Dec. 15, 1959 F. MICHAELS 2,917,696

ELECTRONIC REGULATING CIRCUITS PROVIDED WITH FEED-BACK OF OUTPUT TO INPUT

Filed April 10, 1953 2 Sheets-Sheet 1

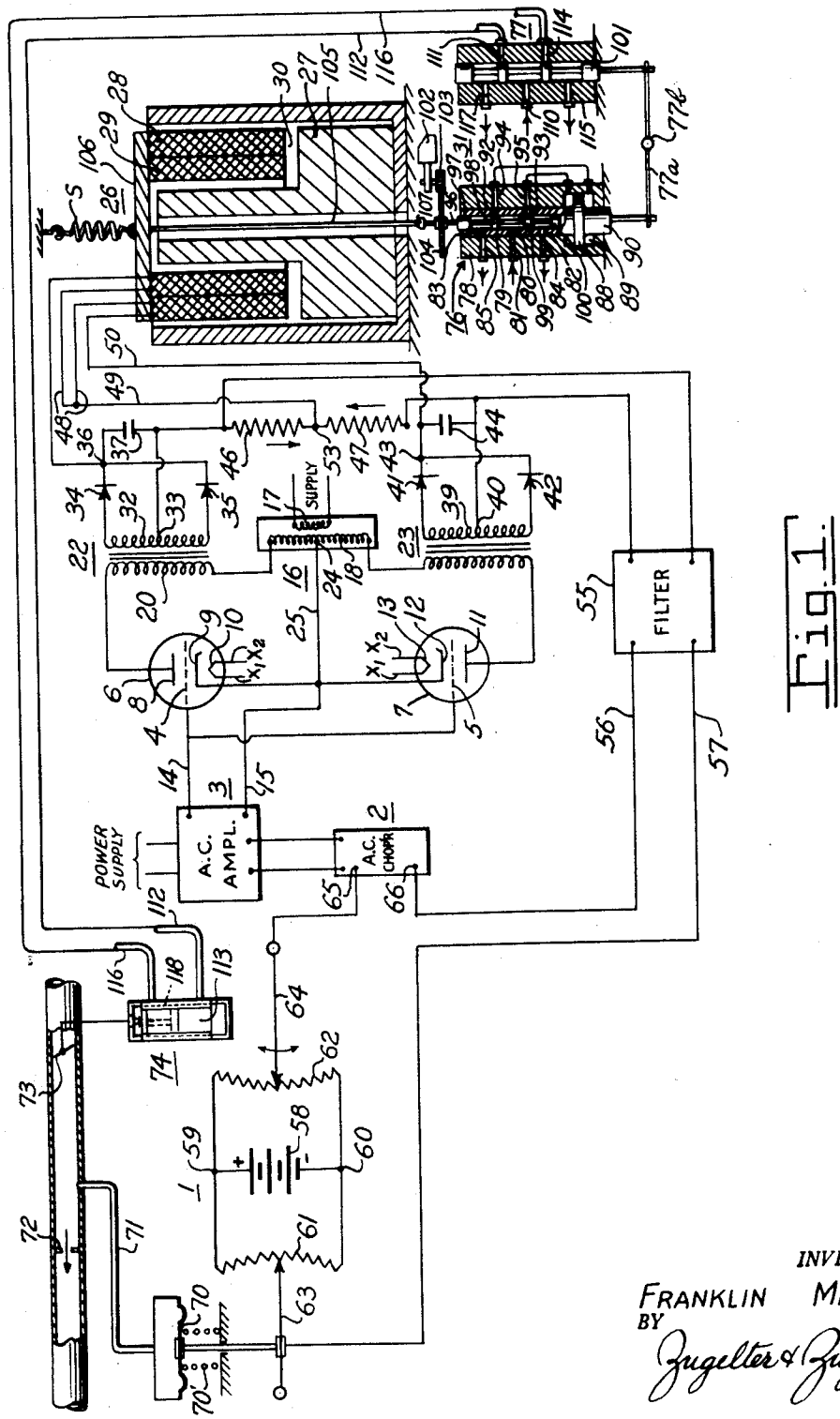


Fig. 1.

INVENTOR.
FRANKLIN MICHAELS
BY
Zugelter & Zugelter
Attys.

