

Oct. 18, 1966

HUNG C. LIN ET AL

3,280,338

CONSTANT CURRENT BIASING CIRCUIT

Filed June 27, 1961

2 Sheets-Sheet 1

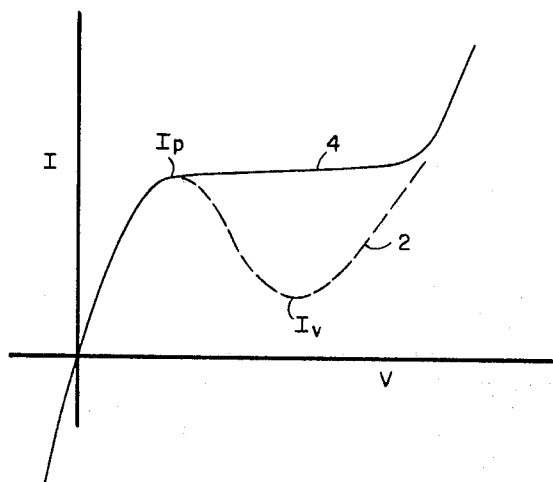


Fig. 1.

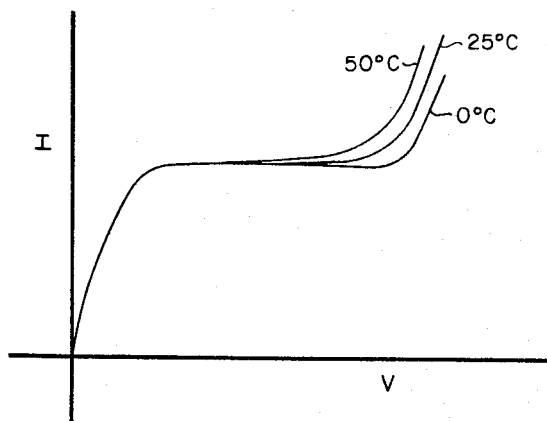


Fig. 2.

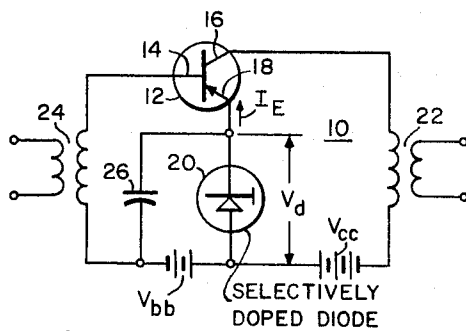


Fig. 3.

WITNESSES

Edwin E. Basler
James F. Young

INVENTORS
Hung C. Lin and
Paul F. Pittman

BY *Ernest P. Kippel*
ATTORNEY

Oct. 18, 1966

HUNG C. LIN ET AL

3,280,338

CONSTANT CURRENT BIASING CIRCUIT

Filed June 27, 1961

2 Sheets-Sheet 2

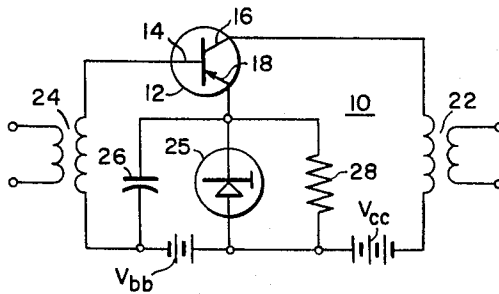


Fig. 4.

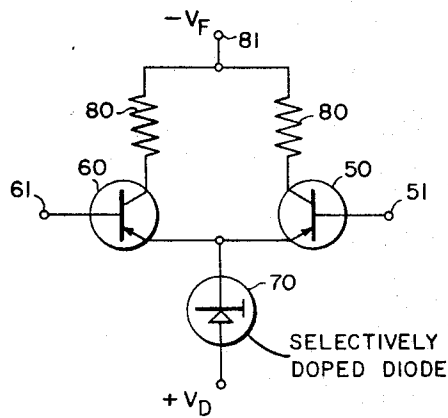


Fig. 6.

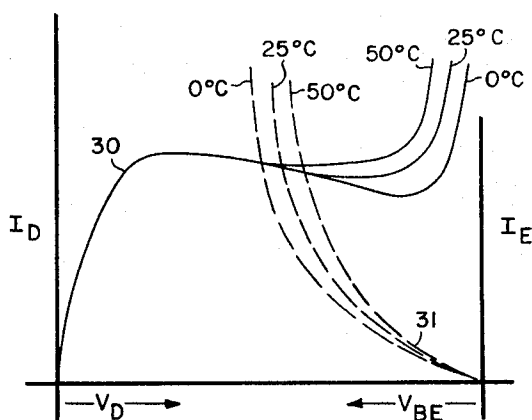


Fig. 5.

