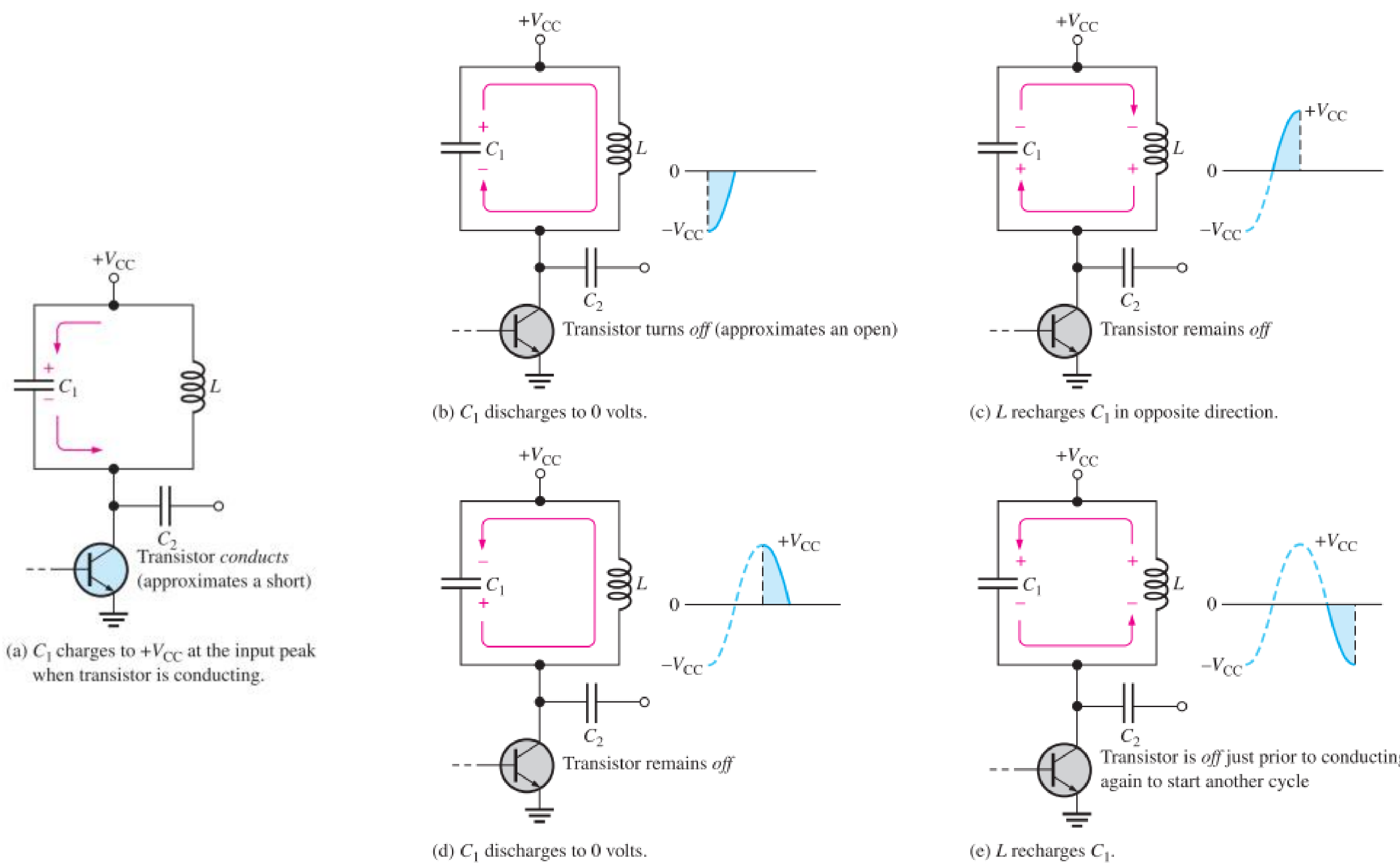


$$f_r = 1/(2\pi\sqrt{LC})$$

▲ FIGURE 7–24

Tuned class C amplifier.

