TRANSISTORS

Transistors are semiconductor devices that have three or more electrodes. The term *transistor* was derived from the words *transfer* and *resistor*. There are many different types of transistors with individual characteristics, but the basic theory of operation is the same for all of them. See figure 2-1 for a schematic symbol.

The *junction transistor* triode *(triode* meaning three electrodes) has three elements and two PN junctions. These three elements are:

1. The *emitter*, which gives off or *emits* current carriers (electrons or holes);

2. The *base*, which controls the flow of the current carriers; and

3. The *collector*, which collects the current carriers.

A metal lead or contact is attached to each element or section to allow the transistor to be connected to the external circuitry. Transistors are classed as PNP or NPN according to the arrangement of the N and P materials.

Transistors have two PN junctions. One PN junction is between the emitter and the base (called the *emitter-base* or *EB* junction); the other PN junction is between the collector and the base (called the *collector-base* or *CB* junction). Because the junction transistor has two PN junctions, it is sometimes called a *bipolar* device. One type of junction transistor is formed by introducing a thin region of P type material between two regions of N type material in a single crystal of germanium or silicon. The transistor so formed is called an *NPN* transistor. By introducing a thin region of N type material between two regions of P type material, a PNP transistor is formed.

TRANSISTOR BIASING

For normal operation of a transistor, the following rules apply:

1. The *emitter base* junction is normally *forward biased*. (See figure 2-2 for schematic symbol.)

2. The *collector base* junction is *reverse biased*. (See figure 2-3 for schematic symbol.)

CLASSIFICATION OF AMPLIFIERS

Amplifiers may be classified or grouped in a number of ways. The methods we will discuss are classification by *use*, *frequency range*, and *class of operation*.

Classification by Use

Amplifiers may be grouped in the way they are used in a circuit. Recall that the circuit, voltage, and power gains of an amplifier are dependent on several factors; namely, configuration, size of the load resistor, transistor type, etc. An amplifier designed to produce a large current gain is called a *current amplifier*, and one that provides a large voltage gain is called a *voltage amplifier*. A power amplifier is one which must deliver large amounts of output power. (See figure 2-4 and table 2-1.)

Classification by Frequency

An amplifier may be classified also be the range of frequencies it is capable of amplifying properly. A *DC amplifier* is one which is able to amplify DC (zero hertz) applied to its input. DC amplifiers are often found in oscilloscopes and computer circuits. An *audio amplifier*, as the name implies, operates in the audio range, which is about 15Hz to 20kHz.

Radio frequency amplifiers are operated in the radio frequency (RF) spectrum from about 10kHz to 300GHz or higher. RF amplifiers are commonly used in radio receivers and transmitters.

Lastly, the *video amplifier*, which is also called a *wide band amplifier*, can amplify all frequencies from a few hertz to several megahertz. They are used in television and radar systems.

Classification by Class of Operation

There are four classes of operation for amplifiers. They are *class A*, *class AB*, *class B*, and *class C*. The class of operation is determined by the amount of bias and the amplitude of the input signal.

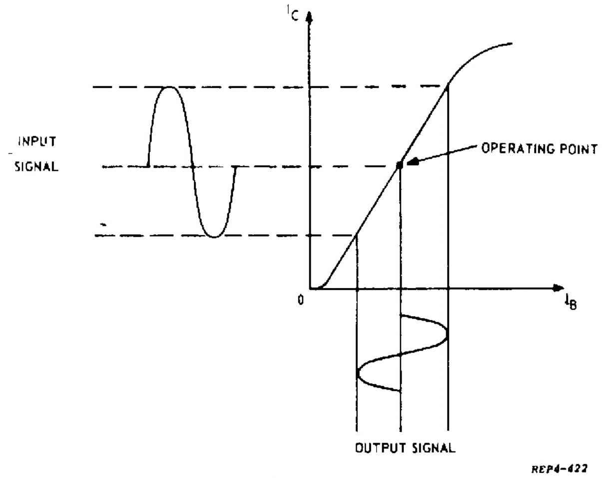

Figure 2-5. Class A Operation

CLASS A. These amplifiers operate within the linear portion of the collector characteristic curves. Figure 2-5 uses a transfer curve to illustrate class A operation. The initial operating point is established in the middle of the linear portion of the curve. The input signal will cause the base current to vary up and down along the curve. This will cause a corresponding change in collector current. For class A operation, the amplifier current never goes beyond the linear portion of the curve. The input signal will cause the base current to vary up and down along the curve. This will cause a corresponding change in collector current. For class A operation, the amplifier current never goes beyond the linear portion of the curve. This results in an output signal which is an exact replica of the input. Notice that collector current flow during 100 percent (or 360°) of the output cycle.

