Introduction to Amplifiers

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CHAPTER 1

AMPLIFIERS

LEARNING OBJECTIVES

Learning objectives are stated at the beginning of each chapter. These learning objectives serve as a preview of the information you are expected to learn in the chapter. The comprehensive check questions are based on the objectives. By successfully completing the OCC/ECC, you indicate that you have met the objectives and have learned the information. The learning objectives are listed below.

Upon completion of this chapter, you will be able to:

1. Define amplification and list several common uses; state two ways in which amplifiers are classified.

2. List the four classes of operation of, four methods of coupling for, and the impedance characteristics of the three configurations of a transistor amplifier.

INTRODUCTION

This chapter is a milestone in your study of electronics. Previous modules have been concerned more with individual components of circuits than with the complete circuits as the subject. This chapter and the other chapters of this module are concerned with the circuitry of amplifiers. While components are discussed, the discussion of the components is not an explanation of the working of the component itself (these have been covered in previous modules) but an explanation of the component as it relates to the circuit.

The circuits this chapter is concerned with are AMPLIFIERS. Amplifiers are devices that provide AMPLIFICATION. That doesn't explain much, but it does describe an amplifier if you know what amplification is and what it is used for.

WHAT IS AMPLIFICATION?

Just as an amplifier is a device that provides amplification, amplification is the process of providing an increase in AMPLITUDE. Amplitude is a term that describes the size of a signal. In terms of a.c., amplitude usually refers to the amount of voltage or current. A 5-volt peak-to-peak a.c.signal would be larger in amplitude than a 4-volt peak-to-peak a.c. signal. "SIGNAL" is a general term used to refer to any a.c. or d.c. of interest in a circuit; e.g., input signal and output signal. A signal can be large or small, ac. or d.c., a sine wave or nonsinusoidal, or even nonelectrical such as sound or light. "Signal" is a very general term and, therefore, not very descriptive by itself, but it does sound more technical than the word "thing". It is not very impressive to refer to the "input thing" or the "thing that comes out of this circuit."

Perhaps the concept of the relationship of amplifier-amplification-amplitude will be clearer if you consider a parallel situation (an analogy). A magnifying glass is a magnifier. As such, it provides magnification which is an increase in the magnitude (size) of an object. This relationship of magnifier-magnification-magnitude is the same as the relationship of amplifier-amplification-amplitude. The analogy is true in one other aspect as well. The magnifier does not change the object that is being magnified; it is only the image that is larger, not the object itself. With the amplifier, the output signal differs in amplitude from the input signal, but the input signal still exists unchanged. So, the object (input signal) and the magnifier (amplifier) control the image (output signal).

An amplifier can be defined as a device that enables an input signal to control an output signal. The output signal will have some (or all) of the characteristics of the input signal but will generally be larger than the input signal in terms of voltage, current, or power.

USES OF AMPLIFICATION

Most electronic devices use amplifiers to provide various amounts of signal amplification. Since most signals are originally too small to control or drive the desired device, some amplification is needed.

For example, the audio signal taken from a record is too small to drive a speaker, so amplification is needed. The signal will be amplified several times between the needle of the record player and the speaker. Each time the signal is amplified it is said to go through a STAGE of amplification. The audio amplifier shown connected between the turntable and speaker system in figure 1-1 contains several stages of amplification.

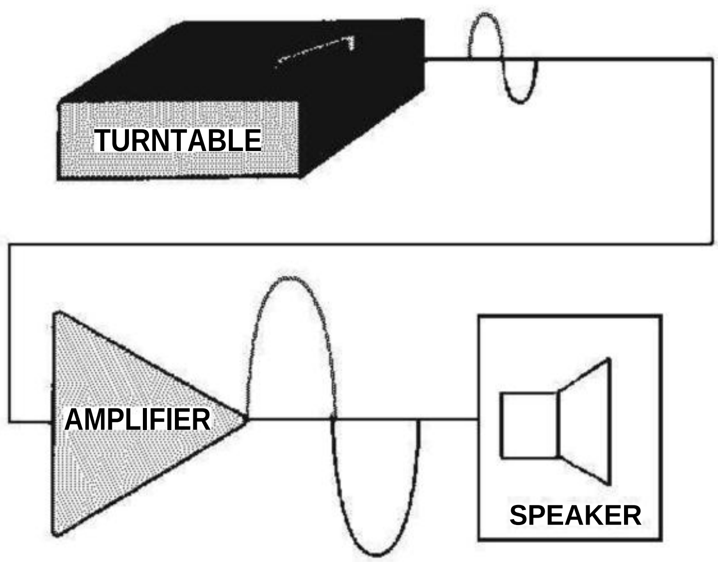


Figure 1-1.—Amplifier as used with turntable and speaker.

Notice the triangle used in figure 1-1 to represent the amplifier. This triangle is the standard block diagram symbol for an amplifier.

Another example of the use of an amplifier is shown in figure 1-2. In a radio receiver, the signal picked up by the antenna is too weak (small) to be used as it is. This signal must be amplified before it is sent to the detector. (The detector separates the audio signal from the frequency that was sent by the transmitter. The way in which this is done will be discussed later in this training series.)

