

Chapter 5

AMPLIFIERS

OUTLINE

- ▼ Amplifiers
- ▼ Decibels
- ▼ Logarithms
- ▼ Common BJT Amplifier Configurations
- ▼ Transistor Amplifier Troubleshooting Techniques
- ▼ Other Transistor Amplifier Configurations
- ▼ Operational Amplifiers

OBJECTIVES

Given various electronic devices, symbols, and diagrams, you will be able to accomplish the following objectives:

- ▼ Calculate decibel gain and loss.
- ▼ Identify common-emitter, common-base, and common-collector amplifier configurations.
- ▼ Describe the proper techniques to troubleshoot transistors amplifier circuits.
- ▼ Identify FET amplifier circuits.
- ▼ Identify operational amplifier configurations and phase relationships.
- ▼ Identify other types of amplifiers.

Amplifiers

In Chapter 4, we defined amplification as the ability of a circuit to take a small change in input (current and/or voltage) and produce a large change in output (current and/or voltage). The frequency ranges that amplifier circuits are operated in are used to classify them. In this chapter, we will examine the operating principles of three basic audio-frequency amplifier devices: the BJT, the FET, and the OP Amp. However, before we begin this discussion, we must build a proper foundation by acquiring a deeper understanding of the most important aspect of amplifier circuits—gain.

Calculating Amplifier Gain

- ▼ As stated in Chapter 4, the gain of an amplifier is a ratio of the output voltage, current, or power as compared to the input voltage, current, or power.

- ▼ Gain may be expressed in decibels. Typically, combinations of several types amplifier circuits, called stages, are connected together to produce significant signal output amplification.

- ▼ Since the output of an amplifier is expected to be greater than its input, gain can be mathematically expressed as follows:

$$\text{Gain} = \frac{\text{Output}}{\text{Input}}$$

- ▼ The letter “A” is typically used to symbolize gain or amplification in electronic circuits.

- ▼ There are three types of gain: current gain, voltage gain, and power gain. By adding a subscript, we can specify the type of gain achieved.

Voltage Gain

$$A_v = \frac{V_{\text{out}}}{V_{\text{In}}} \quad (\text{Voltage Gain})$$

- ▼ **Example.** The input voltage to an amplifier stage is .15V and its output voltage is 10V. Using the formula shown above, calculate the amplifier gain.

$$A_v = \frac{10\text{V}}{.15\text{V}} \quad A_v = 66.7$$

Current Gain

$$A_I = \frac{I_{out}}{I_{in}} \quad (\text{Current Gain})$$

- **Example.** Calculate the current gain of an amplifier with an input value of $50\mu\text{A}$ and an output value of 2mA .

$$A_I = \frac{2\text{mA}}{50\mu\text{A}} \quad A_I = 40$$

Power Gain

$$A_p = \frac{P_{out}}{P_{in}} \quad (\text{Power Gain})$$

- **Example.** Calculate the gain for an amplifier with input power of $.5\text{W}$ and an output power of 10W .

$$A_p = \frac{10\text{W}}{.5\text{W}} \quad A_p = 20$$

- Notice that gain is not expressed in units such as volts, amps, or watts. Gain simply means that the output has been amplified that many times greater than the input.

Decibels

- The Decibel is a unit of measure for expressing the ratio of two amounts of power gain. The abbreviation for the decibel is dB.

- Decibels are related to sound, where one dB is the smallest increase or decrease that the human ear can detect. For example, if a 10 Watt input is increased to a 100 Watt output, the signal power has been increased 10 times, or 10dB. The same amplifier will increase a 0.5 Watt input to a 5 Watt output. The gain is still the same, 10dB. The increases in both cases sound the same to the human ear.

- This method of measuring increases in sound with decibels is called “logarithmic”. It more nearly reflects the way the human ear identifies increases in sound levels.

Logarithms

- ▼ Logarithms are exponents that indicate the power to which a number is raised. They are often used to describe the performance of audio systems.
- ▼ Common logarithms are based on powers of ten. For example, in the equation $10^3 = 1000$, the exponent 3 can also be called the logarithm of the number 1000 to the base 10. This is expressed as $\log_{10} 1000 = 3$ and is read "The logarithm to the base 10 of the number 1000 is 3."
- ▼ Any positive number can be converted to a common logarithm.
- ▼ When the output of any part of an amplifier system is greater than the input, a positive gain (+dB) will be produced. Likewise, when the output of any part of an amplifier system is less than the input, a negative gain (-dB) will be produced.

Formulas

dB Power Gain

$$\text{dB power gain} = 10 \times \log_{10} \frac{P_{\text{out}}}{P_{\text{in}}}$$

- ▼ Example. An input signal to a power amplifier is .1W while its output signal is 5W. What is the power gain of this amplifier in decibels?

$$\begin{aligned} \text{dB power gain} &= 10 \times \log_{10} \frac{5\text{W}}{.1\text{W}} \\ &= 10 \times \log_{10} (50) \\ &= 10 \times 1.7 \text{ (1.6989 rounded up)} \\ &= 17. \end{aligned}$$

dB Voltage Gain

$$\text{dB voltage gain} = 20 \times \log_{10} \frac{V_{\text{out}}}{V_{\text{in}}}$$

- ▼ Although the decibel is based on the ratio of the output power to input power, it can also be used to describe the ratio of two voltages. There is one slight stipulation, however. For voltage amplifiers, the input and output resistances must be equal.

- If the resistances are not equal, the dB voltage gain will not be equal to the dB power gain. The formula for voltage gain uses a factor of 20 instead of 10 as in the power gain formula. The number 20 is used because power varies as the voltage is squared.
- Examine the formula for power when the resistance is known.

$$\text{Power} = \frac{V^2}{R}$$

Example. Using the formula for voltage gain, what is the decibel gain for an amplifier that has an input voltage of .2V and an output signal of 15V?

$$\begin{aligned} \text{dB voltage gain} &= 20 \times \log_{10} \frac{15V}{.2V} \\ &= 20 \times \log_{10} (75) \\ &= 20 \times 1.875 \\ &= 37.5 \end{aligned}$$

- Another reason that decibels are used to express amplifier gain is for convenience. If the gain or loss of the amplifier stages is given in decibels, simply add the numbers to compute the overall gain.

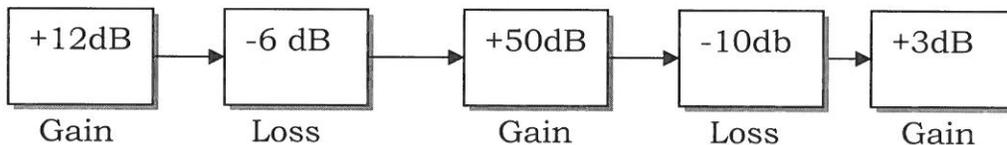


Figure 5-1

$$\text{Overall Gain} = +12 - 6 + 50 - 10 + 3 = 49\text{dB}$$

Common BJT Amplifier Configurations

- The amplification of a BJT is dependent upon the change in the transistor's resistance.
- Regardless of the configuration type, the transistor element behaves like a variable resistor and its resistance is varied with a change in its input signal.
- The three BJT configurations are the Common Emitter, the Common Collector, and the Common Base, as shown below in Figure 5-2.

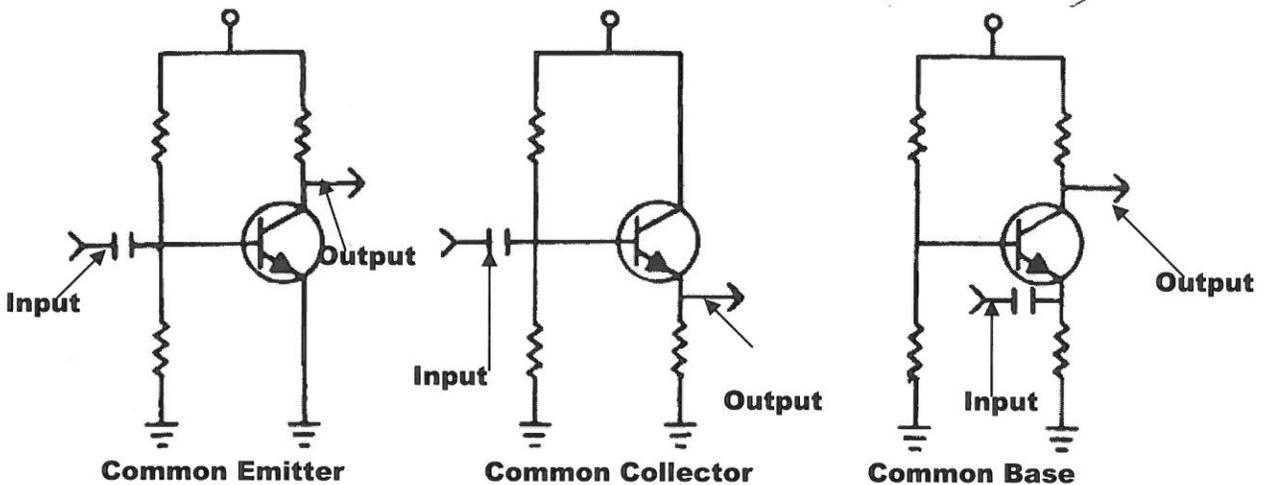


Figure 5-2

- ✦ A simple method to determine the type of BJT amplifier configuration shown is to identify the element where input is applied. Next, identify the element where the output signal is taken. The remaining element determines the name of the configuration.

