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Keller

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[54] **INTEGRATED CIRCUIT CURRENT SUPPLY**

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[30] **Foreign Application Priority Data**

Nov. 18, 1972 Germany 2256640

[52] **U.S. Cl.** **323/4;** 323/23

[51] **Int. Cl.²** **G05F 1/56**

[58] **Field of Search** 307/296, 297; 323/1, 4, 323/8, 17, 23, 25

[56] **References Cited**

UNITED STATES PATENTS

3,246,233	4/1966	Herz	323/4
3,508,081	4/1970	Matsuda	323/4 UX
3,754,181	8/1973	Kreitz et al.	323/1

FOREIGN PATENTS OR APPLICATIONS

778,918	2/1968	Canada	323/4

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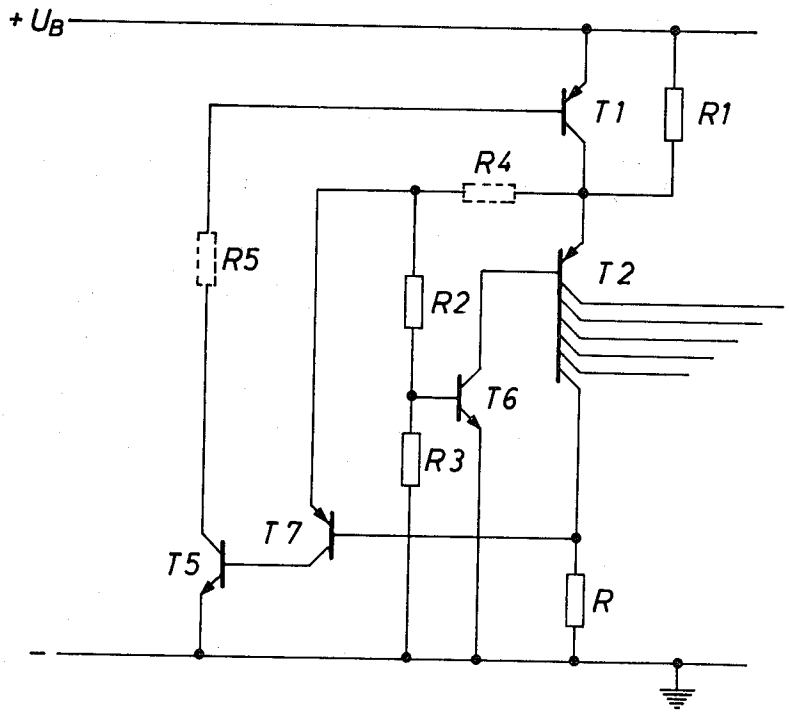
[57] **ABSTRACT**

In a multicollector constant current source commonly used as a resistor in low power ICs (frequency divider for watches), there is provided a current supply transistor having a low base substrate capacitance and a multicollector current splitting transistor. A current supply transistor and a multicollector current distribution transistor are provided. A regulating amplifier having an output coupled to the base of the current supply transistor and having inputs coupled to at least one collector of the multicollector transistor extracts a reference voltage for keeping the current flowing in the collector constant.

