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HIGH STABILITY REGULATED VOLTAGE SUPPLY

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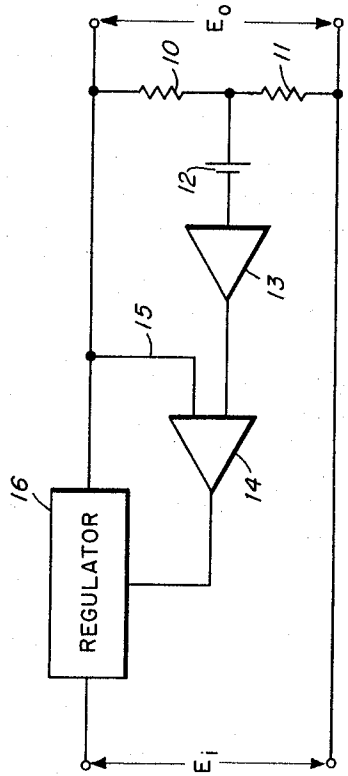


FIG. 1

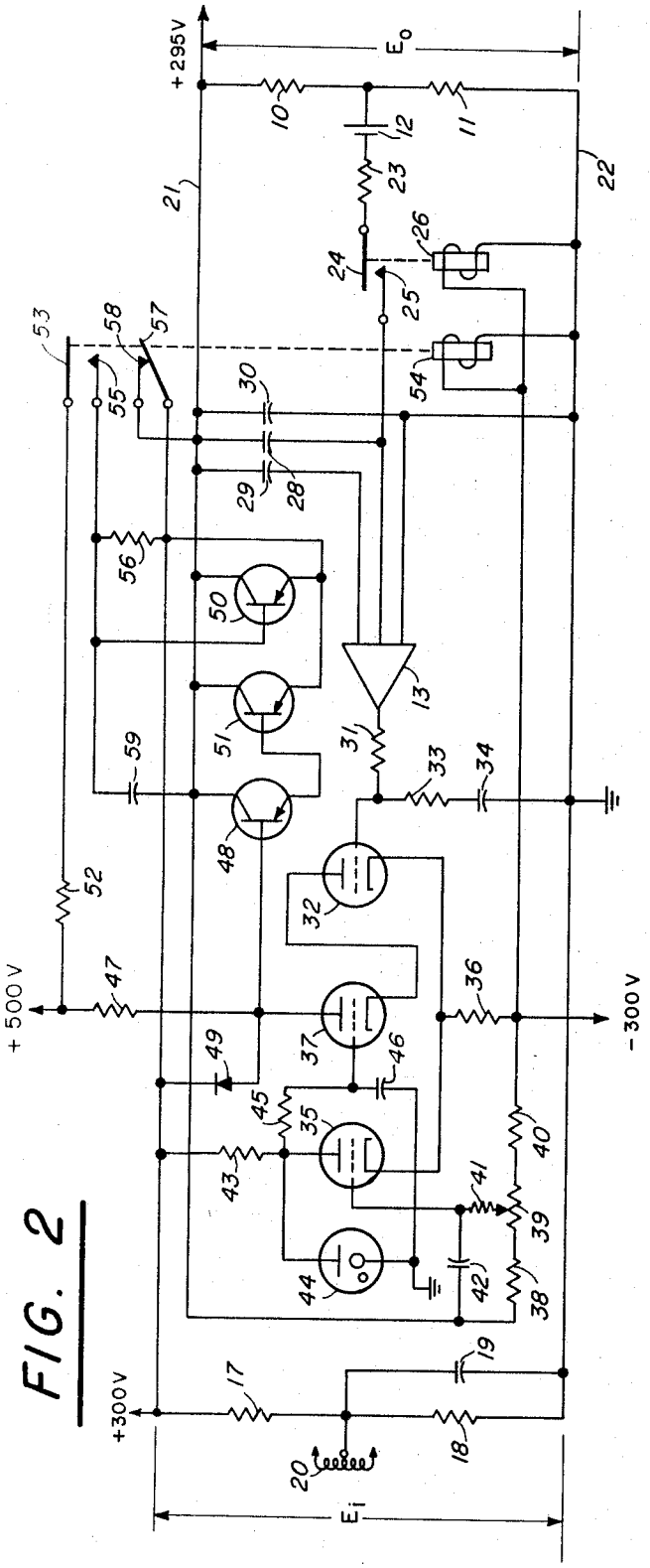


FIG. 2

INVENTORS
ROBERT D. STRAIT
ROBERT W. SANDERS

BY

Fowler, Whitham, Roy & Miller
ATTORNEYS

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HIGH STABILITY REGULATED VOLTAGE SUPPLY

