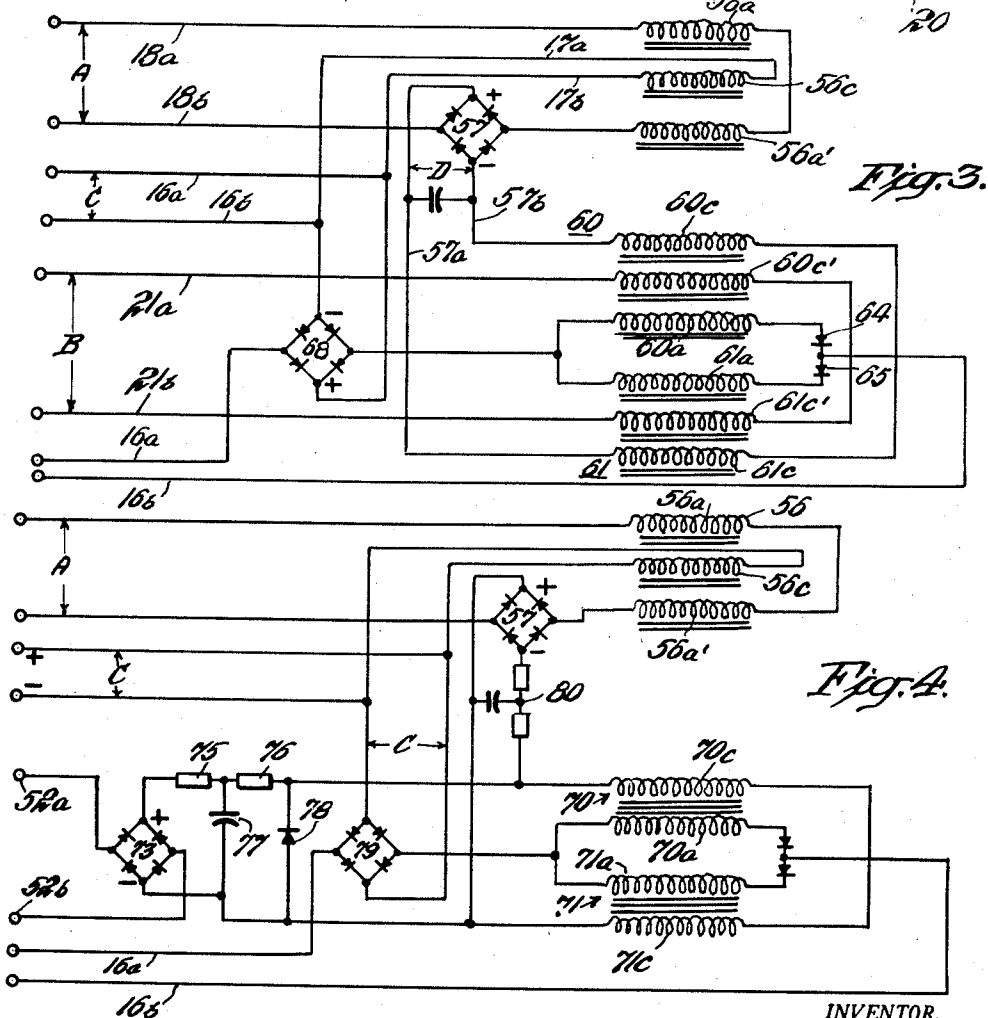
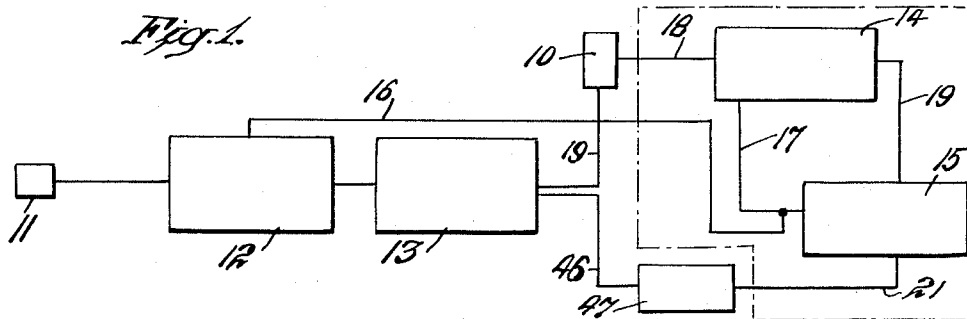


