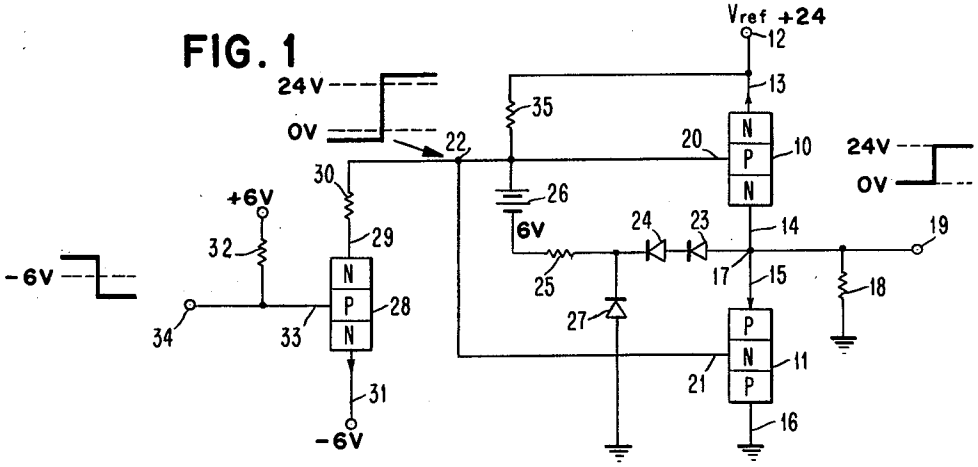
March 16, 1965 D. WORTZMAN 3,174,054

VOLTAGE SWITCH WITH REGULATED OUTPUT CURRENT

Filed April 8, 1960

FIG. 1



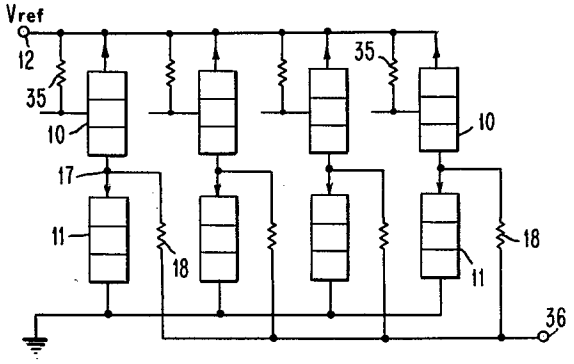


FIG. 2

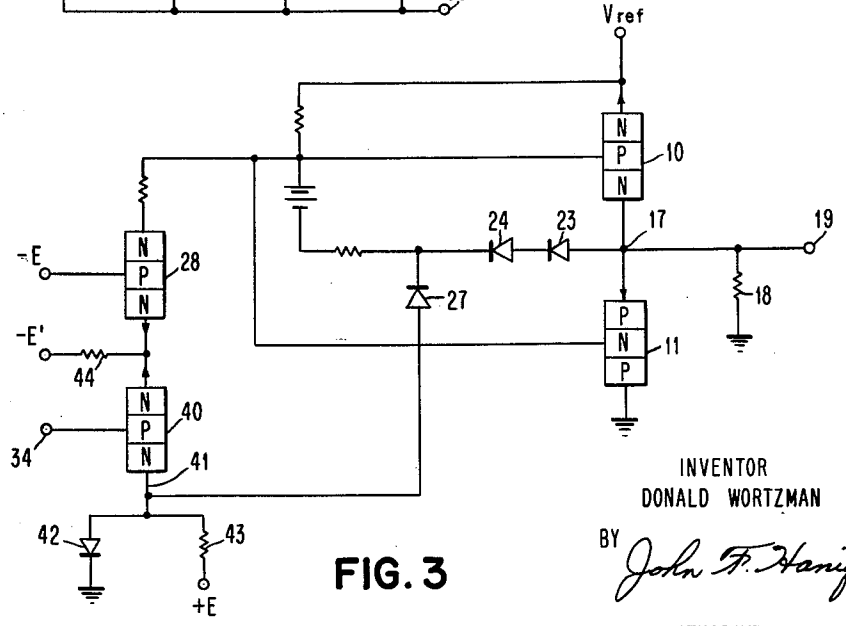


FIG. 3

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VOLTAGE SWITCH WITH REGULATED OUTPUT CURRENT

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The present invention relates to electronic switches and, more particularly, to a voltage switch for developing an analog voltage proportional to a digital representation.

