

Description

The invention relates to an amplifier arrangement comprising at least

—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 circuit which is arranged between the base of the first transistor and the base of the second transistor and which comprises the series arrangement of at least a second semiconductor junction and a third semiconductor junction which are poled in the same direction as the base-emitter junction of the first transistor, and a fourth semiconductor junction which is poled in the same direction as the base-emitter junction of the second transistor, and

—an input which is coupled to the bases of the first transistor and the second transistor, for receiving an input signal.

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 an amplifier in which the 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 base 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 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 coupled 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 this arrangement is

that it has a limited output voltage swing and, consequently, a limited efficiency. In the known arrangement the input signal is applied to the bases of the first transistor and the second transistor *via* a third transistor is arranged as an emitter follower, which third transistor is of the same conductivity type as the first transistor and the second transistor. For the maximum output voltage the voltage on the base of the third transistor is substantially equal to the second supply voltage. The voltage of the output is then equal to the second supply voltage minus the sum of the base-emitter voltages of the first transistor and the third transistor and the diode voltages across the two diodes arranged in the base line of the first transistor.

It is the object of the invention to improve the known amplifier arrangement of the class-G type in such a way that the arrangement has a larger output voltage swing and hence a higher efficiency. In accordance with the invention an arrangement of the type specified in the opening paragraph is characterized in that the third terminal is coupled to a point between the third semiconductor junction and the fourth semiconductor junction by means of the series arrangement of a first resistor and a first current source, and a capacitor is arranged between the first terminal and that end of the first resistor which is not connected to the third terminal. By means of the amplifier arrangement in accordance with the invention it is possible to drive the output of the arrangement to substantially the second supply voltage, so that a considerably higher efficiency is obtained than with the known arrangement.

It is to be noted that United States Patent Specification 4,001,707 describes a class-G amplifier whose circuit design bears some resemblance to the circuit arrangement in accordance with the invention, but whose operation differs from that of the arrangement in accordance with the invention. In this known amplifier no diodes are arranged between the bases of the first transistor and the second transistor, but instead a resistor having a high resistance is included. However, this resistor prevents the first transistor from being saturated after the second transistor has been driven into saturation. The voltage drop across this resistor limits the output voltage swing of the arrangement to a considerable extent.

A preferred embodiment of the invention is characterized in that the first transistor and the second transistor are each constituted by a Darlington pair and between the point between the third semiconductor junction and the fourth semiconductor junction and the base of the first transistor a fifth semiconductor junction is arranged in series with the second semiconductor junction and the third semiconductor junction, which fifth semiconductor junction is poled in the same direction as the second semiconductor junction and the third semiconductor junction.

A further embodiment is characterized in that the arrangement comprises a third transistor

which is arranged as an emitter follower, which transistor has its emitter coupled to the bases of the first transistor and the second transistor and which has a base to which the input signal is applied. When the second transistor is turned on the input resistance of the arrangement is substantially halved, which gives rise to switching distortion. By driving the first transistor and the second transistor *via* an emitter follower, the input resistance of the arrangement is increased, thereby reducing the switching distortion. This embodiment may be characterized further in that the third transistor is of a conductivity type opposite to that of the first transistor and the second transistor and, by means of a second current source, has its emitter coupled to that end of the first resistor which is not connected to the third terminal. As in the amplifier arrangement in accordance with the invention the first current source drives the second semiconductor junction and the third semiconductor junction into conduction, the emitter-follower transistor may of a conductivity type opposite to that of the first transistor and the second transistor.

As the voltage on that end of the first transistor which is not connected to the third terminal varies with the input voltage, the first current source and the second current source, in accordance with a further embodiment, may be replaced by a second resistor and a third resistor, respectively.

The amplifier arrangement in accordance with the invention is very suitable for use in a push-pull amplifier, which may be characterized in that it comprises a first amplifier arrangement and a complementary second amplifier arrangement, in which the emitters of the complementary first transistors of the first amplifier arrangement and the second amplifier arrangement are connected to a common first terminal for connection to a common load, in which the second terminal and the third terminal of the first amplifier arrangement serve for applying the positive first supply voltage and the positive second supply voltage respectively, and in which the second terminal and the third terminal of the second amplifier arrangement serve for applying the negative first supply voltage and the negative second supply voltage respectively. If the amplifier arrangements are each driven by a respective third transistor which is arranged as an emitter follower and which is of a conductivity type opposite to that of the corresponding first transistor and the corresponding second transistor, this push-pull amplifier may be characterized further in that in the first amplifier arrangement and the second amplifier arrangement the emitter of the third transistor is connected directly to the base of the first transistor, and the collectors of the complementary third transistors are coupled to the common first terminal. By connecting the emitters of the third transistors direction to the first transistors, only two diodes are required between the bases of the third transistors in order to obtain class-AB operation of the push-pull amplifier. In comparison with the known arrange-

ment this yields a substantial reduction of the number of diodes necessary for such operation.

