

PATENT SPECIFICATION

1,197,657

DRAWINGS ATTACHED.

Date of Application (No. 39899/68) and filing Complete Specification: 21 Aug., 1968.

Application made in United States of America (No. 663,871) on 28 Aug., 1967.

Complete Specification Published: 8 July, 1970.



Index at acceptance:—H3 T(1A2, 1A3, 2A1N, 2J, 2N1, 2P, 2T2X, 2T2Z, 2T3J, 2V, 2W2, 2W3, 3J, 3N, 3VX, 4A2, 4C, 4E1N, 4E2N, 4M, 4X, 5E, 5P, 5S); H3 A(1A3, 3N, 4C1).

International Classification:—H 03 f 3/04.

COMPLETE SPECIFICATION.

Electrical Circuit.

We, RCA CORPORATION, formerly known as Radio Corporation of America, a corporation under the laws of the State of Delaware, United States of America, of 30 Rockefeller Plaza, City and State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electrical circuits constructed in integrated circuit form, and is especially useful in electronic equipment of the type wherein the solid state integrated circuit transistors are to cooperate with a vacuum tube amplifying device. As used herein, the term "integrated circuit" refers to a unitary or monolithic semiconductor device or chip which is the equivalent of a network of interconnected active and passive elements.

The generation of heat in an integrated circuit must not exceed the ability of its packaging to dissipate the heat into the surroundings of the package. Many integrated circuits, particularly those designed for an especial purpose, contain several stages of circuitry. Space upon the surface of the chip of such an integrated circuit is at a premium.

To make reasonably close tolerance integrated-circuit resistors, a 200 ohm per square resistance diffusion is normally used. This is also used to form the bases of the integrated-circuit transistors. Such resistors take up excessive room on the chip if they exceed a very few kilohms in value. The currents in the integrated circuit stages consequently are likely to range from a quar-

ter milliampere to two milliamperes. The supply voltage to the chip must be chosen to be appropriately low since there are several stages of circuitry at such currents and a thermal dissipation limitation on the package of the integrated circuit which may be of the order of two to five hundred milliamperes.

This reduces the dynamic range available in the output stage of the integrated circuit. The signal output swing cannot exceed the supply voltage applied to the integrated circuit chip. The available dynamic range of the stage is determined by the noise generated in the integrated circuitry and by the restricted B supply voltage applied to the chip. This supply voltage typically might be between seven and twelve volts.

Circuitry of the type described tends to have two shortcomings. Firstly, insufficient dynamic range is available to provide audio circuitry with a satisfactory signal-to-noise ratio. Secondly, the output voltage is not quite large enough to drive a subsequent vacuum-tube amplifier in most designs using a single vacuum-tube power amplifier. However, such an arrangement may be the only feasible circuitry containing integrated circuitry based on an economic comparison with other forms of circuitry.

It is possible to overcome these restrictions upon the design by using a separate, higher-voltage source of operating potential for the final stage of the integrated circuit. The number of terminals available to connect the integrated circuit with its external world is severely limited. It is accordingly desirable to apply this operating potential to the output stage of the integrated circuit through the terminal which already exists

to couple the output signal of this final integrated circuit stage to subsequent circuitry. If the final stage is a common-emitter or common-base configuration, the resistor returning the collector electrode of the transistor to the higher-voltage source of operating potential will be external to the chip.

It seldom is economic to provide a separate power supply for providing a source of operating potential to the final stage of the integrated circuit. It is advantageous to use a higher-voltage power supply which already exists in the environment in which the integrated circuit is utilized. This supply, particularly in a vacuum-tube circuit environment, may have a potential greater than the collector-to-emitter or collector-to-base breakdown potentials which the integrated circuit transistor can withstand. This can destroy the integrated circuit when the power to the integrated-circuit and vacuum-tube system is switched on or off.

However, a more subtle problem is also encountered. The degree of control which can be exercised over the masking and diffusion processes used to form integrated circuits is limited, and this in turn makes the resistors on an integrated circuit exhibit a wide absolute tolerance. Typically, the 200 ohm per square P-material resistors have a $\pm 30\%$ tolerance. Also, one must remember that these resistors have a marked sensitivity to temperature of the order of $+19$ parts per thousand per degree Centigrade temperature rise. The biasing of an integrated amplifier of the proposed type is dependent upon the ratio of its resistance to the resistance of an external resistor. It is clear that such biasing will be quite indeterminate and may subject the integrated circuit to potentials larger than its breakdown potential. This tendency is greater when the potential swings needed to drive the vacuum tube stage are nearly as great as the breakdown potentials of the integrated device.