Analog-to-digital and digital-to-analog converters often employ a voltage-addition ladder network for developing an analog voltage proportional to a digital representation. There will be a resistor for each order of the digital information having a value proportional to the weight of the order. The analog voltage is developed by selectively applying a reference potential or ground to the weighted resistors under control of the digital information. The reference potential is attenuated different amounts through the weighted resistors and then combined at the common output of the resistors to develop the analog voltage. Suitable switching means must be provided, responsive to the digital representation, for selectively applying to the weighted resistors the reference voltage or ground.

Systems are presently being developed for performing arithmetic operations by combining analog techniques with digital techniques. These systems require switching means, responsive to digital information, for selectively applying to the weighted resistors of a voltage-addition ladder network either ground potential or a reference voltage which has been previously generated to represent a numerical quantity.

Voltage-addition converters of prior art systems have been inadequate for several reasons. Since each of the resistors energized by the digital information must provide a voltage proportional to the order of the digital information, the impedances required must be of different values. This has necessitated the use of a specially designed switching means for each stage of the ladder network. The power supply used to provide the reference voltage to all the stages of the ladder network has had to be an expensive, closely regulated supply. Converting the N stage binary number to an analog voltage representation will require the reference voltage to be applied to N weighted resistors. The reference voltage may be applied to 2^N different combinations of weighted resistors, requiring the reference voltage source to regulate for 2^N different load conditions.

In hybrid systems, utilizing analog and digital techniques for numerical computation, a particular digital to analog converter may be fed with a reference voltage generated by a previous digital to analog converter. The reference voltage applied to a particular stage may be of a varying nature. Difficulties have arisen in prior systems for providing a switching means adapted to accurately switch either a ground potential or a reference voltage, which may vary from a maximum amount to zero to the weighted resistors of the ladder network.

It is the object of the present invention to provide a new and improved transistor voltage switch which is self-regulating with respect to a voltage source.

It is an important object of the invention to provide a new and improved voltage switch suitable for use in voltage-addition ladder networks.

It is an additional object of the present invention to provide a new and improved voltage switch suitable for switching a varying reference potential or ground potential to an output load.

It is also an object of the present invention to provide a transistor voltage switch suitable for use in a voltage-addition ladder network wherein the regulated reference voltage is not required to furnish saturating current to the transistors.

It is an additional object of the present invention to provide a transistor voltage switch suitable for use in a voltage-addition ladder network wherein the current drain on the regulated voltage reference is a constant value regardless of the permutation arrangement of weighted resistors connected to the reference voltage source.

It is a further object of the invention to provide a new and improved voltage switch which is relatively simple in construction and inexpensive to manufacture.

It is another object of the present invention to provide a new and improved voltage switch suitable for several uses without requiring expensive re-design.

In accordance with the invention, a voltage switch is provided which comprises a series connection of the emitter-collector paths of a first and second transistor of opposite conductivity type. The output, to which is applied either a reference voltage connected to the first transistor or ground connected to the second transistor, is taken from the electrical connection between the two transistors. A floating supply is provided as part of a biasing means which normally causes the first transistor to be non-conductive and the second transistor conductive. The floating supply is suitable for supplying the necessary current to the first transistor to place it in saturation. A voltage level responsive means including a third transistor, which forms part of the biasing means, is provided for changing the conductivity state of the first and second transistors. The reference potential connected to the first transistor, and ground, connected to the second transistor are then alternately applied through the respective low resistance emitter-collector paths to the output. When the reference voltage is not connected to the load through the first transistor, an equal load is provided for the reference voltage by way of a resistor connected between the reference voltage and the floating power supply.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a circuit diagram of the voltage switch in accordance with a particular form of the present invention;

FIG. 2 is an incomplete circuit diagram of a voltage-addition ladder network employing the voltage switch of the present invention;

FIG. 3 is a circuit diagram of a voltage switch in accordance with a modified form of the invention;

Referring now to FIG. 1 of the drawing, a voltage switch there represented comprises a first transistor 10 and a second transistor 11. A series path is described from a terminal 12, to which is applied a reference voltage, to ground through the emitter 13 and collector 14 of transistor 10 and emitter 15 and collector 16 of transistor 11. The collector 14 of transistor 10 and the emitter 15 of transistor 11 are connected together at a junction point 17.