Common Emitter Amplifier

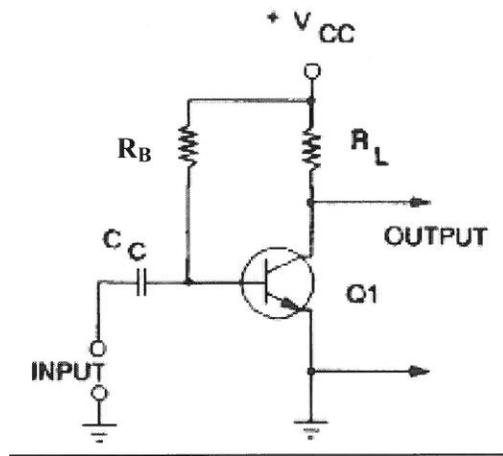


Figure 5-3

- Figure 5-3 is another example of a common emitter amplifier. Notice that the input signal is applied to the base and the output signal is taken off the collector element.

- The common emitter is the only one of the three BJT configurations to present phase inversion. The input and output signals are 180° out of phase.

- The transistor Q1 is responsible for signal amplification.

- The resistor R_L is called the collector load resistor. Without R_L , the voltage on the collector would always be equal to $+V_{CC}$. The collector load resistor makes the collector to ground voltage change as the transistor resistance changes.

- The resistor R_B and the resistance of the base emitter junction provide the necessary forward bias for the transistor. R_B is also a very large resistor that is used to limit the amount of current that flows through the base.

- The coupling capacitor C_C serves two purposes. It is used to couple or connect the AC signal to the amplifier input. It is also used to block the DC voltages present on one side of the capacitor from reaching the other side. These DC voltages are used to provide proper bias voltages for the amplifier circuit.

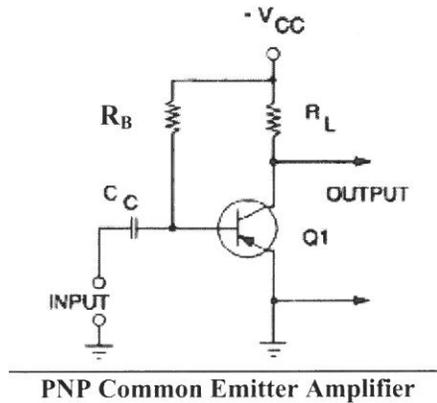
- In Figure 5-3, there are two paths for current flow. Ninety-five to ninety-nine percent of current flows from ground through the emitter to the collector through R_L to $+V_{CC}$, while the remainder of the current (1-5%) flows from ground through the emitter, to the base, through R_B to $+V_{CC}$.

- Typically, the common emitter amplifier has an input resistance of 500-1.5k Ω , while its output resistance is around 30k-50k Ω .

- It has voltage gain of 300-1000, current gain of 25-50, and the highest power gain of the three configurations, between 25-40 dB.

- Because the common emitter provides all three forms of gain, it is the most useful of three. The common emitter amplifier is a universal amplifier and works best in most amplifier applications.

- Figure 5-4 is an example of a PNP common emitter amplifier configuration. Notice that V_{CC} is negative for the PNP configuration. For this reason, PNP and NPN transistors are not directly interchangeable in circuits.



PNP Common Emitter Amplifier
Figure 5-4



Activity 2

The Common Emitter Amplifier

Determine whether each statement is true or false.

1. In a common-emitter amplifier, the input signal is applied to the emitter.
2. The output signal is taken from the base in a common-emitter amplifier.
3. Common emitter amplifiers show a 180° phase inversion between the input and output signals.

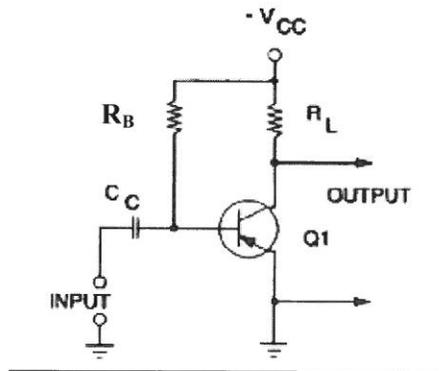


Figure 5-5

Use Figure 5-5 to answer the questions 4 through 7.

4. The coupling capacitor C_C is used to couple a/an _____ signal to the amplifier input.
5. R_L is called a _____ resistor.
6. R_B is a (large/small) _____ resistor which _____ (limits/increases) the amount of current flowing through the base.
7. The component that allows the amplifier to develop an output voltage signal is _____.

Common Base Amplifier

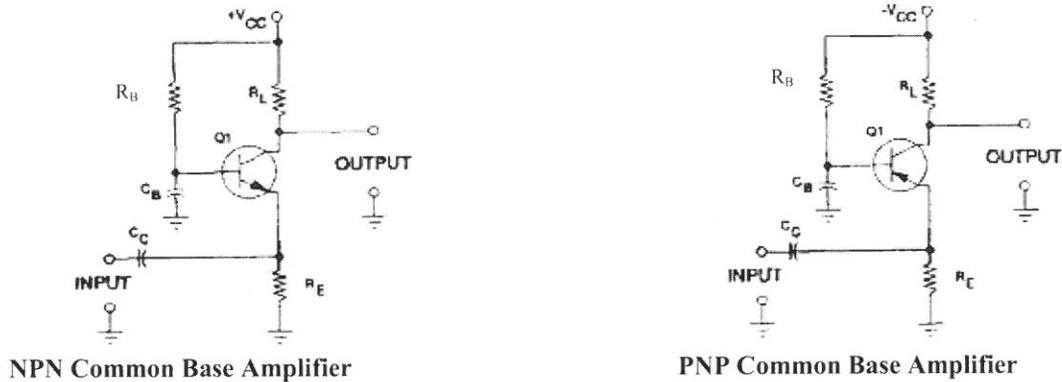


Figure 5-6

- A common base amplifier configuration is shown in Figure 5-6. Notice that the input signal is applied to the emitter element and the output signal is taken from the collector element.
- As with the common emitter amplifier, R_L is the collector load resistor. Without R_L , the voltage of the collector would always be equal to V_{CC} .
- R_B is a very large resistor that helps provide proper biasing for the transistor and limits the amount of current that flows through the base region.

- ✦ R_E develops the bias voltage for the emitter element.

- ✦ C_C is a coupling capacitor used to couple the AC signal to the amplifier input. It is also used to block the DC voltages used to bias the amplifier from reaching the other side of the capacitor.

- ✦ C_B is AC ground.

- ✦ There are two paths for current flow. Using the NPN configuration of Figure 5-6, 95-99% of current flows from ground through R_E to the collector through R_L to V_{CC} . The other path for current flow is from ground through the base element, to R_B to $+V_{CC}$.

- ✦ The current paths are the same for the PNP configuration with one exception. Since V_{CC} is negative, the direction of current flows is from $-V_{CC}$ to ground.

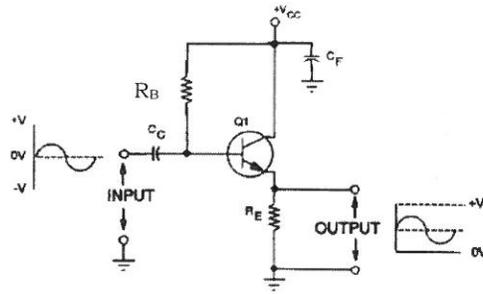
- ▼ Because the input signal is applied across the forward biased emitter-base junction resistance of the transistor, the input impedance for a common base is the lowest of all three amplifier configurations, 30-150 Ω .

- ▼ The output impedance for the common base is the highest of the three amplifiers. Because the output voltage is developed across the reverse-biased collector base junction, the output impedance ranges between 300k-500k Ω . This makes the common base amplifier very useful with low-impedance signal sources. It is also a good performer at radio frequencies.