Dec. 15, 1959 F. MICHAELS 2,917,696

ELECTRONIC REGULATING CIRCUITS PROVIDED WITH FEED-BACK OF OUTPUT TO INPUT

Filed April 10, 1953 2 Sheets-Sheet 2

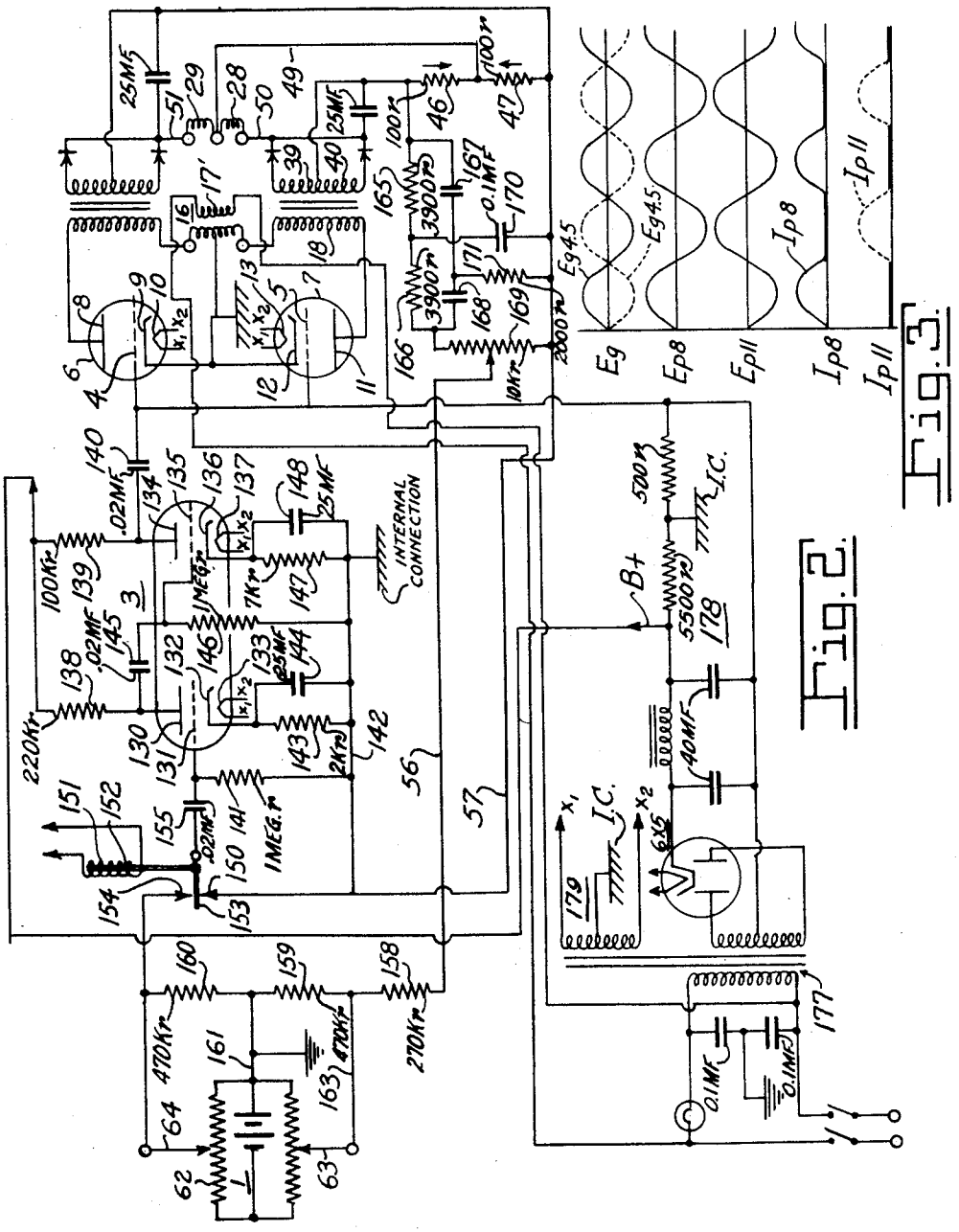


Fig. 3.

Fig. 2.

INVENTOR.
FRANKLIN MICHAELS
BY
Zugelter & Zugelter
Attys.

