## SINGLE-STAGE AMPLIFIERS

Practical amplifier circuits usually require other components besides a valve or transistor. This Information Sheet explains why other components are necessary and summarises the characteristics of the most common single-stage amplifier circuits.

### D.C. CONDITIONS IN A TRANSISTOR STAGE

For a transistor to amplify without significant distortion the collector current with no signal applied (known as the standing collector current) must be set so that the collector voltage is at an intermediate value between the supply rails.

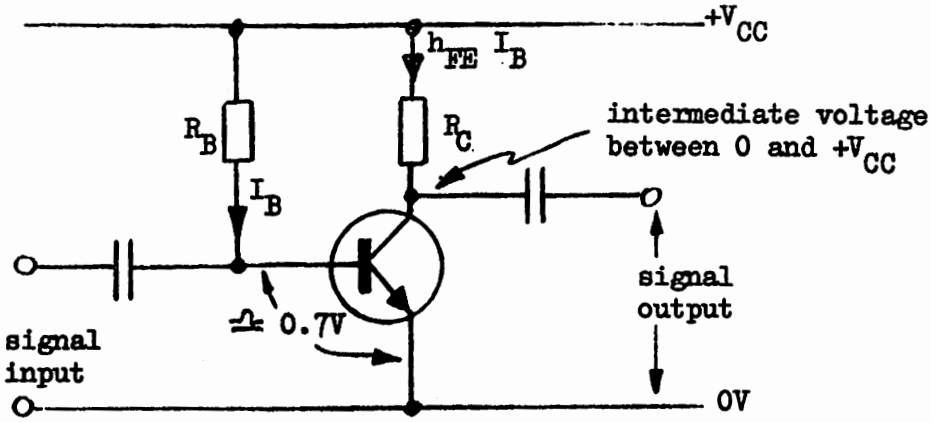


Fig. 1 : A simple transistor amplifier

The simplest way of achieving this is to connect a resistor $R_B$ as shown. This feeds a current $I_B$ into the base. The collector current is thus $h_{FE}\ I_B$, and this flows through $R_C$ giving a voltage drop across it. The resulting collector voltage thus depends upon the values of $R_C$, $R_B$ and $h_{FE}$.

The problem with this simple circuit is that the collector voltage depends on $h_{FE}$, the value of which can vary by $\pm$ 50% between transistors of the same type.

A better and much more common arrangement is shown in Figure 2. In this circuit the base voltage is set by $R_1$ and $R_2$ and the emitter voltage is set by $R_E$.

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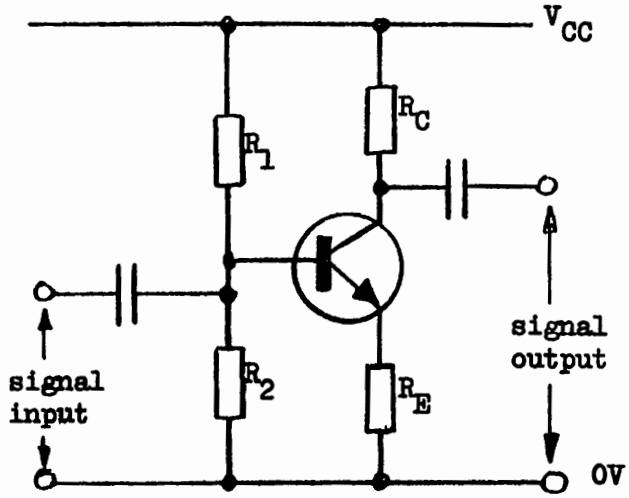


Fig. 2 : An improved transistor amplifier

This circuit uses more components than the previous one but has the advantage that the collector voltage depends only upon the resistor values and is almost entirely independent of the value of $h_{FE}$.

TYPICAL SMALL SIGNAL TRANSISTOR AMPLIFIER

The gain of the circuit of Figure 2 is $\frac{R_C}{R_E}$, i.e. typical values $R_C$ = 15 kΩ. $R_E$ = 1 kΩ gives a gain of 15.

The gain can be raised to $gmR_C$ by connecting a capacitor (typically 100 μF for an audio frequency amplifier) across $R_E$. Thus the complete circuit of the amplifier is shown in Figure 3 with typical component values.

