Chapter 7

Audio Amplifiers

The audio amplifier employed in the radio receiver comprises one or more stages of amplification coupled to an output stage for matching and powering a loudspeaker. Much depends on the *output power* required. An output power of about 0·005 to 0·01 watts (5 to 10 milliwatts) is high enough to operate high impedance headphones; and about 0·05 to 0·1 watts (50 to 100 milliwatts) a very small loudspeaker. Larger speakers to a portable transistor radio may require 0·2 to 1 watt output. Output power for conventional domestic radios is in the order of 2 to 5 watts; and for H-Fi, about 10 watts upwards.

The primary requirement of an amplifier is to produce power amplification or *gain* of the *af* signal. At the same time it should do this with minimum *frequency distortion* and maximum *linearity. Frequency distortion* occurs when the amplification is not the same on all frequencies, thus the frequency components are not represented at their correct relative strength (some frequencies being emphasized and others depressed). *Linearity* refers to the true reproduction of the actual waveform of the signals.

Frequency distortion is related to the gain of the amplifier. Ideally the relationship between gain and frequency should be a straight, parallel line. In practice this is impossible to achieve over the whole *af* range. In particular there will be a marked loss of gain at each end of a frequency range, i.e. at the lower frequencies and the higher frequencies – Fig. 46.

Provided the rest of the curve is reasonably linear, the addition of a *tone control* will normally satisfy most listening requirements. When more exact reproduction is required as in Hi-Fi, frequency distortion, where present, can be compensated by equalization circuits. These aim at introducing compensation of an opposite nature to smooth out the frequency response curve.

The type of distortion produced by *non-linearity* is usually more

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noticeable, and therefore less acceptable. As a general rule, the greater the gain extracted from a single stage, the greater the degree of distortion. No practical amplifier has exactly linear characteristics, even at low gain, but non-linearity shows up increasingly with increasing gain. Basically, therefore, a large number of individual amplifier stages, all operating at low or moderate gain should give less overall linear distortion than one or two stages operating at high gain. In practice it is necessary to adopt a compromise solution based on arriving at an acceptable level of distortion in order to avoid an excessive number of separate stages. Additional stages can, in fact, introduce other troubles. In any case the question of distortion is not significant in the final output stage, where other forms of distortion can be present. Ultimately, too, the loudspeaker itself can be the main source of distortion in the whole system. It is a waste of effort to design an audio amplifier circuit with excellent linearity characteristics only to operate a poor quality loudspeaker from it. Conversely, a Hi-Fi quality loudspeaker cannot be expected to compensate for the distortion inherent with a poor quality audio amplifier.

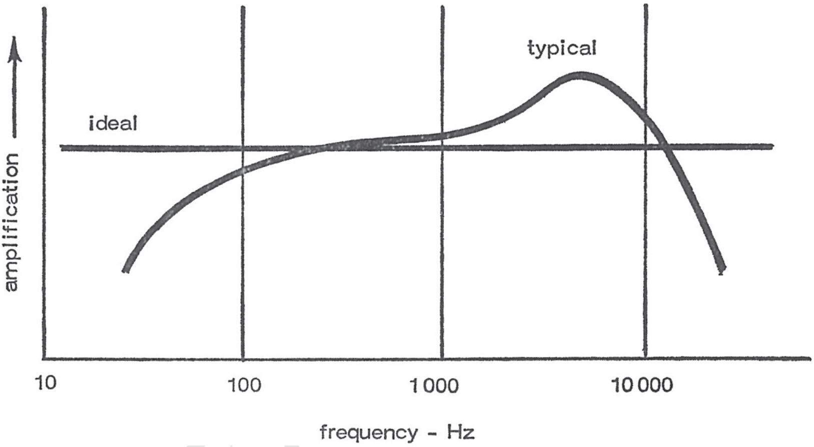

Fig. 46 Amplifiers do not amplify all frequencies by the same amount.

For this reason it is really necessary to design the audio amplifier

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'backwards', i.e. start with a selection of speakers and their requirements and work backwards to the first stage of amplification. This first demands some knowledge of the characteristics of amplifier circuits.

Class A Amplifiers

The simplest form of amplifier circuit is a single transistor with bias and input signal voltage such that the collector current always flows. This is known as Class A operation. It has the advantage of producing a low distortion as well as being simple to design and construct, but the disadvantage of drawing a relatively high current all the time.