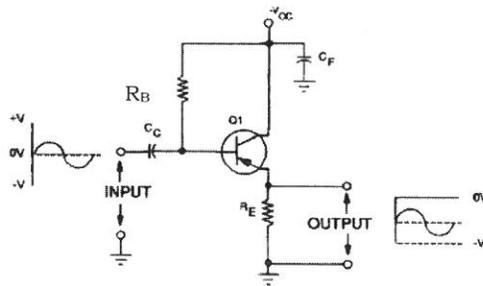
- ▼ Unlike the common emitter, the common base has no phase inversion between its input and output signals.

- ▼ Finally, the common base has a voltage gain of 500-1500 and power gain of 20-30 dB, however it is not capable of providing any current gain. The current gain of the common base is less than one. Remember, 100% of current flows through the emitter element, therefore, the input current will always be higher than the output current for the common base.

Common Collector Amplifier



A. NPN Common Collector



B. PNP Common Collector

Figure 5-7

- Figure 5-7 shows both NPN and PNP configurations of a common collector amplifier.
- The common collector is also called an emitter follower. The input signal is applied to the base and the output signal is taken from the emitter.

- ▼ Because the output is taken from the emitter, R_E functions as the collector load resistor.

- ▼ As with the other configurations, R_B is a biasing resistor that prohibits the amount of current that flows through the base.

- ▼ C_C is a coupling capacitor, and C_F provides an AC ground.

- ▼ There are two paths for current flow. Using the NPN configuration of Figure 5-7a, 95-99% of current flows from ground through R_E to the collector to V_{CC} . The other path for current flow is from ground through the base element, to R_B to $+V_{CC}$.

- ▼ The current paths are the same for the PNP configuration (Figure 5-7b) with one exception. Since V_{CC} is negative, the direction of current flow is from $-V_{CC}$ to ground.

- Because the input is applied across the reverse biased base-collector region, the input impedance is the highest of the three amplifiers, 20k-500k Ω .

- The output impedance is the lowest of the three amplifiers, 50-1k Ω since the output is developed across the emitter element. Because of this fact, the common-collector is primarily used as an isolation amplifier or a buffer amplifier. Its high input impedance loads the signal source very lightly. Only a very small signal current will flow. Therefore, the signal source has been isolated (buffered) from the loading effects of the rest of the circuit.

- The common collector has the highest current gain of the three configurations, 25-50. This is because the output is taken from the emitter element (remember, 100% flows through the emitter element). The common collector also has good power gain, 10-20dB, however it is not capable of producing any voltage gain (less than one). The amplitude of the voltage output signal will always be less than the input signal.



Activity 3

The Common Base and Common Collector Amplifiers

Determine whether each statement is true or false.

1. The common base amplifier has the input signal applied to the emitter, and the output is taken from the collector.
2. The common collector amplifier has the output signal taken from the base.
3. The input impedance of a common collector is high and the output impedance is low.
4. The common base amplifier has a voltage gain of less than one.

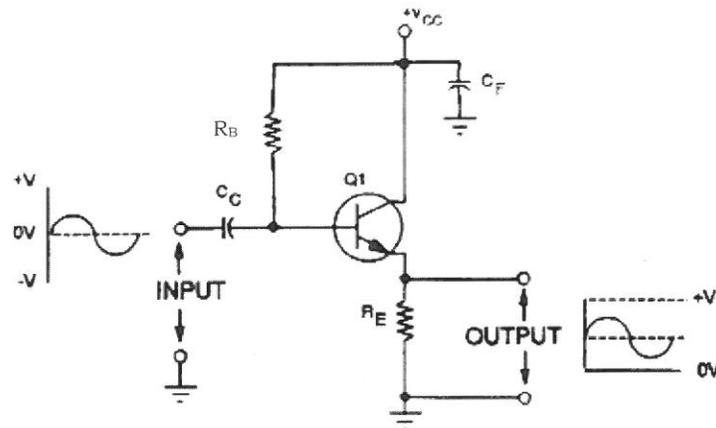


Figure 5-8

Use Figure 5-8 to answer questions 5 through 7.

5. This transistor configuration is called the _____.
 - a. common base.
 - b. common emitter.
 - c. common collector.

6. The purpose of C_F is to provide _____.
- bias voltage for the collector
 - develop the output signal
 - an AC ground.
7. The input and output signals are _____.
- 180° out-of-phase.
 - In-phase

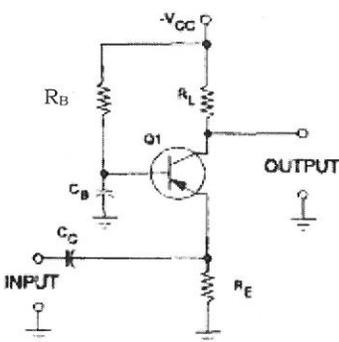


Figure 5-9

Use Figure 5-9 to answer questions 8 through 10.

8. This transistor configuration is called the _____.
- common base.
 - common emitter.
 - common collector.
9. The purpose of C_B is to _____
- determine forward bias for the circuit.
 - develop the output signal
 - provide an AC ground.
10. This transistor amplifier has _____ input impedance and _____ output impedance.

Transistor Amplifier Troubleshooting Techniques

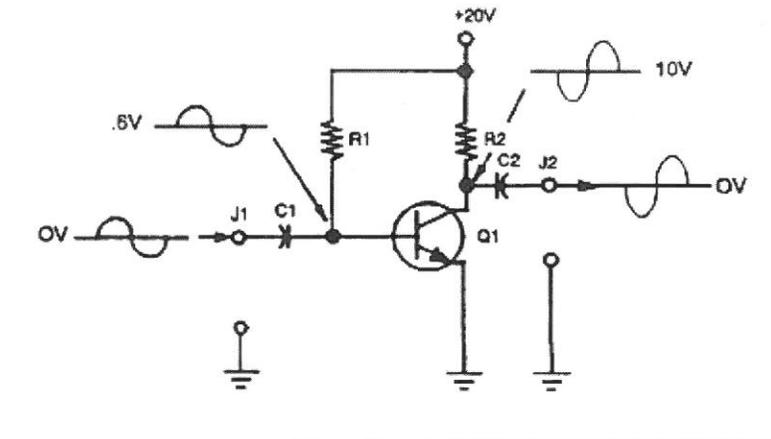


Figure 5-10

Transistor Amplifier Malfunctions

- A malfunctioning amplifier circuit will normally see one of three indications at the output: no output (0V), reduced gain, or distorted output. An oscilloscope is vital in determining the faulty amplifier stage. You must also know the normal output signal of each amplifier stage.
- To determine if an amplifier stage is working properly, check the output and input signals of the amplifier with an oscilloscope. If the output shows one of the three indications mentioned above and the input is good, that stage is faulty.

- When troubleshooting a multistage amplifier circuit, you waste valuable time checking the output for every stage.

- Check the output of the last stage. Naturally, if the output is good, the circuits are working properly. If the output of the last stage is bad, check the input to the first stage.

- If the input to the first stage is good and the output of the last stage is bad, check the output of a stage in the middle of the stages. For instance, if there were ten stages, the next logical point to check for a good signal would be the input or output of stage five. This method is called the half-split method of troubleshooting.

Component Malfunctions

Refer to figure 5-10

- **Q1 open.** No output signal. The DC voltage level measured at the collector will be close to or equal to V_{CC} .

- **Q1 Short.** A shorted transistor can have a short from base to emitter, base to collector, collector to emitter, or collector to base to emitter. The output voltage in most cases is 0V at the collector of Q1.

- ▼ **R1 open.** No base voltage; Q1 will be cutoff and a voltage equal to V_{CC} will be measured at the collector.

- ▼ **R1 short.** The possibility of R1 shorting without causing other circuit troubles is unrealistic. V_{CC} will be applied to the base and the transistor will be destroyed.

- ▼ **R2 open.** Q1 will be saturated. The output of the collector will be 0V.

- ▼ **C1 Open.** The input AC signal would not be passed to the base of Q1. Both sides of the capacitor should be checked for an AC signal.

- ▼ **C1 Short.** A signal will still be provided, however the bias of Q1 would be changed.

▼ **C2 Open.** The AC output of the collector will not be passed to the output J2.

▼ **C2 Short.** Output voltage would still have a DC reference. Capacitors block DC and pass AC.

Troubleshooting Techniques

- **Analyze Circuit.** Identify the type of circuit and bias configuration. Review circuit operations. The circuit normal operating conditions must be known before you can determine whether or not it is malfunctioning.

- **Check The Output Voltage.** If you are troubleshooting a multi-stage amplifier, use the half-split method. Record your voltage readings.

- **Check The Input Voltage.** Analyze voltage readings and determine the most probable fault.

- **Resistance Checks.** Once you have narrowed down the possibilities, remove all power and use the ohmmeter to verify the problem.



Activity 4

Transistor Amplifier Troubleshooting Techniques

Answer the following questions.