1

3,280,338

CONSTANT CURRENT BIASING CIRCUIT

Hung C. Lin, Pittcairn, and Paul F. Pittman, Pittsburgh, Pa., assignors to Westinghouse Electric Corporation, Pittsburgh, Pa., a corporation of Pennsylvania

Filed June 27, 1961, Ser. No. 119,969

4 Claims. (Cl. 307—88.5)

The present invention relates generally to constant current biasing circuits and more particularly, relates to a constant current biasing circuit for a transistor.

It is highly desirable that an ideal constant current source exhibits two terminals, a low voltage drop thereacross and good temperature stability. Conventionally, a high resistance element in series circuit combination with a high voltage supply may be used to serve as a constant current source, but the high voltage results in a high dissipation in the series resistor. The common-base collector characteristics of a transistor exhibit a constant current, but the circuit is inherently more complicated than that of the two terminal device and a secondary current reference is still required in the emitter of the transistor. The current of a reverse-biased semiconductor junction is constant over a wide range of voltage, but the poor temperature stability of such an arrangement makes it impractical. Other constant current devices such as the ballast tube or the field effect varistor usually have high voltage drops resulting in considerable wasted power.

The advent of semiconductor devices exhibiting a quantum mechanical tunneling phenomena has lead to new constant current biasing circuits for a transistor stage. Its relative temperature stability has led to temperature stabilization circuits for a transistor stage.

The present invention makes use of the portion of the volt-ampere characteristic curve of such a device wherein the peak to valley current ratio is substantially unity, thereby providing a constant current portion of the characteristic curve over a preselected range of voltage of predetermined polarity.

An object of the present invention is to provide a constant current circuit for a transistor stage.

Another object of the present invention is to provide a constant current source for a current switching stage.

Another object of the present invention is to provide a temperature compensating circuit for a transistor wherein the emitter current varies with a negative temperature coefficient.

Another object of the present invention is to provide a constant current source circuit having substantially less dissipated power than circuits of the prior art.

Another object of the present invention is to provide a constant current source circuit having excellent temperature stability in comparison with sources of the prior art.

Further objects and advantages of the present invention will be readily apparent from the following detailed description taken in conjunction with the drawing, in which:

FIG. 1 is a characteristic curve of a device utilized in an illustrative embodiment of the present invention;

FIG. 2 is a characteristic curve of a device utilized in the present invention illustrating its relative insensitivity to temperature changes;

FIG. 3 is an illustrative embodiment of the present invention;

FIG. 4 is a schematic diagram of an alternate embodiment of the present invention;

FIG. 5 is the characteristic curves of two separate devices utilized in another alternate embodiment of the present invention; and,

FIG. 6 is a schematic diagram of another alternate embodiment of the present invention.

A semiconductor device exhibiting a negative resist-

2

ance in the first quadrant of the current-voltage characteristic curve due to quantum mechanical tunneling is characterized by the curve 2 in FIG. 1. One of such devices is the tunnel diode. For reverse bias, the resistance of the tunnel diode is small. In the forward direction of voltage across the tunnel diode, the current therethrough increases to a sharp maximum I_p on a portion of the characteristic curve referred to as the low voltage side. Further increase in the voltage across the diode results in the negative resistance portion of the characteristic curve wherein the current through the diode drops to a deep and broad minimum, referred to as the valley current I_v . Still further increases in the voltage across the diode causes the current to increase again on a portion of the characteristic curve referred to as the high voltage side. The break-over or threshold current level as determined by the peak tunneling current I_p is herein referred to as the threshold or excitation level of the diode. For the purposes of this specification, the term "tunnel diode" is herein meant to include all devices exhibiting the aforementioned characteristics. Tunnel diodes conventionally have peak-to-valley current ratios of five or more. The present invention, however, utilizes in some of its embodiments, a tunnel diode having a peak-to-valley current ratio of substantially unity, as illustrated by the characteristic curve 4 in FIG. 1. It can be seen from the characteristic curve 4 that the device has a constant current region curve 4 that the device has a constant current region over a preselected range of voltage values of predetermined polarity wherein the peak-to-valley current ratio is substantially equal to unity. Such a device can be readily made by doping the diode in an appropriate manner to provide a selected peak-to-valley ratio according to the impurity concentration. From FIG. 2 it can be seen that the temperature stability of a tunnel diode having a peak-to-valley current ratio of substantially unity is excellent since the tunneling effect, which accounts for the constant current region of the characteristic curve, is relatively insensitive to temperature. Accordingly, it can be seen that such a tunnel diode has a low voltage drop and high incremental resistance, and as such, functions as an inductance by exhibiting a low direct current but high alternating current resistance.

