

March 16, 1965

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3,174,095

BILATERAL CONSTANT VOLTAGE SOURCE

Filed Nov. 18, 1960

FIG. 1

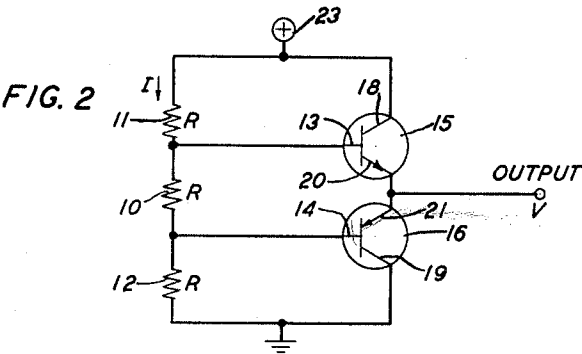
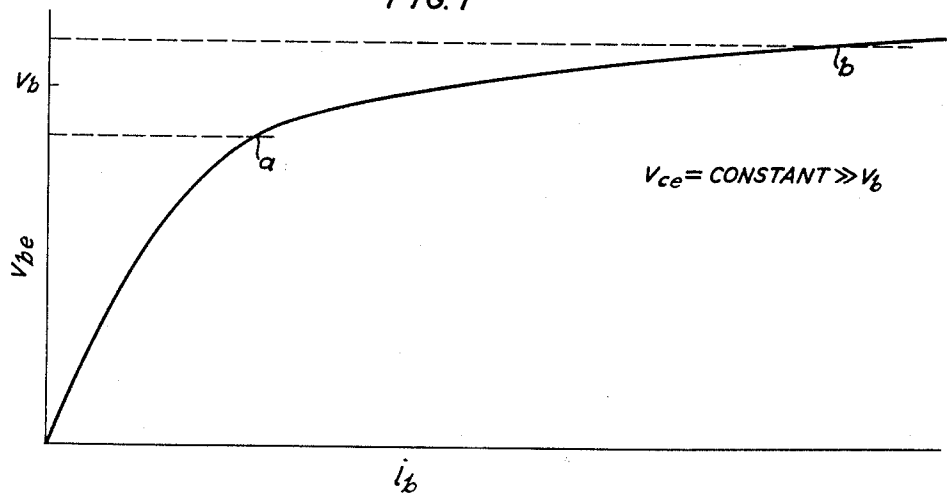
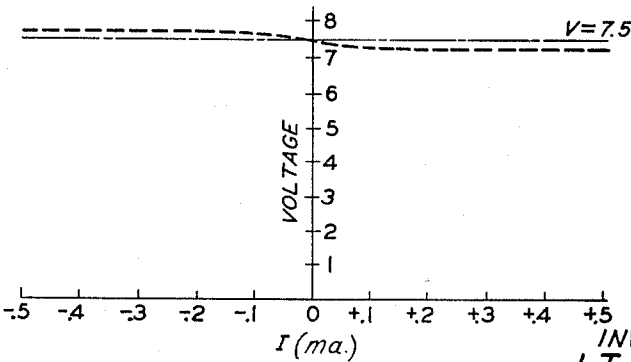


FIG. 3



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3,174,095

BILATERAL CONSTANT VOLTAGE SOURCE

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Filed Nov. 18, 1960, Ser. No. 76,354

3 Claims. (Cl. 323--22)

This invention relates to voltage sources and more particularly to voltage sources having a low output impedance.

Vacuum tubes and transistors require bias voltage supplies which are capable of maintaining a constant electrode potential at all times. These electrode potentials must be held constant even under conditions where due to the particular operation of the device current reversals take place at the electrodes. A similar situation exists when a voltage source is connected to a collection of circuits some or all of which may supply current at various times, but all of which require a constant input voltage. In such a situation the voltage source is placed under the severe requirement of maintaining a constant voltage regardless of the direction of current flow.

An object of this invention is to provide a voltage source having a low output impedance which is bilateral in the sense that it is capable of delivering current to or accepting current from an external circuit.

A related object of this invention is to provide such a constant voltage bilateral circuit with a minimum of circuit complexity and cost.

