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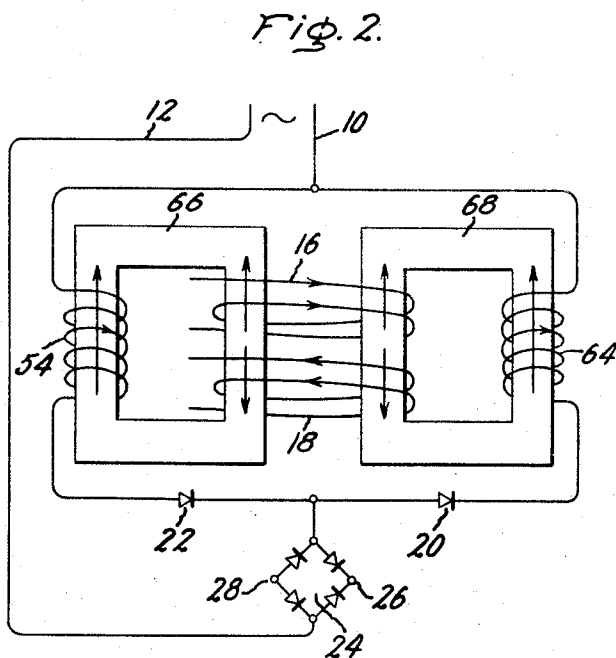
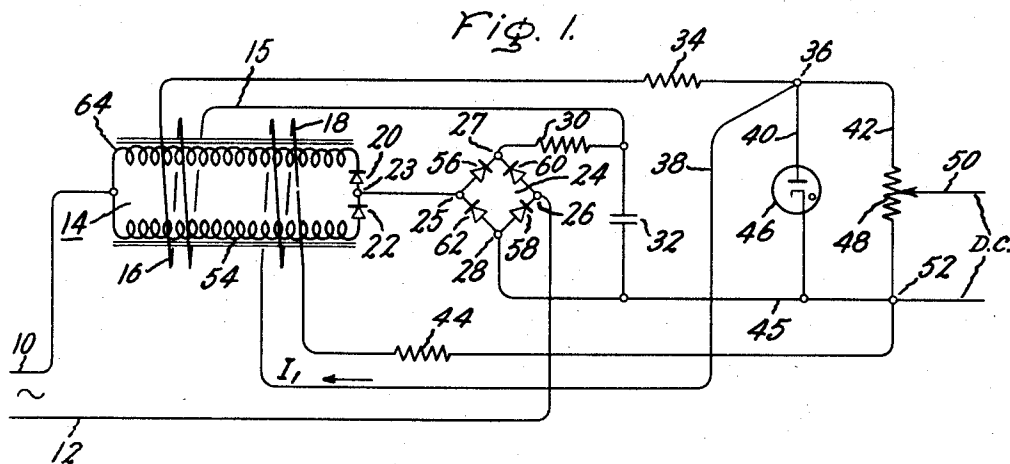
V. J. LOUDEN

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VOLTAGE REFERENCE CIRCUIT

Filed March 19, 1957

2 Sheets-Sheet 1



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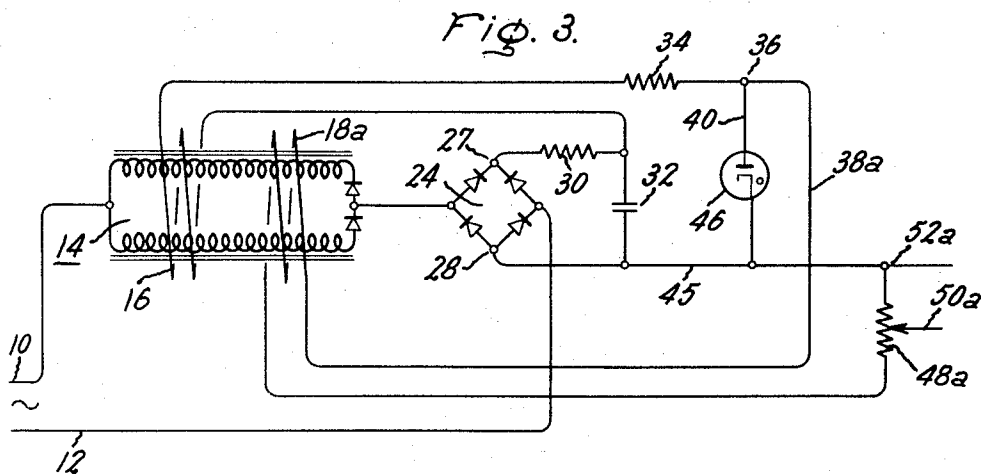
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VOLTAGE REFERENCE CIRCUIT

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9 Claims. (Cl. 321-19)

This invention relates to a voltage reference circuit and, more particularly, to a voltage reference circuit for providing an accurate D.-C. voltage reference from a variable A.-C. line voltage.