Another embodiment is characterized in that the collector-emitter path of a further transistor is arranged between the bases of the complementary first transistors, a first further resistor being arranged between the base and the emitter and a second further resistor between the base and the collector of said fourth transistor. The further transistor together with the further resistors constitutes an artificial zener diode, which replace the diodes between the bases of the third transistors in order to obtain class-AB operation. This results in a substantially reduced temperature dependence of the quiescent-current setting. In this embodiment one of the third transistors may be dispensed with if the push-pull amplifier is characterized in that the base of the first transistor of one of the two amplifier arrangements is connected to the emitter of a second further transistor which is of a conductivity type opposite to that of the relevant first transistor and which is arranged as an emitter follower, a first further current source connecting the emitter of the second further transistor to that end of the first resistor of the relevant amplifier arrangement which is not connected to the third terminal and a second further current source connecting the base of that first transistor which is not connected to the second further transistor to that end of the first resistor of the relevant amplifier arrangement which is not connected to the third terminal.

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

Fig. 1 is a basic diagram of an amplifier arrangement in accordance with the invention,

Fig. 2 is the circuit diagram of an amplifier arrangement derived from the arrangement shown in Fig. 1,

Fig. 3 shows a push-pull amplifier in accordance with a first embodiment of the invention,

Fig. 4 shows a push-pull amplifier in accordance with a second embodiment of the invention, and

Fig. 5 shows a push-pull amplifier in accordance with a third embodiment of the invention.

Fig. 1 is a 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. A diode D_1 connects the collector of the transistor T_1 to a terminal 4 for a first supply voltage V_1 . The collector-emitter path of a second NPN transistor T_2 is connected in series with the collector-emitter path of the transistor T_1 , which transistor T_2 has its collector connected to a terminal 10 for a second supply voltage V_2 which is higher than the first supply voltage V_1 . The series arrangement of the diodes D_2 , D_3 and D_4 is arranged between the base of the transistor T_1 and the base of the transistor T_2 , the diodes D_2 and D_3 being poled in the same direction as the base-emitter junction of the transistor

T_1 and the diode D_4 being poled in the same direction as the base-emitter junction of the transistor T_2 . The terminal 10 for the supply voltage V_2 is connected to the junction point 4 of the diode D_3 and the diode D_4 by means of the series connection of a resistor R_1 and the emitter-collector path of a PNP transistor T_4 . The base of the transistor T_4 is connected to a reference voltage V_{R1} and constitutes a current source. The junction point 5 of the emitter of the transistor T_4 and the resistor R_1 is connected to the output 2 of the amplifier arrangement by means of a capacitor C_1 . The base of the transistor T_1 is connected to the emitter of an emitter-follower transistor T_3 . The emitter of this transistor is connected to the junction point 5 by means of a current source comprising a transistor T_5 whose base is at the reference voltage V_{R1} . The collector of the transistor T_3 is connected to the terminal 11, which is common to the first supply voltage V_1 and the second supply voltage V_2 .

The arrangement operates as follows. The input voltage V_i is applied to the base 6 of the transistor T_3 . For low input voltage V_i the voltage on the anode of the diode D_4 is lower than the first supply voltage V_1 , so that the transistor T_2 is cut off. The collector of the transistor T_1 is then connected to the first supply voltage V_1 via the diode D_1 . The input voltage V_i on the base of the transistor T_1 appears also on the output 2 and is applied to the junction point 5 via the bootstrap capacitor C_1 . As a result of this, the voltages on the emitter 5 and the collector 4 of the transistor T_4 vary in the same way with the input voltage V_i . The same applies to the voltages on the emitter and the collector of the transistor T_5 . In this situation if the base current of the transistor T_1 is ignored, the entire current from the current source T_4 is applied to the transistor T_3 via the diodes D_3 and D_2 . When the input voltage V_i increases the diode D_4 and the transistor T_2 will be turned on above a specific voltage. As a result of this, the voltage on the emitter 3 of the transistor T_2 also increases, so that the diode D_1 is turned off at a specific voltage. The collector of the transistor T_1 is then connected to the second supply voltage V_2 via the collector-emitter path of the transistor T_2 . The current from the current source T_4 through the diode D_4 increases and the current through the diodes D_3 and D_2 decreases. As the input voltage V_i increases further, the voltage on the base of the transistor T_2 becomes higher than the supply voltage V_2 , so that the transistor T_2 is saturated. Since the voltage on the emitter 5 of the transistor T_4 varies with the input voltage via the bootstrap capacitor C_1 , the transistor T_4 cannot be saturated. Subsequently, the transistor T_1 is bottomed, enabling the input voltage to increase until the situation is obtained in which the entire current from the current source T_5 flows into the base of the transistor T_1 and no current flows in the transistor T_3 . The input voltage then cannot increase any further, so that the maximum output voltage is reached. The voltage V_o at the output 2 is then equal to:

$$V_{O\text{MAX}} = V_2 - (V_{\text{CEST2}} + V_{\text{CEST1}}) \quad (1)$$

where

V_{CEST1} = the collector-emitter voltage of the transistor T_1 in the case of saturation, and

V_{CEST2} = the collector-emitter voltage of the transistor T_2 in the case of saturation.