2 Claims, 6 Drawing Figures



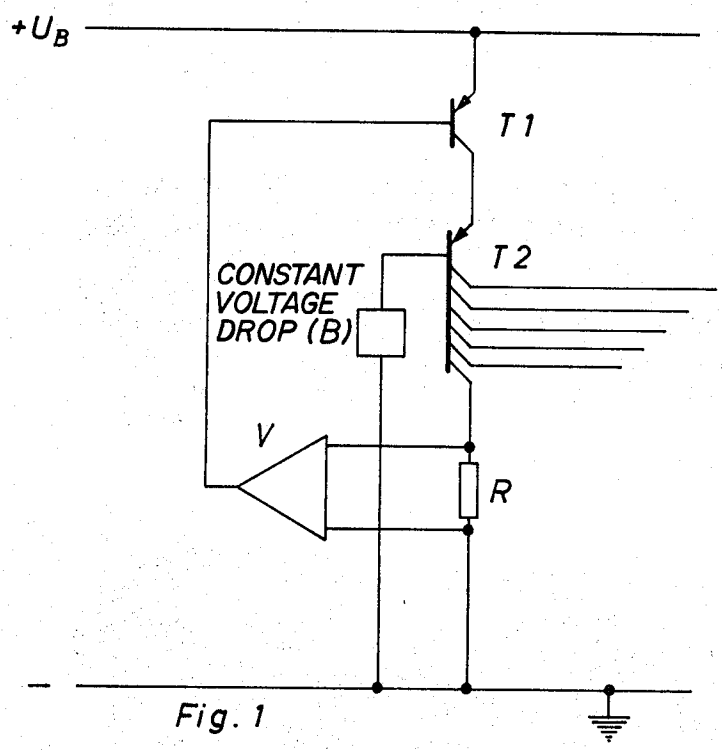

+U_B
T 1
T 2
CONSTANT
VOLTAGE
DROP (B)
V
R
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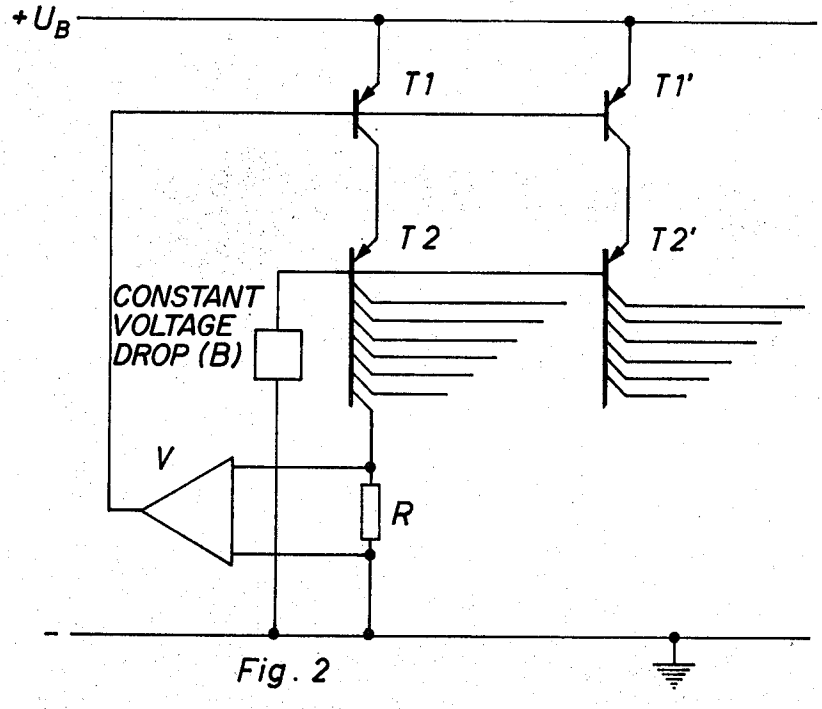
Fig. 1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T1
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T 2
T2'
CONSTANT
VOLTAGE
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Fig. 2

