

Description

The invention relates to a switching amplifier having an input, an output, a class B output stage comprising a first and second transistor, whose main current paths are arranged in series between power supply terminals and means for inhibiting current flow in the output in such a way that the output is isolated from the input and assumes a high-impedence state.

Such amplifiers may *inter alia* be used in sample-and-hold circuits in order to isolate the input of, for example, a Miller integrator from a signal input. Such an amplifier used for this purpose is known from IBM Technical Disclosure Bulletin, Vol. 19, No. 11, April 1977, pages 4211—4212. This amplifier comprises a pnp-differential pair with signal take-off *via* an npn-current mirror. An isolating diode is arranged between the collector of the output transistor of this current mirror—which collector is connected to the output—and the collector of the associated pnp-transistor of the differential pair. In order to switch off the amplifier the flow of current in the current mirror is inhibited by draining the collector currents of the transistors of the differential pair *via* two diodes. As a result of this, the current mirror transistors are turned off and the diode is also turned off, so that no current flows in the output. The drawback of this amplifier is that the amplifier does not have a class-B output stage and that the output is connected to the collector of a transistor (the output transistor of the current mirror) and to the cathode of the diode, which cathode is equivalent to an emitter. The stray capacitances involved in the case of the collector have different, in particular larger values than in the case of the diode so that the turn-off transient of the transistor is larger than the turn-off transient of the diode and, as a consequence, the two turn-off transients do not compensate for each other at the output.

A switching amplifier of the kind mentioned in the opening paragraph is known from "Electronic Design" Vol. 18, No. 11, May 24, 1970 page 90. This article shows a switchable class A amplifier output-stage comprising a first transistor which is arranged as an emitter-follower and a second transistor of the same conductivity type which is arranged as a current source. The base of the first transistor is connected to the input and the emitter thereof is coupled to the output *via* a diode. The collector of the second transistor is connected to the output. The base of the first transistor is further connected to a gating input. The base of the second transistor is connected *via* a diode to this gating input. The first transistor and the current source are switched-off by connecting this gating input to the negative supply terminal, whereby the diode in the emitter line of the first transistor prevents the reverse breakthrough of the base-emitter junction of the first transistor. This known class-A amplifier shows the same drawback as the amplifier known from the said IBM-article since the output of the ampli-

fier is again connected to the collector of a transistor and to the cathode of a diode.

In the Electronic Design-article it is mentioned that a similar switching technique can be used with class-B output stages without describing or showing any further details thereof.

If the switching amplifier is a class-B amplifier it is often necessary to equip this class-B amplifier with two output transistors of the same conductivity type in order to achieve a sufficiently high bandwidth, because in most IC techniques only transistors of one of the two conductivity types can be fabricated with satisfactory high-frequency properties. However, again this presents the problem that the output is connected both to the collector of a switched transistor and to the emitter of a switched transistor, which results in annoying switching transients at the output.

U.K. Patent Application GB 2 076 605 describes a class-B amplifier with a first and second output transistor of the same conductivity type. The emitter of the transistor is connected directly to the output of the amplifier and the collector of the second transistor is connected to this output *via* a diode which has the same forward direction as the collector current direction of the second transistor. In driving the first and the second transistors the voltage across the base-emitter junction of the first transistor and the diode is held equal to two diode voltages so as to obtain a class-B operation with a smooth cross-over behaviour.

It is the object of the invention to provide a switching amplifier of the type set forth in the opening paragraph, which can have satisfactory high-frequency properties, which can produce a comparatively small amount of switching transients and which can have a class-B output. The invention is characterized in that the first and the second transistors are of a first conductivity type, the emitter of the first transistor being connected to the output and being coupled to the collector of the second transistor, and said means comprise a first semiconductor junction which is arranged in the collector circuit of the second transistor between the collector of said second transistor and the output and which has a forward direction corresponding to the collector current direction of the second transistor and switching circuit which, in response to a switching signal, changes the direct voltages on the base of the first transistor and on a point between said first semiconductor junction and the collector of the second transistor relative to the voltage on the output in such a way that the first transistor and the first semiconductor junction are turned off, the switching circuit being arranged to carry the collector current of the second transistor at least initially when the semiconductor junction is turned off, so that initially the second transistor can remain conductive.

As the first transistor and the semiconductor junction are turned off *via* the switching circuit whilst at least initially the second transistor need not be turned off, the first transistor and the semiconductor junction can give rise to capacitive

switching transients of substantially equal magnitude, which largely compensate for each other on the output. It can be arranged that in the switched-on condition the first and the second transistor together function as a class-B output stage with satisfactory high-frequency properties.

There are several alternative possibilities for the take-over of the first and the second transistor in class-B operation. For example, the inventive principle may be applied to *inter alia* the class-B amplifier in accordance with US-A-4,300,103.

With respect to the turn-off of the first semiconductor junction and the take-over of the collector current of the second transistor the switching amplifier in accordance with the invention may further be characterised in that the switching circuit comprises a third transistor of the first conductivity type whose emitter electrode is connected to the point between said semiconductor junction and the collector of the second transistor, the voltage on the base of said third transistor being switched relative to the voltage on the output in response to the switching signal so as to turn off the first semiconductor junction, after which the third transistor carries the collector current of the second transistor.