United States Patent Office 2,917,696
Patented Dec. 15, 1959

2,917,696

ELECTRONIC REGULATING CIRCUITS PROVIDED WITH FEED-BACK OF OUTPUT TO INPUT

Franklin Michaels, Orrville, Ohio, assignor to Hagan Chemicals & Controls, Inc., a corporation of Pennsylvania

Application April 10, 1953, Serial No. 347,950

6 Claims. (Cl. 321—2)

This invention relates to electrical regulating systems, and more particularly to electrical systems in which relatively small changes in direct current voltage or current are amplified, and the amplified output utilized to energize a regulating element having a neutral position.

An object of the invention is to provide a system of the type referred to above, in which the output is fed back to the input whereby the relation of the input and output is maintained at a substantially constant ratio, even though the output voltages tend to decrease with tube and recifier ageing, and the gain of the amplifier is thereby stabilized.

A further object of the invention is to provide a system of the above type with a feed-back circuit in which the output is connected in series with, but in opposed relation to, the input to the circuit to thereby stabilize the gain of the amplifier.

From the following description and accompanying drawings, the above and other objects of the invention will be apparent to those having ordinary skill in the art to which it pertains.

In the drawings:

Figure 1 is a more or less diagrammatic view of regulating apparatus, including an electric circuit provided with a feed-back of the output into the input and arranged and constructed in accordance with a form of the invention;

Fig. 2 is a more or less diagrammatic view of the circuit of Fig. 1, in which the components thereof are illustrated in greater detail; and

Fig. 3 is a view showing the voltage and current relations in a stage of amplification in Figs. 1 and 2.

The tube types and the values of impedance, both capacitive and resistive, for the circuit illustrated in Figures 1 and 2 may be as shown in the drawings.

In Fig. 1 of the drawings is illustrated a circuit having a source 1 of input voltage or current that varies in magnitude and sign with a variable condition to be regulated. The voltage from source 1 is passed through a chopper 2 to an A.C. amplifier 3. The amplified output voltage of the amplifier 3 is supplied to the control grids 4 and 5 of tubes 6 and 7, respectively. Tube 6 is provided with a plate 8, a heated cathode 9 and a heater 10. Tube 7 is provided with a plate 11, a heated cathode 12 and a heater 13. Grids 4 and 5 are connected to output conductor 14 of amplifier 3, and the heated cathodes 9 and 12 of tubes 6 and 7 are connected to output conductor 15 of amplifier 3. Operating voltage for the plates 8 and 11 of tubes 6 and 7 is supplied by a supply transformer 16, having a primary winding 17 and a secondary winding 18. The opposite terminals of winding 18 are connected to plates 8 and 11, respectively, through primary windings 20 and 21, respectively, of transformers 22 and 23. Transformer winding 18 has a mid tap 24, which is connected by a conductor 25 to the heated cathodes 9 and 12.

Curve $Eg4$, 5 in full lines shows the grid voltage for the condition when terminal 65 is, say, more positive than terminal 66; and the curve $Eg4$, 5 in dotted lines the grid

voltage when terminal 66 is more positive than terminal 65. The amplitude of the grid voltage curve $Eg4$, 5 is proportional to the voltage between terminals 65 and 66, and its phase is determined by the polarity of the voltage between these terminals.

Graphs EP_8 and EP_{11} show the phase relationships of the voltages applied to plates 8 and 11, and graphs IP_8 and IP_{11} represent the plate currents passed by plates 8 and 11 and their phase relationships. In graph IP_8 the solid and dotted lines represent the current passed by plate 8 when the grid voltage $Eg4$, 5 has the phase relationship to EP_8 indicated by the solid and dotted lines $Eg4$, 5, respectively. The current passed by plate 11 under corresponding conditions is represented by the solid and dotted lines, respectively, of the graph IP_{11}.

The output of transformers 22 and 23 is rectified and supplied, for example, to an elecromagnetic control element 26. The particular control element 26 illustrated includes a magnetic core 27 having a pair of coil windings 28 and 29, movable in the air gap 30 of the core, and a pilot valve mechanism 31 operated by the coil windings. The particular control element 26 has a neutral position and two maximum on positions—one on either side of neutral—as will be explained infra. The control element has many intermediate control positions between neutral and the maximum on positions. Coil windings 28 and 29 are normally suspended in a neutral position by a spring S.