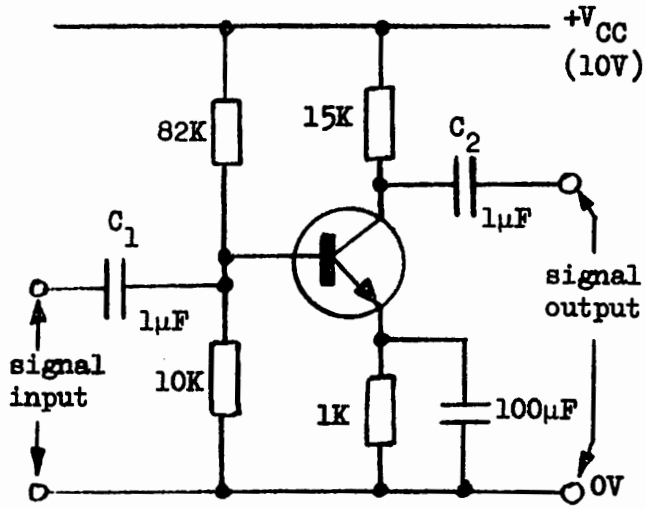


Fig. 3 : A practical transistor amplifier based on the circuit of Fig. 2

Capacitors $C_1$ and $C_2$ keep the d.c. voltages on the base and collector terminals away from the preceeding and following stages.

Input Impedance

The base-emitter junction of the amplifier shown in Figure 3 is forward biased and thus the input impedance is approximately the resistance of a forward biased diode - about 1 kΩ.

Output Impedance

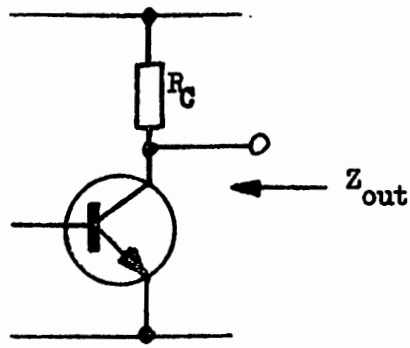


Fig. 4 : Output Impedance of Amplifier

The output impedance comprises $R_C$ in parallel with the effective resistance between the collector and each of the other electrodes.

The collector-base junction is always reverse-biased and so the collector-base and collector-emitter resistances are very high indeed.

The output resistance is thus effectively $R_C$.

OTHER CIRCUIT CONFIGURATIONS

In the circuit of Figure 3 the input signal is applied between the base and emitter and the output signal appears between the collector and emitter.

In other words the emitter is common to both the input and output circuits.

This type of amplifier is therefore often called a COMMON EMITTER amplifier.

THE COMMON BASE AMPLIFIER

The circuit of the common base amplifier is similar to that of the common emitter amplifier. The significant difference is that the signal input is applied to the emitter, i.e. the base terminal is common to the input and output circuit. For correct operation the base voltage must be prevented from varying at signal frequency. Capacitor $C_B$ ensures this by shunting a.c. signals at the base to earth.

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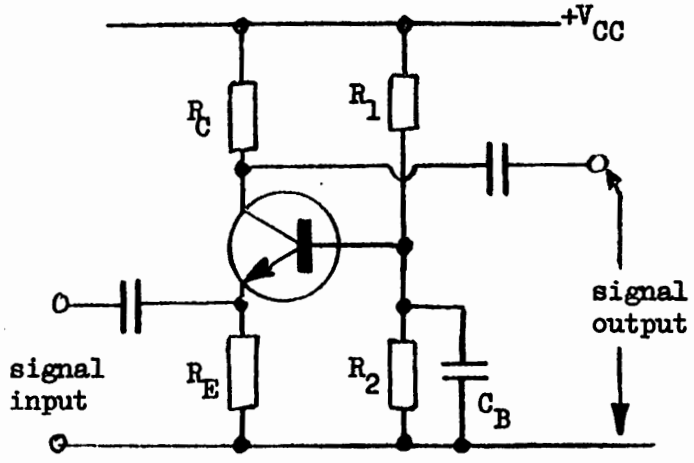


Fig. 5 : A Common Base Amplifier

Characteristics of the common base amplifier

The common base amplifier has a high voltage gain and a current gain of unity. It has a very low input impedance (typically 10 Ω). The output impedance is approximately $R_C$.

