

Description

The invention relates to a push-pull amplifier comprising:

—a preamplifier stage having a first and a second output,

—an output amplifier stage which comprises a first and a second transistor of opposite conductivity types, whose collector-emitter paths are arranged in series between two power-supply terminals and whose collectors are coupled to an output terminal, the base of the first transistor being driven by the first output and the base of the second transistor being driven by the second output of the preamplifier stage, and

—means for maintaining the sum of the base-emitter voltages of the first and the second transistor substantially constant, which means comprise a voltage-to-current converter comprising a third transistor, for converting the base-emitter voltage of the first transistor into a current, and a current-to-voltage converter comprising a fourth transistor identical to the third transistor, for converting the current from the voltage-to-current converter into a voltage equal to said base-emitter voltage, the base of the fourth transistor being connected to the base of the second transistor.

Such a push-pull amplifier may be used in audio-amplifier circuits, for example as described in the European Patent Application 85 200 243 filed simultaneously with the present Application and published under EP—A—0156410 on 2nd October 1985.

Such a push-pull amplifier is disclosed in United States Patent Specification US—A—4,366,448, in which a small quiescent current is fed through the output transistors of opposite conductivity types so that the amplifier is operated as a class AB amplifier. The output transistors are therefore driven into partial conduction, which substantially reduces crossover distortion. For a satisfactory crossover behaviour the sum of the base-emitter voltages of the output transistors must be kept substantially constant during driving. A variation of the base-emitter voltage of the first output transistor as a result of driving of this transistor is then accompanied by an equal but opposite variation of the base-emitter voltage of the second output transistor. In the known circuit arrangement a third transistor converts the base-emitter voltage of the first output transistor into a current which is re-converted into a voltage equal to said base-emitter voltage by a fourth transistor whose base is connected to the base of the second output transistor. The voltage between the emitter and the collector of the third transistor is then equal to the sum of the base-emitter voltages of the first and the second output transistor. This voltage is applied to the base of a transistor in whose emitter circuit a diode-connected transistor is arranged. The collector current of this transistor is derived from a current source which is arranged in the common emitter line of a differential

amplifier which constitutes the preamplifier. The resulting negative feedback gives rise to a specific quiescent current in the output transistors.

However, this known circuit arrangement has the disadvantage that owing to the feedback to the preamplifier a comparatively large control loop is obtained, which is likely to give rise to stability problems. Therefore, the invention aims at providing a push-pull amplifier with a stable class AB setting and in which an accurately defined quiescent current flows in the output transistors. According to the invention a push-pull amplifier of the type specified in the opening paragraph is characterized in that the means further comprise a fifth and a sixth transistor arranged as a differential pair and having a first current source arranged in the common emitter line, the base of the fifth transistor being coupled to the input of the current-voltage converter and the base of the sixth transistor being at a reference voltage which is equal to a voltage produced across two diodes by a constant current, the collectors of the fifth and the sixth transistor are each effectively loaded by one of two substantially identical current sources the sum of the currents in which is substantially equal to the current from the first current source, and the collectors of the fifth and the sixth transistor are further coupled to the bases of the first and the second transistor, respectively. In accordance with the invention the sum of the base-emitter voltages of the first and the second output transistor, which sum appears on the input of the current-to-voltage converter, is made equal to a reference voltage by means of a differential amplifier, which reference voltage is equal to the voltage across two diodes through which a specific constant current flows. Since the sum of the base-emitter voltages is equal to the reference voltage, the value of the quiescent current through the output transistors is also defined accurately. As the differential amplifier is a stage which directly precedes the output amplifier the control loop remains small, so that stability problems can be avoided.

An embodiment of the invention may be further characterized in that the emitter areas of the third and the fourth transistor are smaller than that of the first transistor. This embodiment may be characterized still further in that a resistor is arranged in the emitter line of the third and the fourth transistor. Each of these steps ensures that only a fraction of the current through the first output transistor flows through the third and the fourth transistor, so that the dissipation in these transistors remains low.

