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LIMIT SWITCH CIRCUIT WITH VACUUM TUBE SERVO-AMPLIFIERS

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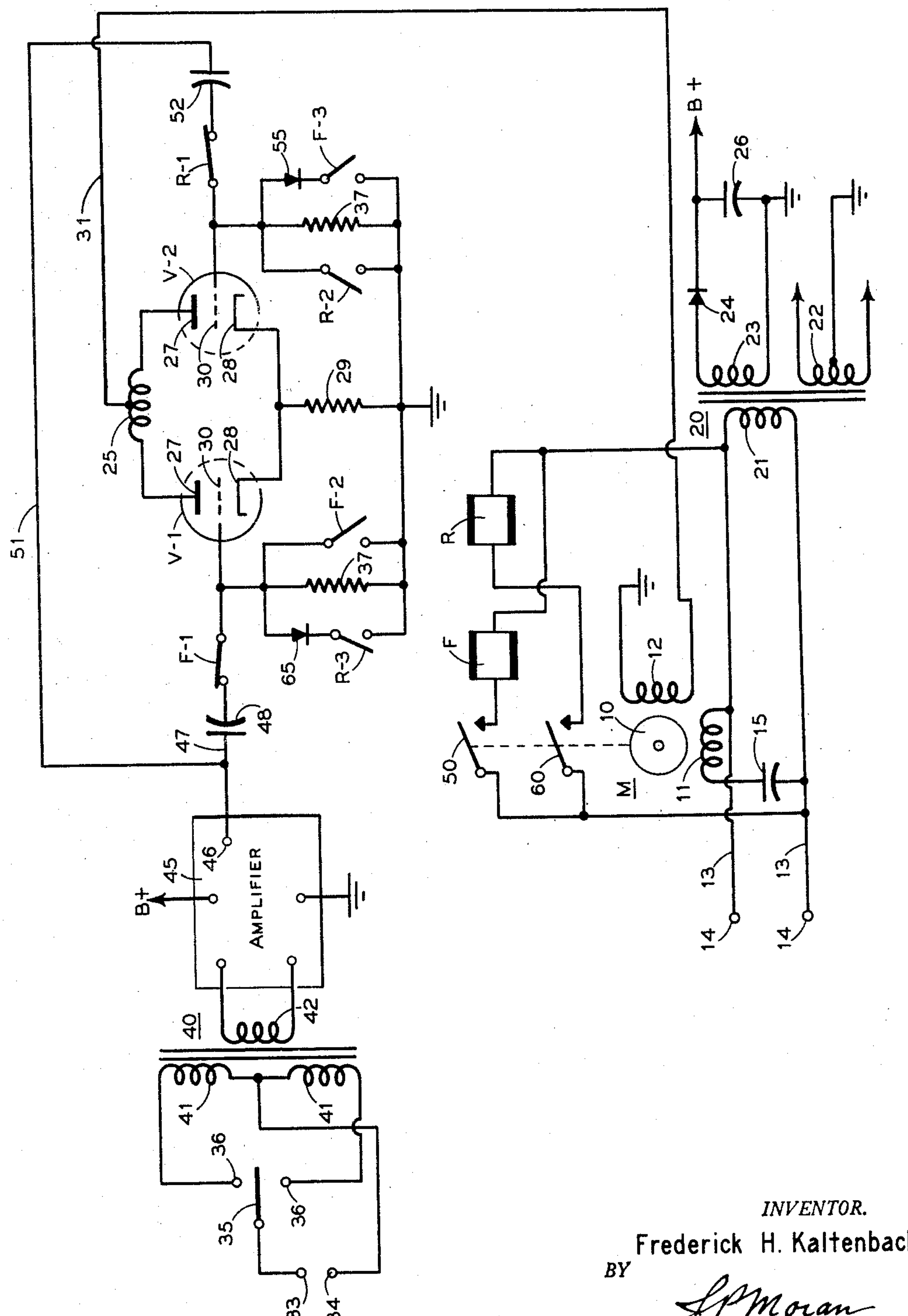

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LIMIT SWITCH CIRCUIT WITH VACUUM TUBE SERVO-AMPLIFIERS

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This invention relates to servomotor systems of the type including limit switches, and, more particularly, to a novel servomotor system of this type including novel means for maintaining stable sensitivity of the system when a limit switch is operated.

