

Feb. 5, 1963

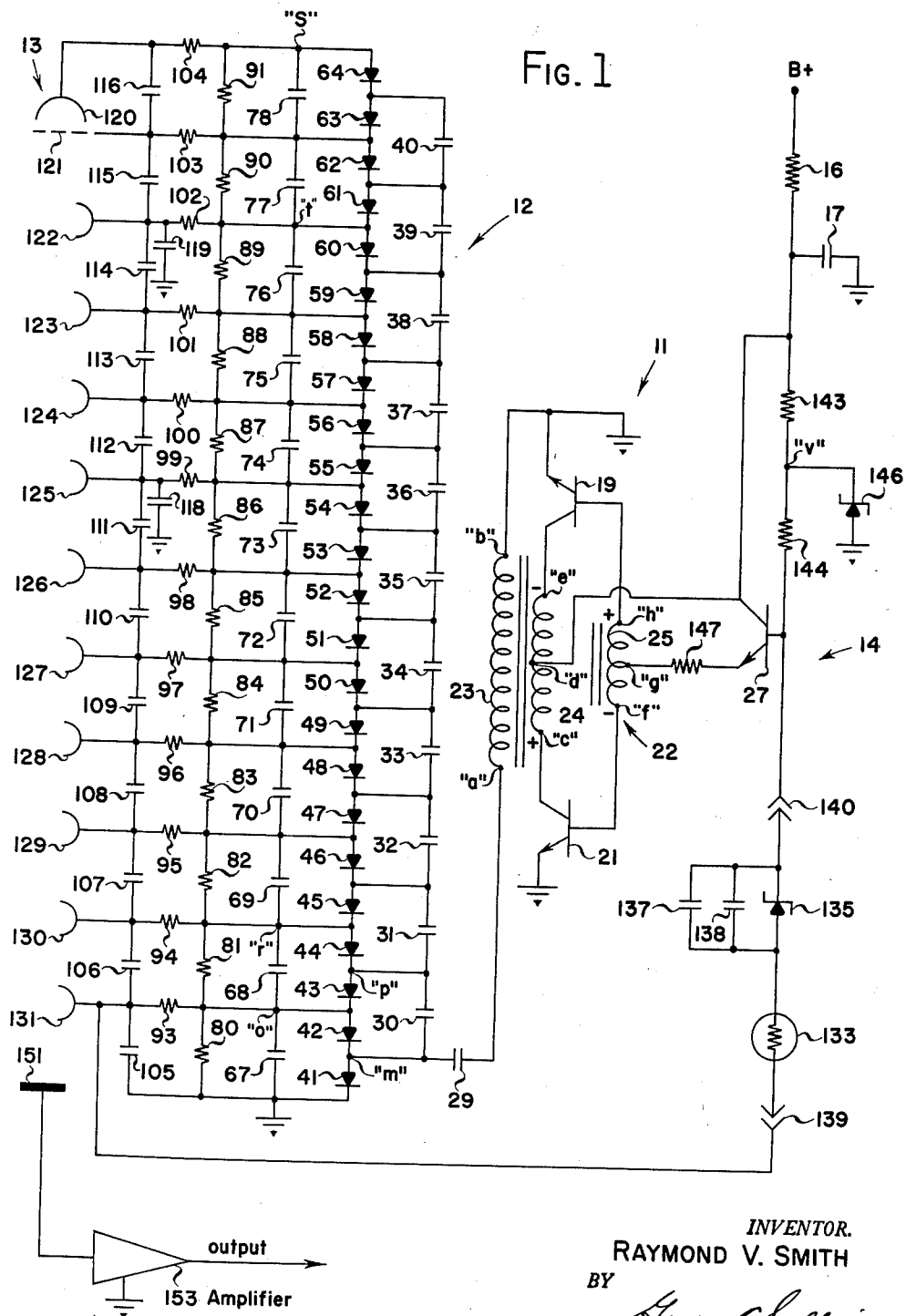
R. V. SMITH

3,076,896

VOLTAGE SUPPLY AND CONTROL SYSTEM

Filed May 1, 1961

2 Sheets-Sheet 1



INVENTOR.
RAYMOND V. SMITH
BY
George Sullivan
Agent

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R. V. SMITH

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2 Sheets-Sheet 2

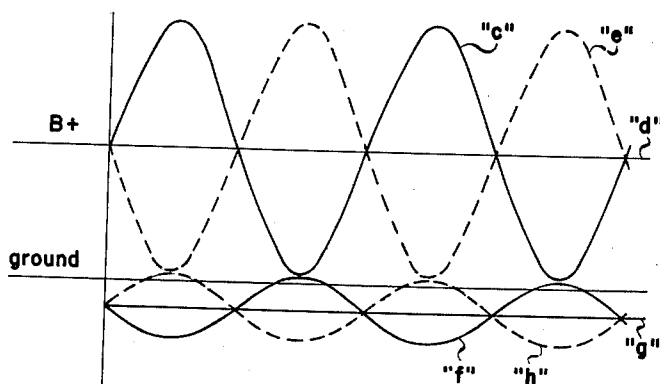


FIG. 2A

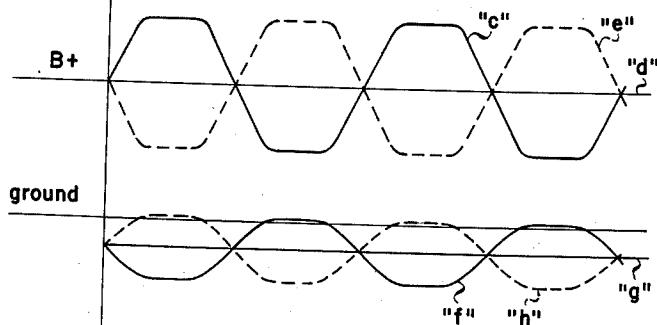


FIG. 2B

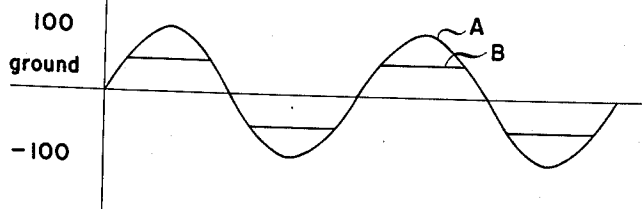


FIG. 2C

INVENTOR.

RAYMOND V. SMITH

BY

George Sullivan
Agent

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3,076,896

VOLTAGE SUPPLY AND CONTROL SYSTEM

Raymond V. Smith, Los Altos, Calif., assignor to Lockheed Aircraft Corporation, Burbank, Calif.

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This invention relates to a voltage supply and more particularly to a voltage supply uniquely adaptable to a photomultiplier device.

In photomultiplier devices it is mandatory that the over-all multiplication factor be kept constant irrespective of load or the intensity of bombardment of the photocathode thereof. Since the latter stages of photomultipliers draw relatively large currents it is necessary that these stages be supplied by a low impedance source. The conventional method for doing this is by means of a voltage divider network consisting of a plurality of series connected resistors which are supplied power by a high voltage D.C. source. By this method it is necessary that the resistance of the resistors connected to these stages be relatively low so when varying currents are drawn, the change in voltage drop across the associated resistor is small and the voltage applied to each of these stages therefore remains relatively constant. The primary disadvantage of a resistive network of this type is, with the high voltages necessary for operation and the low network resistance, there is large power consumption which necessitates a large and frequently complex power source with corresponding voltage control difficulties.