This or a further embodiment of the invention may be further characterized in that the two diodes are diode-connected transistors of opposite conductivity types. In this way the reference voltage is made subject to the same variations, for example temperature variations, as the sum of the base-emitter voltages of the first and the second transistor, so that these variations do not affect the quiescent-current setting.

These embodiments or yet another embodiment may be further characterized in that resistors are arranged in the emitter lines of the fifth and the sixth transistors. This step reduces the gain, which is favourable for the control stability.

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

Figure 1 shows a push-pull amplifier forming an embodiment of the invention, and

Figure 2 shows the circuit arrangement of Figure 1 in more detail.

Figure 1 shows a push-pull amplifier which forms an embodiment of the invention. It comprises a preamplifier stage 10 which is shown schematically and which has supply terminals 11 and 12 connected to the positive power-supply terminal 2 and the negative power-supply terminal 3, in the present case earth respectively. The amplifier stage 10 may be of conventional design or may be constructed as described in European Patent Application 85200243 published under EP-A-0156410 on 2nd October 1985. The amplifier stage 10 has two outputs connected to the inputs 13 and 14 of an output-amplifier stage 20. This stage 20 comprises a PNP output transistor T_1 and an NPN output transistor T_2 , whose collector-emitter paths are arranged in series between the positive and the negative power-supply terminal 2 and 3. The collectors of transistors T_1 and T_2 are connected to the output 4 of the amplifier arrangement, to which output a load may be connected. The base of transistor T_1 is connected to the input 13 and the base of transistor T_2 is connected to the input 14 of the output amplifier stage 20. A resistor R_1 and the base-emitter junction of a transistor T_3 are connected in parallel with the base-emitter junction of transistor T_1 , the collector of said transistor T_3 being connected to one end 5 of a resistor R_2 , whose other end is connected to the emitter of a transistor T_4 whose base is connected to the base of transistor T_2 and whose collector is connected to the power-supply terminal 3. The resistor R_2 and the transistor T_4 are identical to the resistor R_1 and the transistor T_3 respectively. The output stage further comprises a differential amplifier provided with transistors T_5 and T_6 , in whose emitter lines resistors R_3 are arranged. The common-emitter terminal is connected to the negative power-supply terminal 3 by means of a current source $I_1=2I$. The collector of the transistor T_5 is connected to the positive power-supply terminal 2 via a current source $I_2=I$ and to the base of transistor T_2 . Similarly, the collector of transistor T_6 is connected to the power-supply terminal 2 via a current source $I_3=I$ and to the base of transistor T_1 . The base of transistor T_5 is connected to the end 5 of resistor R_2 and the base of transistor T_6 is at a reference voltage equal to the sum of the base-emitter voltages of a diode-connected PNP transistor T_7 and a diode-connected NPN transistor T_8 . A current from the current source I_4 , for example a current of the value $I_4=I/3$, flows through the transistors T_7 , T_8 .

The circuit arrangement operates as follows. It is assumed that the inputs 13 and 14 do not receive a drive signal and that the voltage on point 6 is higher than that on point 5. The collector current of transistor T_6 is then larger than I and the collector current of transistor T_5 is then an equal amount smaller than I . As a result of this, both the base current of transistor T_1 and the base current of transistor T_2 will increase, resulting in an increase of the base-emitter voltages of transistor T_1 and transistor T_2 . Via the voltage-to-current converter T_3 , R_1 , the base-emitter voltage of transistor T_1 is converted into a current, which is re-converted into said base-emitter voltage between point 5 and the base of transistor T_4 by the current-to-voltage converter R_2 , T_4 . The base-emitter voltage of transistor T_2 appears between the base and the collector of transistor T_4 . Due to the increase of the base-emitter voltages of transistors T_1 and T_2 the voltage on the base of transistor T_5 will also increase. In this way the voltage on point 5 is controlled so as to become equal to the voltage on point 6, a small quiescent current flowing in the transistors T_1 and T_2 so that class AB operation is obtained. In the balanced state the currents from the current sources I_2 and I_3 are wholly drained by the transistors T_5 and T_6 . The base currents of the transistors T_1 and T_2 are then furnished by the preamplifier stage 10, which results in a small offset of this stage.

