STARTING POINT

by Robert Penfold

Introducing the fundamentals of electronics for the constructor.

Amplifying Modes

A transistor can be used in three modes of amplification, and these are the **common emitter, common collector** (popularly known as the **emitter follower**), and the **common base** modes. Results obtained in each case are quite different, and each mode of operation has applications where it is ideal, and others where it would be totally useless. We will consider each type of amplifier in turn, concentrating on the characteristics and uses of each type.

Common Emitter

The common emitter mode is certainly the most common mode of amplification, and the reason for this is simply that this type of amplifier has the most useful set of performance characteristics. Figure 1(a) shows the basic common emitter configuration and Figure 1(b) shows a simple common emitter configuration for use with AC signals. Incidentally, the name of this mode of amplification is derived from the fact that the emitter terminal of the transistor is common to both the input and output of the stage, whereas the other two terminals handle only one signal or the other. In other words, one side of the input and one side of the output connect to a common point (which is usually one of the supply rails), and the emitter of the transistor either connects direct to this rail, or is coupled to it in some way. The other two types of amplifier obtained their names in a similar way, but of course have different 'common' terminals.

If we consider the simple configuration of Figure 1(a), with no input applied to TR1 the device is cut off and virtually the full supply voltage is present at its collector. The collector will not be at the full positive supply voltage because a small leakage current will flow between the collector and emitter terminals of TR1, but using a modern silicon device this leakage current will be too low to be of significance in practice (usually only a fraction of a microamp).

If a steadily increasing voltage is applied to the input of the amplifier, TR1 will not start to conduct significantly between its collector and emitter terminals until the base-emitter voltage reaches about 0.6 volts. Raising the input voltage above this threshold level results in TR1 rapidly conducting more heavily and reaching saturation with a base-emitter voltage of only about 0.8 volts. The collector voltage at saturation depends on a number of factors, such as the collector current and particular type of transistor in use, but it is likely to be between about 20 millivolts and 1 volt, and increasing the base-emitter voltage further has no significant effect on this voltage once saturation has been reached.

This type of amplifier obviously gives good voltage gain since a change in input voltage of perhaps only a couple of hundred millivolts or less can give a change in output voltage of several volts or more (a voltage change practically equal to the supply voltage in fact). There is also current gain, of course, since bipolar transistors are current operated devices and providing current gain is their basic function.

A simple DC amplifier of this type is often used to drive loads such as a relay, indicator light, or loudspeaker, but in a practical design it is necessary to have either a resistor in series with the base of the transistor, or a drive circuit having only a limited current drive capability. Otherwise even quite a modest input voltage of (say) about one volt could drive a very high base current into TR1 and destroy the device.

AC Amplifier

In order to amplify an AC signal it is necessary to bias the transistor, and the simplest practical way of doing this is shown in the configuration of Figure 1(b). Applying an AC

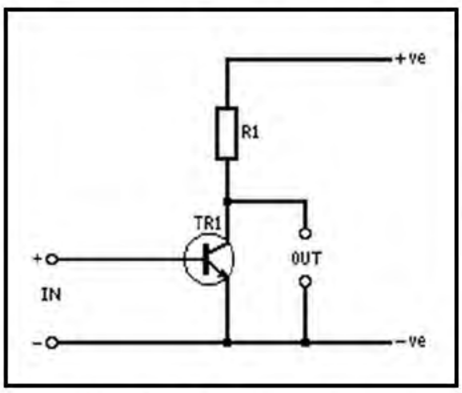

Figure 1(a). A simple DC common emitter stage.

