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(54) **Voltage regulator having a precision thermal current source.**

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(73) Proprietor: **MOTOROLA, INC.**
1303 East Algonquin Road
Schaumburg, IL 60196(US)

(72) Inventor: **Bynum, Byron G.**
1101 E. Sandpiper Drive
Tempe
Arizona Arizona 85283(US)

(74) Representative: **Ibbotson, Harold**
Motorola Ltd
Patent and Licensing Operations - Europe
Jays Close
Viables Industrial Estate
Basingstoke Hampshire RG22 4PD (GB)

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Rank Xerox (UK) Business Services
(3.10/3.6/3.3.1)

Description

This invention relates to current supply circuits and, more particularly, to integrated circuits (IC) capable of producing currents having regulated magnitudes and predetermined temperature characteristics which are suitable to be used to produce a voltage regulator voltage the magnitude and temperature coefficient of which can be set.

There are many circuit and system applications that require current supplies or sources for providing currents having predetermined temperature coefficients (TC) and regulated magnitudes which are independent of supply voltage. More particularly, it is sometimes desirable to utilize a current supply circuit providing a current with a magnitude that has a positive TC that varies directly with absolute temperature. The current can be exploited to cancel the negative TC inherent in the PN junctions of a differential pair of transistors, for instance, so as to enable the gain of a differential amplifier comprising the differential pair of transistors to remain substantially constant with temperature changes. Since IC's generally can include many such differential amplifiers, it may require a current supply circuit of the above described type that can provide a plurality of such currents each having a predetermined magnitude and temperature coefficient associated therewith. A use for such thermal current sources is in conjunction with other circuitry to provide a regulated output voltage having a known TC. This thermal current can be utilized to produce a voltage across a resistor having a positive TC which is then placed in series with the negative TC base-to-emitter voltage of a NPN transistor to provide a zero TC output voltage. These types of voltage regulators are sometimes referred to by those skilled in the art as bandgap voltage regulators.

Prior art voltage regulators commonly include a pair of transistors operated at different current densities. The two transistors are interconnected with associated circuitry so as to develop a voltage therebetween that is proportional to the difference in the respective base-to-emitter voltages (ΔV_{be}). This difference voltage is used to set the current in the emitter of one of the transistors and has a positive temperature coefficient (TC). The thermal emitter current is utilized to produce a voltage that varies directly with absolute temperature which, in turn, is combined with a negative TC voltage to produce a combined voltage having a substantially zero TC.

Although such prior art regulators have significant advantages most, if not all, suffer from serious limitations. For instance, to prevent errors in the thermal current that may be caused by differences in the collector-to-emitter voltages of the two transistors, prior art regulators require complex feedback schemes to inhibit mismatch of the two devices. These schemes are not desirable in the design of integrated circuits as undue chip area is required. Additionally, the voltage level and temperature coefficient of the output regulated voltage of these prior art regulators can not be independently set but rather are determined by the magnitude of the difference voltage ΔV_{BE}. Moreover, prior art regulators can not generate adjustable TC regulated voltages less than the value of a transistor V_{BE} voltage.

Hence, a need exists for an improved integrated thermal current source circuit that overcomes the problems of prior art thermal current source circuits.

An additional need exists for a regulator circuit that does not suffer from the aforementioned limitations of the prior art regulators and which does not require complex feedback circuitry to provide an output voltage that can be set to any voltage and temperature coefficient utilizing a precision thermal current source.

Summary of the Invention

Accordingly, it is an object of the present invention to provide an improved thermal current source circuit.

It is another object of the present invention to provide a circuit for producing a current having a regulated magnitude and temperature coefficient and which is suited to be fabricated in integrated circuit form.

In accordance with the above and other objects there is provided a thermal current supply circuit comprising:

first and second transistors having their bases coupled together and being operated at different predetermined current densities to produce a difference voltage between the emitters thereof having a predetermined positive temperature coefficient;

a first resistor coupled to the emitter of said first transistor for sinking the current therefrom;

a second resistor coupled to the emitter of said second transistor for sinking a portion of the current therefrom;

a third transistor having its collector-emitter path coupled between the emitter of said second transistor and a circuit node (I_{out}); and

feedback circuit means coupled to the collector of said second transistor and being responsive to said second transistor to provide a feedback signal to the base of said third transistor such that the latter sinks current from the emitter of said second transistor of a predetermined magnitude which is proportional to the difference voltage and inversely

proportional to the value of said second resistor, said current flowing through said third transistor to the circuit node having said predetermined positive temperature coefficient.

