

July 8, 1947.

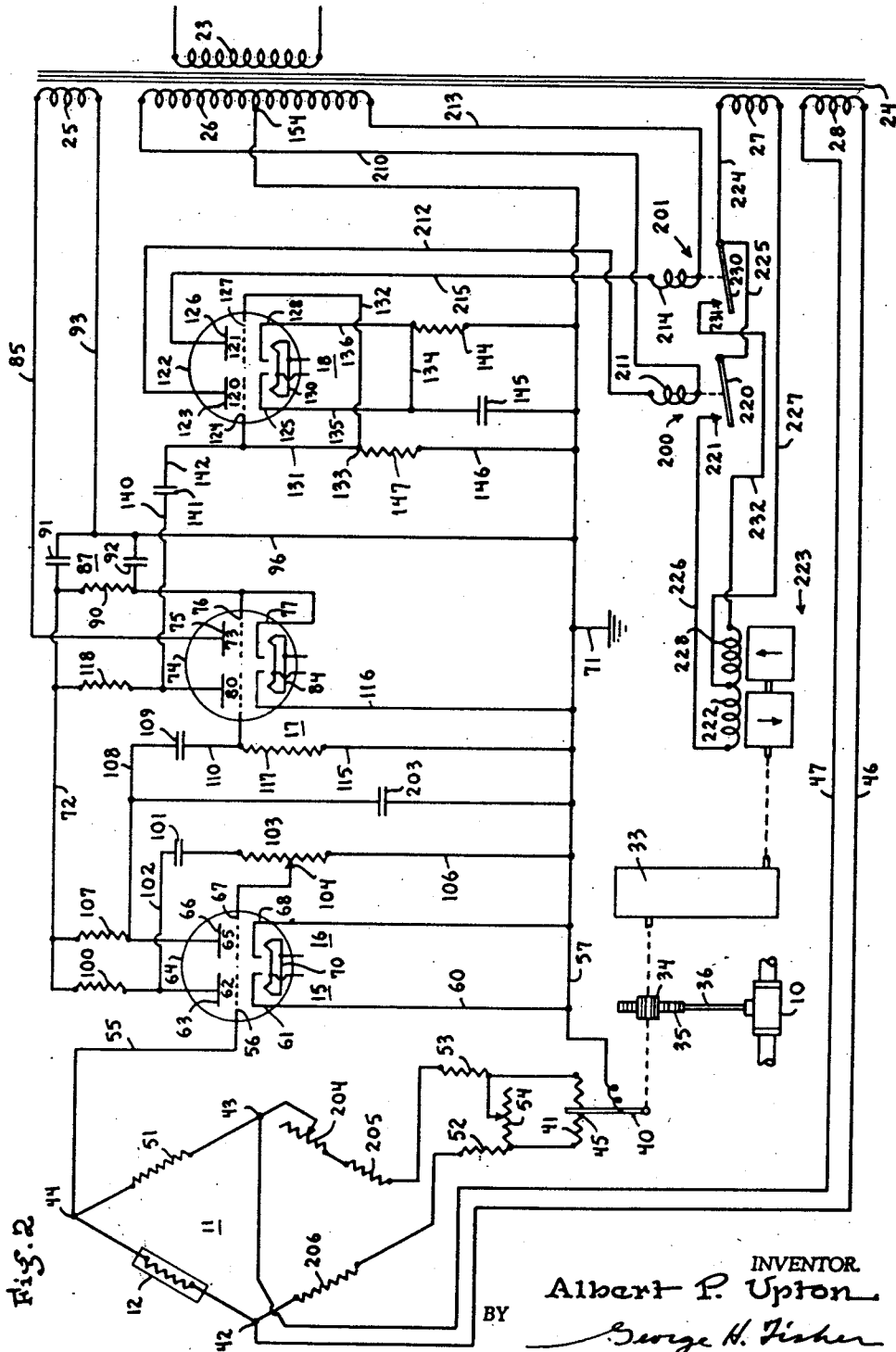
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CONTROL APPARATUS

Filed April 3, 1942

2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,423,534

CONTROL APPARATUS

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Application April 3, 1942, Serial No. 437,561

9 Claims. (Cl. 179-171)

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The present invention relates to electronic amplifier circuits and particularly to an electronic amplifier circuit adapted for use in a system wherein a reversible motor is operated in accordance with changes in the value of a controlling mechanism, which may respond to changes in a variable condition.