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DIMMER COMPENSATING CIRCUIT

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2 Sheets-Sheet 1



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2,933,649

DIMMER COMPENSATING CIRCUIT

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2 Sheets-Sheet 2

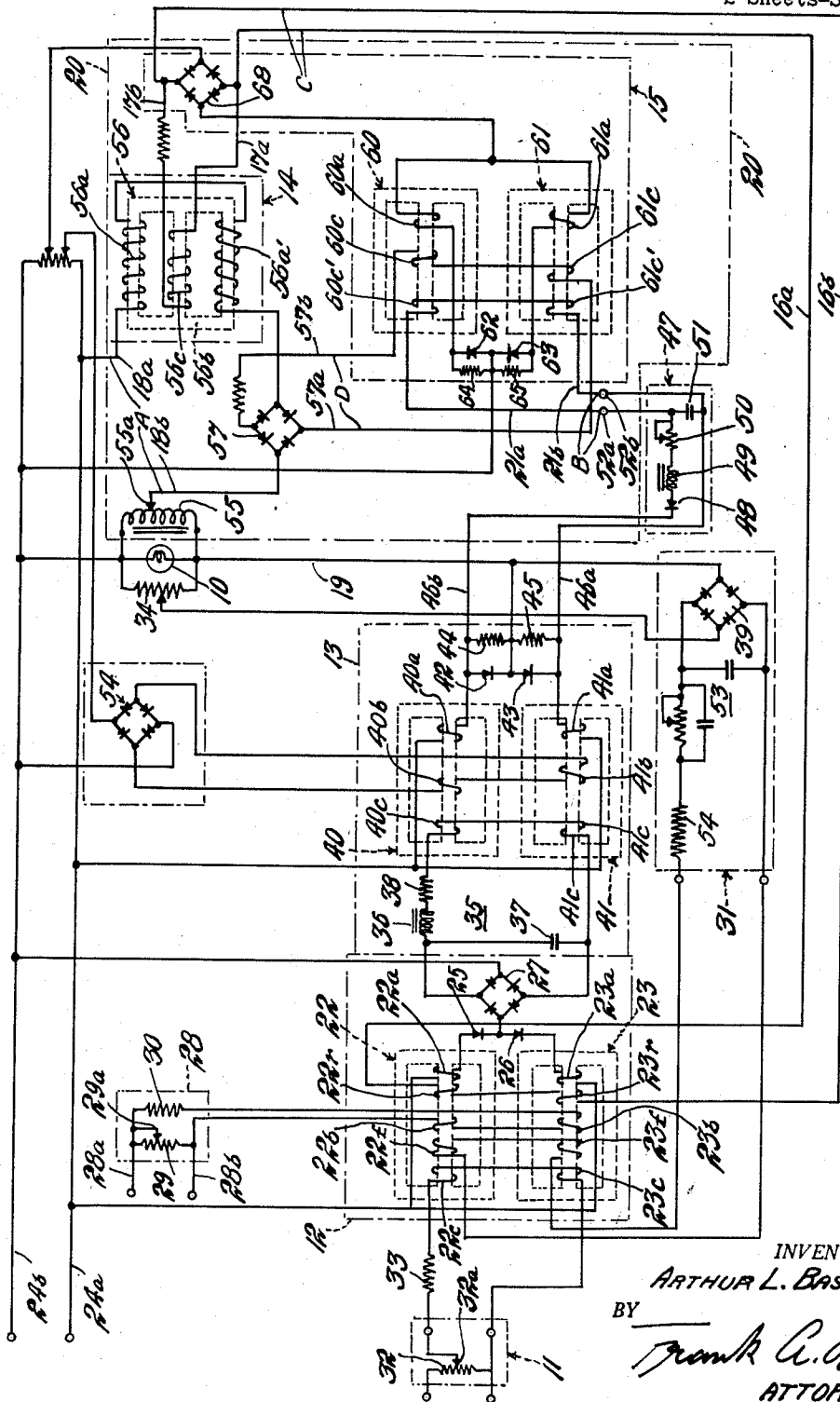


Fig. 2

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DIMMER COMPENSATING CIRCUIT

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The invention relates to variable output voltage circuits and apparatus and is directly particularly to the supplying of an output voltage over a range in a given predetermined relationship with a range of input control voltages irrespective of the value of output current at each voltage.

In electrical apparatus providing an output voltage the output voltage varies with the output current provided by the apparatus. It is often desirable to vary the output voltage over a range of values in response to a range of input control voltages with each output voltage corresponding to an input voltage and at each voltage to provide a range of currents depending on the load. The purpose of this invention is to provide compensating means to maintain each output voltage constant over the range of current so that each output voltage will correspond to a particular input voltage irrespective of the amount of current supplied at that particular output voltage.

This invention is particularly applicable to the remote control of a plurality of incandescent lamps. In the remote control of groups or banks of lamps the operating characteristics of the control apparatus change with loads of different wattage ratings. A given setting of the apparatus will produce different degrees of illumination of a single element depending on the total wattage of all elements. It is preferable that a given setting of the input control will cause the same output voltage to be impressed across each load unit irrespective of the number of elements so loaded.

An object of the invention is to provide an electrical apparatus for delivering a range of currents at each output voltage of a range of output voltages with the particular output voltage remaining constant over the range of currents.

Another object of the invention is to provide an electrical apparatus having a range of output voltages corresponding to a range of input control voltages irrespective of the current provided at each output voltage.

A further object of the invention is to provide an electrical apparatus for supplying a range of output voltages to a load in accordance with a range of input control voltages independent of the wattage of the load.