In the present invention these problems are met by having the internal circuitry of the integrated circuit perform an auxiliary function; namely, a shunt regulating function. This shunt regulating function is performed upon the direct current potential at the output terminal of the integrated circuit which is returned to a source operating potential by means of an external resistor. In accordance with the present invention, there is provided an electrical circuit using feedback for the regulation of direct potential biasing, comprising an integrated circuit; a transistor disposed in said integrated circuit, having an input electrode, an output electrode, a common electrode and exhibiting given breakdown voltages between said output electrode and each of said input and common electrodes, a terminal on said integrated circuit coupled to said output elec-

trode of said transistor and being provided for coupling to an operating potential supply with a direct current impedance, said direct current impedance and said supply being capable of co-acting to produce a quiescent direct potential at said output electrode which may exceed one of said breakdown voltages; said electrical circuit further comprising coupling means including a voltage divider disposed in said integrated circuit coupled to said output electrode and responsive to said quiescent potential for coupling a predetermined portion thereof to said input electrode to reduce said quiescent potential and to stabilize it at a level such that in response to applied input signals, said transistor can develop output signals, the maximum amplitude of which can approach but will not exceed, said breakdown voltage.

The accompanying drawing represents a schematic circuit diagram of an angle modulated wave processing channel for television receivers which may be incorporated in an integrated circuit device.

The schematic circuit diagram of the drawing shows the use of a plurality of three-transistor amplifier stages in the sound channel of a television receiver. The dotted rectangle 10 schematically illustrates a monolithic semiconductor circuit chip. The chip has a plurality of contact areas about its periphery through which connections to the circuit on the chip may be made. For example, the chip 10 has a pair of contact areas 12 and 14 which are adapted to be coupled to a source of frequency modulated (FM) waves.

As to physical dimensions, the chip 10 may be of the order of 50 mils $\times$ 50 mils, or smaller. The manner of implementing the various transistor, diode and resistor functional portions described below in a monolithic chip is known in the art.

FM signals from a suitable source, such as a video detector or video amplifier of the television receiver, are applied to a terminal 16 and coupled through a capacitor 18 to a resonant circuit 20 which is tuned to the 4.5 MHz intercarrier beat between the video and sound carriers of the television signal in accordance with the television standards adopted in the United States of America. The resonant circuit 20 and the coupling capacitor 18 in the present example are external to the chip but are coupled thereto through the contact areas 12 and 14.

The contact area 12 is directly coupled to a first amplifier stage 22 including three transistors 24, 26 and 28. The first two transistors 24 and 26 are connected by resistors 30 and 32 to provide an emitter coupled amplifier and the third transistor 28 is connected by resistors 34 and 36 as

an emitter follower. The output signal developed by the stage 22 appears at the junction of resistors 34 and 36.

The amplifier stage 22 is directly coupled to a similar amplifier stage 38 which also includes three transistors 40, 42 and 44. The first two transistors 40 and 42 are also connected by a pair of resistors 46 and 48 to form the emitter coupled amplifier construction while the third transistor 44 is also connected as an emitter follower, by resistors 50 and 52.

Output signals from the stage 38 are developed across the resistor 52 and applied to a limiter stage 54 including transistors 56, 58 and 60, a diode 62 and a resistor 64. The transistor 60 functions as a constant current source for the limiter stage 54, and is temperature compensated by the diode 62 in a known manner. The transistor 58 portion of the stage 54 is connected through a contact area 66 to drive the primary winding of a discriminator transformer 68. The secondary winding of the discriminator transformer 68 is connected through a pair of contact areas 70 and 72 to the remainder of the discriminator circuit 74. The discriminator circuit 74 is balanced to provide a direct output voltage at a contact area 76 which does not vary with signal level.

The discriminator circuit 74, which is the subject of our copending Application No. 8790/67, now Patent 1,124,276, is of the form of a ratio detector but without the large non-integratable capacitor normally used to obtain peak rectification. The oppositely poled rectifier devices of the discriminator circuit 74 are shown by the reference numerals 78 and 80 while the distributed capacitance of the integrated load resistors 82 and 84 provide filtering of the signal frequency and its harmonics.