An object of the present invention is to construct an improved and simplified electronic amplifier circuit.

Another object of the present invention is to provide an improved circuit for amplifying alternating electrical signals without shifting the phase of said signals.

Another object of the present invention is to provide an improved amplifier adapted for energization from a source of alternating electrical energy and further adapted to amplify signals of the same frequency as said source. A further object is to provide, in such an amplifier circuit means for increasing the stability of the amplifier, that is, means for substantially preventing the appearance of false signals in the amplifier output due to stray electrical effects from said source.

Another object is to provide an improved amplifier for alternating electrical signals, especially adapted for use in a control system wherein the controlling effect is dependent upon the phase of the signals.

A further object of this invention is to provide an amplifier circuit wherein the number of impedance elements, particularly wound impedance elements, is reduced to a minimum.

Another object of the present invention is to provide, in an amplifier circuit having a plurality of stages, an improved voltage supply circuit such that the output circuits of a plurality of said stages may be connected directly in parallel to the terminals of the voltage supply circuit.

A further object of the present invention is to provide an improved amplifier circuit of the type shown in the copending application of Willis H. Gille and John V. Sigford, Serial No. 408,594, filed August 28, 1941, now Patent No. 2,375,988, dated May 15, 1945, and assigned to the assignee of the present application, and in the copending application of Walter P. Wills, Serial No. 421,173, filed December 1, 1941, and assigned to The Brown Instrument Company, a subsidiary of the assignee of the present application.

A further object of the present invention is to provide an improved amplifier circuit wherein phase distortion is reduced by reducing the number of reactive elements in the input and output

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circuits of each stage to a minimum, and wherein reactive elements are used only for coupling between stages and for filtering.

Other objects and advantages of the invention will become apparent from a consideration of the appended claims, specification, and drawing, in which:

Figure 1 represents a circuit diagram of a control system embodying certain features of my invention, and

Figure 2 represents a circuit diagram of a control system embodying certain other features of my invention.

Figure 1

Referring to Figure 1, my invention is shown therein, by way of example, as applied to a control system wherein the position of a valve 10 is modulated in accordance with the balance or unbalance of a bridge circuit 11 including three temperature responsive resistance elements 12, 13 and 14, although of course a larger or smaller number of such elements could be used. In the system, the unbalanced potential of the bridge circuit 11 is applied to the input of an amplifier 15 having three preliminary stages 16 and 17, and an output stage 18. A motor 20, of the split phase type, has one phase supplied directly from a source of power and the other phase supplied from the output circuit of the amplifier output stage 18. Power is supplied to the system from any suitable source of alternating current, to which is connected the primary winding 23 of a transformer 24. Transformer 24 has a plurality of secondary windings 25, 26, 27 and 28. Windings 25 and 26 supply power to the amplifier stages, winding 27 supplies power directly to one winding of the split phase motor 20, and winding 28 supplies power to the bridge circuit 11.

Motor 20 is provided with a pair of field windings 30 and 31 and a rotor 32. As stated above, the motor is of the split phase type, wherein, as is well known in the art, the field windings 31 and 30 are displaced in space phase, and wherein the displacement in time phase of the currents flowing through the windings determines the direction of rotation of the rotor 32. Rotor 32 drives a gear train generally indicated at 33. The output shaft of the gear train 33 is connected to a pinion 34 which engages a rack 35 mounted on stem 36 of the valve 10. The output shaft of gear train 33 also drives a sliding contact 40 across a potentiometer resistance 41.

The bridge circuit 11 has a pair of input terminals 42 and 43 and a pair of output terminals

44 and 45. Output terminal 45 is the point of engagement of slider 40 on potentiometer resistance 41. Input terminals 42 and 43 are connected to the terminals of transformer secondary winding 28 by means of a pair of conductors 46 and 47.

The upper left arm of bridge circuit 11 includes a variable resistance 50 and temperature responsive resistance 12. The upper right arm of bridge circuit 11 includes a fixed resistance 51. The lower left arm of bridge circuit 11 includes a fixed resistance 52 and a portion of potentiometer resistance 41, depending upon the position of slider 40. The lower right-hand arm of bridge circuit 11 includes the temperature responsive resistance elements 13 and 14, fixed resistance 53 and the remaining portion of potentiometer resistance 41. An adjustable resistance 54 is connected across the terminals of potentiometer resistance 41 for a purpose to be described later.