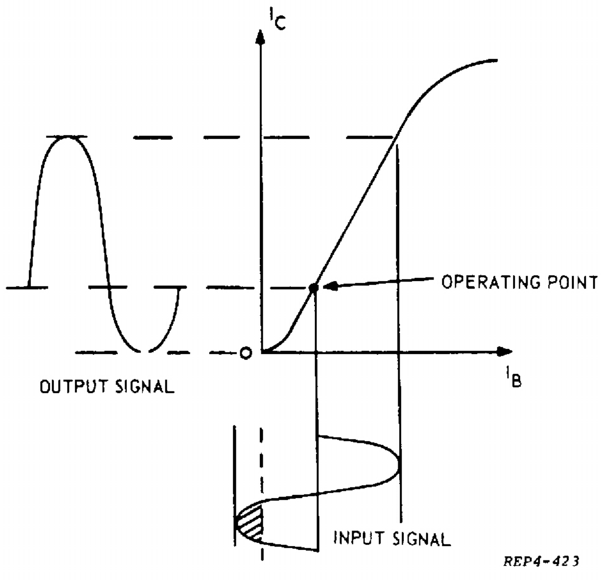

Figure 2-6. Class AB Operation

CLASS AB (Figure 2-6). An amplifier in which the input bias and alternating input signal are such that the output current flows for appreciably more than half, but not the entire, input signal cycle.

CLASS B AMPLIFIER (Figure 2-7). An amplifier in which the input bias is approximately equal to the cutoff value so that the output current is approximately zero when no input signal is applied and flows for approximately half of each cycle when an alternating input signal is applied.

CLASS C AMPLIFIER (Figure 2-8). An amplifier in which the input bias is appreciably greater than the cutoff value, so that the output current is zero when no alternating input signal is applied and flows for appreciably less than half of each cycle when an alternating input signal is applied.

Push-Pull Amplifier

Figure 2-9 shows a simplified schematic diagram of a transformer-coupled, class B, push-pull amplifier. This circuit can be identified by the fact that there is no forward bias network for the base-emitter junction. With no input signal, both transistors are cut off. Each transistor conducts when a positive polarity is felt on its base, on alternate half cycles of the input signal. A positive potential at the top of the T1 secondary causes Q1 to conduct but the negative potential, at the bottom of T1 secondary, holds Q2 cut off. The next alternation reverses the polarities so that Q1 is cut off and Q2 conducts. The output signals combine in output transformer T2.

Greater efficiency is obtained with class B push-pull because neither transistor conducts with no input signal, and no power is wasted.

Push-pull amplifiers will amplify the odd harmonics and cancel the amplification of the even harmonics.

Phase Splitters (Figure 2-10)

Driver stage is a term used to describe the amplifier which is used to supply the *driving* or input signal to the final, or power amplifier, stage. The push-pullpower amplifier input requires two signals equal in amplitude and opposite in phase. A driver stage that supplies two equal amplitude output signals, differing in phase by 180° from a single input is called a *phase splitter* or *phase inverter*.