As the voltages V_{CEST2} and V_{CEST1} are substantially 100 mV, it follows from the above equation that the output 2 can be driven to substantially the second supply voltage V_2 . As a result of this large output voltage swing the amplifier arrangement has a high efficiency.

It is to be noted that, in principle, it is possible to drive the bases of the first transistor T_1 and the second transistor T_2 directly from a signal source without inclusion of an emitter-follower transistor T_3 . However, this has the disadvantage that the input resistance of the arrangement is substantially halved when the transistor T_2 is turned on, which gives rise to switching distortion.

Further, it is to be noted that if driving is effected by means of an emitter-follower transistor T_3 , the emitter of this transistor may in principle be connected to any point between the anode 4 of the diode D_4 and the base of the transistor T_1 . However, the present method of connecting the emitter of the transistor T_3 to the cathode of the diode D_2 has the advantage that changing over from the first supply voltage V_1 to the second supply voltage V_2 is effected at the instant at which the transistor T_1 is saturated, so that the transistor T_1 is driven to an optimum extent.

The principle of using two supply voltages as explained with reference to Fig. 1 may be extended to an arbitrary number of supply voltages. Fig. 2 shows an amplifier arrangement in accordance with the invention using three supply voltages, in which Figure identical parts bear the same reference numerals as in Figure 1. A transistor T_{21} , whose collector is connected to a third supply voltage V_3 , is arranged in series with the collector-emitter path of the transistor T_2 . The collector of the transistor T_2 is connected to the second supply voltage V_2 via a diode D_{21} and the current-source transistor T_4 and T_5 are 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 . Again the series arrangement of three diodes D_4 , D_{22} and D_{24} is arranged between the base of the transistor T_2 and the base of the transistor T_{21} , the diodes D_4 and D_{22} being poled in the same direction as the base-emitter junction of the transistor T_2 and the diode D_{24} being poled in the same direction as the base-emitter junction of the transistor T_{21} .

The operation of the arrangement can be explained simply by means of the principle described with reference to Figure 1. As the current-source transistor T_4 drives the diodes D_{22} , D_3 and D_2 into conduction, the input voltage V_i appears on the anode of the diode D_{24} and the anode of the diode D_4 . For input voltages V_i lower

than the supply voltage V_1 the transistors T_{21} and T_2 are cut off. The collector of the transistor T_1 is then connected to the supply voltage V_1 via the diode D_1 . The voltage on the output 2 is applied to point 5 via the bootstrap capacitor C_1 so that the voltage on the emitter of the transistor T_4 varies with the input voltage. Above an input voltage V_1 equal to the supply voltage V_1 the transistor T_2 is turned on. For a specific input voltage V_1 the diode D_1 is then cut off and the collector of the transistor T_1 is connected to the supply voltage V_2 . As the input voltage V_1 increases further, the transistor T_{21} is turned on and the diode D_{21} is turned off above a specific voltage, so that the collector of the transistor T_1 is coupled to the supply voltage V_3 . If the input voltage V_1 increases still further, the transistors T_{21} , T_2 and T_1 are consecutively bottomed. Bootstrapping the output voltage to the emitter of the transistor T_4 then prevents this transistor from being saturated. The maximum voltage V_0 on the output 2 is now equal to:

$$V_{0MAX} = V_3 - (V_{CEST21} + V_{CEST2} + V_{CEST1}) \quad (2)$$

where

V_{CEST21} = the collector-emitter voltage of the transistor T_{21} in the case of saturation.

The amplifier arrangement in accordance with the invention is very suitable for use in a push-pull amplifier, of which Fig. 3 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_{R2} . The input signal V_{11} 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_2 is arranged between the collector and the base of this transistor T_{15} . The collector of the transistor T_{15} is connected to the positive supply voltage $+V_2$, via a resistor R_1 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_{R1} . The output stage comprises two complementary circuits, which are each substantially identical to the circuit arrangement shown in Fig. 1. Therefore, identical parts bear the same reference numerals as in Fig. 1, the complementary parts being denoted by primes. The arrangement differs from that shown in Fig. 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_2 being

arranged between the base and the emitter of the transistor T_2 to provide a rapid turn-off of the Darlington pair. It is to be noted that 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 . Therefore, an additional diode D_8 must be arranged in series with the diodes D_2 and D_3 to prevent this Darlington pair from being saturated when the Darlington pair T_8 , T_2 is not yet fully conductive. The emitters of the complementary output transistors T_1 and T_1' are connected to the common output 2, to which the load R_L is connected. A resistor R_3 arranged between the emitters of the transistors T_7 and T_7' has the same function as the resistor R_2 .