An improved voltage regulator is also disclosed comprising a thermal current source in accordance with the invention. The voltage regulator provides an output voltage that can be set to a predetermined voltage level and temperature coefficient.

Brief Description of the Drawings

Fig. 1 is a schematic diagram illustrating a thermal current supply of the present invention;
Fig. 2 is a schematic diagram illustrating a second thermal current supply of the invention;
Fig. 3 is a schematic diagram illustrating a third thermal current supply of the invention; and
Fig. 4 is a schematic diagram illustrating a voltage regulator which includes the thermal current supply of Fig. 3.

Detailed Description of the Preferred Embodiments

Turning now to the Figures there are shown several embodiments of thermal current source of the present invention which are suited to be manufactured in integrated circuit form and utilized to establish a regulated voltage. It is understood that corresponding components described in relation to the Figures are designated by the same reference numerals. Fig. 1 illustrates the basic components and interconnection of reference cell 12 of thermal current source 10. Current source 10 is suited for providing fan out to multiple current sources such as NPN transistors 14, 16 and 18 coupled thereto at terminal 20. The collectors of the current source transistors are connected to respective current utilization circuits 22, 24 and 26 each of which requires a current having a predetermined temperature characteristic that varies with absolute temperature.

Reference cell 12 of thermal current source 10 includes a pair of NPN transistors 28 and 30 the emitters of which are respectively coupled via resistors 32 and 34 to the base of NPN transistor 36. The collector-emitter path of transistor 36 is coupled between the emitter of transistor 30 and negative supply conductor 38 to which negative or ground reference voltage -V is supplied. Transistor 28 is connected as a diode having its collector and base interconnected to the base of transistor 30. A pair of current sources 40 and 42 supply currents I_1 and I_2 to the collectors of transistors 28 and 30 respectively and are connected to power supply conductor 44 to which a positive operating voltage V_{cc} is supplied. Feedback is provided to the base of transistor 36 by buffer NPN transistor 46 which has its base coupled to the collector of transistor 30 and its collector-emitter path coupled between conductor 44 and output node 20 (to the base of transistor 36) in series with resistor 48 to negative supply conductor 38.

The concept of the present invention consists of (1) developing a difference voltage having a positive temperature coefficient (TC), (2) utilizing the difference voltage to set the current that flows in the collector of transistor 36 wherein the collector current has a magnitude that varies with absolute temperature, (3) utilizing the negative TC base-emitter voltage drop, V_{BE}, of transistor 36 to develop a current having a negative TC through resistor 56, and (4) summing the two currents at node 62 to produce a combined voltage the value and temperature coefficient of which is controllable.

A difference voltage is produced in the present invention by operating transistors 28 and 30 at different current densities, which as understood, generates a positive difference voltage ΔV_{BE} between the emitters of the two transistors. In the subject invention transistor 28 is operated at a lower current density than transistor 30 by making its emitter area N times larger than the emitter area of transistor 30 (where N is a positive number) and setting I_1 equal to I_2. If resistor 32 equals resistor 34, the voltage developed across the base-emitter of transistor 28 and resistor 32 will equal the voltage developed across the base-emitter of transistor 30 and resistor 34. However, since transistor 28 is operated at the lower current density its base-emitter voltage will be less than the base-emitter voltage of transistor 30 wherein at quiescence the aforementioned difference voltage is established between the emitters thereof. Initially, however, since transistor 28 sinks all of the current I_1 and is operated as a diode it will set the voltage to bias transistor 30. As the emitter of transistor 30 is (1/N) times smaller than the emitter of transistor 28 the former will initially sink a collector current less than the magnitude of I_2. This causes the collector voltage of transistor 30 to rise which turns on feedback transistor 46. Transistor 46 will then source base current drive to transistor 36 thereby rendering it conductive to sink a current, I_T, at its collector from the emitter of transistor 30 until the current flow through the latter equals the current I_2, which is equal to I_1. By forcing the current through transistor 30 to be equal to the current flow through transistor 28 the circuit feedback action produces the difference voltage ΔV_{BE} between the emitters thereof. This establishes the current I_T sank by transistor 36. Thus, from the above it can be shown that in the quiescent operating condition:

$I_1 R_{32} + V_{BE28} = V_{BE30} + (I_2 - I_T) R_{34}$ and
$V_{BE30} - V_{BE28} = \Delta V_{BE}$, then
since $I_1 R_{32} = I_2 R_{34}$

$I_T = \Delta V_{BE}/R34$:

where

ΔV_{BE} = (KT/q)1n N;
K = Boltzman's constant
T = Absolute temperature
q = electron charge

Hence I_T is a thermal current having a magnitude which can be controllably set by the value of R34 and which varies in direct relation to absolute temperature. NPN transistor 46 provides feedback current to bias the base of transistor 36 to ensure that it sinks the correct collector current. Transistor 46 also buffers the fan out base currents of current supply transistors 14, 16 and 18 from affecting the operation of transistors 28 and 30. Resistor 48 is selected to sink a current greater than the sum of the currents flowing through resistors 32 and 34 to assure proper bias current in transistor 46. By grounding the emitter of transistor 36 and coupling the bases of current source transistors 14, 16 and 18 to terminal 20, all of the collector currents of the latter will be thermal currents that vary as I_T varies. These currents can be ratioed to have any desired magnitude by, for instance, utilizing emitter resistors or by emitter area ratioing. Thus, transistor 16 has resistor 49 in its emitter path and transistor 18 is shown as having multi-emitters. Thermal current source cell 12 is relatively independent to variations in the power supply voltage as the collector-emitter voltages of transistors 28 and 30 are well matched since the collector-base voltage of both transistors is substantially equal to zero.

Referring to Fig. 2, a pair of NPN transistors 50 and 52 are shown which improve the precision of thermal current source 10. Transistor 50, which has its collector emitter path coupled between power supply conductor 44 and the bases of transistors 28 and 30 and its base connected to current source 40, buffers the base currents to the latter transistors to reduce error between I_1 and I_2. Similarly, transistor 52, with its collector-emitter path connected between power supply conductor 44 and the base of transistor 46 and its base connected to current source 42, buffers the base current of transistor 46.

Fig. 3 shows a thermal current source 54 which provides an output current I_{out} that has an adjustable temperature coefficient using the concepts disclosed above with respect to current source 10. Thermal current source 54 includes an additional resistor 56 coupled between the base and emitter of transistor 36 of reference cell 12. Iout is therefore equal to:

$I_{out} = I_T + V_{BE36}/R56$; and
$I_{out} = \Delta V_{BE}/R34 + V_{BE36}/R56$,

where V_{BE36} is the base-to emitter voltage of transistor 36; and

R56 is the value of resistor 56.

Since V_{BE} has a positive TC and V_{BE36} has a negative TC, selection of the ratio of R34 to R56 can set the TC of I_{out} either positive, negative or even zero. It is understood that V_{BE} of transistor 36 is well controlled as the collector current thereof is known to be $V_{BE}/R34$.

By way of example, resistors 32 and 34 have been illustrated above as being interconnected to the base of transistor 36. However, it is apparent from the present disclosure that resistors 32 and 34 could also be interconnected at a common node to any source of reference potential as long as transistor 30 is inhibited from becoming saturated. It is also understood that transistor 52 could be used to buffer transistor 46 as illustrated in Fig. 2.

Fig. 4 illustrates voltage regulator 60 of the present invention which includes thermal current source 54 described above. In the preferred embodiment output node 62 is connected in series with additional resistor 64. Transistor 52, which has its base-emitter coupled between the collector of transistor 30 and the base of transistor 46 and its collector coupled to conductor 44 further buffers the collector of transistor 30 from the effects of load currents sourced at node 66 to a load means connected thereto. Additionally, transistor 52 also ensures that the collector voltage of transistor 30 equals the collector voltage of transistor 28 to prevent mismatch between the two transistors. Resistor 68 is connected between the emitter of transistor 52 and output terminal 66 at which is produced regulated output voltage V_{out}.