1. When troubleshooting a transistor amplifier circuit, the most useful piece of test equipment is the _____.
 - a. ohmmeter
 - b. multimeter.
 - c. oscilloscope.

Use the figure below to answer questions 2-4.

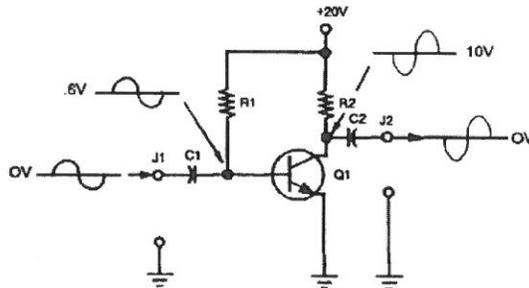


Figure 5-11

2. An input signal is applied to J1, however there is no signal present at the base of Q1. The problem is most likely _____.
 - a. C1 open
 - b. Q1 short
 - c. Q1 open
 - d. R2 short
3. The output voltage at J2 is 0V. Q1 is definitely faulty.
 - a. True
 - b. False

4. The base of Q1 measures 20V. R1 is definitely faulty.

- a. True
- b. False

Other Transistor Amplifier Configurations

Common FET Amplifier Configurations

- There are three FET amplifier configurations. They are the Common Source, the Common Drain, and the Common Gate.

- FET amplifiers are Voltage-controlled devices. They have high input impedance and low noise output impedance.

Common Source

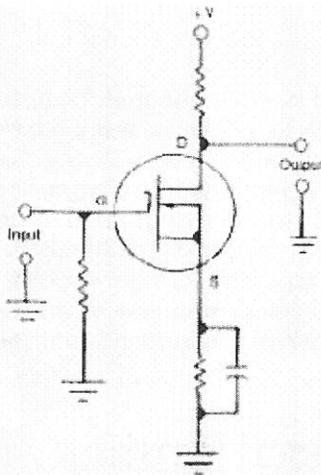


Figure 5-12

- Common Source Amplifiers are similar to the Common Emitter Amplifier. The input is applied to the gate element, and the output is taken from the drain element.

✦ The input and output signals are 180° out of phase.

✦ The Common Source provides high input impedance, and medium to high output impedance. It also has a voltage gain greater than one.

Common Gate

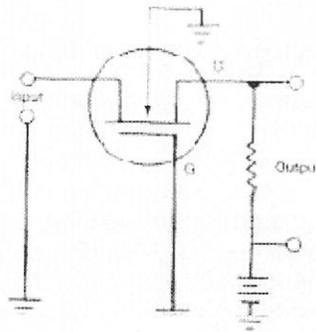


Figure 5-13

✦ The Common Gate is similar to the Common Base Amplifier. The input is to the source and the output is from the drain.

- ▼ The Common Gate Has medium input impedance and high output impedance.

- ▼ One important feature is this amplifier can operate at high frequencies. Because of this factor, the circuit provides low gain to the signal.

- ▼ There is no phase inversion between the input and output voltages.

- ▼ The Common Gate is commonly used in high frequency applications.

Common Drain

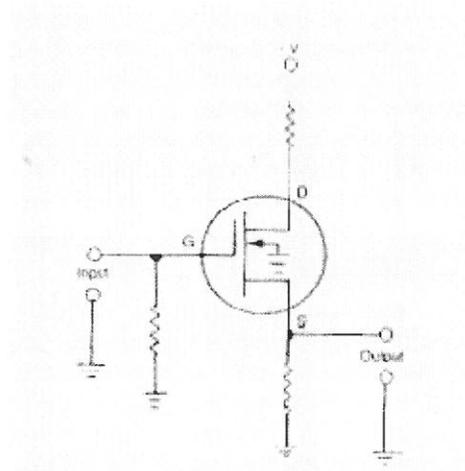


Figure 5-14

- The Common Drain has characteristics similar to the Common Collector Amplifier. It is also called a source follower.
- The input is applied to the gate and the output is taken from the source.
- It has high input impedance and very low output impedance.

- ✦ The voltage gain is less than one and there is no phase inversion between the input and output voltages.

- ✦ Like the Common Collector Amplifier, the Common Drain is primarily used for impedance matching.

Operational Amplifiers (Op Amps)

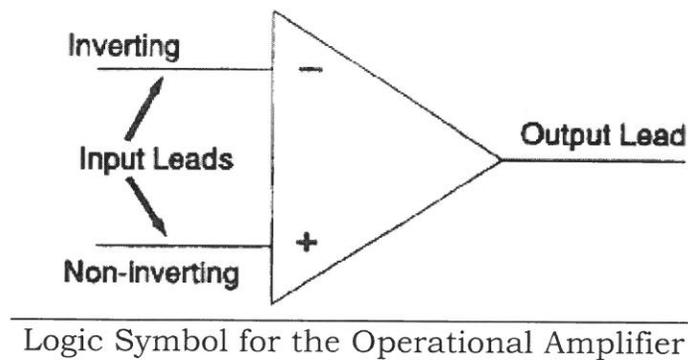
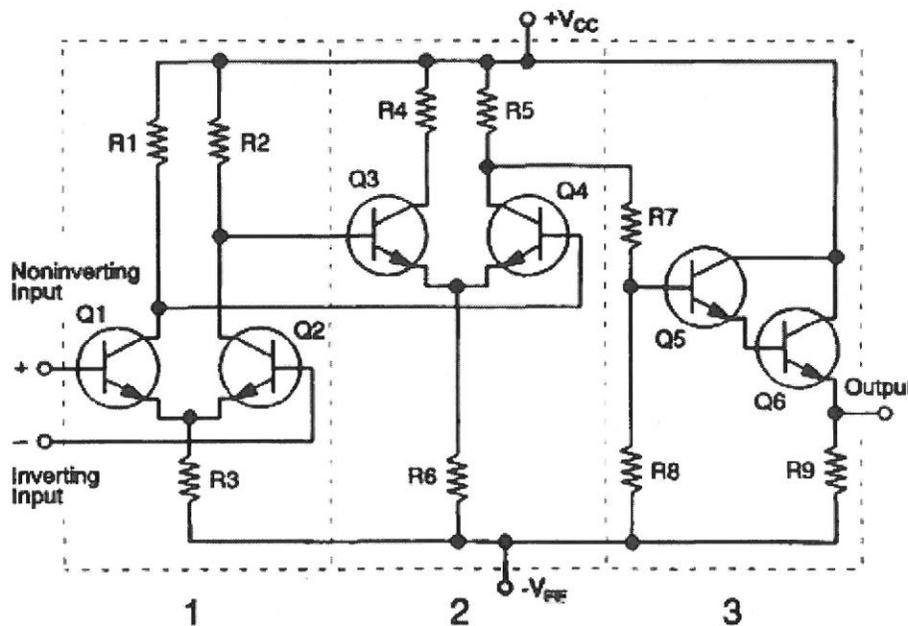


Figure 5-15

- ▼ The primary purpose of an Op Amp is to produce a stabilized, high gain output from a relatively small input(s).
- ▼ The Op Amp is currently manufactured in IC form.
- ▼ It is a direct-coupled, high gain, voltage amplifier that is fabricated on a single chip of silicon.
- ▼ The Op Amp has very high input impedance, very high open-loop gain, and very low output impedance

- Op Amps require both positive and negative supply voltages. These voltages are usually equal in value and ensure an offset (static condition) value of near zero volts.
- Op Amps have two input leads – inverting (-) and non-inverting (+).
- The output terminal must be able to supply both positive and negative output voltages.
- The Op Amp has three stages (see figure 5-16). They are the first differential amplifier stage, second differential amplifier stage, and the emitter follower stage, respectively.



The Major Sections of an Operational Amplifier

Figure 5-16

Differential Amplifier Stage

- ✦ The purpose of a differential amplifier stage is to compare the difference between two signals. There are three modes of operation for the differential amplifier. They are the differential output mode, the common mode, and the single-ended output mode.

- ✦ These differential amplifier modes are utilized in the Op Amp to provide several modes of operation for the Op Amp.

- ✦ The mode of operation of the OP Amp is determined by the input signals.

Emitter Follower Stage

- ✦ The final stage of the Op Amp is the Emitter Follower. This stage provides a stable signal with a low output impedance.

Op Amps

Op Amps can be operated in three modes. The Single-ended input mode, differential input mode, or the common mode.