A still further object of the invention is to provide lamp illumination control apparatus in which the intensity of illumination of each lamp of a plurality of lamps corresponds with a given value of input control irrespective of the number or total number of lamps connected to the output of the apparatus.

Other and further objects of the invention will be apparent from the following detailed description taken in connection with the drawings in which:

Fig. 1 is a block diagram of the main components of the apparatus;

Fig. 2 is a diagrammatic view of the circuit in accordance with the block diagram of Fig. 1;

Fig. 3 is a schematic diagram of the divider circuit apparatus; and

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Fig. 4 is a schematic diagram of another embodiment of the divider circuit apparatus.

In this embodiment the load 10 may comprise one or more incandescent lamps of high wattage. The lamps may be used for lighting stages or other types of areas requiring a high degree of illumination that may be varied over a wide range. The purpose of this apparatus is to control this high wattage load by means of a small, low wattage control 11 such as a rheostat in the order of two watts. The magnetic amplifier stages 12 and 13 may have a capacity from 5–40 kilowatts depending upon the power requirements of the particular installation. The output of stage 13 is connected to the load 10 by line 19. The amplifier stage 12 controls the output of the second stage 13 and is in turn controlled by the control device 11. The control device 11 is adjusted through a range of voltages. Each voltage corresponds to a particular degree of illumination of each lamp of the load. This voltage is constant at each setting. The number of lamps or the total wattage of the load may be changed and the total load current for a particular setting may change but the illumination of each individual lamp will remain the same. In order to maintain the output voltage of stage 13 constant at a particular input voltage, a corrective signal is impressed on stage 12 which is proportional to the quotient resulting from the division of a signal proportional to voltage and a signal responsive to load current. This corrective signal is created by a divider type circuit or unit 20. The divider unit comprises a multiplication apparatus 14 and a subtracting and amplifying circuit 15.

The effect of the circuits 14 and 15 is to provide a signal approximately proportional to the division of the load voltage signal and the load current responsive signal. This quotient is fed back by line 16 to the stage 12 so that as the voltage drops, the amplification of stage 12 is increased. This increases the output voltage of stage 13 which compensates for the decrease in voltage, and thus the output voltage is maintained constant.