A voltage is developed across resistor 64 that is proportional to the current I_{out} combined with the V_{BE} of transistor 36 to produce combined voltage V_{out}. Thus, V_{out} is equal to:

$$V_{out} = V_{BE36} (1 + R64/R56) + \Delta V_{BE} R64/R34 \quad - (4)$$

where R64 is the value of resistor 64.

Hence, by proper selection of resistor ratios, V_{out} can be set to any desired voltage and any temperature coefficient independently of one another.

It is understood that although V_{OUT} is taken at output 66 in the preferred embodiment, a regulated output voltage is also produced at node 62 which could be used as an output voltage of the regulator.

Thus, what has been described above is a novel voltage regulator comprising a thermal current source for providing a thermal current having an adjustable temperature coefficient and means for developing a voltage proportional to the thermal

current and combining the voltage with another voltage of a different temperature coefficient to produce a combined voltage the magnitude and temperature coefficient of which can be independently controlled.

Claims

1. A thermal current supply circuit comprising:

first (28) and second (30) transistors having their bases coupled together and being operated at different predetermined current densities to produce a difference voltage between the emitters thereof having a predetermined positive temperature coefficient;

a first resistor (32) coupled to the emitter of said first transistor for sinking the current therefrom;

a second resistor (34) coupled to the emitter of said second transistor for sinking a portion of the current therefrom;

a third transistor (36) having its collector-emitter path coupled between the emitter of said second transistor and a circuit node (I_{out}); and

feedback circuit means (46) coupled to the collector of said second transistor and being responsive to said second transistor to provide a feedback signal to the base of said third transistor such that the latter sinks current from the emitter of said second transistor of a predetermined magnitude which is proportional to the difference voltage and inversely proportional to the value of said second resistor, said current flowing through said third transistor to the circuit node having said predetermined positive temperature coefficient.

2. The thermal current supply circuit according to claim 1 further comprising:

a third resistor (56) coupled between the base and emitter of the third transistor for providing a current to the circuit node (I_{out}) having a predetermined magnitude and a negative temperature coefficient that is summed with the current flowing through said third transistor, wherein the summed current developed at the circuit node has a controllable magnitude and controllable temperature coefficient which are dependent on the predetermined magnitude of the current flowing through said third transistor and the predetermined magnitude of the current provided by the third resistor.

3. The thermal current supply circuit according to claim 1 or 2 wherein said feedback circuit means (46) comprises a fourth transistor (46) having an emitter coupled to said base of said third transistor, a collector coupled to a first power supply conductor (44), and a base coupled to a collector of said second transistor.

4. The thermal current supply circuit according to claim 3 further comprising:

first conductive means (50) for coupling the collector of said first transistor to said base thereof, said bases of said first and second transistors being coupled together; and

current source means (40, 42) coupled between said first power supply conductor (44) and the collectors of said first and second transistors for supplying current thereto.

5. The thermal current supply circuit according to claim 4 wherein the emitter area of said first transistor is N times the emitter area of said second transistor, where N is a positive number and said feedback circuit means forces the current conducted by said first and second transistors to be substantially equal.

6. The thermal current supply circuit according to claim 5 further comprising:

a fifth transistor (52) having a base coupled to said collector of said second transistor, a collector coupled to said first power supply conductor (44) and an emitter coupled to said base of said fourth transistor (46), said first conductive means includes a sixth transistor (50) having a base coupled to said collector of said first transistor, a collector coupled to said first power supply conductor (44) and an emitter coupled to said base of said first transistor.

7. The thermal current supply circuit according to claim 3, 4, 5 or 6 wherein said feedback circuit means further comprises circuit means (48) coupled between said emitter of said fourth transistor and a second power supply conductor (38) for sinking a predetermined current from said fourth transistor.

8. An integrated voltage regulator (60) comprising a thermal current supply circuit according to claim 2, 3, 4, 5, 6 or 7 and a fourth resistor (64) connected to said circuit node (I_{out}) through which said currents flowing through said third transistor and said second resistor (56) are summed such that a regulated voltage is developed thereacross, the magnitude and temperature coefficient of which can be independently set.