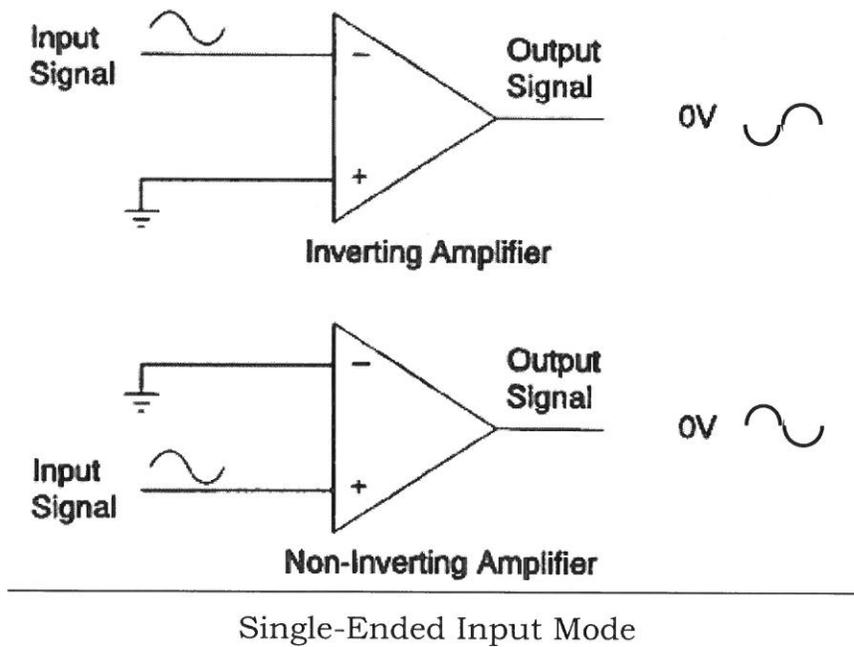
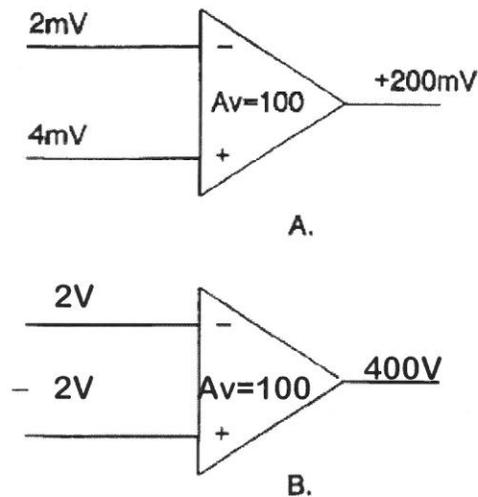


Figure 5-17

- **Single-Ended Input Mode.** In the Single-Ended Input Mode, one input is tied to ground, while an input signal is applied to the other op-amp input. This mode of operation provides good gain across the output.
- As an inverting amplifier, the non-inverting input is grounded and the input signal is applied to the inverting lead. The output is 180° out of phase with the input.
- The non-inverting amplifier has the inverting input grounded and the input signal is applied to the non-inverting lead. The output is in phase with the input.

- ▼ **Differential Input Mode.** In this mode of operation, two input signals are applied to the differential amplifier.
- ▼ The signals can be of equal value, however, they are typically 180° out of phase with each other.
- ▼ The output consists of an amplified version of the difference between the two signals. For example, in Figure 5-18 B, one input voltage peak is 2V and the other input voltage peak is -2V with a gain of 100. The amplified difference is 400V at the output



Differential Input Mode

Figure 5-18

- ▼ **Common Mode.** Two input signals are applied to the Op amp. Both signals are of equal amplitude and are in phase. The output is zero.

- ▼ This mode of operation provides excellent rejection of signals that contain noise, hum or power supply variations.

Voltage Gain

- ▼ The open loop gain of Op Amps is very high. A typical Op Amp might have a gain of 200,000.

- ▼ The term “open loop” refers to the voltage gain of the Op Amp without any feedback connected. Figure 5-18 is an example of an Op-Amp with open loop voltage gain.

- ▼ Except for extremely low-amplitude input voltages, open loop gain will be excessive resulting in distortion (Saturation). Open loop Op Amps also have limited bandwidth.

- ▼ **Closed Loop Gain.** Gain control is normally achieved by using negative feedback. A resistor (R_f) is connected in such a way that the output voltage is fed back into the input circuit and is 180° out of phase with the input voltage. An example of this is shown in Figure 5-19. This decreases gain and prevents immediate saturation. This increases the effective bandwidth of the amplifier.

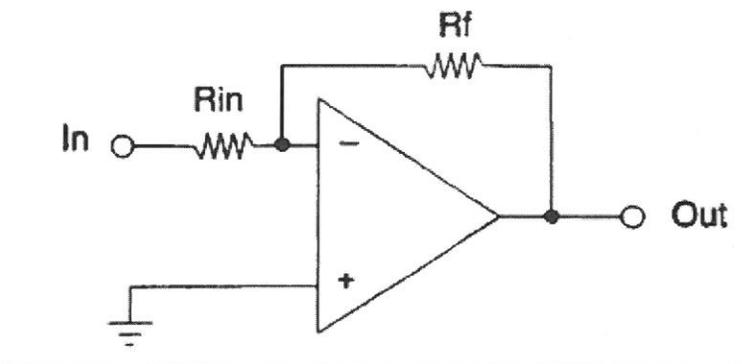


Figure 5-19



Activity 5

Other Transistor Amplifier Configurations

Determine whether each statement is true or false.

1. FET transistor amplifiers are voltage-controlled devices.
2. Low input impedance is a major characteristic of FET transistor amplifiers.
3. Gate current is avoided in JFET amplifiers by keeping the gate-source junction reverse-biased.

Complete the following statements.

4. The configuration shown below is called a _____.

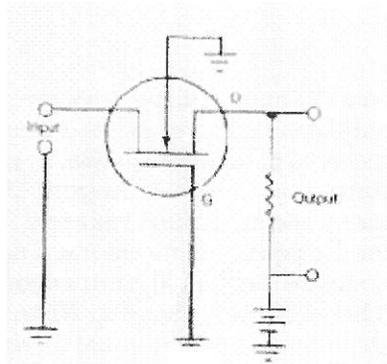


Figure 5-20

- a. Common Source
 - b. Common Drain
 - c. Common Gate
5. In the space provided below, draw the logic symbol for an open-loop gain operational amplifier. (Label inputs and outputs)

The purpose of this chapter is to provide a general understanding of the subject areas addressed. For more information on the topics covered in this unit, refer to the reference books and other study materials listed in the Study Guide for the Basic Electronics Test.

SUMMARY

1. Amplifier gain is determined by dividing the output by the input. Gain, has no unit of measure, and is specified as a voltage, current, or power ratio.
2. The decibel is based on power gain or loss. It can be adapted to voltage gain or loss when the input and output resistances are equal. When the input and output resistances are not equal, the dB voltage gain is not equal to the dB power gain.
3. The three common bipolar amplifier configurations are the common emitter, common base, and the common collector.
4. The common emitter amplifier produces a 180° phase inversion between the input and output voltages.
5. The load resistance and the emitter resistance determine the voltage gain of a common emitter.
6. The common collector amplifier, or emitter follower, has very high input impedance and very low output impedance.
7. The common collector has a voltage gain of less than one.
8. The common base amplifier has low input impedance and high output impedance.
9. The common base amplifier is mainly used as a Radio Frequency amplifier.
10. Any three of the bipolar amplifier configurations can use either PNP or NPN transistors. The major difference is the polarity of the supply voltage.
11. FET transistor amplifiers are voltage-controlled amplifiers. Because of this, their input impedance is very high.
12. The three common FET transistor amplifier configurations are the common source, common drain, and common gate.
13. As with the common-emitter circuit, the common source configuration produces a 180° phase inversion between the input and output voltages.
14. It is necessary to reverse-bias the gate-source junction for proper operation of a JFET transistor amplifier.
15. Operational amplifiers contain differential amplifiers.
16. The operational amplifier has two inputs and can respond to the difference between two input signals. The first input is called the inverted input and the second input is called the non-inverting input.
17. The three modes of operation of an operational amplifier are the single-ended input, differential input, and the common-mode signal input.
18. Operational amplifiers are high-performance amplifiers that are usually constructed in integrated circuit form. Operational amplifiers produce high output voltage gains.

19. *Open loop and closed-loop gain are the two configurations of voltage gain for the operational amplifier.*
20. *The three major sections of an operational amplifier are the first differential amplifier, the second differential amplifier, and the emitter-follower.*

7. Identify the three transistor amplifier configurations.
- Common base, common grid, common output.
 - Common anode, common collector, common base.
 - Common emitter, common collector, common base.
 - Common input, common output, common collector.
8. To determine a transistor amplifier's configuration, identify the element to which the input and output are connected. The remaining element is called the _____.
- base.
 - battery.
 - common element.
 - common collector.
9. In the common collector configuration, the input is applied to the _____, and the output is taken from the _____.
10. The transistor amplifier configuration below is called the _____.