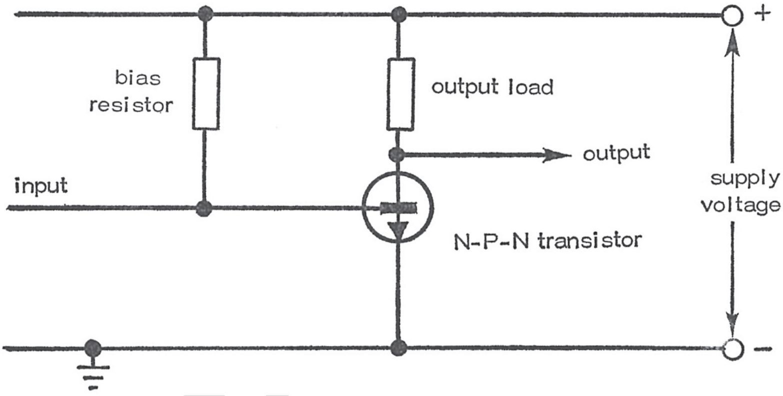

Fig. 47 Basic amplifier circuit using a silicon N-P-N transistor.

The simplest practical form of this type of circuit is shown in Fig. 47, using a single resistor to provide current biasing (*see* Chapter 6). The output load must be of relatively high impedance (several thousand ohms). This can be provided by a second transistor amplifier stage, or if used as an output stage by a step-down transformer to match the characteristically low impedance of a loudspeaker (4–16 ohms nominal) to the stage requirements. The same circuit can be used with a P-N-P transistor or an N-P-N transistor, the only requirement being that the supply voltage is opposite in polarity. Choice of an N-P-N transistor would be preferred as this type is more stable with simple current biasing using a single resistor.

It is more usual, and generally more desirable, to employ voltage

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biasing with emitter feedback, where the basic circuit is as shown in Fig. 48. Again the same type of load is used for the output, and the circuit is identical for a P-N-P transistor and an N-P-N transistor, with supply voltage polarity reversed. Values of suitable bias components can be determined from Chapter 6.

The *power-gain* which can be achieved from such a circuit depends on the transistor characteristics and the load. Transistor characteristics are given in the form of graphs of collector currents (I_C) plotted against collector voltage (V_C) for different values of bias (base current, or I_B). These curves typically take the form shown in Fig. 49 (*see also* Chapter 6).

The collector voltage is the supply voltage, which in theory can be any voltage up to the maximum rating specified from the transistor concerned. The collector current is largely determined by the load, and the bias by the working requirements (but *see also* Chapter 6 again).

The *power* that can be dissipated safely by a transistor is represented by the product of I_C and V_C, and is represented by a single value, i.e. so many watts. This can also be represented by a *load line* drawn on the graph. Any product of power *below* this curve is feasible to use (provided limiting values of either I_C or V_C are not exceeded). Any product of power *above* this line is not usable since it overloads the transistor – Fig. 50. Component values are therefore calculated accordingly.

Note: this also emphasizes that the maximum power rating of a transistor is not simply the product of I_C max and V_C max as it is sometimes supposedly taken to be. In other words it is *never permissible to apply both maximum* V_C *and maximum* I_C *to a transistor simultaneously as this will drastically overload it,* causing it to burn out.

A simple check on individual transistor characteristics will confirm this. For example for an OC84 transistor

$$V_c \text{ max} = 25 \text{ volts}$$
$$I_C \text{ max} = 500 \text{ mA}$$
$$\text{Power max} = 260 \text{ mW}$$

Erroneously employing V_C max with I_C max would give a power of $25 \times 500 = 12{,}500$ milliwatts – nearly 500 times the maximum power rating of the transistor!

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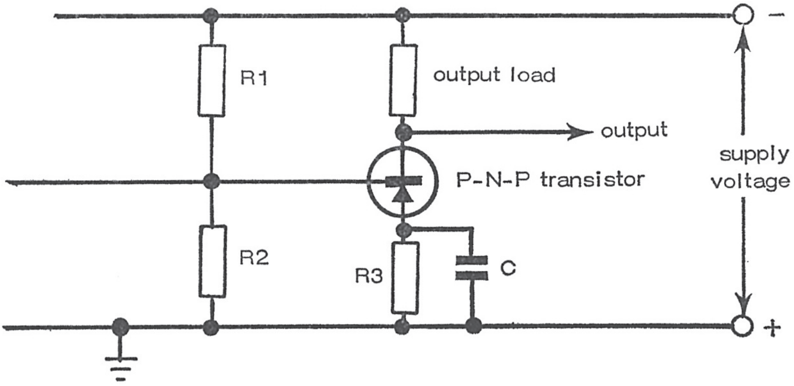

Fig. 48 Basic transistor amplifier with voltage bias provided by R1 and R2. R3 and C are stabilizing components. Polarity is shown for a P-N-P transistor.