The transformer 22 includes a secondary winding 32 having a mid tap 33. The terminals of winding 32 are connected through rectifiers 34 and 35, which can be of the dry area type, such as selenium, to a junction point 36. The mid tap 33 is connected to the junction point 36 through a condenser 37. That arrangement provides full wave rectification of the output voltages of windings 32 and 33.

Transformer 23 includes a secondary winding 39 having a mid tap 40. The terminals of winding 39 are connected through rectifiers 41 and 42 to a junction point 43. The mid tap of winding 39 is connected to the junction point 43 through a condenser 44. Series-connected voltage drop resistors 46 and 47 are connected to mid tap 33 of transformer 32 and to mid tap 40 of transformer 23.

One terminal of each coil 28 and 29 is connected together by a common connection 48 and a conductor 49 to the mid point between resistors 46 and 47. Terminal 50 of coil winding 28 is connected to junction point 43, and terminal 51 of coil winding 29 is connected to junction point 36.

The windings 28 and 29 are so connected that when current flows in one of them, or more current flows in one than the other, the two windings move upwardly; and when current flows in the other, or more current flows in it than in the other, the windings move downwardly, the force urging these windings upwardly or downwardly being a function of the net effect of the currents in them.

With the circuit arrangements as above described, it will be apparent that if the voltage between junction point 53 and junction point 36, and the voltage between junction point 53 and junction point 43 are equal, coil windings 28 and 29 will be equally energized in opposed relation and the coil windings will assume a neutral position. If the voltage between points 53 and 36 is higher than the voltage between points 43 and 53, winding 29 will be energized more than winding 28 and, assuming that the current thus produced in winding 29 causes the coils to move upwardly out of the air gap, the windings 28 and 29 will move upwardly. If the voltage between points 53 and 43 is higher than the voltage between points 53 and 36, winding 28 is energized more than winding 29 and, assuming that the current in winding 28 is in such direction as to cause the windings to move

downwardly into the air gap 30, the windings will move downwardly. Thus the pilot valve mechanism 31 will either be in a neutral position, or towards one or the other of its "on" positions. The valve may be in either full "on" position or in one of many positions between neutral and a full "on" position.

In order to stabilize the gain of the amplifier to compensate for ageing of tubes and rectifiers so that the ratio of output to the input of the amplifier may remain substantially constant for long periods of time, a voltage proportional to the net output current is fed back to, in series with, but in opposed relation to, the voltage supplied by source 1 to the A.C. chopper 2. Thus, the feed-back voltage may at times oppose and at others add to the thermocouple voltage depending upon the polarity of the feedback voltage with respect to the polarity of the thermocouple voltage or the voltage of supply source 1 which is fed to the chopper 2.

It will be seen from Fig. 3 that the tubes 6 and 7 both pass current at all times in varying amounts, and that, therefore, both sets of rectifiers 34, 35 and 41, 42 will pass current at all times. A voltage proportional to the algebraic sum of these two currents appears across resistors 46 and 47; this voltage is proportional to the output of the amplifier, and is the feed-back voltage. This feed-back voltage is passed through filter 55, and then connected in series with the input to the A.C. chopper 2 by conductors 56 and 57, as shown.

If the circuit, including tubes 6 and 7, is initially so adjusted that the output has, for example, a gain of 10 volts on an input of one volt to amplifier 3, the feed-back automatically adjusts the net input so that the gain ratio of 10 to 1, as given by this example, is maintained even though, because of ageing of tubes 6 and 7, or of the rectifiers 34, 35, 41 and 42, the output would decrease if it were not for the adjustment in the input voltage by the feed-back.

By providing a feed-back connection to the input to chopper 2, as above described, the gain of the amplifier stabilized. Consequently, any device which receives that output, whether it is a meter or the regulating element 26, is caused to function accurately and precisely as the ageing factor of the tubes and rectifiers is neutralized.

The variable voltage source 1 comprises a Wheatstone bridge having a source of direct current 58, such as a battery, connected to the input terminals 59 and 60 of the bridge. The bridge includes the resistors 61 and 62, the opposite ends of which are connected by a slide wire contact member 63 to conductor 57, and resistor 62 is connected by a slide wire contact member 64 to the A.C. chopper 2. As shown, contact member 64 is connected to terminal 65 of the chopper 2, while conductor 56 from the filter is connected to terminal 66 of the chopper.