The demodulated signals developed by the discriminator 74 are coupled by means of the contact area 76, a first capacitor 86, a potentiometer 88, a second capacitor 90 and a contact area 92 to the input of an audio frequency amplifier stage 94 constructed in accordance with the present invention and to be described hereinafter. Output signals developed by the stage 94 are coupled by means of a contact area 96 and a third capacitor 98 to an audio frequency output stage including, for example, a vacuum tube 100 for driving a speaker (not shown). A de-emphasis capacitor 102 couples the contact area 76 to a point of reference potential, indicated as ground.

The positive terminal of a d-c supply source for the circuit (which may be subject to some variation) is connected to a contact area 104, while the ground negative terminal is connected to another contact area 106. The supply voltage variation is regulated by the emitter-base breakdown voltage

of a transistor 108, which is connected to the contact area 104 via a resistor 110 and whose collector electrode is left unconnected. Transistors 112, and 114, connected to the contact area 104 and to the transistor 108, serve as emitter followers to isolate the regulated voltage fed to the transistors 24, 26, 28, 40 and 42 from that fed to the transistors 44, 56 and 58.

A pair of transistors 116 and 118 and three resistors 120, 122 and 124 are also included in the circuit of the drawing, and constitute a bias potential supply 126 for the amplifier stages 22 and 38. This supply 126 has been described in our copending Patent Specification No. 1,169,521, and forms no part of the present invention. In a manner analogous to that described therein, the supply 126 develops a voltage across the resistor 124 which is substantially one-half the value of the supply voltage at the end of resistor 120 remote from the collector electrode of transistor 118. The voltage across resistor 124 is independent of temperature and supply voltage variations.

Operating point stability of the amplifier stages 22 and 38 is maintained by use of direct current feedback through resistor 128 around those two stages, with a bypass capacitor 130 connected to the resistor 128 via contact area 132. The limiter stage 54 is then automatically at the proper operating point because the feedback around the amplifier stages 22 and 38 holds the voltage at the base electrode of the transistor 56 at one-half the aforementioned supply voltage.

The limiter stage 54 is thus balanced without being in the feedback loop. This is desirable because the tendency toward oscillation in the feedback loop is reduced by keeping the number of stages as low as possible. Proper bias voltage for the limiter stage 54 is made essentially independent of transistor gain through the use of a resistor 134, connected in the base electrode return of transistor 24 and equal in value to the resistor 128 connected in the base electrode return of transistor 26. Bypass capacitors 136 and 138 are connected to the resistor 134 by means of the contact areas 14 and 140, respectively.

Considering, now the audio frequency amplifier 94 in more detail, it includes a first transistor 150 connected in a circuit configuration driving a second transistor 152 connected as a common emitter stage. More particularly: the base electrode of the transistor 150 is connected to the audio frequency input contact area 92, its collector electrode is connected to the positive potential contact area 104, and its emitter electrode is connected to the base electrode of the transistor 152.

The emitter electrode of the transistor 152 is correspondingly connected by means of 130

4
12
a resistor 154 to the ground contact area 106, while the collector electrode of that transistor is coupled by means of the contact area 96 and a voltage dropping load resistor 156 (located external to the integrated chip 10) to a source of operating voltage, represented in the drawing by the positive potential terminal 158. A first pair of serially connected resistors 160 and 162 couple the collector electrode of transistor 152 to the ground contact 106, while a second such pair of resistors 164 and 166 couple the junction of the resistors 160 and 162 to the base electrode of transistor 150, completing a feedback path via the contact areas 92 and 168.

Of the four last named resistors, all but resistor 166 are included on the integrated chip, as shown. A capacitor 170 is further included to connect the junction of resistors 164 and 166 to ground at the contact area 168 so as to provide full degeneration of the d-c feedback component without affecting a-c signal gain.

Since an audio frequency output tube often costs less than a comparable output transistor, the sound channel construction of the drawing illustrates such a tube 100 being driven by the transistor 152. The signal swing obtainable from the transistor 152 is generally limited to a magnitude comparable to its collector breakdown voltage. Furthermore, a vacuum tube capable of developing maximum power output with that signal swing will be the one that operates most effectively.

In one construction of the sound channel, a 6AQ5 type was used as the audio frequency output tube 100, to match the 30 volt peak-to-peak signal swing obtainable from the monolithic silicon integrated circuit structure of the transistor 152. A +140 volt supply available in the receiver was used as the operating voltage for the transistor 152 and an 82 K ohm resistor was employed as the resistor 156.

With such an arrangement, and with a low value resistor 154 in the emitter circuit of the transistor 152 (e.g. 50 ohms), a quiescent d-c potential of approximately +15 volts was established, and a 30 volt signal swing obtained, at the collector electrode of that transistor. It will be understood that the load resistor 156 is connected external to the integrated chip 10 in order to prevent its power dissipation from exceeding that of the integrated chip and because the chip may be unable to handle directly an input of 140 volts d-c without breaking down.