The present invention obviates the disadvantages of these prior voltage supply devices by providing a unique voltage supply and control system that requires relatively small currents and maintains a constant over-all multiplication factor irrespective of photomultiplier load. This is accomplished by converting B+ power into A.C. power by means of an oscillator and applying the A.C. power to a diode-capacitor voltage multiplier network thereby providing a high voltage D.C. voltage source, each stage of which has consecutive integral multiples of the oscillator output voltage. The voltage multiplier network has a low output impedance and each stage is individually connected through a filter circuit to separate dynodes of the photomultiplier. Effective filtering and impedance characteristics are realized since the dynodes at the low voltage stages of the voltage multiplier network draw more current than the dynodes at the high voltage stages where the A.C. components to be filtered are relatively large and require relatively large resistors in series with the voltage multiplier output. Control of the system is realized by sampling the voltage at the last dynode which reflects both variations in B+ supply voltage and photomultiplier load. This control reflects photomultiplier load by sensing the current drawn by the last dynode and it is therefore possible to maintain a constant over-all photomultiplier multiplication factor by varying the relative potentials between individual dynodes as a function of photomultiplier load. The last dynode potential is applied to a zener diode which is connected to a transistor for controlling the series impedance between the B+ supply and the input to the oscillator, to maintain the dynode at the breakdown voltage of the selected zener diode. Temperature compensated is real-

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ized by employing a thermistor in series with the selected zener diode.

