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ELECTROMAGNETIC APPARATUS

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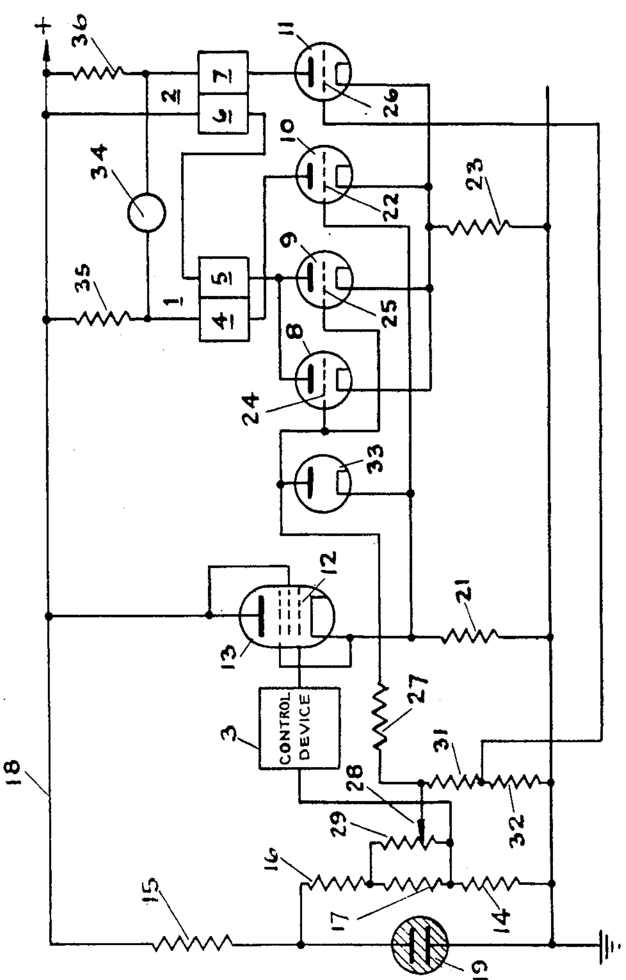

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ELECTROMAGNETIC APPARATUS

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9 Claims. (Cl. 175—320)

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This invention relates to electromagnetic apparatus of the kind arranged to be operated by an electric control signal.

It is well known that the minimum current which will operate a simple electromagnetic relay which is spring biassed to a non-operated position is usually greater than the current which is necessary to hold it in that position when so operated. Thus, when the current in an operating winding of such a relay is increased from zero, the relay will operate at a given value of current but when the current is then reduced the relay will not return to its non-operated position until a much lower value of current is reached. If now the relay forms part of a closed loop servo system in which operation of the relay effects some control which in turn varies the current through the relay winding, this difference between the operating and release currents of the relay may cause overshooting of the servo system.

It is one object of the present invention to provide a relay arrangement in which the above mentioned effect is reduced.

According to the present invention, electromagnetic apparatus of the kind specified comprises two thermionic valves each of which has a control grid, bias resistance connected in a common cathode circuit of the two valves, an electromagnetic device which has two positions of operation and which is arranged to be differentially operated by the currents through the said two valves, control means adapted to supply a signal which may be varied to the control grid of one of the said valves, and means to maintain the voltage on the control grid of the other valve at a predetermined value whereby changes of the voltage on the control grid of the first mentioned valve during operation of the apparatus produces changes in the currents in the two windings which are opposite in sense so that the device may be caused to be moved between its said two positions of operation by varying the voltage supplied by the said control means.

The electromagnetic device may be a differential relay.