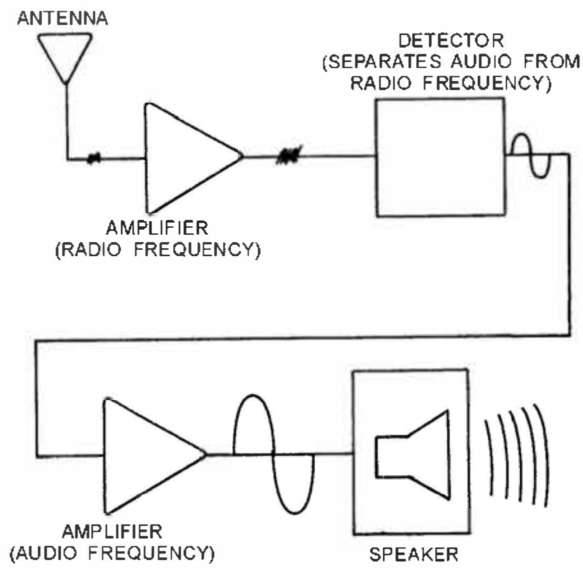


Figure 1-2.—Amplifiers as used in radio receiver.

The audio signal from the detector will then be amplified to make it large enough to drive the speaker of the radio.

Almost every electronic device contains at least one stage of amplification, so you will be seeing amplifiers in many devices that you work on. Amplifiers will also be used in most of the *NEETS* modules that follow this one.

Q-1. What is amplification?

Q-2. Does an amplifier actually change an input signal? Why or why not?

Q-3. Why do electronic devices use amplifiers?

CLASSIFICATION OF AMPLIFIERS

Most electronic devices use at least one amplifier, but there are many types of amplifiers. This module will not try to describe all the different types of amplifiers. You will be shown the general principles of amplifiers and some typical amplifier circuits.

Most amplifiers can be classified in two ways. The first classification is by their function. This means they are basically voltage amplifiers or power amplifiers. The second classification is by their frequency response. In other words what frequencies are they designed to amplify?

If you describe an amplifier by these two classifications (function and frequency response) you will have a good working description of the amplifier. You may not know what the exact circuitry is, but you will know what the amplifier does and the frequencies that it is designed to handle.

VOLTAGE AMPLIFIERS AND POWER AMPLIFIERS

All amplifiers are current-control devices. The input signal to an amplifier controls the current output of the amplifier. The connections of the amplifying device (electron tube, transistor, magnetic amplifier, etc.) and the circuitry of the amplifier determine the classification. Amplifiers are classified as voltage or power amplifiers.

A VOLTAGE AMPLIFIER is an amplifier in which the output signal voltage is larger than the input signal voltage. In other words, a voltage amplifier amplifies the voltage of the input signal.

A POWER AMPLIFIER is an amplifier in which the output signal power is greater than the input signal power. In other words, a power amplifier amplifies the power of the input signal. Most power amplifiers are used as the final amplifier (stage of amplification) and control (or drive) the output device. The output device could be a speaker, an indicating device, an antenna, or the heads on a tape recorder. Whatever the device, the power to make it work (or drive it) comes from the final stage of amplification which is a power amplifier.

Figure 1-3 shows a simple block diagram of a voltage amplifier with its input and output signals and a power amplifier with its input and output signals. Notice that in view (A) the output signal voltage is larger than the input signal voltage. Since the current values for the input and output signals are not shown, you cannot tell if there is a power gain in addition to the voltage gain.

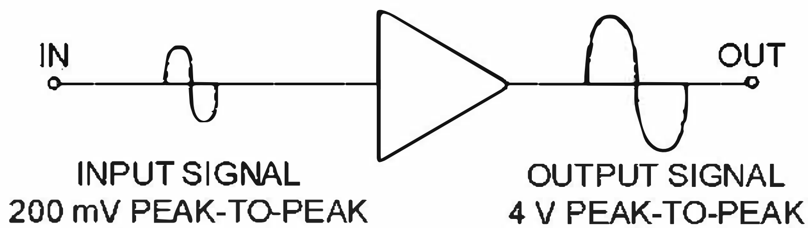


Figure 1-3A.—Block diagram of voltage and power amplifiers.

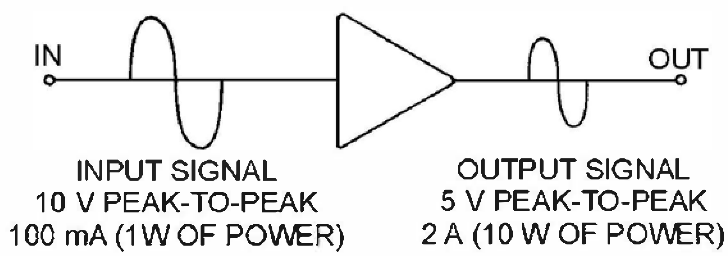


Figure 1-3B.—Block diagram of voltage and power amplifiers.

In view (B) of the figure the output signal voltage is less than the input signal voltage. As a voltage amplifier, this circuit has a gain of less than 1. The output power, however, is greater than the input power. Therefore, this circuit is a power amplifier.

The classification of an amplifier as a voltage or power amplifier is made by comparing the characteristics of the input and output signals. If the output signal is larger in voltage amplitude than the input signal, the amplifier is a voltage amplifier. If there is no voltage gain, but the output power is greater than the input power, the amplifier is a power amplifier.

FREQUENCY RESPONSE OF AMPLIFIERS

In addition to being classified by function, amplifiers are classified by frequency response. The frequency response of an amplifier refers to the band of frequencies or frequency range that the amplifier was designed to amplify.

You may wonder why the frequency response is important. Why doesn't an amplifier designed to amplify a signal of 1000 Hz work just as well at 1000 MHz? The answer is that the components of the amplifier respond differently at different frequencies. The amplifying device (electron tube, transistor, magnetic amplifier, etc.) itself will have frequency limitations and respond in different ways as the frequency changes. Capacitors and inductors in the circuit will change their reactance as the frequency changes. Even the slight amounts of capacitance and inductance between the circuit wiring and other components (interelectrode capacitance and self-inductance) can become significant at high frequencies. Since the response of components varies with the frequency, the components of an amplifier are selected to amplify a certain range or band of frequencies.