In accordance with this invention a pair of transistor-emitter followers of opposite conductivity type isolate a load from a voltage divider. The transistors are provided with a permanent forward base-emitter bias and because of their current gain and the fact that they are of opposite conductivity type the circuit constitutes a constant voltage source which is capable of either delivering current to or accepting current from the external circuit.

The invention will be more fully understood from the following detailed description of a preferred embodiment thereof taken in conjunction with the appended drawings, in which:

FIG. 1 represents the input characteristic, $i_B = f(e_{BE})$ where the collector-emitter voltage is held at a constant value;

FIG. 2 is a schematic diagram of a bilateral constant voltage source embodying the invention; and

FIG. 3 is the voltage regulation curve of the constant voltage source shown in FIG. 2.

A pair of transistors of opposite conductivity type each having substantially the identical input characteristic shown in FIG. 1, are connected in emitter-follower configuration to isolate a voltage divider from a load as shown in FIG. 2. The voltage divider comprises the series combination of resistors 10, 11 and 12. Resistor 10 is connected between the bases 13 and 14 of transistors 15 and 16, respectively. Resistor 11 is connected between the base 13 and collector 18 of n-p-n type transistor 15. Resistor 12 is connected between the base 14 and the collector 19 of p-n-p transistor 16. The emitters 20 and 21 of the transistors are connected together to form a common output terminal, with collector 18 of transistor 15 connected to positive voltage source 23 and collector 19 of transistor 16 connected to ground.

Because the voltage drop across resistor 10 will insure that the base-emitter circuits of both transistors are permanently forward biased the two transistors will always act as emitter followers and isolate the output circuit from the voltage divider. The current gain of the transistors and the low output impedance of the circuit hold the output voltage at a constant value, and because the transistors are of opposite conductivity type and always have forward biased base-emitter circuits the output volt-

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age is held constant even in the face of reversal of the direction of current flow at the output terminal.

FIG. 1 shows the input characteristic curve for both of the transistors. In FIG. 1 the voltage between the base and emitter, V_{BE} , is plotted as a function of the base current, i_B , with the voltage between the collector and emitter, V_{CE} , held at a constant value very much greater than the base-emitter voltage, V_{BE} , at which the transistor will be operated. The curve rises sharply from the origin and then levels off to what approximates a straight line. The leveling off point where the curve begins to approximate a straight line is called the knee of the curve and is shown as point a in FIG. 1.

Because the transistors have substantially identical characteristics the voltage drop from base to emitter, V_{BE} , is the same in each transistor. Since the voltage between collector and emitter, V_{CE} , is very much greater than the voltage between base and emitter, V_{BE} , and since the collector-emitter voltage, V_{CE} , of each transistor has the same value, resistor 10 is very much smaller than either resistor 11 or 12. Because of the current gain of each transistor the base current of each transistor is very much smaller than the current I flowing through resistor 11 and this current, I , therefore flows through all the resistances 11, 10, 12 of the voltage divider. Since the collector-emitter voltage of each transistor is the same, resistors 11 and 12 therefore have equal values of resistance, R , and since V_{CE} is very much greater than V_{BE} , R is greater than the resistance, r , of resistor 10. With current I flowing through the voltage divider and the base-emitter voltage of each transistor at the same value the output voltage V

$$V = \frac{E(R+r/2)}{2R+r} = \frac{E}{2}$$

where r is the resistance of resistor 10, R is the resistance of each of the resistors 11 and 12 and E is the voltage of source 23.

In accordance with the invention both transistors are provided with a permanent forward base-emitter bias to insure their operation as emitter followers. To achieve the best regulation the forward base-emitter bias is made such that for relatively large changes in base current there is little change in the base-emitter voltage. It is obviously important from an inspection of FIG. 1 therefore that the base-emitter bias be such that the transistors operate in the region above the knee, shown as a in FIG. 1 of the characteristic curve. Point b on the characteristic is that base current at which the transistor is dissipating its maximum power, and the transistor should not be operated beyond point b . The range of operation is therefore from point a to point b as shown in FIG. 1 and the resistance r , of resistor 10 is determined so that the base-emitter voltage is at the midpoint, V_b , of the voltages in the region between a and b .