The output voltage of the Wheatstone bridge may be varied by changing the position of slide contact member 63 along the bridge arm 61. Slide contact member 64 may be adjusted to predetermine the control point of the bridge. If slide contact member 63 is to be positioned in accordance with a variable condition to be measured or regulated, it may be actuated by a device responsive to that condition. If, for example, it is desired to measure and/or regulate the pressure in a conduit or pipe line 68 through which a fluid or gas flows, contact member 63 may be actuated by a pressure-responsive means 69 having a diaphragm 70 to which pressure is communicated by a pipe 71 from conduit 68. Diaphragm 70 works against a compression spring 70' so that every position to which the diaphragm is deflected will correspond to a definite value of pressure. Should it be desired to maintain the pressure of the fluid or gas constant at a particular point in the pipe line, an orifice 72 may be provided in the pipe line downstream of the point where pipe 71 is connected into pipe 68. To maintain the pressure constant at that point, a damper or valve 73 may be provided upstream of the point to which pipe 71 is connected into pipe 68, and actuated automatically by a regulator 74 that is controlled by the pilot valve mechanism 31. The control point of the regulating apparatus is adjusted or fixed by the position of slide contact 64. By adjusting contact member 64, the pressure to be maintained in pipe 68 may be preset.

The mode of operation of device 69 and regulator 74, with respect to the contact arm 63, is such as to move arm 63 in such a direction that the output of the bridge 1 will assume, with the feed-back, values that will correspond to that required to maintain the pressure constant at the selected point in pipe 68.

The particular pilot valve mechanism illustrated in the drawings comprises a pilot valve-controlled positioner 76 and a pilot valve 77 actuated by the positioner through a lever 77*a*. The positioner 76 comprises a body 78, having therein a sleeve 79 provided with an inlet port 80 disposed to register with a pressure supply port 81 in the body. Sleeve 79 includes exhaust ports 82 and 83 disposed to register with exhaust ports 84 and 85, respectively. Sleeve 79 is provided at one end with a piston 88 that works in a cylinder 89 in the lower end of body 78. The piston has a stub rod 90 that projects outwardly of the body 78 and is operatively connected to lever 77*a* which is pivoted at 77*b*.

Sleeve 79 is provided with outlet ports 92 and 93 disposed to register with ports 94 and 95, respectively, in body 78, that lead to cylinder 89 at the bottom and top, respectively, of piston 88. The pilot-controlled positioner also includes a valve stem 96 having lands 97, 98, 99 and 100. Lands 97 and 100 seal the opposite ends of the bore of sleeve 79, while lands 98 and 99 are located or positioned to control sleeve ports 92 and 93. When valve stem 96 is raised to a position where inlet port 81 communicates with sleeve port 92 and sleeve port 93 registers with drain port 84, fluid, such as oil, will flow from the supply port 81 through sleeve port 82 and outlet port 94 to the space below piston 88. Therefore, the piston 88 and its sleeve 79 will move upwardly to a position where both ports 92 and 93 are closed, and the piston comes to rest. If the valve stem 96 is moved downwardly, the opposite action takes place, and fluid from the supply source is delivered to the space at the top of piston 88, causing the piston and its sleeve to move downwardly, thereby closing the ports to the cylinder. It will be understood from the arrangements of ports above described that, when fluid is supplied to one side of piston 88, fluid is exhausted from the other side thereof.

Movement of lever 77*a* by piston 88 is utilized to actuate the valve stem 101 of pilot valve 77.

The valve stem 96 is actuated upwardly or downwardly by coils 28 and 29 of device 26. In order that frictional resistance to movement of stem 96 may be reduced to a minimum and movement of the valve stem thereby made easy and substantially unaffected by friction, the valve stem is spun in its bore by means of a motor 102, such as an electric motor, having a pinion 103 that meshes with a gear 104 secured to the valve stem. The valve stem is suspended from a rod 105 secured to a plate 106, secured to the upper ends of coil windings 27 and 28. In order that valve stem 96 may be rotated, it is secured to rod 105 by means of a thrust bearing 107.