NOTE: For explanations of interelectrode capacitance and self-inductance see *NEETS Modules 2—Introduction to Alternating Current and Transformers;* 6—*Introduction to Electronic Emission, Tubes, and Power Supplies;* and 7—*Introduction to Solid-State Devices and Power Supplies.*

The three broad categories of frequency response for amplifiers are AUDIO AMPLIFIER, RF AMPLIFIER, and VIDEO AMPLIFIER.

An audio amplifier is designed to amplify frequencies between 15 Hz and 20 kHz. Any amplifier that is designed for this entire band of frequencies or any band of frequencies contained in the audio range is considered to be an audio amplifier.

In the term rf amplifier, the "rf" stands for radio frequency. These amplifiers are designed to amplify frequencies between 10 kHz and 100,000 MHz. A single amplifier will not amplify the entire rf range, but any amplifier whose frequency band is included in the rf range is considered an rf amplifier.

A video amplifier is an amplifier designed to amplify a band of frequencies from 10 Hz to 6 MHz. Because this is such a wide band of frequencies, these amplifiers are sometimes called WIDE-BAND AMPLIFIERS. While a video amplifier will amplify a very wide band of frequencies, it does not have the gain of narrower-band amplifiers. It also requires a great many more components than a narrow-band amplifier to enable it to amplify a wide range of frequencies.

Q-4. In what two ways are amplifiers classified?

Q-5. What type of amplifier would be used to drive the speaker system of a record player?

Q-6. What type of amplifier would be used to amplify the signal from a radio antenna?

TRANSISTOR AMPLIFIERS

A transistor amplifier is a current-control device. The current in the base of the transistor (which is dependent on the emitter-base bias) controls the current in the collector. A vacuum-tube amplifier is also a current-control device. The grid bias controls the plate current. These facts are expanded upon in *NEETS Module 6*, *Introduction to Electronic Emission, Tubes and Power Supplies,* and *Module 7*, *Introduction to Solid-State Devices and Power Supplies.*

You might hear that a vacuum tube is a voltage-operated device (since the grid does not need to draw current) while the transistor is a current-operated device. You might agree with this statement, but both the vacuum tube and the transistor are still current-control devices. The whole secret to understanding amplifiers is to remember that fact. Current control is the name of the game. Once current is controlled you can use it to give you a voltage gain or a power gain.

This chapter will use transistor amplifiers to present the concepts and principles of amplifiers. These concepts apply to vacuum-tube amplifiers and, in most cases, magnetic amplifiers as well as transistor amplifiers. If you wish to study the vacuum-tube equivalent circuits of the transistor circuits presented, an excellent source is the EIMB, NAVSEA 0967-LP-000-0120, *Electronics Circuits*.

The first amplifier concept that is discussed is the "class of operation" of an amplifier.

AMPLIFIER CLASSES OF OPERATION

The class of operation of an amplifier is determined by the amount of time (in relation to the input signal) that current flows in the output circuit. This is a function of the operating point of the amplifying device. The operating point of the amplifying device is determined by the bias applied to the device. There are four classes of operation for an amplifier. These are: A, AB, B and C. Each class of operation has certain uses and characteristics. No one class of operation is "better" than any other class. The selection of the "best" class of operation is determined by the use of the amplifying circuit. The best class of operation for a phonograph is not the best class for a radio transmitter.

Class A Operation

A simple transistor amplifier that is operated class A is shown in figure 1-4. Since the output signal is a 100% (or 360º) copy of the input signal, current in the output circuit must flow for 100% of the input signal time. This is the definition of a class A amplifier. Amplifier current flows for 100% of the input signal.

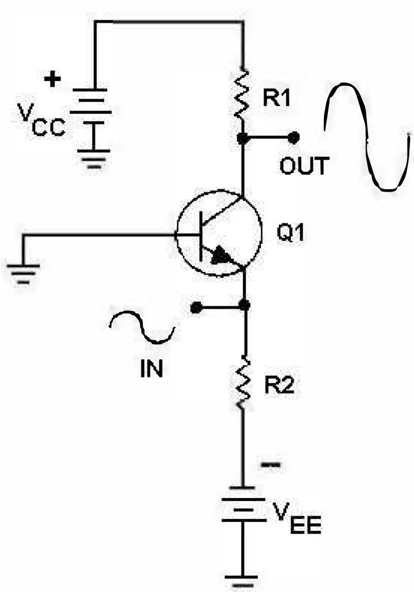


Figure 1-4.—A simple class A transistor amplifier.

The class A amplifier has the characteristics of good FIDELITY and low EFFICIENCY. Fidelity means that the output signal is just like the input signal in all respects except amplitude. It has the same shape and frequency. In some cases, there may be a phase difference between the input and output signal (usually 180º), but the signals are still considered to be "good copies." If the output signal is not like the input signal in shape or frequency, the signal is said to be DISTORTED. DISTORTION is any undesired change in a signal from input to output.

The efficiency of an amplifier refers to the amount of power delivered to the output compared to the power supplied to the circuit. Since every device takes power to operate, if the amplifier operates for 360º of input signal, it uses more power than if it only operates for 180º of input signal. If the amplifier uses more power, less power is available for the output signal and efficiency is lower. Since class A amplifiers operate (have current flow) for 360º of input signal, they are low in efficiency. This low efficiency is acceptable in class A amplifiers because they are used where efficiency is not as important as fidelity.