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 the class-AB operation of the output stage.

Since the diodes D_2 , D_3 and D_5 are into conduction by the current source T_4 , the output of the emitter-follower transistor T_3 may be connected to the base of the transistor T_7 and the transistor T_3 may be a PNP transistor. As a result of this, only two diodes (D_6 and D_7) are necessary between the bases of the transistors T_3 and T_3' for the quiescent-current setting. In the known arrangement using Darlington transistors, ten diodes between the bases of the emitter follower transistors are necessary for the quiescent-current setting. This means that the arrangement in accordance with the invention provides a substantial reduction of the number of diodes. The push-pull principle is known *per se* and will therefore not be discussed in more detail here. As the transistor T_2 together with the transistor T_8 constitutes a Darlington pair, the maximum output voltage is now equal to:

$$V_{0MAX} = +V_2 - (V_{CEST8} + V_{BET2} + V_{CEST1}) \quad (3)$$

where

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

This means that the maximum output voltage is one base-emitter voltage lower than in the case of Fig. 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 push-pull amplifier in accordance with a second embodiment of the invention will be described with reference to Fig. 4. For the sake of simplicity only the output stage which is relevant to the invention is shown and identical parts bear the same reference numerals as in Fig. 3.

In the present embodiment the current-source transistor T_4 is replaced by a resistor R_4 and the current source transistor R_5 is replaced by a resistor R_5 . The bootstrap capacitor C_1 ensures that the signal voltage on the junction point 5 is the same as the signal voltage on the anode 4 of the diode D_4 and the emitter of the transistor T_3 . The voltages across the resistance R_4 and R_5 are therefore constant, so that these resistors again function as current sources.

A push-pull amplifier in accordance with a third embodiment is described with reference to Fig. 5, in which identical parts bear the same reference numerals as in Fig. 4. An artificial zener diode is arranged between the bases of the transistors T_7 and T_7' , which artificial zener diode comprises a transistor T_6 between whose collector and base a resistor R_6 is arranged and between whose base and emitter a resistor R_7 is arranged. The voltage across this transistor T_6 is:

$$V_{CET6} = \left(1 + \frac{R_6}{R_7}\right) V_{BET6} \quad (4)$$

where

V_{CET6} = the collector-emitter voltage of the transistor T_6 .

V_{BET6} = the base-emitter voltage of the transistor T_6 .

The resistors R_6 and R_7 are so chosen that a voltage equal to form diode voltages appears between the bases of the transistors T_7 and T_7' for the quiescent-current setting of the transistors T_7 , T_1 and T_7' , T_1' . The artificial zener diode has the advantage that its temperature dependence is much smaller than that of four series-connected diodes. Moreover, the artificial zener diode between the bases of the transistors T_7 and T_7' enables one of the emitter-follower transistors T_3 and T_3' to be dispensed with. In the present example the transistor T_3 is dispensed with. The base of the transistor T_7 is now only connected to the positive supply voltage $+V_2$ by means of a resistor R_8 , which again operates as a current source. The collector of the transistor T_3' is also connected to the positive supply voltage. The base 6 of the transistor T_3' may be connected directly to the collector of the transistor T_{15} (see Fig. 3), without diodes for the quiescent-current setting being arranged in the collector line. The input voltage on the base of the transistor T_3' appears on the base of the transistor T_7' and, via the artificial zener diode T_6 , R_6 and R_7 , also on the base of the transistor T_7 , so that the transistor T_7 and T_7' are again driven in the same way.

It is to be noted that it is alternatively possible not to dispense with the transistor T_3 and to connect the base of the transistor T_3 to the

negative supply voltage $-V_2$ by means of a resistor R_8' .

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 employed 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".

Finally, it is to be noted that the push-pull amplifier shown in Fig. 3, 4 and 5 may also be constructed using the amplifier arrangement shown in Fig. 2.

Claims

1. An amplifier arrangement comprising at least

—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 circuit which is arranged between the base of the first transistor and the base of the second transistor and which comprises the series arrangement of at least a second semiconductor junction and a third semiconductor junction which are poled in the same direction as the base-emitter junction of the first transistor, and a fourth semiconductor junction which is poled in the same direction as the base-emitter junction of the second transistor, and

—an input which is coupled to the base of the first transistor and the second transistor, for receiving an input signal, characterized in that

—the third terminal is coupled to a point between the third semiconductor junction and the fourth semiconductor junction by means of the series arrangement of a first resistor and a first current source, and

—a capacitor is arranged between the first terminal and that end of the first resistor which is not connected to the third terminal.