Output terminal 44 of bridge 11 is connected by means of a conductor 55 to control electrode 56 of a triode 62 forming a part of the first preliminary stage 15 of the amplifier. Output terminal 45 is connected by means of conductors 57 and 60 to cathode 61 of triode 62. Triode 62 also includes an anode 63.

Triode 62 forms one-half of a twin triode 64 which may be of the type commercially known as type 7F7. The twin triode 64 also includes a second triode 65 including an anode 66, a control electrode 67, a cathode 68, and a suitable heater element 70 for heating the cathodes of both triodes 62 and 65.

Conductor 57, which is grounded at 71, forms the negative terminal of the power supply for the three preliminary stages 15, 16 and 17. Conductor 72 forms a positive terminal of the power supply for these three stages.

A unidirectional potential is supplied between conductors 57 and 72 by means of a rectifier circuit connected to transformer secondary winding 25. This rectifier circuit includes a triode 73, which forms one part of a second twin triode 74 which may also be of the type 7F7. Triode 73 includes an anode 75, a control electrode 76, and a cathode 77.

Twin triode 74 also includes a triode 80 having an anode 81, a control electrode 82, and a cathode 83, and a suitable heater element 84 for heating the cathodes of both triodes 73 and 80.

The rectifier circuit which supplies power to the preliminary stages 15, 16 and 17 may be traced from the upper terminal of transformer secondary winding 25 through a conductor 85, anode 75, cathode 77, a conductor 86, a filter network 87 comprising a resistor 90 and a pair of condensers 91 and 92, and conductor 93 to the lower terminal of transformer secondary winding 25. It will be noted that the control electrode and cathode are connected together and are at the same potential so that the triode 73 is always conductive on each operative half cycle of the triode. The filter network 87 also includes terminals 94 and 95 which are hereinafter referred to as the output terminals of this rectifier circuit. Terminal 94 is connected directly to conductor 72, while terminal 95 is connected to conductor 57 through a conductor 96. The effect of the rectifier circuit is to maintain conductor 72 at a positive potential with respect to conductor 57.

The input circuit of the first preliminary stage 15 may be traced from cathode 61 through conductors 60 and 57, slider 40, bridge circuit output terminal 45, bridge circuit 11, bridge circuit 75

output terminal 44, and conductor 55 to control electrode 56. The output circuit of the first preliminary stage 15 may be traced from positive conductor 72 through a load resistor 100, anode 63, cathode 61, and conductor 60 to negative supply conductor 57.

The output circuit of preliminary stage 15 is coupled to the input circuit of the second preliminary stage 16 by a condenser 101, one terminal of which is connected by a conductor 102 to anode 63, and the other terminal of which is connected to a potentiometer resistance 103 forming a part of the input circuit of second preliminary stage 16. The condenser 101 serves to transmit any A. C. signal appearing in the output circuit of stage 15 to the input circuit of stage 16, while blocking the transmission of any D. C. signal.

A slider 104 cooperates with potentiometer resistance 103 and is connected to control electrode 67 of triode 65. The slider 104 and potentiometer resistance 103 form a gain control for the amplifier circuit in a manner well known in the art. This gain control may be omitted and a plain resistance used in its stead if adjustment of the amount of amplification is not desired.

The input circuit of the second amplifier stage 16 may be traced from cathode 68 through a resistance 105, grounded conductor 57, a conductor 106, a portion of potentiometer resistance 103 and contact 104 to control electrode 67.

The output circuit of second preliminary stage 16 may be traced from positive power supply line 72 through a load resistance 107, anode 66, cathode 68, and resistance 105 to negative power supply line 57.

The resistance 105 operates to bias the control electrode 67 negatively with respect to the cathode 68, by reason of the voltage drop across resistance 105 due to the flow of output current through it.

It has been found that the use of this resistance 105 in the second stage 16 has the effect of increasing the stability of the amplifier circuit. That is, it tends to prevent a shift in phase between the amplifier input and output stages and it tends to prevent the appearance of false signals in the output stage when there is no signal applied to the input. It has also been found that the stability of the circuit is better when this biasing resistance is used in the second stage than when it is used in any of the other stages, and that the stability is better when a biasing resistance is used in the second stage only than when such resistances are used in any combination of two or more stages. It has also been found that the stability is better when no by-passing or filtering condenser is connected in parallel with this resistance.