Class AB Operation

If the amplifying device is biased in such a way that current flows in the device for 51% - 99% of the input signal, the amplifier is operating class AB. A simple class AB amplifier is shown in figure 1-5.

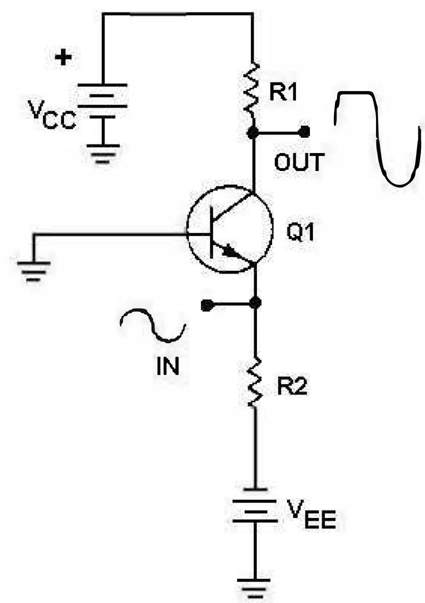


Figure 1-5.—A simple class AB transistor amplifier.

Notice that the output signal is distorted. The output signal no longer has the same shape as the input signal. The portion of the output signal that appears to be cut off is caused by the lack of current through the transistor. When the emitter becomes positive enough, the transistor cannot conduct because the base-to-emitter junction is no longer forward biased. Any further increase in input signal will not cause an increase in output signal voltage.

Class AB amplifiers have better efficiency and poorer fidelity than class A amplifiers. They are used when the output signal need not be a complete reproduction of the input signal, but both positive and negative portions of the input signal must be available at the output.

Class AB amplifiers are usually defined as amplifiers operating between class A and class B because class A amplifiers operate on 100% of input signal and class B amplifiers (discussed next) operate on 50% of the input signal. Any amplifier operating between these two limits is operating class AB.

Class B Operation

As was stated above, a class B amplifier operates for 50% of the input signal. A simple class B amplifier is shown in figure 1-6.

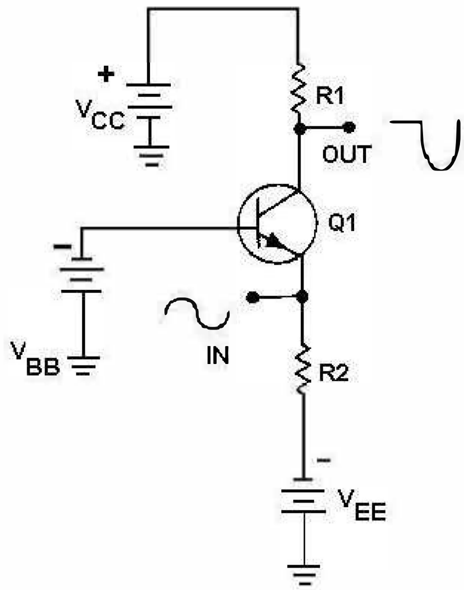


Figure 1-6.—A simple class B transistor amplifier.

In the circuit shown in figure 1-6, the base-emitter bias will not allow the transistor to conduct whenever the input signal becomes positive. Therefore, only the negative portion of the input signal is reproduced in the output signal. You may wonder why a class B amplifier would be used instead of a simple rectifier if only half the input signal is desired in the output. The answer to this is that the rectifier does not amplify. The output signal of a rectifier cannot be higher in amplitude than the input signal. The class B amplifier not only reproduces half the input signal, but amplifies it as well.

Class B amplifiers are twice as efficient as class A amplifiers since the amplifying device only conducts (and uses power) for half of the input signal. A class B amplifier is used in cases where exactly 50% of the input signal must be amplified. If less than 50% of the input signal is needed, a class C amplifier is used.

Class C Operation

Figure 1-7 shows a simple class C amplifier. Notice that only a small portion of the input signal is present in the output signal. Since the transistor does not conduct except during a small portion of the input signal, this is the most efficient amplifier. It also has the worst fidelity. The output signal bears very little resemblance to the input signal.

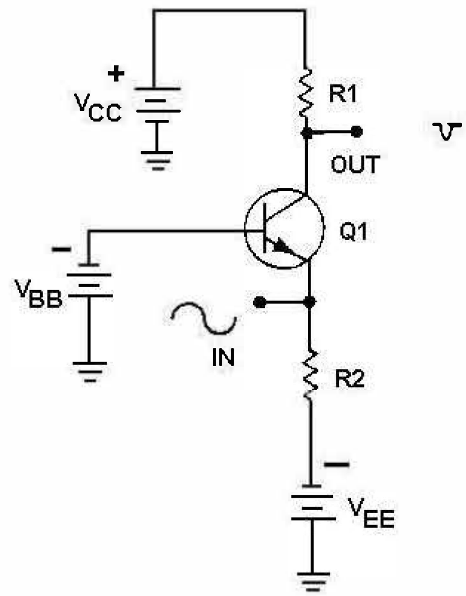


Figure 1-7.—A simple class C transistor amplifier.

Class C amplifiers are used where the output signal need only be present during part of one-half of the input signal. Any amplifier that operates on less than 50% of the input signal is operated class C.

Q-7. What determines the class of operation of an amplifier?

Q-8. What are the four classes of operation of a transistor amplifier?

Q-9. If the output of a circuit needs to be a complete representation of one-half of the input signal, what class of operation is indicated?

Q-10. Why is class C operation more efficient than class A operation?

Q-11. What class of operation has the highest fidelity?