If for example the base current of transistor T_1 increases and that of transistor T_2 decreases when the output stage is driven, the base-emitter voltage of transistor T_1 will increase and the base-emitter voltage of transistor T_2 will decrease. If the increase of the base-emitter voltage of transistor T_1 is larger than the decrease of the base-emitter voltage of transistor T_2 the voltage on the base of transistor T_5 will increase relative to the voltage on the base of transistor T_6 . This causes the base current of transistor T_2 and that of transistor T_1 to decrease, which results in a further decrease of the base-emitter voltage of transistor T_2 and a smaller increase of the base-emitter voltage of the transistor T_1 . In this way the voltage on point 5 is controlled until it has become equal to the voltage on point 6, the increase of the base-emitter voltage of transistor T_1 then being equal to the decrease of the base-emitter voltage of transistor T_2 . During driving large currents may flow in transistor T_1 . The current in transistor T_3 should then be much smaller. For this purpose the emitter area of transistor T_3 is made substantially smaller than that of transistor T_1 . For a further reduction of the currents through this transistor a resistor R_1 is arranged in the emitter line of transistor T_3 in the present embodiment. However, this resistor may be dispensed with if this further reduction is not necessary. Preferably, the reference voltage on the base of transistor T_6 is generated by a diode-connected PNP transistor T_7 and a diode-connected NPN transistor T_8 which are of the same type as PNP transistor T_1 and NPN transistor T_2 respectively. This has the advantage that the

characteristics of these transistors are identical, so that possible variations, such temperature variations, have the same effect on the voltages on the bases of transistors T_5 and T_6 .

As stated in the foregoing the preamplifier stage 10 may be of any conventional design. However, the push-pull amplifier shown in Figure 2 is equipped with a new type of preamplifier which has been described comprehensively in the above mentioned European Patent Application 85200243. Corresponding parts bear the same reference numerals as in Figure 1. The preamplifier 10 comprises a differential amplifier with transistors T_9 and T_{10} whose emitters are connected to the positive power-supply terminal 2 via a current source $I_5=I$ and a current source $I_6=I$ respectively. Further, a resistor R_5 is arranged between the emitters of the transistors T_9 and T_{10} . The collector of transistor T_9 is connected directly to the negative power-supply terminal 3 and the collector of transistor T_{10} is connected to this terminal via a current source I_7 supplying a current of for example $I_7=3.5I$. The current source I_7 is also connected in cascade with transistors T_{11} and T_{12} , whose commoned bases carry a reference voltage V_R . This reference voltage V_R is adequate to keep the current source I_7 operative. The collectors of the transistors T_{11} , T_{12} are connected to the current sources I_3 and I_2 respectively, which each supply currents $2I$ and which are connected to the positive power-supply terminal 2. The collector of transistor T_{10} is connected to the output 4 by a resistor R_9 . In the quiescent state the transistors T_5 and T_6 drain half the current from the respective current source I_2 and the current source I_3 . The other halves of the currents from these current sources and the current from the current source I_6 which flows through transistor T_{10} are drained by the current source I_7 . The residual $0.5 I$ required by the current source I_7 is furnished via the resistor R_9 . This resistor has such a resistance value that the voltage on the output 4 is equal to half the supply voltage. If the collector current of transistor T_{10} for example decreases due to the application of a difference signal between the inverting and the non-inverting input, the additional current required by the current source I_7 will initially cause the current through transistors T_{11} and T_{12} to increase, so that the base current of transistor T_1 increases and that of transistor T_2 decreases. In the manner described with reference to Figure 1 the sum of the base-emitter voltages of transistors T_1 and T_2 is then maintained equal to the reference voltage across the diode-connected transistors T_7 , T_8 by means of the differential amplifier T_5 , T_6 .

The invention is not limited to the embodiments shown. For example, the base-emitter voltage of transistor T_2 may be added to the base-emitter voltage of transistor T_1 via a voltage-to-current converter and a current-to-voltage converter. The remainder of the circuit may then be inverted by replacing the transistors by transistors of opposite conductivity types.