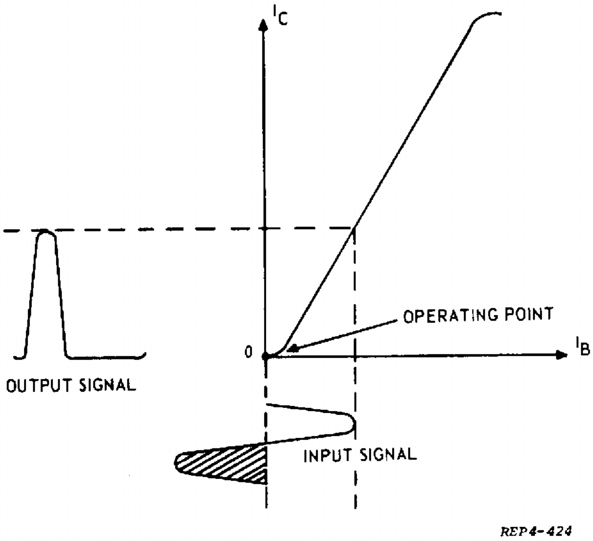

Figure 2-7. Class B Operation

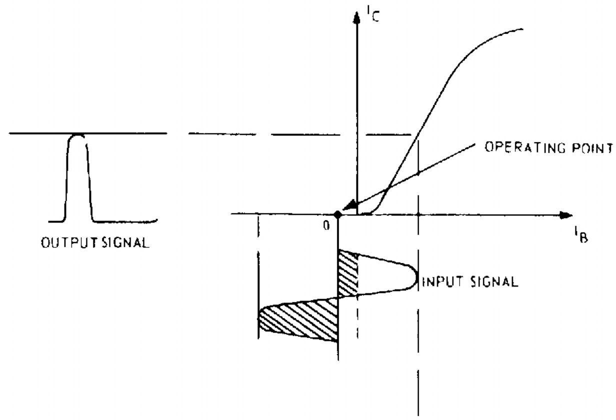

Figure 2-8. Class C Operation

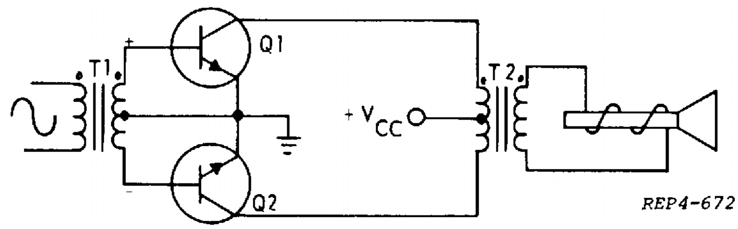

Figure 2-9. Class B Push-Pull Amplifier

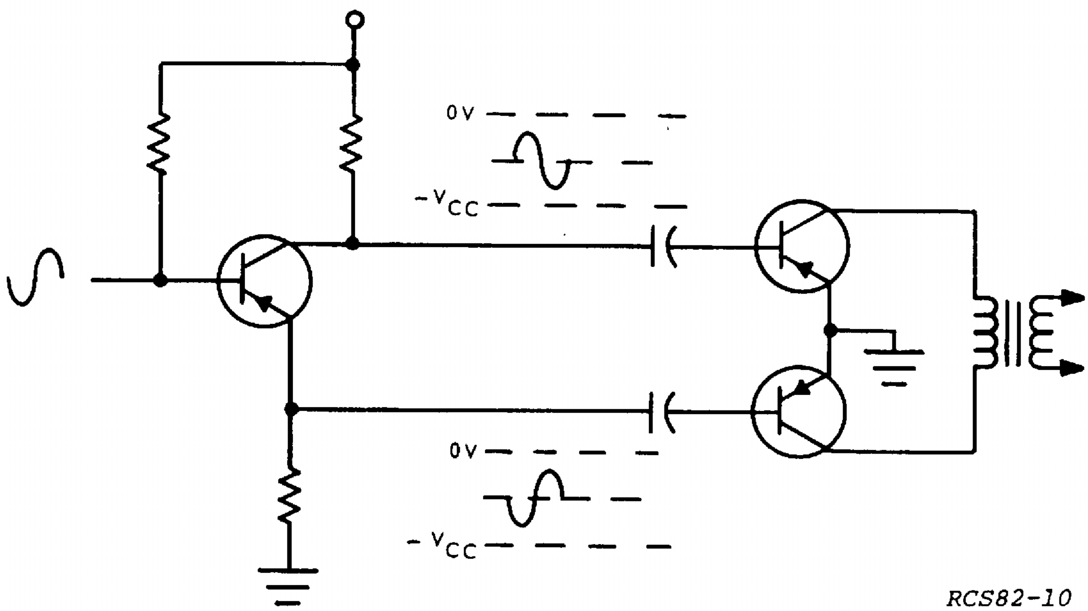

Figure 2-10. Phase Splitter

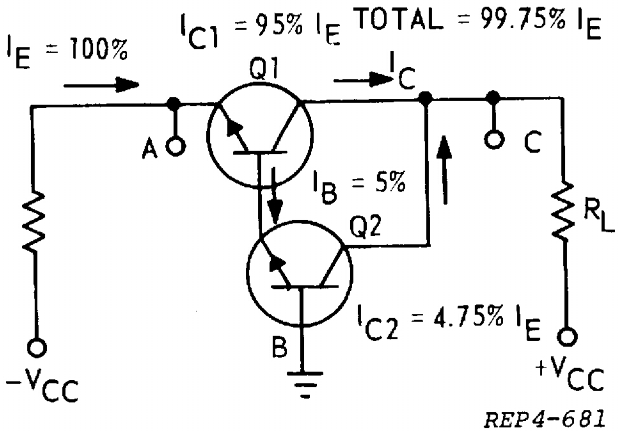

Figure 2-11. Compound-Connected Common Base

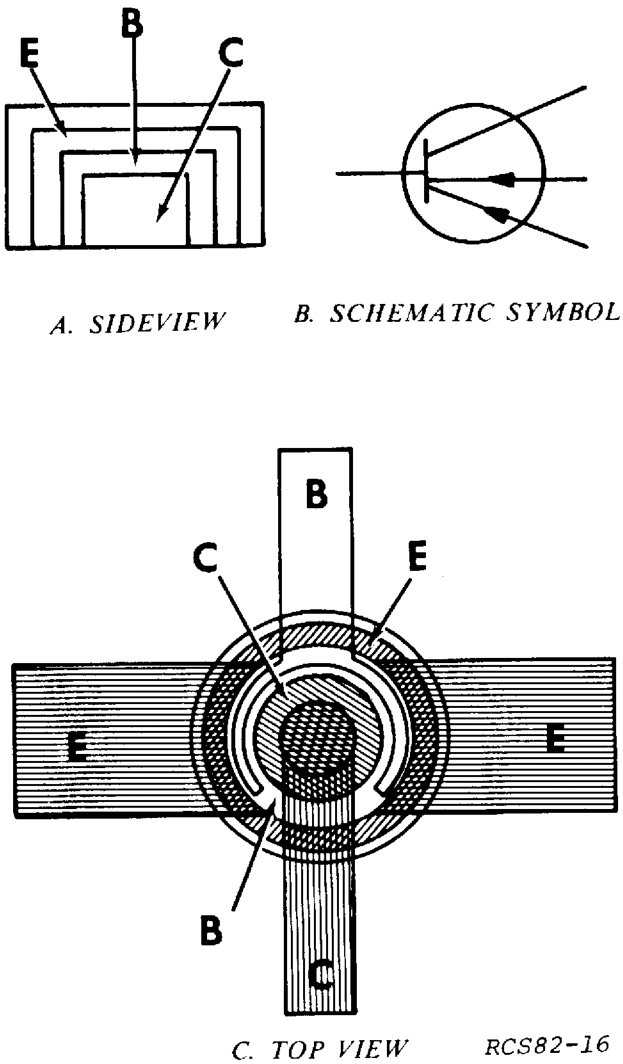

Figure 2-12. Fantail Transistor

Compound-Connected Amplifiers

The current, voltage, and power gains of a transistor amplifier are directly related to alpha; recall the forward current transfer ratio. This factor is the ratio of the outut current (IC) to the input current (IE); the higher the alpha, the higher the current gain of a transistor. A compound-connected amplifier is a circuit designed to increase alpha.

Figure 2-11 shows a compound-connected transistor circuit. Note that the base of transistor Q1 is connected to the emitter of transistor Q2 and that the two collectors are connected in the common-base configuration. The following computations show that *alpha* (that is, the ratio of the total collector current to input current) is greater than that of a single transistor.

For the circuit shown in figure 2-11, assume that alpha is equal to .95. The input current to transistor Q1 is designated IE. If only Q1 were used, the output current (IC) would be .95 times IE.

However, the collector current of Q1 and Q2 add together in the compound-connected circuit. Collector current of Q1 (IC1) is equal to .95 of IE (input). The base current of Q1 (IB) equals the emitter curent less the collector current, or .05 of IE. Since the base current of Q1 is the emitter input current of Q2, the collector current of Q2 is obtained by multiplying alpha (.95) times the emitter current of Q2 (.05). This gives a value of IC2 of .0475. The total current through RL (output current) is equal to the sum of the collector curents of Q1 and A2. So IC1 plus IC2 equals .95 plus .0475 or .9975. This represents an alpha of .9975.

The two compound-connected transistors (figure 2-11) can be considered as a single unit having an emitter (point *A*), a collector (point *C*), and a base (point *B*). The ratio of output current (IC) to input current IE is .9975. This is the forward current transfer ratio for the compound connection, and it represents an increase from a single unit which has an alpha .95.

Compound-connected transistors in a circuit of any configuration can, therefore, be considered as a single unit with a high forward current transfer ratio.

Fantail Trainsistor (Figure 2-12)

Two emitter leads reduce the interelement capacitance and inductance to allow for use of a larger physical size so that higher power can be obtained at a higher frequency.