In Fig. 2 a detailed schematic diagram is shown of the dimming system. The stage 12 comprises a magnetic amplifier having two saturable reactors 22 and 23 with anode windings 22a and 23a connected to the power lines 24a and 24b with rectifiers 25 and 26 connected in series with a respective winding and an output rectifier 27 for providing a D.C. output current.

The bias windings 22b and 23b are provided with a direct current from the bias circuit 28 which is connected to a suitable direct current supply (not indicated) by lines 28a, 28b. The resistor 29 is connected across the lines 28a, 28b and has an adjustable contact 29a for setting the bias current in accordance with the magnetic amplifier characteristics desired. A resistor 30 is provided in series with the bias windings to limit the current to the windings to a predetermined maximum value.

The windings 22f and 23f are connected in series to the output of the feedback circuit 31 connected to the load. The feedback circuit 31 is connected to the rheostat 34 to provide a feedback signal of the proper value. The circuit 31 rectifies the alternating current by means of the full wave bridge rectifier 39 and provides a lead network for anti-hunt and filtering purposes by means of the elements 53 and resistor 54. The windings 22c and 23c are connected in series to the low wattage control 11. The control 11 comprises a potentiometer 32 connected across a low-voltage, direct-current supply in the order of 6 to 12 volts. The amount of voltage impressed across the windings 22c and 23c is determined by the adjustable contact 32a. This contact determines the degree of intensity of illumination of the lamps in the load 10. The higher the voltage across the windings 22c and 23c, the greater the degree of illumina-

tion will be made by the lamps 10. A resistor 33 is connected in series with the control windings 22c and 23c. The D.C. voltage impressed across the potentiometer 32 should preferably be very steady so that the lamps will not change in illumination at a given setting of the contact 32a.

The windings 22r and 23r are connected in series across the output of the divider circuit and particularly connected to the subtraction and amplification circuit 15. The output of the divider circuit corrects the amplification characteristics of stage 12 to compensate for the variations in the characteristics of stage 13 with different values of load. Thus, with a steady D.C. voltage impressed across potentiometer 32 and the correction provided by the windings 22r and 23r, the illumination of each lamp of the load 10 will correspond with a definite setting of the contact 32a, irrespective of the number of lamps in the load and the current drain on the stage 13.

The alternating output of stage 12 is converted by the rectifier 27 to a direct current and smoothed out by the filter 35. The filter 35 comprises a choke 36, a condenser 37 and a resistor 38 in series with the choke. The stage 13 comprises a magnetic amplifier having saturable reactors 40 and 41, each comprising a three-legged core. The output of filter 35 is connected across the control windings 40c and 41c of the reactors 40 and 41 respectively to impress thereon a direct control current for adjusting the output of the stage 13. The reactors are biased by the direct current supplied by the rectifier 79 connected to the supply lines. The anode windings 40a and 41a are connected in parallel between the A.C. power lines 24a and 24b, and have rectifiers 42 and 43 connected in series with the windings 40a and 41a respectively to pass direct current through each winding and provide an alternating current output from the stage 13. Connected in parallel across the rectifiers 42 and 43 are resistors 44 and 45 respectively. The input lines 46a and 46b are connected across the resistors 44 and 45 in series and carry a current to the filter network 47 which comprises a rectifier 48, a choke 49 and a variable resistor 50, all connected in a series. A condenser 51 is connected across the output thereof. The direct current output across the terminals 52a and 52b of the filter 47 provides a direct current that varies so that as the load current increases the direct current signal increases with the output load current of the power stage 13. The lines 20a and 20b are connected to the respective terminals 52a and 52b and impress the current on the subtraction circuit 15.

The variable reactor 55 may be connected in parallel or across the load 10 and has a contact 55a to tap a voltage therefrom proportional to the voltage across the load. The contact 55a is connected to the multiplying circuit 14, to impress thereon a current proportional to the load voltage. The circuit 14 comprises a saturable reactor 56 which has a three-legged core with the anode windings 56a and 56a', wound on the outer legs and a control winding 56c wound on the inner leg. The voltage that is impressed across the control windings 22r and 23r of stage 12 is impressed across the control winding 56c and the current therein determines the degree of saturation of the reactor 56. Thus, an alternating current is passed through the windings 56a and 56a' proportionally to the load voltage.