2. An amplifier arrangement as claimed in Claim 1, characterized in that the first transistor and the second transistor are each constituted by a Darlington pair and between the point between the third semiconductor junction and the fourth semiconductor junction and the base of the first transistor a fifth semiconductor junction is arranged in series with the second semiconductor junction and the third semiconductor junction, which fifth semiconductor junction is poled in the same direction as the second semiconductor

A push-pull amplifier in accordance with a second embodiment of the invention will be described with reference to Fig. 4. For the sake of simplicity only the output stage which is relevant to the invention is shown and identical parts bear the same reference numerals as in Fig. 3.

In the present embodiment the current-source transistor T_4 is replaced by a resistor R_4 and the current source transistor R_5 is replaced by a resistor R_5 . The bootstrap capacitor C_1 ensures that the signal voltage on the junction point 5 is the same as the signal voltage on the anode 4 of the diode D_4 and the emitter of the transistor T_3 . The voltages across the resistance R_4 and R_5 are therefore constant, so that these resistors again function as current sources.

A push-pull amplifier in accordance with a third embodiment is described with reference to Fig. 5, in which identical parts bear the same reference numerals as in Fig. 4. An artificial zener diode is arranged between the bases of the transistors T_7 and T_7' , which artificial zener diode comprises a transistor T_6 between whose collector and base a resistor R_6 is arranged and between whose base and emitter a resistor R_7 is arranged. The voltage across this transistor T_6 is:

$$V_{CET6} = (1 + \frac{R_6}{R_7}) V_{BET6} \quad (4)$$

where

V_{CET6} = the collector-emitter voltage of the transistor T_6 .

V_{BET6} = the base-emitter voltage of the transistor T_6 .

The resistors R_6 and R_7 are so chosen that a voltage equal to form diode voltages appears between the bases of the transistors T_7 and T_7' for the quiescent-current setting of the transistors T_7 , T_1 and T_7' , T_1' . The artificial zener diode has the advantage that its temperature dependence is much smaller than that of four series-connected diodes. Moreover, the artificial zener diode between the bases of the transistors T_7 and T_7' enables one of the emitter-follower transistors T_3 and T_3' to be dispensed with. In the present example the transistor T_3 is dispensed with. The base of the transistor T_7 is now only connected to the positive supply voltage $+V_2$ by means of a resistor R_6 , which again operates as a current source. The collector of the transistor T_3' is also connected to the positive supply voltage. The base 6 of the transistor T_3' may be connected directly to the collector of the transistor T_{13} (see Fig. 3), without diodes for the quiescent-current setting being arranged in the collector line. The input voltage on the base of the transistor T_3' appears on the base of the transistor T_7' and, via the artificial zener diode T_6 , R_6 and R_7 , also on the base of the transistor T_7 , so that the transistor T_7 and T_7' are again driven in the same way.

It is to be noted that it is alternatively possible not to dispense with the transistor T_1 and to connect the base of the transistor T_1 to the

negative supply voltage $-V_2$ by means of a resistor R_8 .

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 employed 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".

Finally, it is to be noted that the push-pull amplifier shown in Fig. 3, 4 and 5 may also be constructed using the amplifier arrangement shown in Fig. 2.

Claims

1. An amplifier arrangement comprising at least

—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 circuit which is arranged between the base of the first transistor and the base of the second transistor and which comprises the series arrangement of at least a second semiconductor junction and a third semiconductor junction which are poled in the same direction as the base-emitter junction of the first transistor, and a fourth semiconductor junction which is poled in the same direction as the base-emitter junction of the second transistor, and

—an input which is coupled to the base of the first transistor and the second transistor, for receiving an input signal, characterized in that

—the third terminal is coupled to a point between the third semiconductor junction and the fourth semiconductor junction by means of the series arrangement of a first resistor and a first current source, and

—a capacitor is arranged between the first terminal and that end of the first resistor which is not connected to the third terminal.

2. An amplifier arrangement as claimed in Claim 1, characterized in that the first transistor and the second transistor are each constituted by a Darlington pair and between the point between the third semiconductor junction and the fourth semiconductor junction and the base of the first transistor a fifth semiconductor junction is arranged in series with the second semiconductor junction and the third semiconductor junction, which fifth semiconductor junction is poled in the same direction as the second semiconductor



tor junction and the third semiconductor junction.

3. An amplifier arrangement as claimed in Claim 1 or 2, characterized in that the first current source is constituted by a second resistor.

4. An amplifier arrangement as claimed in Claim 1, 2 or 3, characterized in that the arrangement comprises a third transistor which is arranged as an emitter follower, which transistor has its emitter coupled to the bases of the first transistor and the second transistor, and which has a base to which the input signal is applied.

