Amplifiers

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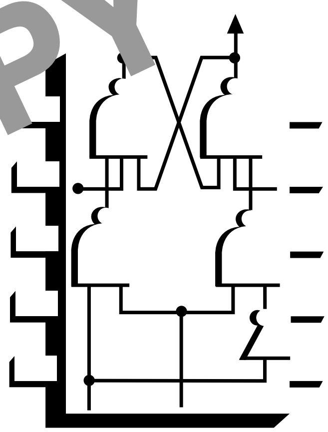
AMPLIFIERS

Lesson One

Introduction to Amplifiers



TPC Training Systems

25301

Lesson

1 Introduction to Amplifiers

TOPICS

Amplifying Circuits
Amplifier Characteristics
Transistor Amplifiers
Transistor Characteristic Curves
Effects of Temperature
Operational Amplifiers
Switching Amplifiers

OBJECTIVES

After studying this Lesson, you should be able to…

- Explain how gain, bandwidth, and distortion relate to amplifier operation.
- Compare bipolar transistor amplifiers and FET amplifiers.
- Explain how to use characteristic curves to predict transistor performance.
- Explain how to use an input/output curve to determine transistor gain.
- Discuss the effect of ambient temperature on amplifier performance.
- Discuss the uses of operational amplifiers and switching amplifiers.

KEY TECHNICAL TERMS

Amplifier 1.01 a circuit or device whose output is greater than its input

Gain 1.07 the ratio of output to input

Half-power point 1.11 a point on a graph indicating the high or low frequency limit at which output power is equal to half the maximum power output

Distortion 1.13 unwanted changes in output signal waveforms

Emitter follower 1.17 another name for the common-collector transistor circuit

To amplify means to make larger or stronger. An amplifier is a circuit that increases (amplifies) signal strength. Most inputs to amplifiers are from low-level devices—for example, microphones in public address systems. Amplifiers increase the signal strength to the power level needed to operate the loud speakers. Amplifiers are used in many kinds of electronic circuits, including pocket calculators, computers, process control devices, televisions, microwave ovens, and digital watches.

In this Unit, you will learn about the many kinds of amplifiers used in industry today and how they work. This Lesson discusses amplifier characteristics, signal distortion, common kinds of amplifiers, the uses of characteristic curves, and the effects of temperature on amplifiers.

Amplifying Circuits

1.01 An *amplifier* is a circuit or device that produces an output greater than its input. Voltage, current, or both may be amplified. In any case, power (the product of current and voltage) is amplified.

1.02 Amplifier components can be either *active* or *passive.* The active component provides amplification.

- An *active* device requires a power supply to operate and can have a measurable power gain. Transistors, electron tubes, and op amps are active devices.
- A *passive* device cannot produce a measurable power gain. Resistors, capacitors, and transformers are passive devices.

1.03 Some components or circuits appear to be amplifiers but are not. For example, although a transformer can increase voltage, it cannot increase power because current decreases proportionately to the increase in voltage. The transformer in Fig. 1-1 has a turns ratio of 1:10. This means that the transformer produces an output of 1200 V from an input of 120 V. That is, the output voltage is ten times the input voltage. An input of 50 A to the transformer primary produces an output of 5 A at the secondary. Power in and power out are:

Input: $120\text{V} \times 50\ \text{A} = 6000\ \text{W}$

Output: $1200\text{V} \times 5\ \text{A} = 6000\ \text{W}$

Therefore, the transformer did not increase or amplify the power.

1.04 A simple *npn* transistor amplifier is shown in Fig. 1-2. The power source is a power supply with a dc voltage (+*V* at the top of the schematic). The input signal is applied to the base of the transistor, and the output is taken from the collector.

1.05 A small input voltage applied to the amplifier diagrammed in Fig. 1-2 produces a small voltage across the base-emitter junction. This small voltage in turn causes a small base current, which follows the input and controls the collector current. The collector

Fig. 1-1. Simple transformer

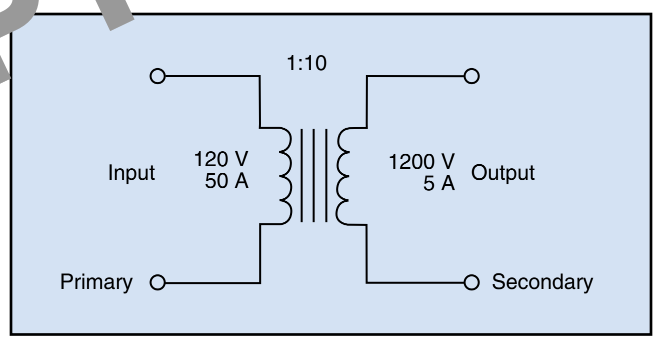
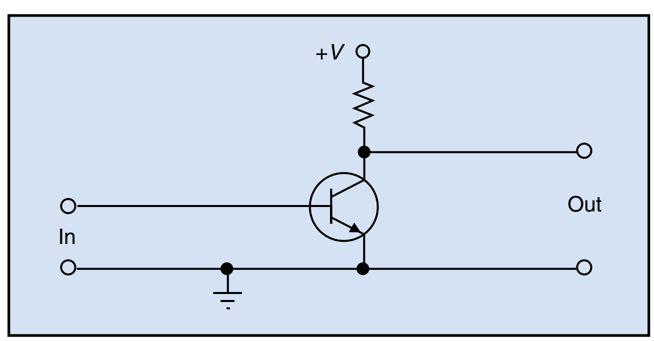


Fig. 1-2. Simple transistor amplifier



current (output current) is much greater than the base current. Because power is equal to voltage times current, the amplifier output power is greater than its input power.

