Feb. 14, 1950 J. P. PALMER 2,497,514

RELAY SERVO

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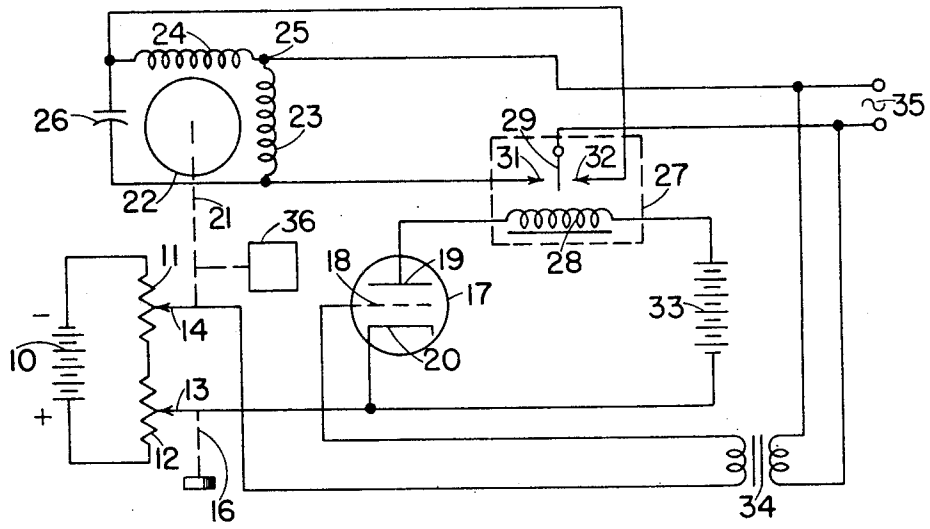

Fig. 1

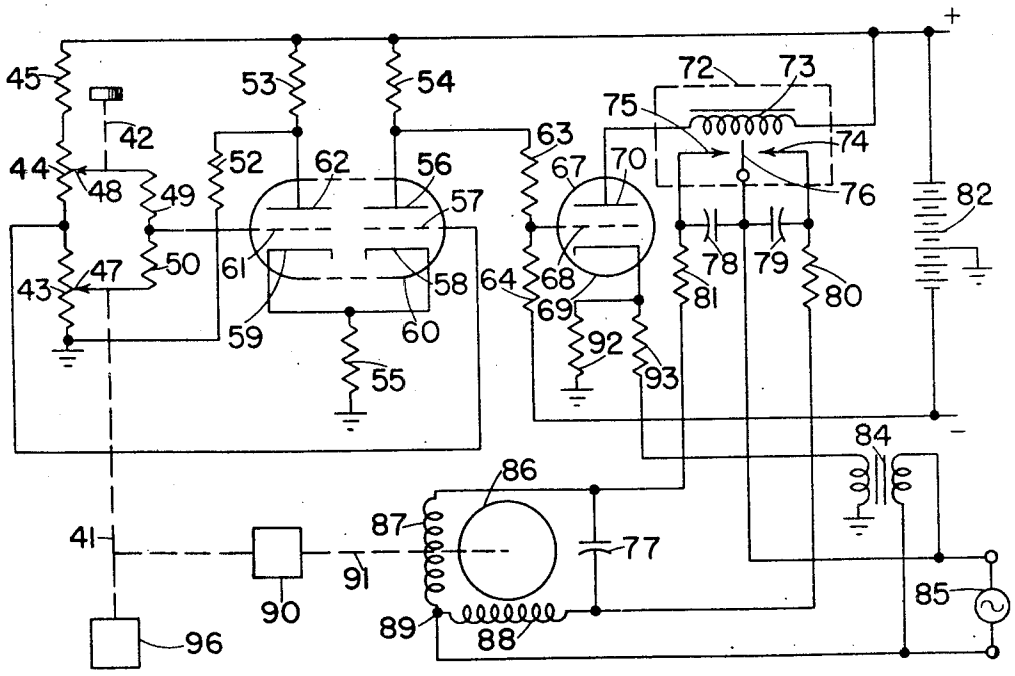

Fig. 2

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RELAY SERVO

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My invention relates to a critically damped relay servo having few components and which is relatively simple in operation but nevertheless exceedingly accurate.