There are many known ways of providing a D.-C. reference from an A.-C. source. However, many of these known circuits are ineffective for a large fluctuation in the source voltage. Other circuits that can effectively control large fluctuations in an A.-C. source are very complex, requiring a large number of components, including a number of voltage regulating or reference devices. Further, in instances where the current drain from the reference circuit is large compared to the current required by the reference device of the circuit, none of the prior art devices will provide a sufficiently accurate D.-C. voltage reference.

Therefore, it is one object of this invention to provide an accurate D.-C. reference regardless of the voltage fluctuation in the A.-C. source.

It is a further object of this invention to provide a D.-C. voltage reference circuit which utilizes a constant current to supply a voltage reference device and an output load to maintain an accurate reference.

Another object of this invention is to provide a voltage reference circuit in which a voltage reference device is used as a reference for a constant current in the circuit.

A still further object of this invention is to provide a voltage reference circuit which will provide an accurate voltage reference even where the current drain from the circuit is large compared to the current required by the voltage reference element of the circuit.

In carrying out this invention in one form, the D.-C. voltage reference circuit has an amplifier means which is connected to a source of alternating current. A rectifier means is placed across the alternating source at the output of the amplifier means to convert the A.-C. current to D.-C. current. Feedback means, in the output of the rectifier means, are provided which are related to the amplifier means such that the current flow through such feedback means tends to decrease the current flow through the amplifier means. Parallel circuits are connected in series with the feedback means, forming a return to the rectifier means. Included in said parallel circuits is a voltage regulator means and a control means, their relation being such that the voltage regulator means maintains the current in the control means substantially constant. The control means is coupled to the amplifier means in such manner that current flow in the control means tends to increase current flow in the amplifier means. The design of the reference circuit is such that a fluctuation in supply voltage does not appreciably affect the current flow in the parallel circuits, thus providing a constant, accurate D.-C. voltage reference across one of the parallel circuits.

This invention will be better understood from the following description considered in connection with the accompanying drawing, wherein:

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Figure 1 is an electrical schematic diagram of one form of a voltage reference circuit of this invention;

Figure 2 is an electrical schematic drawing of the magnetic amplifier of Figure 1 showing the physical arrangement of the windings on one form of saturable cores; and

Figure 3 is an electrical schematic diagram of a modified form of the voltage reference circuit of this invention.

Referring to the drawings wherein like numerals are used to indicate like parts throughout and with particular reference to Figure 1, there is shown one embodiment of the voltage reference circuit of this invention. Alternating current lines 10 and 12 are connected to a source of alternating current (not shown). Connected in series with one of the alternating current lines is an amplifier means, shown as a saturable reactor, having a feedback means and a control means. As shown in Figure 1, the amplifier means takes the form of a magnetic amplifier 14 and is placed in series with the line 10, the magnetic amplifier 14 being provided with a feedback winding 16 and a control winding 18, both windings being magnetically coupled thereto. Rectifying means are provided across the alternating current lines at the output of the magnetic amplifier. In the embodiment illustrated the output side of the magnetic amplifier 14 includes the rectifiers 20 and 22, respectively connected in series with input or gate windings 64 and 54 and poled in the same direction as shown. The output signal taken from a terminal 23 between the rectifiers 20 and 22 is applied to one side of a rectifier bridge 24 at the alternating current terminal 25. The opposite alternating current terminal 26 of rectifier bridge 24 is connected to the line 12 to complete the alternating current circuit. The rectifier bridge includes two direct current terminals, a positive D.-C. terminal 27, and a negative D.-C. terminal 28.

The remainder of the circuit will be described assuming current flow from positive to negative. As an alternating current flows in the magnetic amplifier 14, a direct current will appear at the positive terminal 27 of bridge rectifier 24. A filter circuit comprising a resistor 30 and a capacitor 32 is provided at the positive D.-C. terminal 27 to smooth the ripple present in the rectified direct current. The filtered direct current is then fed by line 15 through the feedback winding 16 of the magnetic amplifier 14 and a resistor 34, connected in series with the winding 16, to a point 36 of the circuit. From point 36 a number of parallel branches are provided for the rectified direct current. As shown, three parallel circuits, 38, 40, and 42, are provided forming the return circuit to the negative terminal 28 of the rectifier bridge. The parallel circuit 38 includes the control winding 18 of the magnetic amplifier 14 and a resistor 44 returning by line 45 to negative terminal 28. A second parallel circuit 40 is provided with a voltage reference device, which is preferably a voltage regulator tube, 46, of the glow discharge type. The cathode of the voltage regulator tube 46 is connected to the negative terminal 28 by line 45. A third parallel circuit 42 contains an output load in the form of a resistor 48 having a movable tap 50, from which the desired direct current reference voltage is obtained. The output D.-C. reference voltage is picked off between a terminal 52 on line 45 and the tap 50, which is adjustable across the resistor 48.

