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REGULATED HIGH VOLTAGE POWER SUPPLY

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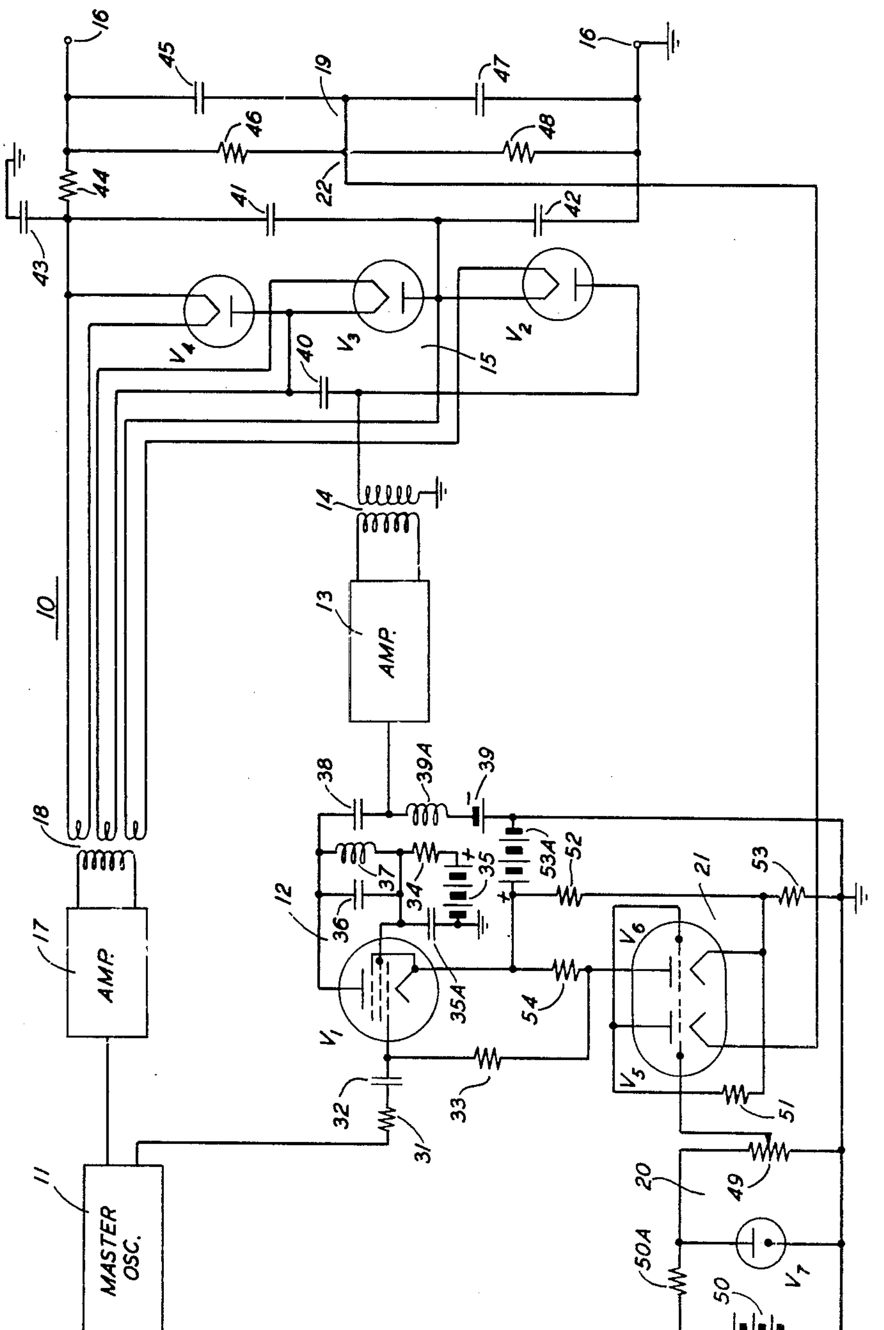

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REGULATED HIGH VOLTAGE POWER SUPPLY

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This invention relates to power supply systems and, more particularly, to a power supply whose output is regulated by electronic control.