Servo devices find extensive use in all manner of systems and frequently a single fire control system, analyzer system, training apparatus or the like will use hundreds of such devices. It is of the utmost importance therefore that such devices be as small as possible and be restricted to as few circuit components as will satisfactorily produce the intended results.

One of the objects of my invention therefore is to provide a relay servo which is simple in construction, has few circuit components but which nevertheless is reliable and accurate in operation.

Another object of my invention is to provide an improved apparatus whereby position and movement of a first device may be accurately translated into corresponding position and movement of a second device operating a load which may be remotely located.

These and other objects and advantages of my invention will be apparent from the following specification when taken with the accompanying drawings in which:

Fig. 1 is a circuit diagram illustrating one form of my invention; and Fig. 2 is a circuit diagram illustrating a modified form of my invention.

Referring to Fig. 1 a manually operable or automatically controlled input shaft 16 is mechanically connected to the adjustable contact 13 of a potentiometer 12. The output shaft 21 which is desired to be moved to the same angular position occupied by input shaft 16, is mechanically connected to movable contact 14 of potentiometer 11 and to a load 36. Potentiometers 11 and 12 identical in value and construction, are connected in series across a potential source indicated diagrammatically by the battery 10.

The relay indicated by the dotted line 27 includes the relay coil 28, contacts 31 and 32 and a vibrating reed armature 29.

This relay is so constructed that the vibrating reed 29 engages contact 31 when the current through the relay coil 28 is below a predetermined minimum, for example —6 ma. On the other hand, when the current in the relay coil exceeds this value, the vibrating reed 29 is caused to engage the contact 32. The relay has a low moment of inertia and may be operated at a rapid rate.

The variable contact 14 of the potentiometer 11 is moved by the output shaft 21 which in turn is operated by a two phase motor 22 having field windings 23 and 24 connected together at the

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point 25, the opposite ends of which are connected respectively to the contacts 31 and 32. Shunted across these windings is a condenser 26 and power for the motor is supplied from alternating current source 35 connected at one side to the common point 25 of the windings 23 and 24 and the other side to the vibrating reed armature 29.

The operation of the motor circuit is as follows: Assuming the current in relay coil 28 is below the predetermined minimum, the armature 29 engages contact 31 and power is supplied from the alternating current source 35 directly across winding 23 and to winding 24 in series with condenser 26. It will thus be seen that the voltage across winding 24 leads that across winding 23 by 90 degrees. Under these circumstances the motor revolves in a counter clockwise direction.

On the other hand if the current in coil 28 exceeds the predetermined minimum, the armature 29 engages the contact 32 and power from alternating source 35 is supplied directly across the winding 24 and to winding 23 in series with condenser 26. Under these changed circumstances, the voltage across winding 23 leads that across winding 24 by 90 degrees and the motor now revolves in a clockwise direction. If the armature 29 is caused to vibrate rapidly between contacts 31 and 32 a torque is applied to the motor which first tends to turn it in a counter clockwise direction and then in a clockwise direction. If the times of engagement over a period of several cycles of the armature 29 with the contacts 31 and 32 are equal, no resultant motion of the motor will take place since it cannot respond to such rapid action.

On the other hand, if the average length of time of engagement of the armature 29 with one of the contacts 31 or 32 is greater than engagement with the other contact over an average of several cycles, there will be a resultant torque on the motor, tending to turn it either in a counter clockwise or clockwise direction, depending on which contact is engaged for the greater length of time.

This operation of the motor is used to position variable contact 14 of potentiometer 11 in exact relation with the actuation of movable contact 13 of the potentiometer 12 in the following manner: Assuming that shaft 16 is actuated in a direction so that the cathode 20 of discharge tube 17 is made less positive, that is to say, the contact 13 is movable upward on the diagram of Fig. 1. There is then, less potential difference between contacts 13 and 14 and less bias is impressed upon