Robert D. Strait and Robert W. Sanders, San Diego, Calif., assignors to the United States of America as represented by the Secretary of the Navy

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1 Claim. (Cl. 323—22)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to a precision power supply and more particularly, to a precision power supply having an extremely stable output voltage and specifically to a precision power supply having an extremely stable output voltage which provides excellent regulation against load changes and drift.

Conventional regulated power supplies are illustrated and described in Terman, Electronic and Radio Engineering, McGraw-Hill, 1955, page 725. In the conventional regulated power supply, such as that just mentioned, the output is sampled, compared against a reference voltage and used to regulate the output of the supply. Other regulated supplies are known which disregard the high speed transients and regulate in response to low frequency changes such as drift.

However, none of the known regulated power supplies have a stability which approaches that of the present invention.

An object of the present invention is to provide a practical precision power supply.

Another object of the present invention is to provide a precision power supply having long term drift stability.

A further object of the present invention is to provide a precision power supply which provides excellent regulation against load changes and transients.

An additional object of the present invention is to provide a precision power supply with an extremely stable output for use in analogue systems associated with statistical processes.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a simplified block diagram of the regulating circuit of the present invention; and

FIG. 2 is a detailed schematic of the power supply of the present invention.

As shown in FIG. 1, an output voltage E_o is sampled by a ratio network comprising resistors **10** and **11** connected in series across E_o. The sample voltage is then compared to that of a standard cell **12**. The difference between the two voltages is treated as an error signal and fed to a D.C. amplifier **13** which is a high gain, very stable unit used primarily to compensate for low frequency changes such as drift.

The error voltage is amplified, inverted, and fed to one grid of a high-gain moderate-bandwidth differential amplifier **14**. High-speed transients induced by rapidly switching loads are corrected by being coupled to the other grid of the diffeerntital amplifier on line **15**. The differential amplifier **14** is D.C.-coupled to a regulator **16**.

In FIG. 2 a regulated supply, 300 volts, is connected across resistors **17** and **18** connected in series. The supply is not completely unregulated in the normal sense in that there must be enough regulation to keep within the dissipation rating of transistor **51**. One end of resistor **18** is connected to ground and the other end is connected to resistor **17**, the other end of which is connected to the

high side of the 300 volt supply. The common junction of resistors **17** and **18** is connected through a capacitor **19** to ground and also connected to the center tap of a transformer **20** which supplies filament voltage for the differential amplifier tubes.

The regulated output E_o appears between lines **21** and **22**. Line **21** corresponds to the +295 volt output and line **22** is at ground potential. Connected between lines **21** and **22** is the ratio network comprising resistors **10** and **11** connected in series. The common point of resistors **10** and **11** is connected to the positive side of a standard cell **12**. The negative side of the standard cell is connected through a current limiting resistor **23** to a switch contact **24** adapted to engage a fixed contact **25** which comprises a portion of a relay **26**. Fixed contact **25** is connected to one input of a D.C. amplifier **13**. Connected between fixed contact **25** and line **21** is a capacitor **28**. Also connected to another input of the D.C. amplifier **13** is a capacitor **29** connected between line **21** and the D.C. amplifier which corresponds to the A.C. input. A ripple filter comprising a capacitor **30** is connected across lines **21** and **22** and a ground terminal also provided for the D.C. amplifier.

The output of the D.C. amplifier is coupled through a resistor **31** as an error voltage to the control grid of a tube **32** which forms part of the differential amplifier. The control grid of tube **32** is connected to ground through a resistor **33** and capacitor **34** connected in series. The combination of resistors **31**, **33** and capacitor **34** functions as a response correcting network introduced to provide loop stability. The cathode of tube **32** and the cathode of a tube **35** are connected in parallel and connected to a minus 300 volt supply through a resistor **36**. The plate of tube **32** is connected directly to the cathode of a tube **37**.