Accordingly, an object of the present invention is to provide a stable, high voltage supply requiring very little power.

Another object of the present invention is to provide a stable, high voltage supply for supplying a photomultiplier device the necessary discrete D.C. voltages.

Still another object of the present invention is to provide a stable voltage supply for a photomultiplier wherein the voltage is supported by a capacitor-diode network.

A further object of the present invention is to provide a voltage supply which has a plurality of individual power supplies connected to individual dynodes of a photomultiplier.

A still further object of the present invention is to provide a voltage supply for a photomultiplier device which maintains the over-all multiplication factor of the photomultiplier constant irrespective of variations of B+ supply voltage and photomultiplier load.

A still further object of the present invention is to provide a D.C. voltage supply, filter and current bleeder network wherein the voltage across each component is maintained at a minimum thereby minimizing component failure.

The specific nature of the invention, as well as other objects, uses and advantages thereof, will clearly appear from the following description and from the accompanying drawing in which:

FIGURE 1 is a schematic illustration of the voltage supply and control circuit of the present invention.

FIGURES 2A, 2B and 2C are curves illustrating the operation of the device shown in FIGURE 1.

In FIGURE 1 is schematically illustrated the circuit of the present invention wherein reference numeral 11 generally denotes the oscillator, reference numeral 12 generally denotes the D.C. voltage multiplier, reference numeral 13 generally denotes the photomultiplier device and reference numeral 14 generally denotes the control system.

Power for operation of the system is obtained from a D.C. source denoted as B+ and is applied to the input of oscillator 11. Resistor 16 and capacitor 17 are provided to filter the A.C. component which may be superposed on the B+ power supply. As will hereinafter become apparent, accurate control of the B+ power source is unnecessary because of the unique compatibilities of the D.C. voltage multiplier, photomultiplier and control system. It has been found that a constant photomultiplier multiplication factor is realized with B+ voltage varying from about 22 to about 35 volts. This is a highly advantageous feature since the photomultiplier may then be battery operated over a relatively long period of time.

Oscillator 11 is of the push-pull type and includes transistor 19, transistor 21, transformer 22 including windings 23, 24 and 25, and is controlled by transistor 27. Upon the initial application of B+ power to the oscillator input, either transistor 19 or transistor 21 will conduct more rapidly than the other since two transistors are never entirely symmetric. Assuming transistor 19 conducts more rapidly than transistor 21, then the rate of change of current from point "d" to point "e" is greater than from point "d" to point "c" of winding 24. Point "c" will thus become positive with relation to point "e," as illustrated,

since voltage drop is proportional to rate of current change across an inductive load. Winding 25 is wound with relation to winding 24 so the flux induced by increasing rate of current flow from point "d" to point "e" causes point "h" to be positive with relation to point "f" of winding 25. Since point "h" is driven positive, transistor 19 will be driven to greater conduction and since point "f" is driven negative, transistor 21 will be driven to lesser conduction. Considering only transistor 19, initially the rate of change of current from point "d" to point "e" is positive, and as the base of transistor 19 is driven more positive and reaches saturation, the rate of change of current from point "d" to point "e" reverses. With this reversal of rate of current change, the flux induced in winding 25 is reversed and point "f" will be driven positive with relation to point "h." As this occurs, transistor 21 will become conducting and transistor 19 will become nonconducting and point "e" will become positive with relation to point "c." As transistor 21 reaches saturation, the rate of change of current from point "d" to point "c" reverses and point "h" becomes positive with relation to point "f." Therefore, transistor 19 becomes conducting and transistor 21 nonconducting and the above described sequences will be repeated. Therefore, there is free running oscillation at a frequency which is established by the oscillator parameters. It should be noted that when the base currents of transistors 19 and 21 are large, the transistors will not saturate until the collectors approach ground potential. However, when the base currents are small, the transistors will saturate prior to the collectors reaching ground potential. These base currents are controlled by the effective collector-emitter resistance of transistor 27 the operation of which will hereinafter be described. Therefore, by varying these base currents, the peak to peak voltage in winding 24 is varied and as a result the peak to peak voltage or amplitude of the signal induced in winding 23 is varied.