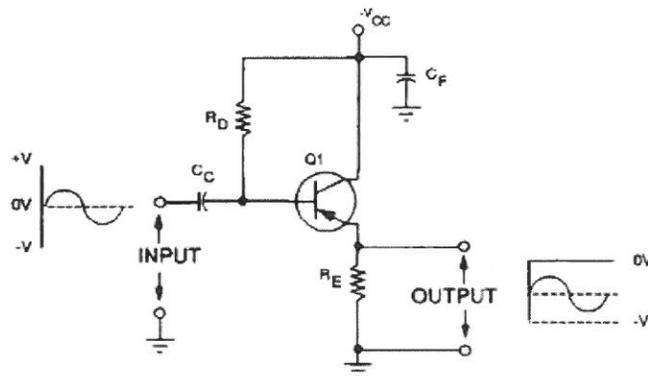


Figure 5-21

- common collector
- common emitter
- common base

11. The transistor amplifier configuration below is called the _____.

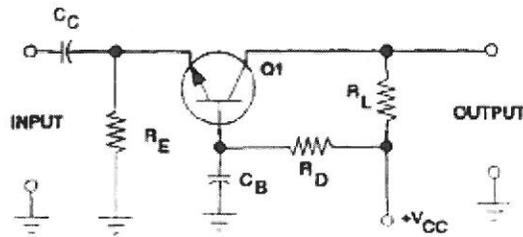
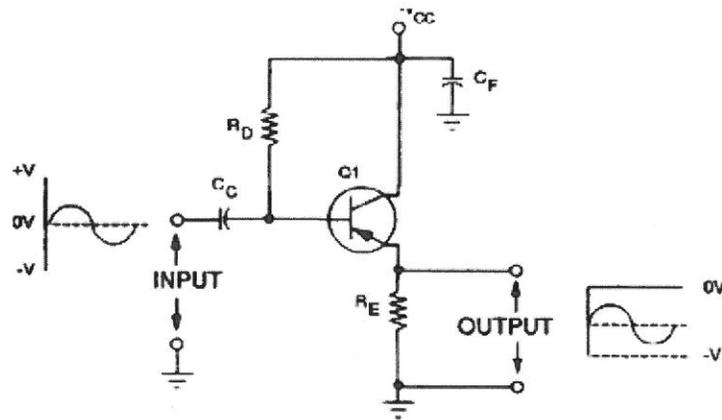


Figure 5-22

- a. common collector
- b. common emitter
- c. common base

Use the figure below to answer questions 12-15.



B. PNP

Figure 5-23

12. The purpose of R_E is to _____.

- a. determine forward bias.
- b. develop the output signal.
- c. Place the emitter at AC ground.

13. The purpose of R_D is to _____.

- a. aid in determining forward bias.
- b. develop the input signal.
- c. determine forward bias.

14. The purpose of C_F is to _____.

- a. connect the output signal to the amplifier circuit.
- b. place the collector at AC ground.
- c. develop the output signal.

15. The output voltage gain is _____.

- a. ten times greater than the input voltage.
- b. the same as the input voltage.
- c. less than one.

Use the figure below to answer questions 16-18.

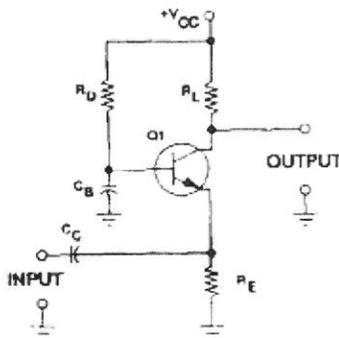


Figure 5-24

16. The purpose of C_B is to _____.

- a. couple the AC input signal to the base.
- b. place the emitter at AC ground.
- c. place the base at AC ground.

17. The input signal is applied to which element of the transistor?

- a. Base
- b. Emitter
- c. Collector

18. The input and output waveforms are _____ with each other.

- a. in phase
- b. 180° degrees out of phase

19. Determine the trouble in the circuit shown below.

- a. R1 is open
- b. R2 is open
- c. Q1 is open
- d. C1 is shorted

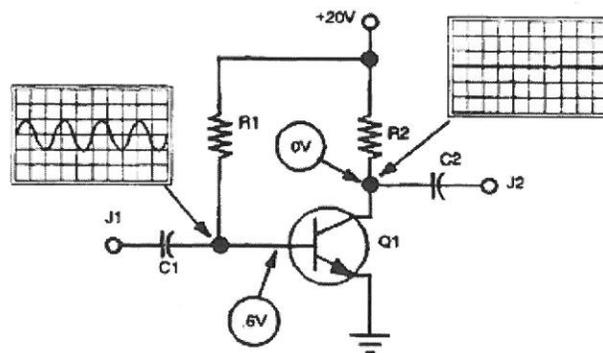


Figure 5-25

20. Determine the trouble in the circuit shown below.

- a. Q1 is shorted
- b. R2 is shorted
- c. C2 is open
- d. Q1 is open

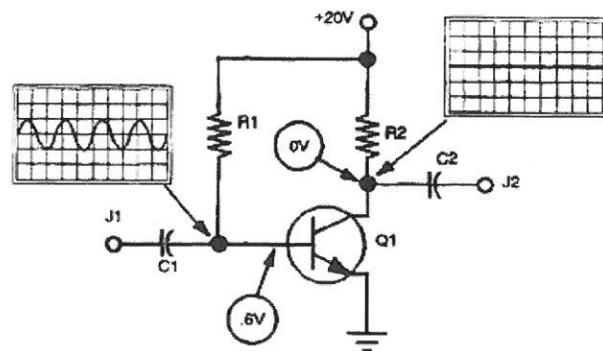


Figure 5-26

21. Determine the trouble in the circuit shown below.

- a. Q1 is shorted
- b. R1 is shorted
- c. R2 is shorted
- d. C2 is open

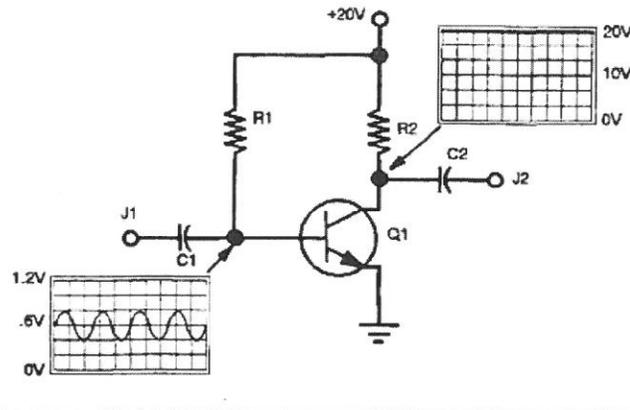


Figure 5-27

Use the circuit below to answer questions 22-24

22. Determine the trouble in the circuit shown below.

- a. Q1 is open
- b. Q1 is shorted
- c. C2 is shorted
- d. R2 is shorted

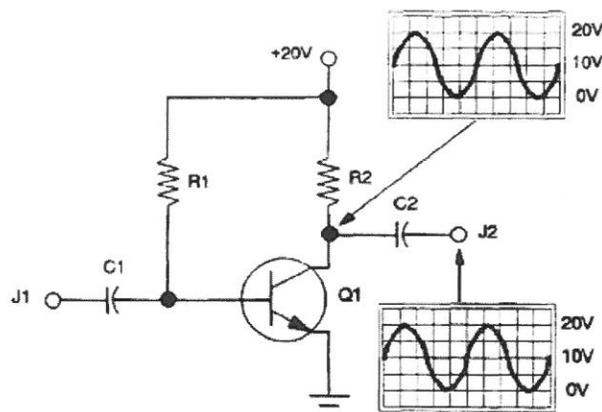


Figure 5-28

23. The input signal is applied to which element of the transistor?

- a. Base
- b. Emitter
- c. Collector

24. The input and output waveforms are _____ with each other.

- a. in phase
- b. 180° degrees out of phase

25. The amplifier configuration below is called the _____.

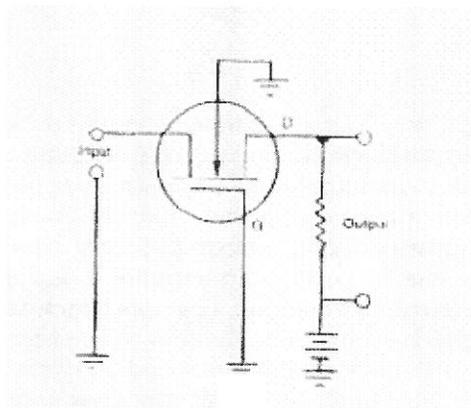


Figure 5-29

- a. Common Source
- b. Common Drain
- c. Common Gate

26. The amplifier configuration below is called _____.

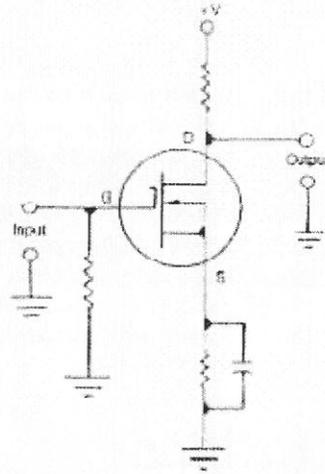


Figure 5-30

- a. Common Source
- b. Common Drain
- c. Common Gate

Use the figure below to answer questions 27-29.