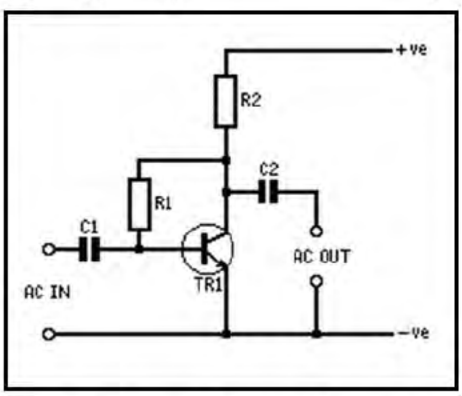

Figure 1(b). A simple AC common emitter stage.

input to the circuit of Figure 1(a) would not give satisfactory results as TR1 would only conduct during part of positive input half cycles, and not at all during negative input half cycles! This would obviously give an output signal that only vaguely resembled the input signal. In the circuit of Figure 1(b), R1 is used to bias TR1 into conduction under quiescent conditions, and ideally it should bring TR1 into a state of conduction that gives a collector voltage of half the supply voltage. C1 and C2 block steady DC signals from entering and leaving the circuit respectively, but varying input and output voltages are allowed to pass.

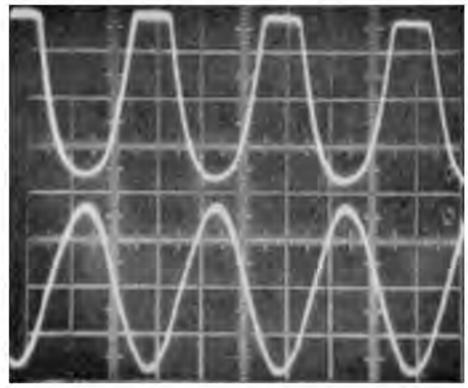

Figure 2(a). Half cycles being clipped.

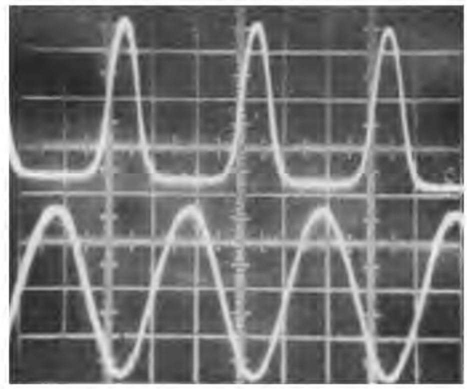

Figure 2(b). Half cycles being clipped.

An AC input signal takes the base of TR1 more positive and causes TR1 to conduct more heavily, with a consequent reduction in collector voltage. Negative input half cycles have the opposite effect with a consequent rise in the collector voltage of TR1. This gives an AC output from C2 that closely resembles the input signal, but the output is much higher in amplitude, and the current taken from the output can be much higher than that consumed at the input. Like the DC version, the circuit therefore gives good voltage, current, and power gain.

There is, of course, a limit to the maximum output voltage that can be provided by the circuit. The peak-to-peak output voltage can at best be marginally less than the supply voltage.

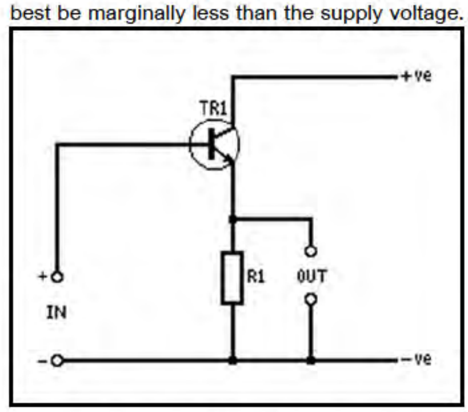

Figure 3(a). A simple DC emitter follower stage.

It can never equal the supply voltage because no practical transistor can achieve a collector voltage of zero when biased into saturation, and if an output current is drawn from the circuit (which would be the case in any practical situation) there must be a voltage drop through R2.

The point of biasing the collector of TR1 to about half the supply voltage is that this enables an output voltage swing which is virtually equal to the supply voltage to be achieved before the voltage at TR1's collector reaches its peak or minimum level. If TR1 was to be biased so that its quiescent collector voltage was only a small

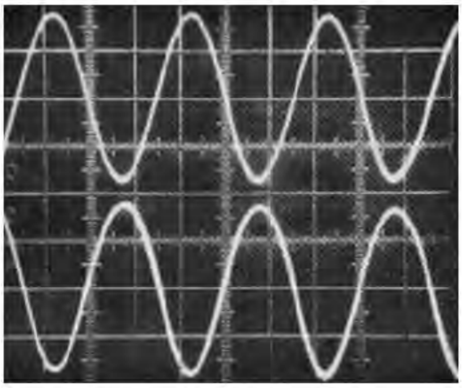

Figure 2(c). Unclipped output.