Problems may be created, however, if either or both of the supply voltage and load resistance suffer variations in their respective absolute values. Variations in the 140 volt operating supply and/or in the nominal value of the resistor 156 which are

in a direction to increase the the d-c potential and signal swing at the transistor 152 collector electrode, for example, may well cause the transistor breakdown voltage to be exceeded. Similar variations, but in the opposite direction on the other hand, may well reduce the effectiveness of the audio output tube 100 since the input drive signal will be diminished below the optimum 30 volt peak-to-peak value required to develop its maximum power output.

Such variations in the d-c potential, are prevented, however, according to the invention, through the use of a negative feedback circuit including the resistors 160 and 162. These resistors form a voltage divider across the transistor 152, whose value remains substantially fixed because the ratio between those resistors in an integrated circuit structure is relatively stable, although their absolute values may vary because of the manufacturing process tolerance.

The precise ratio for resistors 160 and 162 is selected such that the quiescent d-c voltage at their junction less the small d-c drops across the resistors 164 and 166 substantially equals the desired quiescent voltage drop from the base electrode of transistor 150 to ground. That is, equal to the sum of the base-to-emitter voltage drops of the transistors 150 and 152, and the drop across the emitter resistor 154.

With the values shown in the drawing, the voltage drop across resistor 154 is approximately 0.08 volts, the drop across the base-emitter junction of transistor 152 is approximately 0.7 volts (the voltage drop when a transistor fabricated of monolithic silicon operates as a Class A amplifier), and the drop across the base-emitter junction of transistor 150 is approximately 0.5 volts. With a +15 volt d-c level at the collector electrode of transistor 152, therefore, a resistance ratio of approximately 9:1 between resistors 160 and 162 provides the necessary 1.28 volts feedback voltage, the precise ratio being calculable from the values shown in the drawing.

These parameters are such that any change in the quiescent d-c operating point at the collector electrode of transistor 152 causes an offsetting change at the base electrode of the transistor 150 of such a magnitude as to stabilize the d-c voltage at the collector electrode. (In this respect it will be noted that changes in the quiescent current flowing through the small resistor 154 due to variations in the d-c operating point produce only minor effects, so that in essence, a varying d-c potential at the collector electrode of transistor 152 is being compared to a substantially fixed d-c potential at the base electrode of transistor 150.) Any distortion which might otherwise result due to the transistor's collector breakdown

(13)

voltage being exceeded or due to its collector output swing being diminished is thereby minimized.

It will thus be appreciated that by stabilizing the quiescent d-c potential at the collector electrode of the output transistor 152 in the foregoing manner, an unregulated supply source (e.g. $\pm 15\%$ variation) can be used to provide the operating voltage for the transistor 152, and through a 10% voltage dropping load resistor, for example. An output signal swing extending up to, and without exceeding, the breakdown voltage of the transistor 152 can then be obtained, even though the absolute component values in the circuit may vary over a wide range. As was previously mentioned, the 6AQ5 type audio output tube operates most effectively with this signal swing.

It will also be appreciated that the transistor 150 can be omitted from the circuit of the drawing and the operation maintained by changing the ratio of the resistors 160 and 162 so as to stabilize the d-c potential at the base electrode of transistor 152 at a value substantially equal to the drop across its base-emitter junction and across its emitter load resistor 154. The inclusion of the transistor 150, as shown in the drawing, is to be preferred, however, since it permits the use of a large resistor 166 to provide a high input impedance for the stage 94, while restricting the voltage drop across that resistor to be a few tenths of a volt. Were it not for the current gain provided by the transistor 150, a much smaller resistor would be required in order to prevent its tolerance variations from changing the quiescent voltage at the base electrode of transistor 152 by an amount sufficient to cause the collector breakdown voltage to be exceeded.

WHAT WE CLAIM IS:—

1. An electrical circuit using feedback for the regulation of direct potential biasing, comprising an integrated circuit; a transistor disposed in said integrated circuit, having an input electrode, an output electrode, a common electrode and exhibiting given breakdown voltages between said output electrode and each of said input and common electrodes, a terminal on said integrated circuit coupled to said output electrode of said transistor and being provided for coupling to an operating potential supply with a direct current impedance, said direct current impedance and said supply being capable of co-acting to produce a quiescent direct potential at said output electrode which may exceed one of said breakdown voltages; said electrical circuit further comprising coupling means including a voltage divider disposed in said integrated circuit coupled to said output electrode and responsive to said quiescent potential for coupling

a predetermined portion thereof to said input electrode to reduce said quiescent potential and to stabilize it at a level such that in response to applied input signals, said transistor can develop output signals, the maximum amplitude of which can approach but will not exceed, said breakdown voltage.