In many output amplifiers comprising two output transistors of the same conductivity type, such as the output stage described in said U.S. Patent Specification, the first transistor is driven directly by the signal and the drive for the second transistor is derived from *inter alia* the base-emitter voltage of said first transistor. If the principle of the invention is used the second transistor may then be driven to the maximum extent when current flow in the output ceases. In order to preclude this the switching amplifier may further be characterised in that the amplifier comprises a feedback path between the collectors of the third transistor and the second transistor in order to apply negative feedback to the second transistor when the second semiconductor junction is in the cut-off state, so as to reduce the drive to the second transistor after the first semiconductor junction has been turned off.

With respect to the feedback the last-mentioned embodiment may further be characterised in that the feedback path comprises a fourth transistor of a second conductivity type opposite to the first conductivity type, which fourth transistor has its collector connected to the base of the second transistor, its emitter to a current source and to the collector of the third transistor, and its base to a point at reference voltage.

For an optimum combination of the switching circuit with the operation as a class-B output stage which may be required when the amplifier is switched-on, this embodiment may further be characterised in that a second semiconductor junction is arranged between the base of the first transistor and the base of the third transistor, which second semiconductor junction is biased with a constant direct current at least when the switching amplifier is in the non-switched-off state, in order to ensure that in this state the

voltage across the series arrangement of the base-emitter junction of the first transistor and the first semiconductor junction is maintained equal to two diode voltages so as to obtain class-B operation.

In this embodiment it is advantageous if the amplifier comprises switching means for turning off the second semiconductor junction and for rendering conductive a third semiconductor junction when the switching amplifier is switched off, which third semiconductor junction together with the base-emitter junction of the third transistor forms part of a series arrangement between the base of the first transistor and the point between the first semiconductor junction and the collector of the second transistor, in which series arrangement the third semiconductor junction has a forward direction opposite to the forward direction of the base-emitter junction of the third transistor, so that in the switched-off state of the switching amplifier a voltage of substantially zero volts appears between the base of said first transistor and said point between the first semiconductor junction and the collector of the second transistor.

With respect to the switching means this embodiment may further be characterised in that the switching means comprise a fifth and a sixth transistor of the first conductivity type with a common emitter-current source, which fifth and sixth transistors have their collectors connected to a terminal *via* impedances, the base of the first transistor being connected to the collector of the fifth transistor and the base of the third transistor being connected to the collector of the sixth transistor, and means being provided for generating on said terminal a voltage which is substantially one diode voltage higher than the voltage on the output. This embodiment may further be characterised in that the third semiconductor junction is arranged in parallel with the impedance in the collector circuit of the fifth transistor and a fourth semiconductor junction is arranged in parallel with the impedance in the collector circuit of the sixth transistor, the forward direction of said semiconductor junctions being the same as the forward direction of the fifth and the sixth transistor.

A special preferred embodiment of the switching amplifier in accordance with the invention is obtained when the output stage is an output stage as described in Applicant's previously filed Netherlands Patent Application No. 8 002 666 which has been laid open to public inspection. The switching amplifier in accordance with the invention is then further characterised in that a high-frequency transmissive bypass coupling is arranged between the collector of the third transistor and the base of the second transistor.

Using a minimal extension of a known output stage this yields a switching amplifier which meets the requirements. This preferred embodiment combines the basic idea of the invention with an optimum choice of an output stage.

The invention will now be described in more

detail, by way of example, with reference to the drawings, in which

Figure 1 shows a known sample-and-hold circuit in which the switching amplifier in accordance with the invention may be used.

Figure 2 is the circuit diagram of a switching amplifier in accordance with the invention, and

Figure 3 shows a preferred embodiment of the invention.

Figure 1 shows a sample-and-hold circuit as described in the afore-mentioned publication in IBM Technical Disclosure Bulletin, in which circuit the switching amplifier in accordance with the invention may be used. The sample-and-hold circuit has a signal input 1, which also forms a non-inverting input of a switching amplifier 2 having an inverting input 3 and a switching input 17. The output 5 of the switching amplifier 2 is connected to the inverting input of an amplifier 7 which is arranged as a Miller integrator by means of a capacitor 6 and which has its non-inverting input 8 connected to a point of fixed potential, in the present case earth. The output 9 of the sample-and-hold circuit is connected to the output of the amplifier 7, which has a feedback path to the inverting input 3 of the switching amplifier.

As a result of the amplifier 7 point 5 is at a substantially constant potential, in the present case OV (virtual earth). Because of the negative-feedback path the output 9 carries the signal on input 1 — or an amplified or attenuated version of this signal when various resistors are included in known manner. Consequently, this signal on input 1 appears across capacitor 6. If in response to a signal on input 17 amplifier 2 is turned off, the charge on capacitor 6 can no longer change and a sample of the input signal appears on output 9. Point 5 remains virtually at earth potential.

Figure 2 schematically represents the principle of one example of a switching amplifier 2 in accordance with the invention. In view of the bandwidth an npn-npn output stage with transistors T_1 and T_2 has been selected, whose base electrodes receive a drive signal in a manner not shown. For the manner in which these transistors are driven on point 12 and 13 reference is made to *inter alia* said United States Patent Specification No. 4,300,103 and to said Netherlands Patent Application No. 8 002 666. The transistors T_1 and T_2 are arranged in series between power-supply terminals 10 and 11. The emitter of transistor T_1 is connected to the output 4 which, as is indicated by the dashed sign, is virtually at earth potential as a result of the following stage and *via* a semiconductor junction T_3 it is also connected to the collector of transistor T_2 . The collector of transistor T_2 is connected to the emitter of npn-transistor T_4 , whose collector current is drained *via* point 14 in a manner not shown, for example directly to the positive power-supply terminal 11. The base of transistor T_4 is connected to an output 15 and the base of transistor T_1 is connected to an output 16 of a switching device 18 which has a switching input 17. Together with transistor T_4 the switching device 18 forms a switching circuit.