The output of the voltage switch is taken across a load resistor 18 at an output terminal 19. The base 20 of transistor 10 and base 21 of transistor 11 are connected together at a point 22. A source of saturating current for transistor 10 is provided through a path including the base-collector junction of transistor 10, point 17, a pair of similarly poled asymmetrically conductive devices 23 and 24, resistor 25, an unregulated voltage source 26, and the base electrode 20 of transistor 10. An asymmetrically conductive device 27 is provided between ground and the junction of diode 24 and resistor 25. Normal biasing is provided by a voltage level responsive transistor 28. Transistor 28 is connected to point 22 through its collector 29 and resistor 30. The negative potential applied to the emitter 31 of transistor 28, and the positive potential applied through resistor 32 to the base 33 of transistor 28 normally biases the transistor 28 to be conductive. Transistor 28 may be rendered nonconductive by the application of a negative voltage level at terminal 34. Circuit means including a resistor 35 connects the terminal 12 to the base electrode of both transistors 10 and 11 and the unregulated voltage source 26 at point 22.

Considering now the operation of the voltage switch, with transistor 28 normally conducting in saturation, point 22 will be at a potential more negative than ground. Current will be drawn from the base 21 of transistor 11 causing transistor 11 to be saturated. Point 17 and the output at terminal 19 will be at ground potential through the low resistance emitter-collector path of transistor 11. With transistor 28 in saturation, current will also be drawn through forward biased diode 27, resistor 25 and the unregulated voltage source 26. Current drawn through diode 27 will cause the junction of diode 27 and diode 24 to be slightly negative with respect to ground at point 17. The bias created across diodes 23 and 24 would be sufficient to cause one to conduct, but when equally divided between the two, neither has sufficient bias to conduct. In an actual embodiment of the invention, the bias needed to cause conduction, and the voltage drop across the diodes is about 0.3 volt. If 0.3 volt is placed across diodes 23 and 24, each would receive 0.15 volt, so that neither could conduct. An alternate method would be to replace diodes 23 and 24 with a single germanium diode and make diode 27 a silicon diode. Germanium diodes require a greater bias than silicon diodes to cause conduction. As a result, no current is drawn away from emitter 15 of transistor 11, insuring that junction 17 will be maintained at ground potential.

A negative voltage level applied at terminal 34 will render transistor 28 non-conductive. It should be recalled that a transistor starts conducting when either the base-collector or base-emitter junction is forward biased. When transistor 28 is rendered non-conducting, point 22, and therefore base 20, will rise in voltage. When compared with the collector 14 potential as effected by the floating potential of battery 26, the base-collector junction will be forward biased. The unregulated voltage source 26 will now provide saturating current for transistor 10 causing it to conduct heavily. Diodes 23 and 24 will be forward biased because point 17 will be clamped to the plus reference voltage through the low resistance emitter-collector path of transistor 10. As a result, the output terminal 19 across the load 18 now has applied to it the plus reference voltage and has been switched from ground potential to the plus reference voltage. With point 17 at the plus reference voltage, and diodes 23 and 24 conducting heavily, diode 27 will be back biased drawing no current. Since point 22 which is applied to the base 21 of transistor 11 is more positive than the plus reference voltage at point 17, transistor 11 will be rendered nonconductive.

