

Description

The invention relates to an amplifier arrangement, comprising:

- a first transistor having an emitter which is coupled to a first terminal for connection to a load which is coupled to a reference point, and having a collector which is coupled by means of a first semiconductor junction to a second terminal for a first supply voltage,
- a second transistor having a collector-emitter path which is arranged in series with the collector-emitter path of the first transistor, and having a collector which is coupled to a third terminal for a second supply voltage which is higher than the first supply voltage, and
- a third transistor arranged as an emitter-follower and having a base for receiving an input signal and having an emitter which is coupled to the base of the first transistor.

The invention also relates to a push-pull amplifier equipped with such an amplifier arrangement.

Such an amplifier arrangement of the class-G type may be employed as a power amplifier for audio signals. A class-G amplifier is to be understood to mean amplifier in which the effective supply voltage increases in a number of steps depending on the input signal. This results in an amplifier having a high efficiency.

Such an amplifier arrangement is disclosed in United States Patent Specification 3,961,280. In this known arrangement the input signal is applied to the bases of the first transistor and the second transistor via a third transistor arranged as an emitter follower. For low input voltages the second transistor is cut off, so that the first transistor is connected to the first supply voltage. If the input voltage becomes a higher than the first supply voltage, the second transistor is turned on, so that the first supply voltage is disconnected and the first transistor is connected to the second supply voltage.

When the second transistor does not conduct, the voltage across the base-emitter junction of this transistor is at the most equal to substantially the full first supply voltage. In order to preclude breakdown of the base-emitter junction as the result of this voltage, a diode is arranged in the base line of the second transistor. In order to prevent the first transistor from being bottomed and thereby producing distortion when the second transistor is not yet fully conductive, two series-connected diodes are arranged in the base line of the first transistor.

However, a drawback of these diodes is that they limit the swing of the output signal and, consequently, the efficiency of the amplifier arrangement. For the maximum output the voltage on the base of the third transistor is substantially equal to the second supply voltage. The voltage on the output is then equal to the second supply voltage minus the sum of the base-emitter voltage of the first transistor and the third transistor and the diode voltage across the two diodes arranged in the base line of the first transistor.

It is the object of the invention to provide a class-G-type amplifier arrangement which has an improved output-voltage swing in comparison with the known arrangement. In accordance with the invention an amplifier arrangement of the type defined in the opening paragraph is characterized in that

- the third transistor is of a conductivity type opposite to that of the first transistor and the second transistor and its emitter is coupled to the third terminal by means of a first current source,
- a first current path is arranged between the third terminal and an electrode of the third transistor which carries the input signal, which first current path comprises the series arrangement of at least a second current source, the emitter-collector path of a fourth transistor of the same conductivity type as the third transistor, and a second semiconductor junction,
- the emitter of the fourth transistor is coupled to the base of the second transistor,
- a second current path is arranged between the junction point of the first and second transistors and the reference point and comprises the series arrangement of a third semiconductor junction, a fourth semiconductor junction and a third current source,
- a point between the collector of the fourth transistor and the second semiconductor junction is connected to the third current source by means of a fifth semiconductor junction, and
- the base of the fourth transistor is connected to a point between the third semiconductor junction and the fourth semiconductor junction.

With such an amplifier arrangement it is possible to drive the output to a voltage equal to the second supply voltage minus the sum of one base-emitter voltage and two saturation voltages, which yields a substantially improved output voltage swing and hence a substantially improved efficiency. The amplifier arrangement also has the advantage that it can be fully integrated.

In an amplifier arrangement in accordance with the invention, the first transistor and the second transistor are each preferably constituted by a Darlington pair. The maximum output voltage swing is then one base-emitter voltage lower than in the case of single first and second transistors. In this case the maximum output voltage swing can be increased by one base-emitter voltage by bootstrapping. In accordance with a further embodiment the amplifier arrangement may then be characterized in that the first current source and the second current source are connected to the third terminal by means of a first resistor and the first terminal is connected to that end of the first resistor which is not connected to the third terminal by means of a capacitor. This embodiment may be characterized in that the first current source and the second current source are constituted by a second resistor and a third resistor, respectively.