If by means of switching device 18 the voltage on the base of transistor T_4 is increased relative to the virtual earth on output 4 and simultaneously the voltage on the base of transistor T_1 is reduced relative to the virtual earth on output 4, diode T_3 and transistor T_1 are turned off. The stray capacitances which discharge during turn-off are base-emitter capacitances of equivalent capacitances in both cases, so that the discharge currents can compensate for each other on output 4 and no switching transient will arise. Transistor T_2 need not be turned off or need not be turned off simultaneously, for its collector current is transferred from diode T_3 to transistor T_4 and can be sustained. In order to minimize the dissipation transistor T_2 may be turned off or may be set to a low quiescent-current level, for example under control of the switching device 18 or from the collector of transistor T_4 .

Figure 3 shows a preferred embodiment of the invention, which embodiment employs an output stage as described in the afore-mentioned Netherlands Patent Application No. 8 002 666. This output stage comprises output transistors T_1 and T_2 and a diode T_3 between the output 4 and the collector of transistor T_2 . Transistor T_4 has its emitter connected to the collector of transistor T_2 and its base to a signal input 13, to the base of transistor T_1 and to a current source 21 *via* a diode T_6 . *Via* a resistor 19 the collector of transistor T_4 is connected to a current source 20 and the emitter of a pnp-transistor T_5 , whose base is connected to a point 22 which is at a reference voltage V_{ref} and whose collector is connected to the base of transistor T_2 . A bypass capacitor 23 is arranged between the collector of transistor T_4 and the base of transistor T_2 .

In this output stage the product of the collector currents of transistors T_1 and T_2 is maintained constant so that a class-B operation is obtained. The collector current of transistor T_1 is measured by means of its base-emitter voltage and the collector current of transistor T_2 by means of the voltage across diode T_3 . The voltage across the series arrangement of the diode T_3 and the base-emitter junction of transistor T_1 is therefore a measure of the product of the collector currents of transistors T_1 and T_2 . By means of transistor T_4 the voltage across this series arrangement is compared with the substantially constant sum of the voltage across the diode T_6 which is biased by the current source 21 and the base-emitter voltage of transistor T_4 which is biased by the current source 20. The variation of the collector current of transistor T_4 is therefore a measure of the variation of the product of the collector currents of transistors T_1 and T_2 , which variation is counteracted in that a point between the collector of transistor T_4 and the current source 20 is connected to the base of transistor T_2 *via* the emitter-collector path of pnp-transistor T_5 , so that variations in the product of the collector currents of transistors T_1 and T_2 are fed back in a negative sense to the base of transistor T_2 , capacitor 23 being a high-frequency by-pass across transistor

T_5 and resistor 19 preventing transistor T_5 from short-circuiting capacitor 23 for high frequencies. As a result of the presence of the transistor T_4 and diode T_3 this output stage is eminently suitable for use as a switching amplifier in conformity with the principle shown in Figure 2. For this purpose the switching device 18 is arranged between the base of transistors T_4 and T_1 . The device comprises two transistors T_7 and T_8 arranged as a differential pair and having a common emitter-current source 24. The collectors of these transistors are connected to an input 27 which is connected to an input stage, not shown, in such a way that the d.c. level on this point is one diode voltage V_d higher than the direct voltage on the output. However, it is to be noted that there are sample-and-hold circuits in which the sampling capacitor is arranged between an output and earth, so that output 4 does not carry a constant direct voltage but a varying signal voltage when the amplifier is switched on and the sampled signal values after the amplifier has been turned off. The follower action of the output stage ensures that the correct relationship between the voltage on the input 27 and the voltage on the output 4 is maintained when the amplifier is in the switched-on state. When the amplifier is in the turned-off state this relationship can be guaranteed if the voltage on input 27 tracks the voltage on output 4 (in this case with an offset of one diode voltage V_d), for example in a manner as described in US-A-3,694,668, where the voltage on the input of a diode switch is made to track the voltage across a sampling capacitor.

The collectors of transistors T_7 and T_8 are connected to input 27, via resistors 25 and 26 respectively. The collector of transistor T_8 is connected to the base of transistor T_1 and the collector of transistor T_7 is connected to the base of transistor T_4 . Diodes T_9 and T_{10} are arranged in parallel with the resistors 25 and 26.

In order to explain the operation two conditions will be considered:

The switching amplifier is turned on, i.e. a voltage is applied to input 17 such that transistor T_7 conducts and transistor T_8 is cut off. The conduction of transistor T_7 ensures that current from the current source 21 can be drained via diode T_8 , so that the output stage comprising transistors T_1 and T_2 is correctly biased. Since no current flows through resistor 26 input 13 will be at the same voltage V_d as input 27. Consequently, the base of transistor T_1 is at a voltage equal to substantially one diode voltage relative to output 4 so that this transistor can conduct in dependence upon the signal on input 27.