A rectifier 57 is connected between the contact 55a and the anode winding 56a' to provide to the circuit 15 a direct current proportionally to the load voltage.

The circuit 15 comprises two saturable reactors 60 and 61 with the windings 60a, 60c and 60c', wound on the central leg of one reactor and windings 61a, 61c and 61c' wound on the central leg of the other reactor. The control windings 60c' and 61c' are connected in series to the lines 21a and 21b to receive a direct current proportional to the load current supplied to the load 10,

and windings 60c and 61c are connected in series to the lines 57a and 57b to receive a direct current therefrom.

The anode windings 60a and 61a are connected in parallel to alternately receive current from the power lines 24a and 24b. Rectifiers 62 and 63 are connected in series with a respective winding to alternately pass direct current through the anode windings 60a to 61a. Resistors 64 and 65 are in parallel with a respective rectifier. Thus the reactors 60 and 61 operate as a magnetic amplifier. The output is connected to the rectifier 68 to rectify the output of the circuit 15 and provide a direct current over lines 17a, 17b to control winding 56c of the multiplying circuit 14 and over lines 16a, 16b to windings 22r and 23r of the stage 12.

In combining the signals in the multiplication circuit 14 and the subtraction and amplification circuit 15, it is of course understood that it is the fluxes produced by the currents of the signals passing through the respective windings that are being combined. These fluxes are determined by the turns of the windings and the amount of current passing through the windings. The electrical units used in the computations are ampere turns or flux densities and not the currents and the voltages of the signals impressed on the respective windings.

The operation of the divider circuit will be discussed in detail in connection with Fig. 3 of the drawings. The reference numerals in Fig. 3 identify the corresponding elements shown in Fig. 2. A voltage A proportional to the load voltage is impressed across lines 18a and 18b to the divider circuit to pass an alternating current proportional to the load voltage through the lines and windings 56a and 56a' to create a flux in the core 56b. The voltage B responsive to load current is impressed across lines 21a and 21b to the divider circuit to pass a current through the central winding 60c' and 61c' to create a flux in the respective cores. The output lines 16a and 16b of the divider circuit have a direct voltage C impressed thereacross which is proportional to the division of the voltage B by the voltage A. This voltage C is also impressed across the control windings 56c to create another flux in the core 56b. The fluxes are combined so that the output of the saturable reactor 56 of circuit 14 is equal to the product of voltage A and C which is an intermediate voltage D. The voltage D is impressed by lines 57a and 57b across the control windings 60c and 61c to create another flux in the respective cores. As previously stated, the voltage B impresses a current over lines 21a and 21b through the series windings 60c' and 61c'. The windings 60c and 60c' and 61c and 61c' are wound on their respective cores so that the fluxes created in windings 60c' and 61c' are subtractive from the fluxes created by the windings 60c and 61c respectively. The difference of these two fluxes is amplified by the reactors 60 and 61 and the output thereof is impressed across the lines 16a and 16b as voltage C. Thus by multiplying the rectified output signal of circuit 15 by the voltage A and then subtracting the product from the voltage B and amplifying this difference, the voltage C is obtained which is proportional to the quotient resulting from the division of voltage B by the voltage A. This quotient provides a voltage which is responsive to the variations of load voltage and current for different values of load that corrects the characteristics of the stage 13.