The operation of the circuit will now be described, still assuming current flow from positive to negative. As an alternating current flows from the source (not shown), the positive pulses flow through the line 10 through a gate winding 54 of the magnetic amplifier 14,

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and the rectifier 22 to the terminal 25 of bridge rectifier 24. Each positive pulse then flows through rectifier 56 of bridge 24, terminal 27, resistor 30 to feedback winding 16, the resistor 34, and then through the parallel circuits 38, 40, and 42 to the negative terminal 28 of bridge 24. Current then flows through rectifier 58 and terminal 26, back to line 12. For a negative pulse of alternating current, the flow is from line 12 to terminal 26 through rectifier 60, terminal 27 and through the D.-C. circuit, returning to terminal 28 of bridge 24. Flow continues from terminal 28 through rectifier 62, terminal 25, rectifier 20, the other gate winding 64 of magnetic amplifier 14, and back to line 10. The feedback winding 16, control winding 18 and current limiting resistors 34 and 44 are so chosen that the magnetic amplifier 14 fires at a point of its cycle to provide the desired D.-C. reference voltage across the terminal 52 and movable tap 50 for the rated value of the A.-C. line voltage to which this circuit is connected.

The voltage reference tube 46 maintains a substantially constant voltage across its terminals and, therefore, across each of the other parallel circuits 38 and 42. With the impedance of the control winding 18 constant and impedance of resistor 44 constant, a constant current I_1 will be maintained in the control winding 18. Of course, for a constant resistance 48, a constant current will also flow in parallel circuit 42 providing a constant voltage drop across any portion of resistor 48. In order to insure that these currents remain constant, the feedback winding 16 is employed. Should the A.-C. line voltage increase, an increased A.-C. current would tend to flow through the magnetic amplifier 14. As the A.-C. current in the gate windings of the magnetic amplifier 14 tends to increase, the current flow in the feedback winding 16 also tends to increase. However, the feedback winding 16 is wound on the cores of the magnetic amplifier 14 such that an increase in current flow through the winding 16 increases the effective impedance of the magnetic amplifier 14. With the increase in effective impedance of the magnetic amplifier 14 the current flow through the gate windings will provide the necessary voltage drop across the magnetic amplifier to absorb the line voltage increase without a substantial increase in current flow therethrough. This action of the amplifier 14 maintains the current flow in the winding 16 substantially constant. If the magnetic amplifier 14 is of sufficiently high gain, an almost infinitesimal increase in current flow of the feedback winding 16 will provide a large increase in the effective impedance of the magnetic amplifier 14. Of course, should the line voltage of the A.-C. source decrease, tending to cause a decrease in current flow through magnetic amplifier 14, the opposite effect would result; that is, the current through the feedback winding 16 would decrease, causing the effective impedance of the magnetic amplifier 14 to decrease, and thereby hold the current in winding 16 substantially constant. Therefore, it can be readily seen that the above-described circuit will maintain a substantially constant current despite voltage fluctuations of the A.-C. source. This current may be relatively large compared to the current required by the voltage reference tube 46. However, due to the parallel branch circuit arrangement used in this invention, only a small portion of this current will flow in the voltage reference tube 46.

One embodiment of the physical arrangement of the magnetic amplifier windings on saturable cores is shown in Figure 2. A saturable core 66 is provided with magnetic amplifier gate winding 54 while a saturable core 68 is provided with magnetic amplifier gate winding 64. The windings 54 and 64 are so wound on the saturable cores that current flow through the windings causes a magnetic flux to build up as shown in the direction of the arrows. The feedback winding 16 is wound around both of the saturable cores 66 and 68 in a direction such that current flow through winding 16 will cause a magnetic

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flux, which will oppose the magnetic flux maintained by the windings 54 and 64. The control winding 18 is similarly wound on both cores but in a direction such that current flow tends to aid the magnetic flux created by the windings 54 and 64.