Claims

1. A push-pull amplifier comprising:

—a preamplifier stage having a first and a second output,

—an output amplifier stage which comprises a first and a second transistor of opposite conductivity types, whose collector-emitter paths are arranged in series between two power-supply terminals and whose collectors are coupled to an output terminal, the base of the first transistor being driven by the first output and the base of the second transistor being driven by the second output of the preamplifier stage, and

—means for maintaining the sum of the base-emitter voltages of the first and the second transistor substantially constant, which means comprise a voltage-to-current converter comprising a third transistor, for converting the base-emitter voltage of the first transistor into a current, and a current-to-voltage converter comprising a fourth transistor identical to the third transistor, for converting the current from the voltage-to-current converter into a voltage equal to said base-emitter voltage, the base of the fourth transistor being connected to the base of the second transistor,

characterized in that the means further comprise a fifth and a sixth transistor arranged as a differential pair and having a first current source arranged in the common emitter line, the base of the fifth transistor being coupled to the input of the current-voltage converter and the base of the sixth transistor being at a reference voltage which is equal to a voltage produced across two diodes by a constant current, the collectors of the fifth and the sixth transistor are each effectively loaded by one of two substantially identical current sources the sum of the currents in which is substantially equal to the current from the first current source, and the collectors of the fifth and the sixth transistor are further coupled to the bases of the first and the second transistor, respectively.

2. A push-pull amplifier as claimed in Claim 1, characterized in that the emitter area of the third and the fourth transistor is smaller than that of the first transistor.

3. A push-pull amplifier as claimed in Claim 1 or 2, characterized in that a resistor is arranged in the emitter line of the third and the fourth transistor.

4. A push-pull amplifier as claimed in Claim 1, 2 or 3, characterized in that the two diodes are diode-connected transistors of opposite conductivity types.

5. A push-pull amplifier as claimed in any one of the preceding Claims, characterized in that resistors are arranged in the emitter lines of the fifth and the sixth transistors.

Patentansprüche

1. Gegentaktverstärker, bestehend aus

—einer Vorverstärkerstufe mit einem ersten

characteristics of these transistors are identical, so that possible variations, such temperature variations, have the same effect on the voltages on the bases of transistors T_5 and T_6 .

As stated in the foregoing the preamplifier stage 10 may be of any conventional design. However, the push-pull amplifier shown in Figure 2 is equipped with a new type of preamplifier which has been described comprehensively in the above mentioned European Patent Application 85200243. Corresponding parts bear the same reference numerals as in Figure 1. The preamplifier 10 comprises a differential amplifier with transistors T_9 and T_{10} whose emitters are connected to the positive power-supply terminal 2 via a current source $I_5=I$ and a current source $I_6=I$ respectively. Further, a resistor R_5 is arranged between the emitters of the transistors T_9 and T_{10} . The collector of transistor T_9 is connected directly to the negative power-supply terminal 3 and the collector of transistor T_{10} is connected to this terminal via a current source I_7 supplying a current of for example $I_7=3.5I$. The current source I_7 is also connected in cascade with transistors T_{11} and T_{12} , whose commoned bases carry a reference voltage V_R . This reference voltage V_R is adequate to keep the current source I_7 operative. The collectors of the transistors T_{11} , T_{12} are connected to the current sources I_3 and I_2 respectively, which each supply currents $2I$ and which are connected to the positive power-supply terminal 2. The collector of transistor T_{10} is connected to the output 4 by a resistor R_9 . In the quiescent state the transistors T_5 and T_6 drain half the current from the respective current source I_2 and the current source I_3 . The other halves of the currents from these current sources and the current from the current source I_6 which flows through transistor T_{10} are drained by the current source I_7 . The residual $0.5 I$ required by the current source I_7 is furnished via the resistor R_9 . This resistor has such a resistance value that the voltage on the output 4 is equal to half the supply voltage. If the collector current of transistor T_{10} for example decreases due to the application of a difference signal between the inverting and the non-inverting input, the additional current required by the current source I_7 will initially cause the current through transistors T_{11} and T_{12} to increase, so that the base current of transistor T_1 increases and that of transistor T_2 decreases. In the manner described with reference to Figure 1 the sum of the base-emitter voltages of transistors T_1 and T_2 is then maintained equal to the reference voltage across the diode-connected transistors T_7 , T_8 by means of the differential amplifier T_5 , T_6 .