When pilot valve 101 is moved from neutral position, the position shown in the drawings, to a position above neutral, fluid, such as oil, is supplied from a supply port 110 to an outlet port 111 and thence through a pipe 112 to the lower end of a cylinder 113 of regulator 74. At the same time, outlet port 114 of valve 77 is connected to a drain port 115 of a valve so that fluid, such as oil, may be discharged from the upper end of cylinder 113 through a pipe 116, port 114 and outlet port 115. If valve stem 101 is moved downwardly, the motive fluid passes from supply port 110 to port 114, pipe 116 to the upper end of cylinder 113, motive fluid being discharged from the lower end thereof through pipe 112 and ports 111 and

117. Motive fluid supplied to the upper end of cylinder 113 causes a piston 118 therein to move downwardly, whereby valve or damper 73 is moved towards closed position. When fluid is admitted to the lower end of the cylinder 113, the piston moves upwardly, thereby moving valve or damper 73 towards open position.

If it be assumed in the arrangement shown in Fig. 1, that the pressure at the point at which pipe 71 is connected to the interior of pipe 68 is at the predetermined control point value and slide contact arm 63 is in the position indicated, pilot valve positioner 76 and pilot valve 77 will be in neutral or in a steady state position. If, now, the pressure decreases in the pipe line at the location indicated, contact arm 63 is moved upwardly, thereby unbalancing the bridge, so that the voltage supplied to the A.C. chopper 2 becomes more positive. This increment of voltage is repeatedly interrupted by chopper 2 to provide an alternating current input to the A.C. amplifier 3. If the relative outputs of tubes 6 and 7 are such that there is a higher voltage on coil 28 than on coil 29, valve stem 96 moves downwardly, piston 88 moves downwardly, and pilot valve 101 is moved upwardly, whereby fluid is supplied to pipe 116 leading to the bottom of piston 118 in cylinder 113. Regulator 74 will then respond and commence to move damper 73 towards a more open position. When the relative output of tubes 6 and 7 is such as to energize coil 28, the voltage across the outside terminals of resistors 46 and 47, a feed-back voltage is delivered to A.C. chopper 2 which opposes the voltage supplied by the bridge to the chopper. If the pressure at the point where pipe 71 is connected into pipe 68 does not come to a steady state at the desired control point, diaphragm 70 will again move slide contact member 63 to unbalance the bridge and effect further energization of coil-winding 28, whereupon the pilot valve mechanism is reactuated in the manner above described, and damper 73 is moved further toward open position. This operation will continue until the pressure in pipe line 68 is brought to a steady value at the control point.

If the pressure in the pipe 68 increases from the control point value, slide contact member 63 is moved downwardly, whereby the voltage supplied to the A.C. chopper is changed in polarity, with the result that the relative outputs of tubes 6 and 7 change to establish a voltage across points 43 and 36 that will energize coil winding 29 and cause the same to move downwardly, thereby reversing the operation of the pilot valve mechanism 30 and the pilot valve 77, and causing motive fluid to be admitted to the upper end of cylinder 113. When motive fluid is supplied to the upper end of cylinder 113, piston 118 moves downwardly, thereby actuating the damper 73 towards a more closed position and decreasing the pressure in pipe 68 to the value to be maintained. In this instance, the polarity of the feed-back voltage derived from the opposite terminals of resistors 46 and 47 is reversed, which tends to decrease the input voltage to the A.C. amplifier.

The details of the circuit illustrated in Fig. 1 are shown in greater detail in Fig. 2.

Parts or elements of the circuit illustrated in Fig. 2 that correspond with parts and elements described in connection with Fig. 1 are identified by similar reference characters. Values of resistance, capacity and voltage suitable for the circuit are indicated in Fig. 2 for purposes of illustration and example. The symbols "K," "Ω," and MF signify "1000" ohms, ohms and microfarads, respectively.

The amplifier 3 may be a double tube or triode of the "6SL7-GT" type. One triode comprises a plate 130, a control grid 131, a heated cathode 132 and a heater 133. The other triode part of the tube comprises a plate 134, a grid 135, a heated cathode 136 and a heater 137. Plates 130 and 134 are connected in parallel to the B+ side of the power supply through resistors 138 and 139, respectively. Plate 134 is connected to control grid 4 of tube 6 through a condenser 140. Grid 131 is connected through a resistor 141 to a conductor 142. Cathode 132 is connected to conductor 142 by a resistor 143 and a condenser 144 in parallel with the resistor 143. Plate 130 is connected to conductor 142 through a condenser 145 and a resistor 146, in series. Control grid 135 is connected between condenser 145 and load resistor 146. Cathode 136 is connected to conductor 142 by a resistor 147 and a condenser 148, connected in parallel therewith.