The constant current biasing circuit for a transistor is illustrated in the embodiment shown in FIG. 3. The transformer coupled transistor stage 10 comprises a transistor 12 having a base electrode 14, collector electrode 16, and emitter electrode 18. A tunnel diode 20, having a characteristic curve 4 as illustrated in FIG. 1, is connected in series circuit relationship with an output transformer 22 across the emitter-collector circuit of the transistor 12. A means for biasing the emitter-collector circuit is provided by the constant potential source V_{cc} . An input transformer 24 is connected in series circuit relationship with the tunnel diode 20 across the base-emitter circuit. Means for biasing the base-emitter circuit is provided by the constant potential source V_{bb} . A capacitive element 26 is connected across said tunnel diode 20 to provide an alternating current by-pass. The constant potential sources V_{bb} and V_{cc} are selected so that the emitter voltage is considerably larger than the voltage V_d across the tunnel diode 20. Further, the potential sources V_{bb} and V_{cc} are selected to bias the diode 20 into the constant current range. If a load such as the base-emitter junction of the transistor 12 is connected in series circuit relationship with said tunnel diode 20, the current through the load will be held constant even if the load resistance changes within a limited range. The low voltage drop across the tunnel diode is considerably less than that across a biasing resistor connected in series circuit combination with the emitter as in a conventional resistance-stabilized transistor stage. The savings in biasing voltage

is significant in portable equipments such as hearing aids where low supply voltages are the usual mode.

FIG. 4 illustrates how the constant current characteristic of a tunnel diode having a peak-to-valley current ratio of substantially one can also be obtained by connecting a resistance 28 in parallel circuit combination with a tunnel diode 25, having negative resistance characteristics. Circuit elements similar to those used in FIG. 3 have been designated by identical reference characters. Assuming the tunnel diode 25 exhibits a characteristic curve having a negative resistance over a preselected range of preselected polarity, the magnitude of the resistor 28 is selected to be equal in magnitude to the negative resistance of the tunnel diode. The shunt resistance 28 may be either external or integrated with the tunnel diode 25. In either event the constant current characteristic functions in the same manner as the results obtained when using only a tunnel diode having a peak-to-valley current ratio of substantially unity.

The present invention is not limited to constant current biasing of transistors. For instance, by using a tunnel diode exhibiting characteristic curve 30 as shown in FIG. 5, the emitter-current in the transformer coupled transistor stage 10 of FIG. 3 can have a negative temperature coefficient. This condition is best illustrated in FIG. 5 where, as temperature is increased, the transistor base-emitter characteristic curve 31 moves to the right thereby reducing the base-emitter voltage drop V_{be} , thus meeting the tunnel diode characteristic curve 30 at a lower current and compensating in part for the increased collector current with increasing temperature.

The circuit of FIG. 3 was tested and compared with the conventional resistance-biased circuit using the same emitter-bias supply voltage to determine the effect of the tunnel diode 20. The circuit operating the same transistor 12 at three different temperatures showed a marked improvement in temperature stability over the conventional circuit. Three different transistors were tested in the circuit to determine the effect of the tunnel diode on interchangeability. The results were as follows:

Temperature.....	Tunnel Diode			Emitter Resistance		
	0° C.	25° C.	50° C.	0° C.	25° C.	50° C.
Collector Current in Milliampères						
Transistor:						
1.....	7.9	7.7	8.1	6.7	7.7	9.8
2.....		7.7			8.6	
3.....		7.6			8.9	

The results clearly indicate that bias derived from the use of a tunnel diode having a peak-to-valley current ratio of substantially unity is superior to that derived from a resistor from the standpoint of both interchangeability and temperature stability.

