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LIMIT SWITCH SYSTEM FOR SERVO-MOTOR CIRCUITS

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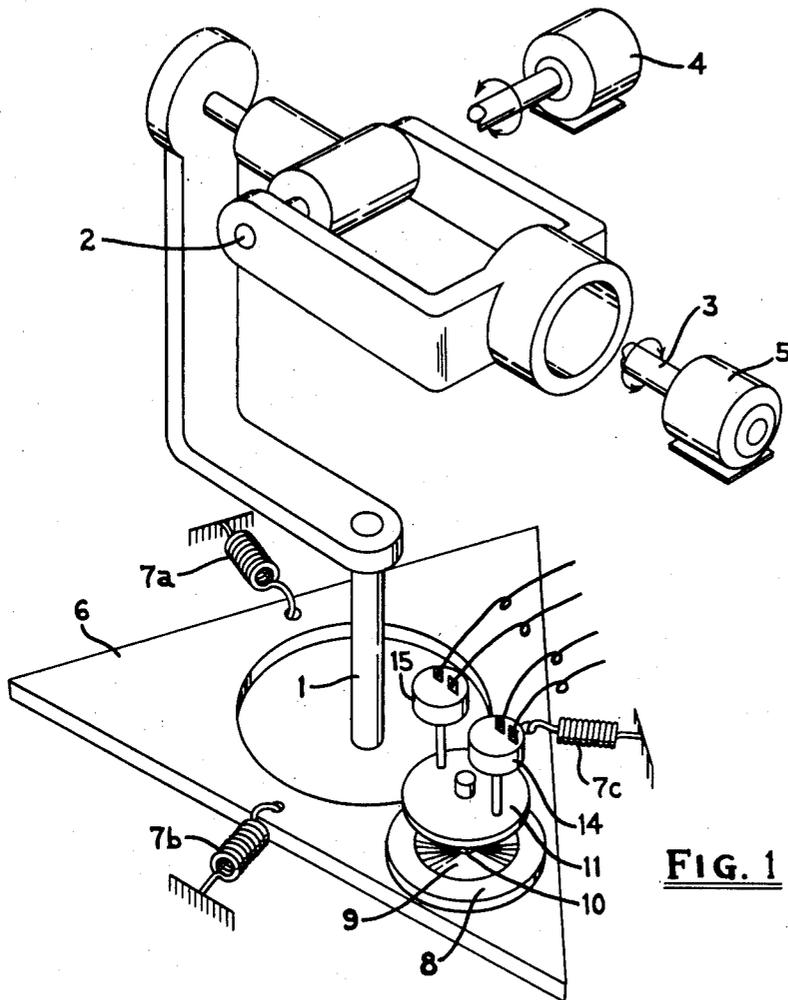


FIG. 1

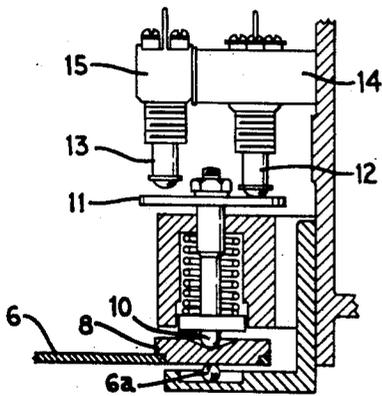


FIG. 2

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LIMIT SWITCH SYSTEM FOR SERVO-MOTOR CIRCUITS

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This invention relates to servo systems and is particularly directed to limit switches for the motor of the system.

The usual servo systems comprise a motor for driving a movable element and a power source for driving the motor, with the power source directly or indirectly responsive to the position of the driven element, after comparison with a command signal. That is, the position of the driven element is made to be analogous to the command signal. Unfortunately, the driven element must have limits of movement, and once those limits are exceeded, the feedback information from which the motor driving power is determined becomes meaningless, and the servo system becomes decalibrated or inoperative.

The object of this invention is an improved servo system in which a motor-driven element may enter and pass limits of motion without losing calibration and without damage to the element.

The principles of this invention will become apparent to those skilled in the servo system art by referring to the specific embodiment hereinafter described and shown in the accompanying drawings in which:

Fig. 1 is a perspective view illustrating a limit switch mechanism of this invention,

Fig. 2 is an elevation partly in section of the principal switches of this invention, and

Fig. 3 is a diagram of limit switch circuits of this invention.

While the servo system here contemplated is particularly useful in fire control systems, it will be seen that the servo system is of general application. In the resolver of Fig. 1 where two right angle shaft rotations are converted to polar motion, each of the two driving motors must be protected should they drive the resolver into its limits of motion. In Fig. 1 the finger 1 is carried upon a gimbal structure with two right angle axes of rotation, 2 and 3. The two motors for driving the finger to any point in a single plane are shown at 4 and 5. The limit of motion of the finger is assumed to be a circle which is defined by a large round opening in the plate 6. That is, when the finger reaches the periphery of the opening of the plate 6 the power to motors 4 and/or 5 must be interrupted or reduced to prevent damage to the mechanism, and to thereafter permit the finger to return to properly calibrated motion within the circle. The particular mechanism shown in Fig. 1 comprises the essential elements of a resolver in which the direction of the finger is made to be analogous to the direction of the bore sight of a rifle. That is, the input to motor 4 may correspond to the deck deflection, *D'd*, on which is mounted the sight of a gun director. The other motor 5 in such a system would receive information corresponding to director elevation, *V'd*.