An amplifier arrangement in accordance with a further embodiment of the invention may be characterized in that the second semiconductor junction is the emitter-base junction of a sixth transistor

arranged as an emitter follower. This preclude the occurrence of distortion as a result of the sudden decrease in input resistance of the arrangement when the second transistor is turned on.

An amplifier arrangement in accordance with the invention is very suitable for use in a push-pull amplifier which comprises two complementary amplifier arrangements in which the emitters of the complementary first transistors are connected to a common first terminal for connection to a common load. This push-pull amplifier may be characterized further in that the third current sources of the two complementary amplifier arrangements are commoned to form one common current source and in that the collectors of the third transistors are coupled to the common first terminal.

Embodiments of the invention will now be described in more detail, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is the basic diagram of an amplifier arrangement in accordance with the invention,

Figure 2 shows a modification of the arrangement of Figure 1,

Figure 3 shows an extended version of the amplifier arrangement of Figure 1,

Figure 4 shows a push-pull amplifier in accordance with a first embodiment of the invention,

Figure 5 shows a push-pull amplifier in accordance with a second embodiment of the invention,

Figure 6 shows a push-pull amplifier in accordance with a third embodiment of the invention, and

Figure 7 shows a push-pull amplifier in accordance with a fourth embodiment of the invention.

Figure 1 shows the basic diagram of an amplifier arrangement in accordance with the invention. The arrangement comprises a first NPN transistor T_1 , whose emitter is connected to the output 2 to which a load R_L is connected. By means of a diode D_1 the collector of the transistor T_1 is connected to a terminal 4 for a first supply voltage V_1 . The collector-emitter path of a second NPN transistor T_2 is arranged in series with the collector-emitter path of the transistor T_1 and the collector of this transistor T_2 is connected to a terminal 10 for a second supply voltage V_2 which is higher than the first supply voltage V_1 . The base of the transistor T_1 is connected to the emitter of a PNP transistor T_3 , arranged as an emitter follower. The emitter of this transistor is connected to the terminal 10 for the supply voltage V_2 by means of a first current source 5 supplying a current I_1 . The current source 5 comprises a PNP transistor T_5 whose base is at a reference voltage V_R . The collector of the transistor T_5 is connected to the terminal 11 which is common to the first supply voltage V_1 and the second supply voltage V_2 . The input signal V_i is applied to the base 6 of the transistor T_3 . A first current path is arranged between the terminal 10 for the supply voltage V_2 and the emitter of the transistor T_3 and comprises the series arrangement of a second current source 7, the emitter-collector path of a PNP transistor T_6 and a diode D_4 , which current source supplies a current I_2 and comprises a PNP transistor T_4 whose base is at the reference voltage V_R . The emitter of the transistor T_6 is connected to the base of the transistor T_2 . A second current path is arranged between the junction point 3 between the transistor T_1 and the transistor T_2 and the common terminal 11 and comprises the series arrangement of a diode D_2 , a diode D_3 and a current source 8. The current I_3 carried by this current source is smaller than the current I_2 supplied by the current source 7. The base of the transistor T_6 is connected to the junction point 9 between the diodes D_2 and D_3 and its collector is connected to the current source 8 by means of a diode D_5 .

The arrangement operates as follows. For low input voltages V_i the transistor T_3 receives the current I_1 from the current source 5 directly and the current I_2 from the current source 7 via the collector-emitter path of the transistor T_6 and the diode D_4 . If the base current of the transistor T_6 is ignored the current I_3 carried by the current source 8 is furnished by the first power supply voltage V_1 via the diodes D_1 , D_2 and D_3 . In this situation the diode D_5 is cut off. The voltage between the base and the emitter of the transistor T_2 is substantially 0 V, because this voltage is equal to the difference between the base-emitter voltage of the transistor T_6 and the voltage across the diode D_2 . Consequently, the transistor T_2 is cut off, so that for low input voltages the collector of the transistor T_1 is connected to the power supply voltage V_1 via the diode D_1 . The input signal V_i is applied to the base of the transistor T_1 via the emitter-follower transistor T_3 . This input signal V_i also appears on the anode of the diode D_5 . The voltage on the cathode of the diode D_5 is three diode voltages lower than the supply voltage V_1 . Therefore, the diode D_5 is turned on for a specific input voltage V_i . A part of the input voltage V_i then appears on the cathode of the diode D_2 . As the input voltage V_i increases further the diode D_2 will become less conductive, so that the current for the current source 8 through the diode D_3 decreases and that through the diode D_5 increases. Above a specific input voltage the diode D_2 is turned off, so that substantially the entire current I_3 flows through the diode D_5 . Then only the base current of the transistor T_6 flows through the diode D_3 . The voltage on the base of the transistor T_2 follows the voltage V_i via the base-emitter junction of the transistor T_6 , the diodes D_3 , D_5 and D_4 , and the base-emitter junction of the transistor T_3 . As this input voltage increases further the transistor T_2 is therefore turned on, so that the voltage on the junction point 3 is also increases. At a specific input voltage the diode D_1 is cut off, so that the collector of the transistor T_1 is connected to the high supply voltage V_2 via the collector-emitter path of the transistor T_2 . As the input voltage V_i increases further the transistor T_4 will be bottomed, so that the voltage on the base of the transistor T_2 cannot increase any further. Subsequently, the transistor T_1 is bottomed and the diode D_4 is cut off. The entire current I_1 from the current source 5 then flows into the base of the transistor T_1 , so that there is no current in the transistor T_3 .