According to a feature of the present invention, electromagnetic apparatus of the kind specified comprises first and second thermionic valves each of which has a control grid, first and second electromagnetic devices which each have two positions of operation and two operating windings, a first winding of the first device and a first winding of the second device being arranged to carry the currents through the first and second valves respectively, a further valve which has a control grid, or more than one such valves connected for parallel operation, the second operating windings of the two electromagnetic devices being connected in series and arranged to carry

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the current, or the combined current, through the further valve or valves in the direction so that the currents in the two windings of each device tend to oppose one another, bias resistance connected in a common cathode circuit of the first and second valves and the further valve or valves, control means adapted to supply a signal which may be varied to the said grid of the first valve, resistance connected between a source of positive voltage and the said grid or grids of the further valve or valves, a rectifier connected between the said grid of the first valve and the said grid or grids of the further valve or valves so as to permit the flow of current to the grid of the first valve, and a connection between the said grid of the second valve and a source of positive voltage whereby the two electromagnetic devices may be operated by varying the voltage supplied by the control means to the said grid of the first valve.

In one arrangement, the control means comprises a device which is adapted to provide a control voltage which may be varied over a range of values on either side of and including zero voltage and a cathode follower stage through which is arranged to be supplied to the control grid of the first valve the control voltage in series with a predetermined voltage. Preferably the ampere-turns in the two windings of each electromagnetic device are arranged to be the same when the control voltage is zero. This condition is satisfied if there are two further valves and these two valves and the first and second valves all have the same electrical characteristics while the turns of the first and second windings of each device are in the ratio two to one. The first and second electromagnetic devices may be differential relays.

One arrangement of apparatus in accordance with the invention will now be described by way of example with reference to the accompanying diagrammatic drawing which shows the circuit of the arrangement.

The arrangement comprises two differential electromagnetic relays 1 and 2 which are arranged to be operated in dependence upon the voltage supplied by a control device 3. The control device 3 supplies a voltage which may be varied over a range of values on either side of zero volts and the relay 1 is required to be operated when the control voltage supplied by the device 3 has a value of +3.5 volts while the relay 2 is required to be operated when the control voltage has —3.5 volts.

The relays 1 and 2 have pairs of operating windings 4, 5 and 6, 7 and these windings 4 to 7 carry the anode currents of four like triode thermionic valves 8, 9, 10 and 11. The windings 5 and 6 are connected in series and carry the combined anode current of the valves 8 and 9. The windings 4 and 7 carry the anode currents of the valves 9

and 11 respectively and the windings 4 and 7 have approximately twice the number of turns of the windings 5 and 6.

The valves 8 to 11 are of the type having a short grid base, that is to say a relatively small change in the bias on the grid of one of these valves when operating under normal conditions causes the valve to be cut off.

The control voltage supplied by the device 3 is added to a stabilised voltage and fed to the control grid 12 of a pentode valve 13 which is connected to operate as a cathode valve stage. This stabilised voltage is developed across a resistor 14 which together with resistors 15, 16 and 17 form a potentiometer between a positive supply line 18 and earth, the necessary voltage stabilisation being effected by a gas discharge device 19 resistors 16, 17 and 14.

The voltage developed across the resistor 21 in the cathode circuit of the valve 13 is thus approximately equal to that of the stabilised voltage across the resistor 14 plus the control voltage supplied by the device 3 and this voltage across the resistor 21 is fed to the grid 22 of the valve 10. A single bias resistor 23 is connected in the cathode circuits of the four valves 8 to 11 and the control grids 24, 25 and 26 of the valves 8, 9 and 11 are supplied with stabilised bias voltages. Thus the grids 24 and 25 are supplied through a resistor 27 from a tapping point 28 on a potentiometer 29 which is connected across the resistor 17 while the grid 26 is supplied from the junction of two series-connected resistors 31 and 32 which are connected between the tapping point 28 and earth. A diode thermionic valve 33 is connected between the grids 24 and 25 of the valves 8 and 9 and the unearthed side of the resistor 21. The diode 33 is thus non-conducting when the voltage across the resistor 21 is greater than that between the tapping point 28 and earth so that the voltage on the grids 24 and 25 is unaffected by changes in the voltage across the resistor 21 under these conditions but, when this voltage is less than that of the tapping point 28, current flows through the diode 33 and the resistor 27 so as to drop the voltage on the grids 24 and 25.

The system described above is adjusted so that when the device 3 is supplying no voltage, equal currents are passing through the windings 4 and 7 of the relays 1 and 2. This condition is determined by means of a voltmeter 34 connected across a pair of like resistors 35 and 36, the position of the tapping point 28 on the resistor 29 being adjusted until the meter 34 gives zero reading.