The base of transistor T_4 is connected to point 27 via diode T_6 and via diode T_9 — which carries substantially a current determined by the difference between the currents from the current sources 21 and 24, so that the voltage across diode T_9 can be equal to that across diode T_6 — and therefore is at a voltage of substantially zero volts relative to output 4. Therefore, one diode voltage may appear across diode T_3 so that diode

T_3 can also conduct. The circuit then operates as a class-B output stage. This condition is represented in Figure 4, which shows that part of the circuit of Figure 3 which is relevant to the present explanation, the non-conductive transistor T_8 and the non-conductive diode T_{10} not being shown. Assuming that no current flows in resistors 26 and 25 a current I_0 supplied by the source 21 will flow through the diode T_6 . If source 24 supplies a current $2I_0$ the current through diode T_9 will also be I_0 and if diodes T_9 and T_6 are identical the voltage across these diodes are also equal, so that the situation is in conformity with the assumption that (substantially) no current flows through the resistor 26. The voltage as a result of the current I_0 through diodes T_6 and T_9 appears between the base of transistor T_1 and the base of transistor T_4 , which is biased at a current which is assumed to be equal to I_0 by current source 20. The sum of the voltages across the junctions of T_6 and T_4 which are biased by currents I_0 , therefore appears between the base transistor T_1 and the cathode of diode T_3 , so that the emitter current I_1 of transistor T_1 and the current I_2 through diode T_3 comply with: $I_1 I_2 = C I_0^2$, where C is a constant.

The switching amplifier is turned off, for which purpose the switching voltage on switching input 17 is such that transistor T_7 is cut off and transistor T_8 conducts. The current from current source 21 then flows via transistor T_8 and no current flows in diode T_6 and diode T_9 , whilst diode T_{10} conducts. The voltage on the base of transistor T_1 is therefore one diode voltage lower than the voltage on input V_d , i.e. a voltage of substantially zero volts relative to output 4, so that transistor T_1 is cut off. The base of transistor T_4 is connected to input 27 via resistor 25, which carries no voltage because transistor T_7 is cut off and is therefore at a voltage equal to substantially one diode voltage, so that the emitter of transistor T_4 is at a voltage of substantially zero volts relative to output 4 and diode T_3 is consequently cut off. Therefore, no current flows in output 4. Transistor T_2 can remain conductive via transistor T_4 , so that transistor T_5 also remains conductive. Since the current flow in diode T_3 ceases as a result of the negative feedback via transistors T_4 and T_5 the collector current of transistor T_2 would tend to keep the voltage across the series arrangement of diode T_3 and the base-emitter junction of transistor T_1 constant and equal to two diode voltages, but as the voltage across diode T_6 is reversed the voltage across the series arrangement of diode T_6 and the base-emitter junction of voltage T_4 will also be substantially zero.

This condition is illustrated by Figure 5, in which diodes T_9 and T_6 and transistor T_7 are not shown because they do not conduct and in which all further parts which are not relevant are also not shown. The current $2I_0$ from the current source 24 is distributed between diode T_{10} and the current source 21, so that a current I_0 flows through diode T_{10} . Apart from the voltage as a result of the base current of transistor T_4 , no voltage drop is produced across the resistor 25,

so that the base of transistor T_4 is at a potential which is one diode voltage higher than that on the base of transistor T_1 and the voltage between the base of transistor T_1 and the cathode of diode T_3 is zero volts.

In Figure 4 it has been assumed that no current flows in the resistor 25 in parallel with the conductive diode T_9 . In reality a current I_R flows in this resistor, which current is equal to the voltage across diode T_9 divided by the resistance value of the resistor 25. This current I_R disturbs the distribution of current between the diodes T_9 and T_8 , so that a direct current will flow through the resistor 26. This may be precluded by selecting for the current source 24 a source which supplies a current $2I_0 + I_R$, so as to provide compensation for the current I_R through the resistor 25. For this purpose it is possible to use for example, the current source shown in Figure 6, where the current $2I_0$ from a source is reflected to the emitters of transistors T_7 and T_8 by means of a current mirror comprising transistors T_{11} and T_{12} and a diode T_{13} . By connecting a resistor 31 in parallel with the diode T_{13} , the resistance of which resistor relative to the diode T_{13} which carries a current $2I_0$, that a current I_R flows through it, the emitters of transistors T_7 and T_8 receive a current $2I_0 + I_R$, thus compensating for the current I_R through the resistor 25 (and the current through resistor 26 in the situation shown in Figure 5).

Claims

1. A switching amplifier having an input, an output, a class-B output stage comprising a first and a second transistor, whose main current paths are arranged in series between power supply terminals and means for inhibiting current flow in the output in such a way that the output is isolated from the input and assumes a high-impedance state, characterized in that the first and the second transistors (T_1 , T_2) are of a first conductivity type, the emitter of the first transistor (T_1) being connected to the output (4) and being coupled to the collector of the second transistor (T_2), and said means comprise a first semiconductor junction (T_3) which is arranged in the collector circuit of the second transistor (T_2) between the collector of said second transistor (T_2) and the output (4) and which has a forward direction corresponding to the collector current direction of the second transistor (T_2) and a switching circuit which, in response to a switching signal, changes the direct voltages on the base of the first transistor (T_1) and on a point between said first semiconductor junction (T_3) and the collector of the second transistor (T_2) relative to the voltage on the output in such a way that the first transistor (T_1) and the first semiconductor junction (T_3) are turned off, the switching circuit being arranged to carry the collector current of the second transistor (T_2) at least initially when the semiconductor junction (T_3) is turned off, so that initially the second transistor (T_2) can remain conductive.

2. A switching amplifier as claimed in claim 1,

characterised in that the switching circuit comprises a third transistor (T_4) of the first conductivity type whose emitter electrode is connected to the point between said semi-conductor junction (T_3) and the collector of the second transistor (T_2), the voltage on the base (15) of said third transistor (T_4) being switched relative to the voltage on the output (4) in response to the switching signal so as to turn off the first semiconductor junction (T_3), after which the third transistor (T_4) carries the collector current of the second transistor (T_2).