Plate 6 is mounted to freely move in all directions in its own plane with as little friction as possible, and is constrained in three directions by coplanar light weight springs 7a, 7b, and 7c. The plate should be supported from below as by unrestrained steel balls 6a rolling be-

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tween the underside of plate 6 and parallel hardened steel bearing surfaces, as suggested in Fig. 2. Mounted upon one corner of the plate is a detent or circular disk-like button 8 with a concentric conical recess 9 also hardened and smooth. A round nosed push rod 10 rides with light pressure normally in the bottom of the recess so that horizontal motion of the disc in any direction moves the plunger 10 upwardly. Carried on the upper end of the push rod is a small plate 11 immediately below the lower ends of the actuating rods 12 and 13 of switches 14 and 15. The upper surface of plate 11 in its lowermost position is just short of actuating the switch 14. However, plunger 13 of switch 15 is spaced above the plate a measured distance so that for a greater lateral travel of plate 6 switch 14 responds, and when finger 1, because of its inertia or for other causes, moves outwardly into the ring an additional distance of, say, one or two degrees of finger movement then switch 15 is actuated. Switch 14 may thus be termed the inner ring switch and switch 15 may be called the outer ring switch.

Referring to the circuit diagram of Fig. 3 it will be found that the inner ring switch 14 and the outer ring switch 15 successively operate to first stop the motors 4 and 5 and to then apply full reversing torque to the motors. In Fig. 3 the servo motor 4 is supplied with primary power of either polarity from the servo amplifier 20. The servo motor 5 is powered by the servo amplifier 21. The upper or direct lead to each motor may be a neutral or ground potential. Feedback (not shown) from the output of the motor to an error determining circuit controls the amplitude and sign of the power output of amplifiers 20 and 21, as is well understood in the servo system art. The dotted lines in Fig. 3 represent mechanical connections between the mechanically movable elements illustrated whereas the solid lines represent the electric connections of the system.

Assume that finger 1 touches the ring 6 and that inner ring switch 14 is closed. Immediately the voltage source at terminals 22 energizes the coils of relays 23 and 24, pulling up their several armatures. Armatures 25 immediately open circuits to the servo amplifier-to-motor circuit and armature 25a connects in series therewith the resistor 26. The resistor 26 is of such ohmic value compared to the impedance of motor 4 and to its power source at 20 that the torque of the motor 4 is reduced not to zero but to a small fraction of its full torque. In normal operation this reduced torque is just sufficient to hold the finger 1 against the limit ring 6 without actuating the outer ring switch 15. If for any reason the finger 1 leaves the ring 6 as by a reversed command signal or by movement of the other motor 5, then switch 14 opens and relays 23 and 24 drop out returning the amplifier-to-motor connections to normal.

As long as the signal of amplifier 20 to the motor is, for example, grounded on the upper lead and the lower lead being negative to drive the finger further into limits, the finger will remain against the ring but with insufficient torque to trip the outer ring switch 15. Should the signal of amplifier 20 reverse, however, to make the lower lead positive, the series resistor 26 will be short circuited by the armature of relay 45 and the motor will drive the finger out of limits under full torque. The particular circuit responsive to this reversed signal for operating relay 45 comprises the amplifier tube 46 in series with the winding of relay 45, the grid circuit of the amplifier 46 being made through the armature 47 of inner ring relay 23. It follows that when the grid circuit of 46 senses the reversed polarity of the motor signal, when the tower lead of servo amplifier 20 becomes positive, the current through 46 and its series winding 45 changes to effect the mentioned short circuit. To avoid relay 45 operation for negative inputs through armature 47 by reason

of a positive charge left on the capacitor 48, a voltage dropping resistor 49 couples the lower plate of this capacitor to ground.

In addition to reducing the motor torque when switch 14 closes, relay 24, through its armature contacts 27, operates the magnetically controlled brakes 28 and 29 to momentarily apply full braking power to both motors 4 and 5. In one application of the invention, where motors 4 and 5 each has a full torque of the order of twenty ounce-inches, a commercial magnetic brake was used in which the motors could be brought to a full stop in less than two degrees of motion of the finger. Preferably, the brakes are of the type which are engaged by spring action to stop the motor and are disengaged by magnetic action to free the motor. That is, when the magnetizing circuit is opened, the brake grabs and stops the motor. Hence, when the relay winding 24 pulls up armature 27 in response to the closure of switch 14, armature 27 first interrupts the power to the brake magnets 28 and 29. Now, according to an important feature of this invention, after a predetermined time delay of, say, .15 second, switch 30a is closed to re-establish the circuit between the brake magnets and their power supply 31, and to remove the brake drag on the motors 4 and 5. A number of devices and circuits may be designed for momentarily opening the magnetic brake circuits including various dash pots and slow return relays. The time delay means shown in Fig. 3, however comprises the amplifier 32 with the time constant condenser-resistor CR in the grid circuit thereof for measuring a delay between periods of cut-off of tube 32. The winding 30 for switch 30a is connected directly in the circuit of tube 32 and stands energized to hold 30a open. In operation, the instant the contacts 27 operate, the power to brake windings 28 and 29 is interrupted. At the same instant the bias source for tube 32 shifts to ground and condenser C starts charging through resistance R. When the bias on the grid finally reaches a sufficiently low value, winding 30 deenergizes permitting 30a to fall and reestablish the brake winding circuit. In one embodiment, the time the brake circuit was interrupted was .15 second.