A well-known and widely used servomotor system employs a pair of grid controlled electronic valves connected in phase detecting relation to operate a reversible electric motor in selected opposed directions in accordance with the relative phase of a suitably amplified signal input voltage applied to the control grids of the valves. The motor may be, for example, a split phase condenser type motor operating a valve or the like. At either limit of movement of the operated member, a limit switch is operated to prevent further movement in the same direction while permitting movement in the reverse direction when the input signal calls for such reverse movement.

As the limit switch included in the energizing circuit for such reverse direction rotation of the motor remains unoperated when the "forward" limit switch has thus been opened, there is a tendency for the motor to "creep back" if the control system is maintained at a desired sensitivity to the input signal. Attempts to eliminate such "creep back" tendency have resulted in undesirable loss of sensitivity in the system.

In accordance with the present invention, an improved servomotor circuit of the limit switch type is provided in which the tendency of the motor to "creep back" when a limit switch is operated is eliminated without in any way reducing the sensitivity of the system to an input signal calling for operation in the reverse direction.

More specifically, a pair of relays are provided each operated whenever the associated limit switch is operated at the limit of operation in one direction. Each relay includes a normally closed switch and a pair of normally open switches. When a relay is operated by operation of its controlling limit switch, the normally closed relay switch is opened to interrupt the signal input to the control grid of the then dominant electronic valve. At the same time, the two normally open relay switches are closed. One of these latter switches shunts the control grid of the dominant electronic valve to ground. The other normally open relay switch connects a diode between the control grid of the other electronic valve and ground. As a result, the two electronic valves are returned to the stable condition existing when there is no signal input, and the motor is held against movement. However, if a "reverse" input signal is received, such other electronic valve causes the motor to turn in the reverse direction, restoring the previously operated limit switch and returning the system to normal.

For an understanding of the invention principle, reference is made to the following description of a typical embodiment thereof as illustrated in the accompanying drawing.

In the drawing the single figure is a schematic wiring diagram of a servomotor limit switch system embodying the invention.

Referring to the drawing, the invention is illustrated as embodied in a servomotor system for operating a split-phase motor M including an armature **10** and windings **11** and **12**. Winding **11** is connected across a supply circuit comprising conductors **13—13** extending from terminals **14—14** connected to a suitable supply of alternating current, winding **11** being connected across conductors **13—13** in series with a condenser **15**. Conductors **13—13** also supply current to the primary winding **21** of a transformer **20** having secondary windings **22** and **23**. Winding **22** supplies the low voltage filament heating supply for the system, whereas winding **23**, through a rectifier **24** and by virtue of a by-pass condenser **26**, supplies B^+ potential for the system.

The second motor winding **12** is arranged to be energized, selectively as to relative phase, through the medium of a pair of grid controlled electronic valves V–**1** and V–**2** which, in the illustrated example, are vacuum tubes and may be a pair of independent tubes or may be two triodes included in the same envelope. For this purpose, a transformer secondary winding **25** is connected at its opposite ends to the plates or anodes **27—27** of tubes V–**1** and V–**2**, the primary winding (not shown) coupled to winding **25** being connected to the A.C. supply circuit. The cathodes **28—28** of the two tubes are commonly connected to ground through a resistor **29**. A conductor **31** connects the midpoint of winding **25** to one end of motor winding **12**, the other end of this winding being grounded.