5. An amplifier arrangement as claimed in Claim 4, characterized in that the third transistor is of a conductivity type opposite to that of the first transistor and the second transistor and, by means of a second current source, has its emitter coupled 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 second current source is constituted by a third resistor.

7. A push-pull amplifier characterized in that it comprises a first amplifier arrangement as claimed in any one of the preceding Claims, and a second amplifier arrangement which is complementary thereto, in which the emitters of the complementary first transistors of the first amplifier arrangement and the second amplifier arrangement are connected to a common first terminal for connection to a common load, in which the second terminal and the third terminal of the first amplifier arrangement serve for applying the positive first supply voltage and the positive second supply voltage respectively, and in which the second terminal and the third terminal of the second amplifier arrangement serve for applying the negative first supply voltage and the negative second supply voltage respectively.

8. A push-pull amplifier as claimed in Claim 7, in which the first amplifier arrangement and the second amplifier arrangement are arrangements as claimed in Claim 4 or 5, characterized in that in the first amplifier arrangement and the second amplifier arrangement the emitter of the third transistor is connected directly to the base of the first transistor, and in that the collectors of the complementary third transistors are coupled to the common first terminal.

9. A push-pull amplifier as claimed in Claim 7, in which the first amplifier arrangement and the second amplifier arrangement are arrangements as claimed in Claim 1, 2 or 3, characterized in that the collector-emitter path of a further transistor is arranged between the bases of the complementary first transistors, a first further resistor being arranged between the base and the emitter and a second further resistor being arranged between the base and the collector of said transistor.

10. A push-pull amplifier as claimed in Claim 9, characterized in that the base of the first transistor of one of the two amplifier arrangements is connected to the emitter of a second further transistor which is of a conductivity type opposite to that of the relevant first transistor and which is

arranged as an emitter follower, a first further current source connecting the emitter of the second further transistor to that end of the first resistor of the relevant amplifier arrangement which is not connected to the third terminal and a second further current source connecting the base of that first transistor which is not connected to the second further transistor to that end of the first resistor of the relevant amplifier arrangement which is not connected to the third terminal.

11. A push-pull amplifier as claimed in Claim 10, characterized in that the first further current source and the second further current source are constituted by a third further resistor and a fourth further resistor respectively.

12. A modification of a circuit as claimed in any of the preceding Claims, wherein one or more of the bipolar transistors are replaced by field effect transistors.

Patentsprüche

1. Verstärkeranordnung, die wenigstens

—einen ersten Transistor mit einem Emittor, der an eine erste Verbindungsklemme nach einer Belastung angeschlossen ist, die wieder mit einem Bezugspunkt verbunden ist, und mit einem Kollektor, der über einen ersten Halbleiterübergang an eine zweite Klemme für eine erste Speisespannung angeschlossen ist,

—einen zweiten Transistor mit einer Kollektor-Emitterstrecke, die in Reihe mit der Kollektor-Emitterstrecke des ersten Transistors angeordnet ist, und mit einem Kollektor, der an eine dritte Klemme für eine zweite Speisespannung höher als die erste Speisespannung angeschlossen ist, und

—eine zwischen der Basis des ersten Transistors und der Basis des zweiten Transistors angeordnete Schaltung, die die Reihenanordnung wenigstens aus einem zweiten Halbleiterübergang und einem dritten Halbleiterübergang, die in der gleichen Richtung wie der Basis-Emitterübergang des ersten Transistors gepolt sind, und einem vierten Halbleiterübergang enthält, der in der gleichen Richtung wie der Basis-Emitterübergang des zweiten Transistors gepolt ist, und

—einen Eingang enthält, der zum Empfangen eines Eingangssignals an die Basis des ersten Transistors und des zweiten Transistors angeschlossen ist, dadurch gekennzeichnet, daß

—die dritte Klemme mit einem Punkt zwischen dem dritten Halbleiterübergang und dem vierten Halbleiterübergang mit Hilfe der Reihenanordnung aus einem ersten Widerstand und einer ersten Stromquelle verbunden ist, und

—ein Kondensator zwischen der ersten Klemme und jenem Ende des ersten Widerstands angeordnet ist, das nicht mit der dritten Klemme verbunden ist.

2. Verstärkeranordnung nach Anspruch 1, dadurch gekennzeichnet, daß der erste Transistor und der zweite Transistor durch je ein Darlington-Paar gebildet werden, und zwischen dem Punkt zwischen dem dritten Halbleiterübergang und



dem vierten Halbleiterübergang und der Basis des ersten Transistors ein fünfter Halbleiterübergang in Reihe mit dem zweiten Halbleiterübergang und dem dritten Halbleiterübergang angeordnet ist, wobei der fünfte Halbleiterübergang in der gleichen Richtung wie der zweite Halbleiterübergang und der dritte Halbleiterübergang gepolt ist.