Under these conditions the diode 33 is non-conducting. The potentiometer formed by the resistors 31 and 32 causes the voltages supplied to the grids 24 and 25 of the valves 8 and 9 to be greater than the grid voltages of the valves 10 and 11 but, because of the lower anode resistance of the valves 8 and 9 the four triodes 8 to 11 are passing approximately the same current. The current through the windings 5 and 6 is thus twice that through the windings 4 and 7 but, since these latter windings have approximately twice the number of turns of the windings 4 and 7, the resulting ampere-turns of each relay 1 and 2 is approximately zero so that both relays are non-operated. If now the control voltages supplied by the device 3 is increased, the diode valve 33 is still non-conducting but as a result of the increase in voltage across the resistor 21 the bias on the grid 22 is increased with the result that there is a rise in the current through the winding 4 of the relay 1. This tends to cause an increase in the bias across the common cathode resistor 23 so that the current through the triode valves 8, 9 and 11 is decreased. This is the situation for all values of the control voltage up to about 4 volts positive at which value the bias across the resistor 23 causes the valves 8, 9 and 11 to be cut off when approximately four times the original current is flowing through valve 10. The relay 1 is selected so that it is operated at a slightly lower value of control voltage, say 3.5 volts at which value a relatively large current will be flowing through the winding 4 with relatively small current through the winding 5. With all positive values of control voltage the valves 8, 9 and 11 are passing approximately the same current so that the ampere-turns of the relay 2 substantially cancel out and that relay is not operated. If, when the relay 1 is operated the control voltage is then reduced, the current in the winding 4 is reduced while the current in the winding 5 is increased. The effect of this is to cause the relay 1 to release at a much higher value of control voltage than would otherwise have been the case if the winding 5 had been omitted.

For all negative values of the control voltage the diode valve 33 is conducting so that the voltage on the grids 24, 25 and 22 are reduced together with the respect to earth while the grid 26 remains at its predetermined voltage. Thus in similar manner to that previously described the current through the valve 11 is increased while that through valves 8, 9 and 10 is reduced so as to cause the relay 2 to operate when the control voltage is approximately −3.5 volts.

It will be appreciated that since the corresponding electrodes of the valves 8 and 9 are connected together these two valves may be replaced by a single valve but then in order to obtain the same operating conditions it would be necessary for the windings 4, 5, 6 and 7 all to have the same number of turns. The pairs of valves 8, 9 and 10, 11 which have been discussed above as separate valves are, in fact, two double-triode valves.

Suitable components and component values for the apparatus described above when the supply line 18 is maintained at a voltage of 250 volts above earth is as follows:

Device 19	Osram valve type QS9510
Valve 13	Osram valve type Z77
Valve 33	Osram valve type D77
Valves 8 and 9	Mullard valve type ECC91
Valves 10 and 11	Mullard valve type ECC91
Winding 4	D. C. resistance of 1,000 ohms
Winding 5	D. C. resistance of 400 ohms
Winding 6	D. C. resistance of 400 ohms
Winding 7	D. C. resistance of 1,000 ohms
Resistor 14	41,000 ohms
Resistor 16	1,500 ohms
Resistor 17	22,000 ohms
Resistor 21	15,000 ohms
Resistor 23	20,000 ohms (variable)
Resistor 27	22,000 ohms
Potentiometer 29	100,000 ohms
Resistor 31	10,000 ohms
Resistor 32	2,200,000 ohms
Resistor 35	6.8 ohms
Resistor 36	6.8 ohms

The control device 3 may be any suitable arrangement which is adapted to supply the necessary control voltage. In one arrangement the servo system described above may be utilised for

frequency control of an oscillation generator, the two relays 1 and 2 each controlling the operation of a motor in one direction and this motor being adapted to tune a resonant cavity which determines the operating frequency of a very high frequency oscillator by movement of a plunger, the control signal being derived from a phase-sensitive device. Such an oscillation generator is described more fully in the specification of abandoned patent application No. 250,683, filed October 10, 1951, refiled as co-pending patent application No. 270,052 on February 5, 1952.