The control grids **30** of valves V–**1** and V–**2** are arranged to have a signal potential applied thereto to control the rotation and direction of operation of motor M, which later may, for example, operate a valve or any other controlled member, the control signal being variable in phase in accordance with the desired direction of rotation of the motor. The control may be applied in any desired manner such as, for example, by applying the output of a telemeter coil directly to amplifier **45**, or by applying a D.C. signal of reversible polarity through a chopper or inverter to transformer **40**. By way of giving a specific example, and not by way of limitation in any manner, the control signal is illustrated as applied to signal input terminals **33—34**. Terminal **33** is connected to a suitable signal sense selector **35**, illustrated, solely by way of example, as a switch arm selectively engageable with either of a pair of contacts **36—36** connected to the outer ends of series connected primary windings **41—41** of transformer **40**. The midpoint or junction of primary windings **41** is connected to terminal **34**. The signal voltage from transformer secondary winding **42** is amplified by amplifier **45** and the amplified signal voltage is taken from output terminal **46** of the amplifier. Output terminal **46** is connected by a conductor **47** through a condenser **48** to grid **30** of valve V–**1**. Similarly, output terminal **46** is connected by a conductor **51** through a condenser **52** to grid **30** of valve V–**2**. Each of the grids **30** is connected to ground through a biasing resistor **37**.

In ordinary operation, motor M is stationary when no signal is applied to grids **30** of valves V–**1** and V–**2**, as both valves conduct equally thus cancelling the tendency of each to cause the motor to rotate. Should an A.C. signal be received, due to, for example, movement of selector **35** into engagement with one or the other of contacts **36**, it is fed into amplifier **45** with its relative phase dependent upon which of contacts **36** is engaged. Upon receipt of such a signal by amplifier **45**, an unbalanced condition is created causing one valve to increase its current and the other valve to decrease its current. This provides a directive effect on the current output of the two valves, and the resulting current flow causes the motor to rotate in a selected direction. Should the signal-phase be shifted 180°, as by selector **35** engaging the other contact **36**, the electronic valve action is reversed as to current flow direction, thus reversing the relative phase of the current supplied to the motor winding 12. This causes motor M to operate in the reverse direction.

At either limit of the operation of the control member, such as a valve for example, a limit switch 50 or 60 is operated either directly by the motor or by the controlled member. For convenience, limit switch 50 will be referred to as the "forward" limit switch whereas limit switch 60 will be referred to as the "reverse" limit switch, these references being solely relative. Limit switch 50 is connected across conductors 13—13 in series with a "forward" relay F, and limit switch 60 is connected across conductor 13—13 in series with a "reverse" relay R. Relay F includes a normally closed relay switch F–1 and a pair of normally open relay switches F–2 and F–3. Similarly, relay R includes a normally closed relay switch R–1 and a pair of normally open relay switches R–2 and R–3. Normally closed relay switch F–1 is connected in series between condenser 48 and the control grid 30 valve V–1, whereas normally closed relay switch R–1 is connected in series between condenser 52 and control grid 30 of valve V–2. Relay switches F–2 and R–2 are respectively connected in shunt with the biasing resistors 37 for the control grids of valves V–1 and V–2 respectively. Relay switch F–3 is arranged, when closed, to connect a diode 55 between the control grid of valve V–2 and ground. Similarly, relay switch R–3 is arranged, when closed by energization of relay R, to connect a diode 65 between control grid 30 of valve V–1 and ground. While the limit switches are illustrated as normally open and the relays as normally "dropped," the arrangement is equally effective with normally closed limit switches operating normally energized or "picked up" relays.

The particular arrangement illustrated operates in the following manner. Should the controlled member operated by motor M reach its limit of movement in the "forward" direction, limit switch 50 is closed. During such "forward" movement, the relative phase of the input signal is such that the current of valve V–1 is increased and that of valve V–2 is decreased. When limit switch 50 is thus closed, relay F is energized to open relay switch F–1 and close relay switches F–2 and F–3. Opening of relay switch F–1 interrupts the control signal supply to control grid 30 of valve V–1, closure of relay switch F–2 connects this control grid to ground, and closure of relay switch F–3 connects diode 55 between control grid 30 of valve V–2 and ground. This results in the two valves returning to their stable condition with no effective operating current being applied to motor M.