In FIGURE 2A are shown the voltage signals at the various points indicated in FIGURE 1 during that period when large base currents are permitted to be drawn by transistors 19 and 21. In FIGURE 2B are shown the voltage signals at the same points when large base currents are not permitted to be drawn by these transistors. Curves A and B of FIGURE 2C represent the voltage induced in winding 23 during the operating conditions shown in FIGURE 2A and 2B, respectively. Winding 23 may have the polarity indicated or it may be reversed by reversal of the direction of winding on the associated core. It should be noted the maximum peak-to-peak amplitude of the signals at points "c" and "e" is limited by the B+ voltage and will have a maximum amplitude of approximately twice the B+ potential. Consequently, for a predetermined turn ratio between windings 23 and 24, the induced voltage in winding 23 is likewise limited. However, the turn ratio is selected so slightly more than 200 volts peak-to-peak may be obtained with about 22 volts B+ power and still realize the necessary current for successful operation. It is to be understood that various turn ratios and B+ voltages may be employed to provide sufficient voltage and current to the particular load which is being supplied by D.C. voltage multiplier 12. It is also to be understood that other types of oscillators may be employed so long as they remain compatible with the hereinafter described D.C. voltage multiplier and control system.

The output of winding 23 of oscillator 11 is applied to the input of D.C. voltage multiplier 12 which includes capacitors 29 through 40, diodes 41 through 64, capacitors 67 through 78, resistors 80 through 91, resistors 93 through 104, capacitors 105 through 116 and capacitors 118 and 119. Assuming the peak-to-peak voltage output of the oscillator is from +100 to -100 volts, then capacitor 29 will initially charge to -100 volts since diode 41 permits electrons to pass only in the direction to bring about this negative charge. A steady state condition is realized after

this initial charge on capacitor 29 and no current will pass through diode 41 when the anode thereof is negative with respect to ground. Therefore, the oscillator input to capacitor 29 is superposed on the negative charge thereon with a resultant signal varying from ground to -200 volts at point "m" of FIGURE 1. Since the anode of diode 42 is positive with respect to point "m" there is flow of electrons to capacitor 67 with a resultant steady state voltage at point "o" of -200 volts. The potential applied to capacitor 30, which is analogous to capacitor 29, varies from 0 to -200 volts (point "m") and the potential applied to the cathode of diode 43, which is analogous to diode 41, is -200 volts (point "o"). In the same manner as described with relation to capacitor 29 and diode 43, the potential at point "p" will vary between -200 and -400 volts. The potential at point "r" will realize a steady state value of -400 volts in the same manner as was described with relation to diode 42 and capacitor 67. This same process is continued through capacitors 31 through 40, diodes 44 through 64 and capacitors 69 through 78 so the steady state potentials applied to the dynodes of photomultiplier 13 are multiples of 200 volts, and the photocathode thereof is at a potential of -2,400 volts.

It is to be understood that various numbers of multiplication stages, and various values of voltages per stage, may be used in particular applications, and the twelve stage voltage multiplier shown in FIGURE 1 is considered to be only exemplary.

Photomultiplier 13 includes photocathode 120 which emits electrons when light impinges thereupon. The number of electrons emitted are relatively few and are accelerated by the field created by the differential potential between photocathode 120 and grid 121. Dynode 122 further accelerates and attracts these electrons and upon their collision therewith results in the release of a greater number of electrons which is some multiple of the number of colliding electrons. This multiplication of electrons is continued by the remaining dynodes. Assuming an individual dynode multiplication factor of four and that ten dynodes are employed, as shown, there is an overall current or electron multiplication factor of 4^{10} or approximately one million. It can therefore be seen the current drawn from voltage supply 12 by dynodes 122 through 131 progressively increases and dynode 131 draws very large current as compared with dynode 122, photocathode 120 or grid 121.

As previously indicated, in photomultiplier devices it is necessary that the over-all multiplication factor of the photomultiplier be kept constant irrespective of load or the intensity of bombardment of the photocathode thereof. Since the latter stages of the photomultiplier draw relatively large currents it is necessary that a low impedance source supply these stages. As previously indicated, the conventional method for doing this is by means of a voltage divider network consisting of a plurality of series connected resistors which are connected to a high voltage D.C. source. However, it is necessary that the resistance of the resistors connected to the latter dynodes be relatively low so when varying currents are drawn by these dynodes the change in voltage drop is small and the voltage on each dynode therefore remains relatively constant irrespective of the variation of current. In order that approximately uniform voltage division be obtained, it is necessary that the over-all resistance of the network be relatively low. In view of the low resistance network and the high voltages necessary for operation, it can be seen there is large power consumption which necessitates a large and frequently complex power source with corresponding voltage control difficulties.