The maximum output voltage is then reached. The voltage V_o on the output 2 is now equal to:

$$V_{OMAX} = V_2 - (V_{CEST4} + V_{BET2} + V_{CEST1}) \quad (1)$$

where

V_{CEST4} = the collector-emitter voltage of the transistor T_4 during saturation,

V_{CEST1} = the collector-emitter voltage of the transistor T_1 during saturation,

and

V_{BET2} = the base-emitter voltage of the transistor T_2 .

As the voltage V_{CEST4} and V_{CEST1} are substantially 100 mV, it follows from the above equation that the output 2 can be driven to the value of the second supply voltage V_2 minus substantially one base-emitter voltage (≈ 0.6 V). As a result of this large output voltage swing the amplifier arrangement has a high efficiency.

Figure 2 is a modification of the arrangement shown in Figure 1, in which identical parts bear the same reference numerals as in Figure 1. During the change-over from the first supply voltage V_1 to the second supply voltage V_2 the voltage between the collector and the base of the transistor T_1 in the arrangement shown in Figure 1 is equal to one diode voltage, namely the sum of the voltages across the diodes D_4 , D_5 , D_3 and the base-emitter junctions of the transistors T_5 and T_2 . This means that during change-over to the second supply voltage V_2 the first transistor T_1 is not yet driven into full conduction. In the embodiment shown in Figure 2, the diode D_4 is replaced by the base-emitter junction of a transistor T_{30} , which has its emitter connected to the collector of the transistor T_5 , its base to the base of the transistor T_3 , and its collector to the common terminal 11. During the change-over from the first supply voltage V_1 to the second supply voltage V_2 a voltage of zero volts appears between the collector and the base of the transistor T_1 , so that changing over is effected at the instant at which the transistor T_1 will be saturated. As a result of this, the transistor T_1 is driven over the entire range of the first supply voltage V_1 , which leads to an increased efficiency. Otherwise, the operation and the output voltage swing of the arrangement are the same as for the arrangement shown in Figure 1.

The principle of two supply voltages as explained with reference to Figure 1 and 2 may be extended to an arbitrary number of supply voltages. Figure 3 shows an amplifier arrangement with three supply voltages, in which identical parts bear the same reference numerals as in Figure 1. A transistor T_{21} has its collector-emitter path connected in series with the collector-emitter path of the transistor T_2 and has its collector connected to a third supply voltage V_3 . The collector of the transistor T_2 is now connected to the second supply voltage V_2 via a diode D_{21} and the current source 7 is connected to the third supply voltage V_3 . The driver circuit for the transistor T_{21} is of the same type as that for the transistor T_2 . A current source 27 supplying a current I_{20} is arranged between the third power supply voltage V_3 and the base of the transistor T_{21} . This current source 27 comprises a transistor T_{24} , whose base is at a reference voltage V_R . The base of the transistor T_{21} is connected to the base of the transistor T_2 by the series arrangement of the emitter-collector path of a transistor T_{25} and a diode D_{24} . The series arrangement of two diodes D_{22} , D_{23} and a current source 28 carrying a current I_{23} is arranged between the junction point 33 between the emitter of the transistor T_{21} and the collector of the transistor T_2 and the common terminal 11. The base of the transistor T_{25} is connected to the junction point 29 between the diode D_{22} and the diode D_{23} and the collector of the transistor T_{25} is connected to the current source 28 by means of a diode D_{25} .