The common base amplifier is used mainly at VHF and UHF because, unlike the common emitter amplifier, its gain does not fall off at high frequencies. It is also sometimes used in video circuits if a stage with a very low input impedance is needed.

THE COMMON COLLECTOR AMPLIFIER (EMITTER FOLLOWER)

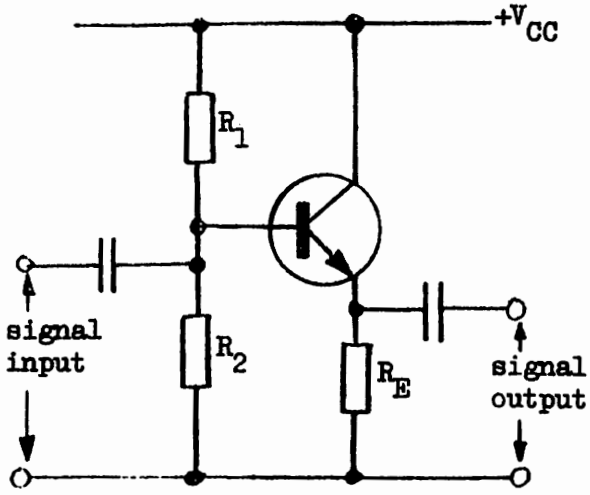


Fig. 6 : A Common Collector Amplifier

In this circuit there is no collector load resistor; the collector is connected directly to the $+V_{cc}$ rail and is thus the common electrode.

The input is applied to the base and the output is taken from the emitter.

Characteristics of the common collector amplifier

This circuit has a high current gain and a voltage gain of unity. It has a very high input impedance (typically 100 kΩ or more) and a very low output impedance (typically 20 Ω or less). It is therefore useful as a so-called 'buffer-stage' between one circuit with a high output impedance and another with a low input impedance. For example it could be used to accept a signal from a common emitter stage (which has a fairly high output impedance) and to drive a common base stage (which has a low input impedance).

TYPICAL VALVE CIRCUITS

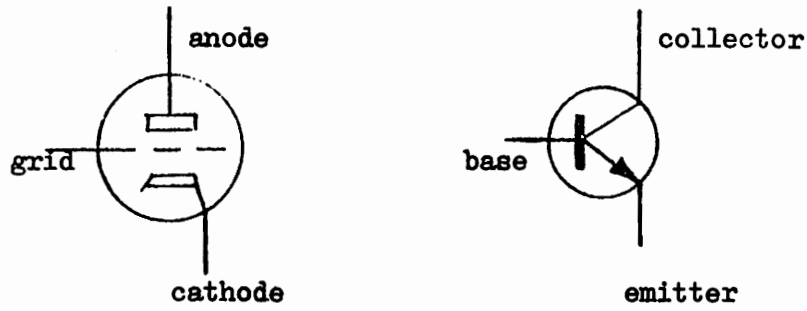


Fig. 7 : Similarity between electrodes of a valve and a transistor

The anode, grid and cathode electrodes of a triode valve correspond roughly with the collector, base and emitter electrodes of a transistor.

The operating principles of valves and transistors are, of course, very different. Nonetheless, direct equivalents of the common emitter, common base and common collector (emitter follower) can be constructed using valves, and their characteristics are essentially similar to the equivalent transistor circuits.

Power Supplies

Most valve circuits require a high-tension (H.T.) supply in the region of 200 - 300 volts. (Some large valves used in transmitters use much higher HT voltages than this). Valves also require a 'low tension' (L.T.) supply to operate the heaters. The voltage used is often 6.3 volts, but other LT voltages are used too.

The overall power consumed in a valve circuit is usually much more than that consumed in a transistor circuit doing the same job. This results

in a lower overall efficiency with valve circuits and also creates cooling and ventilation problems in areas where a lot of valve equipment is installed.

## THE COMMON CATHODE AMPLIFIER

This is roughly equivalent to the common emitter transistor amplifier and it is by far the most common form of valve amplifier.

A typical circuit is shown in Figure 8.