the input of the discharge tube 17 and a greater amount of current is allowed to flow in the output thereof. This output is a pulsating current for the reason that superimposed on a direct current bias provided by the potential drop between contacts 13 and 14 is the alternating potential supplied from transformer 34. The output of discharge tube 17 therefore pulsates above and below the predetermined minimum and the armature 29 vibrates between the contacts 31 and 32. When the output is increased in the manner heretofore described, the output of the discharge tube 17 pulsates about a higher mean and the armature 29 is caused to engage the contact 32 for a greater average length of time than it engages contact 31. This results in a clockwise rotation of the motor 22 in the manner described hereinabove and this in turn results in a motion of movable contact 14 of potentiometer 11 in such a manner that a direct current bias impressed across the input is returned to its original value, that is, a value such that an output is produced in a coil 28 which varies equally above and below the predetermined mean returning the system to its normal operation where armature 29 engages contacts 31 and 32 for equal average lengths of time, thus stopping the motor. It will be seen therefore, that every movement of the input shaft 16 results in an equal amount of movement of the output shaft 21 and that both shafts at all times, seek equal angles of rotation.

Referring now to the modified form of my invention shown in Fig. 2 it will be seen that the input shaft 42 is connected with a movable contact 48 on a potentiometer 44 and the output shaft 41 is in turn connected to movable contact 47 on an identical potentiometer 43. These two potentiometers are connected in series in the manner described in reference to the circuit of Fig. 1 and to a regulated source of potential shown diagrammatically by the battery 82 through a limiting resistor 45. The movable contacts 47 and 48 are electrically connected together through resistors 49 and 50 which together with the portions of potentiometers included between contacts 47 and 48, constitute a bridge network. The mid point of resistors 49 and 50 is connected to the grid 61 of a differential amplifier 60 consisting of a double triode. The other grid 57 of this differential amplifier is connected to a point of fixed potential constituting the juncture of potentiometers 43 and 44. The cathodes 58 and 59 of the amplifier are connected together and to ground through resistance 55. The anode 62 is connected to the source of positive potential 82 through a resistance 53 and preferably although not necessarily, to ground through a resistance 52 whereby a fixed potential is maintained on the anode and greater amplification is obtained. Anode 56 is likewise connected to the potential source 82 through a limiting resistor 54 and likewise coupled to the input of a driver amplifier 67 through resistance 63 and 64. Alternating potential is applied to the input of the driver amplifier 67 in addition to the direct current potential supplied from a differential amplifier by means of the voltage produced across the secondary of transformer 84 connected to the cathode 69 through a resistance dividing network consisting of the resistors 92 and 93, thereby producing a pulsating current in the output of the driver amplifier.

As in the circuit discussed in connection with Fig. 1 the output of the driver amplifier 67 is connected to relay coil 73 operating a vibrating reed 76 to alternately engage contacts 74 and 75, thereby supplying a torque to a two phase motor 86 in the manner heretofore described in connection with Fig. 1. Limiting resistors 80 and 81 and shunt condensers 78 and 79 are provided in the relay contact circuits to reduce the sparking of the contacts when the relay is in operation.

The operation of the circuit of Fig. 2 may be briefly described as follows: When the resistance bridge network, consisting of those portions of potentiometers 43 and 44 which are between contacts 47 and 48 and resistors 49 and 50, is in balance the grids 57 and 61 are at equal potential with respect to their cathodes and equal currents are produced in the output of the respective triode portions of the thermionic discharge tube 60. The common cathode resistor 55 causes the discharge tube 60 to act in the manner of a differential amplifier.

Assuming now that the shaft 42 is so rotated that the contact 48 is moved upwardly as shown in the circuit diagram. Under these circumstances an unbalance is produced in the aforementioned resistance bridge network and in the particular case here discussed the grid 61 is made to assume a less negative potential thereby at the same time causing the cathode potential to increase in a positive direction by reason of the cathode follower action obtained by use of the high resistance 55. The output current of the triode section 59, 61 and 62 therefore increases and the output of the triode section 56, 57 and 58 decreases a substantially like amount.

The potential of the anode 56 therefore increases because of the decreased potential drop across resistance 54 and this increase is impressed upon the input of driver amplifier 67 through the coupling resistance 63 and 64. This increase of input potential, therefore, results in an increase current output through relay coil 73 which results in a greater average time engagement of the contact 76 with the contact 74 in the same manner as discussed above in connection with Fig. 1. This action in turn results in an average torque being placed on the motor causing it to revolve and this rotation transmitted through gearing means 90 operates a load 96 and also results in a rotation of output shaft 41 which causes contact 47 to rotate on the potentiometer 43 until the said contact is moved to such an extent that potential balance is again restored across bridge network consisting of resistors 49, 50 and the portion of potentiometers 43 and 44 which are between the movable contacts 47 and 48.