Amplifier Characteristics

1.06 Every amplifier has characteristics that make it suitable for some applications but not for others. The most important of these characteristics are the following:

- gain
- bandwidth
- distortion.

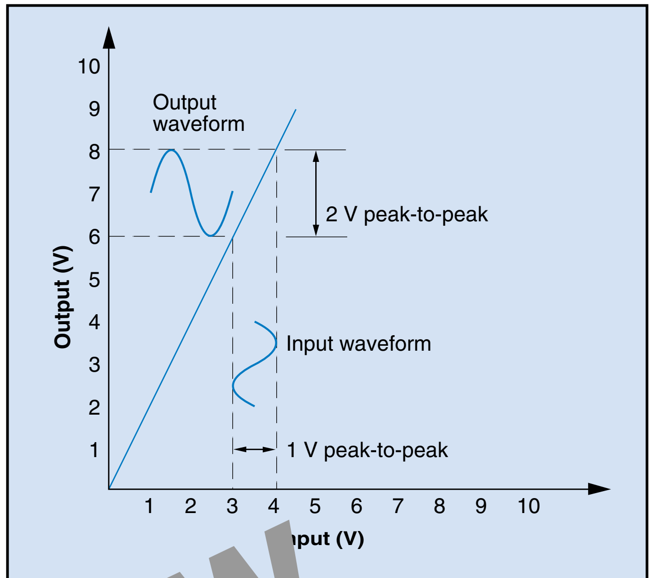
1.07 **Gain.** An amplifier increases the amplitude of an electronic signal. The ratio of output to input is referred to as *gain*. Gain can be expressed as voltage gain, as current gain, or as power gain (the product of voltage and current):

$$\text{gain} = \frac{\text{output}}{\text{input}}$$

For example, if an amplifier has a gain of 2, the amplitude of the output signal is twice as large as the amplitude of the input signal.

1.08 Figure 1-3 shows an amplifier input/output curve. The input is plotted along the horizontal axis and the output is plotted along the vertical axis. The two waveforms have the same shape, but the output is twice as large as the input. If the input measures 1 V, the output measures 2 V. This means that the amplifier has a gain of 2.

Fig. 1-3. Input/output for gain of 2



1.09 Sometimes a single amplifier does not provide enough gain to amplify a signal to the desired level. In this case, several amplifiers can be used in a *cascade* arrangement, in which the output of one amplifier is used as the input to another. For example, in Fig. 1-4, amplifier A and amplifier B each have a gain of 2. The combined gain of the two amplifiers is 4 (2×2), and the amplitude of the output of amplifier B is four times the amplitude of the input to amplifier A. Amplifiers that are connected in this way are referred to as *cascaded*.

1.10 **Bandwidth.** The gain of an amplifier is not the same for all signal frequencies. An amplifier is designed to operate within a certain range of frequencies, referred to as *bandwidth*. That is, the amplifier

Fig. 1-4. Cascaded amplifiers

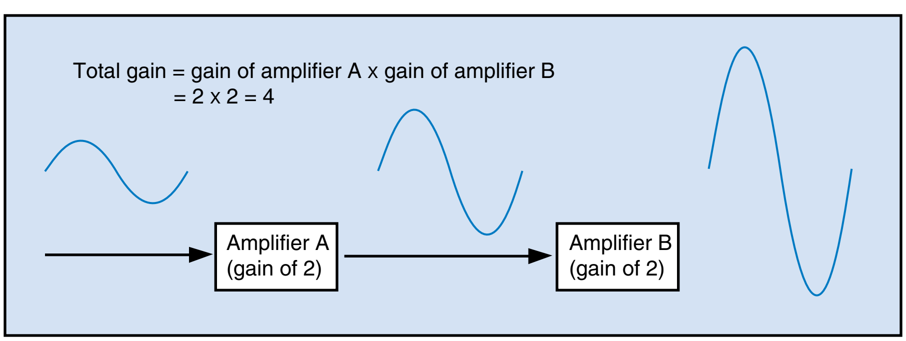
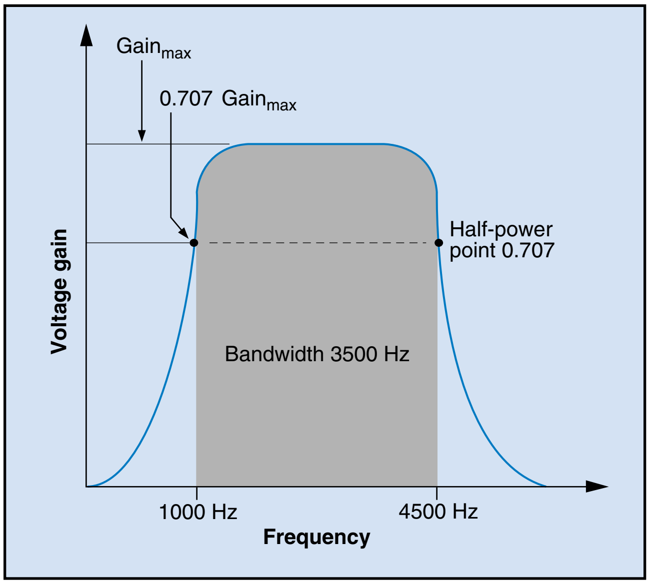


Fig. 1-5. Typical frequency response curve



operates between a lower critical frequency and an upper critical frequency, and the difference between the two critical frequencies is its bandwidth. Voltage gain is maximum at the middle range of frequencies (the *midband*) and decreases both above and below the midband.