Electronically regulated power supplies from a radio frequency alternating source have been found to be limited in their range of regulation. Generally the power supply consists of an oscillator, means for amplifying or multiplying its output, and a rectifier; and regulation is usually achieved by controlling the output of the oscillator in response to a sample of the output voltage fed to the screen grid of the oscillator tube. However, it can be shown that the amount of regulation achieved through such means is necessarily limited to the range of operation of the oscillator tube in that if the change in the output voltage of the supply which is applied to the screen grid causes the amplification of the tube to become less than unity, the condition necessary for oscillation will be destroyed.

It is, accordingly, a primary object of this invention to overcome this dependency of the regulated power supply upon the amplification factor of the oscillator tubes and to provide a regulated power supply system which can operate at any fixed voltage taken from a broad range of possible high and low voltages.

It is a further object of this invention to provide means for regulating the output of a power supply system by controlling the gain of an amplifier therein without affecting the oscillator source.

Furthermore, in power supply systems which make use of multiplier circuits, it has been the practice to heat the filament cathodes of rectifier tubes therein from a source within the voltage generator circuit. Thus, the filament voltage has become a function of the output voltage of the supply, and because the filament voltage must be kept within certain operational limits, the output voltage has been limited proportionately. Consequently, a feature of this invention is the provision of means for supplying the output tubes of a power supply system with a constant voltage the magnitude of which is independent of the voltage of the supply system. Moreover, in order to remove spurious low frequency oscillations generally found in feedback circuits, which may destroy the stability of regulated power supplies, an additional feature of this invention is the incorporation of means for providing a frequency non-sensitive divider in that portion of the feedback circuit where a portion of the output voltage is taken as a sample for feedback purposes.

In accordance with an exemplary embodiment of the present invention, the output of a master oscillator is amplified and applied through a resonant transformer to a series of vacuum tube rectifiers connected in a multiplying circuit. From this multiplying circuit, the output of the power supply is derived. In the output circuit of the power supply is located a frequency non-sensitive voltage divider from which a sample of the output voltage is taken and fed through a direct-current amplifier to the grid of the amplifier in the voltage generator system. By this means, the gain of the amplifier in the voltage generator circuit is controlled by the output of the power supply and varies the output in response to any change in the output. The tubes of the multiplier are maintained at a constant operating voltage by supplying the filament cathodes from an independent transformer energized through an appropriate amplifier from the output of the master oscillator.

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The invention will be more readily understood by referring to the following description, taken in connection with the accompanying drawing forming a part thereof, in which the single figure is a circuit diagram, partially in block schematic form, of a power supply system in accordance with the invention.

Reference will now be made more specifically to the drawing, in which there is shown, by way of example, a power supply system **10** in accordance with the invention. The supply **10** comprises a master oscillator **11** coupled to a radio frequency amplifier **12** in the main voltage generator circuit. Another signal is fed into the amplifier **12** from a direct-current amplifier **21**, the effective operation of which will be described below. The signal from **12** is reamplified in radio frequency amplifier **13** and fed into the resonant transformer **14**. The output of transformer **14** is multiplied and rectified through the tripler **15**, comprising tubes V_2, V_3, V_4, and circuits associated therewith and fed to the supply output terminals **16**. In order to maintain the filaments of the tubes in tripler **15** at constant operational voltage, excitation voltage is drawn from the master oscillator **11** through the radio frequency amplifier **17** to the transformer **18**, which in turn supplies the three tube filaments of the tripler **15** through individual secondary windings. The regulation circuit of the supply **10** includes the frequency non-sensitive voltage divider **19** with inner voltage tap **22**, the constant voltage source **20** and the direct-current amplifier **21**, the latter of which compares the voltage at the tap **22** with that taken from the source **20** and applies the amplified difference voltage to the radio frequency amplifier **12**.