AMPLIFIER COUPLING

Earlier in this module it was stated that almost every electronic device contains at least one stage of amplification. Many devices contain several stages of amplification and therefore several amplifiers. Stages of amplification are added when a single stage will not provide the required amount of amplification. For example, if a single stage of amplification will provide a maximum gain of 100 and the desired gain from the device is 1000, two stages of amplification will be required. The two stages might have gains of 10 and 100, 20 and 50, or 25 and 40. (The overall gain is the product of the individual stages-$10 \times 100 = 20 \times 50 = 25 \times 40 = 1000$.)

Figure 1-8 shows the effect of adding stages of amplification. As stages of amplification are added, the signal increases and the final output (from the speaker) is increased.

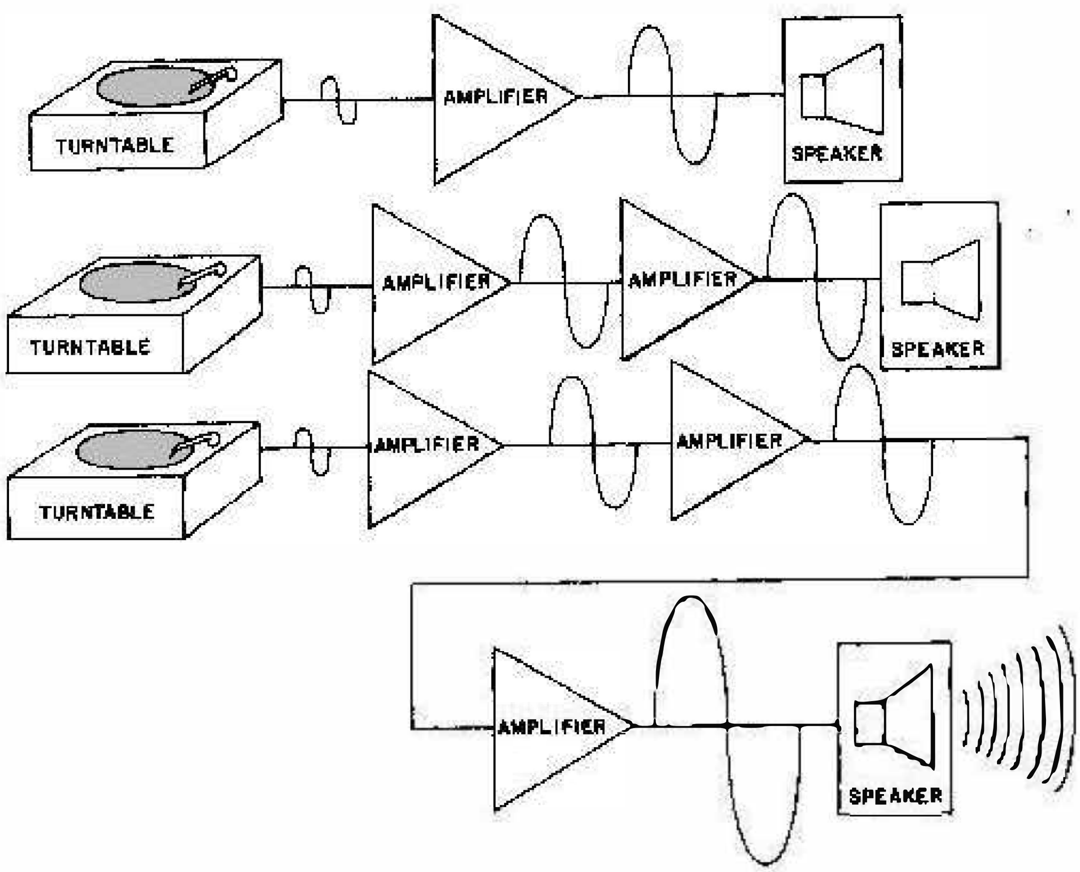


Figure 1-8.—Adding stages of amplification.

Whether an amplifier is one of a series in a device or a single stage connected between two other devices (top view, figure 1-8), there must be some way for the signal to enter and leave the amplifier. The process of transferring energy between circuits is known as COUPLING. There are various ways of coupling signals into and out of amplifier circuits. The following is a description of some of the more common methods of amplifier coupling.

Direct Coupling

The method of coupling that uses the least number of circuit elements and that is, perhaps, the easiest to understand is direct coupling. In direct coupling the output of one stage is connected directly to the input of the following stage. Figure 1-9 shows two direct-coupled transistor amplifiers.

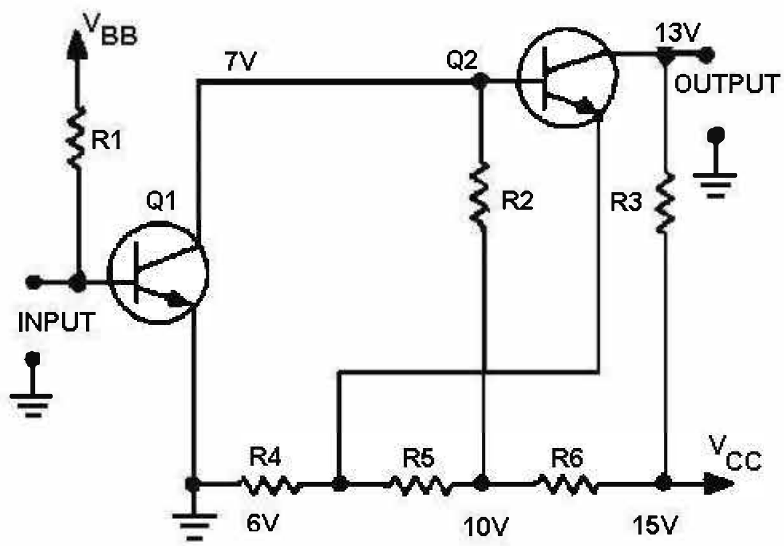


Figure 1-9.—Direct-coupled transistor amplifiers.