1.11 The lower and upper frequency limits are defined by the *half-power points*, the frequencies for which the power output of the signal equals half the maximum power output. Expressed in mathematical terms, the half-power points are the values at which voltage and current are each at 0.707 times maximum, and the power output, therefore, is at about half its maximum:

$$\text{Power output} = 0.707\, V_{max} \times 0.707\, I_{max}$$

$$= 0.50\, P_{max}$$

where V_{max} = maximum output voltage

I_{max} = maximum output current

P_{max} = maximum output power

1.12 The bandwidth for an amplifier is often shown by a graph called a *frequency-response curve*. Figure 1-5 shows a typical frequency-response curve, in this case for an amplifier with an effective frequency range of about 1000 Hz to about 4500 Hz. The bandwidth for this particular amplifier is 3500 Hz (4500 Hz minus 1000 Hz). An amplifier is said to be a *wideband* amplifier if its effective frequency range is large (for example, 10 MHz) and a *narrowband* amplifier if its effective frequency range is small (for example, 10 kHz).

1.13 **Distortion.** An ideal amplifier would reproduce the input signal waveforms exactly with increased amplitude. However, real amplifiers do not reproduce the input signal exactly. There is always at least some small variation between input and output. Unwanted changes in the output signal waveforms are referred to as *distortion*.

1.14 Distortion can occur in the frequency, the amplitude, or the phase of an output signal:

- *Frequency distortion* occurs when some frequencies in the input signal are amplified more than other frequencies.
- *Amplitude distortion* occurs when amplitude changes in the input signal do not produce proportional amplitude changes in the output signal. This is sometimes caused by input signals that exceed amplifier ratings.
- *Phase distortion* occurs when different frequencies in the input signal are shifted in phase by different amounts in the output.

Distortion is an important factor in the selection of an amplifier for a particular application. The amount and kind of distortion in amplifier output depend mostly on the design of the amplifier and may or may not be acceptable for the application.

1.15 You must be very careful when you replace discrete electronic components. If the replacement component does not have exactly the same specifications as the original, the circuit can malfunction, possibly destroying other devices within the circuit. Most manufacturers publish booklets to help you choose the correct component. These publications list the products and show in detail the internal connections, bandwidth, gain, input and output curves, and other useful information. Your company probably stocks one or more of these booklets. These publications also can be obtained from your local parts distributor, usually at no charge.

Transistor Amplifiers

1.16 Two kinds of transistors are used in amplifiers:

- *Bipolar transistors* are current-controlled devices.
- *Field-effect transistors* (*FETs*) are voltage-controlled devices.

A brief refresher of the differences and similarities between bipolar transistors and FETs may be helpful. Current in the bipolar transistor depends on the flow of both majority and minority carriers, but current in a FET depends on majority carriers only. The three terminals of the bipolar transistor are the base, emitter, and collector. In the bipolar *npn* transistor, the emitter-base junction is forward-biased, and the collector-base junction is reverse-biased. In FETs, a channel between the source and drain carries a current in response to a small voltage at the gate. The amplifier circuits are similar—and in some cases, identical—for the two kinds of transistors.

1.17 **Bipolar transistor amplifiers.** The manner in which a transistor is connected in a circuit affects the current through the transistor, the voltage across the transistor, and the transistor power gain. Input and output connections for *pnp* transistors are the same as for *npn* transistors, except that the polarities are reversed. The three basic connections, as shown in Fig. 1-6, are referred to as:

- common emitter
- common base
- common collector, often called an *emitter follower* because the emitter voltage follows the base voltage.

The kind of connection is named for the transistor element at ac ground. For example, in the common-emitter circuit, the input is to the base, the output is from the collector, and the emitter is at ground.

1.18 The characteristics for current gain, voltage gain, power gain, and phase inversion for each of the connections are shown in Fig. 1-6. The function of the amplifier in the application determines how it should be connected. For example, the common-emitter connection provides the highest power gain and has the characteristic of inverting the signal, so you would use that connection when those features were important to the application. Common-emitter and common- collector (emitter-follower) circuits are used most often in industrial electronics. Common-base circuits are used most often in radio frequency circuits.

1.19 **FET amplifiers.** FETs have a very high input impedance, which is their main advantage over bipolar transistors. FET amplifier connections are very