2. An electrical circuit as defined in Claim 1, so arranged that said quiescent direct potential is reduced to and stabilized at a level substantially one-half said given breakdown voltage.

3. An electrical circuit as defined in Claim 1 or 2, in which said direct current impedance includes a resistor and wherein at least one of said operating potential supply and said resistor is subject to variations in its absolute value.

4. An electrical circuit as defined in any one of the preceding claims, in which said output and input electrodes comprise the collector electrode and the base electrode of said transistor, respectively, and wherein said voltage divider includes a pair of resistors serially connected to said collector electrode, and with the junction between said pair being coupled to said base electrode.

5. An electrical circuit as defined in any one of the preceding claims, in which there is also included a second transistor disposed in said integrated circuit and having an input electrode arranged to receive said input signals and said predetermined portion of said quiescent potential, and also having an output electrode coupled to the input electrode of said first transistor.

6. An electrical circuit as claimed in Claim 1, in which said transistor has collector, base and emitter electrodes and exhibits said given breakdown voltage at said collector electrode, said direct current impedance is coupled to said collector, base and emitter electrodes for connecting said transistor in a common emitter amplifier configuration, said direct current impedance including an output load coupling said source of potential to said collector electrode to establish said quiescent direct potential, said voltage divider is coupled to said collector electrode for developing and feeding back to said base electrode a direct voltage of a magnitude sufficient to stabilize said quiescent potential at a level such that in response to input signals applied to its base electrode, said transistor develops at its collector electrode output signal swings, the maximum amplitude of which is comparable to, and without exceeding, said breakdown voltage.

7. An electrical circuit as defined in Claim 6, in which said voltage divider comprises a pair of resistors serially connected to said collector electrode and wherein the ratio between said resistors is such that the voltage developed at their common junction

(13)

voltage being exceeded or due to its collector output swing being diminished is thereby minimized.

It will thus be appreciated that by stabilizing the quiescent d-c potential at the collector electrode of the output transistor 152 in the foregoing manner, an unregulated supply source (e.g. $\pm 15\%$ variation) can be used to provide the operating voltage for the transistor 152, and through a 10% voltage dropping load resistor, for example. An output signal swing extending up to, and without exceeding, the breakdown voltage of the transistor 152 can then be obtained, even though the absolute component values in the circuit may vary over a wide range. As was previously mentioned, the 6AQ5 type audio output tube operates most effectively with this signal swing.

It will also be appreciated that the transistor 150 can be omitted from the circuit of the drawing and the operation maintained by changing the ratio of the resistors 160 and 162 so as to stabilize the d-c potential at the base electrode of transistor 152 at a value substantially equal to the drop across its base-emitter junction and across its emitter load resistor 154. The inclusion of the transistor 150, as shown in the drawing, is to be preferred, however, since it permits the use of a large resistor 166 to provide a high input impedance for the stage 94, while restricting the voltage drop across that resistor to be a few tenths of a volt. Were it not for the current gain provided by the transistor 150, a much smaller resistor would be required in order to prevent its tolerance variations from changing the quiescent voltage at the base electrode of transistor 152 by an amount sufficient to cause the collector breakdown voltage to be exceeded.

WHAT WE CLAIM IS:—

1. An electrical circuit using feedback for the regulation of direct potential biasing, comprising an integrated circuit; a transistor disposed in said integrated circuit, having an input electrode, an output electrode, a common voltage electrode and exhibiting given breakdown voltages between said output electrode and each of said input and common electrodes, a terminal on said integrated circuit coupled to said output electrode of said transistor and being provided for coupling to an operating potential supply with a direct current impedance, said direct current impedance and said supply being capable of co-acting to produce a quiescent direct potential at said output electrode which may exceed one of said breakdown voltages; said electrical circuit further comprising coupling means including a voltage divider disposed in said integrated circuit coupled to said output electrode and responsive to said quiescent potential for coupling

a predetermined portion thereof to said input electrode to reduce said quiescent potential and to stabilize it at a level such that in response to applied input signals, said transistor can develop output signals, the maximum amplitude of which can approach but will not exceed, said breakdown voltage.