Notice that the output (collector) of Q1 is connected directly to the input (base) of Q2. The network of R4, R5, and R6 is a voltage divider used to provide the bias and operating voltages for Q1 and Q2. The entire circuit provides two stages of amplification.

Direct coupling provides a good frequency response since no frequency-sensitive components (inductors and capacitors) are used. The frequency response of a circuit using direct coupling is affected only by the amplifying device itself.

Direct coupling has several disadvantages, however. The major problem is the power supply requirements for direct-coupled amplifiers. Each succeeding stage requires a higher voltage. The load and voltage divider resistors use a large amount of power and the biasing can become very complicated. In addition, it is difficult to match the impedance from stage to stage with direct coupling. (Impedance matching is covered a little later in this chapter.)

The direct-coupled amplifier is not very efficient and the losses increase as the number of stages increase. Because of the disadvantages, direct coupling is not used very often.

RC Coupling

The most commonly used coupling in amplifiers is RC coupling. An RC-coupling network is shown in figure 1-10.

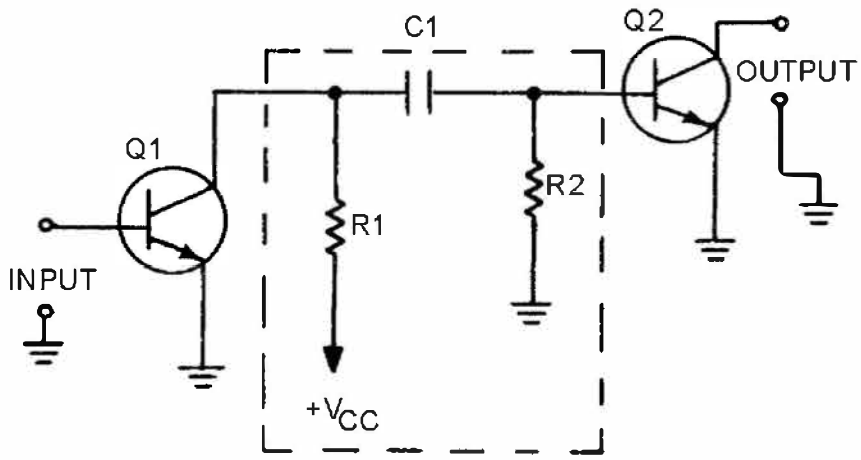


Figure 1-10.—RC-coupled transistor amplifier.

The network of R1, R2, and C1 enclosed in the dashed lines of the figure is the coupling network. You may notice that the circuitry for Q1 and Q2 is incomplete. That is intentional so that you can concentrate on the coupling network.

R1 acts as a load resistor for Q1 (the first stage) and develops the output signal of that stage. Do you remember how a capacitor reacts to ac and dc? The capacitor, C1, "blocks" the dc of Q1's collector, but "passes" the ac output signal. R2 develops this passed, or coupled, signal as the input signal to Q2 (the second stage). This arrangement allows the coupling of the signal while it isolates the biasing of each stage. This solves many of the problems associated with direct coupling.

RC coupling does have a few disadvantages. The resistors use dc power and so the amplifier has low efficiency. The capacitor tends to limit the low-frequency response of the amplifier and the amplifying device itself limits the high-frequency response. For audio amplifiers this is usually not a problem; techniques for overcoming these frequency limitations will be covered later in this module.

Before you move on to the next type of coupling, consider the capacitor in the RC coupling. You probably remember that capacitive reactance (X_C) is determined by the following formula:

$$X_C = \frac{1}{2\pi fC}$$

This explains why the low frequencies are limited by the capacitor. As frequency decreases, X_C increases. This causes more of the signal to be "lost" in the capacitor.

The formula for X_C also shows that the value of capacitance (C) should be relatively high so that capacitive reactance (X_C) can be kept as low as possible. So, when a capacitor is used as a coupling element, the capacitance should be relatively high so that it will couple the entire signal well and not reduce or distort the signal.

Impedance Coupling

Impedance coupling is very similar to RC coupling. The difference is the use of an impedance device (a coil) to replace the load resistor of the first stage.

Figure 1-11 shows an impedance-coupling network between two stages of amplification. L1 is the load for Q1 and develops the output signal of the first stage. Since the d.c. resistance of a coil is low, the efficiency of the amplifier stage is increased. The amount of signal developed in the output of the stage depends on the inductive reactance of L1. Remember the formula for inductive reactance:

$$X_L = 2\pi f L$$

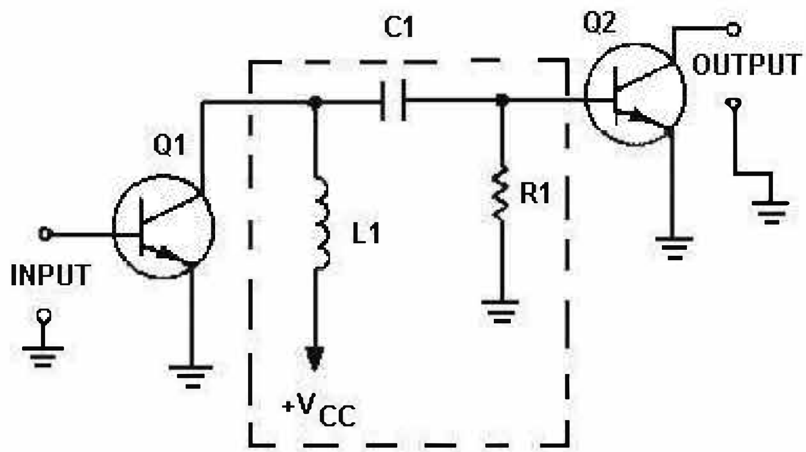


Figure 1-11.—Impedance-coupled transistor amplifier.