Still another alternate embodiment of the present invention is illustrated in FIG. 6 wherein a constant current source is provided for a current switching circuit. A first transistor 50 and a second transistor 60 is connected in a common emitter circuit including a tunnel diode 70 and means for connecting a voltage V_D thereto. The collectors are each commonly connected through respective resistors 80 to a common terminal 81 adapted to be connected to a potential source V_F of opposite polarity to the potential source V_D . The first transistor 50 has an input terminal 51 connected thereto for receipt of a reference input signal. The base electrode of the transistor 60 is connected to an input terminal 61 adapted to receive a variable input signal. The current switching circuit shown in FIG. 6 is characterized by the fact that the emitter current of the conducting transistor is limited by a constant current source. Thus, the transistor is not saturated. A nonsaturated switching circuit has higher speed capabilities. Should the variable input signal to the

input terminal 61 be less than the magnitude of the reference input signal to the input terminal 51 the first transistor 60 is rendered conductive. However, should the variable input signal to the terminal 51 exceed the reference input value to the input terminal 51 then the transistor 50 is rendered conductive. In current switching circuits of the conventional and prior art a common emitter resistor of considerable magnitude is required. A large voltage drop results across the common emitter resistor. In contrast, the present invention provides a constant current source by utilizing a tunnel diode 70 having a characteristic curve 4 as shown in FIG. 1. Accordingly, the power supply requirements of the circuit are greatly reduced since the voltage drop across the tunnel diode 70 is considerably less with the added advantage of a considerably less power dissipation.

While the present invention has been described with a degree of particularity for the purpose of illustration, it is to be understood that all alterations, modifications and substitutions within the spirit and scope of the present invention are herein meant to be included.

We claim as our invention:

1. In an amplifier circuit, a transistor having an emitter electrode, collector electrode and base electrode; means for connecting an input signal to said base electrode; output means connected across the emitter-collector circuits; means for biasing the base-emitter circuit; means for biasing the collector-emitter circuit; and a semiconductor device; said semiconductor device being characterized as having a voltage-ampere characteristic which includes a constant current portion over a preselected range of voltage values of predetermined polarity; said semiconductor device connected in series circuit combination with said emitter and a capacitor connected in parallel circuit relationship with said semiconductor device.

2. A constant current biasing circuit for a transistor having an emitter electrode, collector electrode, and base electrode, comprising, in combination; a tunnel diode connected in series circuit combination with said emitter electrode; means for biasing the base-emitter circuit; means for biasing the collector-emitter circuit; said tunnel diode having a voltage-ampere characteristic which includes a constant current portion extending through a preselected range of voltage values of predetermined polarity wherein the peak-to-valley current ratio is substantially unity; said tunnel diode poled to allow current toward said emitter upon voltage of said predetermined polarity thereacross and a capacitor connected in parallel circuit relationship with said tunnel diode.

3. A transformer-coupled transistor stage comprising, in combination; a transistor having an emitter electrode, collector electrode, and base electrode; a tunnel diode; an output transformer connected in series circuit relationship with said tunnel diode across the emitter-collector circuit; means for biasing the emitter-collector circuit; an input transformer connected in series circuit combination with said tunnel diode in the base-emitter circuit; means for biasing the base-emitter circuit; said tunnel diode being characterized as having a voltage-ampere characteristic which includes a peak-to-valley current ratio of substantially unity over a predetermined range of voltage values of preselected polarity; said tunnel diode poled to allow current toward said emitter in response to a voltage of said predetermined polarity thereacross and a capacitor connected in parallel circuit relationship with said tunnel diode.

4. A common emitter degeneration circuit for temperature stabilization comprising, in combination; a transistor having an emitter electrode, collector electrode and base electrode; means for biasing said base-emitter circuit; the voltage across the base-emitter electrodes varying in accordance with the temperature of said transistor; tunnel diode means having a negative resistance over a portion of its characteristic curve for a selected range of voltage magnitudes of predetermined polarity; said tunnel diode means connected in series circuit relationship with said

5

emitter electrode and poled to allow current to said emitter in response to voltage of said predetermined polarity thereacross; the slope of said characteristic curve of said tunnel diode means in the negative resistance portion being preselected so that an increase in collector current with temperature is compensated by the lower current through said tunnel diode.

References Cited by the Examiner

UNITED STATES PATENTS

2,779,871	1/1957	Patterson	330—69
3,054,910	9/1962	Bothwell	307—88.5
3,090,926	5/1963	Engel	307—88.5 X

6

OTHER REFERENCES

G. E. Tunnel Diode Manual, March 20, 1961.
Hughes Semiconductor Advanced Data Bulletin DS-83A of Hughes Semiconductor Division, Newport Beach, Calif., September 1960.
"Negative Resistance Constants" by Lal C. Verman, Proceedings of the I.R.E., vol. 19, No. 4, April 1931 (p. 679 FIG. 3 relied upon).
"Using the Tunnel Diode" by Eric Gottlieb, Electronic Industries, November 1960, pp. 110-113.

ARTHUR GAUSS, *Primary Examiner.*
JOHN W. HUCKERT, *Examiner.*
J. JORDAN, *Assistant Examiner.*