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VOLTAGE REGULATORS

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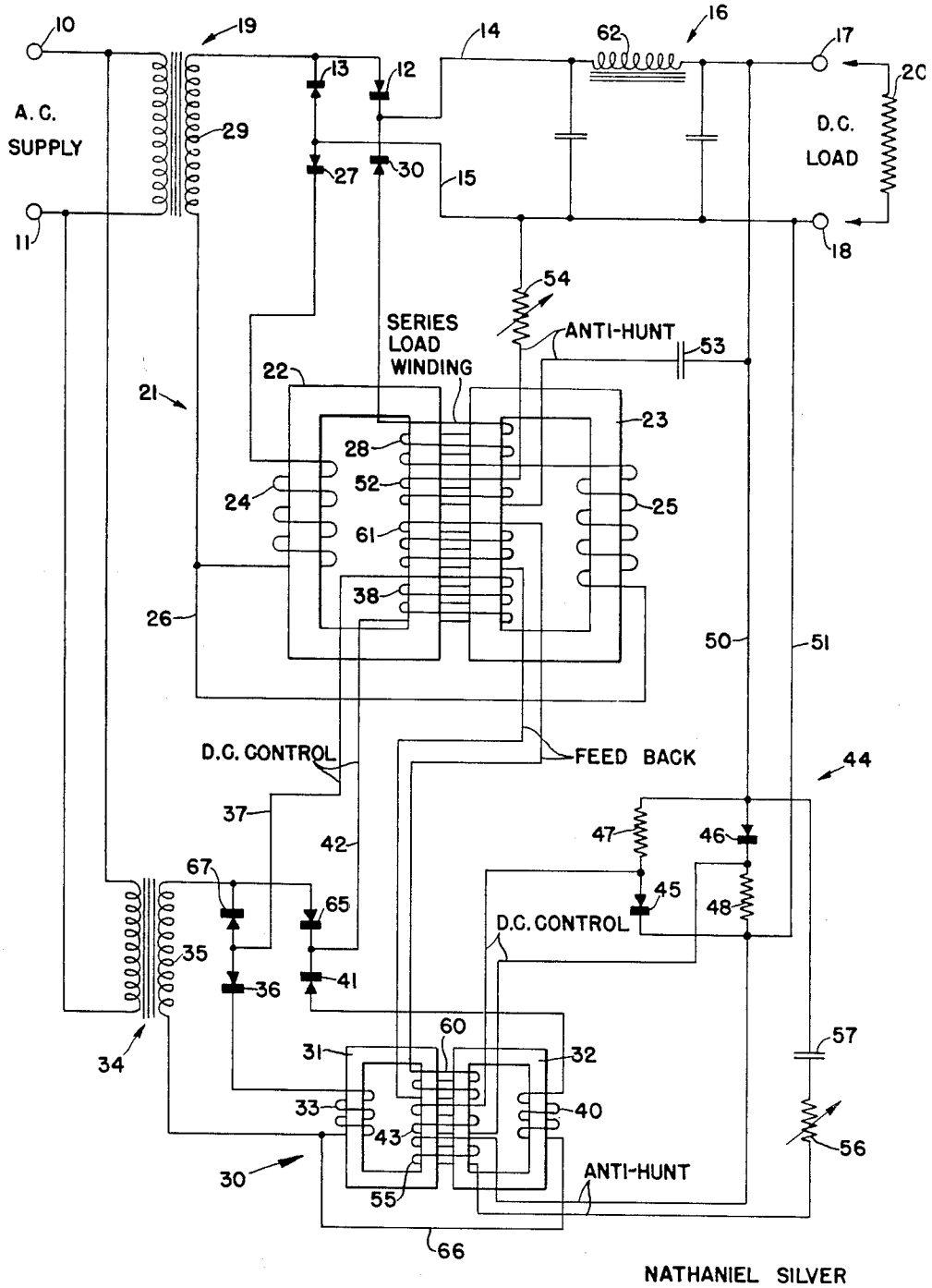

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VOLTAGE REGULATORS

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This invention relates to a voltage regulator which includes two magnetic amplifier units, a bridge sensing circuit, and a winding on one of the magnetic amplifier units which compensates for the load current.