3. A switching amplifier as claimed in claim 2, characterised in that the amplifier comprises a feedback path between the collector of the third transistor (T_4) and the base of the second transistor (T_2) in order to apply negative feedback to the second transistor (T_2) when the first semiconductor junction (T_3) is in the cut-off state, so as to reduce the drive to the second transistor (T_2) after the first semiconductor junction (T_3) has been turned off.

4. A switching amplifier as claimed in claim 3, characterised in that the feedback path comprises a fourth transistor (T_5) of a second conductivity type opposite to the first conductivity type, which fourth transistor (T_5) has its collector connected to the base (12) of the second transistor (T_2), its emitter to a current source (20) and to the collector of the third transistor (T_4), and its base (22) to a point at reference voltage (V_{ref}).

5. A switching amplifier as claimed in claim 4, characterised in that a second semiconductor junction (T_6) is arranged between the base of the first transistor (T_1) and the base of the third transistor (T_4), which second semiconductor junction (T_6) is biased with a constant direct current (21) at least when the switching amplifier is in the non-switched-off state, in order to ensure that in this state the voltage across the series arrangement of the base-emitter junction of the first transistor (T_1) and the first semiconductor junction (T_3) is maintained equal to two diode voltages so as to obtain class-B operation.

6. A switching amplifier as claimed in claim 5, characterised in that the amplifier comprises switching means for turning off the second semiconductor junction (T_6) and for rendering conductive a third semi-conductor junction (T_{10}) when the switching amplifier is switched off, which third semiconductor junction (T_{10}) together with the base-emitter junction of the third transistor (T_4) forms part of a series arrangement between the base of the first transistor (T_1) and the point between the first semiconductor junction (T_3) and the collector of the second transistor (T_2), in which series arrangement the third semiconductor junction (T_{10}) has a forward direction opposite to the forward direction of the base-emitter junction of the third transistor (T_4), so that in the switched-off state of the switching amplifier a voltage of substantially zero volts appears between the base of said first transistor (T_1) and said point between the first semiconductor junction (T_3) and the collector of the second transistor (T_2).

so that the base of transistor T_4 is at a potential which is one diode voltage higher than that on the base of transistor T_1 and the voltage between the base of transistor T_1 and the cathode of diode T_3 is zero volts.

In Figure 4 it has been assumed that no current flows in the resistor 25 in parallel with the conductive diode T_9 . In reality a current I_R flows in this resistor, which current is equal to the voltage across diode T_9 divided by the resistance value of the resistor 25. This current I_R disturbs the distribution of current between the diodes T_9 and T_8 , so that a direct current will flow through the resistor 26. This may be precluded by selecting for the current source 24 a source which supplies a current $2I_0 + I_R$, so as to provide compensation for the current I_R through the resistor 25. For this purpose it is possible to use for example, the current source shown in Figure 6, where the current $2I_0$ from a source is reflected to the emitters of transistors T_7 and T_8 by means of a current mirror comprising transistors T_{11} and T_{12} and a diode T_{13} . By connecting a resistor 31 in parallel with the diode T_{13} , the resistance of which resistor relative to the diode T_{13} which carries a current $2I_0$, that a current I_R flows through it, the emitters of transistors T_7 and T_8 receive a current $2I_0 + I_R$, thus compensating for the current I_R through the resistor 25 (and the current through resistor 26 in the situation shown in Figure 5).

Claims

1. A switching amplifier having an input, an output, a class-B output stage comprising a first and a second transistor, whose main current paths are arranged in series between power supply terminals and means for inhibiting current flow in the output in such a way that the output is isolated from the input and assumes a high-impedance state, characterized in that the first and the second transistors (T_1 , T_2) are of a first conductivity type, the emitter of the first transistor (T_1) being connected to the output (4) and being coupled to the collector of the second transistor (T_2), and said means comprise a first semiconductor junction (T_3) which is arranged in the collector circuit of the second transistor (T_2) between the collector of said second transistor (T_2) and the output (4) and which has a forward direction corresponding to the collector current direction of the second transistor (T_2) and a switching circuit which, in response to a switching signal, changes the direct voltages on the base of the first transistor (T_1) and on a point between said first semiconductor junction (T_3) and the collector of the second transistor (T_2) relative to the voltage on the output in such a way that the first transistor (T_1) and the first semiconductor junction (T_3) are turned off, the switching circuit being arranged to carry the collector current of the second transistor (T_2) at least initially when the semiconductor junction (T_3) is turned off, so that initially the second transistor (T_2) can remain conductive.

2. A switching amplifier as claimed in claim 1,

characterised in that the switching circuit comprises a third transistor (T_4) of the first conductivity type whose emitter electrode is connected to the point between said semi-conductor junction (T_3) and the collector of the second transistor (T_2), the voltage on the base (15) of said third transistor (T_4) being switched relative to the voltage on the output (4) in response to the switching signal so as to turn off the first semiconductor junction (T_3), after which the third transistor (T_4) carries the collector current of the second transistor (T_2).

3. A switching amplifier as claimed in claim 2, characterised in that the amplifier comprises a feedback path between the collector of the third transistor (T_4) and the base of the second transistor (T_2) in order to apply negative feedback to the second transistor (T_2) when the first semiconductor junction (T_3) is in the cut-off state, so as to reduce the drive to the second transistor (T_2) after the first semiconductor junction (T_3) has been turned off.

4. A switching amplifier as claimed in claim 3, characterised in that the feedback path comprises a fourth transistor (T_5) of a second conductivity type opposite to the first conductivity type, which fourth transistor (T_5) has its collector connected to the base (12) of the second transistor (T_2), its emitter to a current source (20) and to the collector of the third transistor (T_4), and its base (22) to a point at reference voltage (V_{ref}).