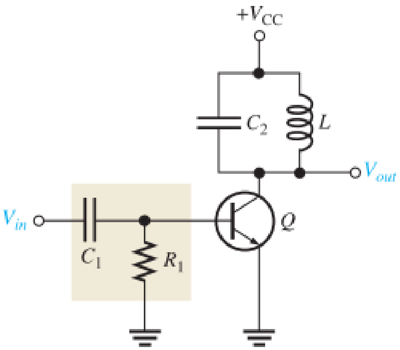
Resonant Circuit Action



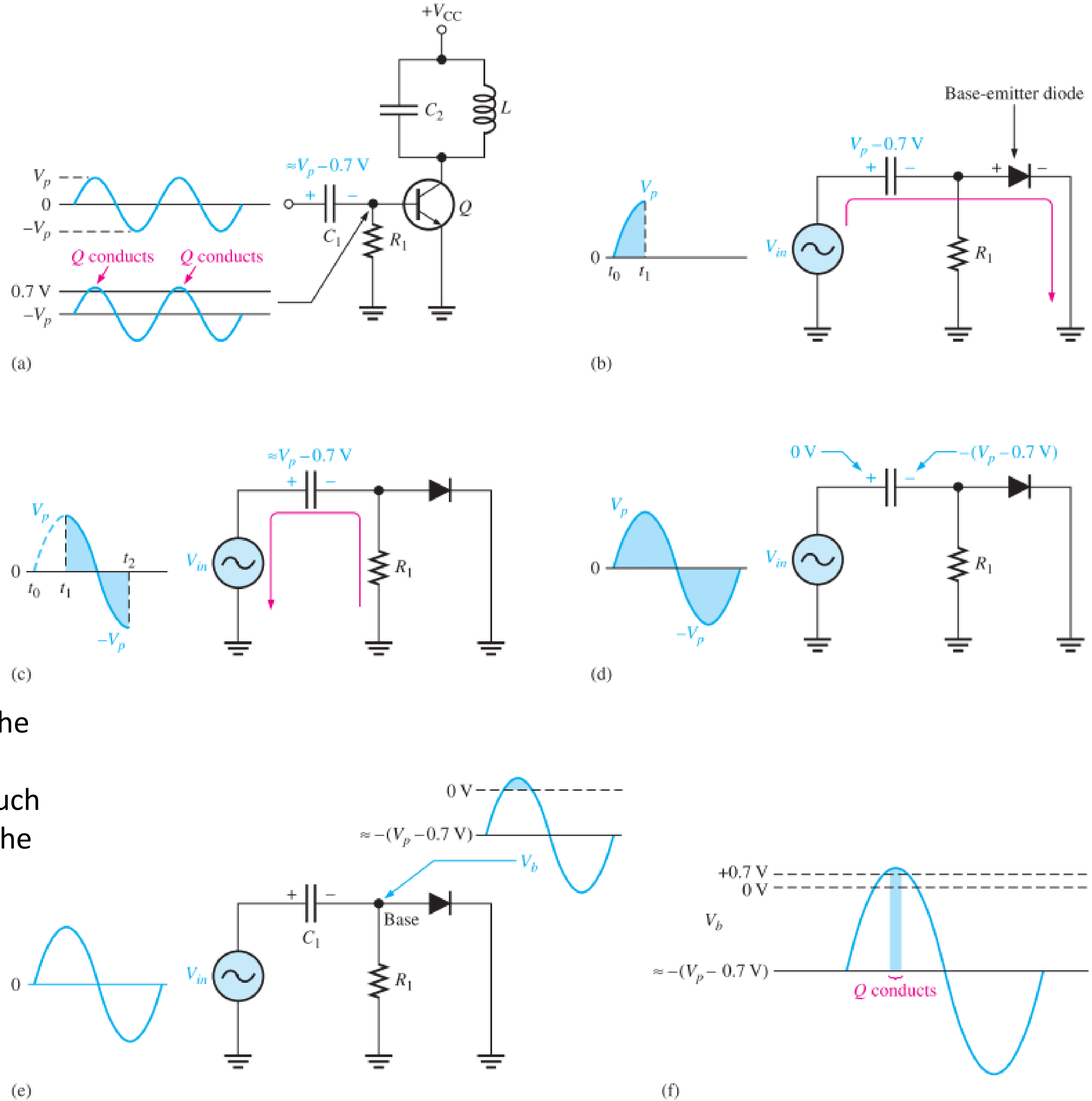
▲ FIGURE 7–25

Resonant circuit action.

Clamper Bias



For good clamping action, the R_1C_1 time constant of the clamping circuit must be much greater than the period of the input signal.



▲ FIGURE 7–28

Clamper bias action.

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Summer 2016

DIFFERENTIAL AMPLIFIER

Basic Internal Arrangement of an Op-Amp.

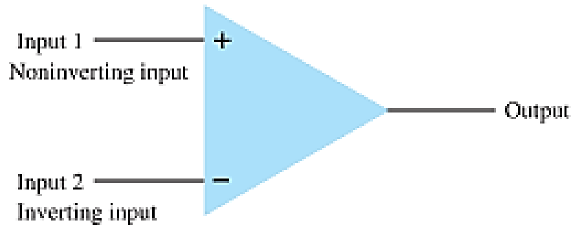
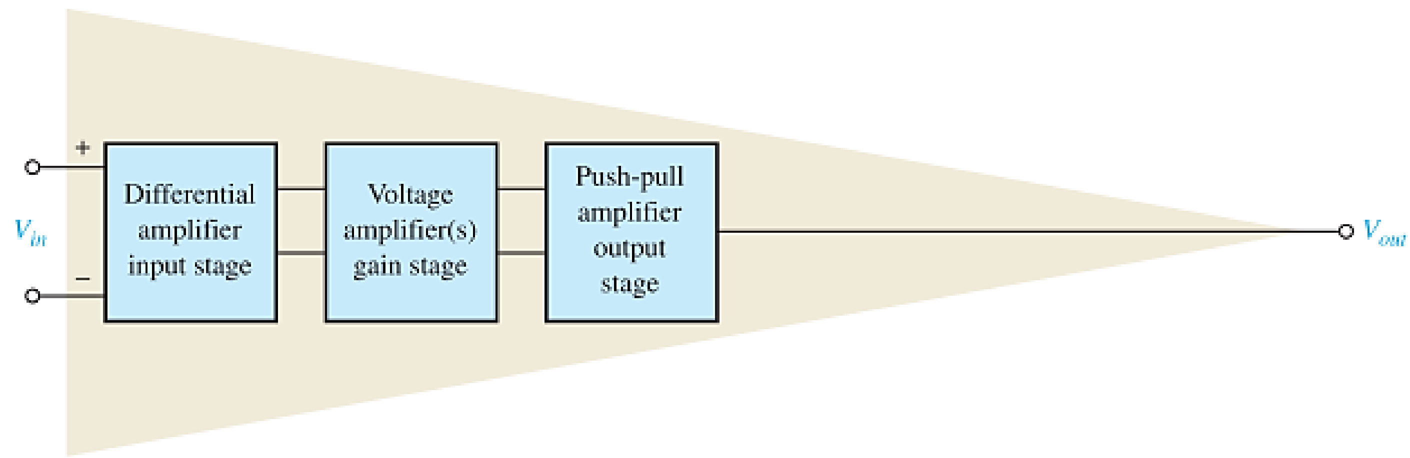


FIG. 10.1
Basic op-amp.