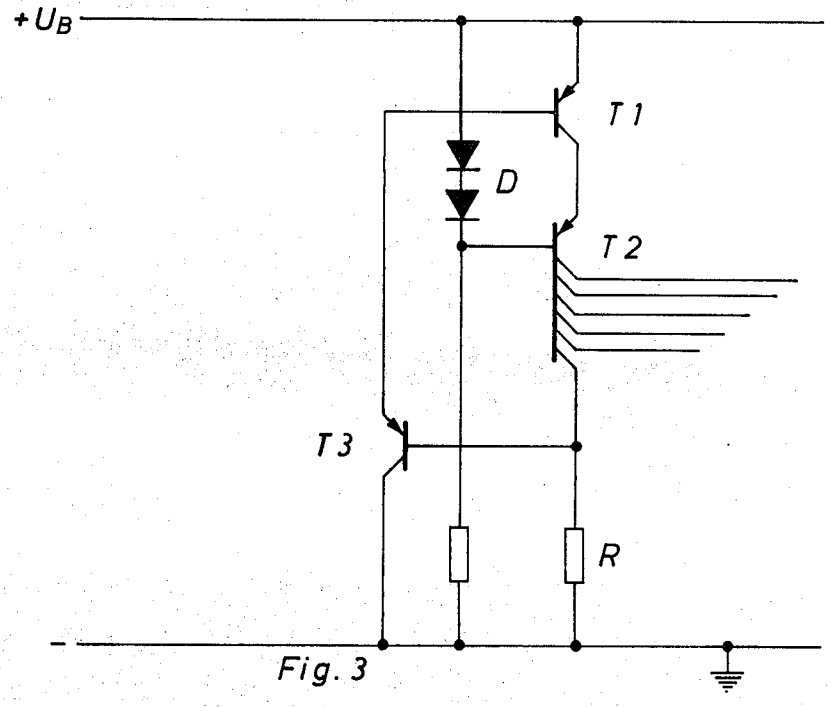

Fig. 3

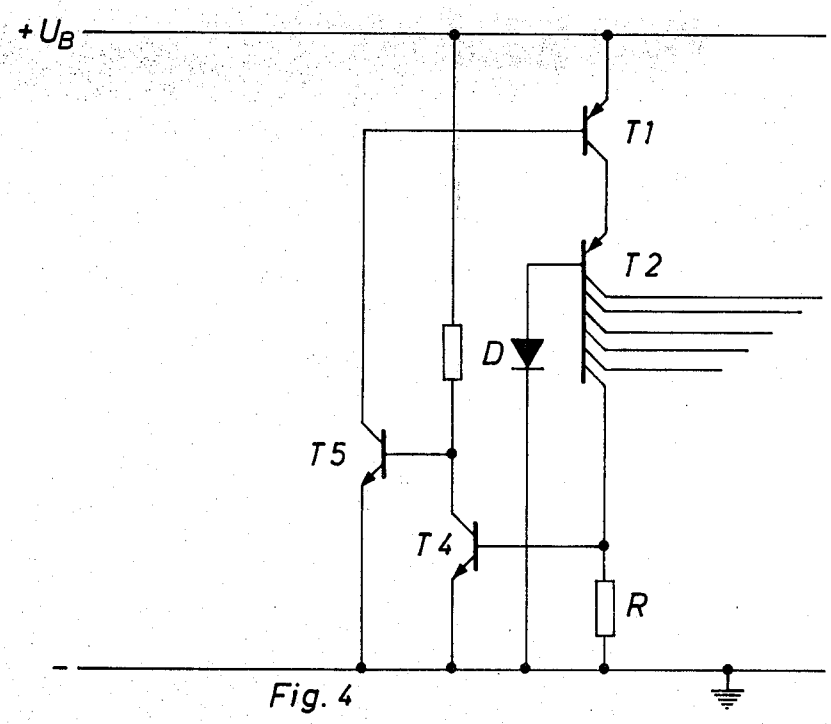

Fig. 4

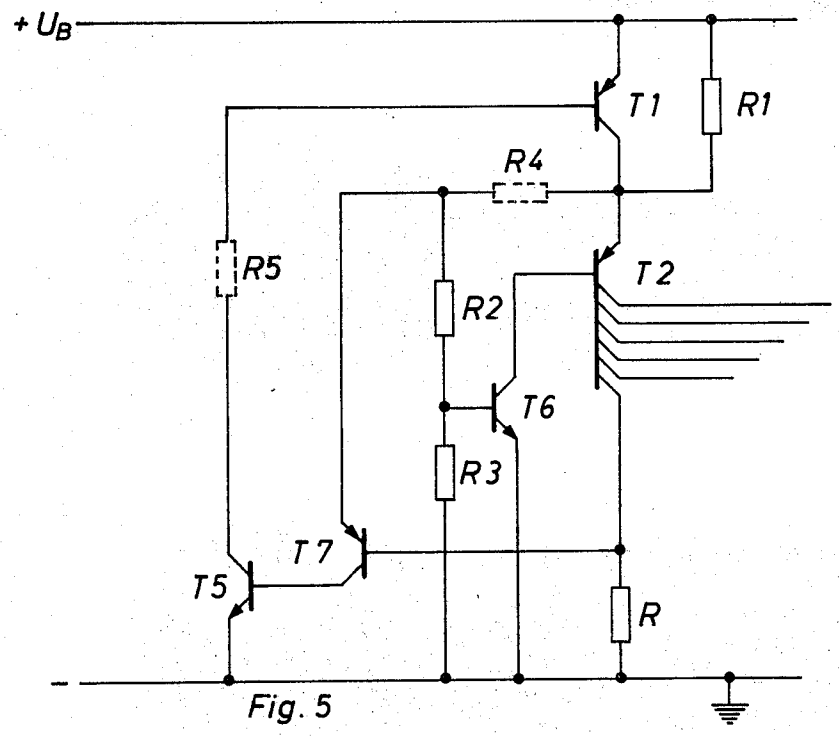

Fig. 5

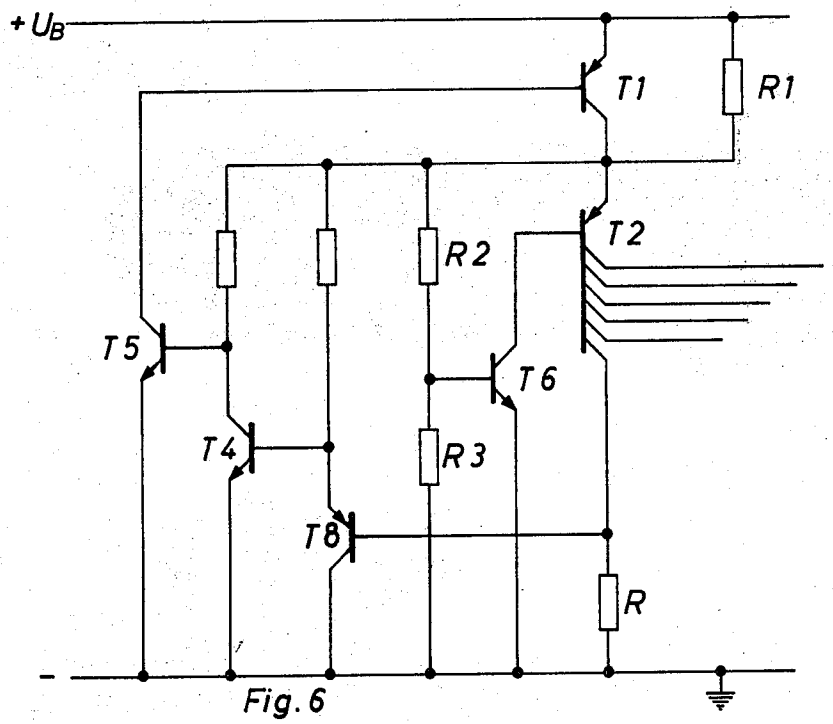

Fig. 6

INTEGRATED CIRCUIT CURRENT SUPPLY

BACKGROUND OF THE INVENTION

This invention relates to a circuit for the current supply of a monolithic integrated circuit comprising a plurality of transistor stages all performing the same or different functions, from a source of supply voltage, in particular from a dry cell battery.

The small size or volume of integrated circuits has generated new possibilities for applying electronic circuit priciples to fields in which up to now were not acceptable for reasons of size or dimensions. In particular, those cases where the integrated circuit must be supplied from an independent source of voltage such as a dry cell battery. As examples for these practical applications, reference is made to electromedical probes, hearing aids, telemetering systems, paging systems, watches, and cameras controlled by automatic shutters.

Since in all of these fields of practical application the employed dry cell battery is supposed to have long service life, the integrated circuit is required to have a small current drain. This, in turn, requires the use of high-ohmic resistors which, however, call for large crystal surfaces.

To avoid the use of high-ohmic resistors in integrated circuits with small power consumption or input, it is already known to replace the latter by so-called constant current sources. According to "IEEE Transactions on Circuit Theory", December 1965, pp. 586 to 590, especially FIG. 3, there may be used a transistor whose base-emitter voltage is kept constant. Moreover, it is known to provide several such constant current sources in integrated circuits wherein for all of the constant current transistors there is provided one common circuit retaining their base-emitter voltage.

On the other hand, and with respect to the multiple use of such constant current sources, it is known to regulate the collector currents via the sum of all base currents of the transistors keeping the current constant.

In both types of multiple replacement of the aforementioned high-ohmic resistors, the surface area of the base-pn-junctions increases with the number of transistors which serve to stabilize the current, and may therefore be considerable in the case of many circuits. This large common base-pn-junction, correspondingly, results in a likewise large capacity with respect to the substrate of the integrated circuit via which the base is connected to the zero point of the circuit with respect to a.c. voltage, because the substrate of integrated circuits is likewise applied to the zero point of the circuit.