The invention has particular reference to a voltage regulator arrangement which is devoid of electron discharge devices and includes no container enclosing a vacuum. The invention has further reference to voltage regulators which employ magnetic amplifier arrangements comprising two saturable cores mounted adjacent to each other.

Many types of voltage regulators have been designed and used which employ electron discharge devices such as triodes and pentodes in amplifier circuits in order to produce a control current which can be applied to a saturable reactor and vary the impedance in a series or parallel circuit to control the output voltage. Other voltage regulators use a single transformer arrangement, the core of which is partially saturated, for voltage regulation without the use of amplifier circuits. These latter regulators have not produced good regulation, the output voltage varying several percent when the input voltage is varied over a range of plus or minus 10 percent. The present invention employs two magnetic amplifier units, the cores of each being operated at a value of magnetic flux which partially saturates the cores. The use of two magnetic amplifiers produces a regulation across the load circuit which is a considerable improvement over the prior art and the absence of electron discharge devices and other elements requiring a vacuum and a heated filament eliminates the failure due to breakage, broken filaments, and short-circuited elements within such devices.

One of the objects of the invention is to provide an improved voltage regulator which avoids one or more of the disadvantages and limitations of prior art arrangements.

Another object of the invention is to provide an accurate voltage regulator which will have long life and not be subject to the failures which are generally inherent in regulators containing electron discharge devices and lamps containing heated filaments.

Another object of the invention is to provide a voltage regulator which is able to withstand considerable vibration and mechanical shock without changing its operating characteristics.

Another object of the invention is to simplify the construction and assembly of voltage regulators.

Another object of the invention is to shorten the reaction time of sensing systems employed in voltage regulators.

The invention comprises an alternating current supply for two saturable core magnetic amplifiers. Each magnetic amplifier includes two similar saturable cores. A load winding encloses a section of each of said cores and is connected in series with a rectifier for producing a direct current magnetizing component for the core material. A bridge sensing circuit which includes two resistors and two dry plate rectifiers is connected across the output terminals of the regulator and supplies direct current for a control winding which encloses both sections of the cores of one

of the magnetic amplifier arrangements. The load windings of this magnetic amplifier are connected through rectifiers to a similar control winding which encloses both sections of the other magnetic amplifier cores. A feature of the invention includes a winding in series with one of the load coils which includes both sections of the second magnetic amplifier core. Other features of the invention include anti-hunt circuits for both magnetic amplifier arrangements and a negative feed-back circuit which includes windings which enclose both sections of the cores in each unit.

For a better understanding of the present invention together with other and further objects thereof, reference is made to the following description taken in connection with the accompanying drawing.

The drawing is a schematic diagram of connections of the voltage regulator.

Referring now to the drawing, input terminals **10**, **11**, are to be connected to an alternating current supply system which may vary in voltage over a wide range of values. A transformer **19** has its primary winding connected to terminals **10** and **11** and its secondary winding connected to rectifiers **12**, **13**, at its upper terminal and to windings on the magnetic amplifier at its lower terminal. The other sides of rectifiers **12**, **13**, are connected to conductors **14** and **15** which in turn are connected through a filter circuit **16** to load terminals **17**, **18**, to which is connected a direct current load **20**.

A first magnetic amplifier **21** includes two similar closed saturable cores **22** and **23**. Two load windings **24** and **25** are wound on core sections of cores **22** and **23**. Each of the load windings has one of its terminals connected to conductor **26** which in turn is connected to secondary winding **29**. The other side of winding **24** is connected to rectifier **27** and conductor **15**. The upper end of winding **25** is connected in series with a third load winding **28** which acts as a compensating control winding responsive to variations in the load circuit. The upper terminal of winding **28** is connected to rectifier **30** which in turn is connected to conductor **14** and terminal **17** through filter **16**.

A second magnetic amplifier **30** includes two similar closed saturable cores **31** and **32** arranged in a manner similar to cores **22** and **23**. One leg of core **31** is enclosed by a load winding **33** which is connected to a source of alternating current **34**, in this case the secondary winding **35** of a transformer. The other side of winding **33** is connected to a rectifier **36** and conductor **37** which is connected to a control winding **38** on the first magnetic amplifier **21**. Control winding **38** and load coil **28** are both wound so as to enclose a section of each of the cores **22** and **23**.