It will thus be apparent that by means of this device an accurate following movement takes place between the output shaft 41 and the input shaft 42 and that the potentials impressed upon the various elements of the differential amplifier are always brought back to their original values, resulting in accurate operation.

While there has been described what is considered the preferred embodiment of the invention, it will be obvious to those skilled in the art to which it appertains that various modifications may be made within the spirit and scope of the invention as set forth in the appended claims.

I claim:

1. In a servo mechanism of the class described, a thermionic amplifier, a source of direct current potential, a potentiometer connected to said source, a second potentiometer connected to said source and to said first potentiometer, variable contacts on said potentiometers, the variable contact on said first potentiometer being mechani-

cally connected to an input shaft, the variable contact on second potentiometer being mechanically connected to an output shaft and both said variable contacts being electrically connected to the input circuit of said amplifier, an alternating current supply, connections from said alternating current supply whereby a pulsating current is produced in said amplifier circuit whose average value is a function of the relative positions of said variable contacts on said potentiometers, a relay comprising an actuating coil, a pair of fixed contacts in opposed relations and a movable contact adapted for alternate engagement with said fixed contacts, said actuating coil being connected in said amplifier output circuit whereby said relay movable contact is caused to alternately engage said fixed contacts in timed relation with the frequency of the pulsating current in said amplifier output circuit, an electrical connection from said movable relay contact to one side of a source of alternating current potential, a connection from one of said fixed contacts to one end of one of a pair of field coils of a two phase motor, a connection from the other of said fixed contacts to one end of the other of said field coils, the other ends of said two field coils being connected together and to the other side of said source of alternating current potential, a condenser connected in parallel with said field coils and to said fixed contacts, and a mechanical connection from said motor to said output shaft whereby movement imparted to said input shaft results in an equal movement of said output shaft.

2. A servo mechanism comprising a resistance bridge having four bridge arms two of which comprise variable potentiometers each having variable contacts one of which is mechanically connected to an input shaft and the other which is mechanically connected to an output shaft, a pair of input terminals and a conjugate pair of output terminals for said bridge, a source of potential connected to said input terminals and a differential amplifier connected to said output terminals, a driver amplifier connected to the output of said differential amplifier, an alternating current source connected to the input of said driver amplifier, a double throw single pole relay connected in the output circuit of said driver amplifier, means whereby said relay is caused to be actuated for alternate engagement of its contacts in substantial timed relation with the frequency of the alternating current and the relative times of engagement with the respective contacts is proportional to the average value of the amplified alternating current in the output circuit of said driver amplifier, rotary means actuated by said relay and means connecting said rotary means to said output shaft whereby motion imparted to said input shaft results in an equal motion of said output shaft.

3. In a servo mechanism, a differential amplifier having a first section and a second section, a common cathode circuit for said sections including a substantially high resistance, an input circuit for said amplifier sections comprising a first potentiometer, a second potentiometer, said potentiometers being connected in series across a source of direct current potential, a connection from the junction of said potentiometers to the grid of said second section, a variable contact for said first potentiometer, a variable contact for said second potentiometer said variable contacts being connected together through a pair of resistors connected in series, a connection from the juncture of said series

resistors to the grid of said first amplifier section, a connection from one of said potentiometer variable contacts to an input shaft, a connection from the other of said variable contacts to an output shaft, a second amplifier connected to the output of said second section of said differential amplifier, an alternating current supply impressed on the input of said second amplifier whereby a pulsating current is produced in the output thereof whose average value is a function of the relative positions of said variable contacts of said potentiometers, and means operated by said pulsating current for imparting movement to said output shaft in accordance with the movement of said input shaft.