It should be particularly noted that an A.C. signal, at a frequency corresponding to the oscillator frequency, is superposed on the D.C. potential of capacitors 67 through 78. This A.C. component at point "o" of voltage multiplier 12 is relatively small; however, this small A.C. component is amplified by the stages of the D.C. voltage

multiplier and at point "s" the A.C. component will be relatively large. It is desirable to filter the A.C. component from voltage applied to the dynodes by means of resistors 93 through 104 and capacitors 105 through 116. Since the A.C. components at points "s" and "r" are large, it is necessary that resistors 104 and 102 have large values of resistance and since the A.C. component at points "o" and "r" are relatively small, the resistance of resistors 93 and 94 may be relatively small. It can therefore be seen that voltage multiplier 12 is uniquely adaptable to a photomultiplier tube since at the photocathode end, the dynode current is small and it is possible to employ a large resistor in series with the voltage supply to filter the large A.C. component; whereas, at the anode end, where the dynodes draw large currents, the A.C. component may be effectively filtered by a small resistor. Consequently, over-all effective filtering is obtained and the voltage on each dynode remains relatively constant irrespective of load since the source impedance is small for dynodes drawing large currents and large for dynodes drawing small currents.

It should be particularly noted that the capacitance of capacitor 116 could be decreased to a value equivalent to the total series capacitance of capacitors 105 through 116 and then connected directly to ground so filtering of the large A.C. component on the photocathode end could be realized by means of resistor 104 and this ground connected capacitor. Likewise, capacitors 106 through 115 could be connected directly to ground provided the capacitance of each is decreased to a value corresponding with the remaining series capacitance. By utilizing a filter system of this type, the voltage across the filter capacitors would be much greater than the individual stage voltage and consequently capacitor failure would more readily occur. It can be seen that by employing the capacitors in series as shown in FIGURE 1 that effective capacitance of the capacitors at the photocathode end is realized, and yet, the voltage across each of these capacitors is limited to a relatively small value as determined by the maximum peak-to-peak voltage of the oscillator output.

It has been found by employing the above described filter system, with a ten volt photomultiplier output, the A.C. component superposed on this ten volt output is only about 50 millivolts peak-to-peak, whereas, when the filter network is not employed, the A.C. component is increased to approximately one-half volt peak-to-peak.

Capacitors 118 and 119 may be used to provide additional filtering and are dependent upon the particular photomultiplier employed. The values of these capacitors may be determined empirically; however, it is to be understood that they are not critical for effective operation of the present invention.

It should be particularly noted that power required by this scheme is virtually only that drawn by the dynodes and there is therefore no wasted power as is the case in resistance network devices. Since the power consumed is very small it is possible to employ a small B+ power supply and utilize an oscillator and control system as herein described. In addition, since linearity is poor in resistance network photomultiplier power supplies, to provide control it has been necessary to employ a high impedance divider across the power supply and parallel with the entire resistance network. Since linearity of the power supply of the present invention is highly stable under varying loads, voltage control is realized by sampling a single stage as will hereinafter be more completely described.

The current drawn by the photomultiplier from capacitors 67 through 78 is relatively small and effective control may be therefore prevented since electrical charge would remain on these capacitors particularly during low load operation. That is, if the hereinafter described control detected the over-all multiplication factor as being too large, the amplitude of the oscillator output signal

would be reduced. However, capacitors 67 through 78 would not rapidly follow this reduced voltage since the current drawn therefrom would be negligible. To provide rapid control, resistors 80 through 91 are provided to discharge capacitors 67 through 78 to ground. The values of resistors 80 through 91 are selected so the current discharged from each of capacitors 67 through 78 is uniform. This is accomplished by series connecting these resistors to ground so the effective resistance is large at the photocathode end and small at the anode end. This same uniform discharge rate could be accomplished by connecting each of resistors 81 through 91 directly to ground and increasing the value of each to correspond with the effective resistance of the series string. However, this latter method has the disadvantage of having the entire stage voltage across each resistor and consequently resistor failure would more readily occur.

The primary purpose of a photomultiplier control system is to maintain a constant over-all multiplication factor which is independent of dynode load or light energy input to the photocathode, and B+ voltage. As previously indicated, in prior systems this control has been accomplished by regulating the power supply by the voltage across a shunting resistor in parallel with the resistance network. Accurate voltage control in these prior systems has been very difficult to realize since it is inherently difficult to provide accurate voltage control of power supplies that have large current requirements. In addition, these prior systems have not compensated for voltage deviations due to variations of current drawn by the individual dynodes.