The exact theoretical reason for the better stability obtained when the resistance 105 is connected in the particular manner described is not known. The existence of such improved stability characteristics has, however, been definitely proven by many experiments.

The output circuit of the second preliminary stage 16 is coupled to the input of the third preliminary stage 17 through a connection which may be traced from anode 66 through a conductor 108, a condenser 109, and a conductor 110 to control electrode 82 of triode 83.

The input circuit of third preliminary stage 17 may be traced from cathode 83 through a conductor 115, grounded conductor 57, a con-

ductor 116, and a resistance 117 to control electrode 82.

The output circuit of the third preliminary stage 17 may be traced from positive supply line 72 through a resistance 118, anode 81, cathode 83, and conductor 115 to negative supply line 57.

Final output stage 18 includes a pair of triodes 120 and 121 which may be included in a twin triode 122. Triode 120 includes an anode 123, a control electrode 124, and a cathode 125. Triode 121 includes an anode 126, a control electrode 127, and a cathode 128. Twin triode 122 also includes a suitable heater element 130 for heating both of the cathodes 125 and 128.

The control electrodes 124 and 127 are connected to a common junction 133 by means of conductors 131 and 132, respectively. Likewise, cathodes 125 and 128 are connected to a common junction 134 by means of conductors 135 and 136, respectively.

The output circuit of the third preliminary stage 17 is coupled to the input circuit of the final stage 18 by a connection which may be traced from anode 81 through a conductor 140, a blocking condenser 141, conductors 142 and 143, to common junction 133 and control electrodes 124 and 127.

The input circuit of the final amplifier stage 18 may be traced from cathodes 125 and 128 to the common junction 134, resistor 144 and its associated parallel by-pass condenser 145, conductor 57, conductor 146, a resistance 147, and conductor 143 to junction 133 and control electrodes 124 and 127.

A filter condenser 150 is connected between junction 133 and conductor 57. The condenser 150 by-passes high-frequency components appearing in the output of stage 17 and passing through the blocking condenser 141, thereby substantially preventing such components from affecting the control electrodes 124 and 127. Condenser 150 is just as effective in this respect as a condenser connected between anode 81 and ground. By connecting the condenser 150 in the manner shown however, it is possible to use a smaller condenser than would be the case if a condenser were connected directly between anode 81 and ground. A condenser connected directly between anode 81 and ground would have to withstand the full voltage across the triode 80, while the condenser 150 is connected only in the relatively low voltage input circuit of triodes 120 and 121. It is, of course, understood that condenser 150 has a relatively high impedance to currents of the supply frequency so as to prevent condenser 150 from effectively shunting resistor 147.

I have found that, by the use of a filter condenser such as the condenser 150, forming a low impedance path to high frequency currents passing between one of the preliminary stage anodes and ground, it is possible to use the simplified voltage supply circuit shown without undue distortion in wave form of the transmitted signal. The use of non-reactive impedances for loads and for biasing in the preliminary stages reduces distortion in phase of the applied signal.

The simplified rectifier circuit used and the simple type of impedances employed provide a circuit which is small in size and light in weight for the amount of power supplied, as compared with amplifier circuits of the prior art.

The output circuit of triode 120 may be traced from the upper terminal of transformer winding 26 through a conductor 151, anode 123, cathode

125, conductor 135, junction 134, resistor 144 and its parallel by-pass condenser 145, grounded conductor 57, a conductor 152, motor winding 30, and a conductor 153 to center tap 154 on transformer secondary winding 26. A buffer condenser 155 and its protective resistor 156 are connected in series between anode 123 and grounded conductor 57.

The output circuit of triode 121 may be traced from the lower terminal of transformer secondary winding 26 through a conductor 160, anode 126, cathode 128, conductor 136, junction 134, resistor 144 and parallel by-pass condenser 145, conductors 57 and 152, winding 30, and conductor 153 to center tap 154 on transformer secondary winding 26. A buffer condenser 161 and a protective resistor 162 are connected in series between anode 126 and grounded conductor 57.

Motor winding 31 is supplied with energy from transformer winding 27 through a circuit which may be traced from the upper terminal of transformer winding 27 through conductor 57, conductor 152, motor winding 31, a conductor 163, a condenser 164, and a conductor 165 to the lower terminal of transformer secondary winding 27.