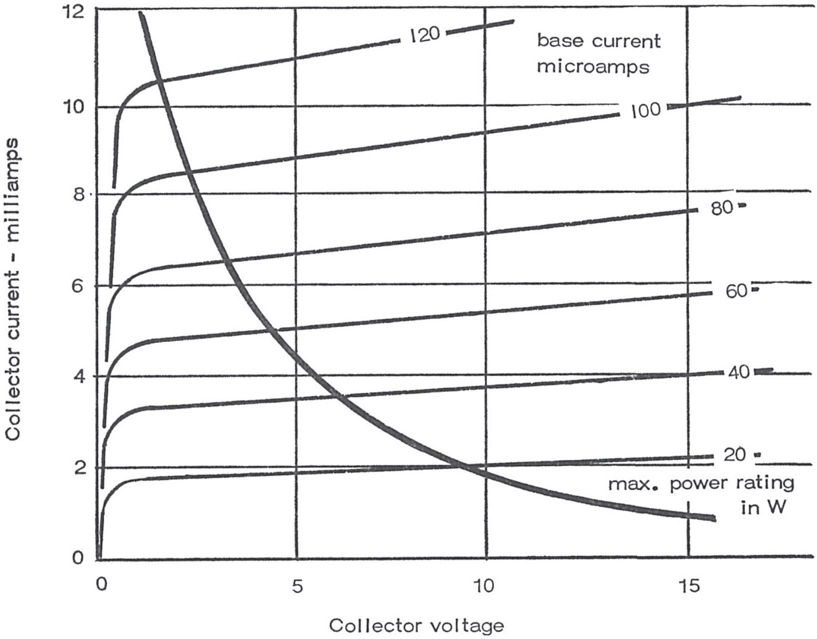

Fig. 49 Illustrating how maximum power rating of a transistor is related to collector current, collector voltage and base current in common emitter configuration.

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The ideal maximum efficiency that can be achieved with Class A operation is 50 per cent, although in practice it is usually substantially less in order to avoid too much distortion, i.e. the amplifier is best operated at well below maximum possible gain to avoid troubles.

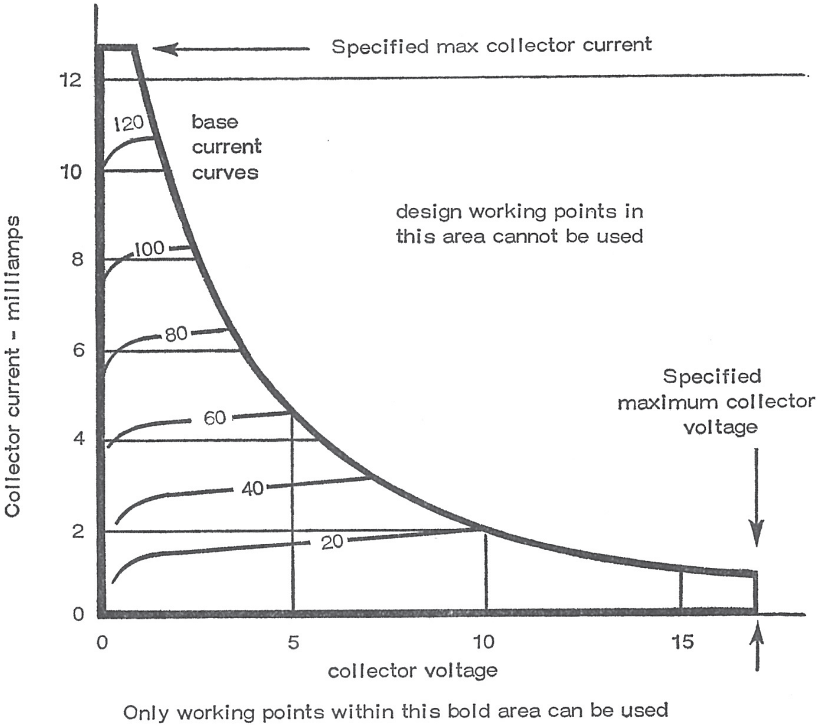

Fig. 50 Working envelope of a transistor as fixed by its power rating, maximum collector current and maximum collector voltage.

Amplifier circuits of this type can form the basis of amplifier stages connecting two or more circuits in series to derive the required amount of gain, whilst operating each stage under reasonably linear characteristics. Some simplification of circuitry is possible, rather than using complete voltage biasing circuits associated with each transistor. The output stage in a modern amplifier circuit, however, is normally a

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push-pull type operating as a class B amplifier. Push-pull circuits may also be used as a *driver* in multi-stage amplifiers.