Since the emitters of the current-stabilizing transistors are connected to the source of supply voltage, temporarily occurring voltage variations of the supply voltage will have a direct effect upon the collector current, because the base, via the large base-substrate capacity, is temporarily retained at its potential, so that the base-emitter voltage which is effective for the control purposes, is subjected to temporary variations. Moreover, the base-substrate capacity has an unfavorable influence upon the tendency towards oscillations of the control circuit.

The described disadvantages of the large occurring base-substrate capacity might be overcome by connecting a common capacitor in parallel to the base-emitter path of all current-stabilizing transistors.

This capacitor, however, would then be required to have such a high capacitance that it could not be included in the integrated circuit. An external capacitor connected to the integrated circuit is required to have small dimensions and a low leakage current.

Moreover, it would require an additional connecting terminal at the integrated circuit which, in turn, would require a larger housing or eliminate the use of standard housings. Thus, the use of a capacitor will, in several ways, cause the circuit to become more expensive.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an integrated circuit current supply which avoids the above mentioned disadvantages, i.e. without the use of a capacitor and with the aid of additional integrated active and, if required, passive individual elements, to avoid the effect of the large base-substrate capacity. In so doing, the invention proceeds from the recognition that some additional integrated individual elements will not substantially cause the entire integrated circuit to become more expensive.

According to a broad aspect of the invention there is provided a current supply circuit for a monolithic integrated circuit containing a plurality of transistor stages comprising a source of supply voltage; a current supply transistor having an emitter coupled to said source of supply voltage and having a base and a collector; at least one current distribution transistor having an emitter coupled to the collector of said current supply transistor, a base coupled to a fixed potential and at least one collector; and a regulating amplifier having an output coupled to the base of said supply current transistor and having first and second inputs coupled to said at least one collector for extracting a reference voltage, said regulating amplifier maintaining said at least one collector current flowing therein constant.

Accordingly, the invention distinguishes over the known prior art, and proposes that for each high-ohmic resistor to be replaced, there is used one current-stabilizing transistor, with the base-emitter paths of these transistors all being connected parallel in relation to one another.

The above and other objects of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a basic circuit diagram of a first embodiment of the invention;

FIG. 2 is a circuit diagram of a second embodiment of the invention;

FIG. 3 is a detailed circuit diagram of the circuit shown in FIG. 1;

FIG. 4 is a circuit diagram of a modified embodiment corresponding to the basic circuit shown in FIG. 1;

FIG. 5 shows a modified embodiment according to FIG. 1; and

FIG. 6 shows a further development of the circuit shown in FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The basic circuit diagram according to FIG. 1, of a first type of embodiment of the invention circuit arrangement shows the supply current transistor T1 having an emitter connected to the positive pole of the source of supply voltage U_B and having a collector sup-

plying the emitter of the current distribution transistor T2. This transistor is shown in FIG. 1 as a multicollector type of transistor, with merely the lowest collector in the drawing being connected across the resistor R to the zero point of the circuit which, in the drawings, is identical to the negative pole of the source supply voltage U_B. All of the remaining collectors are shown in FIG. 1 to be without a further connecting terminal, by which it is meant to imply that these collectors may lead to any suitable stages of an integrated circuit which are to be supplied with current.

The transistors T1 and T2 are shown in FIG. 1 as being of the pnp-type. It is possible, however, to use transistors of the npn-conductivity type provided that the polarity of the source of supply voltage U_B is reversed. Moreover, instead of the multicollector type of transistor T2, it is also possible to choose an arrangement in which several transistors are embodied individually in the integrated circuit, with the base-emitter paths thereof being connected in parallel to one another. It is also possible to provide an arrangement in which transistors embodied individually in the integrated circuit, as well as multicollector types of transistors are used in common, in which case all base-emitter paths of these current distribution transistors are connected in parallel to one another.

The basic current diagram according to FIG. 1 still contains a component B having a constant voltage drop, and to which there is connected the common base of the current distribution transistors, hence in FIG. 1 of the multicollector type current distribution transistor T2. This component, as shown, may be applied to voltage zero, but may just as well be applied to the other pole of the source of supply voltage. The output of the control amplifier V is connected to the base of the current supply transistor T1 while its input is connected to the resistor R. In this way it is accomplished that the collector current of the current distribution transistor T2 flowing across the resistor R, with repsect to a reference voltage contained in the regulating amplifier, is kept constant via the base current of the current distribution transistor T1, thus also ensuring that the currents of the other collectors flowing to the individual stages of the circuit, are kept constant.