The operation of the circuit arrangement can be explained very simply by means of the principle described with reference to Figure 1. For low input voltages V_1 the transistor T_1 is coupled to the first supply voltage V_1 . The transistors T_2 and T_{21} and the diodes D_5 and D_{25} are cut off. The current I_{20} from the current source 27 flows to the emitter of the transistor T_5 via the emitter-collector path of the transistor T_{25} and the diode D_{24} and further to the emitter of the transistor T_3 via the emitter-collector path of the transistor T_5 and the diode D_4 . The current I_{23} carried by the current source 28 is derived from the supply voltage V_2 via the diodes D_{23} , D_{22} and D_{21} . At increasing input voltages V_1 the transistor T_2 is driven into conduction and the first supply voltage V_1 is disconnected, as described with reference to Figure 1. At a further increase the transistor T_2 is driven further into conduction. Above a specific input voltage V_1 the diode D_{25} is turned on. As a result of this, the transistor T_{21} is turned on and the diode D_{22} is turned off, so that above a specific input voltage the second supply voltage V_2 is disconnected and the collector of the transistor T_1 is coupled to the third supply voltage V_3 . As the input voltage V_1 increases further the transistor T_{24} is bottomed. The voltage on the base of the transistor T_{21} then cannot increase any further. If the input voltage V_1 increases even further, the diode D_{24} is cut off, after which the transistor T_2 is bottomed, in which situation the voltage on the base of the transistor T_2 can increase until the transistor T_4 is bottomed. Subsequently, the diode D_4 is cut off and the transistor T_1 is saturated. As a result of this, there is no current in the transistor T_3 , so that the maximum output voltage is reached. The maximum voltage V_0 on the output 2 is then equal to:

$$V_{0MAX} = V_3 - (V_{CEST24} + V_{BET21} + V_{CEST2} + V_{CEST1}) \quad (2)$$

where

V_{CEST24} = the collector-emitter voltage of the transistor T_{24} in the case of saturation.

It is to be noted that in the present embodiment the diode D_4 may be connected to the collector of the transistor T_5 instead of to the emitter. As a result of this, the changeover from the second supply voltage V_2 to the third supply voltage V_3 is effected at the instant at which the transistor T_2 is saturated, so that the transistor T_2 is driven to an optimum extent.

The amplifier arrangement in accordance with the invention is very suitable for use in a push-pull

amplifier, of which Figure 4 shows a first embodiment. The push-pull amplifier comprises an input stage, which in the present embodiment has its simplest form and comprises two transistors T_{11} and T_{12} arranged as a differential pair, whose common emitter terminal is connected to the positive second supply voltage $+V_2$ by means of a current source comprising a transistor T_{10} whose base is at a reference voltage V_R . The input signal V_{in} of the push-pull amplifier is applied between the bases of the transistors T_{11} and T_{12} . The collector of the transistor T_{12} is connected directly to the output of the input stage and the collector of the transistor T_{11} is connected to the said output by means of a current mirror comprising the transistors T_{13} and T_{14} , which output is connected to the input of a Miller stage. In the present example, this Miller stage comprises a transistor T_{15} , whose emitter is connected to the negative supply voltage $-V_2$. A frequency compensation capacitor C_1 is arranged between the collector and the emitter of this transistor T_{15} . The collector of the transistor T_{15} is connected to the positive supply voltage $+V_2$ by the series arrangement of two diodes D_6 and D_7 and a current source comprising the transistor T_9 , whose base is at a reference voltage V_R . The output stage comprises two complementary circuits, which are each substantially identical to the circuit arrangement shown in Figure 1. Therefore, identical parts bear the same reference numerals as in Figure 1, the complementary parts being denoted by primes. The arrangement differs from that shown in Figure 1 with respect to the following points. The transistor T_2 and the transistor T_8 are arranged as a Darlington pair, a resistor R_1 being arranged between the base and the emitter of the transistor T_2 to provide a rapid turn-off of the Darlington pair. A resistor or a diode may be arranged between the base and the emitter of the transistor T_8 for protection purposes, and in the case of a diode its forward direction should be opposite to that of the base-emitter junction of the transistor T_8 . Similarly, the transistor T_1 forms a Darlington pair with a transistor T_7 . The emitters of the complementary output transistor T_1 and T_1' are connected to the common output 2, to which the load R_L is connected. A resistor R_2 arranged between the emitters of the transistors T_7 and T_7' has the same function as the resistor R_1 . The current source 8 is a current source which is common to the two complementary circuits.