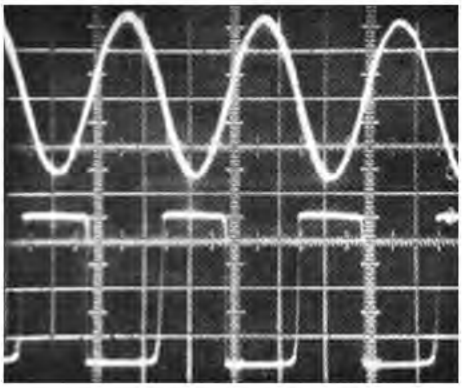

Figure 2(d). Symmetrical clipping

fraction of the supply voltage, then a negative output voltage swing of only very limited proportions would be achievable. Similarly, with TR1's collector biased to almost the positive supply potential only a small positive voltage swing would be possible before the maximum output voltage was reached.

If only a small output voltage swing is likely to occur this is not of great importance, but if the maximum peak-to-peak output level that is needed is a substantial fraction of the supply voltage it becomes essential to have good

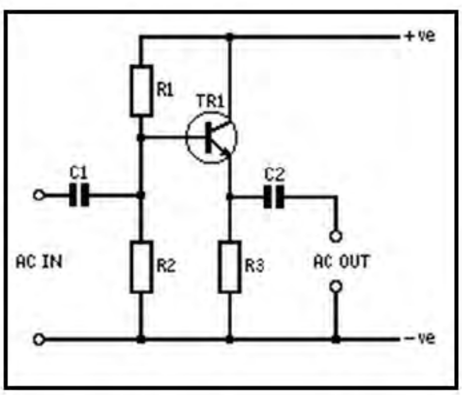

Figure 3(b). A simple AC emitter follower stage.

biasing or the transistor will become switched off or saturated during signal peaks of one polarity. This would result in one set of half cycles being clipped, as shown in Figure 2(a) and 2(b). Correct biasing gives an unclipped output, as shown in Figure 2(c).

Of course, even with ideal biasing it is still possible to overload the amplifier, and this gives symmetrical clipping, as shown in Figure 2(d). Even with the output below the clipping level the output signal is distorted to a certain extent, and no amplifiers are perfectly linear. The main cause of this distortion is the variations in the current gain of a transistor that occur as the collector current varies. A normal bipolar transistor has a level of current gain that increases as collector current increases, although the gain may well reduce somewhat at very high collector currents. These variations in gain are not usually sufficient to cause severe distortion, and are only really of significance in critical applications such as Hi-Fi equipment.

A point that is often of no practical importance, but can in some applications be crucial, is that the signal undergoes an inversion or 180 degree phase shift when it is processed by a common emitter amplifier. Thus a positive going input produces a negative going output, and vice versa.

COMMON EMITTER AMPLIFIER CHARACTERISTICS

High voltage current, and power gain.
Medium input and output impedance (typically several kilohms in each case).
Phase inversion through the circuit.

Common Collector Mode

Figure 3(a) shows the basic common collector (emitter follower) configuration, and Figure 3(b) shows an AC version. Although on the face of it neither of these configurations lives up to its name, with the collector terminal of the transistor being common to neither the input nor the output, this is not in fact the case. Any change in voltage relative to one supply rail will be an identical change in relation to the other supply rail since the two are a fixed potential apart. Thus, although the collector terminal of the transistor does not connect to the negative supply rail direct, it is effectively coupled to it via the supply source.

If we consider the DC version first, with a gradually increasing input voltage to the circuit the voltage across R1 will remain practically zero until the input reaches about 0.6 volts because TR1 will not turn on until this point. Taking the input voltage above this point causes the voltage across R1 to increase, and remain about 0.6 volts below the input voltage. In fact, the difference between the input and output potentials will increase somewhat as the input voltage is raised, due to the increase in the current flow through the collector-emitter terminals of TR1, and the increased base-emitter voltage that this demands.