9. The voltage regulator according to claim 8 further including means for coupling the base of said third transistor to an output of the voltage regulator.

Patentansprüche

1. Thermische Stromversorgungs-Schaltung, welche umfaßt: erste (28) und zweite (30) Transistoren, deren Basisanschlüsse miteinander gekoppelt sind und die mit unterschiedlichen vorbestimmten Stromdichten betrieben werden, um eine Differenzspannung mit einem vorbestimmten positiven Temperatur-Koeffizienten zwischen ihren Emittern zu erzeugen;
einen ersten Widerstand (32), der mit dem Emitter des ersten Transistors gekoppelt ist, um als Senke für den Strom von diesem zu wirken;
einen zweiten Widerstand (34), der mit dem Emitter des zweiten Transistors gekoppelt ist, um als Senke für einen Anteil des Stroms von diesem zu wirken;
einen dritten Transistor (36), dessen Kollektor/Emitter-Strecke zwischen dem Emitter des zweiten Transistors und einem Schaltungsknoten (I_{out}) gekoppelt ist; und
Rückkopplungs-Schaltungsmittel (46), das mit dem Kollektor des zweiten Transistors gekoppelt ist und auf den zweiten Transistor reagiert, um ein Rückkoppelsignal zu der Basis des dritten Transistors zu schaffen, so daß der letztere Strom von dem Emitter des zweiten Transistors einer vorbestimmten Größe senkt, die proportional zu der Differenzspannung und umgekehrt proportional zum Wert des zweiten Widerstandes ist, welcher Strom durch den dritten Transistor zu dem Schaltungsknoten fließt und den vorbestimmten positiven Temperatur-koeffizienten besitzt.

2. Thermische Stromversorgungs-Schaltung nach Anspruch 1, welche weiter umfaßt:
einen dritten Widerstand (56), der zwischen der Basis und dem Emitter des dritten Transistors geschaltet ist, um einen Strom zu dem Schaltungsknoten (I_{out}) zu schaffen mit einer vorbestimmten Größe und einem negativen Temperatur-Koeffizienten, der mit dem durch den dritten Transistor fließenden Strom summiert wird, wobei der summierte an dem Schaltungsknoten entwickelte Strom eine steuerbare Größe und einen steuerbaren Temperatur-Koeffizienten besitzt, die abhängig sind von der vorbestimmten Größe des durch den dritten Transistor fließenden Stromes und der vorbestimmten Größe des durch den dritten Widerstand geschaffenen Stromes.

3. Thermische Stromversorgungs-Schaltung nach Anspruch 1 oder 2, bei der das Rückkoppel-Schaltungsmittel (46) einen vierten Transistor (46) umfaßt, mit einem mit dem Basisanschluß des dritten Transistors gekoppelten Emitter, einem mit einem ersten Stromversorgungs-Leiter (44) gekoppelten Kollektor und einem mit einem Kollektor des zweiten Transistors gekoppelten Basisanschluß.

4. Thermische Stromversorgungs-Schaltung nach Anspruch 3, welche weiter umfaßt:
erstes leitendes Mittel (50) zum Koppeln des Kollektors des ersten Transistors mit seinem Basisanschluß, wobei die Basisanschlüsse des ersten und des zweiten Transistors miteinander gekoppelt sind; und
Stromquellenmittel (40, 42), das zwischen dem ersten Stromversorgungs-Leiter (44) und den Kollektoren des ersten und des zweiten Transistors gekoppelt ist, um Strom dazu zu leiten.

5. Thermische Stromversorgungs-Schaltung nach Anspruch 4, bei der die Emitterfläche des ersten Transistors das N-fache der Emitterfläche des zweiten Transistors ist, wobei N eine positive Zahl ist und das Rückkoppel-Schaltungsmittel den durch den ersten und den zweiten Transistor geleiteten Strom im wesentlichen gleich zu sein zwingt.