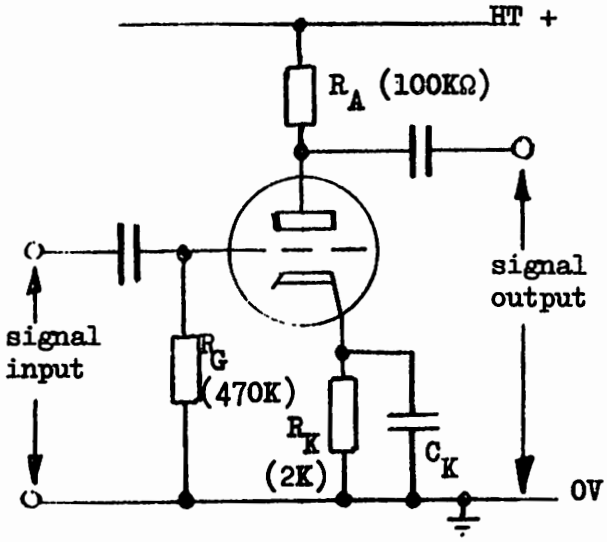


Fig. 8 : A Common Cathode Amplifier

For correct operation the grid must be biased negatively with respect to the cathode. This is achieved by the inclusion of $R_K$; the anode current flowing through this makes the cathode positive with respect to earth. $R_G$ keeps the grid at earth potential and hence the grid is negative with respect to the cathode.

### Input Impedance

The input impedance of a common cathode amplifier is very high; typically several megohms. The value of $R_G$ is usually around 0.5 megohms and so this effectively sets the input impedance.

### Output Impedance

The output impedance of a common cathode amplifier is $R_A$ in parallel with the anode resistance ($r_a$) of the valve. In the case of a triode $r_a$ may be comparable with $R_A$, and so must be taken into account. With pentodes $r_a$ is usually much higher than $R_A$ and the output impedance is approximately $R_A$.

THE COMMON GRID AMPLIFIER (also called the 'grounded grid' or 'earthed grid' amplifier)

Valve amplifiers other than common cathode stages are comparatively rare and the use of common grid stages is confined almost exclusively to very high frequencies. They are sometimes used as R.F. amplifiers in television receivers. Like the common base transistor amplifier they have the advantage that their gain does not fall off at high frequencies; this makes them ideal for VHF and UHF use.

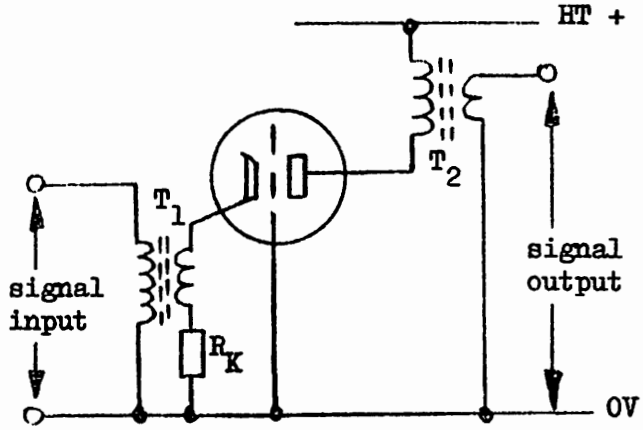


Fig. 9 : A Common Grid Amplifier for use at high radio frequencies

Transformer $T_1$ and $T_2$ are used to match the source and load devices to the low input and high output impedances of the stage. Often a circuit such as this is designed to operate only over a narrow band of frequencies, in which case the primaries of $T_1$ and $T_2$ may be tuned with parallel-connected capacitors.

THE COMMON ANODE (CATHODE FOLLOWER) AMPLIFIER

Like the emitter follower, the cathode follower has a very high input resistance and a low output resistance. A typical circuit is shown in Figure 10.