Fig. 1-6. Bipolar transistor amplifier connections

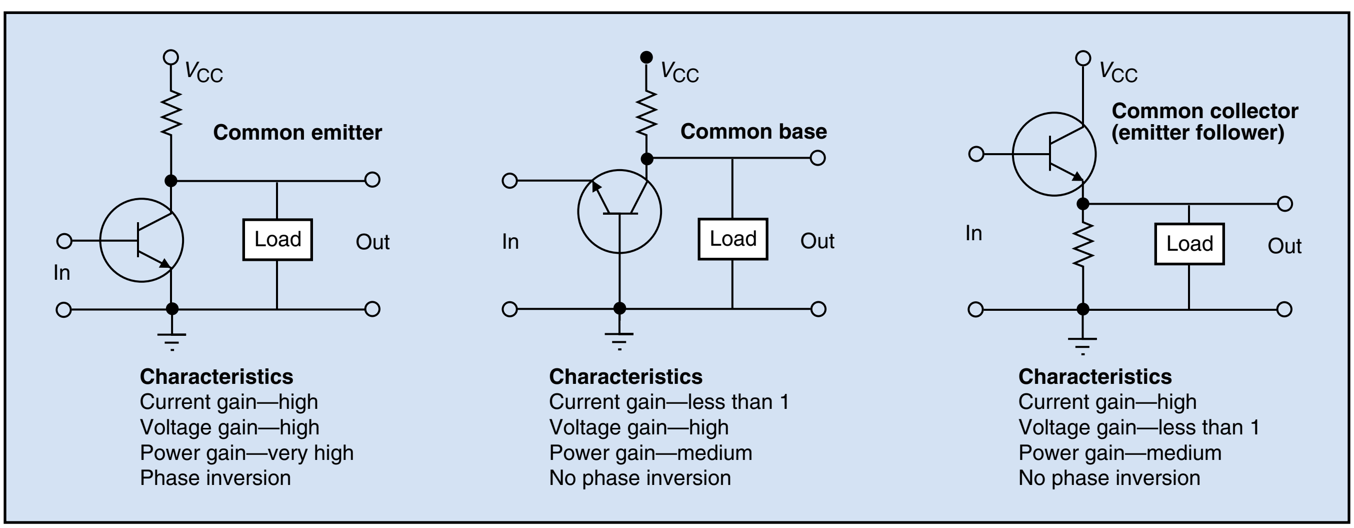
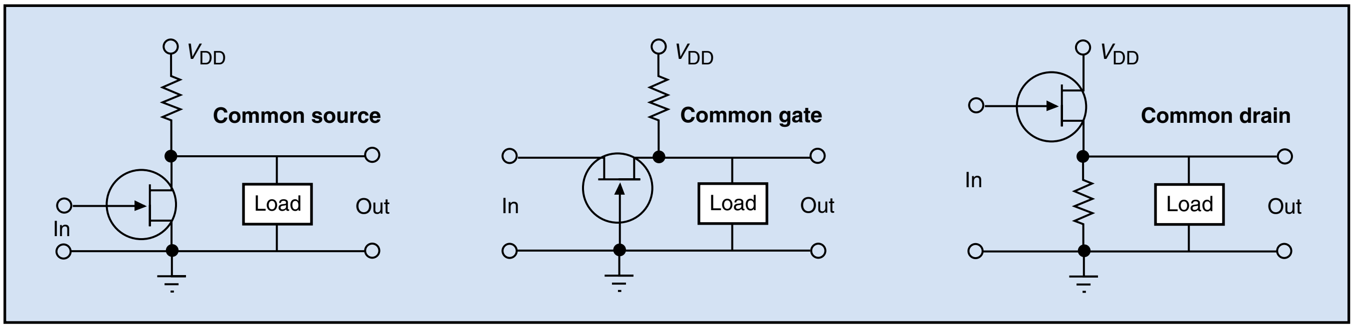


Fig. 1-7. FET amplifier connections



similar to bipolar transistor amplifier connections, but the terminology is different. The three FET elements are called:

- the *source*, which corresponds to the emitter
- the *gate*, which corresponds to the base
- the *drain*, which corresponds to the collector.

The basic FET amplifier connections are referred to as common source, common gate, and common drain.

1.20 FETs usually are referred to as *n*-channel or *p*-channel. They are further differentiated as being JFETs (junction FETs) and MOSFETs (metal-oxide semiconductor FETs), in which the gate is insulated from the channel. Amplifier connections are similar for both *n*-channel and *p*-channel FETs. The three basic connections for an *n*-channel FET are shown in Fig. 1-7.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of the book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. A(n) _________ is a circuit or device that produces an output larger than its input.	1-1. AMPLIFIER Ref: 1.01
1-2. Transistors and op amps are __________ devices, but resistors, capacitors, and transformers are __________ devices.	1-2. ACTIVE; PASSIVE Ref: 1.02
1-3. Name three main characteristics of amplifiers.	1-3. GAIN, BANDWIDTH, AND DISTORTION Ref: 1.06
1-4. An amplifier with an input that is one-half its output has a gain of __________.	1-4. 2 (TWO) Ref: 1.07
1-5. Amplifier bandwidth is that __________ in which gain is nearly maximum and relatively constant.	1-5. FREQUENCY RANGE Ref: 1.10
1-6. An amplifier with a frequency range of 1000 Hz to 3500 Hz has a bandwidth of __________.	1-6. 2500 Hz Ref: 1.12
1-7. Unwanted changes in the output signal waveform are called __________.	1-7. DISTORTION Ref: 1.13
1-8. A bipolar transistor is controlled by __________ and a FET is controlled by __________.	1-8. CURRENT; VOLTAGE Ref: 1.16

Transistor Characteristic Curves

1.21 Manufacturers provide data sheets that show various kinds of characteristic curves to help you select the best amplifier for your particular application. Transistor characteristic curves show how a transistor amplifier can be expected to perform with different combinations of voltage and current. These curves can help you predict transistor performance in a particular circuit. The curves for bipolar transistor curves are derived from current input, but FET curves are derived from voltage input.

1.22 **Bipolar transistor output curves.** Remember that bipolar transistors are current-controlled devices. Output curves, often called *collector curves*, indicate the collector current (measured in amperes) when different voltages are applied between the collector and emitter, with the base current remaining constant. The curves in Fig. 1-8 show the electrical characteristics of an *npn* bipolar transistor. The curves rise at the right because the transistor is heating.