6. Thermische Stromversorgungs-Schaltung nach Anspruch 5, welche weiter umfaßt:
einen fünften Transistor (52) mit einem mit dem Kollektor des zweiten Transistors gekoppelten Basisanschluß, einem mit dem ersten Stromversorgungs-Leiter (44) gekoppelten Kollektor und einem mit dem Basisanschluß des vierten Transistors (46) gekoppelten Emitter, wobei das erste leitende Mittel einen sechsten Transistor (50) enthält mit einem mit dem Kollektor des ersten Transistors gekoppelten Basisanschluß, einen mit dem ersten Stromversorgungs-Leiter (44) gekoppelten Kollektor und einen mit dem Basisanschluß des ersten Transistors gekoppelten Emitter.

7. Thermische Stromversorgungs-Schaltung nach Anspruch 3, 4 oder 6, bei der das Rückkoppel-Schaltungsmittel weiter umfaßt zwischen dem Emitter des vierten Transistors und einem zweiten Stromversorgungs-Leiter (38) gekoppeltes Schaltungsmittel (48) zum Senken eines vorbestimmten Stromes von dem vierten Transistor.

8. Integrierter Spannungsregler (60), welcher umfaßt eine thermische Stromversorgungs-Schal-

tung nach Anspruch 2, 3, 4, 5, 6 oder 7 und einen vierten Widerstand (64), der an dem Schaltungsknoten (I_{out}) angeschlossen ist, durch welchen die durch den dritten Transistor und den zweiten Transistor (56) fließenden Ströme so summiert werden, daß eine geregelte Spannung darüber entwickelt wird, deren Größe und Temperatur-Koeffizient unabhängig voneinander eingestellt werden können.

9. Spannungsregler nach Anspruch 8, welcher weiter enthält Mittel zum Koppeln des Basisanschlusses des dritten Transistors mit einem Ausgang des Spannungsreglers.

Revendications

1. Circuit d'alimentation en courant thermique, comprenant :

des premier et deuxième transistors (28, 30) dont les bases sont connectées ensemble et qui fonctionnent à des densités de courant prédéterminées différentes afin de produire entre leurs émetteurs une tension de différence qui possède un coefficient de température positif;

une première résistance (32) connectée à l'émetteur dudit premier transistor afin d'absorber le courant venant de celui-ci;

une deuxième résistance (34) connectée à l'émetteur dudit deuxième transistor afin d'absorber une partie du courant de celui-ci;

un troisième transistor (36) dont le trajet collecteur-émetteur est connecté entre l'émetteur dudit deuxième transistor et un noeud de circuit (I_{out}); et

un moyen (46) formant un circuit de réaction, qui est connecté au collecteur dudit deuxième transistor et qui répond audit deuxième transistor en fournissant un signal de réaction à la base dudit troisième transistor de façon que ce dernier absorbe le courant venant de l'émetteur dudit deuxième transistor avec une intensité prédéterminée qui est proportionnelle à la tension de différence et inversement proportionnelle à la valeur de ladite deuxième résistance, ledit courant qui passe dans ledit troisième transistor pour arriver au noeud de circuit possédant ledit coefficient de température positif prédéterminé.

2. Circuit d'alimentation en courant thermique selon la revendication 1, comprenant en outre :

une troisième résistance (56) connectée entre la base et l'émetteur du troisième transistor afin de fournir au noeud de circuit (I_{out}) un courant, possédant une intensité prédéterminée et un coefficient de température négatif, qui est additionné au courant passant dans ledit troisième transistor, où le courant additionné qui est établi sur le noeud de circuit possède une intensité ajustable et un coefficient de température ajustable qui dépendent de l'intensité prédéterminée du courant passant dans ledit troisième transistor et de l'intensité prédéterminée du courant fourni par la troisième résistance.

3. Circuit d'alimentation en courant thermique selon la revendication 1 ou 2, ledit moyen (46) formant un circuit de réaction comprend un quatrième transistor (46) dont l'émetteur est connecté à ladite base dudit troisième transistor, dont le collecteur est connecté à un premier conducteur d'alimentation électrique (44), et dont la base est connectée au collecteur dudit deuxième transistor.

4. Circuit d'alimentation en courant thermique selon la revendication 3, comprenant en outre :

un premier moyen conducteur (50) servant à connecter le collecteur dudit premier transistor à ladite base de celui-ci, lesdites bases desdits premier et deuxième transistors étant connectées ensemble; et

un moyen (40, 42) formant une source de courant, qui est connecté entre ledit premier conducteur d'alimentation électrique (44) et les collecteurs desdits premier et deuxième transistors afin de leur fournir du courant.