I claim:

1. Electromagnetic apparatus of the kind arranged to be operated by an electric control signal comprising first and second thermionic valves each of which has a cathode, a control grid and an anode, first and second electromagnetic devices which each has two positions of operation and two operating windings, a first winding of the first electromagnetic device and a first winding of the second electromagnetic device being connected to carry the currents through the first and second valves respectively, a further valve which has a control grid, the second operating windings of the two electromagnetic devices being connected in series to carry the current through the further valve in the direction so that the currents in the two windings of each device tend to oppose one another, bias resistance having a pair of terminals connected in a common cathode circuit of the first and second valves and the further valve, control means adapted to supply a signal which may be varied to the said grid of the first valve, a first source of voltage which is positive relative to the terminal of the bias resistance remote from the cathode, resistance connected between the first source of voltage and the said grid of the further valve, a rectifier connected between the said grid of the first valve and the said grid of the further valve so as to permit the flow of current to the grid of the first valve, a second source of voltage which is positive relative to the terminal of the bias resistance remote from the cathode, and a connection between the said grid of the second valve and the second source of voltage whereby the two electromagnetic devices may be operated by varying the voltage supplied by the control means to the said grid of the first valve.

2. Electromagnetic apparatus according to claim 1 wherein the control means comprises a cathode follower stage, a device which is adapted to provide a control voltage which may be varied over a range of values on either side of including zero voltage, and means to supply a predetermined voltage in series with the control voltage to the said follower stage, and a connection for supplying the output voltage of the cathode follower stage to the grid of the first valve.

3. Electromagnetic apparatus according to claim 2 wherein the ampere-turns in the two windings of each electromagnetic device are arranged to be the same when the control voltage is zero.

4. Electromagnetic apparatus according to claim 1 wherein the first and second electromagnetic devices are differential relays.

5. Electromagnetic apparatus comprising first and second thermionic valves each of which has a cathode, a control grid and an anode, first and second electromagnetic relays which each has two positions of operation and two operating windings, a first winding of the first relay and a first winding of the second relay being connected to carry the anode currents of the first and second valves respectively, a further pair of valves which each have a control grid connected for parallel operation, the second operating windings of the two relays being connected in series to carry the combined anode current through the further valves in the direction so that the currents in the two windings of each relay tend to oppose one another, bias resistance having a pair of terminals connected in a common cathode circuit of the first and second valves and the further valves, control means adapted to supply a signal which may be varied to the said grid of the first valve, a first source of voltage which is positive relative to the terminal of the bias resistance remote from the cathode, resistance connected between the first source of voltage and the said grids of the further valves, a rectifier connected between the said grid of the first valve and the said grids of the further valves so as to permit the flow of current to the grid of the first valve, a second source of voltage which is positive relative to the terminal of the bias resistance remote from the cathode and a connection between the said grid of the second valve and the second source of voltage whereby the two relays may be operated by varying the voltage supplied by the control means to the said grid of the first valve.

6. Electromagnetic apparatus according to claim 5 wherein the pair of further valves and the first and second valves all have the same electrical characteristics while the turns of the first and second windings of each relay are in the ratio two to one.

7. Electromagnetic apparatus according to claim 5 wherein the control means comprises a cathode follower stage, a device which is adapted to provide a control voltage which may be varied over a range of values on either side of and including zero voltage, a means to supply a predetermined voltage in series with the control voltage to the cathode follower stage, and a connection for supplying the output voltage of the cathode follower stage to the grid of the first valve.

8. Electromagnetic apparatus according to claim 7 wherein the pair of further valves and the first and second valves all have the same electrical characteristics while the turns of the first and second windings of each relay are in the ratio two to one so that one relay is operated when the control voltage has a predetermined positive value while the other relay is operated when the control voltage has the same predetermined negative value.

9. Electromagnetic apparatus according to claim 8 wherein the second source of positive voltage is formed by a potentiometer which is connected across the said first source, the said grid of the second valve being connected to a tapping on this potentiometer.

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