As the source of reference voltage of the regulating amplifier V, it is appropriate to use at least one of the base-emitter threshold voltages of the transistors as contained in the regulating amplifier, and which are either referred to the supply voltage or the zero point of the circuit.

FIG. 2 shows the basic circuit diagram of a modified type of embodiment of the invention. According to this circuit, there are provided two current supply transistors T1 and T1′ as well as two current distribution transistors T2 and T2′, with the base-emitter paths of the two current supply transistors being connected in parallel to one another and the base electrodes of the two current distribution transistors being connected to one another. On principle, however, the base of the second current distribution transistor could also be connected to another potential. The splitting of the current supply and current distribution transistors as shown in FIG. 2 is of advantage especially in cases where a portion of the stages contained in the integrated circuit and to be supplied with current, is to be made separable. This may be useful in the case of integrated circuits containing an oscillator with a subsequently arranged frequency divider consisting of flip-flop stages, and which serve the driving of an electromechanical transducer.

Disconnection of individual stages can also be used for switching off all identical halves of the flip-flop stages of the frequency divider, thus enabling a defined setting of the flip-flop stages. Disconnection may be carried out by means of a mechanical or electronic switch which either disconnects or substantially reduces the common base current and/or the common emitter current of the current distribution transistors, or else the base and/or emitter current of the corresponding current supply transistor. Furthermore, it is possible by means of a delayed switching on of these stages upon switching on the source of supply voltage, to safeguard a predetermined switching behavior, such as the aforementioned defined setting of individual flip-flop stages.

FIG. 3 shows an example of embodiment of the arrangement according to FIG. 1, in which the component B with a constant voltage drop consists of the series arrangement of two diodes operated in the forward direction, and which is connected to the positive pole of the source of supply voltage, and supplied across a resistor connected to the zero point of the circuit. The base of the current distribution transistor T2 is applied to the point connecting one of the two diodes in the resistor. Instead of the two diodes D operated in the forward direction and when a sufficiently high supply voltage is available, it is possible to choose a zener diode with the cathode thereof then being connected to the positive pole of the source of supply voltage U_B. In cases where a particularly good temperature compensation of the potential is required at the base of the current distribution transistor, it is also possible to use forward-biased and zener diodes jointly connected in series.

In FIG. 3 the regulating amplifier V is seen to consist of the transistor T3 which, just like the transistors T1 and T2, is of the pnp-conductivity type. Its collector is applied to the zero point of the circuit and its base to the point connecting the resistor R to one of the collectors of the current distribution transistor T2 while its emitter is connected to the base of the current supply transistor T1. In the example of embodiment according to FIG. 3 there is used as the reference voltage of the control amplifier, the difference between the supply voltage U_B and the sum of the base-emitter threshold voltages of both the transistors T1 and T3.

FIG. 4 shows a modified example of embodiment of the arrangement according to FIG. 1, in which the component B with a constant voltage drop consists of a forward-biased diode D serving to connect the base of the current distribution transistor T2 to the zero point of the circuit. Also instead of this diode it is possible to use, as already mentioned hereinbefore, several diodes operated in the forward direction and/or a zener diode.

The regulating amplifier V according to FIG. 1, in the example of embodiment shown in FIG. 4, consists of the two transistors T4 and T5 which are of the same conductivity type, hence of the npn-type, but in opposition to that of the transistors T1 and T2. The emitters of transistors T4 and T5 are applied to the zero point of the circuit while the base of transistor T4 is applied to the connecting point of the resistor R and the associated collector of the current distribution transistor T2. The collector of transistor T4, across a resistor, is ap-

plied to the positive pole of the source of supply voltage U_B, thus controlling the base of transistor T5 whose collector serves to control the base of the current distribution transistor T1. Instead of the positive pole of the source of supply voltage it is also possible to connect the collector resistance of transistor T4 to the emitter of the current distribution transistor T2.

In the example of embodiment according to FIG. 4 the base-emitter threshold voltage of transistor T4 is used as the reference quantity of the regulating amplifier.