The collectors of the transistors T_3 and T_3' are interconnected and are also connected to the output 2. It is to be noted that the collectors of the transistors T_3 and T_3' may alternatively be connected to the emitter of the transistor T_7' and the emitter of the transistor T_7 , respectively or, if resistors having low resistance values are arranged in the emitter lines of the transistors T_1 and T_1' , to the emitter of the transistor T_1' and the emitter of the transistor T_1 , respectively. The output signal of the Miller stage is applied to the bases of the transistors T_3 and T_3' . The diodes D_6 and D_7 , between the bases of the transistors T_3 and T_3' provide a class-AB bias for the output stage. The push-pull principle is known *per se* and is therefore not explained here. Since the transistor T_2 and the transistor T_8 are arranged as a Darlington pair, the maximum output voltage swing is now equal to:

$$V_{OMAX} = +V_2 - (V_{CEST4} + V_{BET8} + V_{BET2} + V_{CEST1}) \quad (3)$$

Consequently, the maximum output voltage is one base-emitter voltage lower than for the arrangement in Figure 1. The minimum output voltage lies equally far above the negative supply voltage $-V_2$ as the maximum output voltage lies below the positive supply voltage $+V_2$.

A second example of a push-pull amplifier in accordance with the invention is described with reference to Figure 5. For simplicity only the output stage, which is relevant to the invention, is shown, and identical parts bear the same reference numerals as in Figure 4. The emitters of the transistors T_4 and T_6 are connected to the terminal 10 for the supply voltage $+V_2$ by means of a resistor R_3 . A capacitor C_2 is arranged between the output 2 and the end 15 of the resistor R_3 which is not connected to the terminal 10. By means of the capacitor C_2 the output signal is bootstrapped, so that the voltage on the collectors of the transistors T_4 and T_6 can be raised above the supply voltage $+V_2$. As far as the operation of the arrangement is concerned this results in the transistor T_8 instead of the transistor T_4 being saturated when the transistors T_8 and T_2 are turned on as a result of an increasing input signal. The collector of the transistor T_8 is now connected to the supply voltage $+V_2$, whilst as a result of bootstrapping the base of the transistor T_8 can be driven beyond this supply voltage. Therefore, the maximum output voltage becomes equal to:

$$V_{OMAX} = V_2 - (V_{CEST8} + V_{BET2} + V_{CEST1}) \quad (4)$$

where

V_{CEST8} = the collector-emitter voltage of the transistor T_8 in the case of saturation.

Bootstrapping results in an increase of the maximum output voltage swing of the arrangement by one base-emitter voltage. It is to be noted that in the present embodiment the current-source transistor T_{10} of the input stage (see Figure 4) is connected directly to the positive second supply voltage $+V_2$ and that the emitters of the transistor T_{13} , T_{14} and T_{15} are connected directly to the negative supply voltage $-V_2$.

A third embodiment of a push-pull amplifier is described with reference to Figure 6, in which identical parts bear the same reference numerals as in Figure 5. In the present invention the current-source transistors T_4 and T_6 are replaced by a resistor R_4 and a resistor R_5 , respectively. As a result of bootstrapping the same signal voltage appears on the base of the transistor T_8 and on the cathode of the diode D_4 as on point 15. Consequently, a constant voltage is obtained across these resistors, so that the resistors R_4 and R_5 again operate as current sources.