3. Verstärkeranordnung nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die erste Stromquelle durch einen zweiten Widerstand gebildet wird.

4. Verstärkeranordnung nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß die Anordnung einen dritten Transistor enthält, die als Emitterfolger geschaltet ist, und dessen Emitter an die Basen der ersten und zweiten Transistoren angeschlossen ist, und dessen Basis das Eingangssignal empfängt.

5. Verstärkeranordnung nach Anspruch 4, dadurch gekennzeichnet, daß der dritte Transistor von einem Leitfähigkeitstyp ist, der dem des ersten Transistors und des zweiten Transistors entgegengesetzt ist, und mittels einer zweiten Stromquelle mit seinem Emitter an jenes Ende des ersten Widerstands angeschlossen ist, das nicht mit der dritten Klemme verbunden ist.

6. Verstärkeranordnung nach Anspruch 5, dadurch gekennzeichnet, daß die zweite Stromquelle durch einen dritten Widerstand gebildet wird.

7. Gegentaktverstärker, dadurch gekennzeichnet, daß er eine erste Verstärkeranordnung nach einem oder mehreren der vorangehenden Ansprüche sowie eine zweite Verstärkeranordnung enthält, die damit komplementär ist, wobei die Emitter der komplementären ersten Transistoren der ersten Verstärkeranordnung und der zweiten Verstärkeranordnung an eine gemeinsame erste Klemme zum Verbinden mit einer gemeinsamen Belastung angeschlossen ist, wobei die zweiten und dritten Klemmen der ersten Verstärkeranordnung zum Anlegen der positiven ersten Speisespannung bzw. der positiven zweiten Speisespannung dienen, und wobei die zweiten und dritten Klemmen der zweiten Verstärkeranordnung zum Anlegen der negativen ersten Speisespannung bzw. der negativen zweiten Speisespannung dienen.

8. Gegentaktverstärker nach Anspruch 7, wobei die ersten und zweiten Verstärkeranordnungen Anordnungen nach Anspruch 4 oder 5 sind, dadurch gekennzeichnet, daß in der ersten Verstärkeranordnung und in der zweiten Verstärkeranordnung der Emitter des dritten Transistors mit der Basis des ersten Transistors direkt verbunden ist, und daß die Kollektoren der komplementären dritten Transistoren mit der gemeinsamen ersten Klemme verbunden sind.

9. Gegentaktverstärker nach Anspruch 7, wobei die ersten und zweiten Verstärkeranordnungen Anordnungen nach Anspruch 1, 2 oder 3 sind, dadurch gekennzeichnet, daß die Kollektor-Emitterstrecke eines weiteren Transistors zwischen den Basen der komplementären ersten Transisto-

ren angeordnet ist, wobei ein erster weiterer Widerstand zwischen der Basis und dem Emitter und ein zweiter weiterer Widerstand zwischen der Basis und der Emitter angeordnet sind.

10. Gegentaktverstärker nach Anspruch 9, dadurch gekennzeichnet, daß die Basis des ersten Transistors einer der beiden Verstärkeranordnungen an den Emitter eines zweiten weiteren Transistors angeschlossen ist, welcher Transistor von einem Leitfähigkeitstyp ist, der den des betreffenden ersten Transistors entgegengesetzt ist und als Emitterfolger geschaltet ist, wobei eine erste weitere Stromquelle den Emitter des zweiten weiteren Transistors zu jenem Ende des ersten Widerstands der betreffenden Verstärkeranordnung verbindet, das nicht mit der dritten Klemme verbunden ist, und eine zweite weitere Stromquelle mit der Basis jenes ersten Transistors, der nicht mit dem zweiten weiteren Transistor verbunden ist, mit jenem Ende des ersten Widerstands der betreffenden Verstärkeranordnung verbindet, das nicht mit der dritten Klemme verbunden ist.

11. Gegentaktverstärker nach Anspruch 10, dadurch gekennzeichnet, daß die erste weitere Stromquelle und die zweite weitere Stromquelle durch einen dritten weiteren Widerstand bzw. einen vierten weiteren Widerstand gebildet werden.

12. Abwandlung einer Schaltung nach einem oder mehreren der vorangehenden Ansprüche, in der einer oder mehrere der bipolaren Transistoren durch Feldeffekttransistoren ersetzt werden.