FIG. 5 shows another modified type of embodiment of the basic arrangement according to FIG. 1. The constant potential for the base of the current distribution transistor T2 is generated in this particular case by the complementary, hence npn-type transistor T6 whose collector is connected to the base of the current distribution transistor T2 and whose emitter is connected to the zero point of the circuit, while the base thereof is connected to the tapping point of the voltage divider consisting of the two voltage dividing resistors R2 and R3. This voltage divider is arranged between the emitter of the current distribution transistor T2 and the zero point of the circuit.

In the example of embodiment shown in FIG. 5, the regulating amplifier V according to FIG. 1 consists of two stages, namely of the transistor T5 (npn-type) constituting the output stage, and of the transistor T7 (pnp-type) which is complementary to the transistor T5 and arranged to precede the latter. Thus, the base of the pnp-type transistor T7 is applied to the point connecting the resistor R and the associated collector of the current distribution transistor T2, while the collector of transistor T7 serves to control the base of transistor T5, and the emitter of transistor T7 is connected to the emitter of the current distribution transistor T2. This connection may also be carried out across the resistor R4 as indicated by the dashline and included in the voltage divider R2, R3. If so required, it is likewise possible for a resistor, namely the resistor R5 as indicated by the dashline in FIG. 5, to be inserted in the connecting line between the collector of transistor T5 and the base of the current supply transistor T1.

In the example of embodiment according to FIG. 5 there is used as the reference quantity of the regulating amplifier the difference between the potential at the emitter of the current distribution transistor T2 as referred to the zero point of the circuit, and the base-emitter threshold voltage of transistor T7. The particular connection of the transistor T6 in common with the base-emitter path of the current distribution transistor T2 may be employed in all cases where a constant voltage is required in electronic circuits, which must be smaller than the base-emitter threshold voltage of a transistor. It is a self-suggesting matter of fact that the base-emitter path of the current distribution transistor T2 may also be replaced in such cases by a diode operated in the forward direction.

Finally, FIG. 5 still shows a further modification of the inventive circuit which is also applicable to all other types of embodiments and which is featured by the fact that the ohmic resistor R1 is connected in parallel to the emitter-collector path of the current supply transistor T1, so that only part of the supply current flows over the base-emitter path.

FIG. 6 shows a further development of the circuit arrangement according to FIG. 5 in which the regulating amplifier consists of three stages, namely of the output stage comprising the npn-type transistor T5, of the intermediate stage comprising the npn-type transistor T4, and of the input stage comprising the pnp-type transistor T8. The latter is applied with its collector to the zero point of the circuit, with its base to the resistor R and with its collector on one hand, across a resistor, to the emitter of the current distribution transistor T2 and, on the other hand, to the base of the npn-type transistor T4. The emitters of transistors T4 and T5 are applied to the zero point of the circuit while the collector of transistor T4 is connected on one hand, across a resistor, likewise to the emitter of the current distribution transistor T2 and, on the other hand, serves to control the base of transistor T5 of the output stage. In the example of embodiment of FIG. 6 there is used as the reference quantity of the regulating amplifier the difference between the base-emitter threshold voltages of the transistors T4 and T8.

Of course, and if so required, it is possible to provide in the embodiments according to FIGS. 3 to 6 for the splitting of the current supply and current distribution transistor as shown in FIG. 2.

It is to be understood that the foregoing description of specific examples of this invention is made by way of example only and is not to be considered as a limitation on its scope.

What is claimed is:

1. A current supply circuit for a monolithic integrated circuit containing a plurality of transistor stages comprising:
- a source of supply voltage having first and second terminals;
- a current supply transistor having an emitter coupled to said source of supply voltage and having a base and a collector;
- a multicollector current distribution transistor having an emitter coupled to the collector of said current supply transistor and having a base;
- a first resistor coupled between one collector of said multicollector current distribution transistor and the zero point of the circuit;
- an ohmic voltage divider coupled between the collector of said current supply transistor and the zero point of the circuit;
- a further transistor having a base coupled to the tapping point of said ohmic voltage divider, wherein the base of said current distribution transistor is coupled to the zero point of the circuit via the collector-emitter path of said further transistor; and
- a regulating amplifier having an output coupled to the base of said current supply transistor and having first and second inputs, said first and second inputs coupled across said resistor for extracting a reference voltage, said regulating amplifier maintaining the current flowing in said one collector constant.

2. A current supply circuit according to claim 1 wherein said further transistor is of a conductivity type opposite to that of said current distribution transistor.

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