Stage#1 → Differential Amplifier

Single-Ended Input & Double-Ended (Differential) Input

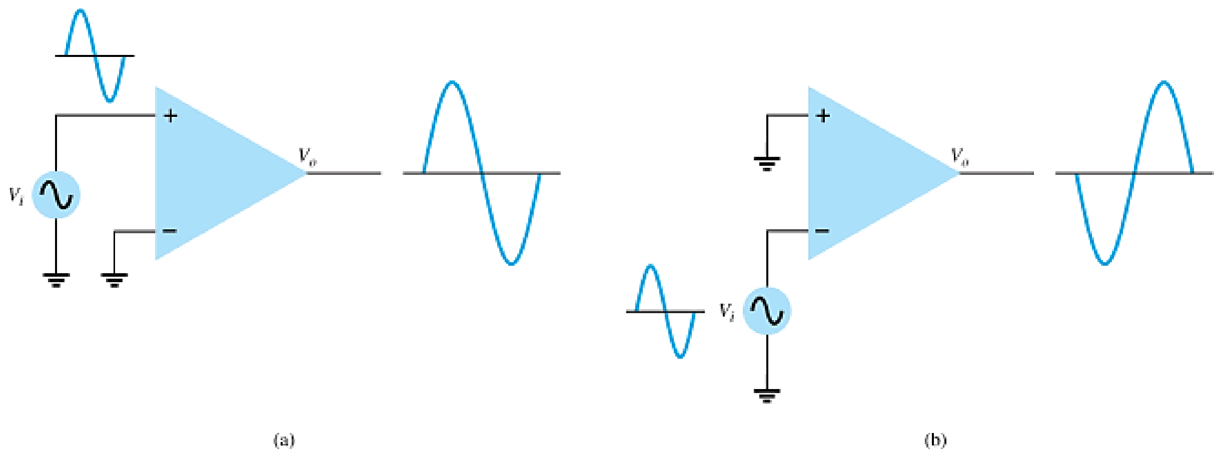


FIG. 10.2
Single-ended operation.

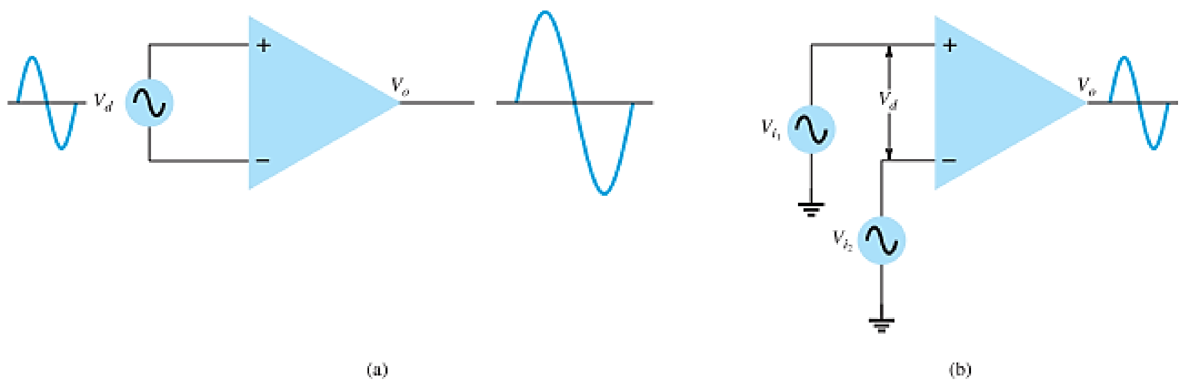


FIG. 10.3
Double-ended (differential) operation.

Double-Ended Output

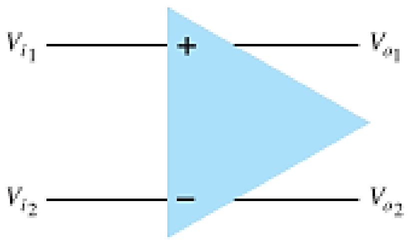


FIG. 10.4
Double-ended input with double-ended output.

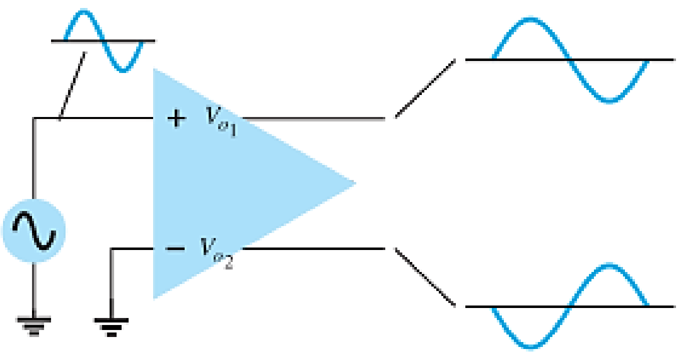


FIG. 10.5
Single-ended input with double-ended output.

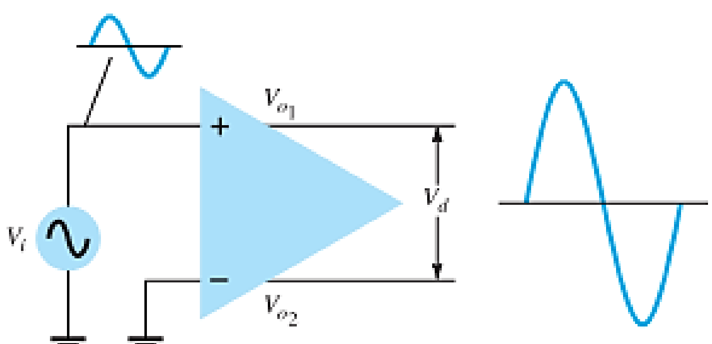


FIG. 10.6
Differential-output.

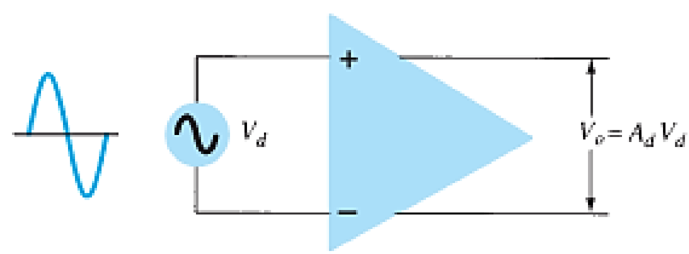


FIG. 10.7
Differential-input, differential-output operation.