Conductor 142 is connected to feed-back conductor 57 and to a terminal or contact member 150 of chopper 2. Chopper 2, as schematically illustrated, comprises a winding 151 and armature 152 actuated thereby, and a contact or switch member 153 actuated by the armature. Contact member 153 vibrates between contact member 150 and a contact member 154. Contact member 154 is connected to slide wire contact member 64 of the Wheatstone bridge 1.

Winding 151 of chopper 2 is supplied with a voltage that is in synchronism with a voltage across transformer winding 17 of transformer 16. As the contact member 153 vibrates between contact members 150 and 154, the voltage output of the Wheatstone bridge 1 is interrupted at the frequency of operation of the chopper, this interrupted voltage amplified by the twin triode amplifier 3. As shown, the vibrating contact member 153 is connected through a condenser 155 to the junction point of resistor 141 and grid 131.

Feed-back conductor 56 is connected to the Wheatstone bridge and contact member 154 of the chopper through series-connected resistors 158, 159 and 160. The junction point between resistors 159 and 160 is connected by a conductor 161 to the positive terminal of the battery of the Wheatstone bridge and to the ground at 162. The junction point between resistors 158 and 159 is connected by conductor 163 to slide wire contact member 63.

Filter 55, as shown, is connected across voltage resistors 46, 47, and comprises series parallel-connected resistors and condensers 165, 166 and 167 and 168, respectively. These series parallel-connected resistors and condensers are, in turn, connected in series with a resistor 169 to a feed-back conductor 57. A condenser 170 is also connected to the junction point of resistors 165 and 166 and feed-back conductor 57, and a resistor 171 is connected between the junction points of condensers 167 and 168 to feed-back conductor 57.

The power supply for the amplifier 3 and tubes 6 and 7 is derived from a power pack 175 of conventional construction. It includes a full wave rectifier 176, a power supply transformer 177 and the output filter circuit 178, from which the connection to the amplifier 3 is made. The power pack also includes a low voltage transformer winding 179 for supplying heating current to the heaters of amplifier 3 and tubes 6 and 7.

In Fig. 2, ground connections are identified by the conventional symbol for ground connection as, for example, at 162. Internal connections for the circuit are indicated by the legends I.C.

From the foregoing description and drawings, it will be apparent that the system is responsive to a source of variable current or voltage of small magnitude, which is converted into an interrupted current of predetermined or desired frequency, and amplified. The amplified output is impressed on tubes which function to develop output voltages that vary in sense and magnitude with the sense and magnitude of the small input current or voltage. The circuit includes a feed-back from the final output, which is connected in series with the input to render the gain of the amplifier stable.

Having thus described the invention, it will be apparent to those skilled in this art that various modifications or changes may be made, not departing from the spirit or the scope of the invention. Therefore, what is claimed as new and desired to be secured by Letters Patent is:

1. A regulating system comprising means for develop-

ing a D.C. of voltage of low magnitude that varies with a condition to be controlled, a chopper for converting said D.C. voltage to A.C. voltage of predetermined frequency, a twin tube amplifier responsive to said chopper voltage as the input thereto and developing an A.C. output voltage, a pair of grid controlled demodulator tubes, each tube having in its plate circuit a transformer having input and output windings, each of said latter windings having a mid-tap terminal, an A.C. voltage supply transformer having its output winding in circuit with the input windings of the plate circuit transformers, the grids of said demodulator tubes being connected to and energized by said amplifier output voltage, full wave rectifier means for each of the output windings of said plate circuit transformers, a load impedance having a neutral point and opposed terminals, the latter being connected to the respective mid-tap terminals of said output windings of the plate circuit transformers, means connecting the terminals of said impedance in series with said D.C. voltage input means for said amplifier to provide feed back voltage varying with the magnitude and the polarity of the voltage difference appearing at said impedance terminals, and regulating means having input elements responsive to the respective voltages existing between the neutral point of said impedance and said mid-tap terminals of said plate circuit output transformer windings.