The present invention provides a unique voltage control system which corrects for both variations in supply voltage as well as variations in current drawn by the dynodes. Voltage control is realized by sensing the voltage of dynode 131 with respect to ground. It can be readily seen that when dynode 131 is not drawing current that this control voltage is the voltage on capacitor 67. Since the voltage output of oscillator 11, and therefore the voltage on capacitor 67, would, without the control system, vary with variations of B+ voltage, this voltage control is responsive to variations of B+ voltage. In addition, the voltage on dynode 131 will also reflect current drawn by this dynode because there is a resultant voltage drop across resistor 93. Since the voltage of each successive stage of voltage multiplier 12 is a consecutive integral multiple of the first stage, control of the first stage will of necessity result in control of the remaining stages.

In operation, when dynode 131 draws current, the voltage drop across resistor 93 causes an amplitude increase of the signal from oscillator 11, since the control system requires that the oscillator maintain the voltage constant on dynode 131. Due to the multiplication characteristics of voltage multiplier 12, the dynodes at the photocathode end of the photo-multiplier will have a greater voltage available per stage, and consequently a greater multiplication factor than the dynodes at the anode end. This is because the dynodes at the photocathode end draw considerably less current than those at the anode end with resultant smaller voltage drops across the filter resistors in series with the dynodes. The value of resistor 93 is selected so a nearly flat over-all gain factor is realized by the photomultiplier during all load conditions. That is, during large loads the potential difference between dynodes 122 and 123 may be 210 volts and the potential difference between dynodes 130 and 131 may be only 190 volts and during small loads may be 201 and 199 volts, respectively. In this manner the over-all photomultiplier gain is maintained at a nearly constant value irrespective of load. Obviously, if only a voltage and not a current responsive control were employed, the over-all multiplication factor would decrease with increased load since the potential difference between dynodes 122 and 123 would be about 200 volts whereas

the potential difference between dynodes 130 and 131 would be about 190 volts due to the large voltage drop across resistor 93. For purpose of illustration these above potential changes have been exaggerated and in practice are considerably less. Even without filter resistors 93 through 104, it is desirable to employ a current responsive control to maintain a constant multiplication factor since each stage of the D.C. voltage multiplier has a finite output resistance which can never be reduced to zero.

Control is accomplished by applying the potential of dynode 131 in series with thermistor 133 and zener diode 135 to the base of transistor 27. Thermistor 133, zener diode 135 and capacitor 137 and 138, which shunt zener diode 135, are interdependent and zener diode 135 is selected to bring about the particular value of photomultiplier gain desired. These components may be prepackaged for particular voltage characteristics and provided with plug-in connections 139-140 to realize ease of selection and assembly. The B+ supply is applied in series through resistors 143 and 144 to the base of transistor 27 and zener diode 146 is selected to have a breakdown voltage of a predetermined value which is less than the B+ supply, 11 volts, for example. Therefore, the current through zener diode 135 is regulated independent of the B+ voltage and the operating point of zener diode 135 is very accurately determined.

For purpose of description, it is assumed that zener diode 135 has a breakdown voltage of 200 volts. In addition, transistor 27 is selected to have a very large current gain and the base thereof draws very little current when conducting. Upon the application of B+ power, zener diode 135 offers infinite impedance and the base of transistor 27 will be driven positive and into a saturation state. Since transistor 27 is saturated, the emitter-collector impedance thereof is minimum and maximum B+ voltage is available to the bases of transistors 19 and 21, as shown by curves "f" and "h" of FIGURE 2A. As previously explained, oscillator 11 will then provide maximum voltage output. D.C. voltage multiplier 12 is very rapidly charged since it draws very little current and the dynodes very rapidly acquire their integer multiple potentials of 200 volts. When dynode 131 has a voltage very slightly greater than 200 volts, zener diode 135 rapidly starts conducting. When zener diode 135 conducts, the current from the base of transistor is shunted through zener diode 135, thermistor 133, resistors 93 and 80 and diodes 42 and 41 to ground. Since this shunting path provides a much smaller impedance than the path through transistors 27, 19 and 21 and resistor 147 to ground, the voltage at the base of transistor 27 very closely approaches ground when zener diode 135 becomes conducting. Therefore, since the base of transistor is driven to ground, the collector-emitter impedance thereof is rapidly increased thereby greatly reducing the current available to the bases of transistors 19 and 21, as shown by curves "f" and "h" of FIGURE 2B. In actual operation the peak-to-peak voltages shown in FIGURE 2B would approach zero when zener diode 135 conducts. If the voltage on dynode 131 then reduces very slightly below 200 volts, zener diode 135 becomes non-conducting and the potential applied to the base of transistor 27 increases thereby greatly reducing the collector-emitter impedance thereof and results in large current being applied to the bases of transistors 19 and 21 and thereby providing maximum voltage output from oscillator 11 and increasing the voltage on dynode 131 back to 200 volts. It should be particularly noted that since voltage multiplier 12 draws very little current and transistor 27 has a high base impedance and draws very little current, the voltage variation at the base of transistor 27 varies from only about .1 volt to about ground potential during normal operation. It can therefore be seen that the response rate of the control system is very rapid and maintains voltage multiplier 12 within extremely close tolerances as determined by