The condenser 164 is chosen so as to form with winding 31 a series resonant circuit. Since this circuit is resonant, the current flowing in it, and hence the current in motor winding 31, is in time phase with the terminal potential of transformer winding 27. The potential at the terminals of winding 31 leads this current by an angle of approximately ninety electrical degrees, due to the inductance of the winding. Such a condenser is commonly provided in connection with split phase motors, as is well known in the art.

Motor winding 30 may receive electrical energy in two ways: (1) by transmission from output stage 18 through conductors 152 and 153, and (2) by induction through transformer action from motor winding 31, when the motor is running.

A condenser 166 is connected across the terminals of motor winding 30. This condenser 166 is so chosen with relation to the impedance of winding 30 when the motor is running, that the two together form a parallel circuit resonant at the supply frequency. It will be seen that condenser 166 and winding 30 form a parallel resonant circuit of high impedance with respect to external currents transmitted to winding 30 through conductors 152 and 153. On the other hand, condenser 166 and winding 30 form a series resonant circuit of low impedance with respect to internal currents induced in winding 30 by transformer action from winding 31.

Condenser 166 and winding 30 are so designed that their impedance to external currents matches the internal impedance of triodes 120 and 121, thereby providing optimum conditions for the transmission of energy in the triode circuits, as is well known in the art.

The fluxes produced by each of the windings 30 and 31 in the motor do not link the other winding when the motor is standing still. When the motor is rotating, however, the armature reaction distorts the magnetic field in the motor so that winding 30 is linked by a portion of the flux produced by winding 31. This flux induces a current in winding 30, which is the current previously referred to as being produced by transformer action under running conditions.

The operation of a split phase motor of the type described herein in connection with an amplifier circuit somewhat similar to the present one is analyzed and described in greater detail in the

compending application of Walter P. Wills, Serial No. 421,173, filed December 1, 1941, assigned to The Brown Instrument Company, a subsidiary of the assignee of the present application.

The values set forth in the following table are provided to illustrate more completely a specific amplifier circuit which has been constructed to carry out the principles of my invention. It should be understood, however, that these values are provided by way of example only, and that other values may be used without departing from the invention.

Reference Numeral	Quantity	Suggested Values
100, 107, 118.....	Resistance.....	$\frac{1}{4}$ Megohm.
105.....	do.....	10 Megohms.
103, 117, 147.....	do.....	1 Megohm.
144.....	do.....	500 Ohms.
90.....	do.....	5 Megohms.
156, 162.....	do.....	10 Megohms.
101, 109, 141.....	Capacitance.....	.05 Microfarad.
91, 92.....	do.....	10 Microfarads.
145.....	do.....	20 Microfarads.
155, 161.....	do.....	.0075 Microfarad.
150, 203.....	do.....	.02 Microfarad.
25.....	Terminal Voltage.....	350 Volts.
26.....	do.....	350 Volts on each side of tap 134.
27.....	do.....	120 Volts.
28.....	do.....	10 Volts.

Operation of Figure 1

The temperature responsive resistance elements 12, 13 and 14 are exposed to temperatures which are individually and collectively indicative of the need for a change in the position of the valve 10. The adjustable resistance 50 is provided so that the position of the valve 10 to be maintained in response to a given set of temperature conditions adjacent the resistances 12, 13 and 14 may be manually determined.

When the bridge circuit 11 is balanced, the output terminals 44 and 45 are at the same potential, and hence no signal is applied to the input circuit of the amplifier. Therefore no signal is produced in the output circuit of the third preliminary stage and no signal is applied to the input circuit of the final stage 18. Triodes 120 and 121 are therefore equally conductive, and the current appearing in the common portion of their output circuit which includes the motor winding 30 is chiefly unidirectional with a small superimposed alternating component of twice the supply frequency. Under these conditions the twin triode 122 is in effect acting as a full wave rectifier. Such a current does not cause any movement of the rotor 32 and in fact the unidirectional component provides a sort of dynamic braking action on the rotor. Therefore, the valve 10 is maintained in the position which it has previously reached.