A second load winding **40** encloses one section of core **32** and is connected between a terminal of winding **33** and a rectifier **41**. The other side of rectifier **41** is connected to conductor **42** and the other side of winding **38**. The degree of saturation in cores **31**, **32**, is controlled by the current in winding **43** which encloses a leg of each of the cores **31**, **32**. Winding **43** is connected to opposite points of a bridge sensing circuit **44** which includes rectifiers **45** and **46** and resistors **47** and **48**. The bridge is supplied with direct current by means of conductors **50** and **51** which are connected to opposite junction points of the bridge circuit. Winding **43** is connected to the other two opposing junction points.

Each magnetic amplifier **21** and **30** is supplied with an anti-hunt circuit, one circuit including a winding **52** on both sections of cores **22** and **23**, a capacitor **53**, and a variable resistor **54**. The other sides of the resistor and the capacitor are connected to terminals **17**, **18**. A similar anti-hunt circuit includes a winding **55** which encloses both sections of cores **31** and **32** and includes in series

connection a varaible resistor 56 and a capacitor 57. The terminals of this anti-hunt circuit are likewise connected to terminals 17 and 18 by way of conductors 50 and 51.

In order to reduce transients and to make the regulator more stable a negative feed-back circuit is connected between the two amplifiers 21 and 30. This circuit includes a winding 60 which encloses both legs of cores 31 and 32 and a similar winding 61 which encloses both legs of cores 22 and 23.

The operation of this circuit is as follows: When an alternating current supply system is connected to terminals 10 and 11 full wave rectification results and direct current power is made available at terminals 17 and 18. When the upper end of winding 29 is positive, the circuit may be traced from this terminal, through rectifier 12, over conductor 14, through inductor 62 of filter 16, to terminal 17, load 20, terminal 18, conductor 15, rectifier 27, load winding 24, conductor 26, and the lower end of winding 29. This portion of the wave supplies core 22 with unidirectional magnetic flux. During the second half of the alternating current cycle when the lower end of winding 29 is positive the circuit may be traced from this terminal over conductor 26, through load winding 25, series load winding 28, rectifier 30, conductor 14, inductor 62, terminal 17, load 20, terminal 18, conductor 15, rectifier 13, and the upper end of winding 29. This portion of the alternating current wave produces a unidirectional flux in core 23. It will be obvious from the above circuit construction that the degree of saturation of cores 22 and 23 determines the reactance of windings 24 and 25, together with winding 28, determines the value of direct current voltage available at terminals 17 and 18 and a change of saturation in cores 22 and 23 will obviously change the output voltage.

Control of the saturation of cores 22 and 23 is maintained by control winding 38. When the upper end of transformer secondary 35 is positive a circuit may be traced from this point through rectifier 65, over conductor 42, through control winding 38, conductor 37, rectifier 36, winding 33, and back to the lower end of winding 35. When the lower end of winding 35 is positive a circuit may be traced from this point over conductor 66, winding 40, rectifier 41, conductor 42, control winding 38, conductor 37, rectifier 67, to the upper end of winding 35. The above described circuits show that control winding 38 receives full-wave rectified current and includes load windings 33 and 40 in series connection so that any variation of the saturation value of cores 31, 32, will influence the current in winding 38 and therefore control the saturation value of cores 22 and 23.

Bridge circuit 44 is composed of two resistors 47 and 48 and two dry plate rectifiers 45 and 46. The resistors are chosen so that their resistance varies only slightly with change in applied voltage while the rectifier units have a nonlinear current-voltage characteristic and their resistance therefore varies considerably with applied voltage. Two opposite junction points of the bridge are connected to the load terminals 17 and 18 and under normal operating conditions the bridge is balanced or nearly so. This means that the current through the opposite junction points and the control winding 43 is either zero or a very small value. When the voltage across the load 20 changes for any reason, the voltage supplied to the bridge 44 causes the bridge to be unbalanced and sends a current (either positive or negative) through winding 43 and thereby changes the saturation value of cores 31 and 32, causing a change in reactance value of windings 33 and 40. The above action causes a change in the current supplied to winding 38 which in turn causes a large change in saturation of cores 22 and 23, thereby changing the reactance value of windings 24 and 25 and changing the impedance in series with the supply circuit so that the voltage across load 20 is returned to its normal value.