Common Mode Operation

- Ideally, the two inputs are equally amplified, and since they result in opposite-polarity signals at the output, these signals cancel, resulting in 0-V output.

- Practically, a small output signal will result.

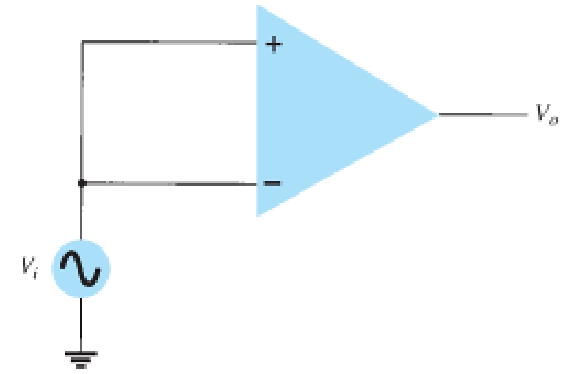


FIG. 10.8
Common-mode operation.

- **Common-Mode Rejection**

- Noise (any unwanted input signal) is generally common to both inputs, the differential connection tends to provide attenuation of this unwanted input while providing an amplified output of the difference signal applied to the inputs.
- This operating feature is referred to as *common-mode rejection* .

Differential Amplifier Circuit

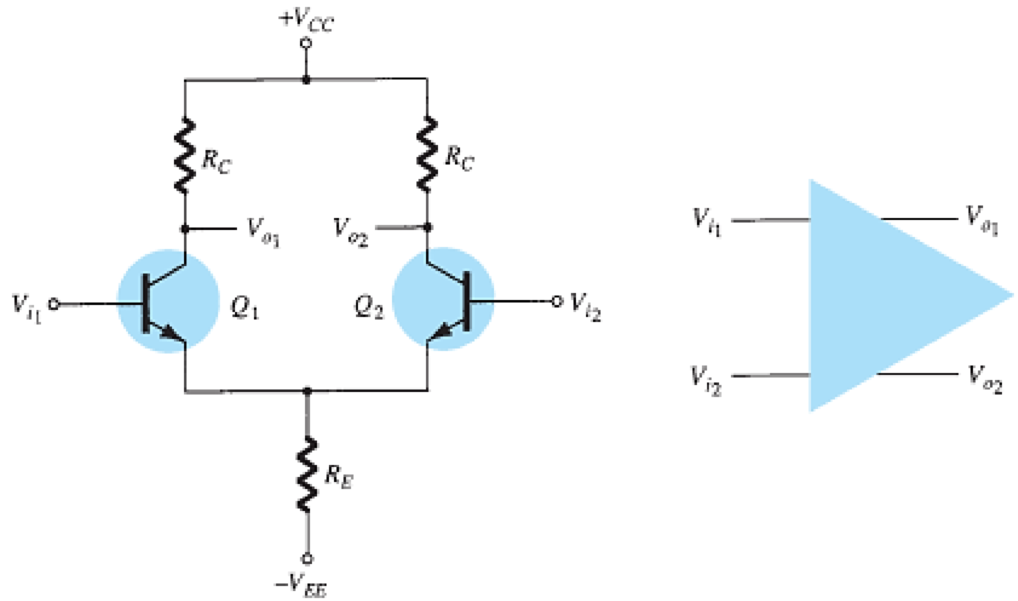


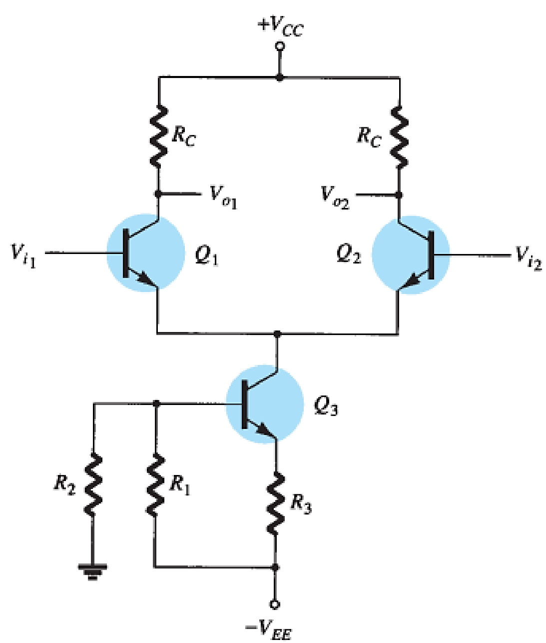
FIG. 10.9
Basic differential amplifier circuit.

Input signal combinations:

- **Single-ended** : If an input signal is applied to either input with the other input connected to ground.
- **Double-ended**: If two opposite-polarity input signals are applied.
- **Common-mode** : If the same input is applied to both inputs.

Use of Constant-Current Source

- A good differential amplifier has a very large difference gain A_d, which is much larger than the common-mode gain A_c.
- The common-mode rejection ability of the circuit can be considerably improved by making the common-mode gain as small as possible (ideally, 0)
- The larger R_E, the smaller is A_c.
- One popular method for increasing the ac value of R_E is using a constant-current source circuit.