- Figure 7 shows a push-pull amplifier in accordance with the fourth embodiment of the invention, and identical parts bear the same reference numerals as in Figure 6. This embodiment differs from that shown in Figure 6 in that the diode D_5 is replaced by an emitter-follower transistor T_{16} , whose emitter is connected to the collector of the transistor T_5 , whose collector is connected to the negative supply voltage $-V_2$, and whose base is connected to the emitter of the transistor T_3 . When in the embodiment shown in Fig. 4 the transistors T_8 , T_2 are turned on the resistance at the emitter of the transistor T_3 decreases suddenly because the resistance which is seen at the base of the transistor T_8 is connected in parallel with the resistance which is seen at the base of the transistor T_7 . This results in a sudden decrease of the input resistance of the arrangement, which leads to distortion of the input signal. By replacing the diodes D_5 by a transistor T_{16} , the resistance which is connected in parallel with the input resistance of the transistor T_7 when the transistors T_8 , T_2 are turned on is increased by a factor equal to the current-gain factor of the transistor T_{16} . Thus, when the transistors T_8 , T_2 are turned on the decrease in the input resistance of the transistor T_3 is substantially smaller, so that the resulting distortion is also reduced substantially. It is to be noted that the emitter-follower transistor T_{16} may also be used in the embodiments shown in Figure 1, 2 and 3.
- The invention is not limited to the embodiments shown. Within the scope of the invention many modifications are obvious to those skilled in the art. For example, the diodes in the present embodiments may be replaced by diode-connected transistors. Further, all or some of the bipolar transistors in the arrangement may be replaced by MOS transistors, in which case "emitter", "collector" and "base" should read: "source", "drain" and "gate", respectively.
- Finally, it is to be noted that the embodiments shown in Figures 4, 5, 6 and 7 may also be equipped with the amplifier arrangement shown in Figure 3.

Claims

1. An amplifier arrangement, comprising:
 - a first transistor having an emitter which is coupled to a first terminal for connection to a load which is coupled to a reference point, and having a collector which is coupled by means of a first semiconductor junction to a second terminal for a first supply voltage
 - a second transistor having a collector-emitter path which is arranged in series with the collector-emitter path of the first transistor, and having a collector which is coupled to a third terminal for a second supply voltage which is higher than the first supply voltage, and
 - a third transistor arranged as an emitter-follower and having a base for receiving an input signal and having an emitter which is coupled to the base of the first transistor, characterized in that
 - the third transistor is of a conductivity type opposite to that of the first transistor and the second transistor and its emitter is coupled to the third terminal by means of a first current source,
 - a first current path is arranged between the third terminal and an electrode of the third transistor which carries the input signal, which first current path comprises the series arrangement of at least a second current source, the emitter-collector path of a fourth transistor of the same conductivity type as the third transistor, and a second semiconductor junction,
 - the emitter of the fourth transistor is coupled to the base of the second transistor,
 - a second current path is arranged between the junction point of the first and second transistors and the reference point and comprises the series arrangement of a third semiconductor junction, a fourth semiconductor junction and a third current source,
 - a point between the collector of the fourth transistor and the second semiconductor junction is connected to the third current source by means of a fifth semiconductor junction, and
 - the base of the fourth transistor is connected to a point between the third semiconductor junction and the fourth semiconductor junction.
2. An amplifier arrangement as claimed in Claim 1, characterized in that the second semiconductor junction is coupled to the emitter of the third transistor.
3. An amplifier arrangement as claimed in Claim 1, characterized in that the second semiconductor junction is the base-emitter junction of a fifth transistor of the same conductivity type as the third transistor, whose base is connected to the base of the third transistor and whose emitter is coupled to the collector of the fourth transistor.
4. An amplifier arrangement as claimed in Claim 1 or 2, characterized in that the first transistor and the second transistor are each constituted by a Darlington pair.
5. An amplifier arrangement as claimed in Claim 1, 2, 3 or 4, characterized in that the first current source and the second current source are connected to the third terminal by means of a first resistor and the first terminal is connected, by means of a capacitor, to that end of the first resistor which is not connected to the third terminal.
6. An amplifier arrangement as claimed in Claim 5, characterized in that the first current source and the second current source are constituted by a second resistor and a third resistor, respectively.
7. An amplifier arrangement as claimed in Claim 1, 2, 4, 5 or 6, characterized in that the second semiconductor junction is the emitter-base junction of a further transistor arranged as an emitter follower.
8. A push-pull amplifier, characterized in that it comprises two complementary amplifier arrangements as claimed in any one of the preceding Claims, in which the emitters of the complementary first transistors