Figure 3 is a modified form of the invention shown in Figure 1. In this modified form the circuit is similar to that shown in Figure 1. However, instead of having three parallel branch circuits from point 36 forming the return line to negative D.-C. terminal 28, only two parallel branch circuits are used. Branch circuit 40 containing the voltage regulator tube 46 is the same as in Figure 1 and performs the same function. Branch circuit 38a, however, contains both the control winding 18a and the output load or resistor 48a. In this embodiment the output resistor performs the function of a current limiting resistor for control winding 18a. In addition, the desired D.-C. reference voltage is picked off the resistor 48a from point 52a and the movable tap 50a. The operation of this modified form of the voltage reference circuit of this invention is the same as previously described with reference to Figure 1.

From the above description, it is readily apparent that the voltage reference circuit of this invention will provide an accurate D.-C. reference voltage regardless of the voltage fluctuations which occur in the alternating current source to which it is connected. Many changes will appear obvious to those skilled in the art. For example, instead of using three parallel circuits, it is obvious that the same result could be obtained by placing the control winding 18 in series with either the voltage reference tube 46 or the variable output resistor 48, thus using only two parallel circuits. It is also obvious that the reference circuit of this invention could also be used to provide a constant current output, if desired, rather than a reference voltage output. Other changes or modifications could also be made in the reference circuit of this invention and amplifier means other than a magnetic amplifier could be used without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed as new and which is desired to secure by Letters Patent of the United States is:

1. An improved voltage reference circuit for converting a fluctuating source of A.-C. voltage to a constant D.-C. voltage output comprising a magnetic amplifier connected in one line of said A.-C. source, a rectifier bridge connected across said A.-C. source at the output of said magnetic amplifier for converting the output of the magnetic amplifier to D.-C., a feedback winding for said magnetic amplifier connected in the output of said rectifier bridge, a number of parallel circuits connected in series with said feedback winding and forming a return circuit to said rectifier bridge, said parallel circuits including a control winding for said magnetic amplifier, a voltage regulator device and an output impedance, the relation between the feedback winding and the control winding being such that the current in the parallel circuits is maintained constant, whereby a constant D.-C. voltage may be obtained from the output impedance.

2. In a voltage reference circuit, a magnetic amplifier connected in one line of an A.-C. source, a rectifier bridge connected across said A.-C. source at the output of said magnetic amplifier, a feedback winding for said magnetic amplifier connected to the output of said rectifier bridge, parallel circuits connected in series with said feedback winding and forming a D.-C. return to said rectifier bridge, a voltage regulator tube contained in one of said parallel circuits providing a constant voltage drop across said parallel circuits, a control winding for said magnetic amplifier contained in another of said parallel circuits, the relation between the feedback winding, the control winding and the voltage regulator being such that a constant current is maintained in said parallel circuits.

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3. An improved voltage reference circuit for converting a fluctuating source of A.-C. voltage to a constant D.-C. voltage output comprising a magnetic amplifier connected in one line of said A.-C. source, a rectifier bridge connected across said A.-C. source at the output of said magnetic amplifier for converting the output of the magnetic amplifier to D.-C., a feedback winding for said magnetic amplifier connected in the output of said rectifier bridge, a number of parallel circuits connected in series with said feedback winding and forming a return circuit to said rectifier bridge, said parallel circuits including a control winding for said magnetic amplifier, a voltage regulator device and an output impedance, said feedback winding being magnetically coupled to said magnetic amplifier in a manner that the current flow through said feedback winding is maintained substantially constant, thereby to deliver a substantially constant current to said parallel circuits, and said voltage regulating device maintaining a substantially constant voltage drop across said parallel circuits, whereby a constant D.-C. voltage may be obtained from said output impedance.

4. In a voltage reference circuit, a magnetic amplifier adapted to be connected in one line of an A.-C. source, a rectifier bridge connected to the output of said magnetic amplifier, said rectifier bridge having a terminal adapted to be connected to another line of said A.-C. source, a feedback winding connected to a D.-C. terminal of said rectifier bridge, said feedback winding being magnetically coupled to said magnetic amplifier such that current flow through said feedback winding is maintained substantially constant, parallel circuits connected in series with said feedback winding and forming a D.-C. return to said rectifier bridge, said parallel circuits containing a voltage regulator device, a control winding for said magnetic amplifier and an output impedance, said voltage regulator device providing a constant voltage drop across said parallel circuits, whereby a constant current is maintained through said output impedance.