5. A switching amplifier as claimed in claim 4, characterised in that a second semiconductor junction (T_6) is arranged between the base of the first transistor (T_1) and the base of the third transistor (T_4), which second semiconductor junction (T_6) is biased with a constant direct current (21) at least when the switching amplifier is in the non-switched-off state, in order to ensure that in this state the voltage across the series arrangement of the base-emitter junction of the first transistor (T_1) and the first semiconductor junction (T_3) is maintained equal to two diode voltages so as to obtain class-B operation.

6. A switching amplifier as claimed in claim 5, characterised in that the amplifier comprises switching means for turning off the second semiconductor junction (T_6) and for rendering conductive a third semi-conductor junction (T_{10}) when the switching amplifier is switched off, which third semiconductor junction (T_{10}) together with the base-emitter junction of the third transistor (T_4) forms part of a series arrangement between the base of the first transistor (T_1) and the point between the first semiconductor junction (T_3) and the collector of the second transistor (T_2), in which series arrangement the third semiconductor junction (T_{10}) has a forward direction opposite to the forward direction of the base-emitter junction of the third transistor (T_4), so that in the switched-off state of the switching amplifier a voltage of substantially zero volts appears between the base of said first transistor (T_1) and said point between the first semiconductor junction (T_3) and the collector of the second transistor (T_2).



7. A switching amplifier as claimed in claim 6, characterised in that the switching means comprise a fifth (T_5) and a sixth transistor (T_6) of the first conductivity type with a common emitter-current source (24), which fifth (T_5) and sixth (T_6) transistors have their collectors connected to a terminal (27) via impedances (25, 26), the base of the first transistor (T_5) being connected to the collector of the fifth transistor (T_5) and the base of the third transistor (T_3) being connected to the collector of the sixth transistor (T_6), and means (T_9) being provided for generating on said terminal (27) a voltage which is substantially one diode voltage higher than the voltage on the output (4).

8. A switching amplifier as claimed in claim 7, characterised in that the third semiconductor junction (T_{10}) is arranged in parallel with the impedance (26) in the collector circuit of the fifth transistor (T_5) and a fourth semiconductor junction (T_9) is arranged in parallel with the impedance (25) in the collector circuit of the sixth transistor (T_6), the forward direction of said semiconductor junctions (T_{10} , T_9) being the same as the forward direction of the fifth (T_5) and sixth (T_6) transistor.

9. A switching amplifier as claimed in any of the Claims 2 to 8, characterised in that a high-frequency transmissive bypass coupling (23) is arranged between the collector of the third transistor (T_3) and the base of the second transistor (T_2).

Patentansprüche

1. Umschaltverstärker mit einem Eingang, einem Ausgang, einer Ausgangsstufe im B-Betrieb mit einem ersten und einem zweiten Transistor, deren Hauptstromwege zwischen Stromversorgungsanschlüssen in Reihegeschaltet sind und Mitteln zur Stromflussverhinderung im Ausgang derart, dass der Ausgang vom Eingang isoliert wird und einen Hochimpedanz Zustand annimmt, dadurch gekennzeichnet, dass der erste und der zweite Transistor, (T_1 , T_2) von einem ersten Leitfähigkeitstyp sind, wobei der Emittor des ersten Transistors (T_1) an den Ausgang (4) angeschlossen und mit dem Kollektor des zweiten Transistors (T_2) gekoppelt ist, und dass die genannten Mittel einen ersten Halbleiterübergang (T_3) enthält, der in der Kollektorschaltung des zweiten Transistors (T_2) zwischen dem Kollektor des zweiten Transistors (T_2) und dem Ausgang (4) angeordnet ist, und eine Durchlassrichtung hat entsprechend der Kollektorstromrichtung des zweiten Transistors (T_2) und einen Umschaltkreis enthält, der, in Beantwortung eines Umschaltsignals die Gleichspannungen an der Basis des ersten Transistors (T_1) und an einem Punkt zwischen dem ersten Halbleiterübergang (T_3) und dem Kollektor des zweiten Transistors (T_2) in bezug auf die Spannung am Ausgang derart ändert, dass der erste Transistor (T_1) und der erste Halbleiterübergang (T_3) abgeschaltet werden, wobei der Umschaltkreis wenigstens an-

fänglich zum Führen des Kollektorstroms des zweiten Transistors (T_2) angeordnet ist, wenn der Halbleiterübergang (T_3) abgeschaltet wird, so dass anfänglich der zweite Transistor (T_2) im leitenden Zustand bleibt.

2. Umschaltverstärker nach Anspruch 1, dadurch gekennzeichnet, dass der Umschaltkreis einen dritten Transistor (T_4) vom ersten Leitfähigkeitstyp enthält, dessen Emittorelektrode an den Punkt zwischen dem Halbleiterübergang (T_3) und dem Kollektor des zweiten Transistors (T_2) angeschlossen ist, wobei die Spannung an der Basis (15) des dritten Transistors (T_4) in bezug auf die Spannung am Ausgang (4) in Beantwortung des Umschaltsignals derart umgeschaltet wird, dass der erste Halbleiterübergang (T_3) abgeschaltet wird, wonach der dritte Transistor (T_4) den Kollektorstrom des zweiten Transistors (T_2) führt.