The formula shows that for inductive reactance to be large, either inductance or frequency or both must be high. Therefore, load inductors should have relatively large amounts of inductance and are most effective at high frequencies. This explains why impedance coupling is usually not used for audio amplifiers.

The rest of the coupling network (C1 and R1) functions just as their counterparts (C1 and R2) in the RC-coupling network. C1 couples the signal between stages while blocking the d.c. and R1 develops the input signal to the second stage (Q2).

Transformer Coupling

Figure 1-12 shows a transformer-coupling network between two stages of amplification. The transformer action of T1 couples the signal from the first stage to the second stage. In figure 1-12, the primary of T1 acts as the load for the first stage (Q1) and the secondary of T1 acts as the developing impedance for the second stage (Q2). No capacitor is needed because transformer action couples the signal between the primary and secondary of T1.

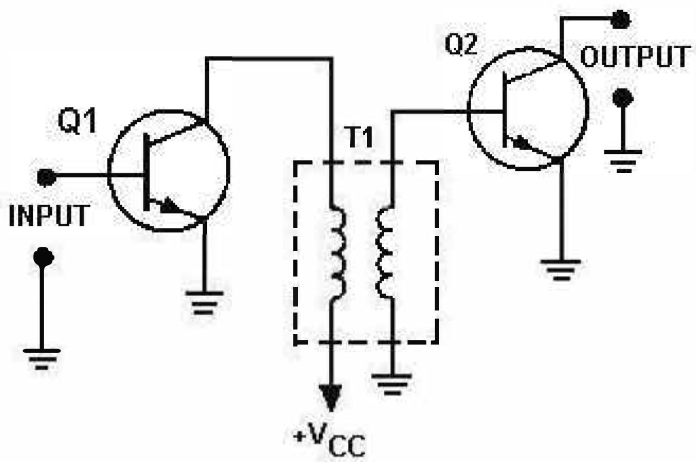


Figure 1-12.—Transformer-coupled transistor amplifier.

The inductors that make up the primary and secondary of the transformer have very little dc resistance, so the efficiency of the amplifiers is very high. Transformer coupling is very often used for the final output (between the final amplifier stage and the output device) because of the impedance-matching qualities of the transformer. The frequency response of transformer-coupled amplifiers is limited by the inductive reactance of the transformer just as it was limited in impedance coupling.

Q-12. What is the purpose of an amplifier-coupling network?

Q-13. What are four methods of coupling amplifier stages?

Q-14. What is the most common form of coupling?

Q-15. What type coupling is usually used to couple the output from a power amplifier?

Q-16. What type coupling would be most useful for an audio amplifier between the first and second stages?

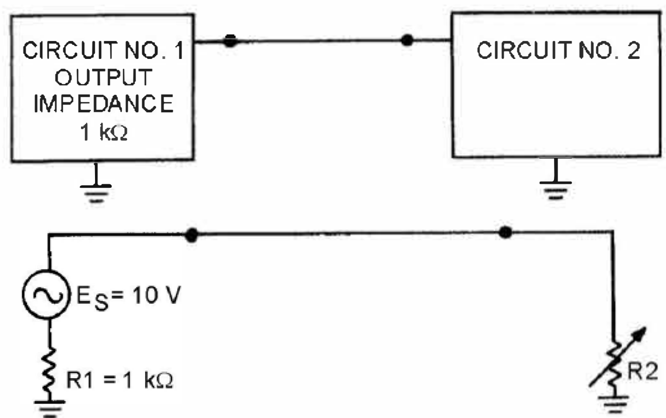
Q-17. What type of coupling is most effective at high frequencies?

IMPEDANCE CONSIDERATIONS FOR AMPLIFIERS

It has been mentioned that efficiency and impedance are important in amplifiers. The reasons for this may not be too clear. You have been shown that any amplifier is a current-control device. Now there are two other principles you should try to keep in mind. First, there is no such thing as "something for nothing" in electronics. That means every time you do something to a signal it costs something. It might mean a loss in fidelity to get high power. Some other compromise might also be made when a circuit is designed. Regardless of the compromise, every stage will require and use power. This brings up the second principle-do things as efficiently as possible. The improvement and design of electronic circuits is an attempt to do things as cheaply as possible, in terms of power, when all the other requirements (fidelity, power output, frequency range, etc.) have been met.

This brings us to efficiency. The most efficient device is the one that does the job with the least loss of power. One of the largest losses of power is caused by impedance differences between the output of one circuit and the input of the next circuit. Perhaps the best way to think of an impedance difference (mismatch) between circuits is to think of different-sized water pipes. If you try to connect a one-inch water pipe to a two-inch water pipe without an adapter you will lose water. You must use an adapter. A impedance-matching device is like that adapter. It allows the connection of two devices with different impedances without the loss of power.

Figure 1-13 shows two circuits connected together. Circuit number 1 can be considered as an a.c. source (E_S) whose output impedance is represented by a resistor (R1). It can be considered as an a.c. source because the output signal is an a.c. voltage and comes from circuit number 1 through the output impedance. The input impedance of circuit number 2 is represented by a resistor in series with the source. The resistance is shown as variable to show what will happen as the input impedance of circuit number 2 is changed.