- Figure 7 shows a push-pull amplifier in accordance with the fourth embodiment of the invention, and identical parts bear the same reference numerals as in Figure 6. This embodiment differs from that shown in Figure 6 in that the diode D_5 is replaced by an emitter-follower transistor T_{16} , whose emitter is connected to the collector of the transistor T_5 , whose collector is connected to the negative supply voltage $-V_2$, and whose base is connected to the emitter of the transistor T_3 . When in the embodiment shown in Fig. 4 the transistors T_8, T_2 are turned on the resistance at the emitter of the transistor T_3 decreases suddenly because the resistance which is seen at the base of the transistor T_8 is connected in parallel with the resistance which is seen at the base of the transistor T_7 . This results in a sudden decrease of the input resistance of the arrangement, which leads to distortion of the input signal. By replacing the diodes D_5 by a transistor T_{16} , the resistance which is connected in parallel with the input resistance of the transistor T_7 when the transistors T_8, T_2 are turned on is increased by a factor equal to the current-gain factor of the transistor T_{16} . Thus, when the transistors T_8, T_2 are turned on the decrease in the input resistance of the transistor T_3 is substantially smaller, so that the resulting distortion is also reduced substantially. It is to be noted that the emitter-follower transistor T_{16} may also be used in the embodiments shown in Figure 1, 2 and 3.
- The invention is not limited to the embodiments shown. Within the scope of the invention many modifications are obvious to those skilled in the art. For example, the diodes in the present embodiments may be replaced by diode-connected transistors. Further, all or some of the bipolar transistors in the arrangement may be replaced by MOS transistors, in which case "emitter", "collector" and "base" should read: "source", "drain" and "gate", respectively.
- Finally, it is to be noted that the embodiments shown in Figures 4, 5, 6 and 7 may also be equipped with the amplifier arrangement shown in Figure 3.

Claims

1. An amplifier arrangement, comprising:
 - a first transistor having an emitter which is coupled to a first terminal for connection to a load which is coupled to a reference point, and having a collector which is coupled by means of a first semiconductor junction to a second terminal for a first supply voltage
 - a second transistor having a collector-emitter path which is arranged in series with the collector-emitter path of the first transistor, and having a collector which is coupled to a third terminal for a second supply voltage which is higher than the first supply voltage, and
 - a third transistor arranged as an emitter-follower and having a base for receiving an input signal and having an emitter which is coupled to the base of the first transistor, characterized in that
 - the third transistor is of a conductivity type opposite to that of the first transistor and the second transistor and its emitter is coupled to the third terminal by means of a first current source,
 - a first current path is arranged between the third terminal and an electrode of the third transistor which carries the input signal, which first current path comprises the series arrangement of at least a second current source, the emitter-collector path of a fourth transistor of the same conductivity type as the third transistor, and a second semiconductor junction,
 - the emitter of the fourth transistor is coupled to the base of the second transistor,
 - a second current path is arranged between the junction point of the first and second transistors and the reference point and comprises the series arrangement of a third semiconductor junction, a fourth semiconductor junction and a third current source,
 - a point between the collector of the fourth transistor and the second semiconductor junction is connected to the third current source by means of a fifth semiconductor junction, and
 - the base of the fourth transistor is connected to a point between the third semiconductor junction and the fourth semiconductor junction.
2. An amplifier arrangement as claimed in Claim 1, characterized in that the second semiconductor junction is coupled to the emitter of the third transistor.
3. An amplifier arrangement as claimed in Claim 1, characterized in that the second semiconductor junction is the base-emitter junction of a fifth transistor of the same conductivity type as the third transistor, whose base is connected to the base of the third transistor and whose emitter is coupled to the collector of the fourth transistor.
4. An amplifier arrangement as claimed in Claim 1 or 2, characterized in that the first transistor and the second transistor are each constituted by a Darlington pair.
5. An amplifier arrangement as claimed in Claim 1, 2, 3 or 4, characterized in that the first current source and the second current source are connected to the third terminal by means of a first resistor and the first terminal is connected, by means of a capacitor, to that end of the first resistor which is not connected to the third terminal.
6. An amplifier arrangement as claimed in Claim 5, characterized in that the first current source and the second current source are constituted by a second resistor and a third resistor, respectively.
7. An amplifier arrangement as claimed in Claim 1, 2, 4, 5 or 6, characterized in that the second semiconductor junction is the emitter-base junction of a further transistor arranged as an emitter follower.
8. A push-pull amplifier, characterized in that it comprises two complementary amplifier arrangements as claimed in any one of the preceding Claims, in which the emitters of the complementary first transistors