3. Umschaltverstärker nach Anspruch 2, dadurch gekennzeichnet, dass der Verstärker einen Rückkopplungsweg zwischen dem Kollektor des dritten Transistors (T_4) und der Basis des zweiten Transistors (T_2) zum Anlegen negativer Rückkopplung an den zweiten Transistor (T_2) enthält, wenn der erste Halbleiterübergang (T_3) sich im Sperrzustand befindet, um die Ansteuerung zum zweiten Transistor zu reduzieren, nachdem der erste Halbleiterübergang (T_3) abgeschaltet wurde.

4. Umschaltverstärker nach Anspruch 3, dadurch gekennzeichnet, dass der Rückkopplungsweg einen vierten Transistor (T_5) eines dem ersten Leitfähigkeitstyp entgegengesetzten zweiten Leitfähigkeitstyp enthält, dieser vierten Transistor (T_5) mit seinem Kollektor an die Basis (12) des zweiten Transistors (T_2), dessen Emittor an eine Stromquelle (20) und an den Kollektor des dritten Transistors (T_4), und seine Basis (22) an einen Punkt mit Referenzspannung (V_{ref}) angeschlossen sind.

5. Umschaltverstärker nach Anspruch 4, dadurch gekennzeichnet, dass ein zweiter Halbleiterübergang (T_6) zwischen der Basis des ersten Transistors (T_1) und der Basis des dritten Transistors (T_4) angeordnet ist, wobei der zweite Halbleiterübergang (T_6) mit einem Konstantgleichstrom (21) wenigstens im nicht abgeschalteten Zustand des Umschaltverstärkers vorgespannt ist, um zu gewährleisten, dass in diesem Zustand die Spannung an der Serienschaltung des Basis-Emitter-Übergangs des ersten Transistors (T_1) und des ersten Halbleiterübergangs (T_3) zum Erzielen von B-Betrieb gleich zwei Diodenspannungen erhalten wird.

6. Umschaltverstärker nach Anspruch 5, dadurch gekennzeichnet, dass der Verstärker Schmittmittel zum Abschalten des zweiten Halbleiterübergangs (T_6) und zum Erhalten des leitenden Zustands eines dritten Halbleiterübergangs (T_{10}) enthält, denn der Umschaltverstärker abgeschaltet wird, und dieser dritte Halbleiterübergang (T_{10}) zusammen mit dem Basis-Emitter-Übergang des dritten Transistors (T_4) einen Teil einer Serienschaltung zwischen der Basis des ersten Transistors (T_1) und dem Punkt zwischen dem ersten Halbleiterübergang (T_3) und dem Kollektor des



zweiten Transistors (T_2) bildet, wobei in dieser Serienschaltung der dritte Halbleiterübergang (T_{10}) eine Durchlassrichtung entgegengesetzt zur Durchlassrichtung des Basis-Emitterübergangs des dritten Transistors (T_4) derart enthält, dass im abgeschalteten Zustand des Umschaltverstärkers eine Spannung von im wesentlichen Null Volt zwischen der Basis des ersten Transistors (T_1) und dem Punkt zwischen dem ersten Halbleiterübergang (T_9) und dem Kollektor des zweiten Transistors (T_2) erscheint.

7. Umschaltverstärker nach Anspruch 6, dadurch gekennzeichnet, dass die Umschaltmittel einen fünften (T_5) und einen sechsten Transistor (T_7) vom ersten Leitfähigkeitstyp mit einer gemeinsamen Emitterstromquelle (24) enthalten, und diese fünften (T_5) und sechsten (T_7) Transistoren mit ihren Kollektoren an einen Anschluss (27) über Impedanzen (25, 26) angeschlossen sind, wobei die Basis des ersten Transistors (T_1) an den Kollektor des fünften Transistors (T_5) und die Basis des dritten Transistors (T_4) an den Kollektor des sechsten Transistors (T_7) angeschlossen sind, und Mittel zum Erzeugen einer Spannung an diesem Anschluss (27) vorgesehen sind und diese Spannung im wesentlichen eine Diodenspannung höher als die Spannung am Ausgang (4) ist.

8. Umschaltverstärker nach Anspruch 7, dadurch gekennzeichnet, dass der dritte Halbleiterübergang (T_{10}) parallel zur Impedanz (26) im Kollektorkreis des fünften Transistors (T_5) und ein vierter Halbleiterübergang (T_9) parallel zur Impedanz (25) im Kollektorkreis des sechsten Transistors (T_7) angeordnet sind, wobei die Durchlassrichtung der erwähnten Halbleiterübergänge (T_{10} , T_9) gleich der Durchlassrichtung der fünften (T_5) und sechsten (T_7) Transistoren ist.

9. Umschaltverstärker nach einem oder mehreren der Ansprüche 2 bis 8, dadurch gekennzeichnet, dass eine durchlässige Hochfrequenz-Überbrückungskopplung (23) zwischen dem Kollektor des dritten Transistors (T_4) und der Basis des zweiten Transistors (T_2) angeordnet ist.