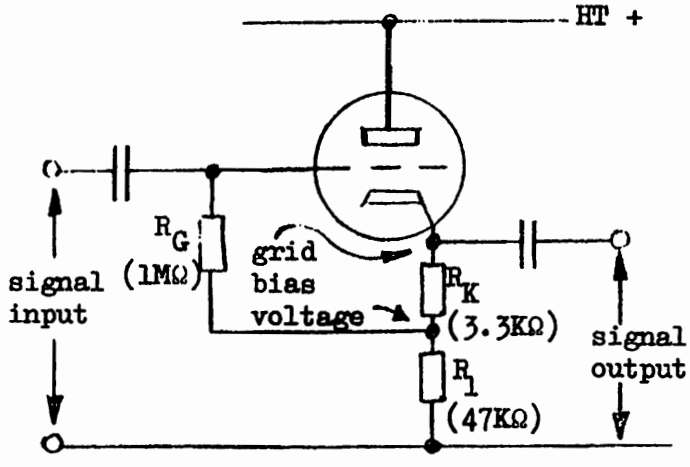


Fig. 10 : A Common Anode Amplifier

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Note that the grid resistor, $R_G$, is returned not to earth, but to the junction of $R_K$ and $R_1$. $R_K$ is the resistor across which the bias voltage is developed. The load resistor is $R_1$.

EXTRA CONSIDERATIONS WHEN USING PENTODES

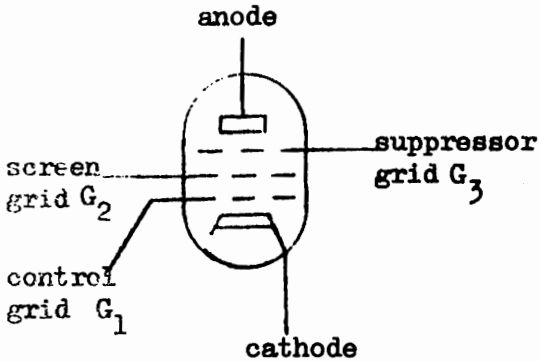


Fig. 11 : The Electrodes of a Pentode Valve

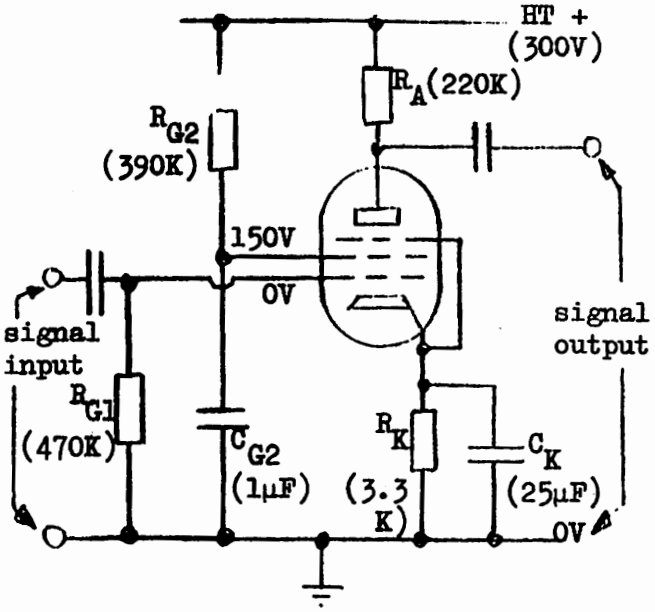


Fig. 12 : A Pentode used as an A.F. Amplifier

Figure 12 shows a typical pentode common cathode amplifier for use at audio frequencies. The control grid and cathode arrangements are exactly as for a triode.

The suppressor grid is usually connected either to the cathode or to earth. (In some valves it is internally connected to the cathode).

The screen grid must be maintained at a positive potential; usually close to the anode potential. This is achieved by resistor $R_{G2}$.

Capacitor $C_{G2}$ short-circuits any signal-frequency component on the screen grid to earth thus maintaining the screen grid at a steady d.c. potential.

## APPENDIX

Comparison of characteristics of common emitter, common base and common collector configurations.

| | Common Emitter | Common Base | Common Collector |
|---|---|---|---|
| Voltage Gain | high - typically 100 | high - typically 100 | unity |
| Current Gain | high - typically 100 | unity | high - typically 100 |
| Power Gain | high - typically 10,000 | medium - typically 100 | medium - typically 100 |
| Input Impedance | medium - typically 1k | low - typically 10Ω | high - typically 100k |
| Output Impedance | typically Rc | typically Rc | low - typically 20Ω |
| Signal Inversion | yes | no | no |

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