Revendications

1. Montage amplificateur comportant au moins —un premier transistor muni d'un émetteur qui est couplé à une première borne pour la connexion à une charge qui est couplée à un point de référence, et d'un collecteur qui est couplé à l'aide d'une première jonction semi-conductrice à une deuxième borne pour une première tension d'alimentation,

—une 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, et

—un circuit qui est disposé entre la base du premier transistor et la base du deuxième transistor et qui comporte le montage en série d'au moins une deuxième jonction semi-conductrice et d'une troisième jonction semi-conductrice, dont le sens de passage est le même que celui de la jonction base-émetteur du premier transistor, et d'une quatrième jonction semi-conductrice dont le sens de passage est le même que celui de la jonction de base-émetteur du deuxième transistor, et

—une entrée qui est couplée aux bases du premier transistor et du deuxième transistor pour la réception d'un signal d'entrée, caractérisé en ce que



—la troisième borne est couplée à un point entre la troisième jonction semiconductrice et la quatrième jonction semiconductrice à l'aide du montage en série d'une première résistance et l'une première source de courant,

—un condensateur est monté entre la première borne et l'extrémité de la première résistance qui n'est pas connectée à la troisième borne.

2. Montage amplificateur selon la revendication 1, caractérisé en ce que le premier transistor et le deuxième transistor sont constitués chacun par une paire Darlington et entre le point entre la troisième jonction semiconductrice et la quatrième jonction semiconductrice et la base du premier transistor est disposée une cinquième jonction semiconductrice en série avec la deuxième jonction semiconductrice et la troisième jonction semiconductrice, cinquième jonction semiconductrice dont le sens de passage est le même que celui de la deuxième jonction semiconductrice et de la troisième jonction semiconductrice.

3. Montage amplificateur selon la revendication 1 ou 2, caractérisé en ce que la première source de courant est constituée par une deuxième résistance.

4. Montage amplificateur selon la revendication 1, 2 ou 3, caractérisé en ce que le montage est muni d'un troisième transistor qui est monté en émetteur-suiveur et dont l'émetteur est couplé aux bases du premier transistor et du deuxième transistor et à la base duquel est appliqué le signal d'entrée.

5. Montage amplificateur selon la revendication 4, caractérisé en ce que le troisième transistor est d'un type de conductivité opposé à celui du premier transistor et du deuxième transistor, son émetteur étant couplé à l'aide d'une deuxième source de courant, 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 deuxième source de courant est constituée par une troisième résistance.

7. Amplificateur équilibré caractérisé en ce qu'il est muni d'un premier montage amplificateur selon l'une des revendications précédentes et d'un deuxième montage amplificateur complémentaire, dans lequel les émetteurs des premiers transistors complémentaires du premier montage amplificateur et du deuxième montage amplificateur sont connectés à une première borne commune pour la connexion à une charge commune, dans lequel la deuxième borne et la troisième borne du premier montage amplificateur servent à appliquer respectivement la première tension

d'alimentation positive et la deuxième tension d'alimentation positive et dans lequel la deuxième borne et la troisième borne du deuxième montage amplificateur servent à appliquer respectivement la première tension d'alimentation négative et la deuxième tension d'alimentation négative.

8. Amplificateur équilibré selon la revendication 7, dans lequel le premier montage amplificateur et le deuxième montage amplificateur sont des montages selon la revendication 4 ou 5, caractérisé en ce que dans le premier montage amplificateur et le deuxième montage amplificateur l'émetteur du troisième transistor est connecté de façon directe à la base du premier transistor, et en ce que les collecteurs des troisièmes transistors complémentaires sont couplés à la première borne commune.

9. Amplificateur équilibré selon la revendication 7, dans lequel le premier amplificateur et le deuxième amplificateur sont des amplificateurs selon la revendication 1, 2 ou 3, caractérisé en ce que le trajet collecteur-émetteur d'un autre transistor est monté entre les bases des premiers transistors complémentaires, une première autre résistance étant disposée entre la base et l'émetteur et une deuxième autre résistance étant montée entre la base et le collecteur dudit transistor.

10. Amplificateur équilibré selon la revendication 9, caractérisé en ce que la base du premier transistor de l'un des deux montages amplificateurs est connectée à l'émetteur d'un deuxième autre transistor, dont le type de conductivité est opposé à celui du premier transistor en question et qui est monté en émetteur-suiveur, une première autre source de courant assurant la connexion de l'émetteur du deuxième autre transistor à l'extrémité de la première résistance du montage amplificateur en question qui n'est pas connectée à la troisième borne et une deuxième autre source de courant assurant la connexion de la base de ce premier transistor qui n'est pas connecté au deuxième autre transistor à l'extrémité de la première résistance du montage amplificateur en question qui n'est pas connecté à la troisième borne.

11. Amplificateur équilibré selon la revendication 10, caractérisé en ce que la première autre source de courant et la deuxième autre source de courant sont constituées par respectivement une troisième autre résistance et une quatrième autre résistance.

12. Une variante d'un circuit selon l'une des revendications précédentes, dans laquelle un ou plusieurs des transistors bipolaires sont remplacés par des transistors à effet de champ.