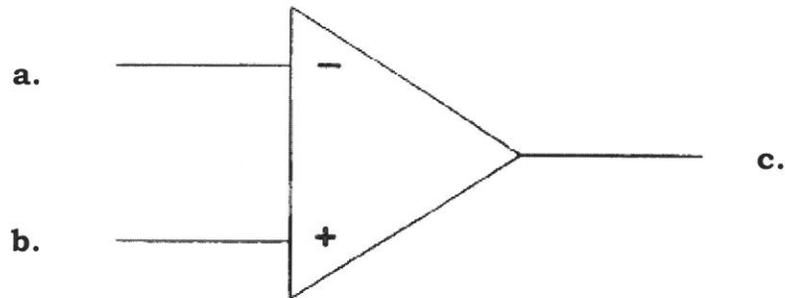


Figure 5-31

27. Identify the leads shown in Figure 5-31.

- a. _____
- b. _____
- c. _____

28. What is meant by single-ended input operation?

29. When one signal is applied to the op amp inverting input and a second signal is applied to the non-inverting input, both signals are present at the same time. This arrangement is called _____.

- a. single-ended input operation.
- b. differential input operation.

30. What are the three stages within an op amp?

- a. _____
- b. _____
- c. _____

31. Which statement identifies the op amp shown below?

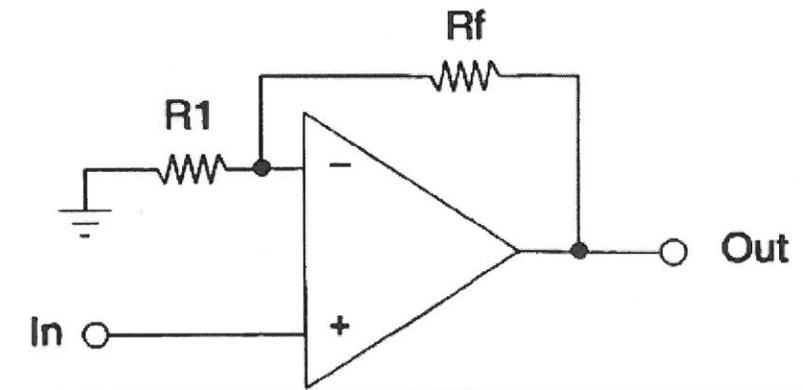


Figure 5-32

- a. Single-ended input, open-loop gain
- b. Single-ended input, closed-loop gain
- c. Differential input, open-loop gain
- d. Differential input, closed-loop gain

Chapter 5 Answer Key

Activity 1

1. True
2. False
3. True
4. True
5. False
6. True
7. 64 dB
8. 38.58dB

Activity 2

1. False
2. False
3. True
4. AC
5. collector load
6. large; limits
7. R_L

Activity 3

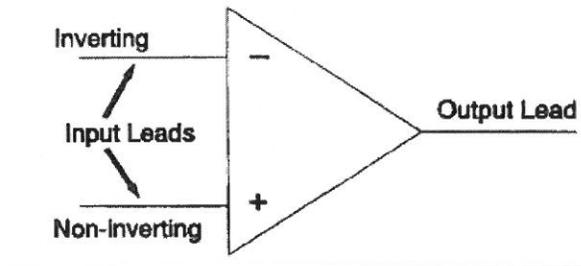
1. True
2. False
3. True
4. False
5. c
6. c
7. b
8. a
9. c
10. low; high

Activity 4

1. c
2. a
3. b
4. b

Activity 5

1. True
2. False
3. True
4. c
- 5.



Chapter 5 Self Test

Answer the following questions.

1. A_V is the symbol for **voltage gain**.
2. A_P is the symbol for **power gain**.
3. In the space below, write the formula for dB power gain.

$$\text{dB power gain} = 10 \times \log_{10} \frac{P_{\text{out}}}{P_{\text{in}}}$$

4. In the space below, write the formula for dB voltage gain.

$$\text{dB voltage gain} = 20 \times \log_{10} \frac{V_{\text{out}}}{V_{\text{in}}}$$

5. Amplification is defined as the ability of a circuit to _____.
 - a. produce a large change in input for a small change in output.
 - b. increase the resistance in direct proportion to the signal amplitude.
 - c. take a small change in input voltage or current and produce a larger change in output voltage or current.**
 - d. take a change in input voltage or current and produce an identical change in the output voltage or current.
6. Gain is a ratio of the _____ divided by the _____.
 - a. input; output
 - b. output; input**
7. Identify the three transistor amplifier configurations.
 - a. Common base, common grid, common output.
 - b. Common anode, common collector, common base.
 - c. Common emitter, common collector, common base.**
 - d. Common input, common output, common collector.

8. To determine a transistor amplifier's configuration, identify the element to which the input and output are connected. The remaining element is called the _____.
- base.
 - battery.
 - common element.**
 - common collector.
9. In the common collector configuration, the input is applied to the base, and the output is taken from the emitter.
10. The transistor amplifier configuration below is called the _____.

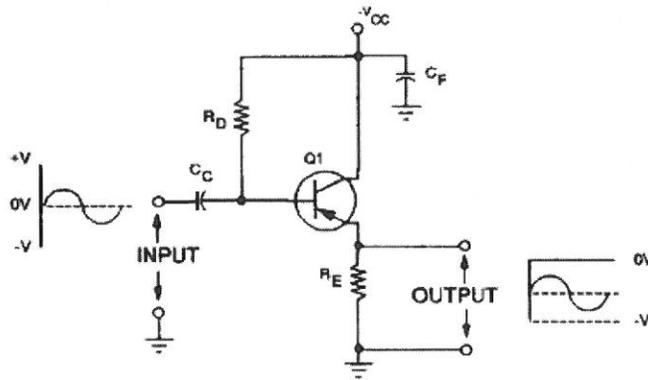


Figure 5-21

- common collector**
- common emitter
- common base

11. The transistor amplifier configuration below is called the _____.

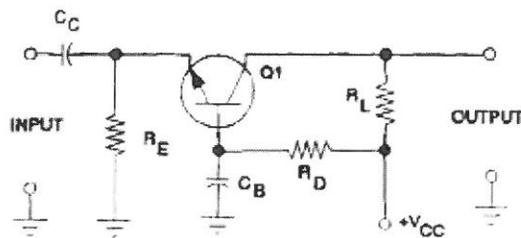


Figure 5-22

- d. common collector
- e. common emitter
- f. common base**

Use the figure below to answer questions 12-15.

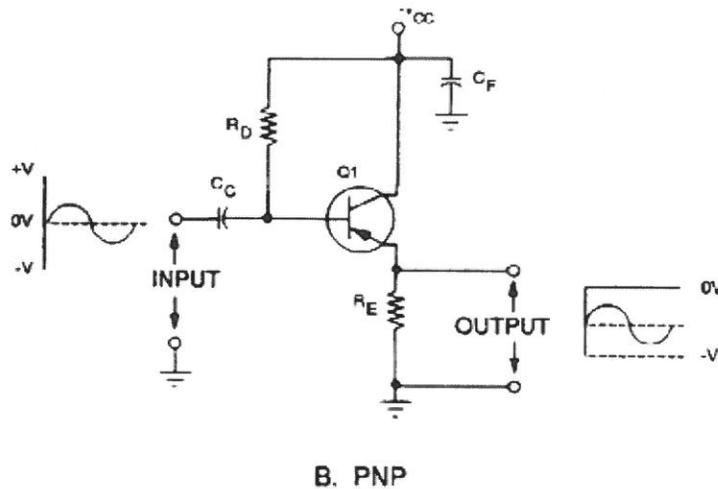


Figure 5-23

12. The purpose of R_E is to _____.

- a. determine forward bias.
- b. develop the output signal.**
- c. Place the emitter at AC ground.

13. The purpose of R_D is to _____.
- aid in determining forward bias.
 - develop the input signal.
 - determine forward bias.**
14. The purpose of C_F is to _____.
- connect the output signal to the amplifier circuit.
 - place the collector at AC ground.**
 - develop the output signal.
15. The output voltage gain is _____.
- ten times greater than the input voltage.
 - the same as the input voltage.
 - less than one.**

Use the figure below to answer questions 16-18.