2. An electrical circuit as defined in Claim 1, so arranged that said quiescent direct potential is reduced to and stabilized at a level substantially one-half said given breakdown voltage.

3. An electrical circuit as defined in Claim 1 or 2, in which said direct current impedance includes a resistor and wherein at least one of said operating potential supply and said resistor is subject to variations in its absolute value.

4. An electrical circuit as defined in any one of the preceding claims, in which said output and input electrodes comprise the collector electrode and the base electrode of said transistor, respectively, and wherein said voltage divider includes a pair of resistors serially connected to said collector electrode, and with the junction between said pair being coupled to said base electrode.

5. An electrical circuit as defined in any one of the preceding claims, in which there is also included a second transistor disposed in said integrated circuit and having an input electrode arranged to receive said input signals and said predetermined portion of said quiescent potential, and also having an output electrode coupled to the input electrode of said first transistor.

6. An electrical circuit as claimed in Claim 1, in which said transistor has collector, base and emitter electrodes and exhibits said given breakdown voltage at said collector electrode, said direct current impedance is coupled to said collector, base and emitter electrodes for connecting said transistor in a common emitter amplifier configuration, said direct current impedance including an output load coupling said source of potential to said collector electrode to establish said quiescent direct potential, said voltage divider is coupled to said collector electrode for developing and feeding back to said base electrode a direct voltage of a magnitude sufficient to stabilize said quiescent potential at a level such that in response to input signals applied to its base electrode, said transistor develops at its collector electrode output signal swings, the maximum amplitude of which is comparable to, and without exceeding, said breakdown voltage.

7. An electrical circuit as defined in Claim 6, in which said voltage divider comprises a pair of resistors serially connected to said collector electrode and wherein the ratio between said resistors is such that the voltage developed at their common junction



when fed back to said base electrode substantially equals the nominal quiescent direct potential established at said base electrode.

- 5 8. An electrical circuit as defined in Claim 6, in which said output load comprises a first resistor, wherein a second resistor is included and coupled to said emitter electrode, and wherein said voltage divider comprises third resistor and fourth resistor serially connected to said collector electrode, the ratio between said third and fourth resistors being such that the voltage developed at their common junction when
10 fed back to said base electrode substantially equals the sum of the voltage drops between said base and emitter electrodes and across said second resistor.

- 15 9. An electrical circuit as defined in Claims 6, 7 or 8, in which the value of said source of operating potential is substantially in excess of said breakdown voltage.

- 20 10. An electrical circuit as defined in Claim 9, in which the voltage drop between said base and emitter electrodes substantially exceeds that across said second resistor.

- 25 11. An electrical circuit as defined in Claim 1, in which said transistor is a first transistor having collector, base and emitter electrodes and exhibiting a predetermined breakdown voltage between the first two of said three electrodes, a second transistor
30 is included having collector, base and emitter electrodes, a signal input terminal is coupled to the base electrode of said second transistor, a signal output terminal is coupled to the collector electrode of said first transistor, a further operating potential supply
35 is used having a value less than said given breakdown voltage, the said supply being an operating potential having a value in excess of said breakdown voltage, a direct
40 connection from the further supply to the collector electrode of said second transistor,

a direct connection from the emitter electrode of said second transistor to the base electrode of said first transistor, a first resistor coupling the said supply to the collector electrode of said first transistor, a second resistor coupling the emitter electrode of said first transistor to a point of reference potential, third and fourth resistors serially connected between the collector electrode of said first transistor and said point of reference potential for developing a predetermined direct voltage defined herein-
50 after at their common junction, fifth and sixth resistors serially connected between the base electrode of said second transistor and said common junction, and a capacitor coupled between the common junction of said fifth and sixth resistors and said point of reference potential, with at least said third
55 and fourth resistors being incorporated in said integrated circuit and with the ratio therebetween being such that the direct voltage developed at their common junction when fed back to the base electrode of said
60 second transistor via said fifth and sixth resistors substantially equals the sum of the voltage drop between the base and emitter electrodes of said first and second transistors and across said second resistor.

- 70 12. An electrical circuit as defined in Claim 11, wherein the further supply supplies a regulated operating potential while the said supply supplies an unregulated potential and wherein said first and second
75 transistors and said second and fifth resistors are additionally included within said integrated circuit.

- 80 13. An electrical circuit substantially as described and illustrated with respect to the accompanying drawing.

T. I. M. SMITH,
Chartered Patent Agent,
50 Curzon Street,
London, W1Y 8EU,
Agent for the Applicants.



* C L H S *