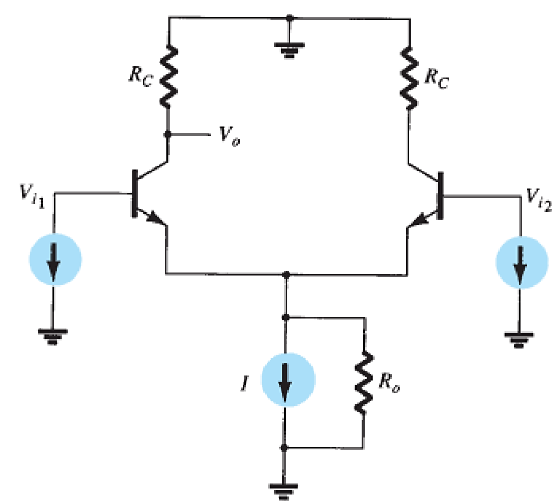


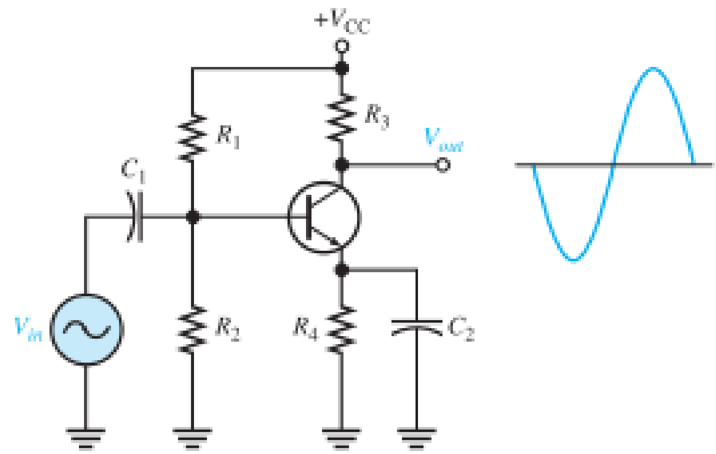
FIG. 10.21
AC equivalent of the circuit of Fig. 10.20.

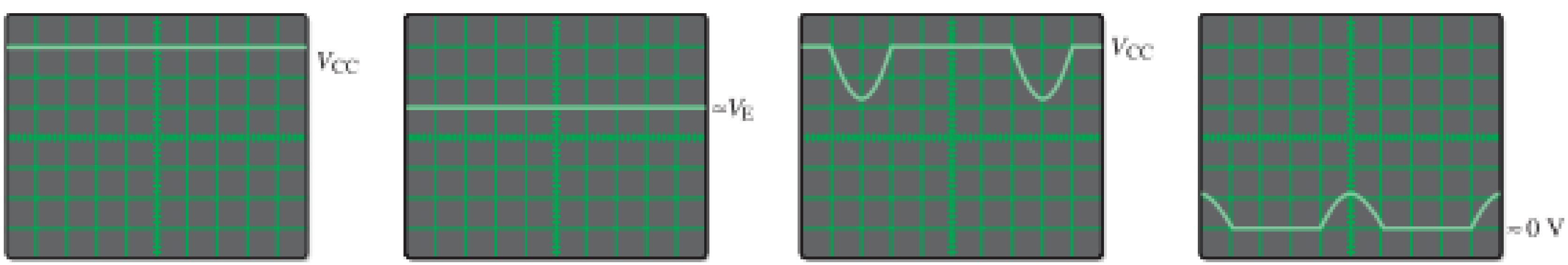
TROUBLESHOOTING

Class A

► FIGURE 7–30

Class A power amplifier with correct output voltage swing.





(a) Transistor in cutoff (b) CE short or R_2 open (c) Q-point shift or R_1 open (d) Transistor in saturation

▲ FIGURE 7–31

Oscilloscope displays showing output voltage for the amplifier in Figure 7–30 for several types of failures.

Class AB

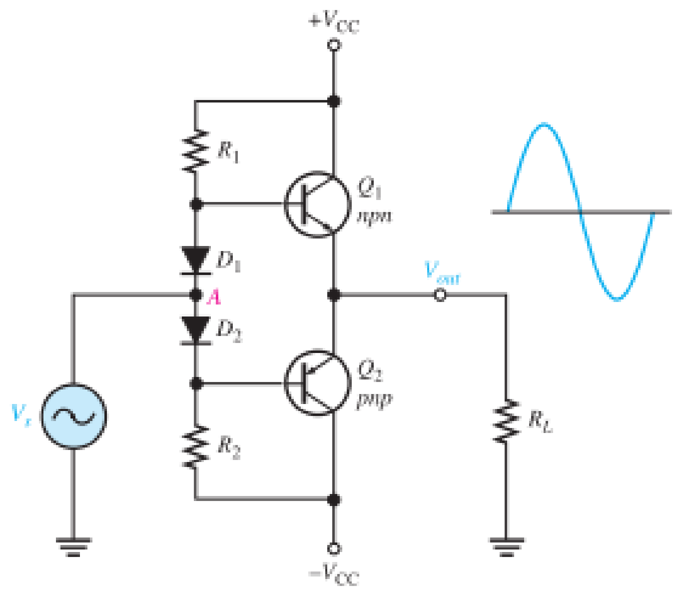
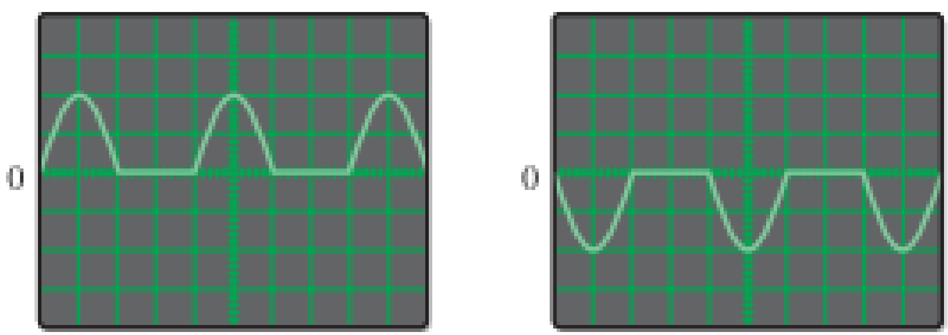


FIGURE 7–32

A class AB push-pull amplifier with correct output voltage.