the selected breakdown voltage of zener diode 135. The above described operation is related to a 200 volt control which assumes that oscillator 11 provides at least a 200 peak-to-peak voltage output. Obviously if 200 volt control were necessary, the peak-to-peak voltage output of oscillator 11 would be selected to have a value considerably greater than 200 volts in order to realize rapid control. It has been found that an oscillator providing a maximum peak-to-peak voltage output of about 200 volts provides very satisfactory control for dynode-to-dynode voltages up to about 175 volts.

It is to be understood that voltage control from slightly greater than zero volts to many thousand volts may readily be obtained by the above described scheme and may be accomplished merely by selecting different oscillator parameters, zener diodes or employing several in series, B+ power supply, D.C. voltage multiplier parameters, etc., and still remain within the scope of this invention.

Capacitors 137 and 138 function as a bypass for the high frequency noise inherent in zener diode 135 and are selected to match the particular diode employed. In addition, the time constant of capacitors 137 and 138 and the resistance of thermistor 133 are selected so the overall feedback loop will operate stably at a variety of operating conditions and thereby obviate hunting.

Since the breakdown voltage characteristic of zener diode 135 varies directly with temperature, thermistor 133 may be provided in series therewith to compensate for this variation. Thermistors have a negative temperature coefficient and the resistance thereof therefore varies inversely with temperature. The characteristics of thermistor 133 are selected to inversely match the characteristics of zener diode 135 such that as the breakdown voltage across the zener diode increases with temperature, the resistance and corresponding voltage drop across thermistor 133 decreases by the same amount. To illustrate, if it is desired to maintain dynode 131 at 100 volts, the breakdown voltage of zener diode 135 may be selected at 97½ volts and the voltage drop across thermistor 133 at 2½ volts, both at room temperature. Therefore, when dynode 131 is at 100 volts, 97½ volts will appear at the anode of zener diode 135 and it will therefore start conducting. If the temperature would rise to about 35° C., the breakdown voltage of zener diode 135 would raise to about 98½ and the resistance of thermistor 133 would decrease so the voltage drop across the thermistor would be about 1½ volts. Therefore, zener diode 135 would again start conducting when dynode 131 was at 100 volts. In this manner the control system provides accurate voltage regulation independent of temperature variations. There are other relatively minor temperature coefficients in the power supply and oscillator and in practice, thermistor 133 is empirically selected to compensate for these as well as the temperature coefficient of zener diode 135.

The output of the above described system is taken from anode 151 of photomultiplier 13 which is applied to the input of amplifier 153 which provides a voltage output indicative of the rate of bombardment of photocathode 120. It is desirable that amplifier 153 have a large input impedance since the anode current is relatively small. This could be accomplished, for example, by employed cascaded emitter follower transistors in amplifier 153.

The following is a tabulation of the values of components employed in the present invention. It is to be understood these values are only exemplary and substantial departure therefrom may be made and still remain within the scope of the present invention. For example, when the power supply is employed to supply high voltage to a source other than a photomultiplier, it may be desirable to change various parameters considering such factors as load, voltage requirements, impedance characteristics, etc. Likewise, substantial de-

parture may be made when different photomultiplier voltages are required.