5. An improved voltage reference circuit for converting a source of fluctuating A.-C. voltage to a constant D.-C. voltage comprising; a magnetic amplifier having its gate windings connected in one line of said A.-C. source, a feedback winding and a control winding magnetically coupled to said magnetic amplifier in such manner that direct current flow in said feedback winding tends to increase the effective impedance of said magnetic amplifier while direct current flow in said control winding tends to decrease the effective impedance of said magnetic amplifier, a rectifier bridge connected across said A.-C. source at the output of said magnetic amplifier for converting alternating current to direct current, means connecting said feedback winding in series with the positive D.-C. terminal of said rectifier bridge whereby all of said converted direct current flows through said feedback winding, a number of parallel circuits connected in series with said feedback winding and forming a return line to the negative D.-C. terminal of said rectifier bridge, one of said parallel circuits including a voltage regulator device to provide a substantially constant voltage drop across said parallel circuits, said control winding and an output impedance being included in said parallel circuits, said parallel circuits being so constructed and arranged that only a small portion of said rectified direct current flows through said voltage regulator device, the elements of said voltage reference circuit being so related that a constant direct current is caused to flow through said output impedance regardless of fluctuations in said A.-C. source whereby a constant D.-C. voltage is obtained from said output impedance.

6. An improved voltage reference circuit for converting a source of fluctuating A.-C. voltage to a constant D.-C. voltage comprising; a rectifier means connected across said A.-C. voltage source for converting said source to

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D.-C. voltage, a saturable reactor connected between said source and said rectifier means, a feedback means and a control means magnetically coupled to said saturable reactor in such manner that current flow in said feedback means increases the effective impedance of said saturable reactor while current flow in said control means decreases the effective impedance of said saturable reactor, circuit means connecting said feedback means in series with the D.-C. output of said rectifier means, parallel circuits connected in series with said feedback means, a voltage reference device included in said parallel circuits for providing a substantially constant voltage drop across said parallel circuits, an output impedance included in said parallel circuits, said control means included in said parallel circuits, the element of said voltage reference circuit being so chosen that a constant D.-C. current is caused to flow through said output impedance regardless of fluctuations in said A.-C. source, whereby a constant D.-C. voltage may be obtained across said output impedance.

7. An improved voltage reference circuit for converting a fluctuating source of A.-C. voltage to a constant D.-C. voltage output comprising; an output impedance, a voltage regulating device in parallel circuit relation to said impedance, rectifying means for converting the A.-C. voltage to D.-C., amplifier means connected between the A.-C. voltage and said rectifying means, feedback means in the output of said rectifying means, control means in parallel circuit relation with said voltage regulating device, said control means cooperating with said feedback means for changing the impedance of said device when the A.-C. voltage fluctuates, the relationship between said feedback means, said control means, and said amplifier means being so chosen that an increase in said source voltage provides an increase in the impedance of said amplifier means, and a decrease in said source voltage provides a decrease in impedance of said amplifier means thereby maintaining the current through said amplifier means substantially constant, circuit means placing said parallel circuitry in series with said feedback means and forming a return to said rectifying means.

8. An improved voltage reference circuit for converting a fluctuating source of A.-C. voltage to a constant D.-C. voltage output comprising; an output impedance, a voltage regulating device in parallel circuit relation to said impedance, rectifying means for converting the A.-C. voltage to D.-C., a saturable reactor connected between the A.-C. voltage and said rectifying means, said reactor varying in impedance in response to fluctuations in the A.-C. voltage, feedback means in the output of said rectifying means for changing the impedance of said reactor when the A.-C. voltage fluctuates, control means in parallel circuit relation with said voltage regulating device and cooperating with said feedback means, the relationship between said feedback means, said control means, and said saturable reactor being such that an increase in A.-C. voltage provides an increase in said reactor impedance, and a decrease in A.-C. voltage provides a decrease in said reactor impedance thereby maintaining the current through said reactor substantially constant, circuit means placing said parallel circuitry in series with said feedback means and forming a return to said rectifying means.

9. An improved voltage reference device for converting a source of fluctuating A.-C. voltage to a constant D.-C. voltage comprising; a rectifying means across said source for converting said A.-C. voltage to D.-C. voltage, amplifier means in circuit relation with said A.-C. source and said rectifying means, feedback means connected in series circuit relation with the D.-C. voltage output of said rectifying means, a number of parallel circuits in series with said feedback means and forming a D.-C. return for said rectifying means, a voltage reference device included in said parallel circuits and maintaining a substantially constant voltage drop across said parallel circuits, an output impedance and a control means included in said parallel circuits, said feedback means and said con-

trol means being so related to said amplifier means that current flow through said feedback means increases the impedance of said amplifier means, while current flow through said control means decreases the impedance of said amplifier means, said feedback means and said control means cooperating to maintain current flow through said amplifier means substantially constant, thereby maintaining a substantially constant current flow through said entire voltage reference device for providing a substantially constant D.-C. voltage drop across said output impedance.

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