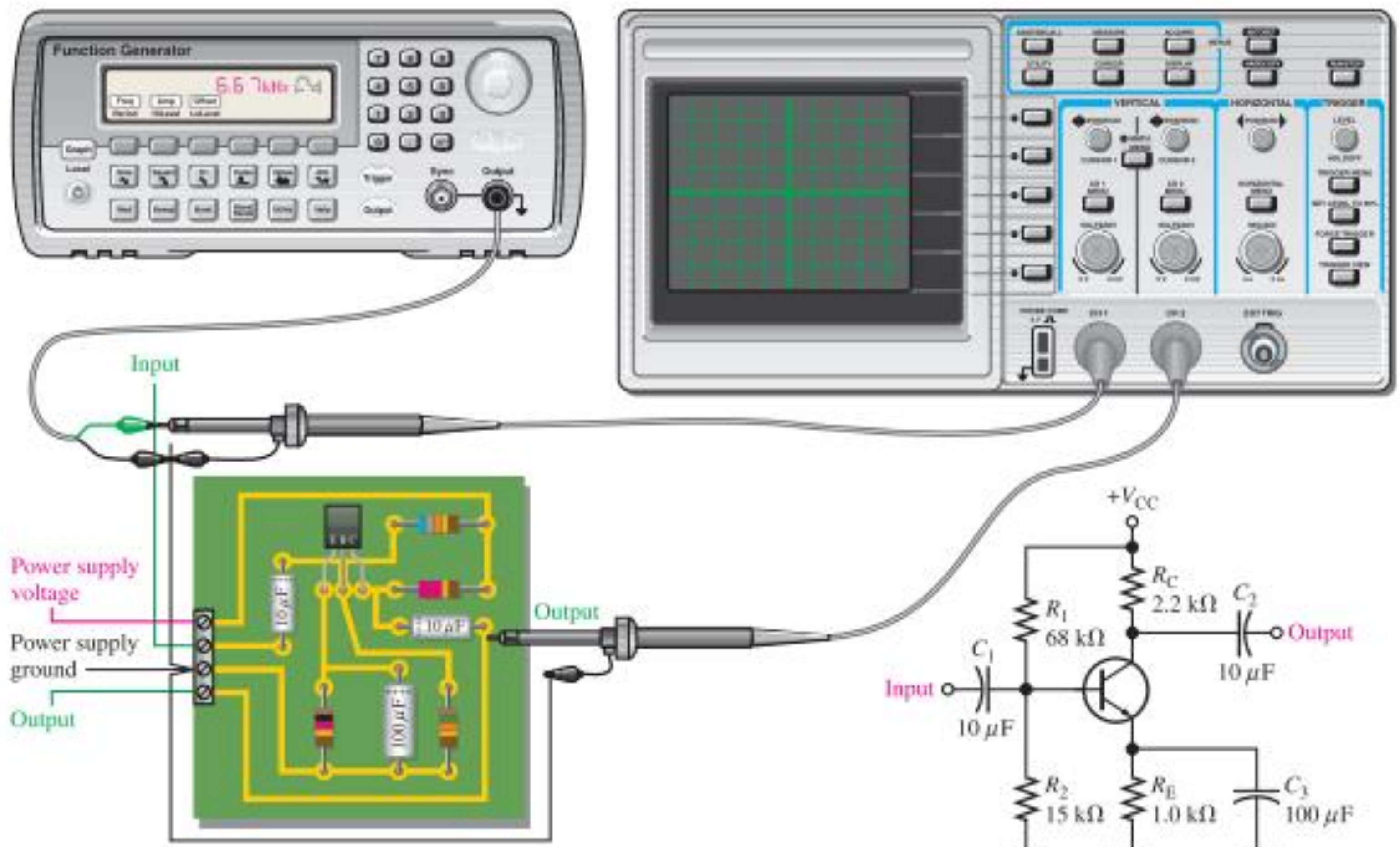
(a) D_1 open or Q_2 base-emitter open

(b) D_2 open or Q_1 base-emitter open

FIGURE 7–33

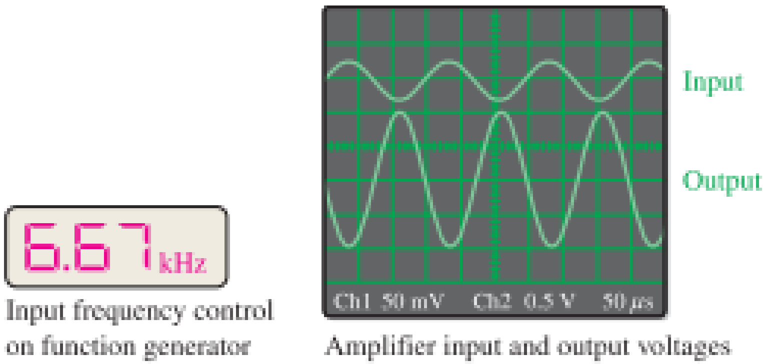
Incorrect output waveforms for the amplifier in Figure 7–32.

Frequency/Amplitude Measurements

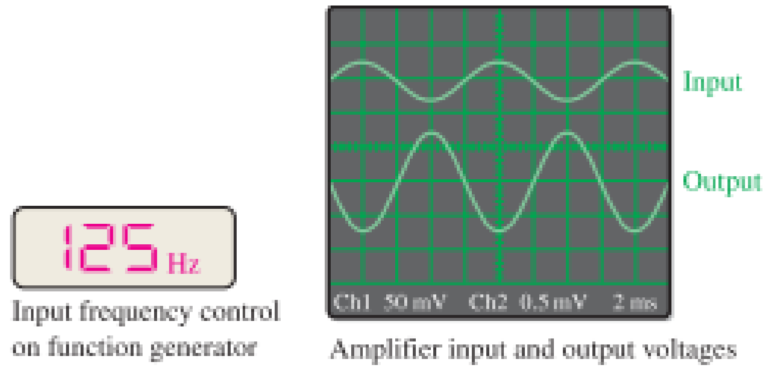


(a) Circuit and test setup for measuring the frequency response of an amplifier

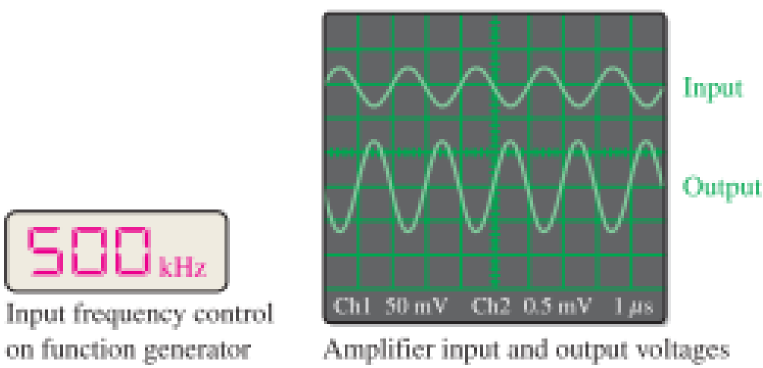
Frequency/Amplitude Measurements..