Components:

Values

16	20 ohms.
17	8 microfarads.
29-40	.01 microfarad.
67-78	.01 microfarad.
80-91	10 megohms.
93	10,000 ohms.
94	20,000 ohms.
95	30,000 ohms.
96	39,000 ohms.
97	51,000 ohms.
98	62,000 ohms.
99	68,000 ohms.
100	82,000 ohms.
101	91,000 ohms.
102	100,000 ohms.
103	110,000 ohms.
104	120,000 ohms.
105-116	.01 microfarad.
118-119	.01 microfarad.
133	10,000 ohms at room temperature.
135	100 volts.
137-138	.01 microfarad.
143	13,000 ohms.
144	43,000 ohms.
146	11 volts.
147	1,000 ohms.
B+	22-35 volts.

In view of the foregoing, it can be seen the present invention provides a small lightweight and highly reliable D.C. high voltage supply. In addition, it is uniquely adaptable for use in conjunction with a photomultiplier in that control is a function of B+ power, photomultiplier load, and temperature, and therefore maintains a constant over-all photomultiplier multiplication factor irrespective of variation of these conditions. Furthermore, reliability of the individual components is enhanced since the voltage across each component is maintained at a minimum.

It is to be understood in connection with this invention that the embodiment shown is only exemplary, and that various modifications can be made in construction and arrangement within the scope of the invention as defined in the appended claims.

What is claimed is:

1. The combination of a photomultiplier device and a power supply, said power supply comprising a diode-capacitor voltage multiplier network having a plurality of discrete D.C. voltage output stages and a low output impedance, each of said output stages being individually connected to separate dynodes of said photomultiplier device, whereby the total power required by said power supply is about the same as the total power supplied by said power supply to said dynodes.

2. The combination of a photomultiplier device and a power supply said power supply comprising a direct current source operatively connected to an oscillator the output of which is operatively connected to the input of a D.C. voltage supply, said D.C. voltage supply comprising a diode-capacitor voltage multiplier network having a plurality of discrete D.C. voltage output stages and a low output impedance, each of said output stages being individually connected to separate dynodes of said photomultiplier device, whereby the total power required by said power supply is about the same as the total power supplied by said power supply to said dynodes.

3. A power supply device comprising a direct current source operatively connected to the input of control means, the output of said control means operatively connected to the input of an oscillator, the output of said oscillator operatively connected to the input of a D.C. voltage supply, said D.C. voltage supply comprising a diode-capacitor voltage multiplier network having a plurality of discrete D.C. voltage output stages, said control means responsive to the voltage at one of said stages for controlling the output current from said control means to maintain the voltage on said stages at approximately constant values.

4. A power supply device comprising a direct current source connected to the collector and base of a transistor, the emitter of said transistor operatively connected to the input of an oscillator, the output of said oscillator operatively connected to the input of a voltage supply having a plurality of discrete D.C. voltage outputs, one of said discrete D.C. voltage outputs operatively connected to the anode of a zener diode, the output of said zener diode operatively connected to the base of said transistor, whereby the voltage at said one of said discrete D.C. voltage outputs is maintained at the breakdown voltage of said zener diode.

5. The combination of a photomultiplier device and a power supply, said power supply comprising a direct current source connected to the collector and base of a transistor, the emitter of said transistor operatively connected to the input of an oscillator, the output of said oscillator operatively connected to the input of a voltage supply having a plurality of consecutive stages having consecutive integral multiple D.C. voltage outputs, each of said consecutive stages operatively connected to consecutive dynodes of said photomultiplier device, a filter network including a plurality of resistors individually connected in series between each stage a respective dynode, one of said dynodes operatively connected to the anode of a zener diode, the output of said zener diode operatively connected to the base of said transistor, whereby the voltage on said dynodes are varied as a function of the load of said photomultiplier to maintain a constant over-all photomultiplier multiplication factor irrespective of load changes of said photomultiplier.

6. The combination of an electron discharge device and a power supply, said electron discharge device being of the electron multiplier type, having at least a plurality of dynodes with secondary electron emitting characteristics and an anode, output means connected to said anode, said power supply comprising a diode-capacitor voltage multiplier network having a plurality of discrete D.C. voltage output stages, each of said dynodes of said electron discharge device being individually connected to a separate output stage of said diode-capacitor voltage multiplier network of said power supply.

7. The combination of a photomultiplier device and a power supply, said power supply comprising a diode-capacitor voltage multiplier network having a plurality of discrete D.C. voltage output stages and a low output impedance, each of the dynodes of said photomultiplier device being individually connected to a separate output stage of said power supply, whereby the total power required by said power supply is about the same as the total power supplied by said power supply to said dynodes.

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