4. In a servo mechanism, a differential amplifier having a first section and a second section, each of said sections including a cathode, grid and anode, a common circuit for said cathodes including a substantially high resistance, an impedance bridge circuit having its input terminals connected to a source of current supply and its conjugate output terminals connected to the respective grids of said differential amplifier sections, means for maintaining the potential applied to the anode of said first differential amplifier section substantially constant, means for varying the impedance of one arm of said impedance bridge in accordance with the position of an input shaft, means for varying the impedance of another arm of said bridge in accordance with the position of an output shaft whereby said bridge circuit is balanced when said input and output shafts assume the same relative positions and is unbalanced when said input and output shafts assume different relative positions, means connected to the output of the second section of said differential amplifier for producing a fluctuating current the average value of which is directly proportional to the amount of unbalance produced in said bridge circuit, switching means operable by and in timed relation to said fluctuating current for actuating a two phase motor in accordance with the average value of said fluctuating current, means connecting said motor to said output shaft whereby said bridge circuit is maintained in balance and said input shaft and said output shaft are caused to assume the same relative positions at all times.

5. In a servo mechanism, a two phase motor connected to an output shaft, means for alternately applying a positive and negative torque to said motor comprising vibrating switching means alternately connecting one or the other of the field windings of said motor to an alternating current source in series with a condenser, means for actuating said switching means to its alternate connecting positions in timed relation to the frequency of the alternating current source and for varying the relative length of time of engagement of said switching means in its alternate actuating position comprising a thermionic amplifier whose input is varied in accordance with the difference in angular positions of an input shaft and said output shaft whereby said output shaft is caused to assume the same position as said input shaft at all times.

6. In a servo mechanism, a two phase motor connected to an output shaft, means for alternately applying a positive and negative torque to said motor comprising vibrating relay switching means alternately connecting one or the other of the field windings of said motor to an alternating current source in series with a condenser, means for actuating said switching means to

its alternate connecting positions in timed relation to the frequency of the alternating current and for varying the relative length of time of engagement of said switch means in its alternate actuating positions comprising a differential amplifier and a resistance bridge network connected to the input of said amplifier, the said bridge network being connected for actuation by an input shaft and said output shaft whereby said bridge is balanced when said input shaft and said output shafts have the same positions and is unbalanced when said input shaft and said output shaft have different angular positions.

7. A servo mechanism comprising a differential amplifier having a first section and a second section, a common cathode circuit for said sections including an unbypassed resistor of substantial resistance whereby a variation in the anode current of one section varies the input potential of the other section, a bridge circuit having four bridge arms, two of which comprise potentiometers having variable contact arms, an input shaft operatively connected to one of said contact arms, an output shaft operatively connected to the other of said contact arms, a pair of input terminals and a pair of conjugate output terminals for said bridge, a source of potential connected to said input terminals and connections from said output terminals to the grids of said differential amplifier sections, a driver amplifier connected to the output of said second differential amplifier section, a source of alternating current potential connected to the input of said driver amplifier and means connected to said driver amplifier output circuit and operated by the current flow therein whereby movement imparted to said input shaft is reflected in an equal movement of said output shaft.

8. In a servo mechanism, a differential amplifier having a first section and a second section, a common cathode circuit for said sections including an unbypassed resistor of substantial resistance whereby a variation in the anode current of one section varies the input potential of the other section, a bridge network having its input terminals connected to a source of supply and having its conjugate output terminals connected respectively to the grids of said amplifier sections, means for varying the impedance of one arm of said bridge network in accordance with the position of an input shaft, means for varying the impedance of another arm of said bridge network in accordance with the position

of an output shaft, means connected to the output circuit of one of said amplifier sections for producing an alternating current having an average value which is a function of the unbalance of said bridge network, relay means operable by said alternating current for controlling the rotation of motor means in accordance with the average value of said alternating current and a mechanical connection between said motor means and said output shaft whereby said bridge network is maintained in balance and the relative position of said input shaft and said output shaft is maintained substantially constant.

9. In a servo mechanism, an amplifier, a bridge network having its input terminals connected to a source of current supply and having its conjugate output terminals connected to the input circuit of said amplifier, means for varying the impedance of one arm of said bridge network in accordance with an input quantity, means for varying the impedance of a second arm of said bridge network in accordance with the position of an output shaft, an alternating current supply, circuit means for imposing alternating current derived from said alternating current supply on said amplifier whereby the output thereof constitutes a pulsating current the average value of which is a function of the unbalance of said bridge network, a double throw single pole relay connected in the output of said amplifier actuated for alternate engagement of its contacts in substantial timed relation with the cyclic variations of said pulsating current, the relative times of engagement with the respective contacts being proportional to the average value of said pulsating current, motor means actuated by said relay and a connection between said motor means and said output shaft.

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