(b) Frequency is set to a midrange value (6.67 kHz in this case).
Input voltage adjusted for an output of 1 V peak.



(c) Frequency is reduced until the output is 0.707 V peak.
This is the lower critical frequency.

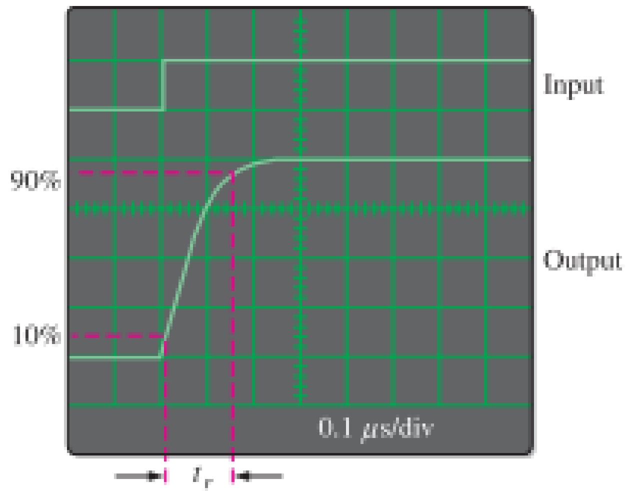


(d) Frequency is increased until the output is again 0.707 V peak.
This is the upper critical frequency.

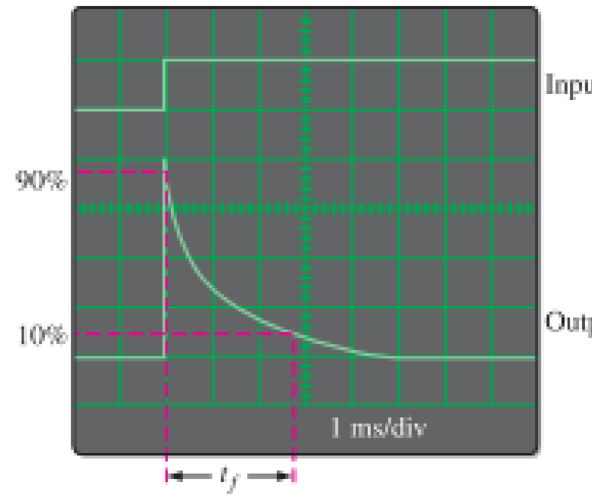
Step Response Measurement

▶ FIGURE 10–51

Measurement of the rise and fall times associated with the amplifier's step response. The outputs are inverted.