R2	I	E_{R2}	P_{R1}	P_{R2}
100 Ω	9 mA	900 mV	82.6 mW	8.3 mW
200 Ω	8.3 mA	1.67 V	69.4 mW	13.9 mW
500 Ω	6.7 mA	3.33 V	44.4 mW	22.2 mW
1k Ω	5 mA	5 V	25 mW	25 mW
2k Ω	3.3 mA	6.67 V	11.1 mW	22.2 mW
5k Ω	1.7 mA	8.33 V	2.7 mW	13.9 mW
10k Ω	.9 mA	9.09 V	.9 mW	8.3 mW

Figure 1-13.—Effect of impedance matching in the coupling of two circuits.

The chart below the circuit shows the effect of a change in the input impedance of circuit number 2 (R2) on current (I), signal voltage developed at the input of circuit number 2 (E_{R2}), the power at the output of circuit number 1 (P_{R1}), and the power at the input to circuit number 2 (P_{R2}).

Two important facts are brought out in this chart. First, the power at the input to circuit number 2 is greatest when the impedances are equal (matched). The power is also equal at the output of circuit number 1 and the input of circuit number 2 when the impedance is matched. The second fact is that the largest voltage signal is developed at the input to circuit number 2 when its input impedance is much larger than the output impedance of circuit number 1. However, the power at the input of circuit number 2 is very low under these conditions. So you must decide what conditions you want in coupling two circuits together and select the components appropriately.

Two important points to remember about impedance matching are as follows. (1) Maximum power transfer requires matched impedance. (2) To get maximum voltage at the input of a circuit requires an intentional impedance mismatch with the circuit that is providing the input signal.

Impedance Characteristics of Amplifier Configurations

Now that you have seen the importance of impedance matching the stages in an electronic device, you may wonder what impedance characteristics an amplifier has. The input and output impedances of a transistor amplifier depend upon the configuration of the transistor. In *Module 7, Introduction to Solid-State Devices and Power Supplies*, you were introduced to the three transistor configurations; the common emitter, the common base, and the common collector. Examples of these configurations and their impedance characteristics are shown in figure 1-14.

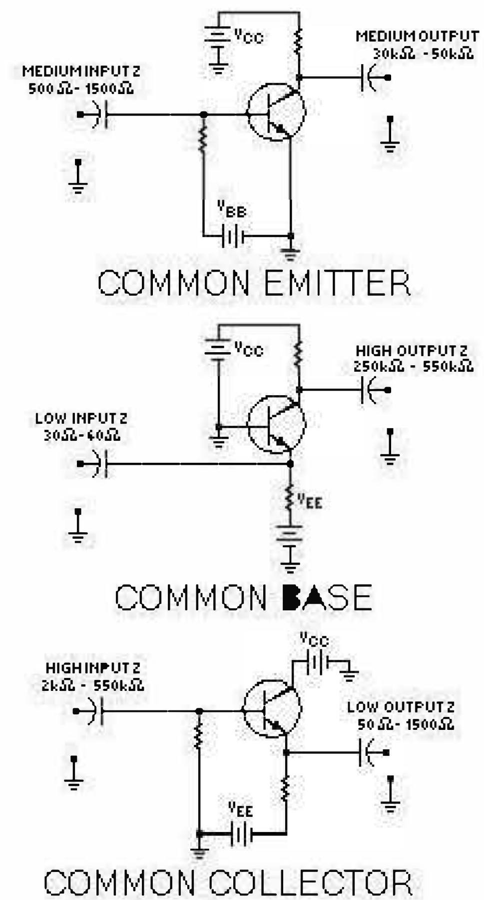


Figure 1-14.—Transistor amplifier configurations and their impedance characteristics.

NOTE: Only approximate impedance values are shown. This is because the exact impedance values will vary from circuit to circuit. The impedance of any particular circuit depends upon the device (transistor) and the other circuit components. The value of impedance can be computed by dividing the signal voltage by the signal current. Therefore:

$$\text{Input Signal Impedance} = \frac{\text{Input Signal Voltage}}{\text{Input Signal Current}}$$

and

$$\text{Output Signal Impedance} = \frac{\text{Output Signal Voltage}}{\text{Output Signal Current}}$$

The common-emitter configuration provides a medium input impedance and a medium output impedance. The common-base configuration provides a low input impedance and a high output impedance. The common-collector configuration provides a high input impedance and a low output impedance. The common-collector configuration is often used to provide impedance matching between a high output impedance and a low input impedance.

If the amplifier stage is transformer coupled, the turns ratio of the transformer can be selected to provide impedance matching. In *NEETS Module 2*, *Introduction to Alternating Current and Transformers,* you were shown the relationship between the turns ratio and the impedance ratio in a transformer. The relationship is expressed in the following formula:

$$\frac{N_P}{N_S} = \sqrt{\frac{Z_P}{Z_S}}$$

Where:

N_P = Number of turns in the primary
N_S = Number of turns in the secondary
Z_P = Impedance of the primary
Z_S = Impedance of the secondary

As you can see, impedance matching between stages can be accomplished by a combination of the amplifier configuration and the components used in the amplifier circuit.

Q-18. What impedance relationship between the output of one circuit and the input of another circuit will provide the maximum power transfer?

Q-19. If maximum current is desired at the input to a circuit, should the input impedance of that circuit be lower than, equal to, or higher than the output impedance of the previous stage?

Q-20. What are the input- and output-impedance characteristics of the three transistor configurations?

Q-21. What transistor circuit configuration should be used to match a high output impedance to a low input impedance?

Q-22. What type of coupling is most useful for impedance matching?