Assume now that because of the inertia of one motor or because of the direction of travel of the other motor, the finger 1 drives into the ring to close the outer ring switch 15. Thereupon, according to the next important feature of this invention, one or both of the amplifier-to-motor circuits is opened and a reversing voltage is applied to the motor through switch 36. Switch 36 is an alternately seated switch in which the N. C. contacts are normally closed and the N. O. contacts are normally open. If for example motor 4 overruns, switch 15 operates to disconnect the source 20 and to connect source 35 through switch 36. Source 35 comprises terminals of both polarities either of which will be chosen at 36 depending on the direction of motor travel at the time the limit switch 36 is operated. By the time the outer ring switch 15 is operated the brake will have been fully applied and released, thereupon the reversing voltage of source 35 applies full reversing torque to the motor 4 to drive figure 1 out of its limits. Once finger 1 is returned to a position inside ring 6 switch 15 opens, reestablishing the amplifier-to motor circuit.

A third limit switch is preferably employed in the system of Fig. 3 to protect the mechanism in case of failure of any of the above described circuits. Geared to the motor shaft of 4 is the lead screw 37 threaded into the follower 38, which follower will travel a limited distance in either direction, and will mechanically force open switches 39 or 40 at either limit of motor travel. Switches 39 and 40 are in series between the amplifier 20 and its motor 4 so that either switch 39 or 40 will interrupt power to the motor.

The circuits described for interrupting the power from amplifier 20 to motor 4 is duplicated in the circuits of amplifier 21 and motor 5, like parts being designated 75

with a suffix *a* to like reference characters. That is, resistance 26a is inserted in the power circuit when the inner ring switch is closed. The brake 29 of motor 5 operates in parallel with the brake 28 on motor 4. The outer ring switch 15a functions to apply the reversing voltage 35a to motor 5 when finger 1 travels through the inner ring. Likewise, motor 5 is geared to lead screw 37a to interrupt the flow of power from the amplifier 21 to motor 5 for ultimate mechanical protection.

Where simple straight line motion is desired, as where finger 1 may need to travel linearly, only one motor need be employed. There are many applications of servo controls where less complex motions than that of the resolver of a fire control system are required.

15 What is claimed is:

1. In combination in a servo system, a signal source, a motor coupled to and driven by said source, a finger driven by said motor and analogous in position to signal information; limit switch mechanism comprising a feeler switch fixedly disposed at and responsive to the approach of said finger to a predetermined extreme of displacement, a fast relay with contacts in the power supply to the motor and with a winding coupled to said feeler switch, a spring actuated-magnetic release brake on the motor shaft, and a fast-brake-slow-make relay responsive to said feeler switch coupled to said magnetic brake to momentarily apply high braking torque to the motor immediately after interruption of power to said motor.

2. The combination defined in claim 1 further comprising a resistor connected in parallel with said contacts of the fast relay so that said resistor is connected in series between the motor and its power supply in response to said feeler switch.

3. In combination in a motor control system, a motor, a power supply for the motor, a power resistor, a limit switch mechanism with a finger driven by the motor, said mechanism including an inner and an outer switch successively responsive to movement of said finger into limit position, a magnetically operated brake connected to the shaft of said motor, means responsive to said inner switch for connecting said power resistor into the motor power supply circuit, and means responsive to the inner switch for momentarily applying full braking power to the motor; and means responsive to the outer switch for applying full reversing power to the motor.

4. In combination in a motor control system, a first and second motor, a power supply for each motor, a finger carried on a gimbal, the motors driving the two axles of the gimbal to move the finger to any point within a circle, a ring with an inside periphery defining said circle, a switch, means coupling said switch to said ring to actuate said switch in response to movement of said ring in any direction, and means responsive to said switch to interrupt the power supply to the motors.

5. In the combination defined in claim 4, said ring comprising a plate with a large central opening of the size of said circle, frictionless bearings supporting said plate for free motion in all directions in the plane of said plate.

6. In the combination defined in claim 5, wherein three springs spaced around the outer periphery of said plate resiliently restrain said movement of the plate.

7. In the combination defined in claim 6, said means for coupling said switch to said ring comprising a shallow conical detent in the face of said plate, a round-nosed plunger riding in the bottom of the detent, and linkage between said plunger and switch for operating the switch upon movement in any direction of the plate.

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