(a) Measurement of output rise time to determine the upper critical frequency

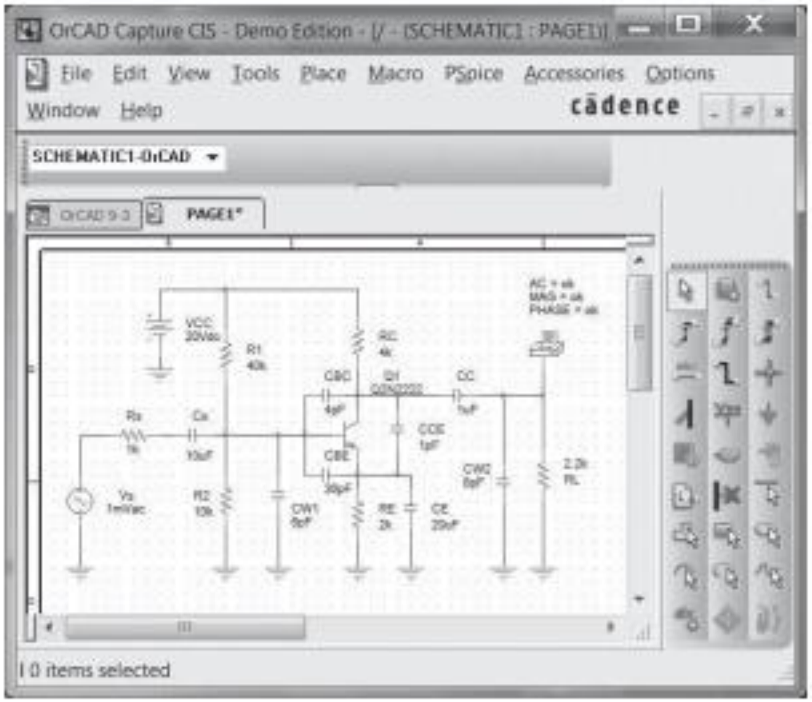


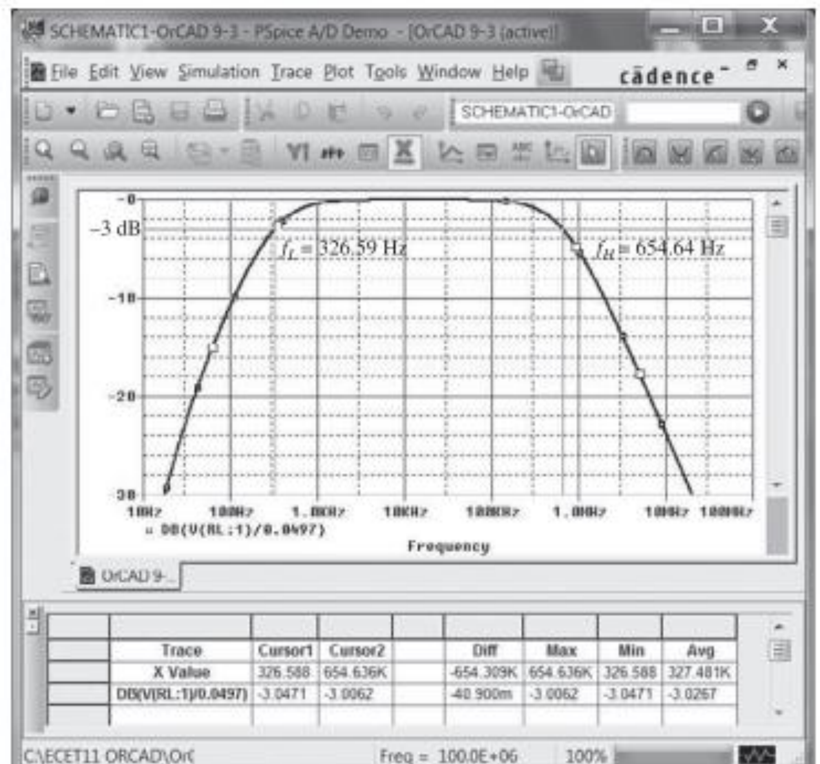
(b) Measurement of output fall time to determine the lower critical frequency

$$f_{cu} = \frac{0.35}{t_r}$$

$$f_{cl} = \frac{0.35}{t_f}$$

Frequency Response using computer analysis





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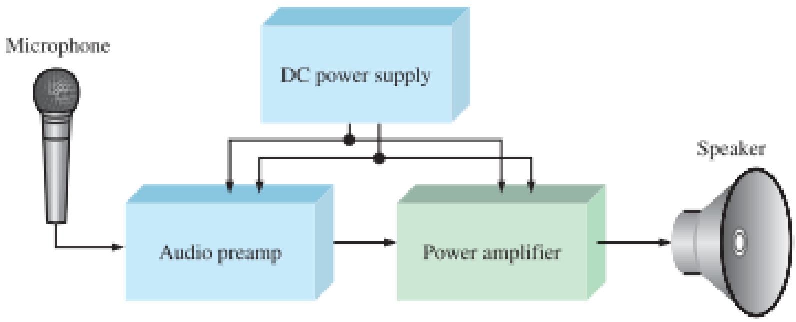
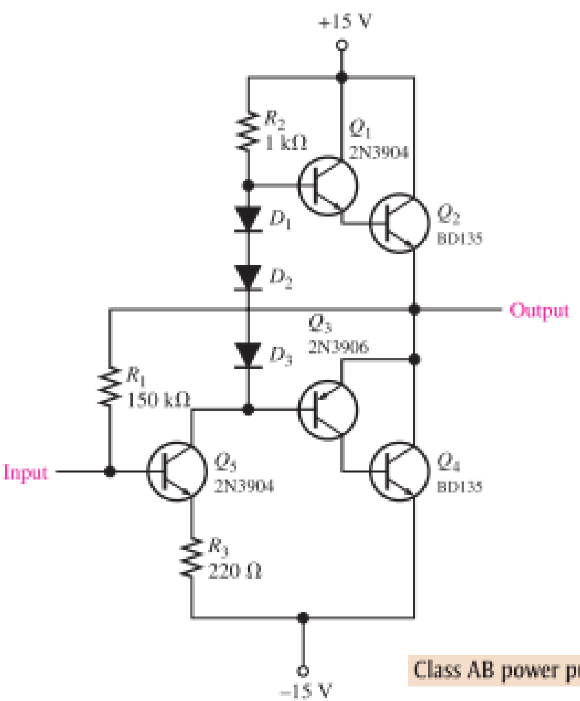
PRACTICAL APPLICATIONS

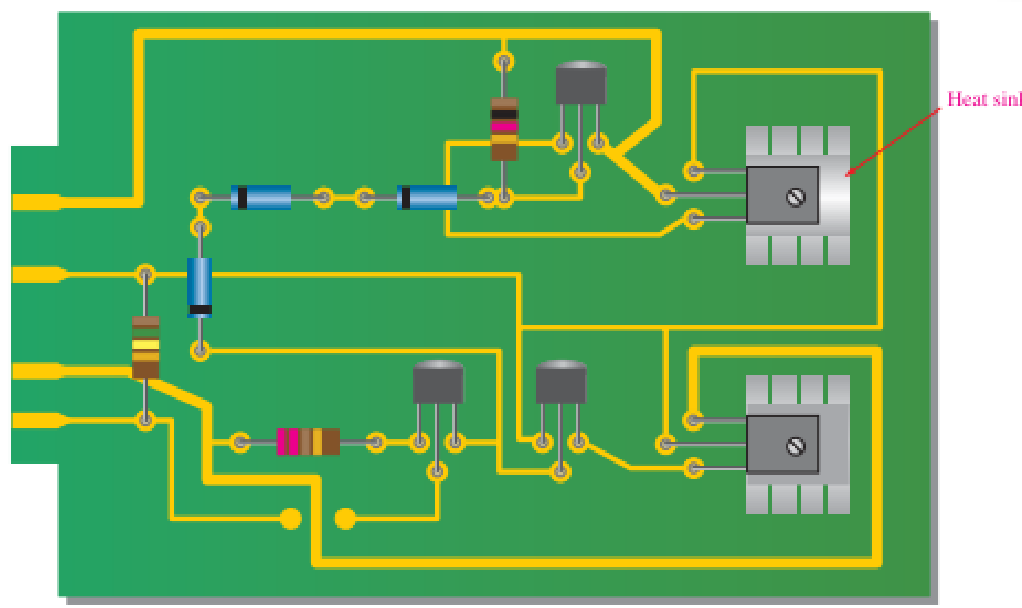
The complete PA system



(a) PA system block diagram


(b) Physical configuration





Class AB power push-pull amplifier.

Tuned Amplifier in FM Receiver circuit

- Search about it ;)

References

- Floyd, chapters: 6-7,10
- Boylestad, chapters: 9-10,12

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