Should the signal switch now be shifted 180°, the amplified signal current applied to grid 30 of valve V–2 causes an increase in the current flow through this valve and thus a 180° reversal in phase of the current through motor winding 12. This causes the motor to operate in the reverse direction and, as the motor "backs up," limit switch 50 is re-opened. Opening of swiftch 50 drops relay F to re-close relay switch F–1 and re-open switches F–2 and F–3, restoring the system to the normal condition illustrated in the drawing.

An analogous sequence of operations occurs when the operated member reaches its limit of movement in the "reverse" direction, and the operation under such conditions is believed sufficiently clear from the foregoing explanation that no detailed description is necessary.

While a specific embodiment of the invention has been shown and described in detail to illustrate the application of the invention principle, it will be understood that the invention may be embodied otherwise without departing from such principle.

What is claimed is:

1. A servo-motor circuit comprising, in combination, an A.C. motor having a winding controlling its direction of rotation; a pair of grid controlled electronic valves connected, in phase-detecting relation, to said winding; signal input means operable to apply a signal voltage to the grid circuits of said valves; a pair of diodes each connected to the grid circuit of one of said valves; and switch means, connected between the grid of each valve and the signal input means and between each diode and ground, and operable by said motor at its limit of operation in each direction to disconnect the grid circuit of one valve from said signal input means, and to connect one of said diodes across the grid circuit of the other valve; said switch means being operable, upon a reversal in the direction of operation of said motor, to reconnect the grid circuit of said one valve to said signal input means, and to disconnect said diode from the grid circuit of the other valve.

2. A servo-motor circuit comprising, in combination, an A.C. motor having a winding controlling its direction of rotation; a pair of grid controlled electronic valves connected, in phase-detecting relation, to said winding; signal input means operable to apply a signal voltage to the grid circuits of said valves; a pair of diodes each connected to the grid circuit of one of said valves; and switch means, connected between the grid of each valve and the signal input means and between each diode and ground, and operable by said motor at its limit of operation in each direction to disconnect the grid circuit of one valve from said signal input means and ground such disconnected grid circuit, and to connect one of said diodes across the grid circuit of the other valve; said switch means being operable, upon a reversal in the direction of operation of said motor, to reconnect the grid circuit of said one valve to said signal input means and to remove such ground, and to disconnect said diode from the grid circuit of the other valve.

3. A servo-motor circuit comprising, in combination, an A.C. motor having a winding controlling its direction of rotation; a pair of grid controlled electronic valves connected, in phase-detecting relation, to said winding; signal input means operable to apply a signal voltage to the grid circuits of said valves; a pair of diodes each connected to the grid circuit of one of said valves; a pair of relay means each having armatures connected between the grid of one valve and the signal input means and between one diode and ground, and each operable to disconnect the grid circuit of one valve from said signal input means, and to connect one of said diodes to ground across the grid circuit of the other valve; and switch means operable by said motor at its limit of operation in each direction to selectively operate one of said relay means; said switch means being operable, upon a reversal in the direction of operation of said motor, to restore the operated relay means to reconnect the grid circuit of said one valve to said signal input means, and to disconnect said diode from the grid circuit of the other valve.

4. A servo-motor circuit comprising, in combination, an A.C. motor having a winding controlling its direction of rotation; a pair of grid controlled electronic valves connected, in phase-detecting relation to said winding; signal input means operable to apply a signal voltage to the grid circuits of said valves; a pair of diodes each connected to the grid circuit of one of said valves; a pair of relay means each having armatures connected between the grid of one valve and the signal input means and ground and between one diode and ground, and each operable to disconnect the grid circuit of one valve from said signal input means and ground such disconnected grid circuit, and to connect one of said diodes to ground across the grid circuit of the other valve; and switch means operable by said motor at its limit of operation in each direction to selectively operate one of said relay means; said switch means being operable, upon a reversal in the direction of operation of said motor, to restore the operated relay means to reconnect the grid circuit of said one valve to said signal input means and to remove such

ground, and to disconnect said diode from the grid circuit of the other valve.