1.23 In Fig. 1-8, collector-emitter voltage (V_{CE}) is plotted along the horizontal axis, and collector current (I_C) is plotted along the vertical axis. The number to the right of each curve is the base current (I_B). Notice that the collector current changes very little—the curve is nearly flat—when increasing collector-emitter voltages are applied while base current remains constant. For example, locate the 50-mA base current on the graph. The collector current for this curve is about 2 A when the collector-emitter voltage is 5 V. When the collector-emitter voltage increases to 25 V, the collector current increases only to about 3 A, an increase of 1 A corresponding to an increase of 20 V.

1.24 Output characteristic curves like these are produced experimentally. A constant base current is applied to the circuit while the value of the collector-emitter voltage is changed. The curve that results is displayed on an oscilloscope screen. This procedure is followed for each selected value of base current. The result is a family of curves like those in Fig. 1-8.

1.25 **FET output curves.** Remember that FETs are voltage-controlled devices. Output curves predict the drain current when different voltages are applied between the drain and source, with the gate-to-source voltage remaining constant.

1.26 The curves shown in Fig. 1-9 on the following page are typical output characteristic curves for a FET. Drain-source voltage (V_{DS}) is plotted along the

Fig. 1-8. Typical *npn* power transistor output curves

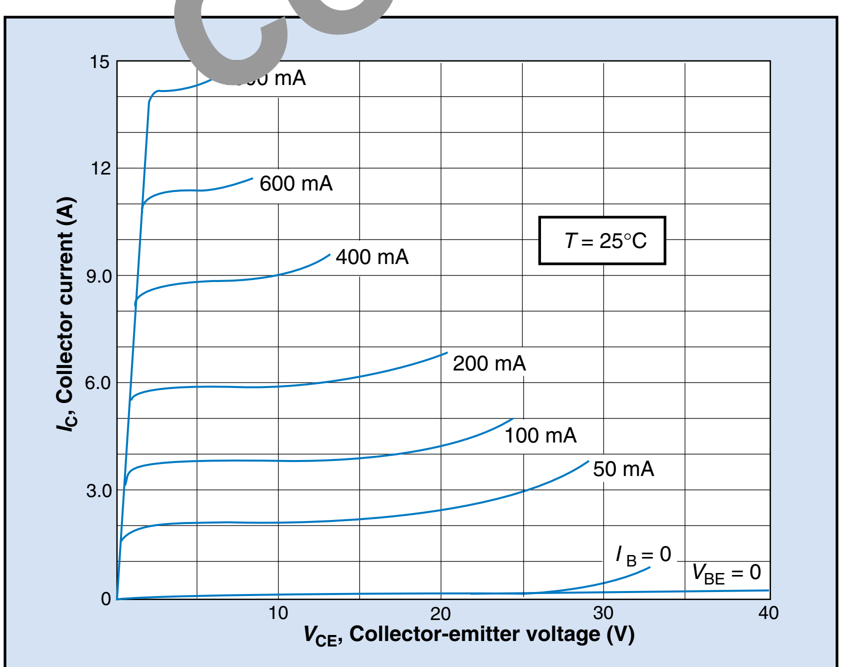
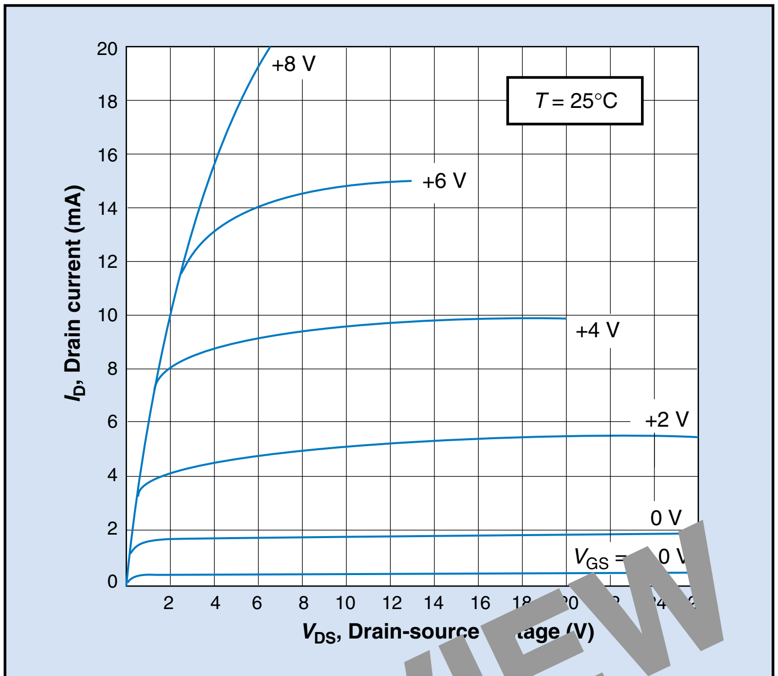


Fig. 1-9. Typical FET output curves



horizontal axis, and drain current (I_D) is plotted along the vertical axis. When a drain-source voltage of 2 V is applied with a gate-to-source voltage (V_{GS}) of +2 V, the drain current is about 4.1 mA. As the drain-source voltage increases to 22 V, the drain current increases only to about 5.5 mA, an increase of about 1.4 mA corresponding to an increase of 20 V.