Let it be assumed that the temperature adjacent the temperature responsive resistance 12 decreases. This causes the value of resistance 12 to decrease. This produces an unbalance of bridge circuit 11 in such a direction that the potential appearing between output terminals 44 and 45 is of the same phase as the potential between terminals 43 and 42, respectively. This potential is, of course, in time phase with the potential occurring at the output terminals of windings 27 and 28, and with the potential supplied to triode 120 in the final output stage 18. This signal is transmitted through the three preliminary stages and appears on the input circuit of the final stage in phase with the output voltage of the triode 120, thereby rendering triode 120 more conductive and the triode 121 less conduc-

tive. The final stage 18 then supplies to the motor winding 30 an alternating potential which is in time phase with the potential in the upper half of transformer secondary winding 26. The current through winding 30 lags behind this potential due to the inductance of the winding. Since winding 31 is continuously energized with current in phase with the supply potential, the two windings 30 and 31 are now energized with currents displaced in phase, and rotation of motor 20 follows. This rotation is transmitted through gear train 33 so as to drive valve 10 towards open position. The change in position of valve 10 causes the slider 40 to move to the left along potentiometer slide wire 41 so as to restore the balance of the bridge circuit 11. As soon as balance is restored, the signal applied to the amplifier again drops to zero, thereby stopping rotation of the motor 20.

In a corresponding manner, an increase of temperature adjacent the temperature responsive resistance 12 causes an unbalance of the bridge circuit 11 in such a direction that the phase of its output potential is shifted in the opposite direction. The potential applied to the input circuit of the final stage 18 is then in phase with the potential supplied to triode 121 from the lower half of transformer secondary winding 26. This potential causes the output current of triode 121 to increase and the output current of triode 120 to decrease. The current then supplied to the motor winding 30 is opposite in phase to that supplied during the operation previously described. Motor 20 therefore rotates in the opposite direction, driving the valve 10 towards its closed position and moving the slider 40 to the right along slide wire 41 to rebalance the bridge circuit 11.

Changes in temperature at points 13 and 14 will similarly result in movement of the valve 10.

It should be apparent from the foregoing description that I have provided an amplifier circuit which is extremely simple and which produces an output current variable in phase in accordance with the phase of the input current, and wherein phase distortion is reduced to a minimum.

The heaters 70, 84 and 130 of the three twin triodes 64, 74, and 122 may be connected to any suitable source of electrical energy.

The variable resistance 54 is provided in order to adjust the amount of unbalance of the bridge circuit necessary to cause a movement of slider 40 from one end of slider 41 to the other and, hence, to move the valve 10 from open to closed position, or vice versa. It will be seen that when the resistance 54 connected in parallel with potentiometer slide wire 41 is at a maximum, the change in balance of the bridge circuit due to a given movement of slider 40 will be at a maximum. On the other hand, if the resistance of 54 is reduced to zero, the movement of slider 40 across the potentiometer slide wire 41 produces no change in the bridge circuit. Therefore, it will be seen that the resistance 54 may be adjusted to such a value that valve 10 will be moved from fully closed to fully open position during a change in the temperature adjacent resistance 12 over any desired range.

Figure 2

Figure 2 shows a somewhat modified form of my invention. In this figure, a pair of relays 200 and 201 are selectively operated by the amplifier to control the direction of rotation of a reversible

motor 223. This motor is of a different type than that shown in Figure 1, and is provided with a pair of windings whose selective energization causes rotation of the motor in one or the other direction.

Circuit elements of Figure 2 which correspond exactly to elements of Figure 1 have been given the identical reference numerals. It will be noted that the only changes are the use of relays, the use of a different type of reversible motor, and some incidental changes in the bridge circuit. Also, in the circuit of Figure 2, the resistance 105 has been omitted from the output circuit of the second preliminary stage 16. The filtering condenser 150 has been omitted from the input circuit of the final stage 18, and its function has been taken over by another filtering condenser 203 connected in the output circuit of the second preliminary stage 16.

In the bridge circuit 11 of Figure 2, only a single temperature responsive resistance element 12 is used. The variable resistances 13, 14 of Figure 1 have been replaced by fixed resistors 205 and 206. The variable resistance 50 of Figure 1 has been replaced by a variable resistor 204 in the lower right-hand arm of the bridge circuit. The operation of the various elements in the bridge circuit remains the same.

The output circuit of triode 120 of Figure 2 may be traced from the upper terminal of transformer secondary winding 26 through a conductor 210, winding 211 of relay 200, a conductor 212, anode 123, cathode 125, junction 134, resistor 144 and parallel by-pass condenser 145, and grounded conductor 57 to center tap 154 of transformer secondary winding 26.

Correspondingly, the output circuit of triode 121 may be traced from the lower terminal of transformer secondary winding 26 through a conductor 213, winding 214 of relay 201, a conductor 215, anode 126, cathode 128, junction 134, resistor 144 and parallel by-pass condenser 145 and grounded conductor 57 to center tap 154 on secondary winding 26.