5. A servo-motor circuit comprising, in combination, an A.C. motor having a winding controlling its direction of rotation; a pair of grid controlled electronic valves connected, in phase-detecting relation, to said winding; signal input means operable to apply a signal voltage to the grid circuits of said valves; a pair of diodes each connected to the grid circuit of one of said valves; a pair of normally closed switches each connected in series between said signal input means and one of said grid circuits; a pair of normal open switches each connected in series between one of said diodes and ground across one of said grid circuits; and limit means operable by said motor at its limit of operation in each direction to open the normally closed switch in one grid circuit and close the normally open switch in the other circuit; said limit means being operable, upon a reversal in the direction of operation of said motor, to restore said switches to their normal condition.

6. A servo-motor circuit comprising, in combination, an A.C. motor having a winding controlling its direction of rotation; a pair of grid controlled electronic valves connected, in phase-detecting relation, to said winding; signal input means operable to apply a signal voltage to the grid circuits of said valves; a pair of diodes each connected to the grid circuit of one of said valves; a pair of normally closed switches each connected in series between said signal input means and one of said grid circuits; a pair of first normally open switches each connected between one of said grid circuits and ground; a pair of second normally open switches each connected in series between one of said diodes and ground across one of said grid circuits; and limit means operable by said motor at its limit of operation in each direction to open the normally closed switch in one grid circuit and close the first normally open switch therein, and to close the second normally open switch in the other grid circuit; said limit means being operable, upon a reversal in the direction of operation of said motor, to restore said switches to their normal condition.

7. A servo-motor circuit comprising, in combination, an A.C. motor having a winding controlling its direction of rotation; a pair of grid controlled electronic valves connected, in phase-detecting relation to said winding; signal input means operable to apply a signal voltage to the grid circuits of said valves; a pair of diodes each connected to the grid circuit of one of said valves; a pair of normally closed switches each connected in series between said signal input means and one of said grid circuits; a pair of normally open switches each connected in series between one of said diodes and ground across one of said grid circuits; a pair of relay means each operable to open the normally closed switch in one grid circuit and close the normally open switch in the other

circuit; and switch means operable by said motor at its limit of operation in each direction to selectively operate one of said relay means; said switch means being operable, upon a reversal in the direction of operation of said motor, to restore the operated relay means to restore said switches to their normal condition.

8. A servo motor circuit comprising, in combination, an A.C. motor having a winding controlling its direction of rotation; a pair of grid controlled electronic valves connected, in phase-detecting relation, to said winding; signal input means operable to apply a signal voltage to the grid circuits of said valves; a pair of normally closed switches each connected in series between said signal input means and one of said grid circuits; a pair of normally open switches each connected between one of said grid circuits and ground; a pair of relay means each operable to open the normally closed switch in one grid circuit and close the normally open switch therein; and switch means operable by said motor at its limit of operation in each direction to selectively activate one of said relay means; said switch means being operable, upon a reversal in the direction of operation of said motor, to deactivate the activated relay means to restore said switches to their normal condition.

9. A servo-motor circuit comprising, in combination, an A.C. motor having a winding controlling its direction of rotation; a pair of grid-controlled electronic valves connected in phase-detecting relation to said winding; signal input means operable to apply a signal voltage to the grid circuits of said valves; a pair of diodes each connected to the grid circuit of one of said valves; a pair of normally closed switches each connected in series between said signal input means and one of said grid circuits; a pair of first normally open switches each connected between one of said grid circuits and ground; a pair of second normally open switches each connected in series between one of said diodes and ground across one of said grid circuits; a pair of relay means each operable to open the normally closed switch in one grid circuit and close the first normally open switch therein, and to close the second normally open switch in the other grid circuit; and switch means operable by said motor at its limit of operation in each direction to selectively activate one of said relay means; said switch means being operable, upon a reversal in the direction of operation of said motor, to deactivate the activated relay means to restore said switches to their normal condition.

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