1.27 **Using output characteristic curves.** Output curves can be used in many ways, including determining leakage current. For example, look again at the curves shown in Fig. 1-8. Assume that V_{CE} is equal to 15V. For $I_B = 0$, you might expect I_C also to be equal to 0. But the $I_B = 0$ curve shows that I_C has a value of about 0.1A. This current is called *leakage current* and is indicated as I_{CEO}. The leakage current increases slightly as the collector-emitter voltage increases and increases rapidly as the temperature of the junction increases.

1.28 Output curves also can be used to predict transistor current gain. To determine the gain, divide the change in I_C (collector current) by the change in I_B (base current):

$$\text{gain} = \frac{\text{change in } I_C}{\text{change in } I_B}$$

For example, the curves in Fig. 1-8 tell you that I_C is equal to 0.1A when $I_B = 0$ and $V_{CE} = 15$ V. Now look at the curve for $I_B = 100$ mA. For V_{CE} constant at 15 V, I_C is equal to 3.9 A. So:

$$\text{Change in } I_B = 100 \text{ mA} - 0 \text{ mA}$$
$$= 100 \text{ mA}$$
$$= 0.1 \text{ A}$$
$$\text{Change in } I_C = 3.9 \text{ A} - 0.1 \text{ A}$$
$$= 3.8 \text{ A}$$

The current gain is the change in I_C divided by the change in I_B:

$$\text{gain} = \frac{3.8 \text{ A}}{0.1 \text{ A}}$$
$$= 38$$

In this example, the current gain for this transistor operating in its normal operating range is 38. This is referred to as the *small signal current gain* and is represented by the symbol h_{FE}.

1.29 **Input characteristic curves.** An input characteristic curve is a graph of base current versus base-emitter voltage. You can use input curves to predict transistor base-emitter voltage when the transistor is connected as a common-emitter amplifier. For example, the curve shown in Fig. 1-10 indicates that, in order to generate a base current of 0.5 A, you need a voltage across the base-emitter junction of 0.98 V. This tells you that any biasing circuit you use with this transistor must provide this voltage or the amplifier will not operate as designed.

Effects of Temperature

1.30 A transistor's electrical characteristics change as the *ambient temperature* (surrounding temperature) changes. Transistors are particularly sensitive to high temperatures. Increases in ambient temperature can cause a transistor to fail or can cause its life to be shortened. Two important characteristics affected by temperature are:

- *power dissipation* (power loss caused by the heat generated by the transistor during the amplification process)
- collector current.

1.31 **Power dissipation.** You know that electric circuits, including amplifiers, generate power—and, as a result, heat. Transistors are limited in the amount of power that they can *dissipate* (get rid of) without being damaged. Therefore, transistor manufacturers provide a power dissipation rating for each transistor they make.

1.32 The amount of power that a transistor can dissipate decreases as temperature increases. This relationship is sometimes shown in a *power derating curve*—for example, the curve shown in Fig. 1-11 for a typical power transistor. This transistor can safely dissipate 300 mW at a temperature of 25°C. However, if the ambient temperature increases to 75°C, the transistor can safely dissipate only about 100 mW. In other words, power dissipation for this transistor decreases from 300 mW to 100 mW with a 50°C increase in ambient temperature.

Application 1-1

A small plastics manufacturing company depended on an automatic control unit designed several years ago to control a number of steps in the production process. After working as expected for over four years, a series of malfunctions began to develop in the system. In each case, the problem was with one of several similar output transistors. Because these transistors were rated at 50 watts and were dissipating only 40 watts, the technicians were more than somewhat perplexed.

Eventually, a consultant had to be called to try to solve the problem. He checked the circuit thoroughly and found that all the voltages were well within the manufacturer's specifications. However, he noticed that the temperature in the room was rather warm. After questioning the manager at some length, he learned that two large motors had been installed in the room at

Fig. 1-10. Typical input characteristic curve

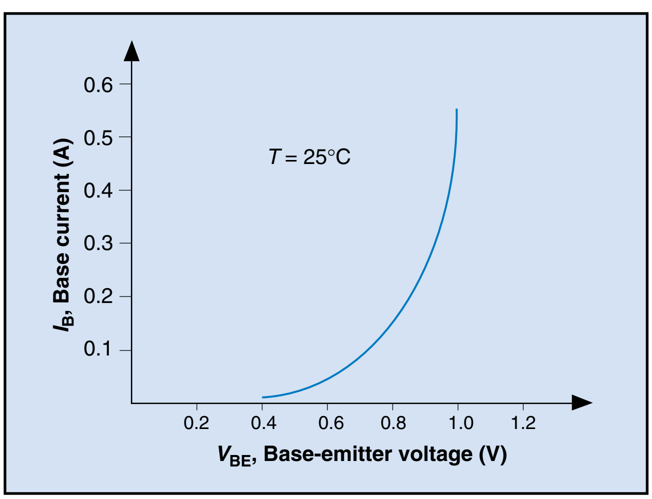
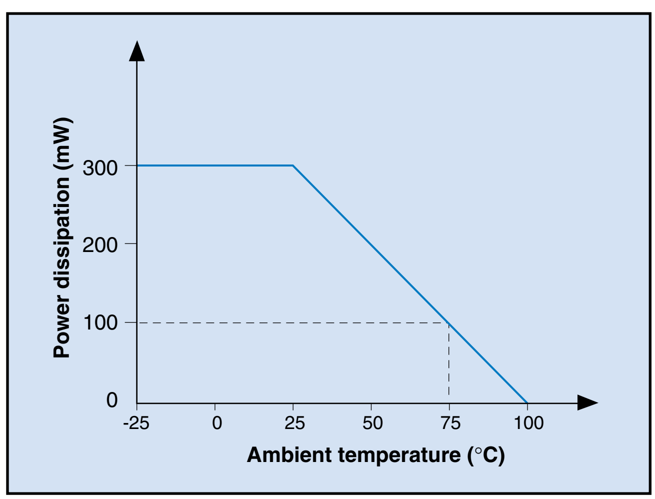


Fig. 1-11. Typical power derating curve



approximately the same time the control system began malfunctioning. The consultant monitored the room temperature and found that it often exceeded 45°C. He checked the transistor specifications, which stated that the transistor was rated at only 30 watts at that temperature.