Class B Amplifiers

The immediate advantage offered by a push-pull class B amplifier is that the output power obtained is considerably greater than double the power of a single transistor. Also the average current drain is very much lower than with Class A operation because the transistors are biased so that their working point is near cut-off and quiescent current is virtually zero. (Fig. 51 shows a 'working' diagram of Class B operating characteristics.)

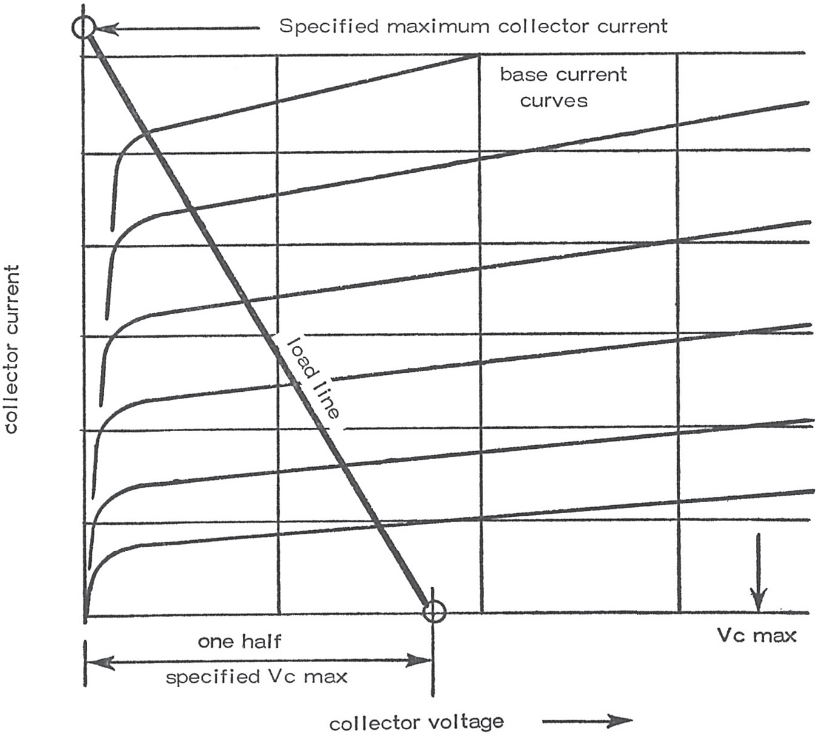

Fig. 51 Load line superimposed on transistor characteristics for a Class B amplifier.

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Apart from much lower current consumption, making it more suitable for battery operated circuits, the efficiency of a Class B output can approach 80 per cent. It does have its inherent limitations, however, and in particular a proneness to crossover distortion. This is distortion produced at the change-over point when working is transferred from one transistor to another (changing from 'push' to 'pull' and 'pull' to 'push').

Crossover distortion will be most marked if both transistors are biased exactly to cut-off. It can be overcome, or at least the residual distortion can be substantially reduced, by selecting the bias so that, one transistor does not cut-off until the other has stopped conducting i.e. there is a slight overlap at the changeover. Unfortunately the amount of overlap will tend to change both with the operating temperature of the transistors and any change in the supply voltage. Equally, differences in the spread of characteristics of different transistors of the same type can make design for optimum bias difficult or even impossible without further 'cut and try' adjustment of values. It is possible to incorporate compensating components in the circuit design to minimize the undesirable effects of temperature and characteristic spread. If necessary the supply voltage can also be stabilized (e.g. by means of a zener diode).

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A Practical Class B Circuit

A basic push-pull transformerless output circuit is shown in Fig. 52, using a complementary pair of transistors TR2 and TR3 and a driver transistor TR1. Bias quiescent voltage for TR2 and TR3 is set by the value of R1 (which can be a variable resistor) the value of which is less than R2. This second resistor acts to stabilize the bias supply. Additional very low value resistors inserted between the emitters of TR2 and TR3 and the connecting point to C2 will improve thermal stability. Alternatively, R1 could be paralleled with a thermistor.

Direct coupling of a transistor output to a low impedance load in this circuit may seem a direct contradiction of previous explanations of transistor characteristics (e.g. *see* Chapter 6). The difference in this case is that the transistors employed are power transistors which characteristically have a *low* output impedance and can thus be connected directly to a low impedance speaker without the need for an output transformer.

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