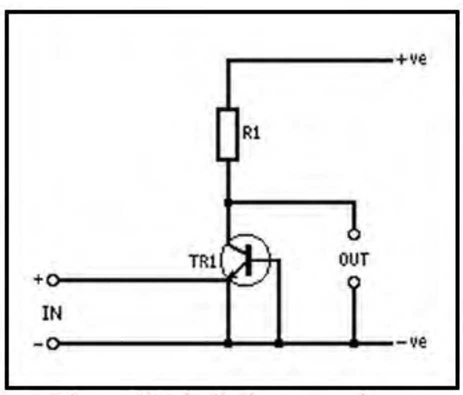

Figure 4(a). The basic common base configuration.

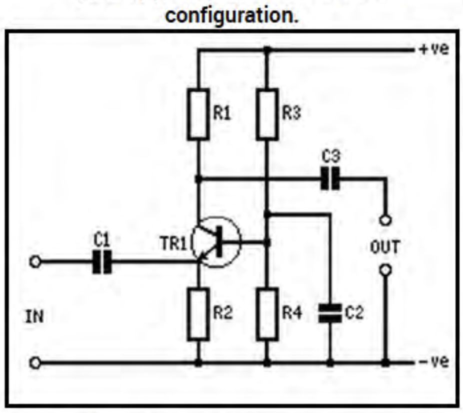

Figure 4(b). A simple AC common base amplifier.

This configuration obviously gives a voltage gain of less than unity, but it does give the full current gain of the transistor which could be quite high in practice. The input current needed to fully drive a common emitter amplifier and a comparable emitter follower stage are much the same since the output current required and the gain of the transistor will be identical. However, the input voltage needed to fully drive an emitter follower is much higher than that required by a common emitter stage, and the input impedance of an emitter follower is obviously comparatively high. This ability to match a high impedance signal source to a low impedance load makes the emitter follower a very useful electronic circuit which is frequently employed in practical designs.

In the AC version of the circuit R1 and R2 are used to bias the input of the amplifier to slightly more than half the supply potential so that quiescent output voltage is half the supply voltage. C1 and C2 are the input and output DC blocking capacitors.

EMITTER FOLLOWER AMPLIFIER CHARACTERISTICS

Less than unity voltage gain, but good current and power gain.
High input impedance and low output impedance.
No phase change through the circuit.

Common Base Mode

Common base amplifiers are not used a great deal, and do not have very useful characteristics. Figure 4(a) and Figure 4(b) show the basic DC and AC common base modes respectively.

In order to switch on TR1 in Figure 4(a), it is necessary to take the emitter about 0.6 volts negative, and then only a marginal increase in this signal is necessary in order to cause TR1 to saturate. Although this configuration seems in many ways similar to the common emitter mode, an important difference is that the output current flows through the input path of a common base circuit, but does not in the case of a common emitter circuit. This gives a common base stage a current gain of only about unity and a low input impedance. Provided load resistor R1 has a fairly high value, the circuit has a reasonably high voltage gain, but this gives the circuit a high output impedance.

In the AC version R3 and R4 supply a positive bias to the base of TR1, which is more convenient in practice than negative biasing the emitter, and has the same effect of biasing TR1 into conduction. The bias circuit is arranged to give a quiescent voltage of about half the supply voltage at the collector of TR1. C2 couples the base of TR1 to the negative supply rail at AC but does not affect the DC bias conditions. The biasing can only operate properly if there is a DC path from the emitter of TR1 to the negative supply, and this is provided by R2. C1 and C3 are the input and output coupling capacitors.

COMMON BASE AMPLIFIER CHARACTERISTICS

Good voltage gain, about unity current gain, and moderate power gain.
Low input impedance and high output impedance.
No phase change through the circuit.

The circuits shown in this article all use NPN transistors, but the configurations are the same using PNP devices with the only exception that all polarities are reversed.