Relay 200 controls the operation of a switch arm 220 into and out of engagement with a fixed contact 221. When switch arm 220 engages contact 221, an energizing circuit is completed for winding 222 of motor 223. This circuit may be traced from the upper terminal of transformer winding 27 through conductors 224 and 225, switch arm 220, contact 221, a conductor 226, motor winding 222, and a conductor 227 to the lower terminal of transformer secondary winding 27.

Relay 201 controls the operation of a switch arm 230 into and out of engagement with a fixed contact 231. When switch arm 230 engages contact 231, an energizing circuit is completed for winding 228 of motor 223. This circuit may be traced from the upper terminal of transformer secondary winding 27 through conductor 224, switch arm 230, contact 231, a conductor 232, motor winding 228 and conductor 227 to the lower terminal of transformer secondary winding 27.

When the bridge circuit is balanced, no potential is present at the bridge output terminals 44 and 45. Therefore, no signal is transmitted to the input circuit of the final stage 18, and the triodes 120 and 121 are equally conductive.

The impedance of relay windings 211 and 214 is so designed that the relays do not move their associated switch arms to their attracted position unless the conductivity of one of the triodes 120 and 121 has been increased substantially above

its normal value by the application of an alternating current signal of proper phase relationship to the input circuit of the final stage 18.

If the temperature adjacent resistance 12 decreases, its resistance decreases, and a potential appears between output terminals 44 and 45 which is in phase with the potential between terminals 42 and 43, respectively. This potential at the terminals 44 and 45 is amplified by the three preliminary stages and applied to the input circuit of the final stage 18 without any substantial shift in phase. Since it is in phase with the terminal voltage of secondary winding 28, it is also in phase with the voltage supplied from the upper half of secondary winding 26 to the triode 120, and out of phase with the voltage supplied to triode 121. Triode 120 therefore becomes more conductive, energizing relay 200 and thereby causing motor 223 to drive slider 40 to the left so as to rebalance the bridge 11, and simultaneously to open valve 10 so that more heat is supplied to the space adjacent resistance 12.

When a rise in the temperature adjacent resistance 12 takes place, the potential appearing at terminals 44 and 45 is in the opposite phase from the case previously considered, and accordingly causes the energization of relay 201, thereby energizing motor winding 228. Motor 223 then drives slider 40 to the right to rebalance bridge 11, and simultaneously moves valve 10 towards closed position, thereby reducing the supply of heat to the space adjacent resistor 12.

If desired, the impedance of relay windings 211 and 214 may be so designed that both relays attract their armatures when the bridge circuit is balanced. If used in this way, the two motor windings 222 and 228 oppose each other under balanced conditions, resulting in a stalled motor with a sort of braking action, which may aid in preventing overrunning of the motor.

The operation of the circuits shown in Figure 2 is analogous to the operation of the circuits of Figure 1, and it is believed that further description of its operation is unnecessary.

While I have shown and described certain preferred embodiments of my invention, modifications will readily occur to those who are skilled in the art, and I therefore wish my invention to be limited only by the scope of the appended claims.

I claim as my invention:

1. In an electronic amplifier circuit including a plurality of stages, each stage having an input circuit and an output circuit, means for supplying said stages with rectified alternating electrical energy, means including a blocking condenser for coupling the output circuit of each stage with the input circuit of the succeeding stage, and filter means for one of said output circuits comprising a condenser connected directly to said blocking condenser and directly across the input circuit of the succeeding stage.

2. An electronic amplifier circuit, comprising in combination, three stages of amplification, each stage having an electronic discharge device and an input and an output circuit, the discharge devices of said three stages having substantially the same electrical characteristics, means for supplying a signal voltage to the input circuit of the first stage, and means in only the intermediate of said three stages for producing a degenerative feedback effect to suppress any tendency of any two adjacent stages to cooperate in the generation of oscillatory voltages, said last named means consisting of an unbypassed resistor com-

mon to the input and output circuits of said intermediate stage.

3. An electronic amplifier circuit, comprising in combination, three stages of amplification, each stage having an input circuit and an output circuit, a resistor common to the input and output circuits of the intermediate one of said three stages for biasing said input circuit negatively, said other two stages having unbiased input circuits, power supply means comprising a rectifier and filter network adapted for connection to a source of alternating electrical energy and having a pair of output terminals, and direct conductive connections between said output terminals and the output circuits of each of said stages.