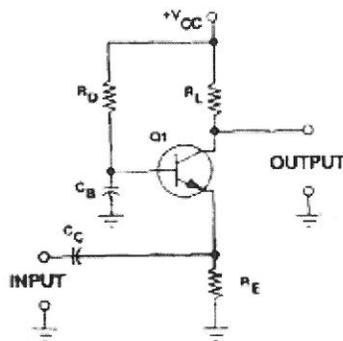


Figure 5-24

16. The purpose of C_B is to _____.
- couple the AC input signal to the base.
 - place the emitter at AC ground.
 - place the base at AC ground.**
17. The input signal is applied to which element of the transistor?
- Base
 - Emitter**
 - Collector

18. The input and output waveforms are _____ with each other.

- a. in phase
- b. 180° degrees out of phase

19. Determine the trouble in the circuit shown below.

- a. R1 is open
- b. R2 is open**
- c. Q1 is open
- d. C1 is shorted

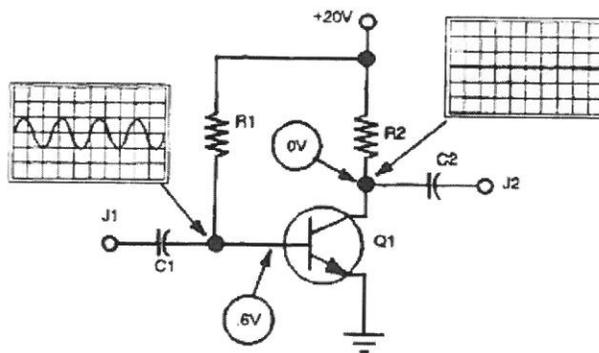


Figure 5-25

20. Determine the trouble in the circuit shown below.

- a. Q1 is shorted**
- b. R2 is shorted
- c. C2 is open
- d. Q1 is open

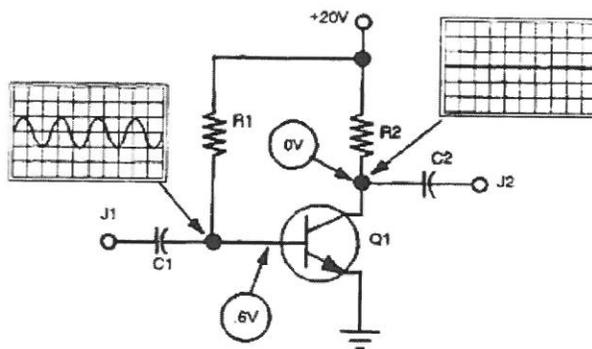


Figure 5-26

21. Determine the trouble in the circuit shown below.

- a. Q1 is shorted
- b. R1 is shorted
- c. R2 is shorted**
- d. C2 is open

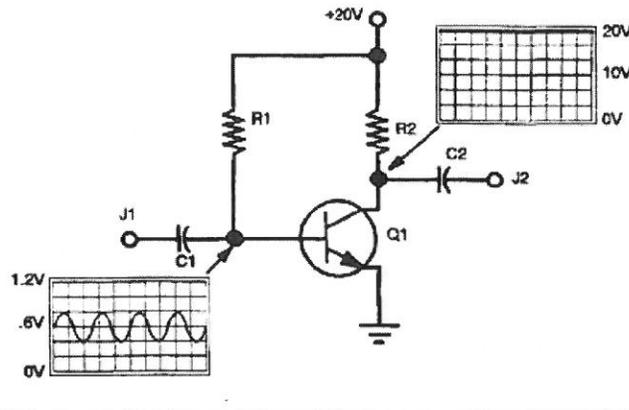


Figure 5-27

Use the circuit below to answer questions 22-24

22. Determine the trouble in the circuit shown below.

- a. Q1 is open
- b. Q1 is shorted
- c. C2 is shorted**
- d. R2 is shorted

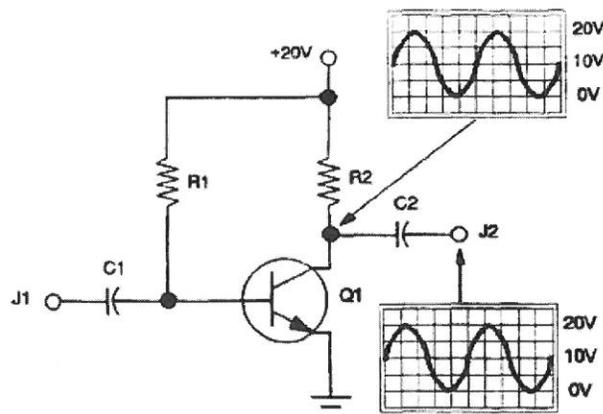


Figure 5-28

23. The input signal is applied to which element of the transistor?
- a. **Base**
 - b. Emitter
 - c. Collector
24. The input and output waveforms are _____ with each other.
- a. in phase
 - b. **180° degrees out of phase**
25. The amplifier configuration below is called the _____.

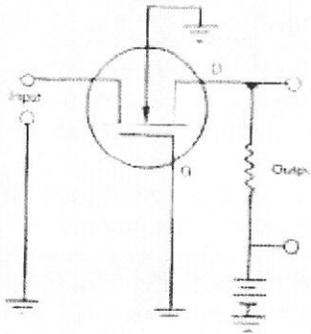


Figure 5-29

- d. Common Source
- e. Common Drain
- f. **Common Gate**

26. The amplifier configuration below is called _____.

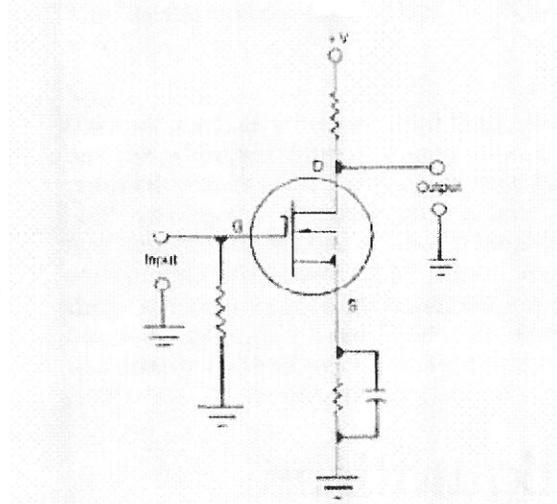


Figure 5-30

- a. **Common Source**
- b. Common Drain
- c. Common Gate

Use the figure below to answer questions 27-29.

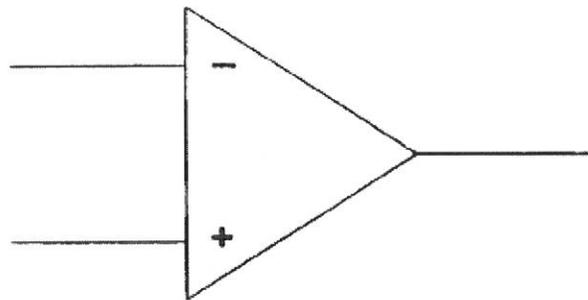


Figure 5-31

27. Identify the leads shown in Figure 5-31.

- a. **Inverting**
- b. **Non-inverting**
- c. **Output**

28. What is meant by single-ended input operation?

There is only one input. The other input is grounded.

29. When one signal is applied to the op amp inverting input and a second signal is applied to the non-inverting input, both signals are present at the same time. This arrangement is called_____.

- a. single-ended input operation.
- b. **differential input operation.**

30. What are the three stages within an op amp?

- a. **First Differential Amplifier**
- b. **Second Differential Amplifier**
- c. **Emitter Follower**

31. Which statement identifies the op amp shown below?

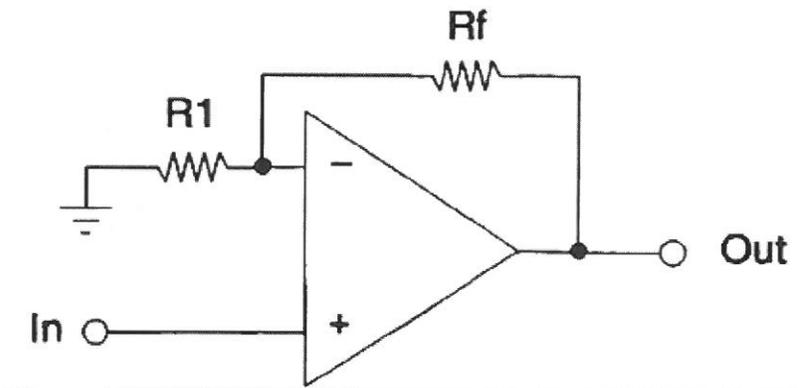


Figure 5-32

- a. Single-ended input, open-loop gain
- b. **Single-ended input, closed-loop gain**
- c. Differential input, open-loop gain
- d. Differential input, closed-loop gain