When the winding 40a is supplying the main current to the load 10, the current passes through the rectifier 42 to the load. Lines 46a and 46b are connected across the network of rectifiers 42, 43 and resistors 44, 45 to obtain a signal current to be supplied to the windings 60c' and 61c'. A path is provided for the current through the filter 47 to the terminal 52b through line 21b to the winding 61c' and thence to the winding 60c' in series therewith to the line 21a to the terminal 52a to the resistor 50 and the choke 49 of the filter 47, and then through the rectifier 48 to the line 46b. The main current supplied to the incandescent load does not increase

proportionally with increase in load voltage. At the low voltages, the current increases at a high rate and at the higher voltages the increase is substantially reduced. A dry disc selenium-type rectifier has a general opposite variation with respect to current and voltage. At low voltages the increase in current is very slight. As the voltage is increased, the current increases at a great rate. Therefore, the variation in increase in signal current through the windings 60c' and 61c' is inverse. The combination of effects provides a corrective signal in the cores 60 and 61 which varies with the main current. Thus, although the main current and main voltage do not vary linearly, the signals developed for providing a corrective voltage vary essentially linearly. Thus, the corrective signal produced by the divider circuit varies essentially linearly with the main voltage and produces a linear correction.

If a load 10 is supplied with current from stage 13 in which the main current varies linearly with the main voltage then the lines 46a and 46b may be connected across a resistor in the connecting lines to the load 10 or connected in any suitable fashion which would provide a voltage that would vary with the current. It is thus seen that various types of circuits may be used with corrective factors to compensate for non-linear variations between main current and main voltage. Also the divider circuit could be arranged to produce a corrective signal that does not vary linearly with the main voltage where it would be desirable to have a corrective relationship between the divider circuit 20 and the main voltage that is non-linear. This invention is not intended to be limited to any specific form of the divider circuit, but is readily adaptable to various types of desired embodiments.

A substantially continuous direct current is supplied to the control windings 60c' and 61c' and 60c and 61c. The circuit 47 smooths the current supplied to windings 60c' and 61c' and a circuit 80, shown in Fig. 4, may be connected between the rectifier 57 and the windings 70c and 71c. Thus, a substantially continuous flux is supplied to the reactors 60 and 61 to control the current passing through the anode windings. A substantially continuous current is supplied from the rectifier 68 to the control winding 56c to continuously supply a control flux to the reactor 56. The system remains at equilibrium and responds quickly to changes in the value of the output voltage and output current. The change in the system is initiated by the change in the output current or output voltage. These changes are reflected in the various windings.

Fig. 4 is a modification of the circuit illustrated in Fig. 3 and described hereinbefore.

In Fig. 3 the saturable reactors 60 and 61 each have two control windings 60c, 60c', and 61c, 61c'. The modified saturable reactors 70 and 71 of Fig. 4 each have a single control winding 70c and 71c, respectively. The control windings 70c and 71c are connected in series across a full wave bridge rectifier 73 which is connected across the terminals 52a, 52b. The current signal which varies with load current is rectified by the rectifier 73 and the direct current smoothed out by the filter 74 comprising resistors 75, 76 and condenser 77. A rectifier 78 is connected across the output of the filter to by-pass current. The direct current passes through the windings 70c, 71c. The direct current from the rectifier 57 in series with the multiplier windings 14 passes through the windings 70c and 71c in the opposite direction to the current from the rectifier 73. The currents flow in opposite directions in relation to one another so that the current in the windings 70c, 71c is the difference of those two currents or the difference between the current relating to the load current and the product of the current proportional to the load voltage and the amplified difference. The magnetic amplifier multiplies this difference by a high amplification factor. The multiplied difference is rec-

tified by the rectifier 68 and supplied to the windings 22a, 23a over lines 16a, 16b and to the control winding 56c.

As indicated hereinbefore the divider circuit may be utilized in the control of the output of various types of electrical power type apparatus and is not limited to the illumination control circuits. The circuit may be modified and adapted to different types of apparatus without departing from the invention as set forth in the appended claims.