2. A regulating system comprising means for developing a D.C. voltage of low magnitude that varies with a condition to be controlled, a chopper for converting said D.C. voltage to A.C. voltage of predetermined frequency, a twin tube amplifier responsive to said chopper voltage as the input thereto and developing an A.C. output voltage, a pair of grid controlled demodulator tubes, each tube having in its plate circuit a transformer having input and output windings, each of said latter windings having a mid-tap terminal, an A.C. voltage supply transformer having its output winding in circuit with the input windings of the plate circuit transformers, the grids of said demodulator tubes being connected to and energized by said amplifier output voltage, full wave rectifier means for each of the output windings of said plate circuit transformers, a load impedance having a neutral point and opposed terminals, the latter being connected to the respective mid-tap terminals of said output windings of the plate circuit transformers, means connecting the terminals of said impedance in series with said D.C. voltage input means for said amplifier to provide feed back voltage varying with the magnitude and the polarity of the voltage difference appearing at said impedance terminals, and control means actuated by said respective demodulator tube output voltages.

3. A system as in claim 1 in which the output winding of the supply transformer is connected in series with the input windings of the plate circuit transformers.

4. A regulating system comprising means for developing a D.C. voltage of low magnitude that varies with a condition to be controlled, a chopper for converting said D.C. voltage to A.C. voltage of predetermined frequency, a twin tube amplifier responsive to said chopper voltage as the input thereto and developing an A.C. output voltage, a pair of grid controlled demodulator tubes, each tube having in its plate circuit a transformer having input and output windings, each of said latter windings having a mid-tap terminal, an A.C. voltage supply transformer having its output winding in circuit with the input windings of the plate circuit transformers, the grids of said demodulator tubes being connected to and energized by said amplifier output voltage, full wave rectifier means for each of the output windings of said plate circuit transformers, a load impedance having a neutral point and opposed terminals, the latter being connected to the respective mid-tap terminals of said output windings of the plate circuit transformers, means connecting the terminals of said impedance in series with said D.C. voltage input means for said amplifier to provide feed back voltage varying with the magnitude and the polarity of the voltage difference appearing at said impedance terminals, and means energized by and actuated in accordance with the output voltages of said demodulator tubes.

5. In a regulating system the combination of means for developing a unidirectional voltage varying in magnitude and polarity with a variable condition to be controlled, means for converting such voltage into two amplified and opposing alternating current voltages, said means including a pair of vacuum tubes each having anode, cathode and control electrodes, the cathodes being coupled in parallel to the unidirectional voltage developing means, means for applying an A.C. voltage to the anodes of said tubes, means coupled to said anodes for rectifying and differentially combining the outputs of said tubes, said means including an impedance having two end terminals and an intermediate terminal spaced from said end terminals, means for connecting said spaced terminals in series with said varying source of unidirectional voltage to provide a feed back voltage that varies with the polarity of and the voltage difference between said spaced impedance terminals, and a regulating device having input elements responsive to the output voltages of said tubes.

6. In a regulating system the combination of means for developing a unidirectional voltage varying in magnitude and polarity with a condition to be controlled, means for converting said unidirectional voltage to A.C. voltage, amplifier means for amplifying said A.C. voltage and developing an output signal voltage, means responsive to said output signal voltage for developing two opposing alternating current voltages, said output signal responsive means including a pair of vacuum tubes each having anode, cathode and control electrodes, the cathodes being coupled in parallel to the unidirectional voltage developing means, means for applying an A.C. supply voltage to the anodes of said tubes, means coupled to said anodes for rectifying and differentially combining the outputs of said tubes, said means including an impedance having two end terminals and an intermediate terminal spaced from the end terminals, means connecting said end terminals in circuit with said unidirectional voltage developing means so as to be in series with the voltage thereof to provide a feed back voltage that is proportional to the difference between the voltages at said end terminals and varying in polarity therewith, and a regulating means having input elements responsive to the output voltages of said tubes.

References Cited in the file of this patent

UNITED STATES PATENTS

2,154,375	Chambers	Apr. 11, 1939
2,177,556	Walker	Oct. 24, 1939
2,349,685	Trucksess	May 23, 1944
2,398,421	Frische	Apr. 16, 1946
2,429,466	Jones	Oct. 21, 1947
2,446,563	Upton	Aug. 10, 1948
2,503,880	Mah	Apr. 11, 1950
2,622,192	Tarpley	Dec. 16, 1952
2,685,000	Vance	July 27, 1954
2,694,114	Kalfaian	Nov. 9, 1954
2,737,547	Deming	Mar. 6, 1956
2,798,905	Graham	July 9, 1957