Revendications

1. Amplificateur de commutation comportant une entrée, une sortie, un étage de sortie de classe B muni d'un premier transistor et d'un deuxième transistor, dont les trajets de courant principaux sont disposés en série des bornes d'alimentation et de moyens pour éviter la circulation de courant dans la sortie de façon que la sortie soit isolée l'entrée et assume un état d'impédance élevée, caractérisé en ce que les premier et deuxième transistors (T_1 , T_2) sont d'un premier type de conduction, l'émetteur du premier transistor (T_1) étant connecté à la sortie (4) et couplé au collecteur du deuxième transistor (T_2), et lesdits moyens comprennent une première jonction semiconductrice (T_3), qui est disposée dans le circuit de collecteur du deuxième transistor (T_2) entre le collecteur dudit deuxième transistor (T_2) et la sortie (4) et qui présente un sens conducteur correspondant au sens du courant

traversant le collecteur du deuxième transistor (T_2) et un circuit de commutation qui, en réponse à signal de commutation, change les tensions continues à la base du premier transistor (T_1) et à un point situé entre ladite première jonction semiconductrice (T_3) et le collecteur du deuxième transistor (T_2) par rapport à la tension à la sortie de façon à provoquer le blocage du premier transistor (T_1) et de la première jonction semiconductrice (T_3), le circuit de commutation étant conçu de façon que, lors du blocage de la jonction semiconductrice (T_3), il peut être traversé au moins initialement, par le courant de collecteur du deuxième transistor (T_2), de sorte qu'initialement le deuxième transistor (T_2) peut rester conducteur.

2. Amplificateur de commutation selon la revendication 1, caractérisé en ce que le circuit de commutation comporte un troisième transistor (T_4) du premier genre de conduction, dont l'électrode d'émetteur est connectée au point situé entre ladite jonction semiconductrice (T_3) et le collecteur du deuxième transistor (T_2), la tension à la base (15) dudit troisième transistor (T_4) étant commutée par rapport à la tension à la sortie (4) en réponse au signal de commutation en vue de bloquer la première jonction semiconductrice (T_3), après quoi troisième transistor (T_4) est traversé par le courant de collecteur du second transistor (T_2).

3. Amplificateur de commutation selon la revendication 2, caractérisé en ce que l'amplificateur comporte un trajet de réaction entre le collecteur du troisième transistor (T_4) et la base du deuxième transistor (T_2) afin d'appliquer une contre-réaction au deuxième transistor (T_2) lorsque la première jonction semiconductrice (T_3) est à l'état de blocage, en vue de réduire l'excitation au deuxième transistor après blocage de la première jonction semiconductrice (T_3).

4. Amplificateur de commutation selon la revendication 3, caractérisé en ce que le trajet de réaction comporte un quatrième transistor (T_5) d'un deuxième type de conduction, qui est opposé au premier type de conduction, le collecteur du quatrième transistor (T_5) étant connecté à la base (12) du deuxième transistor (T_2), son émetteur à une source de courant (20) et au collecteur du troisième transistor (T_4), et sa base (22) à un point soumis à une tension de référence (V_{ref}).

5. Amplificateur de commutation selon la revendication 4, caractérisé en ce qu'une deuxième jonction semiconductrice (T_6) est prévue entre la base du premier transistor (T_1) et la base du troisième transistor (T_4), deuxième jonction semiconductrice (T_6) qui est polarisée par un courant continu constant (Z1) au moins lorsque l'amplificateur de commutation est à l'état non bloqué, afin d'assurer qu'à cet état, la tension aux extrémités du montage en série de la jonction base-émetteur du premier transistor (T_1) et la première jonction semiconductrice (T_3) est maintenue égale à deux tensions de diode afin d'obtenir le mode de fonctionnement de classe B.



6. Amplificateur de commutation selon la revendication 5, caractérisé en ce que l'amplificateur comporte des moyens de commutation pour le blocage de la deuxième jonction semiconductrice (T_6) et pour rendre une troisième jonction semiconductrice (T_{10}) conductrice lorsque l'amplificateur de commutation est mis hors service, cette troisième jonction semiconductrice (T_{10}), ensemble avec la jonction base-émetteur de troisième transistor (T_4) formant une partie d'un montage en série entre la base du premier transistor (T_1) et le point situé entre la première jonction semiconductrice (T_3) et le collecteur du deuxième transistor (T_2), montage en série dans lequel la troisième jonction semiconductrice (T_{10}) a un sens conducteur opposé au sens de conducteur de la jonction base-émetteur du troisième transistor (T_4), de façon qu'à l'état de déclenchement de l'amplificateur de commutation, une tension de pratiquement 0 V apparaisse entre la base dudit premier transistor (T_1) et ladit point entre la première jonction semiconductrice (T_3) et le collecteur du deuxième transistor (T_2).

7. Amplificateur de commutation selon la revendication 6, caractérisé en ce que les moyens de commutation comportent des cinquième (T_8) et sixième (T_7) transistors du premier type de conduction présentant une source de courant

d'émetteur commune (24), les collecteurs des cinquième (T_8) et sixième (T_7) transistors étant connectés à une borne (27) par l'intermédiaire d'impédances (25, 26), la base du premier transistor (T_1) étant connectée au collecteur du cinquième transistor (T_8) et la base du troisième transistor (T_4) étant connectée au collecteur du sixième transistor (T_7), et dans moyens étant prévus pour la formation, sur ladite borne (27), d'une tension qui est essentiellement supérieure d'une tension de diode à la tension à la sortie (4).

8. Amplificateur de commutation selon la revendication 7, caractérisé en ce que la troisième jonction semiconductrice (T_{10}) est montée en parallèle avec les impédances (26) dans le circuit de collecteur du cinquième transistor (T_8) et une quatrième jonction semiconductrice (T_9) est montée en parallèle avec l'impédance (25) dans le circuit de collecteur du sixième transistor (T_7), le sens conducteur desdites jonction semiconductrices (T_{10} , T_9) étant le même que le sens conducteur des cinquième (T_8) et sixième (T_7) transistors.

9. Amplificateur de commutation selon l'une des revendications 2 à 8, caractérisé en ce qu'un couplage de dérivation à transmission à haute fréquence (23) est disposé entre le collecteur du troisième transistor (T_4) et la base du deuxième transistor (T_2).