Revendications

1. Montage amplificateur comportant:

—un premier transistor muni d'un émetteur qui est couplé à un premier point pour la connexion d'une charge couplée à un point de référence et d'un collecteur qui est couplé à un deuxième point pour la connexion d'une première tension d'alimentation à l'aide d'une première jonction semi-conductrice

—un deuxième transistor muni d'un trajet collecteur-émetteur qui est monté en série avec le trajet collecteur-émetteur du premier transistor, et d'un collecteur qui est couplé à une troisième borne pour une deuxième tension d'alimentation qui est plus élevée que la première tension d'alimentation et

—un troisième transistor monté en émetteur-suiveur et muni d'une base pour la réception d'un signal d'entrée et d'un émetteur qui est couplé à la base du premier transistor, caractérisé en ce que

—le troisième transistor est d'un type de conductivité opposé à celui du premier transistor et du deuxième transistor et son émetteur est couplé à la troisième borne à l'aide d'une première source de courant,

—un premier trajet de courant est disposé entre la troisième borne et une électrode du troisième transistor qui présente le signal d'entrée, lequel premier trajet de courant comporte le montage en série d'au moins une deuxième source de courant, le trajet émetteur-collecteur d'un quatrième transistor du même type de conductivité que le troisième transistor et une deuxième jonction semiconductrice,

—l'émetteur du quatrième transistor est couplé à la base du deuxième transistor,

—un deuxième trajet de courant est réalisé entre le point de jonction des premier et deuxième transistors et le point de référence et comporte le montage en série d'une troisième jonction semiconductrice, d'une quatrième jonction semiconductrice et d'une troisième source de courant,

—un point entre le collecteur du quatrième transistor et la deuxième jonction semiconductrice est connecté à la troisième source de courant à l'aide d'une cinquième jonction semiconductrice et

—la base du quatrième transistor est connecté à un point entre la troisième jonction semiconductrice et la quatrième jonction semiconductrice.

2. Montage amplificateur selon la revendication 1, caractérisé en ce que la deuxième jonction semiconductrice est couplée à l'émetteur du troisième transistor.

3. Montage amplificateur selon la revendication 1, caractérisé en ce que la deuxième jonction semiconductrice est la jonction base-émetteur d'un cinquième transistor du même type de conductivité que le troisième transistor, dont la base est connectée à la base du troisième transistor et dont l'émetteur est couplé au collecteur du quatrième transistor.

4. Montage amplificateur selon la revendication 1 ou 2, caractérisé en ce que le premier transistor et le deuxième transistor sont constitués chacun par une paire Darlington.

5. Montage amplificateur selon la revendication 1, 2, 3 ou 4, caractérisé en ce que la première source de courant et la deuxième source de courant sont connectées à la troisième borne à l'aide d'une première résistance et la première borne est connectée à l'aide d'un condensateur à l'extrémité de la première résistance qui n'est pas connectée à la troisième borne.

6. Montage amplificateur selon la revendication 5, caractérisé en ce que la première source de courant et la deuxième source de courant sont constituées respectivement par une deuxième résistance et une troisième résistance.

7. Montage amplificateur selon la revendication 1, 2, 4, 5 ou 6, caractérisé en ce que la deuxième jonction semiconductrice est la jonction émetteur-base d'un autre transistor monté en émetteur-suiveur.

8. Amplificateur équilibré, caractérisé en ce qu'il comporte deux montages amplificateurs complémentaires selon l'une des revendications précédentes, les émetteurs des premiers transistors complémentaires étant connectés à une première borne commune pour la connexion à une charge commune.

9. Amplificateur équilibré selon la revendication 8, caractérisé en ce que les troisièmes sources de courant des deux montages amplificateurs complémentaires constituent une source de courant commune.

10. Amplificateur équilibré selon la revendication 8 ou 9, caractérisé en ce que les collecteurs des troisièmes transistors sont couplés à la première borne commune.

11. Variante d'un circuit selon l'une des revendications précédentes 1 à 10, dans laquelle un ou plusieurs transistors bipolaires sont remplacés par les transistors à effet de champ.