The master oscillator **11** may have any suitable form; for example it can be of the type disclosed in the R. V. L. Hartley Patent 1,356,763, issued October 26, 1920. The output of this oscillator can be, for example, in the range of 2 to 10 volts and at a frequency in the 200 kilocycles per second range. The oscillator **11** is coupled through the anti-sing resistor **31** and the capacitor **32** to the control grid of the pentode V_1 of the amplifier **12**. Also coupled to the control grid of V_1 through resistance **33** is the direct-current amplifier **21**, the function of which will be disclosed below. The suppressor grid of V_1 is tied to the cathode and the screen grid is held at a positive potential by a direct-current source **35** connected to ground through resistor **34**. A by-pass condenser **35A** is also connected between the screen grid and ground. The potential on the plate is supplied by the source **35** through resistor **34** and the LC circuit of capacitor **36** and inductor **37**, the latter circuit serving to tune the plate circuit of the tube V_1 to resonance. Amplifiers **12** and **13** are coupled by capacitor **38**, the input circuit of the amplifier **13** also including a voltage source **39** connected through the inductor **39A** which maintains the proper bias on the tubes in amplifier **13**.

Step-up transformer **14**, which is excited by the output of amplifier **13**, supplies a constant operational voltage to the three diodes of V_2, V_3, and V_4 comprising the tripler **15** with which the charging condensers **40**, **41** and **42** are also associated. Triplers of this type are old in the electrical art. It is more fully described, for example, in Terman's Radio Engineers' Handbook (1943), page 593. In the supply output circuit, there are the high frequency by-pass circuits comprising capacitors **43**, **45** and **47** and resistor 44. Across the output terminals 16 is a frequency non-sensitive divider 19 consisting of resistors 46 and 48 and capacitors 45 and 47. To those familar with the art, it is well known that in feedback amplifier circuits of this type the loop gain-frequency ratio must be maintained above certain cut-off limits to prevent spurious low frequency oscillations in the circuit. (This subject is more completely covered in Terman, Radio Engineers' Handbook, 1943, page 222 et seq.) In order to prevent the voltage divider made up of resistors 46 and 48 from contributing to the cut-off characteristics of the feedback loop, it is made frequency-non-sensitive by the addition of capacitors 45 and 47. To accomplish this purpose successfully it is necessary that the resistors and capacitors be of such magnitude that $C_{45} \times R_{46} = C_{47} \times R_{48}$.

For purposes of regulation, a sample of the output voltage is taken from the tap 22 of the voltage divider and applied to the cathode of tube V_5 in the amplifier 21. Applied to the grid of the same tube is the voltage taken from the movable arm of the potentiometer 49, the resistance element of which is connected in parallel with the voltage regulator tube V_7. The latter is supplied from a suitable direct-current source 50 through resistor 50A. Potential for the plate of tube V_5 is derived from the source 53A through the resistor 51 and the voltage divider 52 and 53 which plate is connected to the grid of the tube V_6. The potential on the plate of tube V_6 comes from the direct-current source 53A through the resistor 54 and the cathode of the tube is given its potential from the same source through the voltage divider 52 and 53. Plate responses of the tube V_6, representing the difference between the output voltage sample and the fixed voltage from the tube V_7, are then fed through the resistor 33 to the control grid of the tube V_1 in the amplifier 12, which amplifier gain responds inversely to any change in the output of the power supply, thereby causing the output to be constant.