The invention is not limited to the embodiments shown. For example, the base-emitter voltage of transistor T_2 may be added to the base-emitter voltage of transistor T_1 via a voltage-to-current converter and a current-to-voltage converter. The remainder of the circuit may then be inverted by replacing the transistors by transistors of opposite conductivity types.

Claims

1. A push-pull amplifier comprising:

—a preamplifier stage having a first and a second output,

—an output amplifier stage which comprises a first and a second transistor of opposite conductivity types, whose collector-emitter paths are arranged in series between two power-supply terminals and whose collectors are coupled to an output terminal, the base of the first transistor being driven by the first output and the base of the second transistor being driven by the second output of the preamplifier stage, and

—means for maintaining the sum of the base-emitter voltages of the first and the second transistor substantially constant, which means comprise a voltage-to-current converter comprising a third transistor, for converting the base-emitter voltage of the first transistor into a current, and a current-to-voltage converter comprising a fourth transistor identical to the third transistor, for converting the current from the voltage-to-current converter into a voltage equal to said base-emitter voltage, the base of the fourth transistor being connected to the base of the second transistor,

characterized in that the means further comprise a fifth and a sixth transistor arranged as a differential pair and having a first current source arranged in the common emitter line, the base of the fifth transistor being coupled to the input of the current-voltage converter and the base of the sixth transistor being at a reference voltage which is equal to a voltage produced across two diodes by a constant current, the collectors of the fifth and the sixth transistor are each effectively loaded by one of two substantially identical current sources the sum of the currents in which is substantially equal to the current from the first current source, and the collectors of the fifth and the sixth transistor are further coupled to the bases of the first and the second transistor, respectively.

2. A push-pull amplifier as claimed in Claim 1, characterized in that the emitter area of the third and the fourth transistor is smaller than that of the first transistor.

3. A push-pull amplifier as claimed in Claim 1 or 2, characterized in that a resistor is arranged in the emitter line of the third and the fourth transistor.

4. A push-pull amplifier as claimed in Claim 1, 2 or 3, characterized in that the two diodes are diode-connected transistors of opposite conductivity types.

5. A push-pull amplifier as claimed in any one of the preceding Claims, characterized in that resistors are arranged in the emitter lines of the fifth and the sixth transistors.

Patentansprüche

1. Gegentaktverstärker, bestehend aus

—einer Vorverstärkerstufe mit einem ersten



und einem zweiten Ausgang,

—einer Ausgangsverstärkerstufe, die einen ersten und einen zweiten Transistor von entgegengesetzten Leitfähigkeitstypen enthält, deren Kollektor-Emitterstrecken in Reihe zwischen zwei Stromversorgungsanschlüssen und deren Kollektoren mit einem Ausgangsanschluß verbunden sind, wobei die Basis des ersten Transistors durch den ersten Ausgang und die Basis des zweiten Transistors durch den zweiten Ausgang der Vorverstärkerstufe getrieben wird, und

—Mitteln zum im wesentlichen Konstanthalten der Summe der Basis-Emitterspannung, und diese Mittel enthalten einen Spannungs/Stromwandler mit einem dritten Transistor zum Umsetzen der Basis-Emitterspannung des ersten Transistors in einen Strom, und einen Strom/Spannungswandler mit einem dem dritten Transistor gleichen vierten Transistor zum Umsetzen des Stroms aus dem Spannungs/Stromwandler in eine Spannung gleich der Basis-Emitterspannung, wobei die Basis des vierten Transistors mit der Basis des zweiten Transistors verbunden ist,