When transistor 10 is fully conductive, the plus reference voltage will be connected to point 17 and an amount of current will be drawn from the reference depending upon the size of the load resistor 18. Resistor 35 has been included between the reference voltage and point 22 to draw an amount of current from the voltage reference, when transistor 10 is non-conductive, equal to the current drawn by the load resistor 18 when transistor 10 is conductive. As a result, the voltage reference will be required to furnish the same amount of current independent of the conductivity state of transistor 10. Since the current drawn from the plus voltage reference is maintained at a constant value, a less expensive regulated voltage source may be used. Without this feature, the reference voltage would be required to furnish several values of current especially when the voltage switch is used in a voltage-addition ladder network with many combinations of output loads on the voltage reference. No matter how many voltage switches of the present invention are required in a voltage-addition network, each stage provided will always draw the same amount of current from the voltage reference no matter what the combination of voltage switches have been energized.

FIG. 2 shows a partial arrangement of a voltage-addition ladder network employing the present invention. The resistors 18 correspond to the load resistor 18 shown in FIG. 1. The resistors 18 will be weighted to correspond to the weight of its respective order of digital information. The reference voltage is applied at terminal 12 of the ladder network. The analog voltage which is to assume a value proportional to the digital representation is developed at terminal 36.

The voltage switch shown in FIG. 1 must be modified if it is to be used in a hybrid system for accomplishing arithmetical operations utilizing both analog and digital techniques. In the hybrid systems, a first digital-to-analog converter may be feeding an analog voltage to a succeeding digital-to-analog converter. It is possible that a preceding converter may be feeding an analog voltage of zero volts to a succeeding stage to represent a digital input of zero. The voltage switch shown in FIG. 1 would not be capable of accurately switching the point 17 from ground to the reference voltage which might be zero volts. When transistor 10 is saturated, clamping point 17 to the reference voltage, diodes 23 and 24 are fully conductive. For normal positive values of the reference voltage, diode 27 will be back biased. As the reference voltage approaches a value just slightly more positive than ground, the bias across diode 27 will approach a value which will cause diode 27 to start conducting. The output potential at point 17 will therefore be clamped to a value equal to the slight drop in potential across diode 27.

FIG. 3 shows a modified arrangement of the voltage switch of FIG. 1 for allowing the accurate switching of a reference voltage of zero volts to point 17. Identical components of FIG. 1 and FIG. 3 are given the same numeral designations. The conductivity state of diode 27 is more accurately controlled by including a transistor 40 in the circuit. In the normal state, transistor 40 is non-conductive and transistor 28 is conductive as in FIG. 1. The collector 41 of transistor 40 is connected to a voltage divider network consisting of diode 42 and resistor 43. The plate of diode 27 is connected to the junction of the collector 41 and the voltage divider network. When transistor 40 is non-conductive the plate of diode 27 will be held at approximately ground potential corresponding to the ground shown connected to diode 27 in FIG. 1. Transistor 11 will be normally conductive, as before, clamping the point 17 at ground potential. A positive rise in potential applied at terminal 34 will cause transistor 40 to become conductive. The plate of diode 27 will now be placed at a potential more negative than ground through the low resistance emitter-collector path of transistor 40. The negative potential at the plate of diode 27 will insure that diode 27 will always be back biased and never conductive even though point 17, which is now clamped to the reference voltage, should become zero volts. The basic voltage switch shown in FIG. 1 is now

capable of use in a hybrid arithmetic system where the reference voltage applied to the voltage switches might approach a value of zero.

While a voltage switch for use with a positive reference voltage is shown, it will be apparent to those skilled in the art that a negative reference voltage switch may be made from this invention by reversing all voltages, diodes and the conductivity type of the transistors.

It is apparent from the description that use of an expensive highly regulated voltage source is not necessary with the present invention. The reference voltage may be generated, for instance, from a simple and inexpensive Zener diode system. Since the voltage switch is provided with saturating current from a source other than the reference source, high current output will not be required from the reference source. The small amount of current required from the reference source has been shown to be a constant value no matter what combination of voltage switches has been energized by digital information inputs. It has also been shown that the voltage switch of the present invention may be of one simple design regardless of the value of the reference voltage or the weighted load resistors.