4. An electronic amplifier circuit, comprising in combination, at least three stages of amplification, each stage having an input circuit and an output circuit, a resistor common to the input and output circuits of the intermediate one of said three stages for biasing said input circuit negatively, said other two stages having unbiased input circuits, power supply means comprising a rectifier and filter network adapted for connection to a source of alternating electrical energy and having a pair of output terminals, direct conductive connections between said output terminals and the output circuits of each of said stages, and filter condenser means connected directly across a portion of one of said output circuits.

5. An electronic amplifier circuit, comprising in combination, three stages of amplification, each stage having an input circuit and an output circuit, a resistor common to the input and output circuits of the intermediate one of said three stages for biasing said input circuit negatively, said other two stages having unbiased input circuits, power supply means comprising a rectifier and filter network adapted for connection to a source of alternating electrical energy and having a pair of output terminals, direct conductive connections between said output terminals and the output circuits of each of said stages, filter condenser means connected across a portion of one of said output circuits and in series with said filter network, a pair of input terminals adapted for direct conductive connection to a source of alternating electrical signals, non-inductive means for coupling said input terminals and the input circuit of the first stage, and further non-inductive coupling means between each output circuit and the input circuit of the next succeeding stage.

6. An electronic amplifier circuit, comprising in combination, at least three stages of amplification, each stage having an input circuit and an output circuit, a resistor common to the input and output circuits of the intermediate one of said three stages for biasing said input circuit negatively, said other two stages having unbiased input circuits, power supply means comprising a rectifier and filter network adapted for connection to a source of alternating electrical energy and having a pair of output terminals, direct conductive connections between said output terminals and the output circuits of each of said stages, filter means for one of said output circuits comprising a condenser connected across the input circuit of the succeeding stage, a pair of input terminals adapted for direct conductive connection to a source of alternating electrical signals, non-inductive means for coupling said input terminals and the input circuit of the first stage,

and further non-inductive coupling means between each output circuit and the input circuit of the next succeeding stage.

7. In a multi-stage amplifier, a plurality of electronic discharge devices, each of which comprises a container and a group of electrodes within said container including an anode, a cathode, and a control electrode, at least one of said devices containing two such groups, a filter network, connections between said filter network and the anode and cathode of only one of the two groups of electrodes of said one discharge device such that said anode and cathode function as a half wave rectifier to supply a pulsating unidirectional voltage to said filter network, connections between the anodes, cathodes, and control electrodes of the remaining groups of electrodes forming a plurality of amplification stages, each having an input and an output circuit, said filter network having a pair of output terminals, and direct connections between said pair of output terminals and the output circuit of each amplification stage.

8. In an electronic amplifier circuit for amplifying an alternating signal voltage, said amplifier circuit including a plurality of stages, each stage having an input circuit and an output circuit, means for supplying said stages with rectified alternating electrical energy, means including a blocking condenser for coupling the output circuit of each stage with the input circuit of the succeeding stage, and filter means for one of said output circuits comprising a condenser connected directly to said blocking condenser and directly across the input circuit of the succeeding stage, said last named condenser having a high impedance to current of the frequency of said signal voltage but of low impedance to current of relatively high frequency.

9. In an electronic amplifier circuit for amplifying an alternating signal voltage, said amplifier circuit including a plurality of stages, each stage having an input circuit and an output circuit, means for supplying said stages with rectified alternating electrical energy of the same frequency as said signal voltage, comprising a rectifier and a filter including condenser means, coupling condenser means for coupling the output circuit of each stage with the input circuit of the succeeding stage, and filter means for one of said output circuits comprising a condenser connected directly across the input circuit of the succeeding stage, said last named condenser having a capacity which is relatively small as compared with that of said first named filter.

ALBERT P. UPTON.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,289,947	Wills	July 14, 1942
2,154,375	Chambers	Apr. 11, 1939
1,947,084	Hayden	Feb. 13, 1934
2,306,479	Jones	Dec. 29, 1942
2,255,757	Bierwirth	Sept. 16, 1941
2,020,275	Beers	Nov. 5, 1935
2,324,279	Clark	July 13, 1943
1,942,587	Whitman	Jan. 9, 1934
2,113,164	Williams	Apr. 5, 1938
2,203,689	Macdonald	June 11, 1940
2,209,369	Wills	July 30, 1940