5. Circuit d'alimentation en courant thermique selon la revendication 4, où l'aire d'émetteur dudit premier transistor est N fois plus grande que l'aire d'émetteur dudit deuxième transistor, où N est un nombre positif, et ledit moyen formant un circuit de réaction amène les courants conduits par lesdits premier et deuxième transistors à être sensiblement égaux.

6. Circuit d'alimentation en courant thermique selon la revendication 5, comprenant en outre :

un cinquième transistor (52) dont la base est connectée audit collecteur dudit deuxième transistor, dont le collecteur est connecté audit premier conducteur d'alimentation électrique (44) et dont l'émetteur est connecté à ladite base dudit quatrième transistor (46), ledit premier moyen conducteur comportant un sixième transistor (50) dont la base est connectée audit collecteur dudit premier transistor, dont le collecteur est connecté audit premier conducteur d'alimentation électrique (44) et dont l'émetteur est connecté à ladite base dudit premier transistor.

7. Circuit d'alimentation en courant thermique selon la revendication 3, 4, 5 ou 6, où ledit moyen formant un circuit de réaction comprend en outre un moyen (48) formant un circuit, qui est connecté entre ledit émetteur dudit quatrième transistor et un deuxième conducteur d'alimentation électrique (38) afin d'absorber un courant prédéterminé provenant dudit quatrième transistor.

8. Régulateur de tension intégré (60) comprenant un circuit d'alimentation en courant thermique selon l'une quelconque des revendications 2,3,4,5,6 et 7 et une quatrième résistance (64) connectée audit noeud de circuit (I_{out}) dans lequel lesdits courants traversant ledit troisième transistor et ladite deuxième résistance (56) sont additionnés, de sorte qu'une tension régulée est créée aux bornes de celle-ci, l'amplitude et le coefficient de température de cette tension régulée pouvant être fixés indépendamment.

9. Régulateur de tension selon la revendication 8, comportant en outre un moyen servant à connecter la base dudit troisième transistor à une sortie du régulateur de tension.