In keeping with the spirit of the invention, it is possible to ground the positive output terminal instead of the negative one as shown in the drawing and make other minor changes in the circuit constants in order to provide a negative regulated power supply voltage. While there are a number of possible values suitable for use in the circuit elements, values used in an operative embodiment of the supply system 10 (for an output voltage of 20 kilovolts in operation from a master oscillator frequency of 200 kilocycles at 10 volts) are:

Resistor 31	60,000 ohms.
Condenser 32	500 micromicrofarads.
Resistor 33	11,000 ohms.
Resistor 34	100 ohms.
Source 35	400 volts.
Condenser 35A	0.1 microfarad.
Condenser 36	0.012 microfarad.
Inductor 37	100 microhenry.
Condenser 38	0.001 microfarad.
Source 39	45 volts.
Inductor 39A	1 millihenry.
Condenser 40	500 micromicrofarads.
Condenser 41	500 micromicrofarads.
Condenser 42	500 micromicrofarads.
Condenser 43	500 micromicrofarads.
Resistor 44	0.2 megohm.
Condenser 45	500 micromicrofarads.
Resistor 46	200 megohm.
Condenser 47	0.1 microfarad.
Resistor 48	1 megohm.
Potentiometer 49	50,000 ohms.
Source 50	200 volts.
Resistor 50A	7,500 ohms.
Resistor 51	1 megohm.
Resistor 52	68,000 ohms.
Resistor 53	0.13 megohm.
Source 53A	200 volts.
Resistor 54	0.56 megohm.
Tube V_1	6V6.
Tube V_2	1B3.
Tube V_3	1B3.
Tube V_4	1B3.
Tube V_5	½ 6SL7.
Tube V_6	½ 6SL7.
Tube V_7	0C3/VR105.

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

What is claimed is:

1. In a power supply adapted to feed a load which may vary, a source of alternating voltage, an amplifier connected to said alternating voltage source, means for rectifying the output of said amplifier, means for obtaining from the rectified voltage a multiplied output voltage comprising a plurality of heated filament-cathode discharge tubes and means associated with the source for applying constant filament voltage to said discharge tubes, means for obtaining from the multiplied output voltage a fixed portion of said voltage as a sample, a constant voltage source, means for comparing said sample voltage and the output of said constant voltage source to obtain a difference voltage, a direct-current amplifier supplied with said difference voltage, means for applying the output of said direct-current amplifier to the input of said amplifying means to thereby regulate said multiplied output voltage, and means for eliminating spurious low frequency oscillations in the sampler circuit comprising two series resistors connected across said multiplied output voltage, and a capacitor in parallel with each resistor and the said resistors and capacitors having such values that the product of the values of one resistor and capacitor in parallel is equal to the product of the values of the other resistor and capacitor.

2. In a power supply adapted to feed a load which may vary, a source of alternating voltage, an amplifier connected to said alternating voltage source, means for rectifying the output of said amplifier, means for obtaining from the rectified voltage a multiplied output voltage, means for obtaining from the multiplied output voltage a fixed portion as a sample, a constant voltage source, means for comparing said sample and the output of said constant voltage source to obtain a difference voltage, means for applying said difference voltage to the input of said amplifying means to thereby regulate said output voltage, and means for eliminating spurious low-frequency oscillations in the sampler circuit, said means comprising two series resistors across the supply output and a capacitor in parallel with each resistor and said resistors and capacitors having values such that the product of the values of one resistor and parallel capacitor combination is equal to the product of the value of the other resistor and capacitor.

3. The power supply according to claim 2 in which said constant voltage source comprises a direct current source, a voltage regulator tube and a variable resistance potentiometer, said direct-current source, tube and the resistance element of said potentiometer being connected in a parallel circuit.

4. In a power supply adapted to feed a variable load connected across its output terminals, a source of radio frequency alternating voltage, an amplifier connected to the output of said alternating voltage source, means for rectifying the output of said amplifier, means including a heated filament discharge tube for obtaining from said rectifying means a multiplied output voltage, means connected to said alternating voltage source for supplying said discharge tube with filament voltage, voltage divider means for obtaining a fixed portion of said multiplied output voltage as a sample, a source of constant voltage, means for comparing said sample with said constant volt-

age to obtain a difference voltage, means including a direct-current amplifier for applying said difference voltage to said first-named amplifier to regulate said multiplied output voltage, and means for reducing spurious low frequency oscillations in said power supply comprising means for rendering the said sample obtaining means substantially frequency nonsensitive.

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