I claim:

1. An illumination control apparatus comprising incandescent illuminating means, a power amplifier having an input control and an output providing a current and voltage for said incandescent illuminating means, a full wave selenium rectifier connected to the output to pass the output current through alternate halves of the rectifier, a first saturable reactor having a first ferromagnetic core with a first control winding coupled to said rectifier to receive an inverse current from the rectifier, a second control winding creating a flux in said core opposing said first control winding flux to produce a resultant differential flux in said core and a main winding for passing a signal responsive to the differential flux, a second saturable reactor having a second ferromagnetic core with a second main winding coupled to the output of said power amplifier to receive a voltage signal proportional to the output voltage, said second saturable reactor having a third control winding for controlling the current through said winding, rectifier means connecting said first main winding with said third control winding to pass a current proportional to the signal of said first main winding, second rectifier means in series with said second main winding, said second rectifier means coupled to said second control means to provide said second control means with an intermediate direct current signal responsive to the product of the current proportional to the signal of the first main winding and the voltage signal to subtractively combine the fluxes of said signals to produce an amplified differential signal proportional to the quotient of the output current and voltage of said power amplifier, and means for connecting the output of said second rectifier means to said power amplifier to vary the characteristics of said amplifier so that each output voltage of the amplifier corresponds to a particular setting of the input control irrespective of the output current supplied to the incandescent illuminating means.

2. An electrical system comprising means for supplying output voltage and current to a load, means for producing a first signal linearly responsive to changes in the output voltage, means for producing a second signal linearly responsive to changes in output current, means for multiplying the first signal by a corrective signal to produce an intermediate signal and means for subtractively combining the second signal and the intermediate signal to produce a corrective signal proportional to the quotient of the output voltage and current, means for impressing said corrective signal on said means for multiplying the first signal and the corrective signal, and means for impressing said corrective signal on the supply to maintain a given output voltage constant with variations in output current.

3. A control apparatus for providing a corrective signal proportional to the quotient of a first and second input signals comprising a first electrical means having a first input and a corrective input and an intermediate output, said first electrical means factorially combining signals impressed on said first input and said corrective input to produce an intermediate signal proportional to the resultant of the factorially combined input signal and corrective signal, a second electrical means having an intermediate input and a second input and a corrective output, said second electrical means differentially combining the intermediate signal and the second input signal to produce an output corrective signal proportional to the difference

of the intermediate signal and the second input signal across said corrective output, means for connecting said intermediate output of said first electrical means to the intermediate input of said second electrical means and means for impressing a first input signal on said first input and a second input signal on said second input to produce a corrective signal in the corrective output of said second electrical means proportional to the quotient of the first and second input signals on application of the first and second input signals to said respective electrical means.

4. A divider type apparatus for producing an output signal proportional to the quotient of a first input signal and a second input signal comprising a first saturable reactor having a ferromagnetic core with a first control winding for receiving a first input signal creating a controlling flux in said core, a second control winding for receiving an intermediate signal creating a flux in said core opposing the flux of said first control winding and a first main winding for passing a current to produce a corrective signal; a second saturable reactor having a second ferromagnetic core with a second main winding for receiving a second input signal and having a third control winding for controlling the current through said second main winding, means for connecting said third control winding to said first control winding to pass a current proportional to the corrective signal of said first main winding; rectifier means in series with said second main winding; said rectifier means coupled to said second control winding to provide an intermediate signal responsive to the product of the second input signal applied to the second main winding and the corrective signal passed by the first main winding to subtractively combine the fluxes of the intermediate signal and the first input signal to make the corrective signal proportional to the quotient of the first and second input signals.

5. An apparatus for supplying electric current and voltage over a range in a predetermined relationship comprising electric power means having an output supplying electric current and voltage over a range; a first electrical means having a first input coupled to the output of said electric power means to receive a voltage signal therefrom, a third input for receiving a corrective signal and an intermediate output; said first electrical means factorially combining the voltage signal and the corrective signal to produce an intermediate signal proportional to the resultant of the factorially combined voltage signal and corrective signal; a second electrical means having an intermediate input coupled to the intermediate output of said first electrical means for receiving the intermediate signal, a second input coupled to the output of said electric power means for receiving a current signal, and an output coupled to the corrective input of said first electrical means and coupled to the electric power means; said second electrical means having means to subtractively combine the intermediate signal and the current signal to produce in the output of said second electrical means the corrective signal proportional to the quotient of the supply current and voltage and apply to said corrective third input of said first electrical means and to said electric power means to vary the characteristics of said power means so that the supply voltage and current is varied over a range in a predetermined relationship.

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