It will be evident from the above description that this device will produce voltage regulation without the use of winding 28 but it has been found that a wider range of voltage variation on terminals 10 and 11 can be regulated by the use of this compensating winding in series with winding 25. When load 20 is changed so as to draw more current from the supply line and through windings 25 and 28, the action of winding 28 increases the saturation of cores 22 and 23 thereby reduces the reactance values of windings 24 and 25 and compensates for the increased voltage drop across these two windings. The action of winding 28 is to compensate for changes in load without the need for the usual regulating action caused by the bridge circuit 44 and amplifier circuit 30, these circuits being used mainly when the voltage of the alternating current supply is varied.

It has been found by experiment that the time constants of the circuits involved produce a result which is sometimes greater than the required result. That is, an "over-shooting" effect is often evident. This results in an oscillatory condition which is generally described as hunting. In order to counteract this effect, an anti-hunt circuit is includes in each magnetic amplifier and the ends of these circuits are connected to the load terminals. Each circuit includes a series capacitor 53 and 57 so that no direct current from the load terminals passes through windings 52 and 55 and only the rapid variations of the voltage across terminals 17 and 18 are communicated to these windings. When transients or other abrupt changes in the direct current voltage are present the action of windings 52 and 55 causes a damping action and hunting is eliminated.

It has also been found that transient voltage surges within the amplifier system can be reduced by providing a feedback circuit which includes windings 60 and 61. A rapid variation of flux in cores 31 and 32 produces a current in windings 60 and 61 which acts in a negative manner to oppose the flux generated by the current in control winding 38. This action is transient and does not affect the amplifying action of the two magnetic amplifiers for voltage changes which do not include high frequency transient effects.

While there have been described and illustrated specific embodiments of the invention, it will be obvious that various changes and modifications can be made therein without departing from the field of the invention which should be limited only by the scope of the appended claims.

I claim:

1. A voltage regulator for an alternating current supply circuit comprising; a first magnetic saturable core arrangement which includes two similar closed cores; a first winding on one section of one of said cores which is connected in series with a terminal of said supply circuit, a rectifier, and the negative terminal of an output circuit which is connected to a direct current load; a second winding on one section of the other of said cores which is connected in series with said terminal of the supply circuit, a winding which encloses a section of both of said cores, a rectifier, and the positive terminal of said output circuit; a second magnetic saturable core arrangement which includes two similar closed cores; a first winding on one section of one of said cores which is connected in series with a source of alternating current, a rectifier, and a first control winding which encloses a section of both of the cores in said first core arrangement; a second winding on a section of the other of said cores of the second core arrangement which is connected in series with said source of alternating current, a rectifier, and the other terminal of the control winding on the first core arrangement; a second control winding which encloses a section of both of the cores in said second core arrangement, said second control winding coupled to a sensing circuit which is coupled to the direct current load and is responsive to voltage variations thereon; rectifiers connected to one terminal

of the alternating current supply circuit for supplying full wave rectification to the load circuit; and rectifiers connected to said source of alternating current for supplying full wave rectification to said first control winding.

2. A voltage regulator as set forth in claim 1 which includes a negative feed-back circuit comprising a winding which encloses both cores of said first core arrangement connected to a winding which encloses both cores of said second core arrangement.

3. A voltage regulator as set forth in claim 1 which includes an anti-hunt circuit for each of the magnetic core arrangements, said anti-hunt circuits each including a winding which encloses both sections of said magnetic cores and which are connected in series with a capacitor to the load circuit.

4. A voltage regulator as set forth in claim 1 in which the sensing circuit includes a four-armed bridge containing two resistors and two dry plate rectifiers.

5. A voltage regulator as set forth in claim 4 in which said bridge sensing circuit comprises the two resistors connected in opposite sides of the bridge and the dry plate rectifiers are also connected in opposite sides, a first pair of opposite junction points of the bridge are connected to the load terminals, and a second pair of opposite junction points are connected to said second control winding.

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