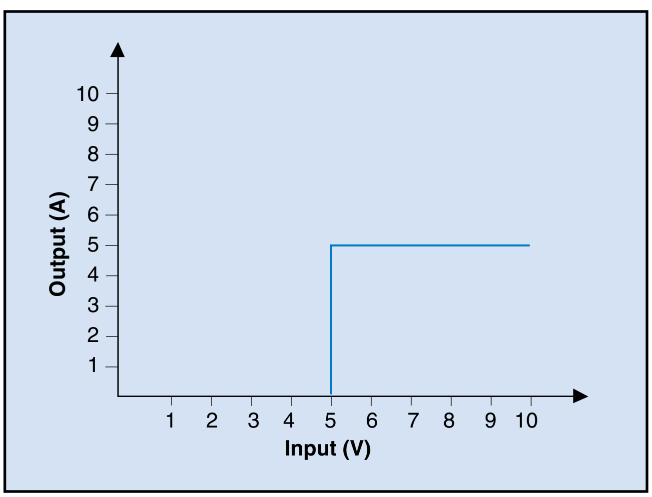
The consultant offered several solutions. The main three were to use bigger transistors, to move the motors, or to move the control unit. The simplest solution was to move the control unit to a new location just outside the room, a location where the temperature never exceeded 25°C. After moving the control system, the transistors again worked as expected, free of problems.

1.33 **Collector current.** As ambient temperature increases, the collector current also increases. Conversely, as ambient temperature decreases, the collector current also decreases. The base current and collector-emitter voltage also are affected by changes in temperature. Manufacturers provide output characteristic curves showing the relationship between temperature changes and increases or decreases in collector current. These curves can be very useful in helping you predict amplifier performance and thus avoiding potential temperature-related problems.

Operational Amplifiers

1.34 Operational amplifiers, usually referred to as simply *op amps*, are the most commonly used kind of amplifiers. Op amps are *integrated circuits* (ICs). In general, op amps are preferred to other kinds of amplifiers, mainly because they are very small and are suitable for a wide variety of applications. Op amps simplify electronic circuit design and increase efficiency. They are the subject of Lesson Four in this Unit.

Fig. 1-12. Switching amplifier response



1.35 Op amps are designed to amplify signals over a wide frequency range. Their exact gain and frequency response characteristics are determined by external components. Their general characteristics include the following:

- very high gain
- high input impedance
- low output impedance.

1.36 Most op amps have two inputs and one output. The amplifier senses the difference in voltage between the two inputs and amplifies the difference. For this reason, op amps also are referred to as *differential amplifiers*.

Switching Amplifiers

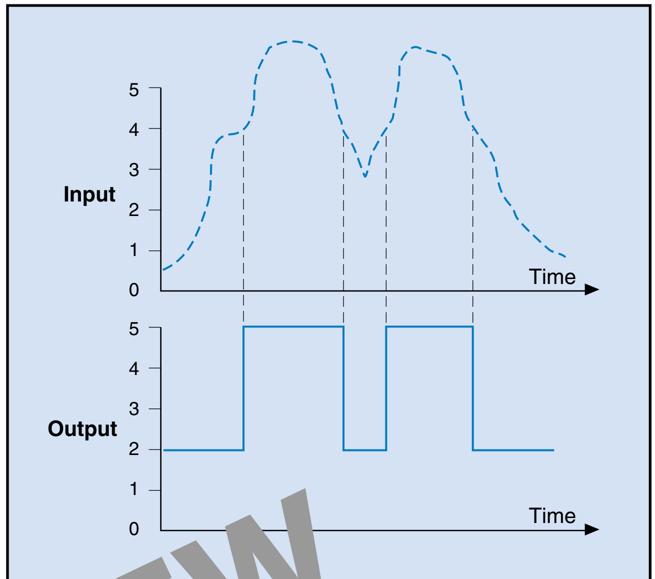
1.37 The amplifiers discussed so far have all been *linear* amplifiers. That is, during operation within the effective range, the output signal is proportional to the input, and the input and output waveforms are very similar. Some applications require an amplifier for which the waveforms are different for the input and the output, and for which the output is not proportional to the input—that is, the application requires a *nonlinear* response. Most linear amplifiers can be operated as nonlinear devices if the normal linear operating limits are exceeded. A *switching amplifier* produces nonlinear responses.

1.38 The response curve of a switching amplifier is shown in Fig. 1-12. The input is plotted on the horizontal axis and the output is plotted on the vertical axis. Note that this amplifier has an output of 0 A until the input increases to 5 V. For inputs equal to or greater than 5 V, the output switches to 5 A. The amplifier is said to be *saturated* when the input is 5 V or greater.

1.39 Switching amplifiers are used in many industrial applications—for example, in automatic liquid level circuits. As the level in the tank decreases, a sensor sends an increasing voltage signal. When the voltage reaches a predetermined value, a pump is activated to fill the tank to a certain level. The low-power signal from the sensing device is sent to a switching amplifier, and the signal from the amplifier is powerful enough to turn on the pump. In this way, the pump motor can be indirectly controlled by the liquid-level detector.