While the applicant does not wish to be limited to any particular set of circuit constants, the following constants have proved to be useful in a voltage switch of the type represented in FIG. 1:

Resistor 25	1.1K
Resistor 30	698
Resistor 32	22K
Diode 23	IN461
Diode 24	IN461
Diode 27	IN461
Transistor 10	IBM 083
Transistor 11	IBM 033
Transistor 28	IBM 065
Battery 26	6 volts
+V ref	24 volts
+E	6 volts
−E	6 volts

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

I claim:

1. A voltage switch for accurately applying a first voltage or a second voltage to the first terminal of an output load the second terminal of which is connected to an output reference potential, comprising in combination: a first and second transistor, each of said transistors having base, collector and emitter electrodes, the emitter-collector path of said transistors being in series between the first and second voltages, the collector of one of said transistors and the emitter of the other of said transistors being connected to the first terminal of said load at a common point, a source of biasing reference potential, biasing means including an unregulated voltage source connected between said biasing reference potential and the base electrode of both of said transistors for biasing said second transistor to be normally conductive and said first transistor normally non-conductive, input circuit means connected to said biasing means, said biasing means responsive to a change in voltage level at said input means for changing the conductivity state of both said transistors, impedance means having an impedance equal to the impedance of the output load connecting the first voltage to said base electrodes and said unregulated voltage, and means connecting said common point to a point between said biasing reference potential and said unregulated voltage source, controlled by said biasing means for blocking the flow of current from the common point of said transistors through said unregulated voltage source when said second transistor is in its normally conductive state.

2. A voltage switch for accurately applying a first voltage or a second voltage to the first terminal of an output load the second terminal of which is connected to an output reference potential, comprising in combination: first and second transistors, each of said transistors having base, collector and emitter electrodes, the emitter-collector path of said transistors being in series between the first and second voltages, the collector of said first transistor and the emitter of said second transistor being connected to the first terminal of said load at a common point, a source of biasing reference potential, biasing means including an unregulated voltage source connected between said biasing reference potential and the base electrode of both of said transistors for biasing said second transistor to be normally conductive and said first transistor normally non-conductive, input circuit means connected to said biasing means, said biasing means responsive to a change in voltage level at said input means for changing the conductivity state of both said transistors, circuit means connecting the first voltage to said base electrodes and said unregulated voltage, and means connecting said common point to a point between said biasing reference potential and said unregulated voltage source, controlled by said biasing means for passing the flow of current from the collector to the base of said first transistor through said unregulated voltage source when changed to its conductive state.

3. A voltage switch for accurately applying a first voltage or a second voltage to the first terminal of an output load the second terminal of which is connected to an output reference potential, comprising in combination: first and second transistors, each of said transistors having base, collector and emitter electrodes, the emitter-collector path of said transistors being in series between the first and second voltages, the collector of said first transistor and the emitter of said second transistor being connected to the first terminal of said load, a source of biasing reference potential, biasing means including an unregulated voltage source connected between said biasing reference potential and the base electrode of both of said transistors for biasing said second transistor to be normally conductive and said first transistor normally non-conductive, input circuit means connected to said biasing means, said biasing means responsive to a change in voltage level at said input means for changing the conductivity state of both said transistors, circuit means connecting the first voltage to said base electrodes and said unregulated voltage, and a pair of series connected, similarly poled, asymmetrically conductive devices connected between said unregulated voltage source and the collector and emitter of said first and second transistors respectively, controlled by said biasing means, said pair of asymmetrically conductive devices adapted to pass saturating current for said first transistor through said unregulated voltage source when said first transistor is conductive and block the flow of current to said unregulated voltage source when said second transistor is conductive.

4. A voltage switch in accordance with claim 3 wherein said biasing means includes an asymmetrically conductive device connected between said source of biasing referene potential and said unregulated voltage source poled to be non-conductive when said first transistor is conductive and conductive when said second transistor is conductive.

5. A voltage switch in accordance with claim 4 wherein said biasing means includes a third normally non-conductive transistor responsive to the change in voltage level at said input means adapted to apply a voltage to said asymmetrically conductive device more negative than the first voltage when said first transistor is con-

ductive and a voltage equal to the second voltage when said second transistor is conductive.

6. A voltage switch in accordance with claim 3 wherein said circuit means is an impedance which causes a current drain on the first voltage equal to the current drain caused by the load, independent of the conductivity state of said first transistor.

7. A voltage switch in accordance with claim 3 wherein said unregulated voltage source provides the saturating current for said first transistor.

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