Another ratio network comprising resistor **38**, potentiometer **39** and resistor **40** connected in series between line **21** and the minus 300 volt supply is provided which is utilized to sample the high speed transient voltages which appear at the output of the power supply. A movable arm of the potentiometer is coupled through a resistor **41** to the control grid of tube **35**. A coupling capacitor **42** is connected between line **21** and the grid of the tube **35** for fast response to high speed transients. The unregulated voltage supply is connected through a resistor **43** to the plate of tube **35** and also to the plate of a VR tube **44**, the cathode of which is connected to ground. Also connected to the plate of tube **35** is one side of resistor **45** the other side of which is connected directly to the control grid of tube **37**. Capacitor **46** is connected from the control grid of tube **37** to ground.

The plate of tube **37** is connected through a resistor **47** to a 500 volt supply and also connected to the base of a transistor **48**. Transistor **48** is kept from going positive through a diode **49** connected between the base and the 300 volt supply. The collector of transistor **48** is connected directly to line **21**, the 295 volt regulated supply, and also connected through a capacitor **59** to the base of a transistor **50**. The emitter of transistor **48** is connected directly to the base of a transistor **51**. The emitters of transistors **50** and **51** are connected together and connected to the unregulated 300 volt supply while the collectors of transistors **50** and **51** are connected together and connected to line **21**, the 295 volt regulated output voltage.

The positive 500 volt supply is connected through a resistor **52** to a movable contact **53** of a relay **54**. A fixed contact **55** which is adapted to engage the movable contact **53** is connected through a resistor **56** to the unregulated supply voltage and also connected to the base of transistor **50**.

In addition, a movable contact **57** of relay **54** engages

a fixed contact 58 in the unenergized position of relay 54. Movable contact 57 is connected to the unregulated supply while the fixed contact 58 is connected to the regulated output.

The D.C. amplifier 13 shown in the present invention is a commercial unit, Model A–14, made by Electro-Instruments, Incorporated. The amplifier is slightly modified to separate the A.C. and D.C. inputs, however, in all other respects it is substantially the same as the unit commercially sold.

The amplifier is quite stable, having a drift of less than 4 micro-volts per 200 hours. Some of the internal feedback loops were removed to take advantage of the high gain available which is in excess of 10^6. This change alone would have reduced the D.C. input impedance to a low value, about 10 kilohms, which was undesirable. Such a low input impedance, in conjunction with the current limiting resistor 23, would have reduced the gain in the system by a factor of 5. Resistor 23 is rather large for the purpose of protecting the cell but it does, in addition, improve the integration obtained through capacitor 28.

In that the D.C. amplifier in the present invention is intended for microvolt error signals, any D.C. voltage other than the signal voltage at the D.C. input of the amplifier must be held to an absolute minimum. Any leakage, whatever the source, will introduce an off-set. It is necessary that capacitor 28 be of exceptionally good quality from the leakage point of view. In the invention a polystyrene capacitor which has a leakage resistance of 10^{14} ohms is utilized. Such a type of capacitor is necessary to reduce the off-set to an acceptable value.

Protective circuits are incorporated, as well as a definite sequence for the different voltages to the power supply. The unregulated voltage is applied first, which charges all capacitors. Transistors 50 and 51 are protected from the current surge, since they are shorted initially by contacts 57 and 58 of relay 54. Secondly, the plus 500 volt supply is applied. The diode 49 connected from the base of the transistor 48 to the emitters of the transistors 50 and 51 protects the transistors should the plate voltage at tube 37 tend to go above the 300 volt supply.

The minus 300 volts is applied last. In addition to supplying the necessary negative voltage for the regulator, it also activates the protective relays 54 and 26. The short across the transistors 50 and 51 is removed, the standard cell is connected to the system through switch contacts 24 and 25 and a plus 2 volts is applied to the base of the transistor 50 through resistor 52 and switch contacts 53 and 55. The transistor 50 is in saturation when the short is removed and, due to the R.C. combination of resistor 56 and capacitor 59, is slowly cut off. This permits the system's regulating circuit to operate and regulate. Otherwise the system might stay saturated, which could be harmful to the standard cell 12. The differential amplifier which comprises tubes 32, 35 and 37 has a high gain with a moderate bandwidth, to accommodate switching transients that result from rapidly switching loads. These transients are fed to the grid of tube 35 by capacitor 42. There is no phase reversal from this grid to the output of the amplifier.