1.40 The output response to input for a typical switching amplifier is shown in Fig. 1-13. Although the input has many levels as it increases and decreases irregularly, the output has only two levels—high and low. The output level changes when the input increases above or decreases below a preset value.

Fig. 1-13. Output vs input for typical switching amplifier



1-9. Characteristic curves describe bipolar transistor performance in terms of ________ input and FET operation in terms of ________ input.	1-9. CURRENT; VOLTAGE Ref: 1.21
1-10. The output curves of bipolar transistors are called __________ curves.	1-10. COLLECTOR Ref: 1.22
1-11. On FET output curves, drain-source voltage is plotted along the _________ axis, and drain current is plotted along the __________ axis.	1-11. HORIZONTAL; VERTICAL Ref: 1.26, Fig. 1-9
1-12. If an output curve shows a change in collector current of 3 A and a change in base current of 100 mA, the transistor's gain is __________ .	1-12. 30 Ref: 1.28
1-13. The amount of power a transistor can dissipate __________ as temperature increases, as shown in a power ________ curve.	1-13. DECREASES; DERATING Ref: 1.32
1-14. Op amps amplify signals over a(n) __________frequency range and have __________ gain.	1-14. WIDE; VERY HIGH Ref: 1.35
1-15. Amplifiers with two inputs and one output are called __________ amplifiers.	1-15. DIFFERENTIAL Ref: 1.36
1-16. A switching amplifier provides ________ responses.	1-16. NONLINEAR Ref: 1.37

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. The value that all amplifiers increase is

- ☐ a. current
- ☐ b. power
- ☐ c. resistance
- ☐ d. voltage

1-2. A transistor amplifier with an input of 5 V at 1 A and an output of 25 V at A has a gain of

- ☐ a. 1
- ☐ b. 2
- ☐ c. 5
- ☐ d. 10

1-3. The bandwidth of an amplifier with half-power points at 1 MHz and 10 MHz is __________ MHz.

- ☐ a. 1
- ☐ b. 5
- ☐ c. 9
- ☐ d. 10

1-4. Which of the following transistor amplifier connections provides the highest power gain?

- ☐ a. Common base
- ☐ b. Common collector
- ☐ c. Common emitter
- ☐ d. Emitter follower

1-5. The main advantage of FETs over bipolar transistors is that FETs have a very high

- ☐ a. current gain
- ☐ b. input impedance
- ☐ c. output impedance
- ☐ d. voltage gain

1-6. What is the current gain of a transistor with an output curve that shows that I_C = 1 A when I_B = 0.1 A, and I_C = 5 A when I_B = 0.5 A?

- ☐ a. 0.5
- ☐ b. 1
- ☐ c. 5
- ☐ d. 10

1-7. As temperature increases, transistor power dissipation __________ and collector current __________ .

- ☐ a. decreases; decreases
- ☐ b. decreases; increases
- ☐ c. increases; decreases
- ☐ d. increases; increases

1-8. Op amps have a

- ☐ a. high output impedance
- ☐ b. low input impedance
- ☐ c. narrow frequency range
- ☐ d. very high gain

1-9. Which of the following is a differential amplifier?

- ☐ a. Bipolar transistor amplifier
- ☐ b. FET amplifier
- ☐ c. JFET amplifier
- ☐ d. Op amp

1-10. A response curve that shows an output of zero for inputs of 10 V or less and an output of 5 A for inputs of greater than 10 V is typical for a(n) ________ amplifier.

- ☐ a. cascading
- ☐ b. linear
- ☐ c. operational
- ☐ d. switching

SUMMARY

Amplifier circuits use transistors or integrated circuits to increase the power of electronic signals. An amplifier is a circuit or device whose output—voltage, current, or power—is greater than its input.

Amplifier characteristics determine suitability for an application. Gain, bandwidth, and distortion are three important amplifier characteristics. *Gain* is the ratio of output to input. *Bandwidth* is the range of frequencies in which gain is nearly maximum and relatively constant. *Distortion* describes unwanted changes in the output signal waveforms.

Bipolar transistor amplifiers are classified as common-emitter, common-base, and common-collector, depending on how the transistor is connected to the input and output. FET amplifiers are classified as common-source, common-gate, and common-drain.

Transistor characteristic curves show amplifier performance when various combinations of voltage and current are applied to the circuit. This information is helpful both in choosing an amplifier for a circuit and in recognizing amplifier failure. Characteristic curves also show how temperature affects an amplifier. Power derating curves show the relationship between maximum power dissipation and changes in temperature.

Other kinds of amplifiers include operational amplifiers (op amps) and switching amplifiers. Op amps are very high-gain IC amplifiers that are compact in size and can be used in many kinds of applications. Switching amplifiers produce nonlinear two-level responses.

Answers to Self-Check Quiz

1-1. b. Power. Ref: 1.01

1-2. c. 5. Ref: 1.07

1-3. c. 9. Ref: 1.12

1-4. c. Common emitter. Ref: 1.18, Fig. 1-6

1-5. b. Input impedance. Ref: 1.19

1-6. d. 10. Ref: 1.28

1-7. b. Decreases; increases. Ref: 1.32, 1.33

1-8. d. Very high gain. Ref: 1.35

1-9. d. Op amp. Ref: 1.36

1-10. d. Switching. Ref: 1.38