dadurch gekennzeichnet, daß die Mittel weiter einen fünften und einen sechsten Transistor enthalten, die als differentielles Paar geschaltet und mit einer ersten Stromquelle in der gemeinsamen Emitterleitung angeordnet sind, wobei die Basis des fünften Transistors mit dem Eingang des Strom/Spannungswandlers gekoppelt ist und die Basis des sechsten Transistors eine Referenzspannung gleich einer an zwei Dioden durch einen Konstantstrom erzeugten Spannung führt, daß die Kollektoren des fünften und sechsten Transistors je aus einer der beiden im wesentlichen gleichen Stromquellen wirksam geladen werden, in denen die Summe der Ströme im wesentlichen gleich dem Strom aus der ersten Stromquelle ist, und daß die Kollektoren des fünften und sechsten Transistors weiter mit den Basen des ersten bzw. des zweiten Transistors gekoppelt sind.

2. Gegentaktverstärker nach Anspruch 1, dadurch gekennzeichnet, daß das Emittergebiet des dritten und des vierten Transistors kleiner ist als das des ersten Transistors.

3. Gegentaktverstärker nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß in der Emitterleitung des dritten und des vierten Transistors ein Widerstand angeordnet ist.

4. Gegentaktverstärker nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß die zwei Dioden als Dioden geschaltete Transistoren von entgegengesetzten Leitfähigkeitstypen sind.

5. Gegentaktverstärker nach einem der vorangehenden Ansprüche, dadurch gekennzeichnet, daß in den Emitterleitungen des fünften und des sechsten Transistors Widerstände angeordnet sind.

Revendications

1. Amplificateur push-pull comprenant:

—un étage préamplificateur muni d'une première sortie et d'une seconde sortie,

—un étage amplificateur de sortie comprenant un premier et un deuxième transistor de types de conductivité opposés, dont les trajets collecteur-émetteur sont montés en série entre deux bornes d'alimentation, dont les collecteurs sont couplés à la borne de sortie, la base du premier transistor étant excitée par la première sortie et la base du deuxième transistor étant excitée par la deuxième sortie de l'étage préamplificateur et

—des moyens pour maintenir la somme des tensions de base-émetteur des premier et deuxième transistors pratiquement constante, moyens qui comprennent un convertisseur tension-courant muni d'un troisième transistor et servant à convertir la tension de base-émetteur du premier transistor en un courant, et un convertisseur courant-tension muni d'un quatrième transistor analogue au troisième transistor et servant à convertir le courant du convertisseur tension-courant en une tension égale à ladite tension de base-émetteur, la base du quatrième transistor étant connectée à la base du deuxième transistor,

caractérisé en ce que les moyens sont en outre munis d'un cinquième et d'un sixième transistor disposés comme paire différentielle et présentant une première source de courant disposée dans la ligne d'émetteur commune, la base du cinquième transistor étant couplée à l'entrée du convertisseur de courant de tension et la base du sixième transistor étant à une tension de référence qui est égale à une tension engendrée dans deux diodes par un courant constant, les collecteurs des cinquième et sixième transistors sont chargés chacun de façon effective par l'une de deux sources de courant pratiquement identiques, la somme des courants dans ces derniers étant pratiquement égale au courant provenant de la première source de courant, les collecteurs des cinquième et sixième transistors étant en outre couplés respectivement aux bases des premier et deuxième transistors.

2. Amplificateur push-pull selon la revendication 1, caractérisé en ce que les surfaces d'émetteur des troisième et quatrième transistors sont plus petites que celles du premier transistor.

3. Amplificateur push-pull selon la revendication 1 ou 2, caractérisé en ce qu'une résistance est disposée dans la ligne d'émetteur des troisième et quatrième transistors.

4. Amplificateur push-pull selon la revendication 1, 2 ou 3, caractérisé en ce que les deux diodes sont des transistors montés en diode de types de conductivité opposés.

5. Amplificateur push-pull selon l'une des revendications précédentes, caractérisé en ce que des résistances sont disposées dans les lignes d'émetteur des cinquième et sixième transistors.



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