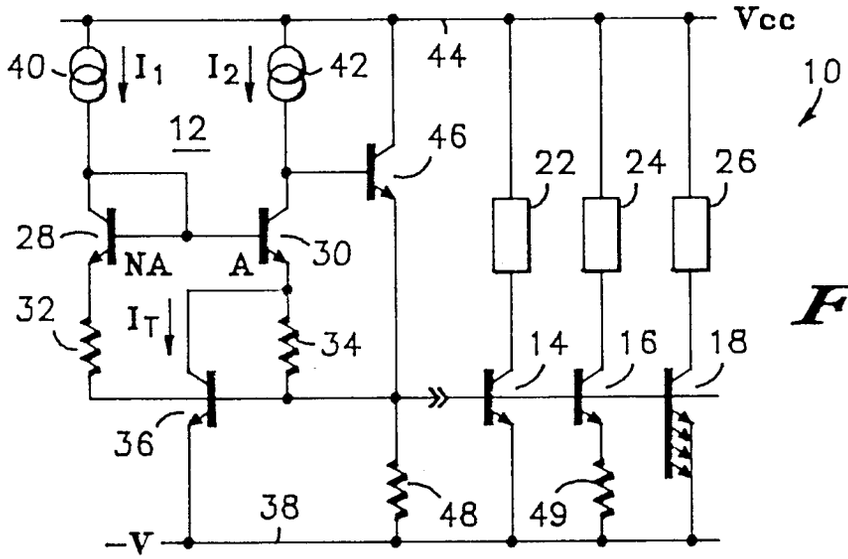


FIG. 1

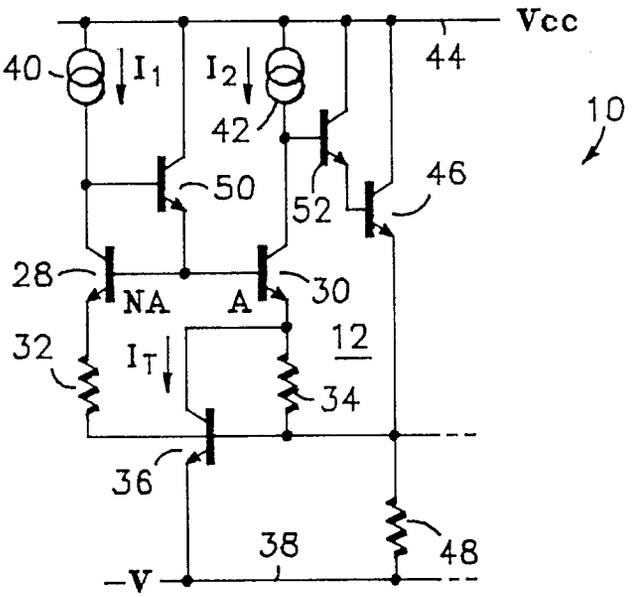


FIG. 2

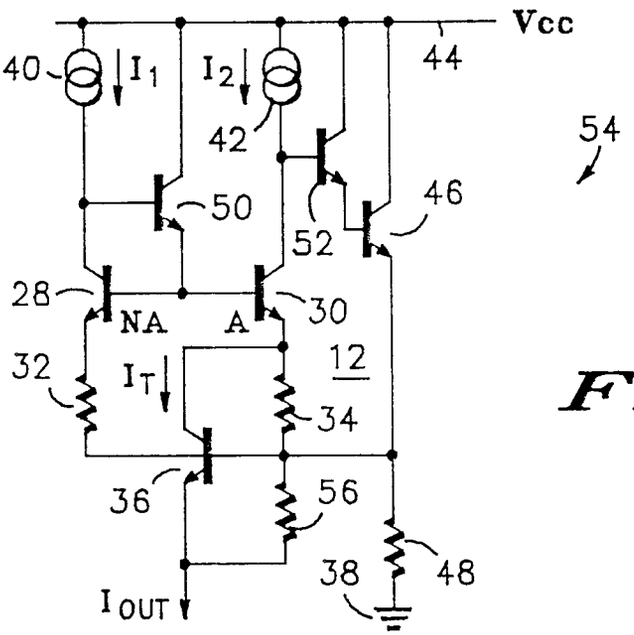


FIG. 3

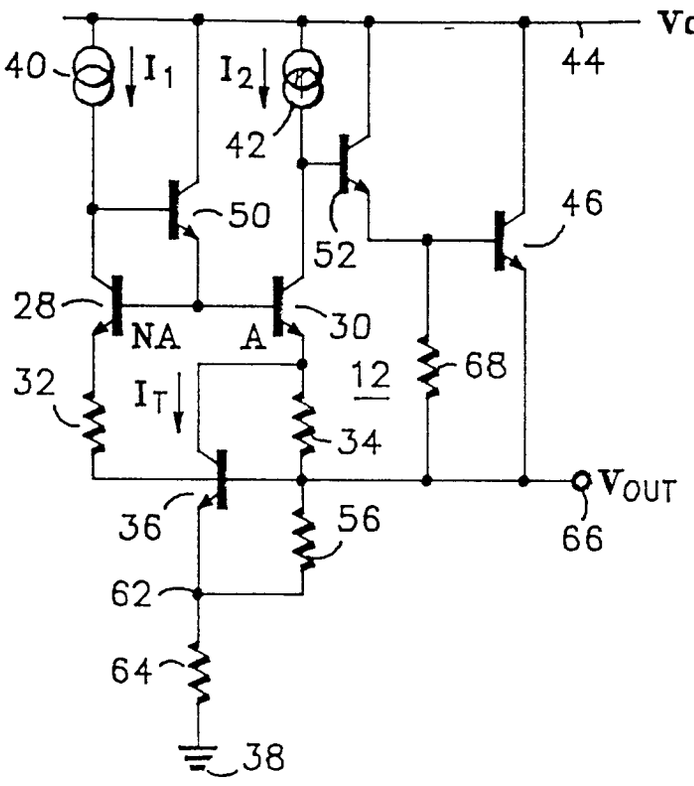

Vcc
40
I1
I2
42
44
60
50
46
52
28
NA
A
30
32
IT
12
68
34
VOUT
36
56
66
62
64
38

FIG. 4