It will be noted that 32 and 37 form a cascade amplifier. Tubes were chosen for use in the differential amplifier having a high transconductance, but they were limited to 200 volts between plate and cathode, thus the necessity of multiple tubes to withstand the higher voltage. From the control grid of 32 to the collector of transistor 51, the gain is fairly small, but the main purpose is for D.C. coupling from the D.C. amplifier 13.

The output of the D.C. amplifier must be maintained at ground potential to minimize leakage current, which is readily accomplished by returning the common cathode of the differential amplifier to the negative supply through current limiting resistor 36. The ground potential is maintained by adjusting the potentiometer 39 in the grid circuit of tube 35. This means that the static level of the grid of 32 can be set at ground potential.

After the starting sequence noted above and consequently with all voltages applied to the circuit, transistor 51 operates as a conventional series regulator between the 300 v. input and the 295 v. output. It should be understood that in actual usage, a load would be connected to the 295 v. output, i.e., across E_o. As in well known series-type voltage regulators, the variable internal resistance of transistor 51 in series with the load or network of resistors 10 and 11 is used to maintain the output voltage at the desired level. The internal resistance of transistor 51 is dependent on the bias supplied to it by transistor 48. The latter transistor is driven by the voltage detecting portion of the circuit comprising two sampling means, one responsive to low and high frequency variations of significant order and the other to low and high frequency components having incremental values. The latter sampling means permits the supply to maintain its output voltage within a very high precision manner.

In operation, any significant variations in output voltage are supplied to the grid of tube 35 which constitutes one input of the differential amplifier 14 of FIG. 1. High frequency components of the noted significant variations are bypassed directly to the noted grid by capacitor 42 whereas the lower frequency components are supplied through resistor 38. Incremental variations detected by the divider comprising resistances 10 and 11 are supplied to the D.C. amplifier 13 for amplification to suitable levels for driving the grid of tube 32, the other input of the differential amplifier. Since transistor 51 is coupled to the differential amplifier by transistor 48, an emitter follower, the transistor 51 is responsive to both the significant and incremental variations on the line as represented by the differential amplifier output.

It should be noted that transistor 50 together with the RC circuit comprising resistor 56 and capacitor 59 provides a smooth transition between the time when transistor 51 is shorted and that time at which it is brought into the line as a series regulating element.

When two ratio networks are utilized, one responsive to the high speed switching transients and the other extremely responsive, i.e., supersensitive to low speed changes due to drift, a precision power supply which has the capability of providing an extremely stable output is had.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claim the invention may be practiced otherwise than as specifically described.

What is claimed is:

A regulated voltage power supply for receiving an unregulated voltage and producing a high precision regulated voltage therefrom comprising;

a series regulating element having first and second inputs and an output,

said regulating element having an internal resistance between said first input and said output and being responsive to signals at its second input to vary its said internal resistance proportionally,

said first input of said regulating element being the input of said regulated supply and said output of said element being the output of said supply,

a differential amplifier having first and second inputs and an output and responsive to differences in signals at its said first and second inputs for producing a signal at its output indicative of such differences,

means for supplying said differential amplifier output to said second input of said regulating element,

first voltage sampling means connected to said output of said supply and adapted to produce a first error

signal indicative of any variance of the voltage at said supply output from a desired voltage,

said first differential amplifier input being connected to receive said first error signal,

said first sampling means including a bypass capacitor for directly supplying transient signals from said supply output to said first differential amplifier input,

second voltage sampling means for comparing said supply output with the voltage of a standard cell and producing a second error signal indicative of any incremental difference between said output of said supply and said standard cell,

a D.C. amplifier for coupling said second error signal to said second input of said differential amplifier,

whereby said supply is responsive to substantial and incremental changes in its output voltage to automatically correct therefor.

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JOHN F. COUCH, *Primary Examiner.*

W. E. RAY, K. D. MOORE, *Assistant Examiners.*