Therefore

$$r(I) = V_b + V_b$$

$$r = \frac{V_b + V_b}{E/2R} = 4 \frac{V_b}{E} R$$

Since the current, I , flowing in the voltage divider must be much greater than the base current, i_b , of the transistors, the resistance R of the resistors 11 and 12 is determined from the equation

$$R(I) = \frac{E}{2} - V_b$$

where I is much greater than any value of base current i_b , in the range of operation ($a-b$) shown in FIG. 1.

FIG. 3 illustrates a typical voltage regulation curve where the circuit employed one 1778 p-n-p Western Electric transistor and one 1853 n-p-n Western Electric transistor, the voltage of source 23 was +15 volts, R was

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510 ohms, r was 27 ohms, and the output voltage was 7.5 volts over a range from 0 to ± 5 milliamperes.

When a negative output voltage with respect to ground is required the polarity of source 23 is negative. The transistors are then inserted in the circuit of FIG. 2 with the p-n-p transistors as transistor 15 and the n-p-n transistor as transistor 16. In all other respects the operation of the circuit is as above described.

The output voltage of the constant voltage source is

$$V \approx \frac{R_{12}}{R_{11}} \times E$$

where R_{12} is the value of resistance of resistor 12 and R_{11} is the value of resistance of resistor 11. Thus, by using transistors of opposite conductivity type having substantially identical characteristics the output voltage of the constant voltage source can be made any constant percentage of the input voltage.

It is to be recognized that no two transistors of opposite conductivity type have exactly the same characteristics although they may have substantially identical characteristics as described above. In accordance with this invention it is not necessary for the constant voltage source to function properly that exactly identical transistors be used and if non-identical transistors are deliberately used the output voltage V will differ from the calculated value

$$V \approx \frac{R_{12}}{R_{11}} \times E$$

due to the fact that the emitter voltages will now no longer be equal to the voltage at the midpoint of resistor 10 since the base emitter voltages of the transistors are no longer equal.

The maximum load current which the constant voltage source is capable of delivering with a given pair of transistors may be extended by inserting resistors in the collector circuits of each of the transistors. This increase in allowable load current may be such that the base current of the transistors is now no longer negligible compared with the current I flowing through the divider. In such an event the resistors 11 and 12 of the divider should be lowered in value, but their ratio R_{12} over R_{11} held constant so that a larger divider current is drawn while maintaining a constant output voltage.

It is to be understood that the above-described arrangements are illustrative of the application of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A bilateral constant voltage source which comprises, in combination, a pair of transistors of opposite conductivity type each having an emitter electrode, a collector electrode, and a base electrode, an output connection joining the emitter electrodes of both of said transistors, a first resistor connected between the base and collector electrodes of one of said transistors, a second resistor

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connected between the base and collector electrodes of the other of said transistors, a source of direct voltage connected between the collector electrodes of said transistors and poled in the direction of positive emitter current flow in both of said transistors, and a third resistor connected between the base electrodes of said transistors to provide both of said transistors with a permanent forward emitter bias, whereby the voltage at said output connection is held at a substantially constant percentage of the voltage of said source regardless of the magnitude or direction of load current flowing in said output connection.

2. A bilateral constant voltage source which comprises, in combination, a pair of transistors of opposite conductivity type each having an emitter electrode, a collector electrode, and a base electrode, an output connection joining the emitter electrodes of both of said transistors, a first resistor connected between the base and collector electrodes of one of said transistors, a second resistor substantially equal to said first resistor in resistance connected between the base and collector electrodes of the other of said transistors, a source of direct voltage connected between the collector electrodes of said transistors and poled in the direction of positive emitter current flow in both of said transistors, and a third resistor substantially less than said first and second resistors in resistance connected between the base electrodes of said transistors to provide both of said transistors with a permanent forward bias, whereby the voltage at said output connection is held at substantially constant percentage of the voltage of said source regardless of the magnitude or direction of load current flowing in said output connection.

3. A bilateral constant voltage source which comprises, in combination, a pair of transistor emitter-follower stages, each of said stages containing a transistor of opposite conductivity type from the other, means connecting the transistor of each of said stages as load impedance of the other, an output connection common to both of said stages, a source of direct voltage connected between the transistor collector electrodes of said stages and poled in the direction of positive emitter current flow in both of said stages, and means to provide both of said stages with a permanent forward base-emitter bias, whereby the voltage at said output connection is held at a substantially constant percentage of the voltage of said sources regardless of the magnitude or direction of load current flowing in said output connection.

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